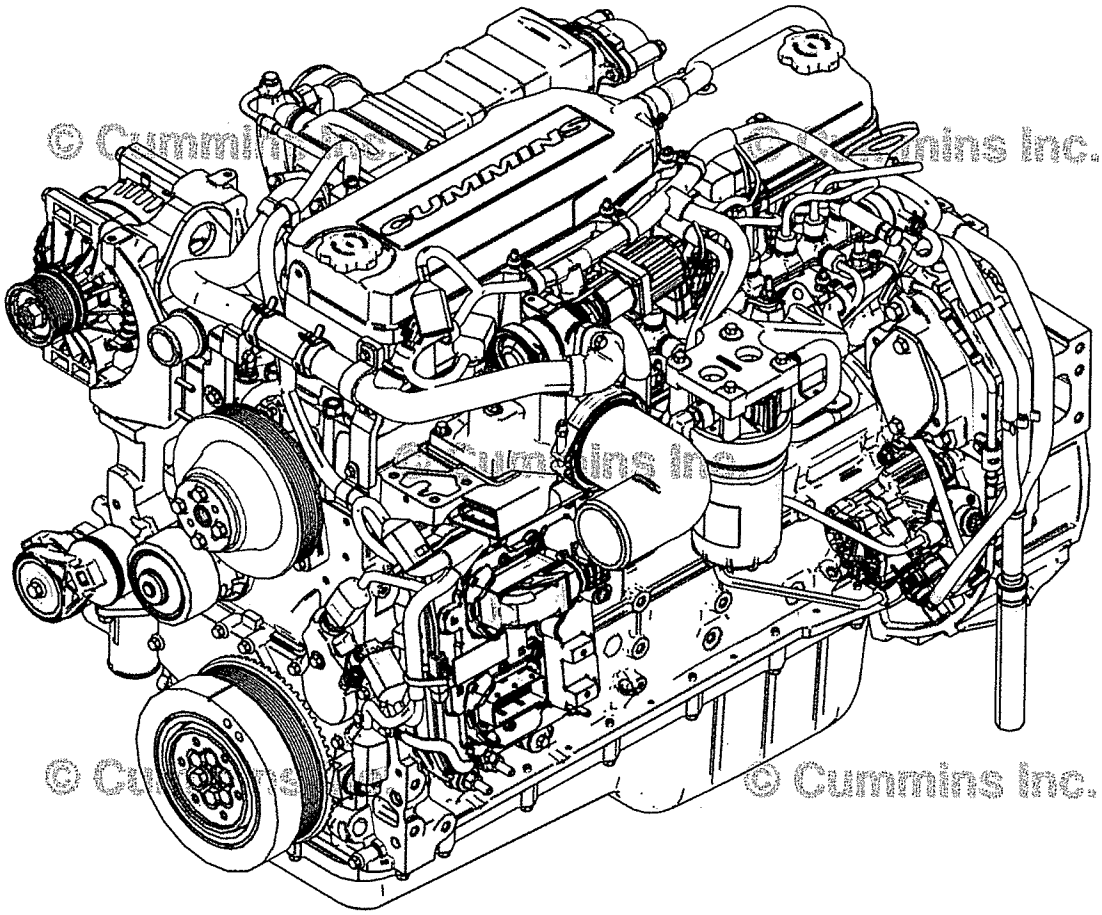
Service Manual
QSB6.7 CM2350 B105
Volume 2



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Foreword

This manual provides instructions for troubleshooting and repairing this engine in the chassis. Component and assembly rebuild procedures are provided in the engine shop manual. Refer to Section i - Introduction for instructions on how to use this manual.

Read and follow all safety instructions. Refer to the WARNING in the General Safety Instructions in Section i - Introduction.

The manual is organized to guide a service technician through the logical steps of identifying and correcting problems related to the engine. This manual does not cover vehicle or equipment problems. Consult the vehicle or equipment manufacturer for repair procedures.

A series of specific service manuals (for example: Shop, Specifications, and Alternative Repair) are available and can be ordered by Contacting your local area Cummins Regional office. A Cummins Regional office listing is located in Service Literature (Section L).

The repair procedures used in this manual are recommended by Cummins Inc. Some service procedures require the use of special service tools. Use the correct tools as described.

Cummins Inc. encourages the user of this manual to report errors, omissions, and recommendations for improvement. Please use the postage paid, pre-addressed Literature Survey Form in the back of this manual for communicating your comments.

The specifications and rebuild information in this manual are based on the information in effect at the time of printing. Cummins Inc. reserves the right to make any changes at any time without obligation. If differences are found between your engine and the information in this manual, contact a Cummins Authorized Repair Location or call 1-800-DIESELS (1-800-343-7357) toll free in the U.S. and Canada.

The latest technology and the highest quality components are used to manufacture Cummins engines. When replacement parts are needed, we recommend using only genuine Cummins or ReCon® exchange parts.

Table of Contents

Section i - Introduction

Section Contents

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About the Manual

General Information

This Service Manual is intended to aid in determining the cause of engine related problems and to provide recommended repair procedures. Additionally the manual is intended to aid mechanics in disassembly, inspecting parts for reuse, rebuilding and assembly of components.

The manual is divided into sections. Each section is equivalent to a group used in Cummins' filmcard system. Some sections contain **reference** numbers and **procedure** numbers. **Reference** numbers provide general information, specifications, diagrams, and service tools where applicable. **Procedure** numbers are used to identify and reference specific repair procedures for correcting the problem and describe specific rebuild procedures.

This manual **does not** contain fuel systems electronic troubleshooting. Use the troubleshooting trees in this manual, if there are no electronic fault codes.

This manual is designed so the troubleshooting trees are used to locate the cause of an engine problem. The troubleshooting trees then direct the user to the correct repair procedure. The repair procedures within a section are in numerical order. However, the repair steps within a given procedure are organized in the order the repair **must** be performed regardless of the numerical order of the steps. The user **must** use the contents pages or the index at the back of the manual to locate specific topics when **not** using the troubleshooting trees.

How to Use the Manual

General Information

This manual is divided into the same group system used for previous manuals and the Cummins' filmcard system. Section 00 is organized into a logical sequence of engine disassemble/assemble, all other sections are in numerical sequence. Refer to the Table of Contents at the front of the book to determine the section that details the desired information.

The disassemble/assemble sections of this manual is divided into the same group system used for previous manuals and the Cummins' filmcard system.

Section 00 is organized into a logical sequence of engine disassemble/assemble, all other sections are in numerical sequence. Refer to the Table of Contents at the front of the book to determine the section that details the desired information.

Each section contains the following in sequence:

- Table of Contents
- Required Service Tool Listings
- General Information containing the basic service, maintenance, design and revision information necessary to assist in the rebuild of an engine or a component
- Procedure instructions for the disassembly, inspection, maintenance, and assembly that can be required to rebuild an engine; additional procedures that are **not** necessary during **every** rebuild, but can be necessary, are included. These procedures depend on the length of time an engine has been in service and the conditions of the parts.

All the procedures are identified with a name and a number. Each digit in the procedure number has a specific meaning.

The first three digits of the number refer to the specific section that the procedure can be found within the manual. In this example, "001" represents Section 01 - Cylinder Block. This number will range from 000 to 022.

The second three digits of the number are unique and refer to a specific subject. In this example, "028" represents Cylinder Liner. This number will range from 001 to 999.

Refer to Section V for specifications recommended by Cummins Engine Company, Inc. for your engine. Specifications and torque values for each engine system are given in that section.

NOTE: Discharge of oil or oily water into or upon the water is a direct violation of today's laws. Violators are subject to a penalty of various monetary charges. Dispose of these substances in accordance with standards set by the local enviromental governing agency.

Symbols

General Information

The following symbols have been used in this manual to help communicate the intent of the instructions. When one of the symbols appears, it conveys the meaning defined below:

WARNING - Serious personal injury or extensive property damage can result if the warning instructions are **not** followed.

CAUTION - Minor personal injury can result or a part, an assembly, or the engine can be damaged if the caution instructions are **not** followed.

Indicates a **REMOVAL or DISASSEMBLY** step.

Indicates an **INSTALLATION or ASSEMBLY** step.

INSPECTION is required.

CLEAN the part or assembly.

PERFORM a mechanical or time **MEASUREMENT.**

LUBRICATE the part or assembly.

Indicates that a **WRENCH or TOOL SIZE** will be given.

TIGHTEN to a specific torque.

PERFORM an electrical **MEASUREMENT.**

Refer to another location in this manual or another publication for additional information.

The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

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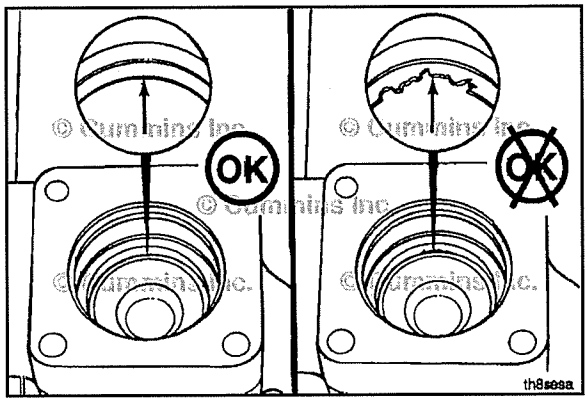
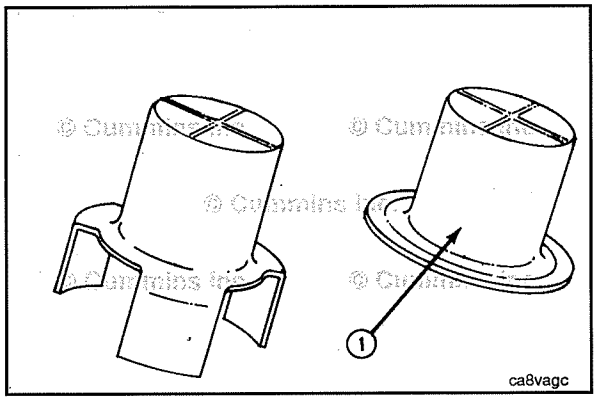


Illustrations

General Information

Some of the illustrations throughout this manual are generic and will **not** look exactly like the engine or parts used in your application. The illustrations can contain symbols to indicate an action required and an acceptable or **not** acceptable condition.



The illustrations are intended to show repair or replacement procedures. The procedure will be the same for all applications, although the illustration can differ.

General Safety Instructions

Important Safety Notice

⚠WARNING⚠

Improper practices, carelessness, or ignoring the warnings can cause burns, cuts, mutilation, asphyxiation or other personal injury or death.

Read and understand all of the safety precautions and warnings before performing any repair. This list contains the general safety precautions that **must** be followed to provide personal safety. Special safety precautions are included in the procedures when they apply.

- Work in an area surrounding the product that is dry, well lit, ventilated, free from clutter, loose tools, parts, ignition sources and hazardous substances. Be aware of hazardous conditions that can exist.
- **Always** wear protective glasses and protective shoes when working.
- Rotating parts can cause cuts, mutilation or strangulation.
- Do **not** wear loose-fitting or torn clothing. Remove all jewelry when working.
- Disconnect the battery (negative [-] cable first) and discharge any capacitors before beginning any repair work. Disconnect the air starting motor if equipped to prevent accidental engine starting. Put a "Do **Not** Operate" tag in the operator's compartment or on the controls.
- Use ONLY the proper engine barring techniques for manually rotating the engine. Do **not** attempt to rotate the crankshaft by pulling or prying on the fan. This practice can cause serious personal injury, property damage, or damage to the fan blade(s) causing premature fan failure.
- If an engine has been operating and the coolant is hot, allow the engine to cool before slowly loosening the filler cap to relieve the pressure from the cooling system.
- **Always** use blocks or proper stands to support the product before performing any service work. Do **not** work on anything that is supported ONLY by lifting jacks or a hoist.
- Relieve all pressure in the air, oil, fuel, and cooling systems before any lines, fittings, or related items are removed or disconnected. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do **not** check for pressure leaks with your hand. High pressure oil or fuel can cause personal injury.
- To reduce the possibility of suffocation and frostbite, wear protective clothing and ONLY disconnect liquid refrigerant (Freon) lines in a well ventilated area. To protect the environment, liquid refrigerant systems **must** be properly emptied and filled using equipment that prevents the release of refrigerant gas (fluorocarbons) into the atmosphere. Federal law requires capturing and recycling refrigerant.
- To reduce the possibility of personal injury, use a hoist or get assistance when lifting components that weigh 23 kg [50 lb] or more. Make sure all lifting devices such as chains, hooks, or slings are in good condition and are of the correct capacity. Make sure hooks are positioned correctly. **Always** use a spreader bar when necessary. The lifting hooks **must not** be side-loaded.
- Corrosion inhibitor, a component of SCA and lubricating oil, contains alkali. Do **not** get the substance in eyes. Avoid prolonged or repeated contact with skin. Do **not** swallow internally. In case of contact, immediately wash skin with soap and water. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. IMMEDIATELY CALL A PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.
- Naptha and Methyl Ethyl Ketone (MEK) are flammable materials and **must** be used with caution. Follow the manufacturer's instructions to provide complete safety when using these materials. KEEP OUT OF REACH OF CHILDREN.
- To reduce the possibility of burns, be alert for hot parts on products that have just been turned off, exhaust gas flow, and hot fluids in lines, tubes, and compartments.
- **Always** use tools that are in good condition. Make sure you understand how to use the tools before performing any service work. Use ONLY genuine Cummins® or Cummins ReCon® replacement parts.
- **Always** use the same fastener part number (or equivalent) when replacing fasteners. Do **not** use a fastener of lesser quality if replacements are necessary.
- When necessary, the removal and replacement of any guards covering rotating components, drives, and/or belts should only be carried out be a trained technician. Before removing any guards the engine **must** be turned off and any starting mechanisms **must** be isolated. All fasteners **must** be replaced on re-fitting the guards.
- Do **not** perform any repair when fatigued or after consuming alcohol or drugs that can impair your functioning.

- Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.
- Do **not** connect the jumper starting or battery charging cables to any ignition or governor control wiring. This can cause electrical damage to the ignition or governor.
- **Always** torque fasteners and fuel connections to the required specifications. Overtightening or undertightening can allow leakage. This is critical to the natural gas and liquefied petroleum gas fuel and air systems.
- **Always** test for fuel leaks as instructed, as odorant can fade.
- Close the manual fuel valves prior to performing maintenance and repairs, and when storing the vehicle inside.
- Coolant is toxic. If **not** reused, dispose of in accordance with local environmental regulations.
- The catalyst reagent contains urea. Do **not** get the substance in your eyes. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water. Do **not** swallow internally. In the event the catalyst reagent is ingested, contact a physician immediately.
- The catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. Always wear protective gloves and eye protection when handling the catalyst assembly. Do not get the catalyst material in your eyes. In Case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water.
- The Catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. In the event the catalyst is being replaced, dispose of in accordance with local regulations.
- California Proposition 65 Warning - Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

General Repair Instructions

General Information

This system incorporates the latest technology at the time it was manufactured; yet, it is designed to be repaired using normal repair practices performed to quality standards.

⚠WARNING⚠

Cummins Inc. does not recommend or authorize any modifications or repairs to components except for those detailed in Cummins Service Information. In particular, unauthorized repair to safety-related components can cause personal injury or death. Below is a partial listing of components classified as safety-related:

1 Air Compressor
2 Air Controls
3 Air Shutoff Assemblies
4 Balance Weights
5 Cooling Fan
6 Fan Hub Assembly
7 Fan Mounting Bracket(s)
8 Fan Mounting Capscrews
9 Fan Hub Spindle
10 Flywheel
11 Flywheel Crankshaft Adapter
12 Flywheel Mounting Capscrews
13 Fuel Shutoff Assemblies
14 Fuel Supply Tubes
15 Lifting Brackets
16 Throttle Controls
17 Turbocharger Compressor Casing
18 Turbocharger Oil Drain Line(s)
19 Turbocharger Oil Supply Line(s)
20 Turbocharger Turbine Casing
21 Vibration Damper Mounting Capscrews
22 Manual Service Disconnect
23 High Voltage Interlock Loop
24 High Voltage Connectors/Connections and Harnesses
25 High Voltage Battery System
26 Power Inverter
27 Generator Motor
28 Clutch Pressure Plate

- Follow all safety instructions noted in the procedures
- Follow the manufacturer's recommendations for cleaning solvents and other substances used during repairs. Some solvents have been identified by government agencies as toxic or carcinogenic. Avoid excessive breathing, ingestion and contact with such substances. **Always** use good safety practices with tools and equipment
- Provide a clean environment and follow the cleaning instructions specified in the procedures
- All components **must** be kept clean during any repair. Contamination of the components will cause premature wear.
- Perform the inspections specified in the procedures
- Replace all components or assemblies which are damaged or worn beyond the specifications

- Use genuine Cummins new or ReCon® service parts and assemblies
- The assembly instructions have been written to use again as many components and assemblies as possible. When it is necessary to replace a component or assembly, the procedure is based on the use of new Cummins or Cummins ReCon® components. All of the repair services described in this manual are available from all Cummins Distributors and most Dealer locations.
- Follow the specified disassembly and assembly procedures to reduce the possibility of damage to the components

Welding on a Vehicle with an Electronic Controlled Fuel System

⚠CAUTION⚠

Disconnect both the positive (+) and negative (-) battery cables from the battery before welding on the vehicle. Attach the welder ground cable no more than 0.61 meters [2 feet] from the part being welded. Do not connect the ground clamp of the welder to any of the sensors, wiring harness, electronic control units or the components. Direct welding of any electronic components must not be attempted. Sensors, wiring harness, and electronic control unit should be removed if nearby welding will expose these components to temperatures beyond normal operation. Additionally, all electronic control unit connectors must be disconnected

General Cleaning Instructions

Definition of Clean

Parts **must** be free of debris that can contaminate any engine system. This does **not** necessarily mean they have to appear as new.

Sanding gasket surfaces until the factory machining marks are disturbed adds no value and is often harmful to forming a seal. It is important to maintain surface finish and flatness tolerances to form a quality sealing surface. Gaskets are designed to fill small voids in the specified surface finish.

Sanding gasket surfaces where edge-molded gaskets are used is most often unnecessary. Edge-molded gaskets are those metal carriers with sealing material bonded to the edges of the gasket to seal while the metal portion forms a metal to metal joint for stability. Any of the small amounts of sealing material that can stick to the parts are better removed with a blunt-edged scraper on the spots rather than spending time polishing the whole surface with an air sander or disc.

For those gaskets that do **not** have the edge molding, nearly all have a material that contains release agents to prevent sticking. Certainly this is **not** to say that some gaskets are **not** difficult to remove because the gasket has been in place a long time, has been overheated or the purpose of the release agent has been defeated by the application of some sealant. The object however is just to remove the gasket without damaging the surfaces of the mating parts without contaminating the engine (don't let the little bits fall where they can not be removed).

Bead blasting piston crowns until the dark stain is removed is unnecessary. All that is required is to remove the carbon build-up above the top ring and in the ring grooves. There is more information on bead blasting and piston cleaning later in this document.

Cummins Inc. does **not** recommend sanding or grinding the carbon ring at the top of cylinder liners until clean metal is visible. The liner will be ruined and any signs of a problem at the top ring reversal point (like a dust-out) will be destroyed. It is necessary to remove the carbon ring to provide for easier removal of the piston assembly. A medium bristle, high quality, steel wire wheel that is rated above the rpm of the power tool being used will be just as quick and there will be less damage. Yes, one **must** look carefully for broken wires after the piston is removed but the wires are more visible and can be attracted by a magnet.

Oil on parts that have been removed from the engine will attract dirt in the air. The dirt will adhere to the oil. If possible, leave the old oil on the part until it is ready to be cleaned, inspected and installed, and then clean it off along with any attracted dirt. If the part is cleaned then left exposed it can have to be cleaned again before installation. Make sure parts are lubricated with clean oil before installation. They do **not** need to be oiled all over but do need oil between moving parts (or a good lube system priming process conducted before cranking the engine).

Bead blasting parts to remove exterior paint is also usually unnecessary. The part will most likely be painted again so all that needs happen is remove any loose paint.

Abrasive Pads and Abrasive Paper

The keyword here is "abrasive". There is no part of an engine designed to withstand abrasion. That is they are all supposed to lock together or slide across each other. Abrasives and dirt particles will degrade both functions.

⚠WARNING⚠

Abrasive material must be kept out of or removed from oil passages and parts wear points. Abrasive material in oil passages can cause bearing and bushing failures that can progress to major component damage beyond reuse. This is particularly true of main and rod bearings.

Cummins Inc. does **not** recommend the use of emery cloth or sand paper on any part of an **assembled** engine or component including but **not** limited to removing the carbon ridge from cylinder liners or to clean block decks or counterbores.

Great care **must** be taken when using abrasive products to clean engine parts, particularly on partially assembled engines. Abrasive cleaning products come in many forms and sizes. All of them contain aluminum oxide particles, silicon carbide, or sand or some other similar hard material. These particles are harder than most of the parts in the engine. Since they are harder, if they are pressed against softer material they will either damage the material or become embedded in it. These materials fall off the holding media as the product is used. If the products are used with power equipment the particles are thrown about the engine. If the particles fall between two moving parts, damage to the moving parts is likely.

If particles that are smaller than the clearance between the parts while they are at rest (engine stopped), but larger than the running clearance then damage will occur when the parts move relative to each other (engine started). While the engine is running and there is oil pressure, particles that are smaller than the bearing clearance are likely to pass between the parts without damage and be trapped in the oil filter. However, particles larger than the bearing clearance will remove material from one part and can become embedded in one of the parts. Once embedded in one part it will

abrade the other part until contact is no longer being made between the two parts. If the damage sufficiently degrades the oil film, the two parts will come into contact resulting in early wear-out or failure from lack of effective lubrication.

Abrasive particles can fly about during cleaning it is **very** important to block these particles from entering the engine as much as possible. This is particularly true of lubricating oil ports and oil drilling holes, especially those located downstream of the lubricating oil filters. Plug the holes instead of trying to blow the abrasive particles and debris with compressed air because the debris is often simply blown further into the oil drilling.

All old gasket material **must** be removed from the parts gasket surfaces. However, it is **not** necessary to clean and polish the gasket surface until the machining marks are erased. Excessive sanding or buffing can damage the gasket surface. Many newer gaskets are of the edge molded type (a steel carrier with a sealing member bonded to the steel). What little sealing material that can adhere is best removed with a blunt-edged scraper or putty knife. Cleaning gasket surfaces where an edge-molded gasket is used with abrasive pads or paper is usually a waste of time.

⚠WARNING⚠

Excessive sanding or grinding the carbon ring from the top of the cylinder liners can damage the liner beyond reuse. The surface finish will be damaged and abrasive particles can be forced into the liner material which can cause early cylinder wear-out or piston ring failures.

Tape off or plug all openings to any component interior before using abrasive pads or wire brushes. If really necessary because of time to use a power tool with abrasive pads, tape the oil drillings closed or use plug and clean as much of the surface as possible with the tool but clean around the oil hole/opening by hand so as to prevent contamination of the drilling. Then remove the tape or plug and clean the remaining area carefully and without the tool. DO NOT use compressed air to blow the debris out of oil drilling on an assembled engine! More likely than **not**, the debris can be blown further into the drilling. Using compressed air is fine if both ends of the drilling are open but that is rarely the case when dealing with an assembled engine.

Gasket Surfaces

The object of cleaning gasket surfaces is to remove any gasket material, not refinish the gasket surface of the part.

Cummins Inc. does **not** recommend any specific brand of liquid gasket remover. If a liquid gasket remover is used, check the directions to make sure the material being cleaned will **not** be harmed.

Air powered gasket scrapers can save time but care must be taken to **not** damage the surface. The angled part of the scraper must be against the gasket surface to prevent the blade from digging into the surface. Using air powered gasket scrapers on parts made of soft materials takes skill and care to prevent damage.

Do **not** scrape or brush across the gasket surface if at all possible.

Solvent and Acid Cleaning

Several solvent and acid-type cleaners can be used to clean the disassembled engine parts (other than pistons. See Below). Experience has shown that the best results can be obtained using a cleaner that can be heated to 90° to 95° Celsius (180° to 200° Fahrenheit). Kerosene emulsion based cleaners have different temperature specifications, see below. A cleaning tank that provides a constant mixing and filtering of the cleaning solution will give the best results. Cummins Inc. does not recommend any specific cleaners. Always follow the cleaner manufacturer's instructions. Remove all the gasket material, o-rings, and the deposits of sludge, carbon, etc., with a wire brush or scraper before putting the parts in a cleaning tank. Be careful not to damage any gasket surfaces. When possible, steam clean the parts before putting them in the cleaning tank.

⚠WARNING⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturers recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Experience has shown that kerosene emulsion based cleaners perform the best to clean pistons. These cleaners should **not** be heated to temperature in excess of 77°C (170°F). The solution begins to break down at temperatures in excess of 82°C (180°F) and will be less effective.

Do **not** use solutions composed mainly of chlorinated hydrocarbons with cresols, phenols and/or cresylic components. They often do **not** do a good job of removing deposits from the ring groove and are costly to dispose of properly.

Solutions with a pH above approximately 9.5 will cause aluminum to turn black; therefore do **not** use high alkaline solutions.

Chemicals with a pH above 7.0 are considered alkaline and those below 7.0 are acidic. As you move further away from the neutral 7.0, the chemicals become highly alkaline or highly acidic.

Remove all the gasket material, o-rings, and the deposits of sludge, carbon, etc., with a wire brush or scraper before putting the parts in a cleaning tank. Be careful to **not** damage any gasket surfaces. When possible use hot high

pressure water or steam clean the parts before putting them in the cleaning tank. Removing the heaviest dirt before placing in the tank will allow the cleaner to work more effectively and the cleaning agent will last longer.

Rinse all the parts in hot water after cleaning. Dry completely with compressed air. Blow the rinse water from all the capscrew holes and the oil drillings.

If the parts are **not** to be used immediately after cleaning, dip them in a suitable rust proofing compound. The rust proofing compound **must** be removed from the parts before assembly or installation on the engine.

Steam Cleaning

Steam cleaning can be used to remove all types of dirt that can contaminate the cleaning tank. It is a good method for cleaning the oil drillings and coolant passages

⚠WARNING⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

Do **not** steam clean the following components:

- Electrical Components
- Wiring Harnesses
- Belts and Hoses
- Bearings (ball or taper roller)
- Electronic Control Module (ECM)
- ECM Connectors
- Capacitive Coil Driver Module (CCD)
- Ignition Coils and Leads
- NOx Sensor
- Fuel Control Valve
- Throttle Driver and Actuator.

Plastic Bead Cleaning

Cummins Inc. does **not** recommend the use of glass bead blast or walnut shell media on **any** engine part. Cummins Inc. recommends using **only** plastic bead media, Part Number 3822735 or equivalent on any engine part. **Never** use sand as a blast media to clean engine parts. Glass and walnut shell media when **not** used to the media manufacturer's recommendations can cause excess dust and can embed in engine parts that can result in premature failure of components through abrasive wear.

Plastic bead cleaning can be used on many engine components to remove carbon deposits. The cleaning process is controlled by the use of plastic beads, the operating pressure and cleaning time.

⚠CAUTION⚠

Do not use bead blasting cleaning methods on aluminum pistons skirts or the pin bores in any piston, piston skirt or piston crown. Small particles of the media will embed in the aluminum or other soft metal and result in premature wear of the cylinder liner, piston rings, pins and pin bores. Valves, turbocharger shafts, etc., can also be damaged. Follow the cleaning directions listed in the procedures.

⚠CAUTION⚠

Do not contaminate wash tanks and tank type solvent cleaners with the foreign material and plastic beads. Remove the foreign material and plastic beads with compressed air, hot high pressure water or steam before placing them in tanks or cleaners. The foreign material and plastic beads can contaminate the tank and any other engine parts cleaned in the tank. Contaminated parts may cause failures from abrasive wear.

Plastic bead blasting media, Part Number 3822735, can be used to clean all piston ring grooves. Do **not** sure any bead blasting media on piston pin bores or aluminum skirts.

Follow the equipment manufacturer's cleaning instructions. Make sure to adjust the air pressure in the blasting machine to the bead manufacturer's recommendations. Turning up the pressure can move material on the part and cause the plastic bead media to wear out more quickly. The following guidelines can be used to adapt to manufacturer's instructions:

1 Bead size: U.S. size Number 16 — 20 for piston cleaning with plastic bead media, Part Number 3822735

2 Operating Pressure — 270 kPa (40 psi) for piston cleaning. Pressure should not cause beads to break.

3 Steam clean or wash the parts with solvent to remove all of the foreign material and plastic beads after cleaning. Rinse with hot water. Dry with compressed air.

⚠CAUTION⚠

The bead blasting operation must not disturb the metal surface. If the metal surface is disturbed the engine can be damaged due to increased parts clearance or inadequate surface finish on parts that move against other parts.

When cleaning pistons, it is **not** necessary to remove all the dark stain from the piston. All that is necessary is to remove the carbon on the rim and in the ring grooves. This is best done by directing the blast across the part as opposed to straight at the part. If the machining marks are disturbed by the blasting process, then the pressure is too high or the blast is being held on one spot too long. The blast operation **must not** disturb the metal surface.

Walnut shell bead blast material is sometimes used to clean ferrous metals (iron and steel). Walnut shell blasting produces a great amount of dust particularly when the pressure if the air pressure on the blasting machine is increased above media manufacturer's recommendation. Cummins Inc. recommends **not** using walnut shell media to clean engine parts due to the risk media embedment and subsequent contamination of the engine.

Cummins Inc. now recommends glass bead media **NOT** used to clean any engine parts. Glass media is too easily embedded into the material particularly in soft materials and when air pressures greater than media manufacturer's recommend are used. The glass is an abrasive so when it is in a moving part, that part is abrading all the parts in contact with it. When higher pressures are used the media is broken and forms a dust of a very small size that floats easily in the air. This dust is very hard to control in the shop, particularly if **only** compressed air (and not hot water) is used to blow the media after it is removed from the blasting cabinet (blowing the part off inside the cabinet may remove large accumulations but never removes all the media).

Bead blasting is best used on stubborn dirt/carbon build-up that has **not** been removed by first steam/higher pressure washing then washing in a heated wash tank. This is particularly true of pistons. Steam and soak the pistons first then use the plastic bead method to safely remove the carbon remaining in the grooves (instead of running the risk of damaging the surface finish of the groove with a wire wheel or end of a broken piston ring. Make sure the parts are dry and oil free before bead blasting to prevent clogging the return on the blasting machine.

Always direct the bead blaster nozzle "across" rather than directly at the part. This allows the bead to get under the unwanted material. Keep the nozzle moving rather than hold on one place. Keeping the nozzle directed at one-place too long causes the metal to heat up and be moved around. Remember that the spray is **not** just hitting the dirt or carbon. If the machining marks on the piston groove or rim have been disturbed then there has **not** been enough movement of the nozzle and/or the air pressure is too high.

Never bead blast valve stems. Tape or use a sleeve to protect the stems during bead blasting. Direct the nozzle across the seat surface and radius rather than straight at them. The object is to remove any carbon build up and continuing to blast to remove the stain is a waste of time.

Fuel System

When servicing any fuel system components, which can be exposed to potential contaminants, prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. If the surrounding areas are **not** cleaned, dirt or contaminants can be introduced into the fuel system.

The internal drillings of some injectors are extremely small and susceptible to plugging from contamination. Some fuel injection systems can operate at very high pressures. High pressure fuel can convert simple particles of dirt and rust into a highly abrasive contaminant that can damage the high pressure pumping components and fuel injectors.

Electrical contact cleaner can be used if steam cleaning tools are **not** available. Use electrical contact cleaner rather than compressed air, to wash dirt and debris away from fuel system fittings. Diesel fuel on exposed fuel system parts attracts airborne contaminants.

Choose lint free towels for fuel system work.

Cap and plug fuel lines, fittings, and ports whenever the fuel system is opened. Rust, dirt, and paint can enter the fuel system whenever a fuel line or other component is loosened or removed from the engine. In many instances, a good practice is to loosen a line or fitting to break the rust and paint loose, and then clean off the loosened material.

When removing fuel lines or fittings from a new or newly-painted engine, make sure to remove loose paint flakes/chips that can be created when a wrench contacts painted line nuts or fittings, or when quick disconnect fittings are removed.

Fuel filters are rated in microns. The word micron is the abbreviation for a micrometer, or one millionth of a meter. The micron rating is the size of the smallest particles that will be captured by the filter media. As a reference, a human hair

is 76 microns [0.003 in] in diameter. One micron measures 0.001 mm [0.00004 in.]. The contaminants being filtered out are smaller than can be seen with the human eye, a magnifying glass, or a low powered microscope.

The tools used for fuel system troubleshooting and repair are to be cleaned regularly to avoid contamination. Like fuel system parts, tools that are coated with oil or fuel attract airborne contaminants. Remember the following points regarding your fuel system tools:

- Fuel system tools are to be kept as clean as possible.
- Clean and dry the tools before returning them to the tool box.
- If possible, store fuel system tools in sealed containers.
- Make sure fuel system tools are clean before use.

Acronyms and Abbreviations

General Information

The following list contains some of the acronyms and abbreviations used in this manual.

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society of Testing and Materials
ATDC	After Top Dead Center
BTU	British Thermal Unit
BTDC	Before Top Dead Center
°C	Celsius
CAN	Controller Area Network
CO	Carbon Monoxide
CCA	Cold Cranking Amperes
CARB	California Air Resources Board
C.I.B.	Customer Interface Box
C.I.D.	Cubic Inch Displacement
CNG	Compressed Natural Gas
CPL	Control Parts List
cSt	Centistokes
DEF	Diesel Exhaust Fluid
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECM	Engine Control Module
EFC	Electronic Fuel Control
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
°F	Fahrenheit
ft-lb	Foot-Pound Force
FMI	Failure Mode Indentifier
GVW	Gross Vehicle Weight
Hg	Mercury
hp	Horsepower
H_2O	Water
inHg	Inches of Mercury
in H_20	Inches of Water
ICM	Ignition Control Module
IEC	International Electrotechnical Commission
km/l	Kilometers per Liter
kPa	Kilopascal
LNG	Liquid Natural Gas
LPG	Liquified Petroleum Gas
LTA	Low Temperature Aftercooling
MCRS	Modular Common Rail System
MIL	Malfunction Indicator Lamp
MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter

NOx	Mono-Nitrogen Oxides
NG	Natural Gas
O2	Oxygen
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
PID	Parameter Identification Descriptions
ppm	Parts Per Million
psi	Pounds Per Square Inch
PTO	Power Takeoff
REPTO	Rear Power Take Off
RGT	Rear Gear Train
rpm	Revolutions Per Minute
SAE	Society of Automotive Engineers
SCA	Supplemental Coolant Additive
SCR	Selective Catalytic Reduction
STC	Step Timing Control
SID	Subsystem Identification Descriptions
TDC	Top Dead Center
VDC	Volts of Direct Current
VGT	Variable Geometry Turbocharger
VS	Variable Speed
VSS	Vehicle Speed Sensor

Notes

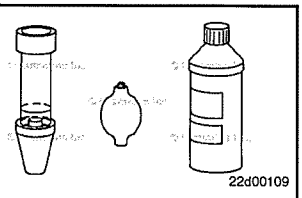
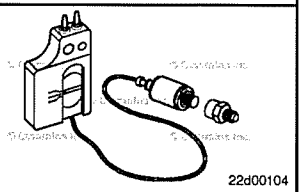
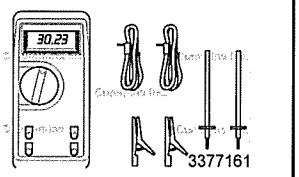
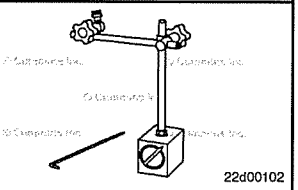
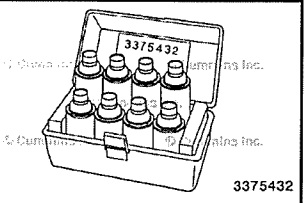
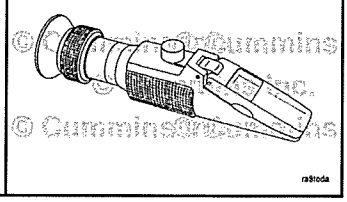
Section 8 - Cooling System - Group 08

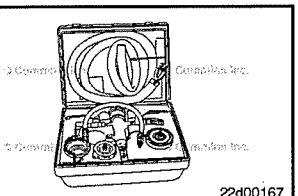
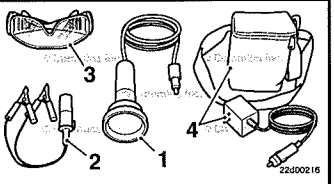
Section Contents

Service Tools

Cooling System

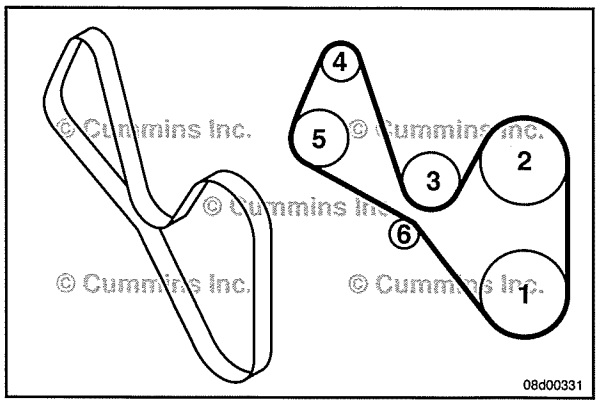
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3822985	**Combustion Gas Leak Tester** Used to test for combustion gasses in the cooling system.	
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction. Use with multimeter, Part Number 3164488 or 3164489.	
3164488 or 3164489	**Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amperes). 3164488 - Standard meter. 3164489 - Automotive meter with built in temperature adapter and tachometer.	
3377399	**Magnetic Base Indicator Holder** Used in conjunction with Dial Indicator. Metric, Part Number 3824564. SAE, Part Number 4918289.	
3375432	**Crack Detection Kit** Used to detect cracks in engine components.	
CC-2800	**Refractometer** The Fleetguard® refractometer is used to check the charge condition of a conventional battery.	

Tool No.	Tool Description	Tool Illustration
3824319	**Coolant Dam/Pressure Tester** Used with shop air pressure, the coolant dam creates a vacuum, holding the coolant in with little or no coolant loss.	 22d00167
3163338	**Black Light Lamp (12-VDC)** Used with fluorescent tracer to locate coolant and/or oil leaks. Lamp operates off vehicle battery or portable rechargeable battery included in kit. Oil tracer Part Number 3376891, coolant tracer, Part Number 3377438.	 22d00216

Drive Belt, Cooling Fan (008-002)

General Information



Due to the number of drive belt arrangements, this procedure does **not** cover all available cooling fan drive belt routing.

To make sure the cooling fan drive belt is routed correctly upon installation, make a diagram of the cooling fan belt routing prior to removing the belt as shown in the illustration.

The cooling fan belt routing typically consists of the following components, but may **not** include all of them:

1 Crankshaft pulley/vibration damper

2 Fan pulley

3 Water pump pulley

4 Refrigerant compressor pulley

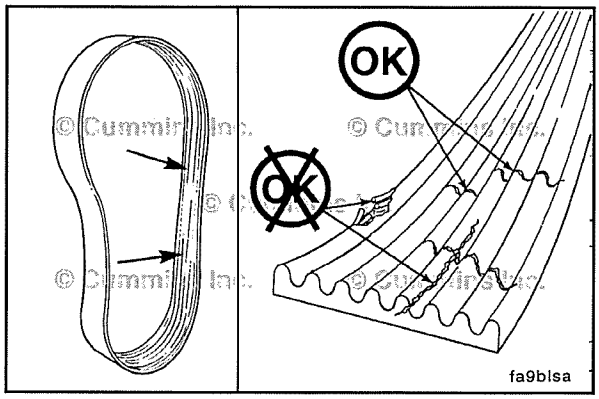
5 Alternator pulley

6 Tensioner idler pulley.

NOTE: Some engine driven belts are installed/supplied by the vehicle's original equipment manufacturer (OEM). See the OEM service manual for removal and installation instructions.

Maintenance Check

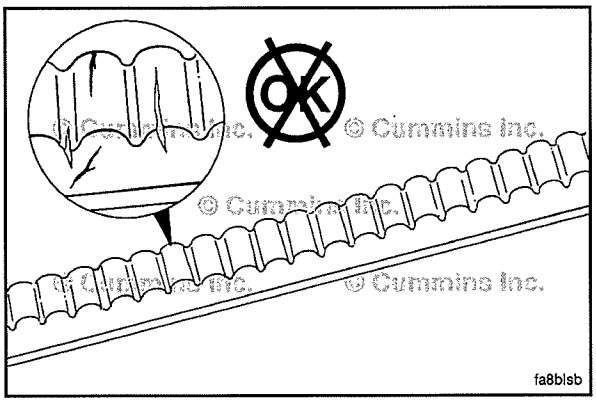
Poly-Vee Belt



Inspect the belts daily. Check the belt for intersecting cracks. Traverse (across the belt width) cracks are acceptable. Longitudinal (direction of belt length) cracks that intersect with transverse cracks are **not** acceptable. Replace the belt if it is frayed or has pieces of material missing. See Section A for belt adjustment and replacement procedures.

Belt damage can be caused by:

- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment
- Oil or grease on the side of the belts.



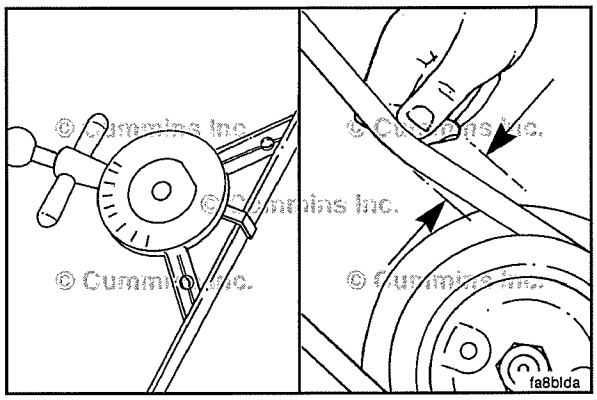
Cogged Belt

Inspect the belts daily. Replace the belts if they are cracked, frayed, or have chunks of material missing. Small cracks are acceptable.

Adjust the belts that have a glazed or shiny surface, which indicates belt slippage. Correctly installed and tensioned belts will show even pulley and belt wear. See Section A for belt adjustment and replacement procedures.

Belt damage can be caused by:

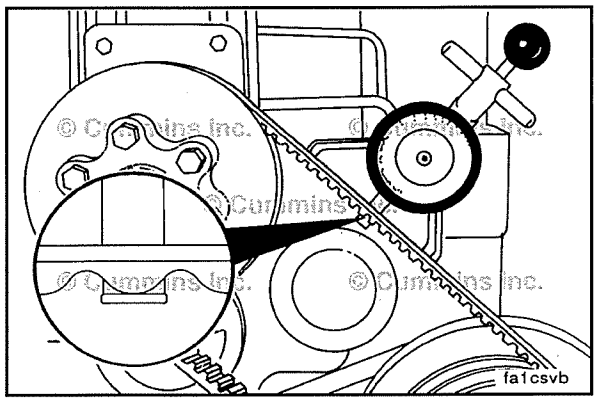
- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment
- Oil or grease on the the belts.



Measure the belt tension in the center span of the pulleys.

See the Belt Tension Chart in Section V for the correct gauge and tension value for the belt width used.

An alternate method (deflection method) can be used to check belt tension by applying 110 N [25 lbf] force between the pulleys on v-belts. If the deflection is more than one belt thickness per foot of pulley center distance, the belt tension **must** be adjusted.

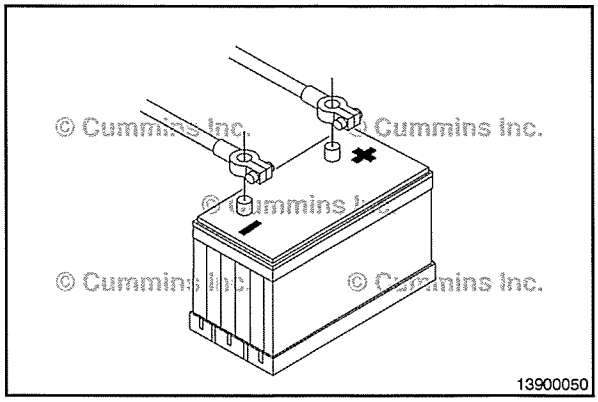


For cogged belts, make sure that the belt tension gauge is positioned so that the center tensioning leg is placed directly over the high point (hump) of a cog. Other positioning will result in incorrect measurement.

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

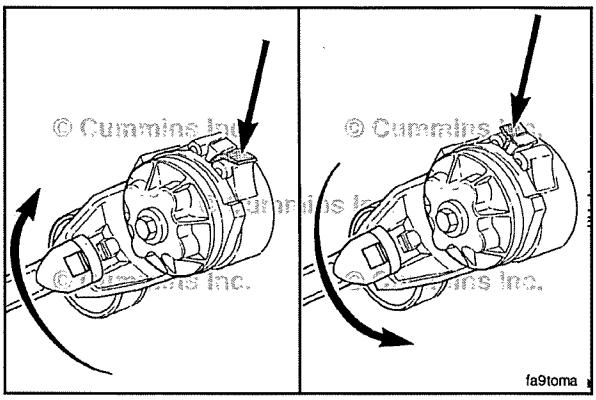
- Disconnect the battery cables. Refer to the OEM service manual.



Remove

⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

The belt tensioner winds in the direction that the spring tang is bent over the tensioner body. To loosen the tension on the belt, rotate the tensioner to wind the spring tighter.



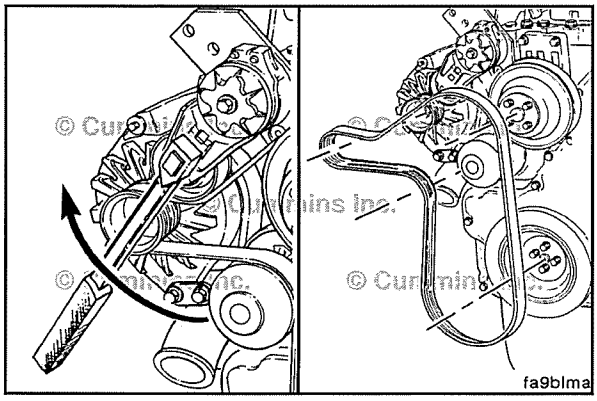
⚠CAUTION⚠
Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to break.

NOTE: Make a diagram of the belt arrangement prior to removing the drive belt. This aids in installation and proper routing of the cooling fan drive belt.

NOTE: The location of the belt tensioner can vary, depending on the front engine accessory arrangement.

Pivot the tensioner in the direction of the spring tang to remove the belt.

Remove the belt.



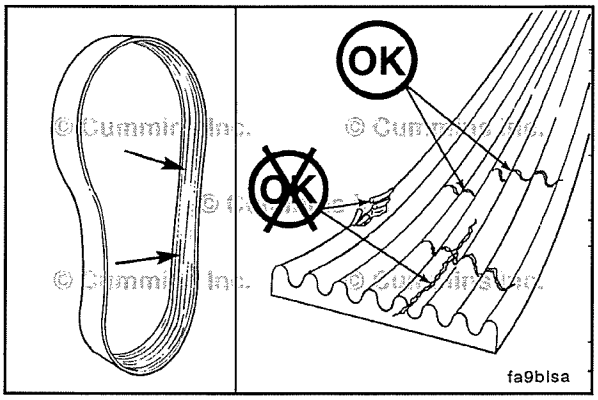
Clean and Inspect for Reuse

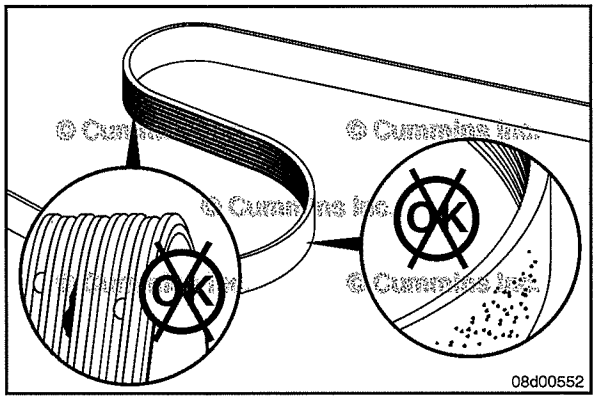
Inspect the drive belt for damage.

Transverse (across the belt) cracks are acceptable.

Longitudinal (direction of belt ribs) cracks that intersect with transverse cracks are **not** acceptable.

If the belt is frayed, punctured, or material is missing, the belt is unacceptable for reuse and **must** be replaced.





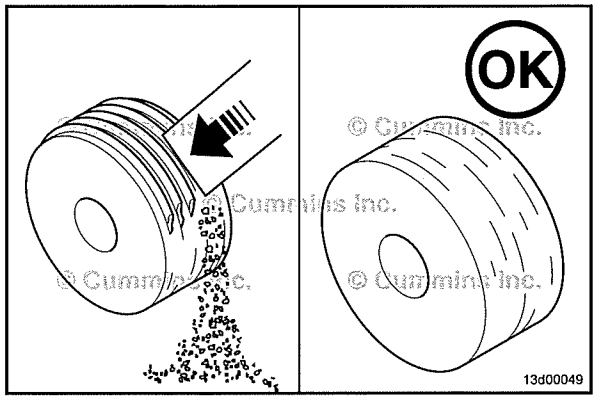
Inspect the belt grooves for:

- Embedded debris
- Uneven/excessive rib wear
- Exposed belt cords.

Inspect the backside of the belt for:

- Glazing (high heat)
- Embedded debris
- Exposed belt cords.

If any of the above conditions are present, the belt is unacceptable for reuse and **must** be replaced.



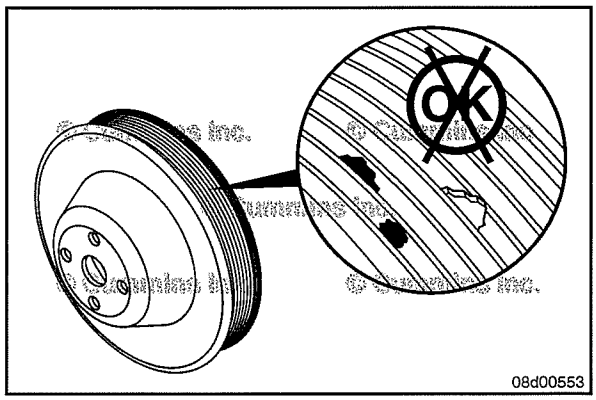
Inspect the idler and drive pulleys for wear or cracks.

Plastic pulleys often have a build-up of road dirt and belt material that is **not** to be confused with wear.

The dirt can be removed with a suitable tool to check for wear.

Clean, check, and reuse all pulleys in the front end accessory drive if **not** damaged, rather than replacing. Pulleys damaged from embedded debris **must** be replaced.

Inspect the tensioner. Refer to Procedure 008-087 in Section 8.



Inspect all system pulleys for embedded debris:

- Rocks, stones
- Metal
- Belt material.

Remove the debris from the grooves of the pulley. If the pulley has been deformed as a result of foreign material embedment, the pulley **must** be replaced.

Install

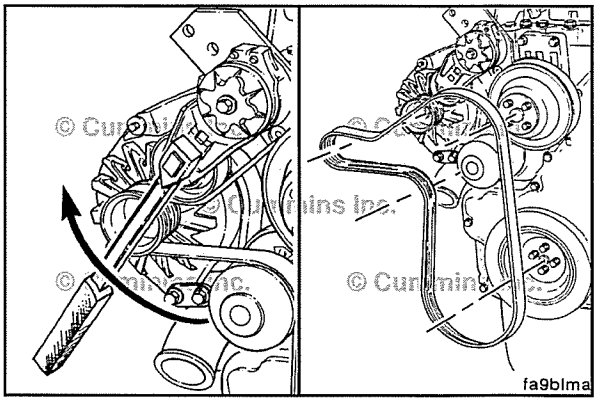
⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

Route the drive belt on the engine using the belt diagram created in the Remove section. Do **not** install the belt over the water pump pulley at this time.

Pivot the tensioner in the direction of the spring tang and install the drive belt, slipping the belt over the water pump pulley last.

Slowly release the tensioner to apply tension to the drive belt.

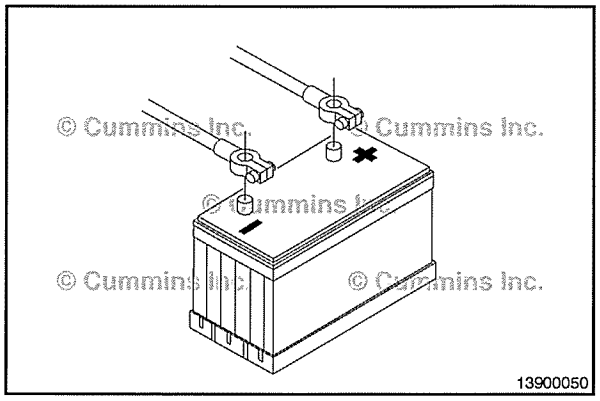
Check the alignment of the belt with the tensioner and the rest of the front end accessory drive.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

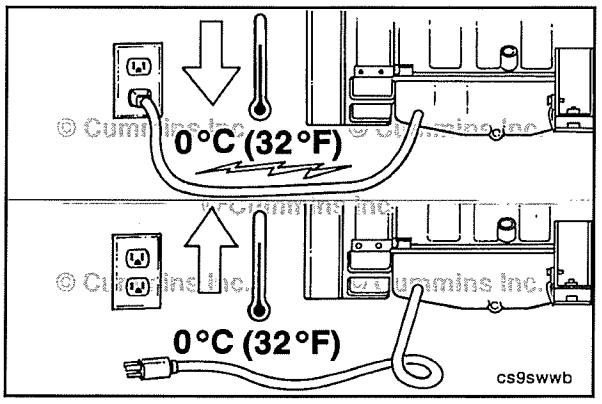
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for belt squeal. Excessive belt squeal indicates belt slippage.
- If belt squeal is present, check the routing of the belt to make sure that the belt is installed correctly on each pulley.

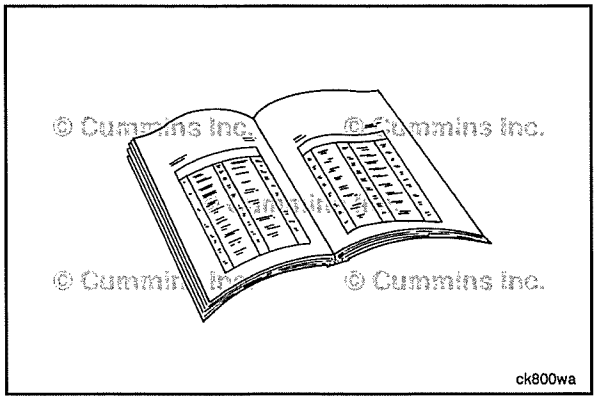


Coolant Heater (008-011)

General Information

Some heaters will operate continuously when plugged into the correct voltage electrical socket. Operate them **only** when the ambient temperature is below 0°C [32°F].





Preparatory Steps

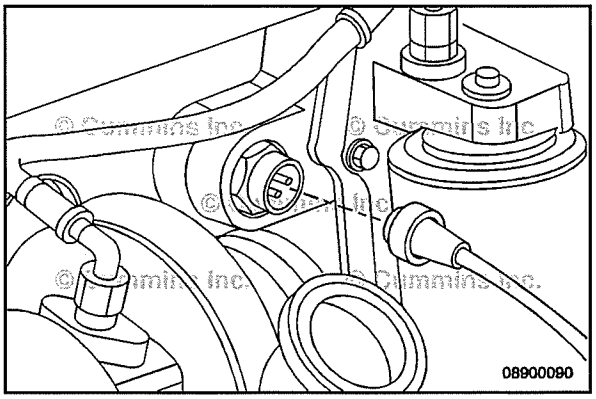
⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠

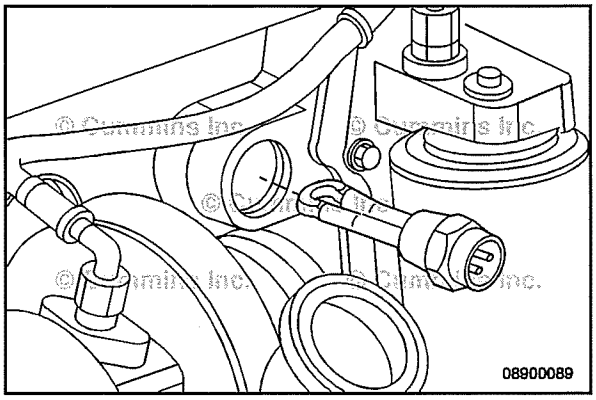
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain at least 19 liters [5 gal] from the cooling system. Refer to Procedure 008-018 in Section 8.



Remove

The threaded coolant heater is located adjacent to the lubricating oil cooler. Disconnect the block heater electrical cord.



Unscrew the coolant heater from the block.

Remove the coolant heater from the block.

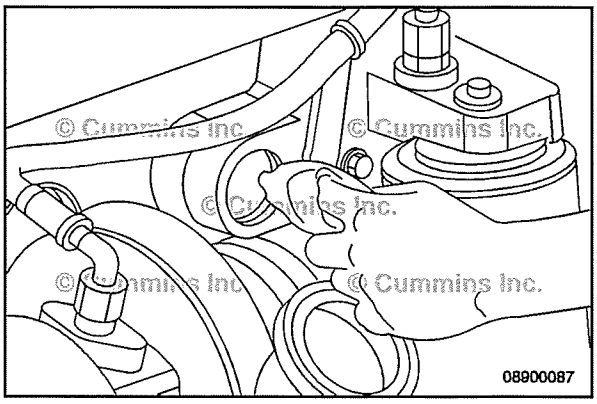
Clean and Inspect for Reuse

Clean the coolant heater port thoroughly with a clean rag.

Make sure there are no burrs, metal shavings, or sharp edges that can cut the o-ring.

Clean the coolant heater thoroughly with a clean rag. Make sure the heating element is free of debris and buildup and the sealing area is clean.

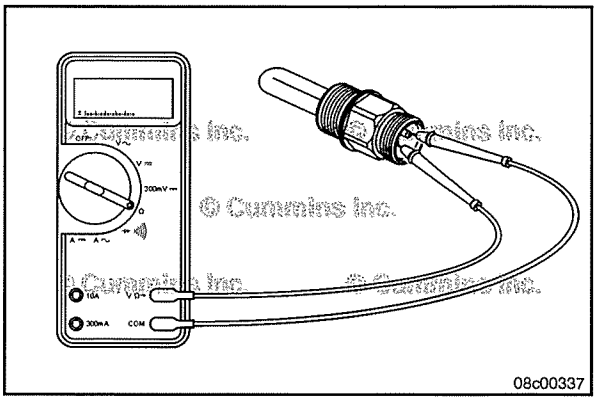
Check the coolant heater for cracks on the element.



⚠WARNING⚠
To reduce the possibility of personal injury, due to electrical shock, do not touch the electrical supply wires or component while the testing procedure is in action.

Measure the coolant heater resistance. The resistance **must** read between 18.2 and 21.1 ohms.

Coolant Heater Resistance (Ohms)	
MIN	**MAX**
18.2	21.1

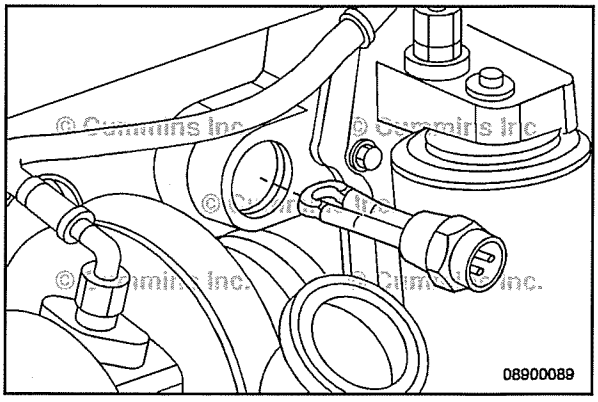


Install

Apply pipe sealant, Part Number 3375066, to the threads of the coolant heater.

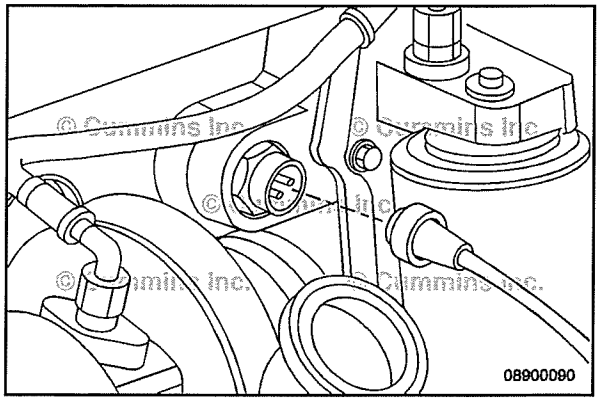
Install the coolant heater into the cylinder block and tighten.

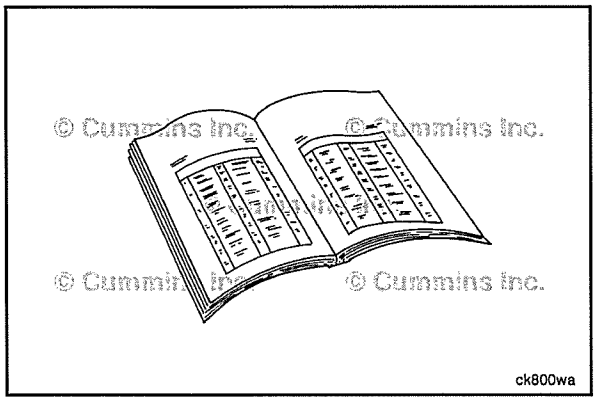
Torque Value: 55 N•m [41 ft-lb]



Insert the power cord into the socket. Be careful to align the pins with the sockets of the power cord. Tighten the retaining nut by hand.

NOTE: Do **not** apply power to the element until the cooling system is filled, and the engine has run long enough for the thermostat to open and allow the air to escape.



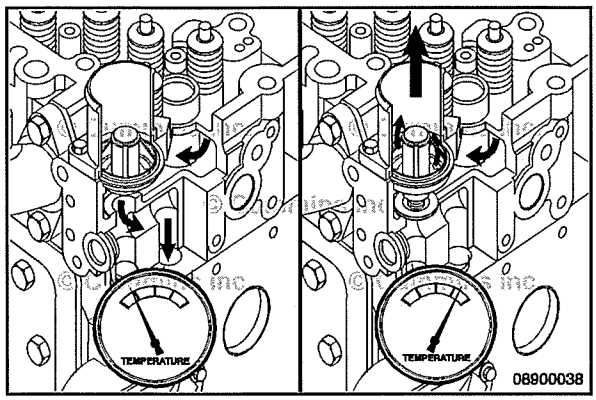


Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine to check for leaks.
- Connect power to the heating element to check for proper operation.



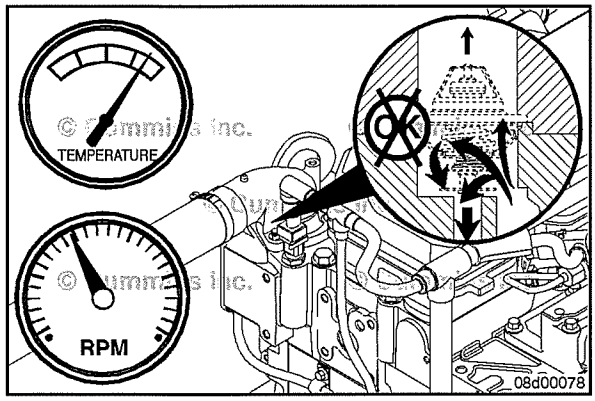
Coolant Thermostat (008-013)

General Information

The thermostat controls the engine coolant temperature. When the coolant temperature is below the operating range, engine coolant is bypassed back to the inlet of the water pump. When the engine coolant temperature reaches the operating range, the thermostat opens, seals off the bypass, and forces engine coolant to flow to the radiator or the heat exchanger.

NOTE: Some applications use an original equipment manufacturer (OEM) supplied remote mounted thermostat. Refer to the OEM service manual for location. Refer to the OEM service manual for remote mounted thermostat removal and installation instructions.

An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.

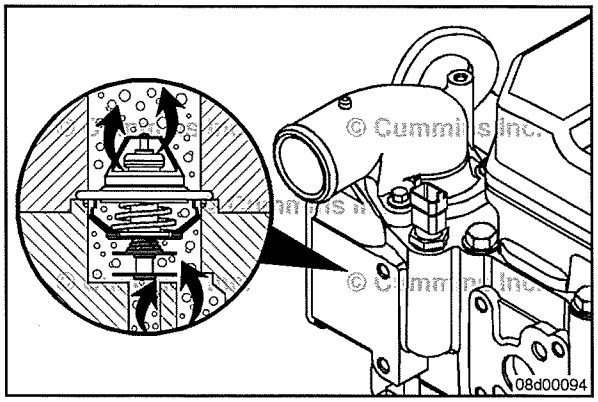


△CAUTION△
Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the water pump inlet. This can cause the engine to overheat.

⚠CAUTION⚠

A missing check ball can cause the engine to run cold, resulting in engine damage.

The thermostat contains two check balls to vent air past the thermostat when it is closed. This helps to vent air during the cooling system fill process.

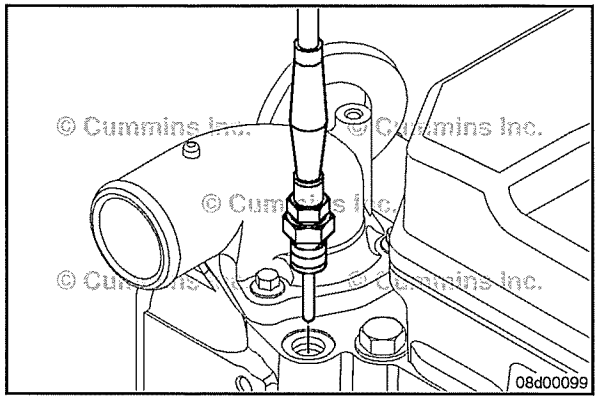


Leak Test

If the thermostat is suspected to be leaking, the following steps can be performed to check for leakage.

The following check **must** be performed with the thermostat closed for 1 minute of engine operation.

Use an electronic service tool to monitor the coolant temperature. The coolant temperature should be less than 38°C [100°F] to make sure the thermostat does **not** open during the test.

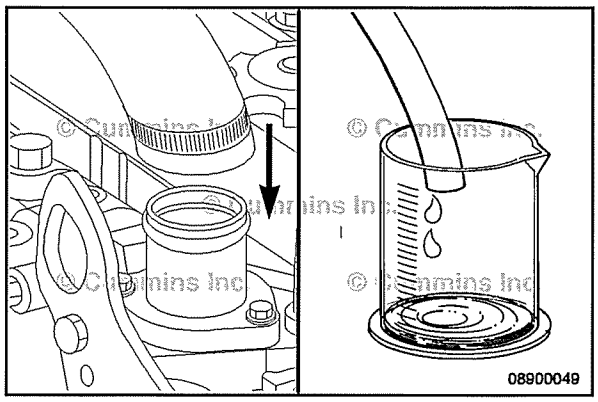


Disconnect the radiator top hose from the water outlet connection.

Install a hose of the same size on the water outlet connection. It must be long enough to reach a remote, dry container that will be used to collect coolant.

Install and tighten a hose clamp on the outlet connection.

Place the other end of the hose in the dry container.



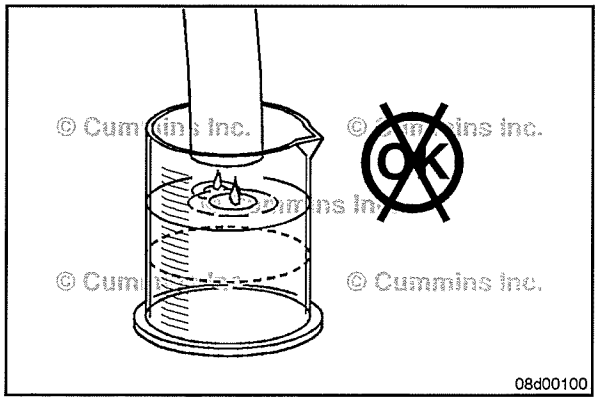
The coolant temperature should be monitored during this test to determine if the coolant temperature reaches the nominal opening temperature of the thermostat. See the Measurement section of this procedure for nominal opening temperature. If the thermostat opens during this test, the test is invalid and **must** be repeated.

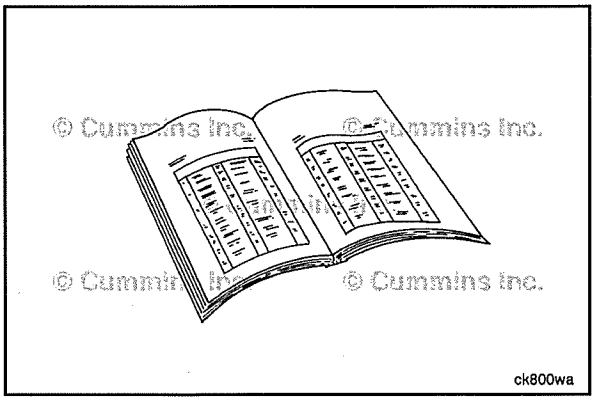
Operate the engine at rated rpm for 1 minute.

Stop the engine and measure the amount of coolant collected in the container.

The amount of coolant **must not** be more than 100 cc [3.3 fl oz].

If more than 100 cc [3.3 fl oz] of coolant is collected, the thermostat is leaking and **must** be replaced.





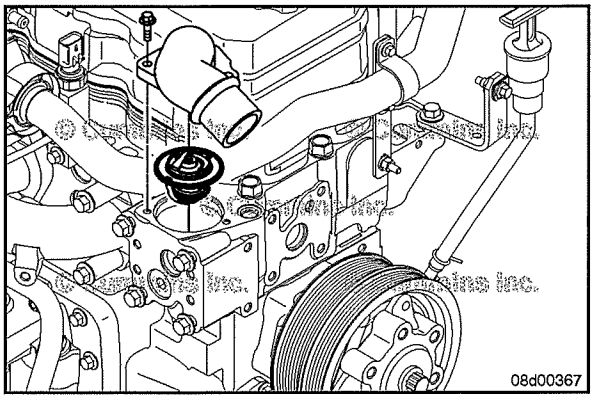
Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the battery cables. Refer to the OEM service manual.
- Drain the coolant below the level of the thermostat. Refer to Procedure 008-018 in Section 8.
- Disconnect the upper radiator hose from the water outlet connection. Refer to the OEM service manual.

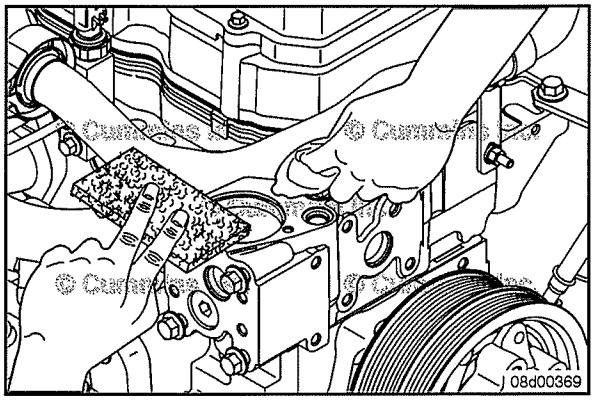


Remove

Remove the water outlet connection capscrews.

Remove the water outlet connection.

Remove the thermostat.



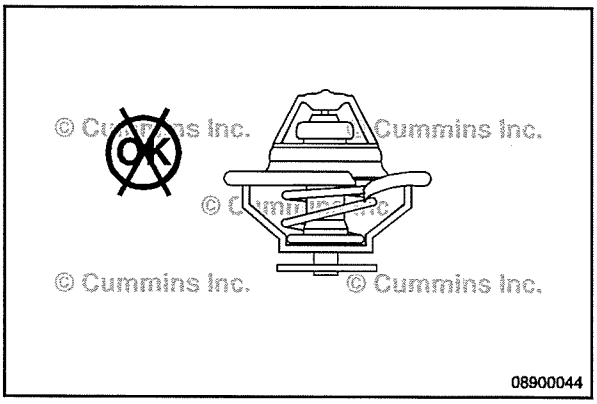
Clean and Inspect for Reuse

△CAUTION△
Do not let any debris fall into the thermostat cavity when cleaning the gasket surfaces. Damage to the cooling system and engine can occur.

Clean the mating surfaces with an abrasive pad, Part Number 3823258, or equivalent, and a clean cloth.

Inspect the thermostat for external damage. Also inspect for cracks, embedded debris, missing check balls, damaged seat, and other damage.

Replace the thermostat if any damage is found.

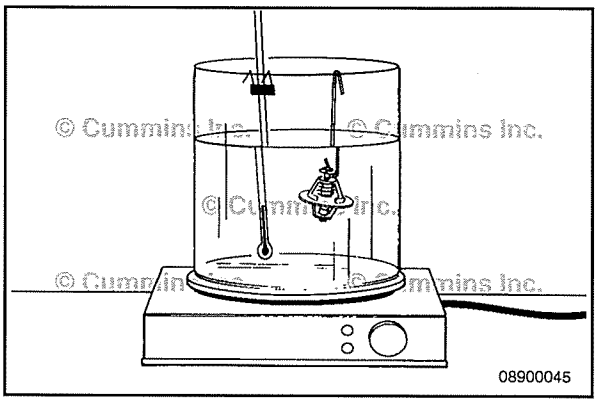


Measure

If the thermostat is suspected to be malfunctioning, the opening temperature of the thermostat should be measured to determine if the thermostat is functioning correctly.

NOTE: Do **not** allow the thermostat or thermometer to touch the container.

Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.

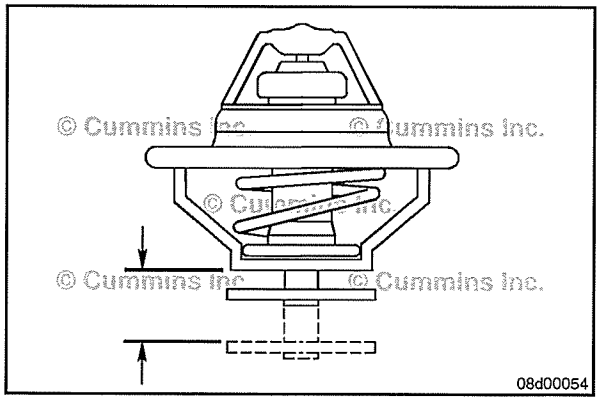


Heat the water and check the thermostat as follows:

The nominal operating temperature is stamped on the thermostat.

The thermostat **must** meet the following criteria:

Thermostat Opening Temperature			
	°C		°F
Initial Opening	86	MIN	186
	89	MAX	193
Fully Opened	97	MAX	207

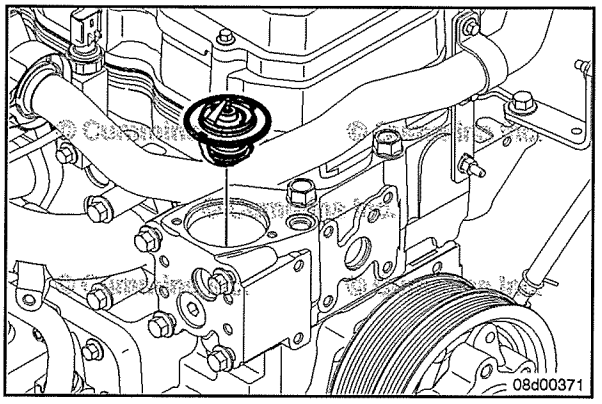


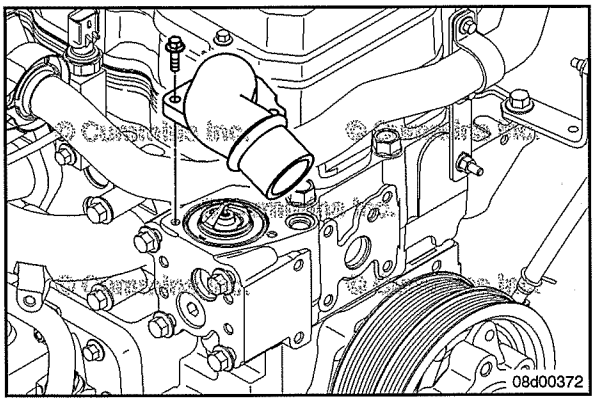
Install

⚠CAUTION⚠
Always use the correct thermostat and do not operate the engine without a thermostat installed. The engine can overheat if operated without a thermostat because the path of least resistance for the coolant is through the bypass to the pump inlet. An incorrect thermostat can cause the engine to overheat or run too cold.

NOTE: If a previously installed thermostat is being used, make sure a new thermostat seal is used.

Install the thermostat into the thermostat housing.

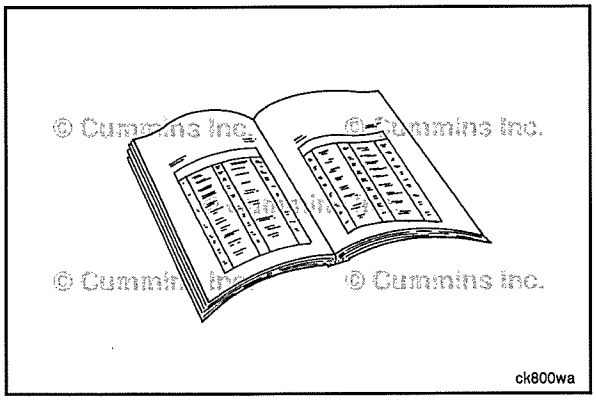




Install the water outlet connection and mounting capscrews.

Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]



Finishing Steps

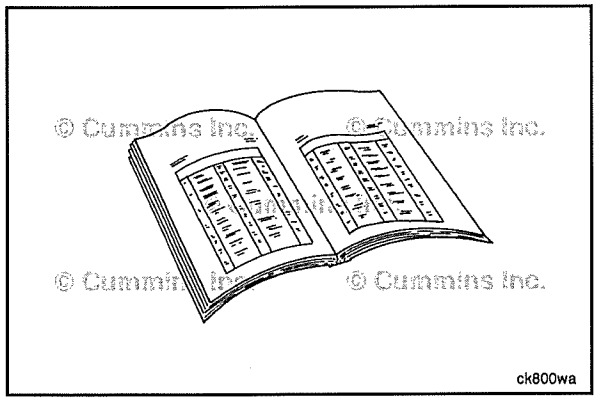
⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△CAUTION△

Always vent the engine during filling to remove air from the coolant system, or overheating can result.

- Connect the upper radiator hose to the water outlet connection. Refer to the OEM service manual.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Coolant Vent Lines (008-017)

General Information

△CAUTION△

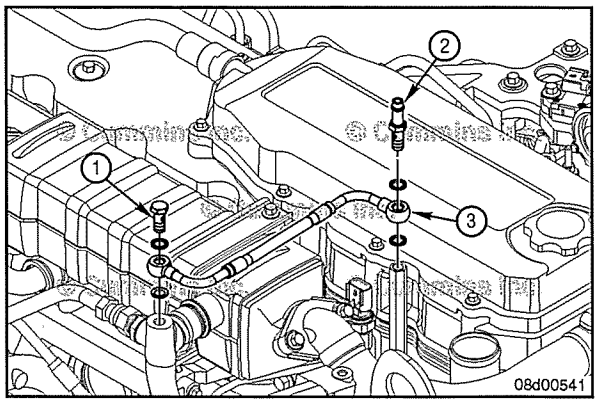
Inadequate venting can result in a cooling system failure.

The vent line routing depends on the turbocharger mounting configuration. This procedure covers both configurations.

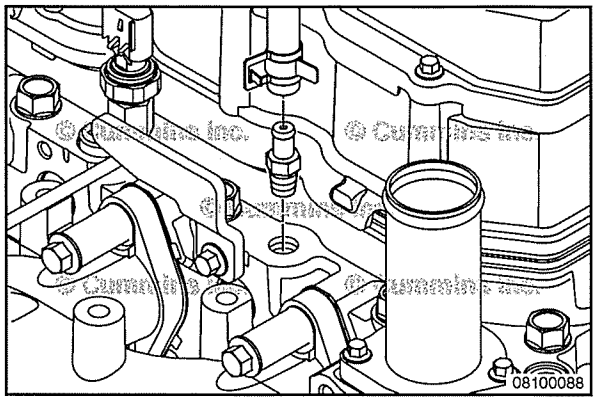
The vent line is required to remove air from the cooling system to reduce the possibility of water pump and exhaust gas recirculation (EGR) cooler cavitation.

The vent line (3) is plumbed into the EGR cooler coolant return line and cylinder head.

An OEM vent line (**not** shown) is then routed from the vent fitting to the coolant recovery/expansion tank.



Engines with a high mount turbocharger have two vent ports on the EGR cooler and a separate vent line on the cylinder head. The EGR cooler vent line attaches to the variable geometry turbocharger actuator vent line connection.

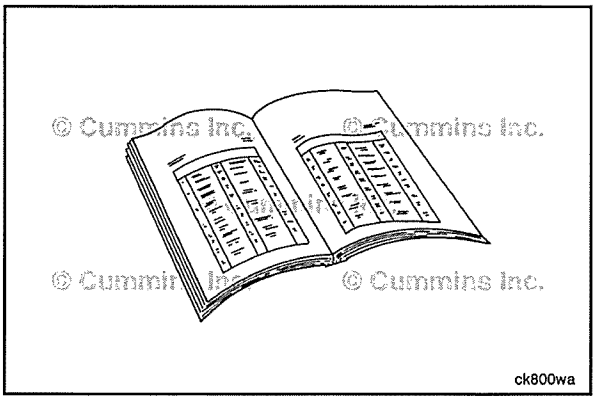


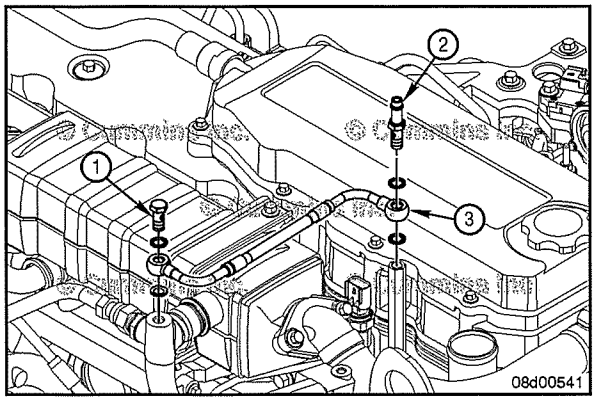
Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant below the level of the EGR cooler. Refer to Procedure 008-018 in Section 8.
- Disconnect the OEM vent line from the cylinder head adapter vent fitting. Refer to the OEM service manual.





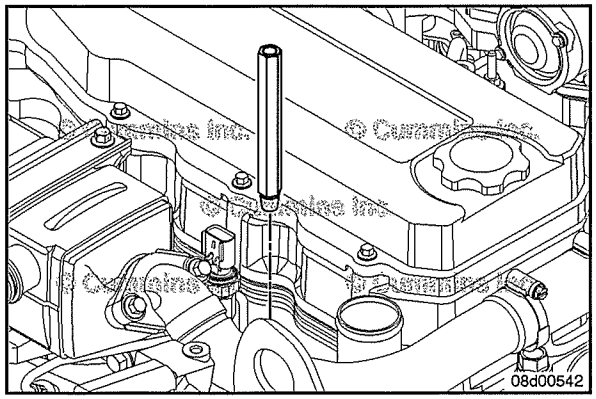
Remove

Remove the banjo bolt (1) from the EGR cooler coolant return line.

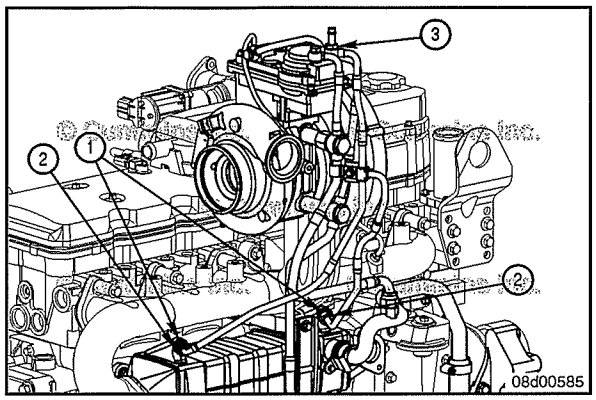
Remove the vent fitting (2) from the cylinder head adapter.

NOTE: It can be necessary to apply a counter torque to the cylinder head adapter in order to remove the vent fitting.

Remove the vent line (3).



Remove the cylinder head adapter from the cylinder head.

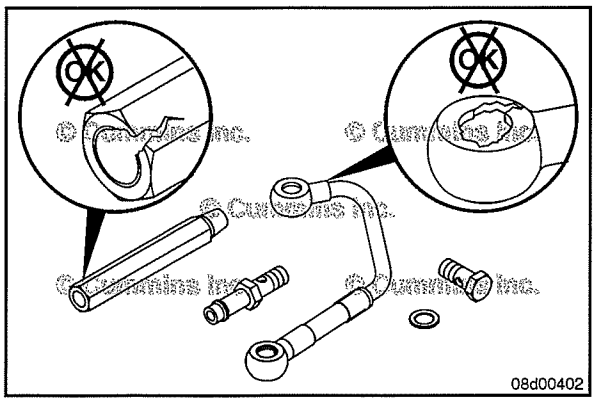


For the high mount turbocharger:

Remove the banjo bolt from the turbocharger (3).

Remove the vent line mounting nuts from the EGR cooler (2).

Remove the fittings from the EGR cooler (1).



Clean and Inspect for Reuse

Inspect the o-rings/sealing washers for damage.

Inspect the vent line, banjo bolt, cylinder head adapter, and fitting for cracks or other damage.

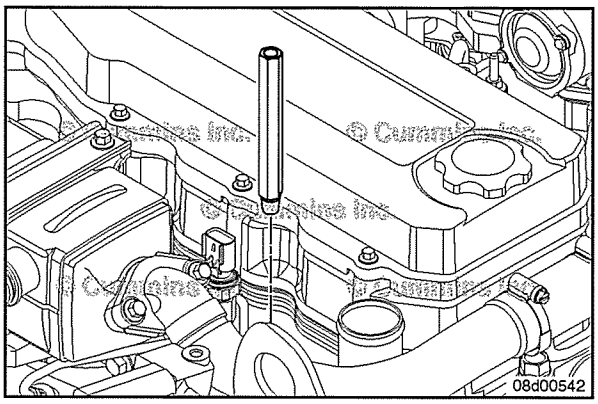
Replace if needed.

Install

Apply a film of pipe sealant, Part Number 3375066, or equivalent, to the threads.

Install the cylinder head adapter into the cylinder head.

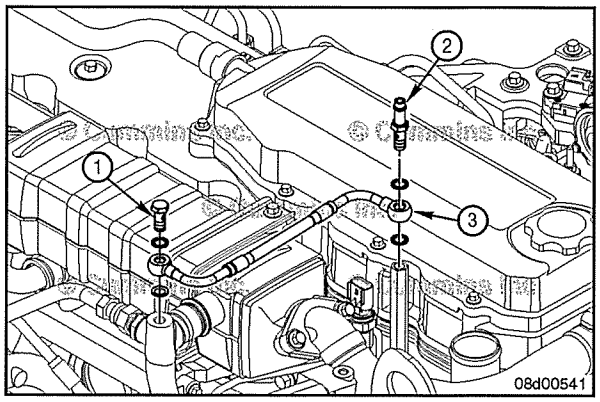
Torque Value: 25 N•m [221 in-lb]



Install the vent line and new sealing washers on the EGR cooler and cylinder head adapter.

Install the banjo bolt and new sealing washers in the EGR cooler and the vent fitting into the cylinder head adapter.

Torque Value: 7 N•m [62 in-lb]



For the high mount turbocharger:

Install the fittings to the EGR cooler vent ports (1).

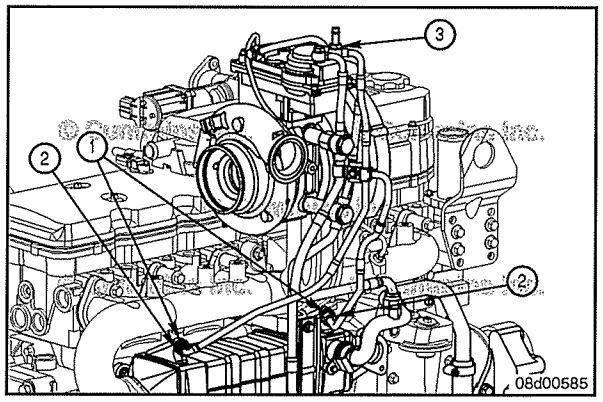
Torque Value: 24 N•m [212 in-lb]

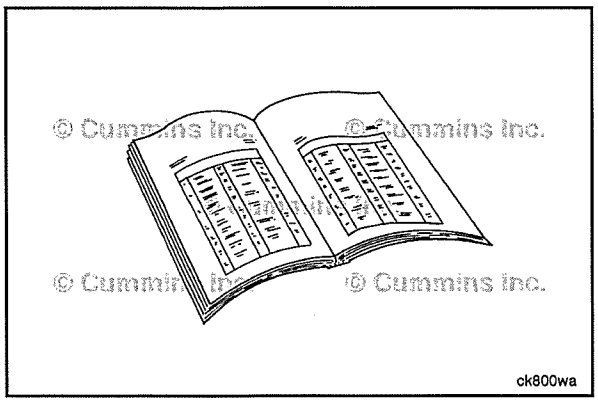
Install the vent line mounting nuts to the EGR cooler (2).

Torque Value: 15 N•m [133 in-lb]

Install the banjo bolt to the turbocharger (3).

Torque Value: 7 N•m [62 in-lb]



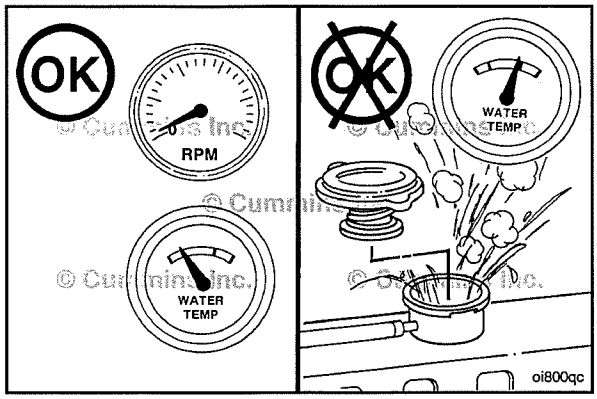


Finishing Steps

⚠CAUTION⚠

During all coolant fill procedures, all coolant flow valves to equipment heating systems must be opened in order to purge air from those systems and from the base engine cooling system. These valves must remain open during the engine cooling system de-aeration process. Make sure adequate coolant levels are maintained in the coolant reservoir during the entire fill procedure. Special care must be taken when filling EGR cooler equipped engines to make sure all air is purged from the cooling system.

- Connect the OEM vent line. Be sure the line runs continuously uphill after connecting. Refer to OEM service manual.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Cooling System (008-018)

General Information

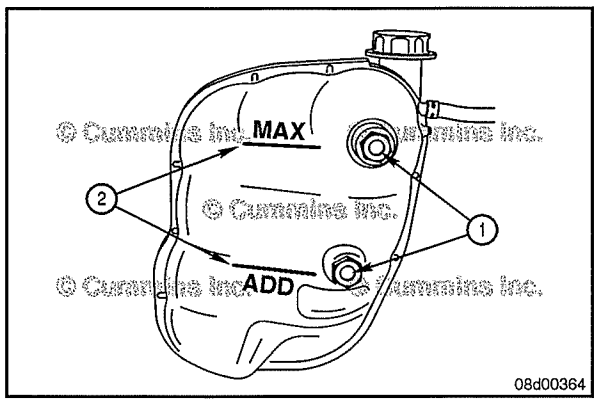
⚠WARNING⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: Never use a sealing additive to stop leaks in the coolant system. This can result in coolant system plugging and inadequate coolant flow, causing the engine to overheat.

The engine coolant level **must** be checked daily.

NOTE: In order for proper engine operation coolant system pressure to be reached, the pressure cap **must** be installed prior to starting and warming the engine. If the pressure cap is installed or removed while the engine is hot, the cooling system will not reach or maintain the proper operating pressure.



⚠CAUTION⚠

Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool below 50°C [120°F] before adding coolant.

NOTE: Use the following procedure to inspect the engine coolant level sensor. Refer to Procedure 019-017 in Section 19.

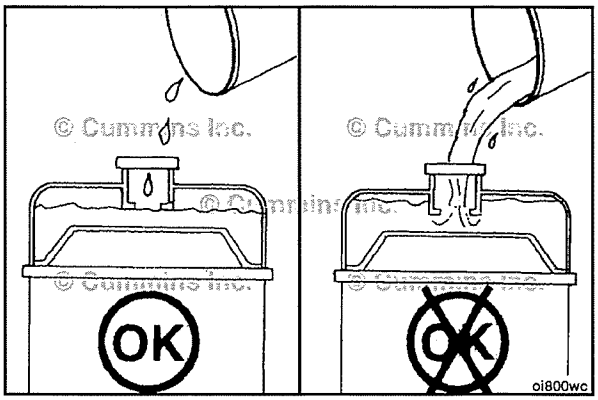
On applications that use a coolant recovery system, check to make sure the coolant is at the appropriate level on the coolant recovery tank for the engine temperature.

Many coolant recovery/expansion tanks, or are made of a semi-clear material (**not** shown) to aid in checking the coolant level without removing the radiator cap.

NOTE: Some radiators have two fill necks, both of which **must** be filled when the cooling system is drained.

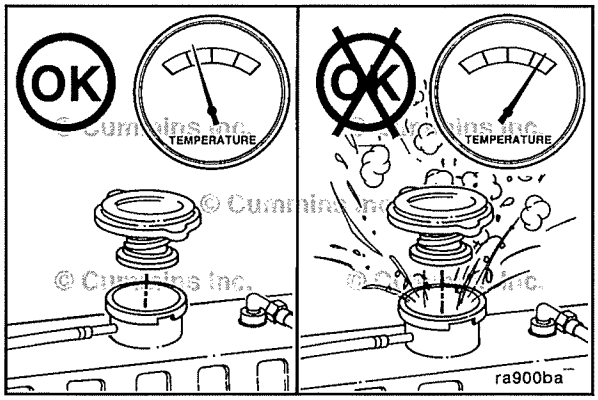
On applications that do **not** use a coolant recovery system, the top tank of the radiator is used to check and top off the coolant level. **Never** remove the radiator cap when the cooling system is hot.

Check and refill when the cooling system is cool enough to touch (below 49°C [120°F]). Coolant level should be maintained at the bottom of the filler neck. Refill only with a pre-mixed, fully formulated coolant compliant with Cummins Inc. coolant recommendations.



Drain

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.



Position the vehicle or equipment on a level surface.

Isolate the engine from the vehicle cooling system by closing coolant flow valves to the equipment heating systems before initiating repair. This will prevent the heater circuit from draining, minimizing the chance for air pockets to be present during the fill process. Refer to the original equipment manufacturer (OEM) service manual for system isolation valve locations.

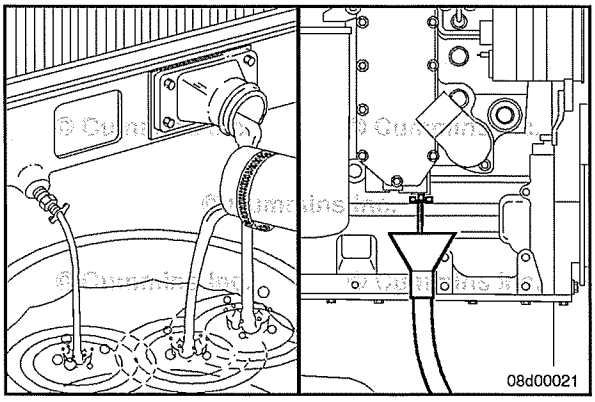
This air can be very difficult to purge in some applications that have several feet of plumbing and multiple heater cores.

NOTE: If the coolant is being changed, or if the cooling system is being flushed, it is desirable to leave the coolant flow valves to the equipment heating systems open, in order to completely drain the system.

Use the OEM service manual for any special coolant drain and fill requirements.

These special instructions can also be located near the cooling system access or fill door on the vehicle.

Remove all cooling system fill caps to allow the coolant to drain completely.

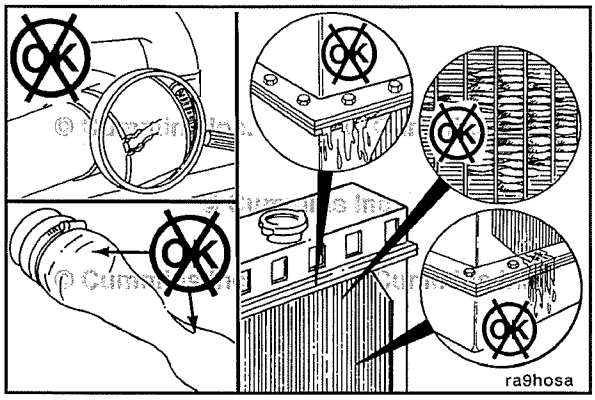


⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

NOTE: If the coolant will be reused, use a clean container to drain the coolant. Cover the container to prevent coolant contamination after draining.

Drain the cooling system by opening the drain valve on the radiator and by opening the drain valve on the bottom of the engine oil cooler housing. A drain pan with a capacity of 57 liters [15 gal] is adequate in most applications.

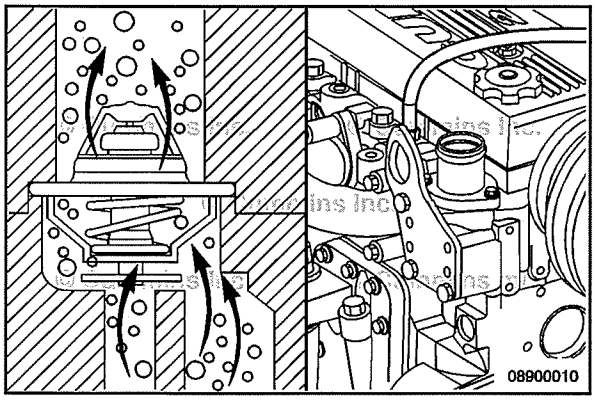
After the cooling system is completely drained, close the drain valves. Refer to the OEM service manual for complete cooling system drain information.



Check for damaged hoses and loose or damaged hose clamps. Replace as required.

Check the radiator for leaks, damage, and buildup of dirt.

Clean and replace as required.



Flush

⚠CAUTION⚠
The system must be filled properly to prevent air locks or serious engine damage can result. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

To be sure air is vented during the fill process:

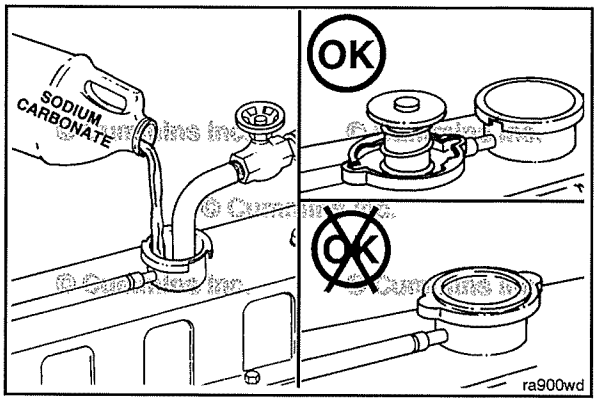
- Some thermostats have check balls that allow air to vent through the thermostat when the thermostat is closed.
- An air vent port connection, which connects to the top tank/coolant recovery tank of the cooling system, is located next to the water outlet.

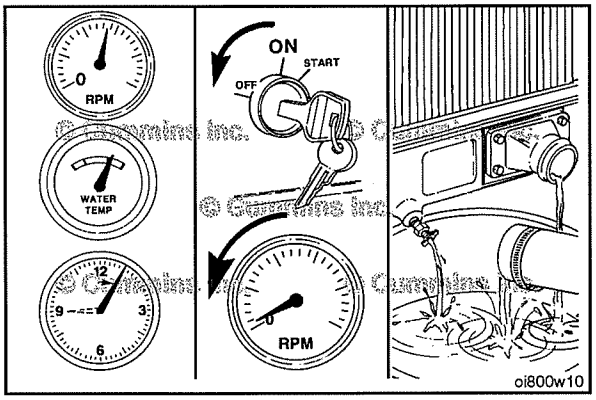
This provides adequate venting for a maximum fill rate of 19 liters [5 gal] per minute.

NOTE: An alternate to using sodium carbonate, as outlined in this procedure, is to use Restore™.

Restore™ is a heavy-duty cooling system cleaner that removes corrosion products, silica gel, and other deposits. The performance of Restore™ is dependent on time, temperature, and concentration levels. An extremely scaled or flow-restricted system, for example, can require higher concentrations of cleaners, higher temperatures, longer cleaning time, or the use of Restore Plus™. Up to twice the recommended concentration levels of Restore™ can be used safely. Restore Plus™ **must** be used **only** at its recommended concentration level. Extremely scaled or fouled systems can require more than one cleaning.

NOTE: Do **not** install the radiator cap. The engine is to be operated without the cap for this process.





⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. Dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not stand near the surge tank or radiator while operating the engine with the pressure cap OFF. If the vehicle is equipped with fill door on the side of the surge tank, keep it closed due to coolant expansion.

⚠CAUTION⚠
Do not operate the engine with the pressure cap off at temperatures above 93°C [200°F]. This can result in potential engine damage by cavitation of the water pump and localized boiling.

⚠CAUTION⚠
Before topping off coolant, allow the system temperature to cool to ambient. This will ensure that an adequate amount of coolant is available to the water pump during all periods of operation.

⚠CAUTION⚠
Do not relieve the system pressure while hot in order to "top off" immediately before returning the vehicle to service. The system will not be able to generate the pressure through the expansion of the coolant necessary for operation. This can result in potential engine damage by cavitation of the water pump and localized boiling.

Fill the cooling system with a mixture of sodium carbonate and water (or a commercially available equivalent) to the capacity or level stated in the OEM service manual.

NOTE: Adequate venting is provided for a maximum fill rate of 19 liters [5 gal] per minute.

Unless indicated otherwise by the OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the cooling system. Refer to the OEM service manual for valve locations.

Wait 2 to 3 minutes without starting the engine to allow the system to naturally purge entrained air and the coolant level to stabilize.

Add plain water to bring the level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through the heater core(s). The blower **must** be turned ON.

With the cooling system fill cap removed:

- Operate the engine at LOW IDLE for 2 minutes.
- Shut the engine OFF and add plain water to bring the level back to FULL.

With the cooling system fill cap removed:

- Start the engine.

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

Operate the engine at HIGH IDLE until the thermostat opens.

Allow the engine to return to LOW IDLE 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

Shut the engine OFF and check the coolant level according to the OEM service manual recommendations and add coolant, if necessary, to bring it back to the FULL level.

Install the cooling system fill cap.

Operate the engine for 1 to 1½ hours with the coolant temperature above 80°C [176°F].

Shut the engine OFF. Allow the coolant temperature to drop to 50° C [122° F] before draining the cooling system.

Drain the cooling system.

⚠WARNING⚠
Do not stand near the surge tank or radiator while operating engine with pressure cap off. If the vehicle is equipped with a fill door on the side of the surge tank, keep it closed due to coolant expansion.

⚠CAUTION⚠
Do not operate the engine with the pressure cap off at temperatures above 93°C [200°F]. This can result in potential engine damage by cavitation of the water pump and localized boiling.

NOTE: Do **not** install the radiator cap.

Fill the cooling system with good quality water to the capacity or level stated in the OEM service manual.

Unless indicated otherwise by OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the cooling system. See the OEM service manual for valve locations.

Wait 2 to 3 minutes, without starting the engine, to allow the system to naturally purge entrained air and the coolant level to stabilize.

Add plain water to bring the level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through heater core(s). The blower **must** be turned ON.

With the cooling system fill cap removed:

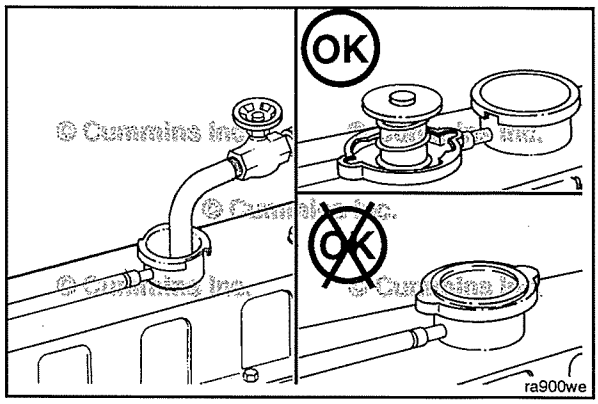
- Operate the engine at LOW IDLE for 2 minutes
- Shut the engine OFF and add plain water to bring the level back to FULL.

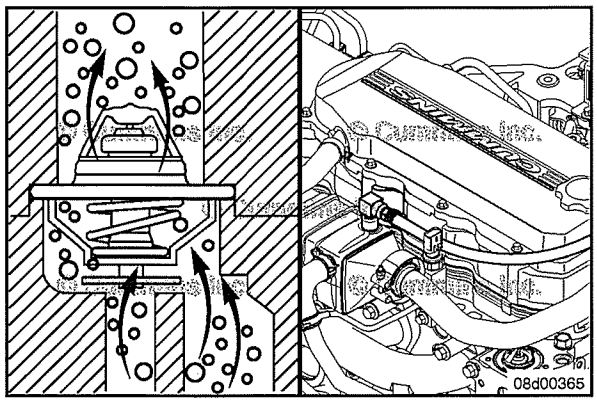
With the cooling system fill cap removed:

- Start the engine
- Operate the engine at HIGH IDLE until the thermostat opens.

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

Allow the engine to return to LOW IDLE for 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.





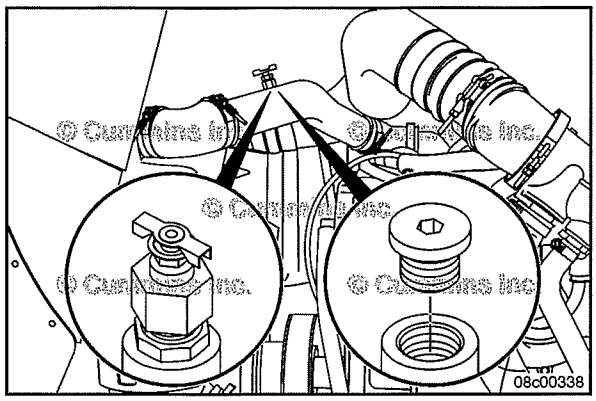
Fill

⚠CAUTION⚠
The system must be filled properly to prevent air locks or serious engine damage can result. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

Make sure air is vented during the fill process:

- Some thermostats have check balls that allow air to vent through the thermostat when the thermostat is closed.
- An air vent port connection, which connects to the top tank/coolant recovery tank of the cooling system, is located next to the water outlet.

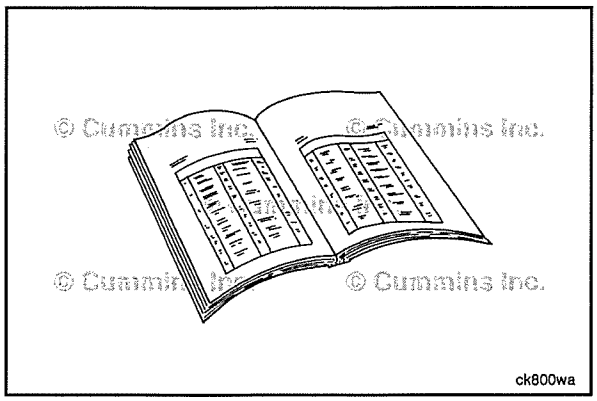
The system has a design maximum fill rate of up to 19 liters [5 gal] per minute.



NOTE: Some applications may be equipped with a manual bleed valve which is to be opened to make sure of a proper fill. The upper radiator pipe is a common location for bleed valves. The illustration is for reference **only**.

If applicable, open the manual bleed valve before filling the cooling system.

Once properly filled, make sure to close the manual bleed valve.



⚠CAUTION⚠
Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

See the following for engine coolant specifications. Refer to Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.

NOTE: If the coolant is reused, inspect it for signs of contamination.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Do not stand near the surge tank or radiator while operating the engine with the pressure cap off. If the vehicle is equipped with a fill door on the side of the surge tank, keep it closed due to coolant expansion.

△CAUTION△
Do not operate the engine with the pressure cap off at temperatures above 93°C [200°F]. This can result in potential engine damage by cavitation of the water pump and localized boiling.

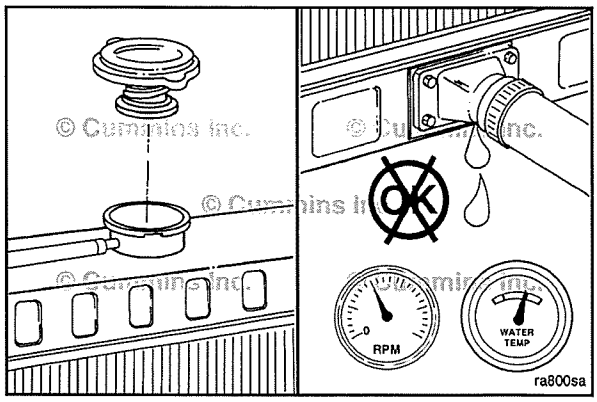
△CAUTION△
Topping off the system while hot is not recommended when using the fill door on transit bus applications equipped with surge tanks. Bringing the level to the bottom of the door while the system is hot will not provide adequate volume of coolant for lower operating temperatures. This can result in cavitation of the water pump and greatly increase the potential for engine damage.

△CAUTION△
Before topping off coolant, allow the system temperature to cool to ambient. This will ensure that an adequate amount of coolant is available to the water pump during all periods of operation.

△CAUTION△
Engine and component damage may result if adequate cool down time is not given after the cooling system pressure has been relieved in order to "top off". System pressure is only generated with temperature rise of coolant. Closing the cooling system while hot will not allow pressure to build.

Remove the cooling system fill cap.

Fill the cooling system to the capacity or level stated in the OEM service manual, using a mixture of 50 percent water and 50 percent ethylene glycol or propylene glycol antifreeze.



Sequence of Events for Coolant Fill and Deaeration

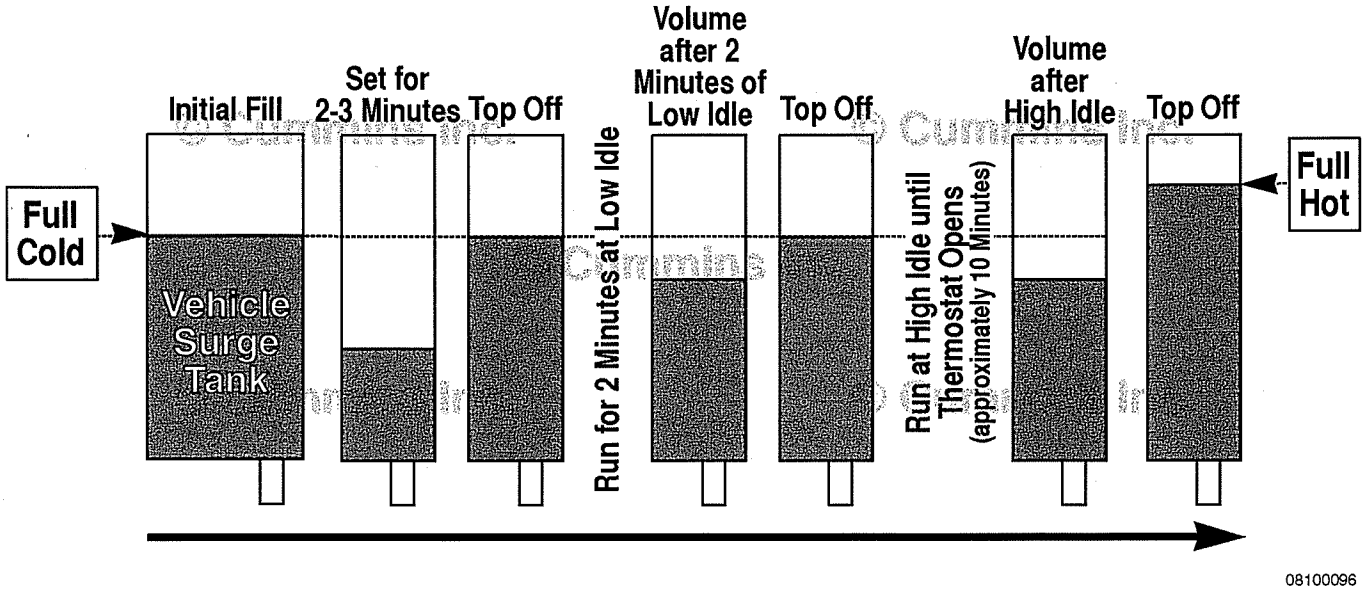


Figure 1: Sequence of Events for Coolant Fill and Deaeration.

NOTE: If all coolant drained from the system was collected, the same volume or more **must** go back into the system. If any drained coolant remains after filling, this is an indication of an air pocket which **must** be purged before returning the vehicle to service.

Unless indicated otherwise by OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the heating circuit. See the OEM service manual for valve locations.

Wait 2 to 3 minutes, without starting the engine, to allow the system to naturally purge entrained air and coolant level to stabilize.

Add a 50/50 mixture to bring the coolant level back to the FULL cold level.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through heater core(s). The blower **must** be turned ON.

With the cooling system fill cap removed:

- Operate the engine at LOW IDLE for 2 minutes.
- Shut the engine OFF and add coolant to bring the level back to the FULL cold level, using 50/50 mixture.

With the radiator pressure cap off:

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

- Start the engine.
- Operate the engine at HIGH IDLE until the thermostats open.

Allow the engine to idle 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

- Shut the engine OFF.
- Top off coolant to the FULL hot level.
- It is the responsibility of the customer to check the cold coolant level and top up if necessary.

NOTE: Certain applications may require an additional 10 minutes of operation time at HIGH IDLE for complete deaeration. For best results, reference the OEM coolant fill procedure for specific instructions.

Allow the engine to cool to 50°C [176°F], then install the pressure cap. Operate the engine until it reaches a temperature of 80°C [176°F] and check for coolant leaks.

Reference Figure 1 for a graphic explanation of the fill process.

Cooling System Diagnostics (008-020)

General Information

The following procedure covers common troubleshooting steps to help identify:

- Engine overheat causes. See the Initial Check section of this procedure.

NOTE: At the end of this procedure, a worksheet is provided to record any measured values taken during troubleshooting. The worksheet will help in gathering and analyzing the data.

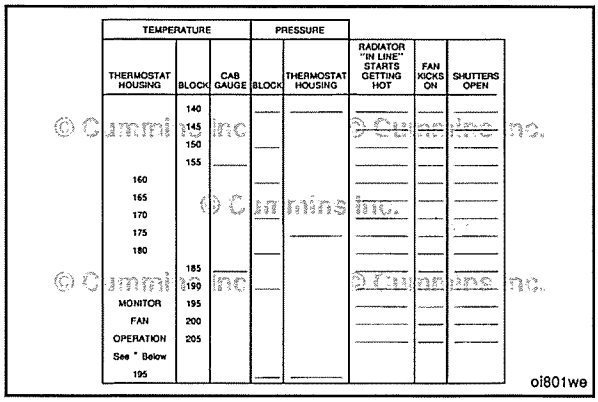
- External and internal coolant leaks/loss. See the Pressure Test section of this procedure.
- Combustion gas leaks into the cooling system. See the Test section of this procedure.

If the coolant reaches an unacceptable level in the recovery/expansion tank, a fault code should become active that will illuminate an instrument lamp and impose a power derate. This low level is detected by a coolant level switch mounted in the coolant surge/recovery tank.

In the event of a cooling system-related malfunction, it is recommended that coolant level switches be checked for proper operation. Refer to the OEM service manual for operational checks and repairs.

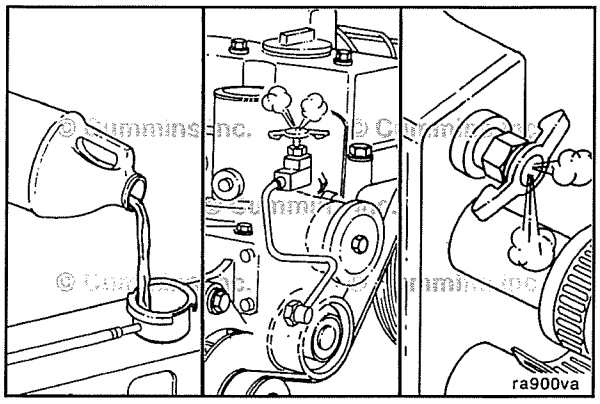
Removal and installation of the coolant level switch for diagnostics is **not** recommended. This poses a high likelihood of damage, due to the plastic construction of the switch. The coolant level switch **must only** be removed from the surge/recovery tank when replacing it with a new switch. Be certain **not** to overtighten the switch when installing. Most switches have a very low torque value, which can be found in the OEM service manual.

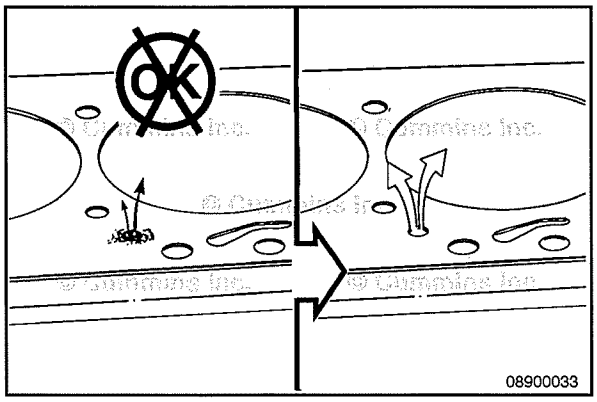
Coolant level switches are very susceptible to improper Ph levels. For this and other reasons, it is imperative that the coolant be maintained in accordance with the following service bulletin. Refer to Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.



The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

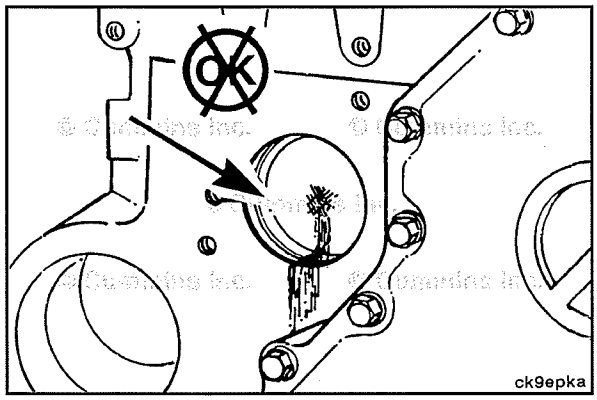
NOTE: The engine or system has a leak if frequent addition of coolant is necessary. Find and repair the leak.





Obstructions in the coolant passages will reduce coolant flow, which can lead to overheating.

NOTE: The small holes in the head gasket are especially susceptible to plugging. Their size is critical. Do **not** enlarge the size of the orifices. Doing so will disturb the coolant flow and will not solve an overheating problem.

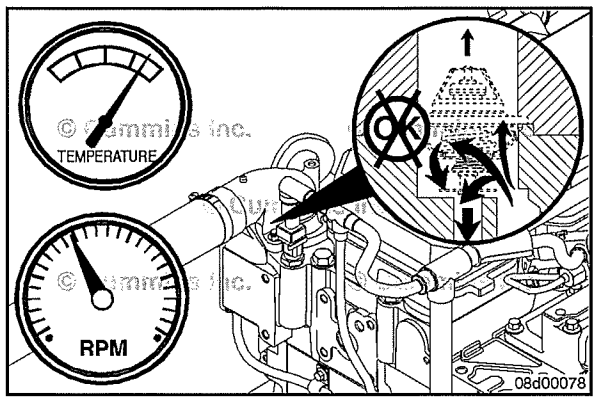


Water will cause rust formation, reducing the flow in the smaller coolant passages.

Also, water used as a coolant for even a relatively short period can result in the expansion plugs rusting through, which will allow the coolant to leak.

Use a 50/50 mixture of coolant and water to fill the coolant system.

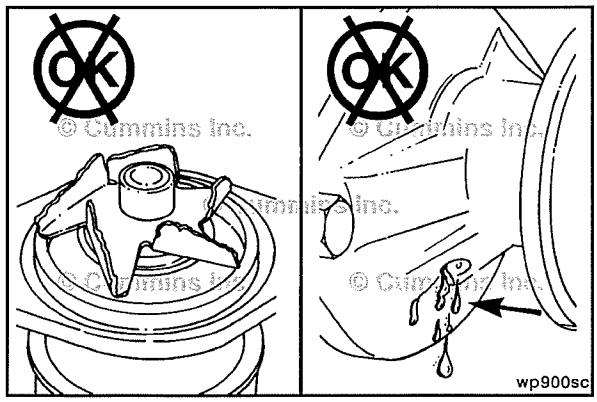
NOTE: A sudden loss of coolant from a heavily loaded engine can result in severe damage to the pistons and cylinder bore.



Thermostat

⚠CAUTION⚠
Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the water pump inlet. This can cause the engine to overheat.

There are different temperature range thermostats available depending on the engine type and application. The part number and nominal operating temperature are stamped on the thermostat. To verify that the correct temperature range and part number thermostat is installed, make sure to reference the appropriate part information resources. Refer to Procedure 008-013 in Section 8.



Water Pump

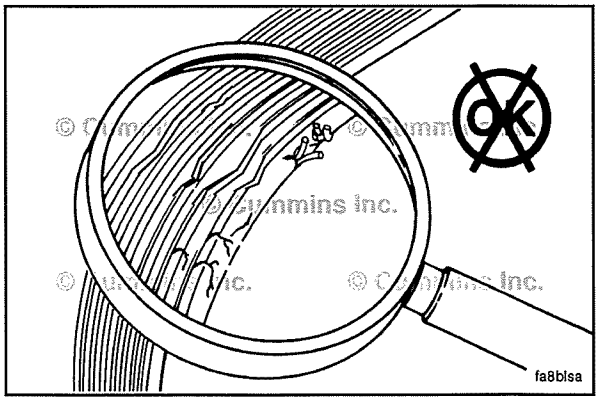
A damaged or an incorrect water pump can lead to an engine overheat condition. To verify that the correct water pump is installed, reference the appropriate part information resources. Refer to Procedure 008-062 in Section 8.

Belt and Belt Tensioner

A worn/incorrect belt, belt tensioner, or misaligned pulley can cause:

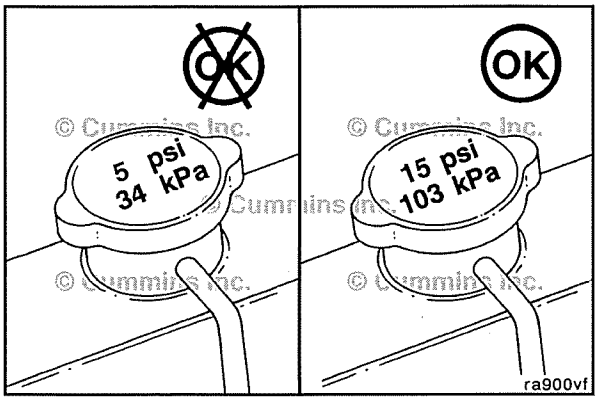
- Belt slip
- Belt jump or "walk off"
- Noise
- Belt breaks and shredding
- Component bearing seizure.

This can reduce water pump and/or cooling fan rotation speeds, resulting in an engine overheat condition. Refer to Procedure 008-002 in Section 8. Refer to Procedure 008-087 in Section 8.



Pressure Cap

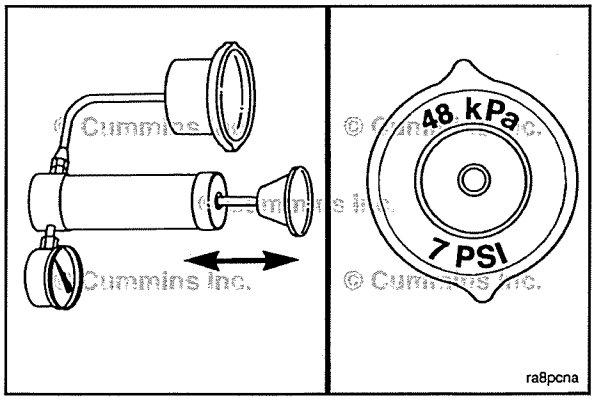
A commonly overlooked item when troubleshooting the cooling system is the radiator pressure/expansion tank cap. The cooling system is designed to use a pressure cap to prevent boiling of the coolant. An incorrect, damaged, or malfunctioning cap can result in the loss of coolant and in an engine overheat condition. Refer to the OEM service manual for the recommended pressure cap rating. Use the following procedure for the Cummins Inc. recommended minimum pressure cap rating. Refer to Procedure 008-018 in Section 8.



An incorrect or malfunctioning cap can also result in the loss of coolant and in an engine overheat condition.

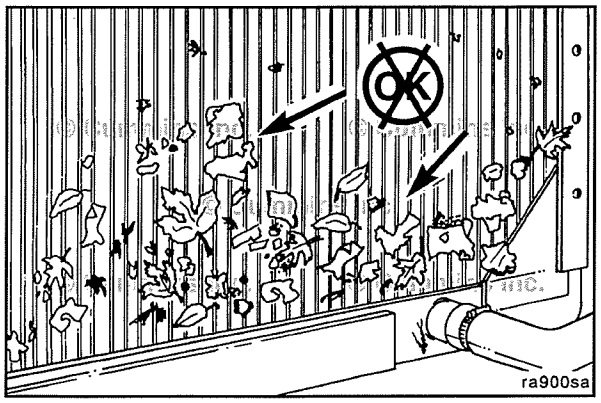
Pressure test the radiator cap. Refer to the OEM service manual.

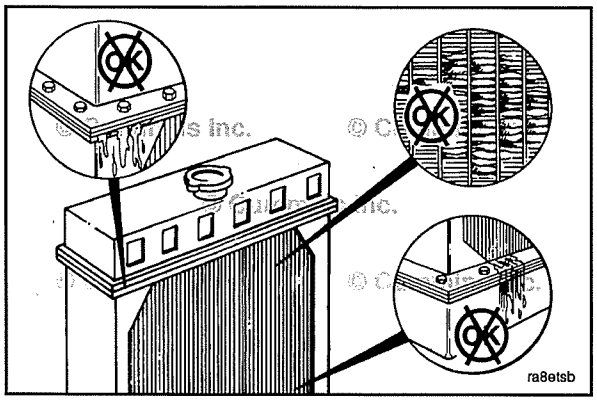
The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.



Radiator

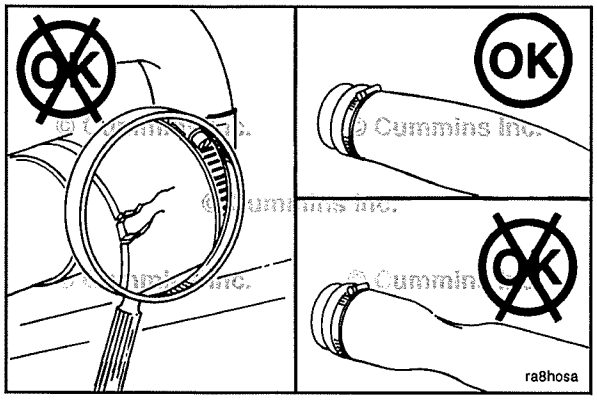
Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (such as paper, straw, lint, and dust) can obstruct the fins and stop the flow of air, which will reduce the cooling effect of the radiator.





The radiator **must** be inspected for bent/broken fins and coolant leaks periodically.

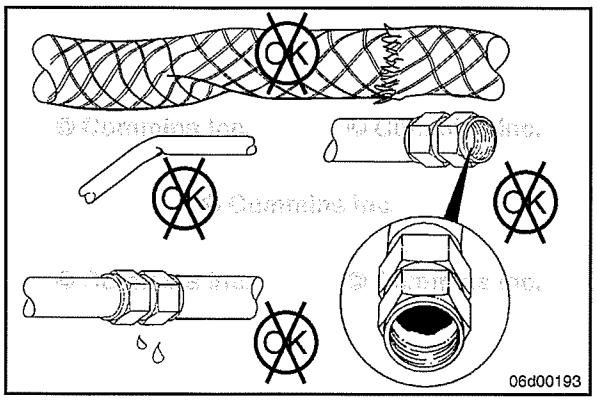
For maintenance, removal, or installation of the radiator, refer to the OEM service manual.



Coolant Hoses

Collapsed or damaged coolant hoses can result in engine heating problems. Make sure to inspect all hoses for cracks, cuts, or collapsing. Replace any damaged hoses.

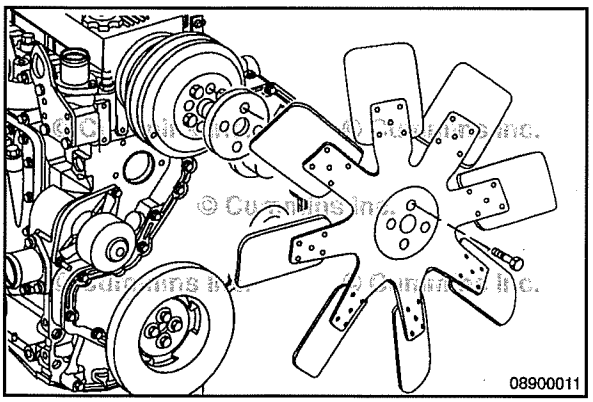
NOTE: Silicone engine coolant hoses will exhibit swelling due to the elasticity of the hose.



Aftertreatment Diesel Exhaust Fluid (DEF) Coolant Lines and Fittings

The aftertreatment DEF system contains coolant lines to heat the aftertreatment DEF tank and cool the aftertreatment DEF dosing valve.

Inspect aftertreatment DEF coolant lines and fittings for leaks, blockages, or restrictions.



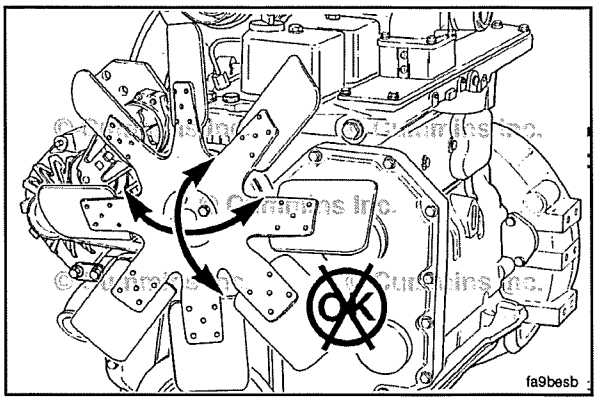
Cooling Fan

The engine cooling fan is typically driven by a crankshaft-driven belt. In some applications, the fan is located off the engine for a remote mounted cooling system.

The cooling fan is supplied by the OEM and they **must** be contacted for any service-related information. This procedure **only** highlights some of the items related to cooling fans.

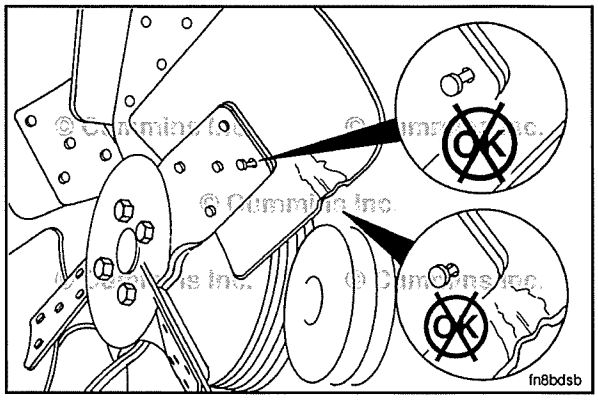
If the fan is belt-driven, a slipping belt will result in a slower fan speed and reduced cooling. A malfunctioning automatic belt tensioner can be the problem. Refer to Procedure 008-087 in Section 8.

Check the bearings in the fan hub and other pulleys to make sure they are **not** causing excessive belt vibration and slippage. Refer to Procedure 008-036 in Section 8.

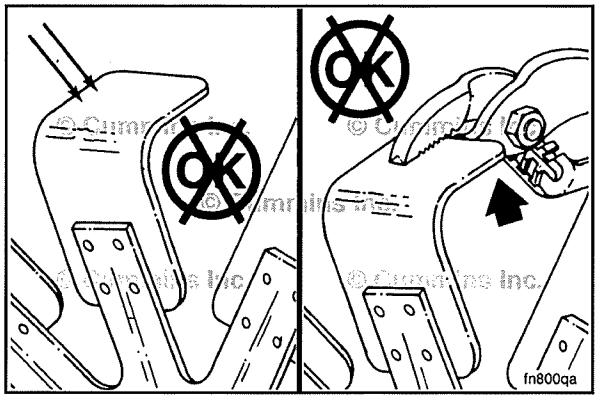


The cooling fan **must** be inspected periodically. Check for cracks, loose rivets, and bent or loose blades.

Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.

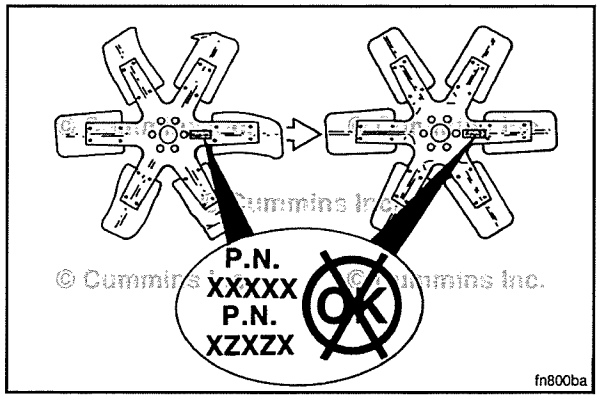


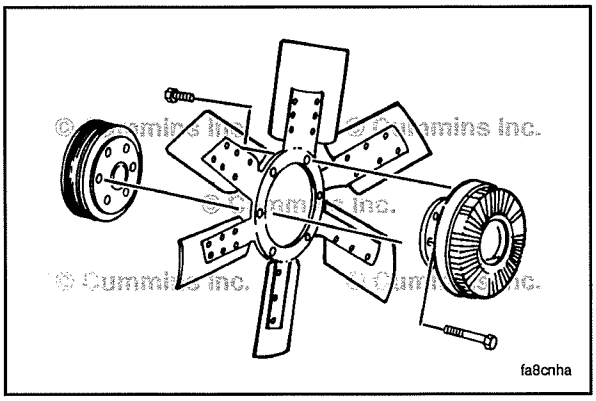
⚠WARNING⚠
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.



Replace a damaged cooling fan with an exact equivalent cooling fan **only**. Although same size cooling fans can appear similar, there are potential differences in the blade pitch and profile.

Some cooling fans can be installed backwards. Check to make sure the fan is pushing or pulling air in the proper direction.





Fan Drive

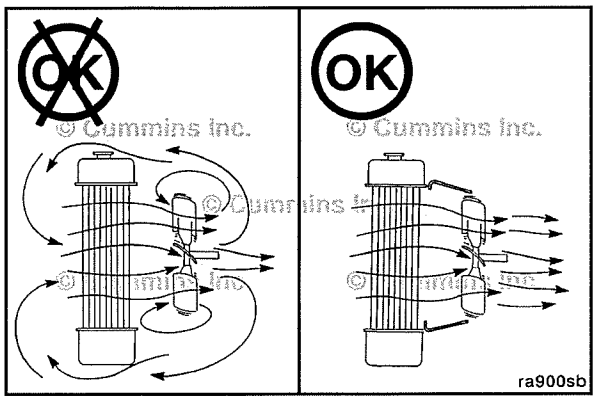
A malfunctioning fan drive can cause engine cooling problems.

Various fan drive configurations are used to determine when the fan is driven, which include:

- Direct drive - the fan is engaged all of the time
- Air engaged/disengaged clutch
- Electric/electromagnetic clutch
- Viscous clutch
- Hydraulic drive
- Crankshaft/Power Takeoff (PTO) driven.

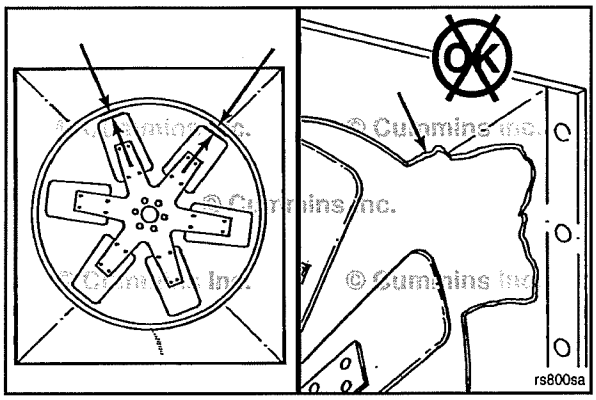
If the speed of the fan is controlled by an electronic hydraulic controller, check that the controller is plugged in and functioning properly. Depending on the system design, an inactive hydraulic controller will cause the fan to always run at either high or low speed. Running at high speed may create excessive loads on the engine; running at low speed may lead to engine overheating.

Use the following procedure for information on electromagnetic fan clutches supplied by Cummins Inc. Refer to Procedure 008-026 in Section 8. For other fan clutches, refer to the OEM service manual.



Fan Shroud Assembly

A fan shroud assembly is used to direct the airflow provided by the cooling fan. A missing or damaged fan shroud will reduce the amount of air flow provided by the cooling fan and can cause an engine coolant overheat condition.

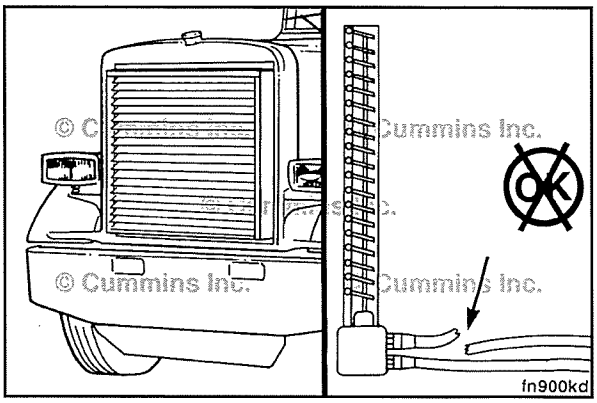


Check the fan shroud for damage and/or contact with the cooling fan. Replace any damaged components. Refer to the OEM service manual.

Radiator Shutters

Shutters are designed to control airflow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much airflow and the engine running cold.

NOTE: Make sure the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks. Refer to the OEM service manual.

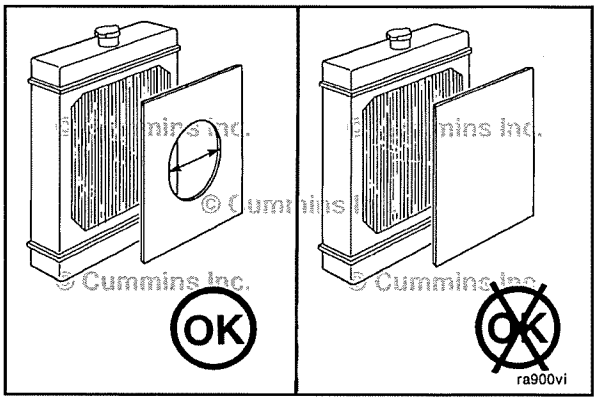


Winter Fronts

Winter fronts can be used to reduce the engine warm-up time and help maintain engine heat in cold climate locations.

The winter fronts should **only** cover part of the frontal area of the cooling system, leaving part of the frontal area open to air flow. Use the following procedure for the minimum required air passage area. Refer to Procedure 008-018 in Section 8.

Failure to leave part of the front area open to airflow or leaving the winter fronts installed when ambient temperatures increase can lead to an engine overheat condition.

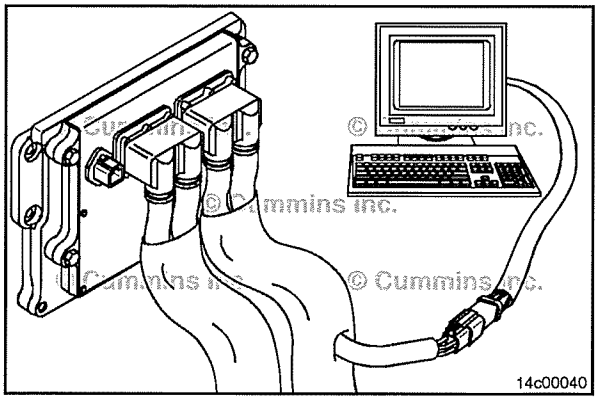


Initial Check

Connect an electronic service tool to the vehicle's data link.

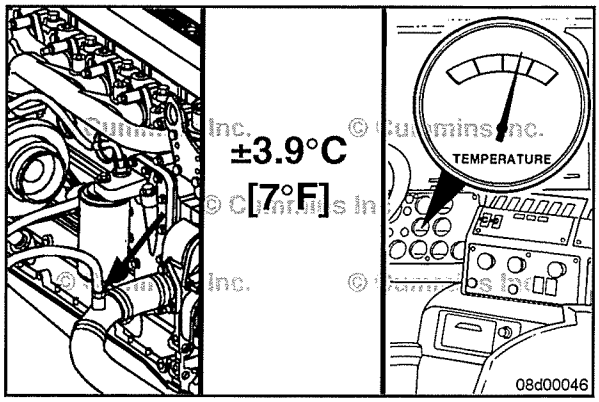
Turn the keyswitch to the ON position.

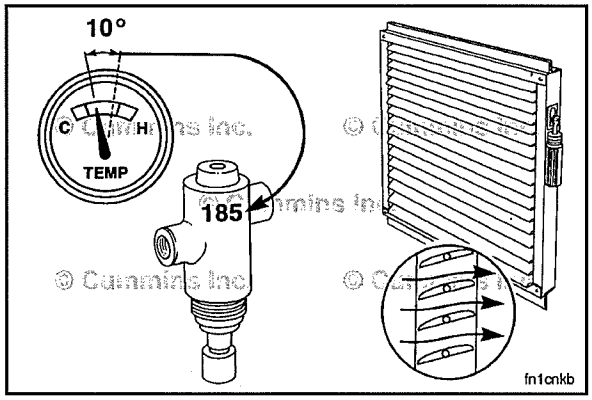
Monitor the coolant temperature with the electronic service tool.



If equipped with an in-dash coolant temperature gauge, monitor coolant temperature with an electronic service tool and compare the cab temperature gauge reading. Replace the cab temperature gauge if it is **not** within the manufacturer's specifications of the correct reading.

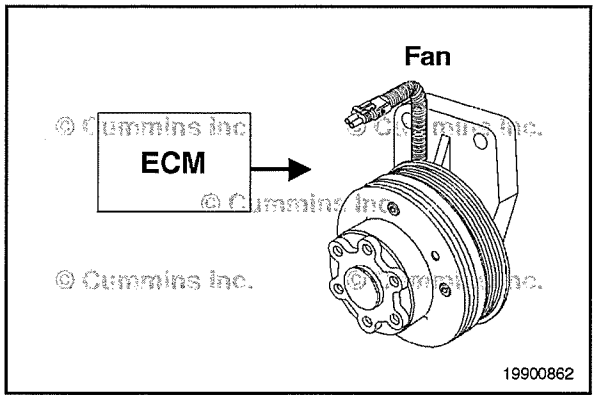
If the manufacturer's specifications are **not** available, replace the gauge if it is **not** within ±3.9°C or ±7°F of the correct reading.





For vehicles equipped with temperature controlled shutters, check the coolant temperature at which the shutters open and close. Compare this value to what is stamped on the shutter control.

Cummins Inc. recommends that the shutters open at 85°C [185°F] engine coolant temperature.



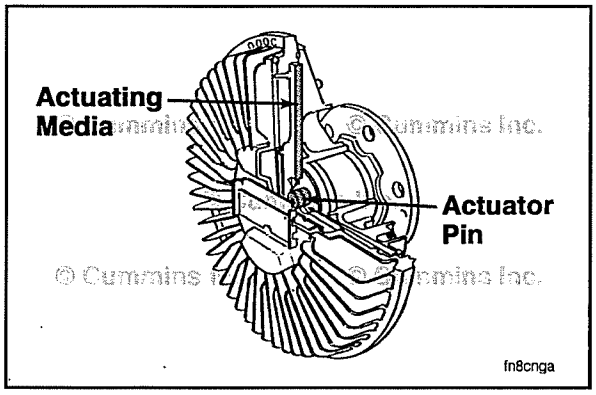
If equipped with a temperature controlled cooling fan clutch, check the coolant temperature at which the fan clutch engages.

If the fan clutch engagement is controlled by a fan control on the vehicle, compare the recorded value to what is stamped on the fan control and/or reference the OEM service manual.

If the fan clutch engagement is controlled by the engine's engine control module (ECM), the engagement coolant temperature is a set value that can **not** be changed. If the fan clutch does **not** engage, check to make sure the fan control logic parameter is set correctly.

The ECM is capable of using either a zero ("0") VDC or system voltage signal to engage the fan clutch. The exact enable logic can be selected in the Features and Parameters section of INSITE™ electronic service tool.

Cummins Inc. recommends that the fan engage at 99°C [210°F] engine coolant temperature.



If equipped with a viscous fan drive, check the coolant temperature at which the fan engages. Viscous fan clutches are typically activated by a built-in sensor behind the radiator that monitors air temperature.

NOTE: Some viscous fan drives can be electronically controlled.

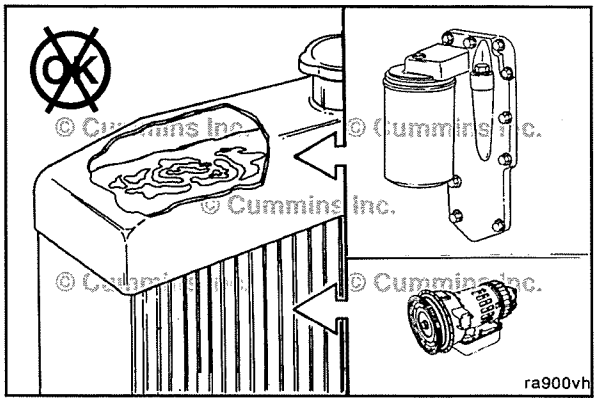
When the air temperature reaches a specific level, depending on the temperature setting of the sensor used, the temperature-sensing control moves an actuator that allows viscous fluid to engage the fan drive and increase the fan speed. For more information, refer to the OEM service manual.

Cummins Inc. recommends that the fan engage at 99°C [210°F] engine coolant temperature.

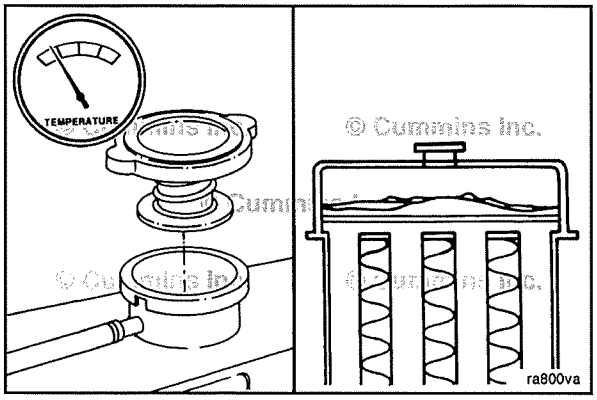
Pressure Test

The operating pressure of the cooling system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems: cylinder head gasket, lubricating oil cooler, etc.

Transmission/power steering/hydraulic fluid can also leak into the coolant through radiator fluid coolers, if equipped. Refer to the OEM service manual.



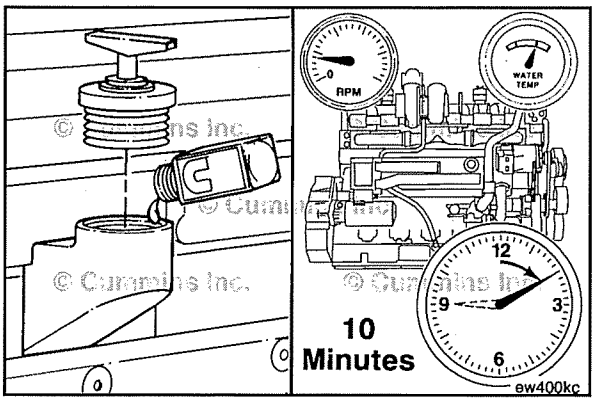
Check the coolant level and fill if necessary. Refer to Procedure 008-018 in Section 8.



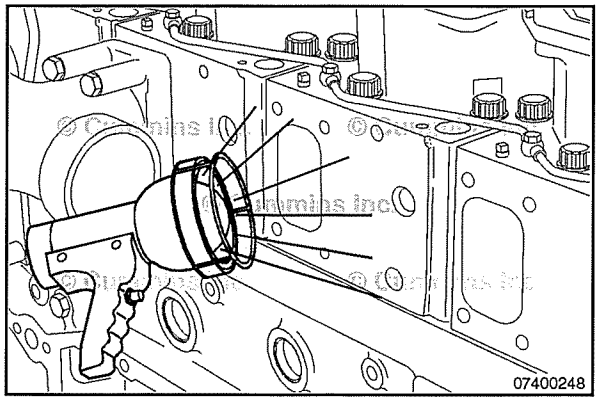
To aid in determining the location of the coolant leak, it may be necessary to add fluorescent tracer, Part Number 3377438, to the coolant.

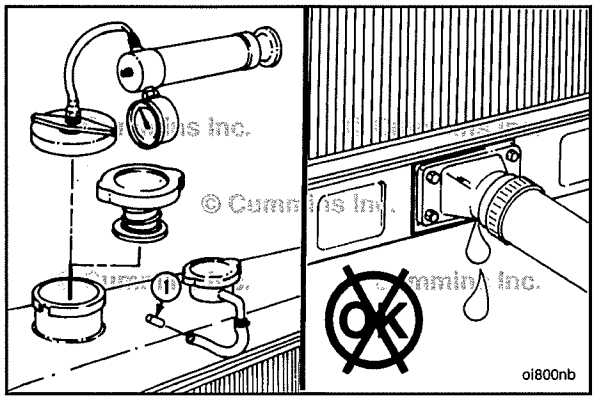
Add one unit of fluorescent tracer to each 38 liters [10 gal] of coolant.

Idle the engine for 5 to 10 minutes or until normal operating temperature is reached, to allow the dye to circulate through the cooling system.



Use a high intensity black light, Part Number 3163337, or equivalent, to illuminate the dye.



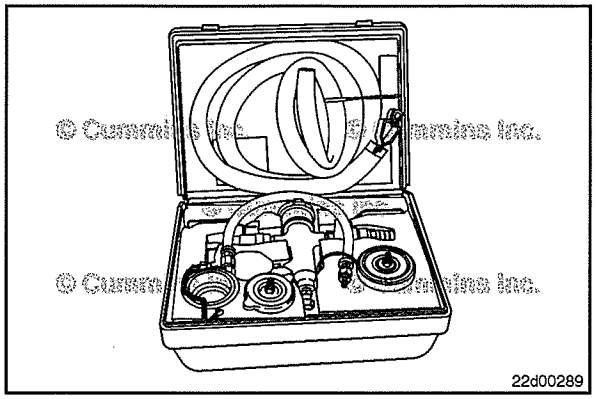


⚠CAUTION⚠
Do not apply more than 138 kPa [20 psi] air pressure to the cooling system. The water pump seal can be damaged.

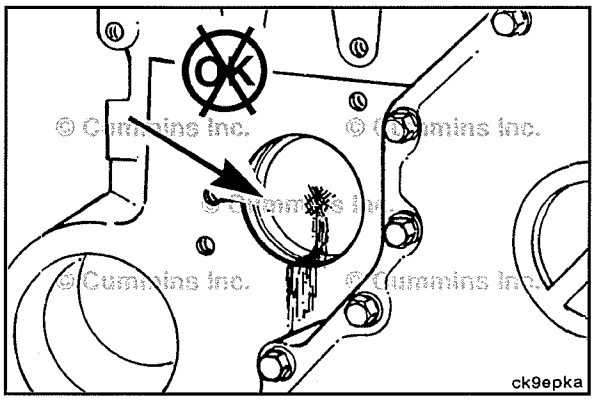
If the radiator is equipped with a pressure relief valve, plug the overflow line (1).

Install the pressure tester on the radiator fill neck or surge tank, if equipped, and apply air pressure.

Measurements		
	kPa	psi
Air Pressure	138	20



The Coolant Dam™/Pressure Tester service tool, Part Number 3824319, can also be used to pressurize the cooling system. The Coolant Dam™/Pressure Tester uses shop air rather than a hand air pump.



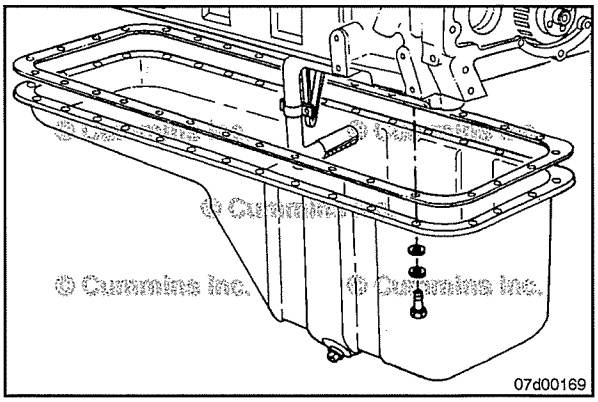
For external coolant leaks, inspect the exterior of the engine and repair if necessary.

Pay close attention to areas around the:

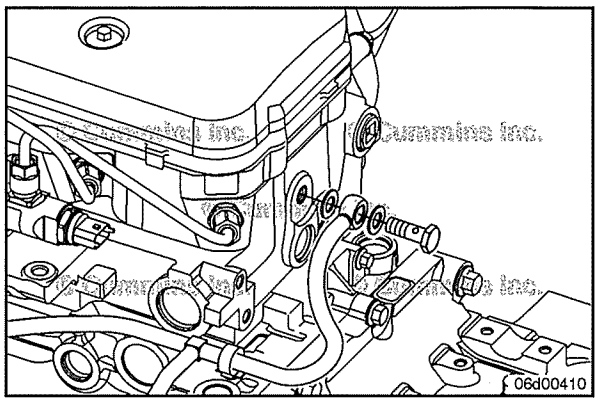
- Lubricating oil cooler. Refer to Procedure 007-003 in Section 7.
- Water pump. Refer to Procedure 008-062 in Section 8.
- Air compressor head gasket. Refer to Procedure 012-014 in Section 12.
- Cup plugs. Refer to Procedure 017-002 in Section 17.
- Pipe plugs. Refer to Procedure 017-007 in Section 17.
- Exhaust gas recirculation (EGR) cooler. Refer to Procedure 011-019 in Section 11.
- EGR coolant lines. Refer to Procedure 011-031 in Section 11.
- Variable geometry turbocharger. Refer to Procedure 010-033 in Section 10.
- Variable geometry turbocharger coolant lines. Refer to Procedure 010-041 in Section 10.

For internal coolant leaks, inspect the interior of the engine. It may be necessary to remove the following components to look for signs of a coolant leak:

- Rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Turbocharger oil drain line. Refer to Procedure 010-045 in Section 10.



For suspected fuel in the coolant or coolant in the fuel, disconnect the fuel drain connection at the rear of the cylinder head. Refer to Procedure 006-013 in Section 6.

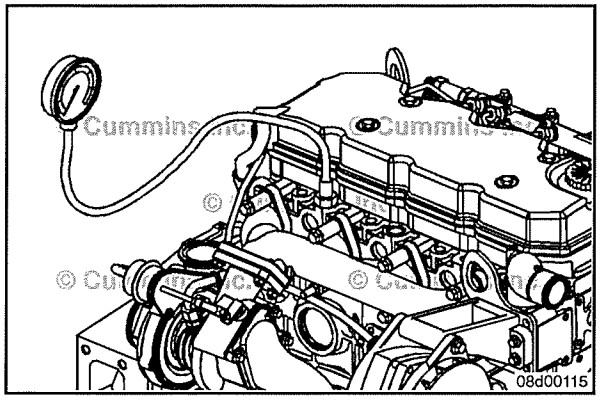


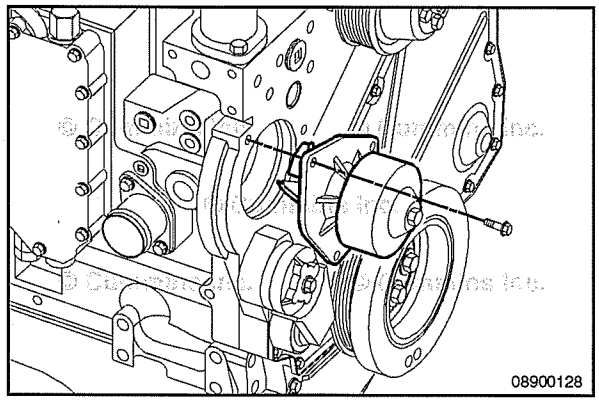
Coolant Pressure Check

Measure the coolant pressure at the coolant tap number 5 or coolant tap number 6 on the exhaust side of the cylinder head.

Coolant pressure can be affected by the following:

- Radiator pressure cap
- Debris in the cooling system
- OEM cooling options such as in-cab heaters and torque converter cooling
- Air in the cooling system
- Incorrect initial cooling system fill
- Less than 50/50 antifreeze mixture
- Engine operation at high altitude.



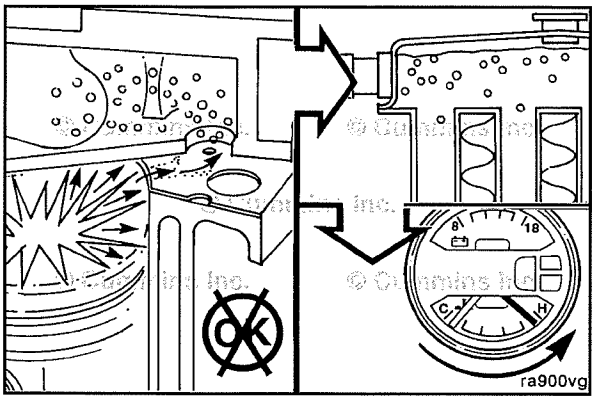


Record the block pressure at 60°C [140°F], closed thermostat, at high idle.

Record the cylinder head pressure at 60°C [140°F], closed thermostat, at high idle.

If the cylinder head coolant pressure is less than 138 kPa [20 psi] at high idle and without a pressure cap, do the following:

- Check the belt tension and condition.
- Remove the water pump, inspect the impeller integrity and check for slippage on the shaft. Refer to Procedure 008-062 in Section 8.

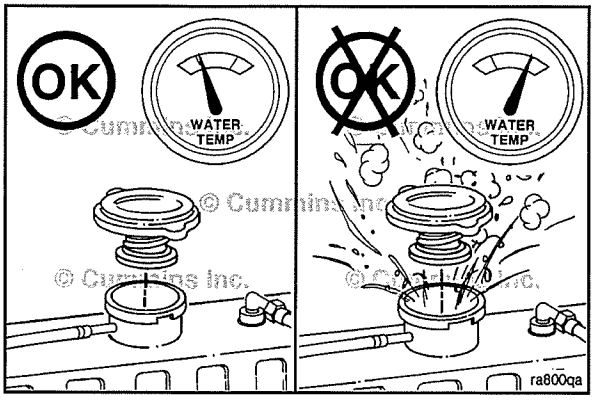


Test

Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket or a crack in the cylinder head leaks compression gases to the cooling system.

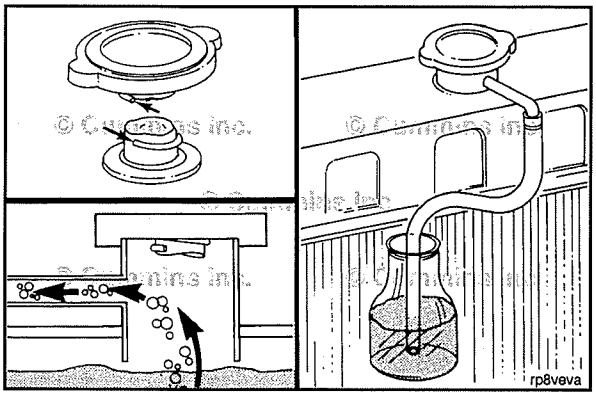
NOTE: All cab heaters and air conditioners **must** be turned off, and the engine fan control **must** be turned to the AUTOMATIC position, if applicable.



Overflow Method

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Allow the engine to cool and remove the radiator cap.



Install a radiator pressure cap that has had the spring and the pressure relief valve removed to allow free flow from the overflow tube.

Attach a rubber hose to the radiator overflow connection.

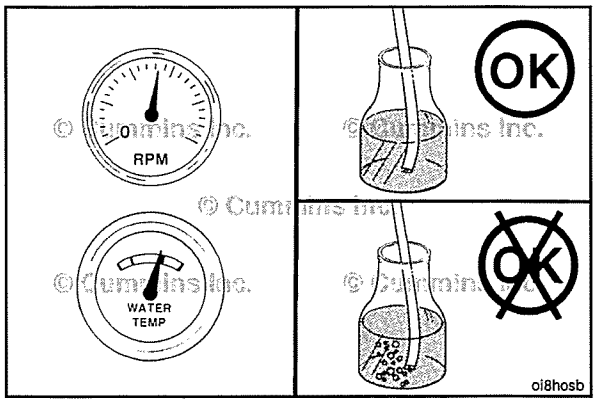
Put the free end of the hose below the coolant level in a container of water.

NOTE: The pressure cap **must** be tightly sealed in the top of the radiator fill neck.

Operate the engine at rated rpm until it reaches a temperature of 82°C [180°F].

Check for a continuous flow of air bubbles from the hose in the water container.

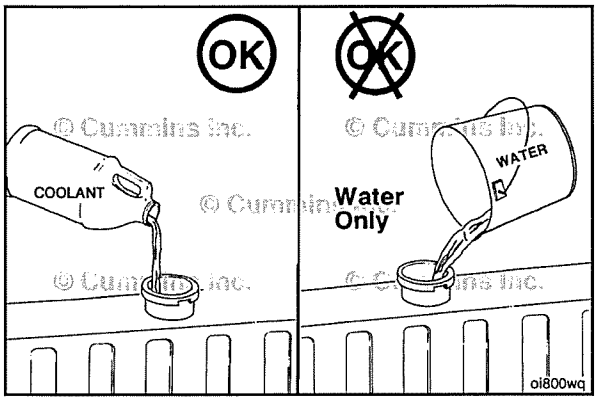
NOTE: The engine coolant temperature **must** be stable to perform this test. An increasing coolant temperature will give a false indication of air, due to expansion of the coolant in the system.



Combustion Gas Leak

Use a combustion gas tester, Part Number 3822985, or equivalent, to test for combustion gases in the cooling system.

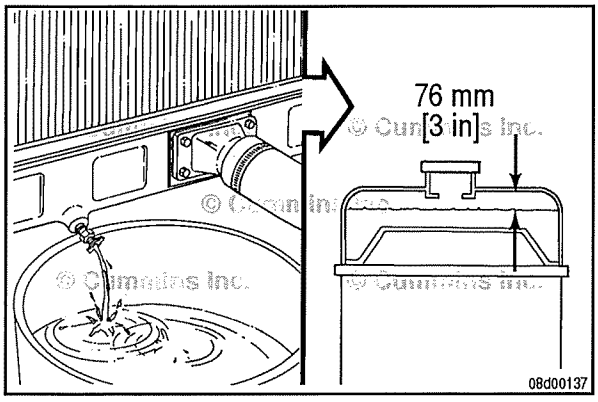
It is recommended that the cooling system contain a mixture of 50-percent antifreeze and 50-percent water during the combustion gas leak test. The use of water **only** can result in a color change in the test fluid from blue to turquoise or light green during the test. This is **not** an indication of a combustion gas leak.



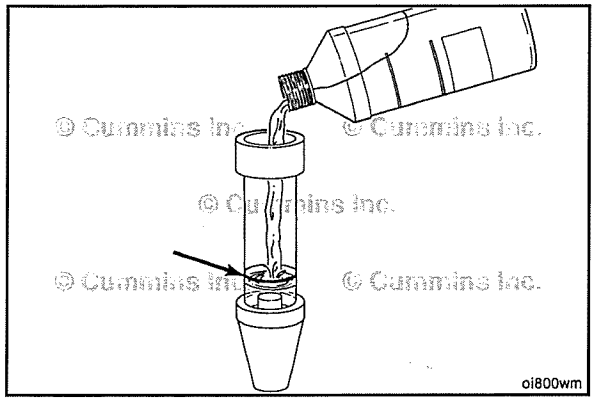
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

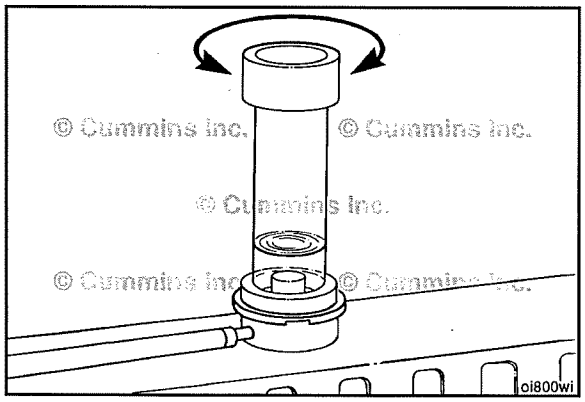
Drain the coolant level down approximately 76 mm [3 in] below the radiator cap seal ledge in the radiator fill neck.

If the coolant is above this point, the coolant can contaminate the test fluid, causing the test to be ineffective.

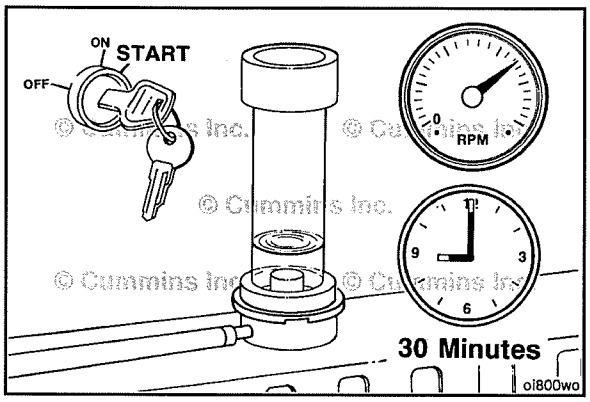


Pour the test fluid into the combustion gas leak test instrument until it is up to the yellow fill line on the instrument.

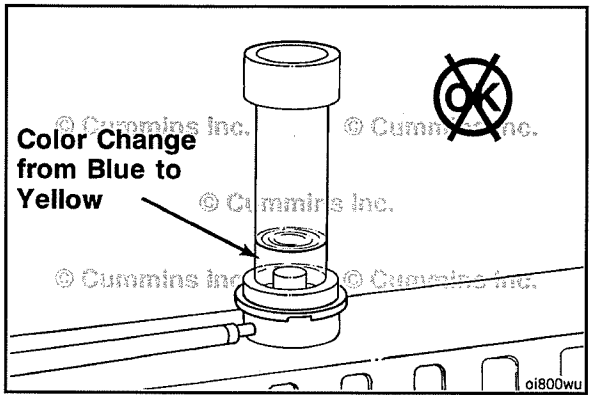




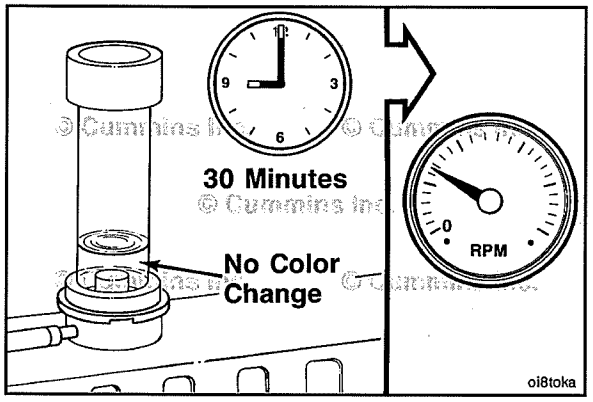
Insert the rubber tip of the combustion gas leak test instrument into the radiator fill neck. Hold the instrument down firmly and turn it back and forth to make certain that an airtight seal is formed between the tester and the radiator fill neck.



Start the engine and run at high idle for approximately 30 minutes. Monitor the engine temperature and color of the test fluid during engine operation. Do **not** allow the engine temperature to exceed 100°C [212°F] during the test.

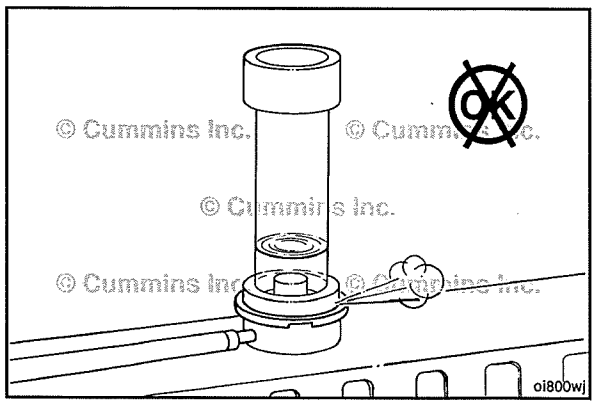


If the color of the test fluid changes from blue to yellow or green anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of test fluid changes from blue to yellow or green.



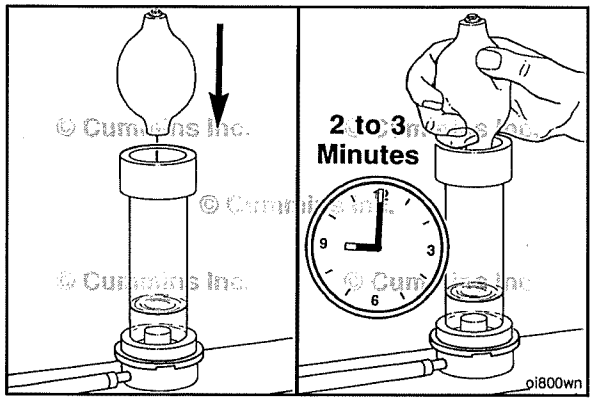
If the color of the test fluid does **not** change from blue to yellow or green during the 30-minute test period, return the engine to low idle.

Check the test instrument to make sure it is firmly sealed in the radiator fill neck.

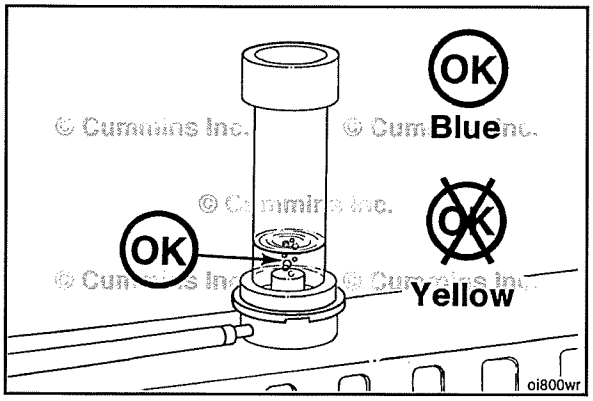


Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.

If the color of the test fluid remains blue, combustion gases are **not** entering the cooling system. If the color of the test fluid changes from blue to yellow or green, combustion gases are entering the cooling system and further investigation is required to determine the source of the combustion leak.

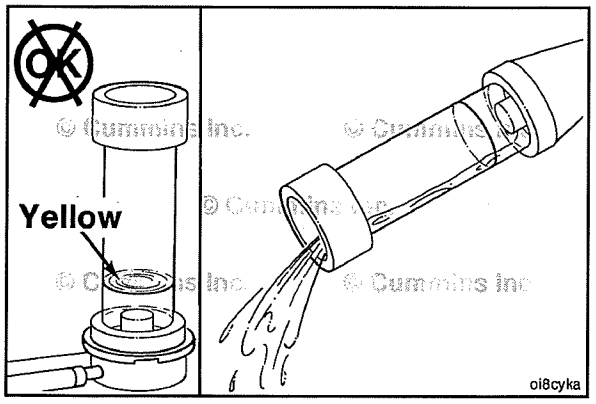


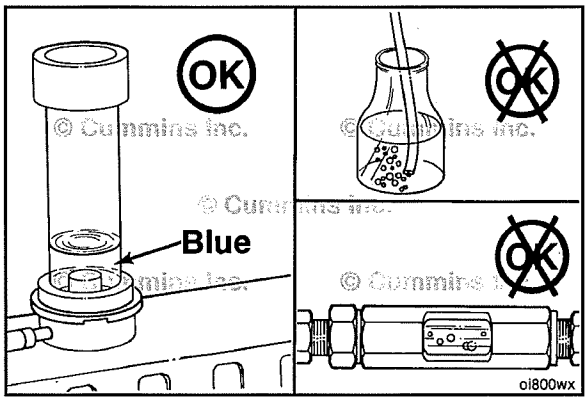
As the cooling system warms up to operating temperature, air will be expelled through the combustion gas tester in the form of bubbles in the test fluid. This is due to normal expansion of the coolant. Do **not** mistake the presence of air bubbles in the tester as combustion gases or air leaks into the cooling system. A change in the color of the test fluid from blue to yellow or green is the **only** indication of combustion gases in the cooling system.



A positive result from the combustion gas leak tester indicates cylinder head gasket or cylinder head casting leakage. Refer to Procedure 002-004 in Section 2.

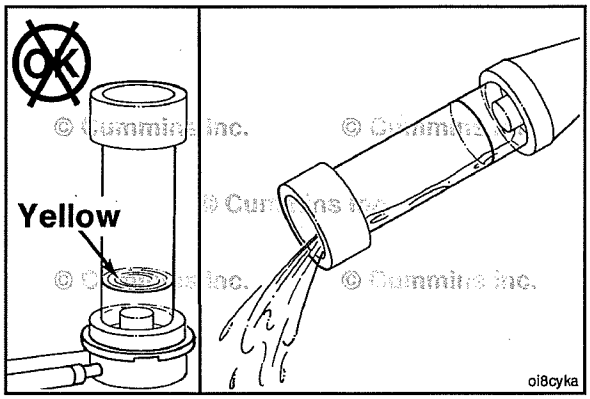
NOTE: Discard the tester fluid if it has indicated positive.





A negative result from the combustion gas leak tester, coupled with a continuous flow of air bubbles from the previous test, indicates the following:

- Damaged fan, shutter, or heater air control valve
- Air compressor head or head gasket leakage
- Air entrained due to a damaged radiator check valve or incorrect fill.
- Air entrained due to a damaged radiator check valve, incorrect fill, or restricted vent lines.



Analyzing the Data

Check the color of fluid in the combustion gas leak tester. A yellow or green color will indicate a combustion leak. A blue color will indicate there is no leak. This information will help isolate the source of air in the cooling system, if any.

NOTE: The test kit is **not** sensitive enough to detect very small combustion gas leaks.

Do **not** rule out combustion gas leaks if the combustion gas leak test does **not** indicate a combustion gas leak.

Worksheet

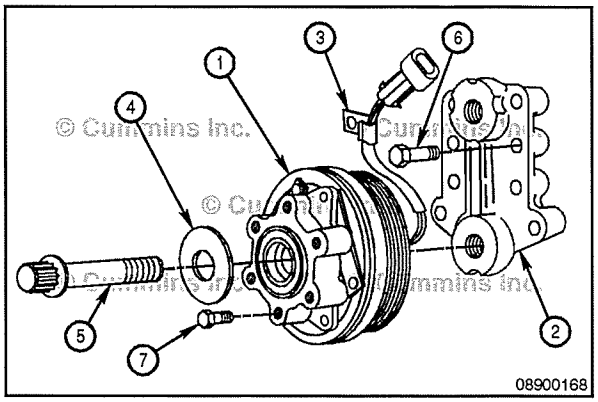
Fill in the blanks with the test data as the test is being run. Record the cylinder head coolant pressure and cab gauge coolant temperature reading at each of the thermostat housing temperature points listed on the left side of the matrix below. Mark when the radiator line gets hot, when the fan starts operating, and when the shutters open.

Coolant Temperature (°F)	Pressure					
Thermostat Housing	Cab Gauge	Cylinder Head	Radiator "In Line" Starts Getting Hot	Fan Starts Operating	Shutters Open	Notes
140						Engine at high idle throughout test
145						Monitor for air throughout test
150						
155						Start monitoring radiator "in" line
160						
165						
170						
175						
180						
185						
190						
195						

200						
205						Cool engine down

Fan Clutch, Electric (008-026)

General Information

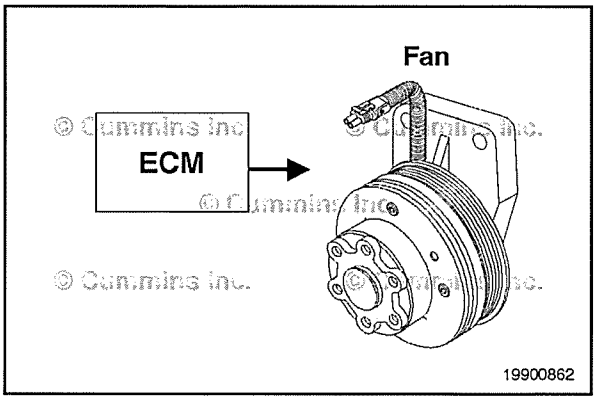


⚠WARNING⚠

The cooling fan will engage when the engine is started. To reduce the possibility of serious personal injury, keep your hands clear of the fan's path when starting the engine and during engine operation.

The Cummins Inc. developed electromagnetic fan clutch product is an integrated package with the clutch, bracket, shaft, bearings, pulley, and fan spacer designed as a unit. When cooling is needed, an electromagnet engages the fan. The fan is either fully engaged or fully disengaged. The electromagnetic fan clutch is driven by a poly-vee drive belt and is available with an accessory drive for vee-drive belts.

All fan clutches can be controlled by the engine control module (ECM). The ECM monitors coolant temperature and intake manifold temperature to determine when to engage the cooling fan. Some applications have additional sensors monitored by the ECM for fan control (for example, air conditioner pressure and transmission temperature). The OEM can also install a manual override switch to engage the clutch manually at the operator's command.

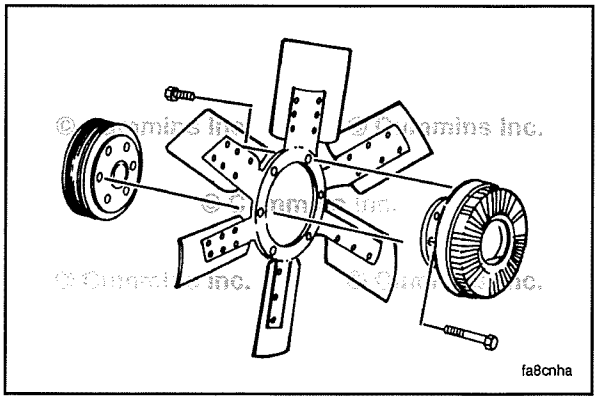


The ECM is capable of using either a 0-VDC or 12-VDC signal to engage the fan clutch. The exact enable logic can be selected in the Features and Parameters section of INSITE™ electronic service tool.

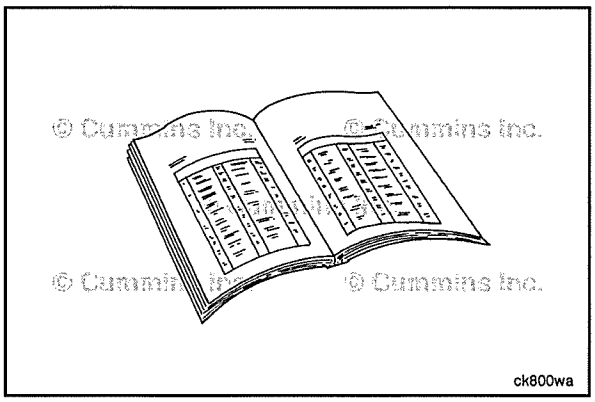
Refer to the equipment manufacturer's service manual for fan clutch troubleshooting and repair information.

These are various fan clutch types:

- Air engaged
- Air disengaged
- Electric
- Viscous
- On-off.



This procedure **only** applies to Cummins Inc. supplied electromagnetic fan clutches. For other fan clutches, refer to the original equipment manufacturer (OEM) service manual for all service related information.

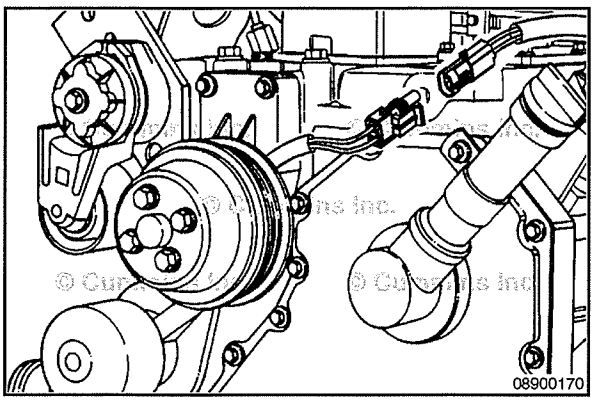


Preparatory Steps

⚠WARNING⚠

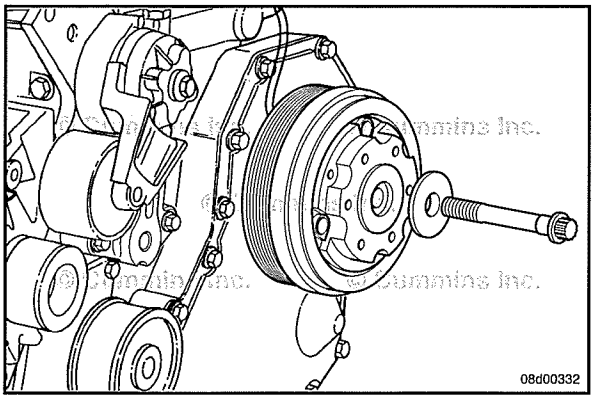
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the OEM service manual.
- Remove the cooling fan and spacers. Refer to the OEM service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.



Remove

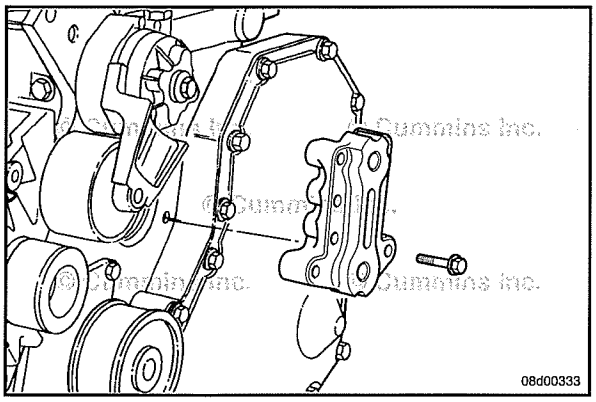
Disconnect the fan clutch connector on the base harness from the fan clutch.



NOTE: As the electric fan clutch mounting fastener is loosened, make sure to support the clutch.

NOTE: The electric fan clutch mounting capscrew has an external Torx™ head.

Remove the electric fan clutch mounting capscrew, washer, and electric fan clutch.



NOTE: Prior to removing the electric fan clutch support bracket, note the mounting location and orientation of the bracket. The mounting bracket can be installed in different orientations for different fan drive arrangements.

NOTE: Note the location of the P-clip for the electric fan clutch wiring harness pigtail.

Remove the electric fan clutch support bracket and mounting capscrews.

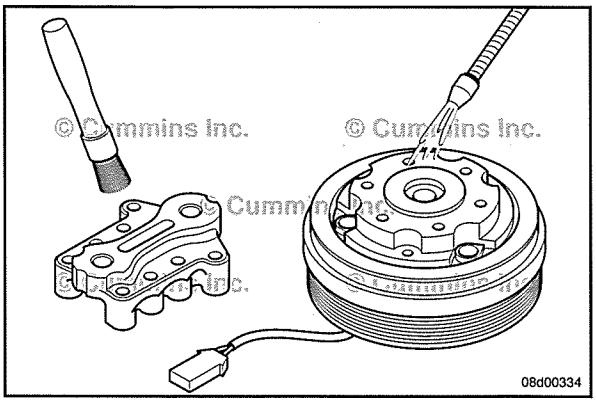
Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

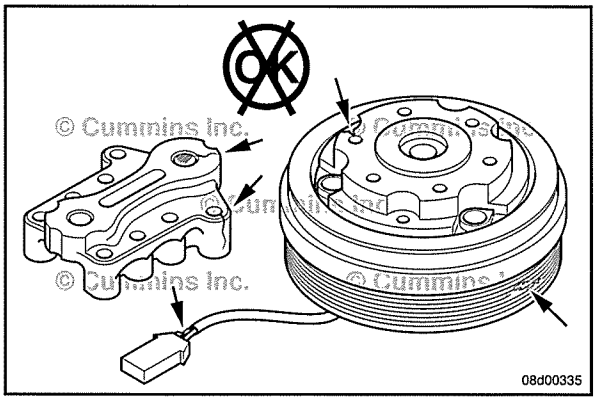
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the fan clutch and bracket with solvent.

Dry with compressed air.



Inspect the fan clutch and bracket for damage.

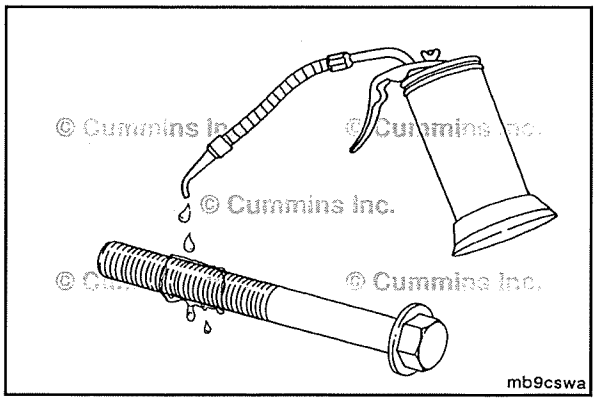


Install

Do **not** use Loctite® or any other thread locking compounds. Make sure capscrew head surface and threads are clean and free of debirs.

Use new capscrew if any damage is fouund.

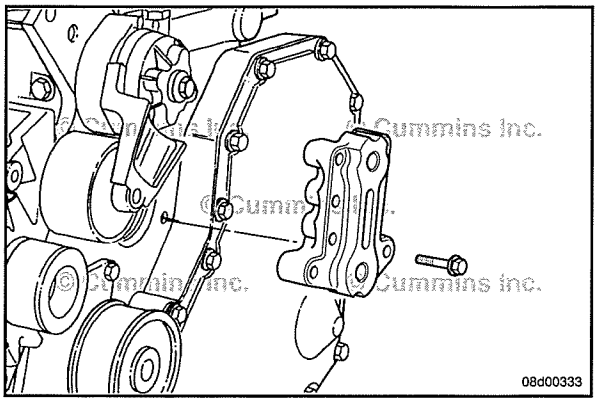
Lubricate the threads and underside of the capscrew head with clean 15W-40 engine lubricating oil.

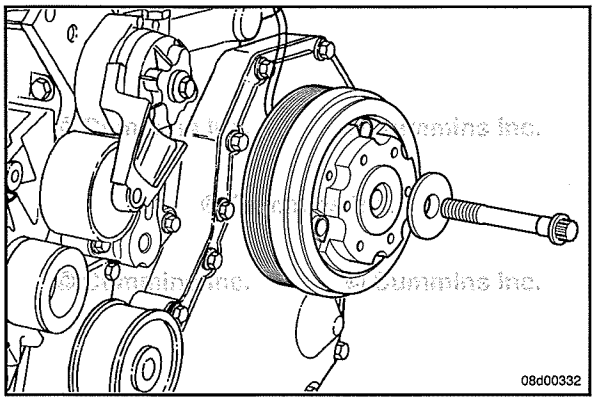


NOTE: Make sure to install the electric fan clutch mounting bracket in the same orientation and location as removed. The mounting bracket can be installed in different orientations for different fan drive arrangements.

Install the electric fan clutch support bracket, wiring harness pigtail P-clip, and mounting capscrews.

Torque Value: 33 N•m [24 ft-lb]





⚠CAUTION⚠

Correct loading of the fan clutch joint is necessary for proper cooling system operation. An over-torqued or under-torqued capscrew, caused by the use of air powered tools, an out-of-calibration wrench, or other methods could lead to significant damage to the front end accessory drive.

NOTE: The electric fan clutch mounting capscrew has an external Torx™ head.

Install the electric fan clutch, washer, and mounting capscrew.

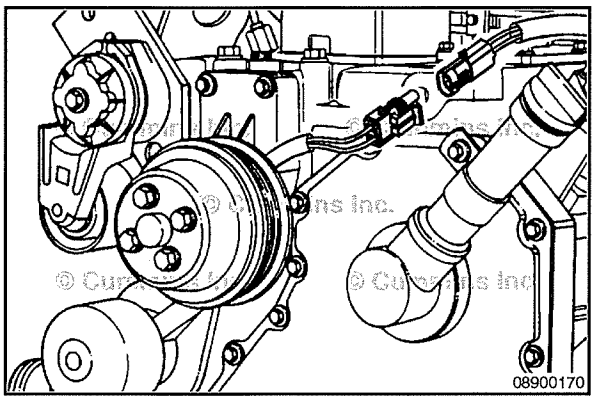
Prior to tightening the capscrew, rotate the fan clutch so that the wires coming out of the back of the fan clutch are captured by the P-clip. Bend the P-clip over by hand to secure the wires.

NOTE: Make sure that wires are **not** being pulled at the fan clutch.

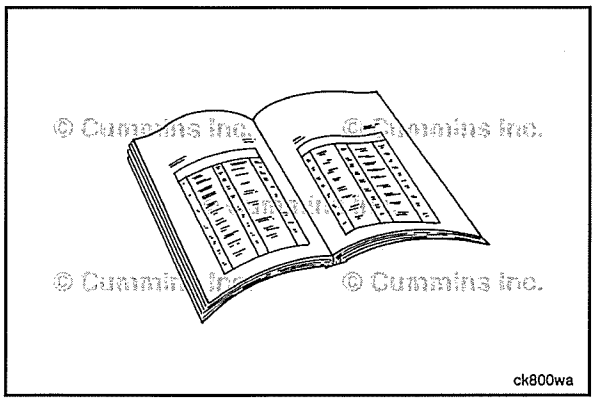
Tighten the fan clutch mounting capscrew.

Torque Value:

Step 1	102 N•m	[75 ft-lb]
Step 2	Rotate 60 degrees	



Connect the fan clutch connector on the base harness to the fan clutch.



Finishing Steps

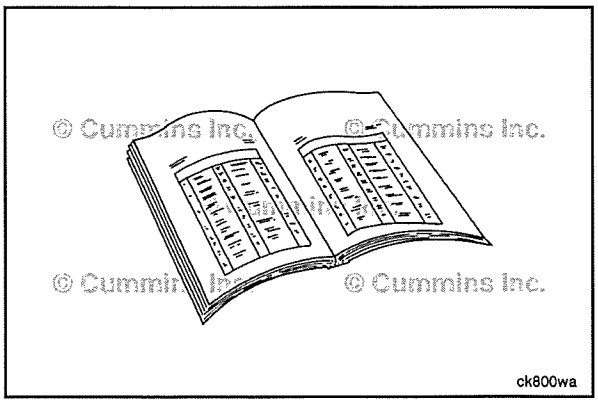
⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the cooling fan and spacers. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Fan Hub, Belt Driven (008-036)

Preparatory Steps



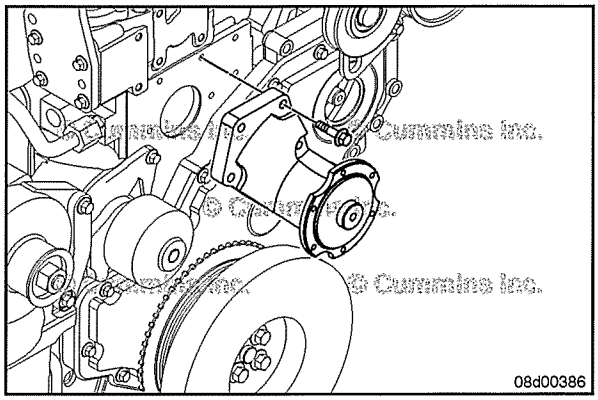
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Use the following procedure if equipped with Cummins® Electric Fan Clutch option. Refer to Procedure 008-026 in Section 8.

NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

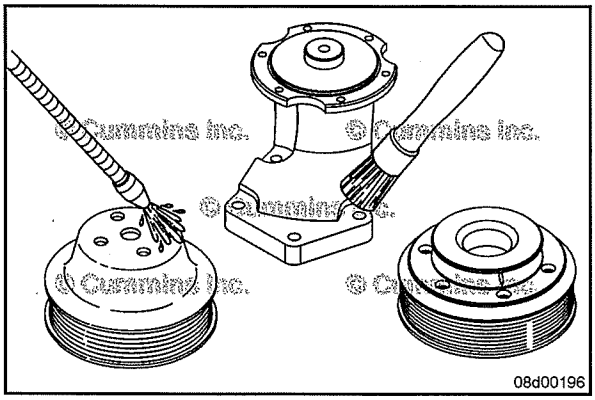
- If required, remove the cooling fan. Refer to the OEM service manual.
- Remove the fan pulley and spacer. Refer to Procedure 008-039 in Section 8.

Remove



NOTE: There are many available fan hub configurations. Be sure to note the location, orientation, and mounting pattern of the hub prior to removal from the engine.

Remove the four capscrews and the fan hub.



Clean and Inspect for Reuse

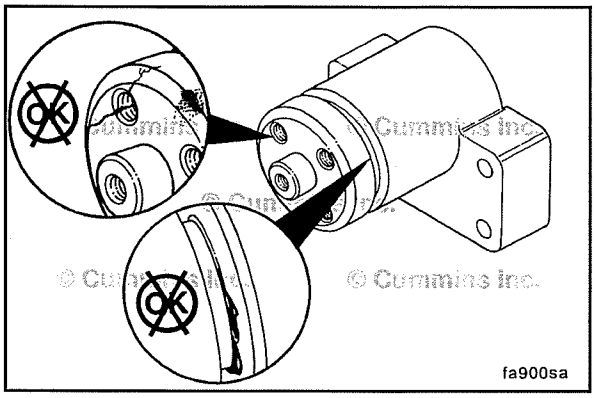
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Do not expose the cooling fan drive belt to solvents, acids, or alkaline materials for cleaning. Belt damage can result.

Clean the fan hub and fan pulley with solvent.

Dry with compressed air.

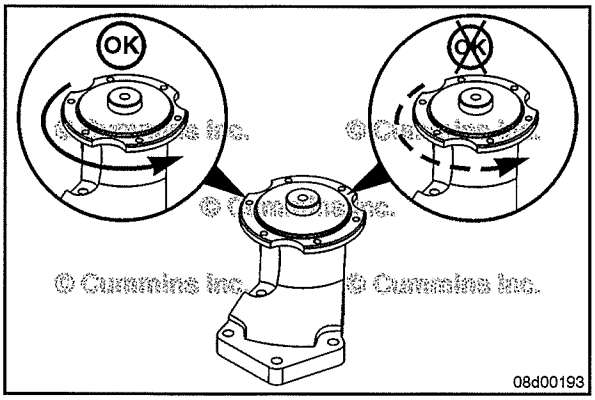


Inspect the fan hub for indications of oil seal leakage.

Inspect the fan hub for cracks or other damage.

Inspect the fan hub chamfer and pulley mating surface for damage.

Replace the fan hub if damage is found.



Turn the fan hub by hand to check for freedom of rotation.

The fan hub **must** spin freely without any wobble or excessive end clearance.

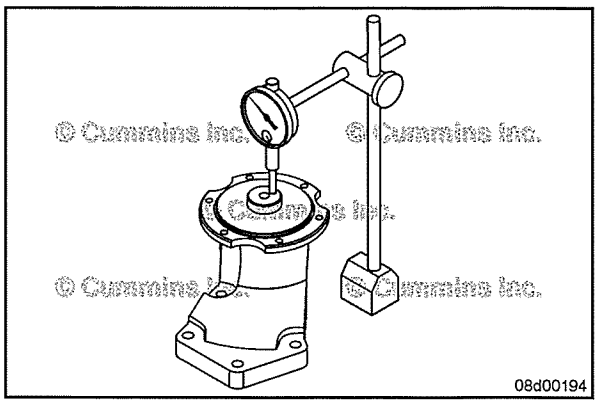
Inspect the fan hub bearing for wear.

The bearing **must** have a minimal amount of side-to-side or end-play movement.

Replace the fan hub if the end play is out of specification.

Fan Hub End Play		
mm		in
0.15	MAX	0.006

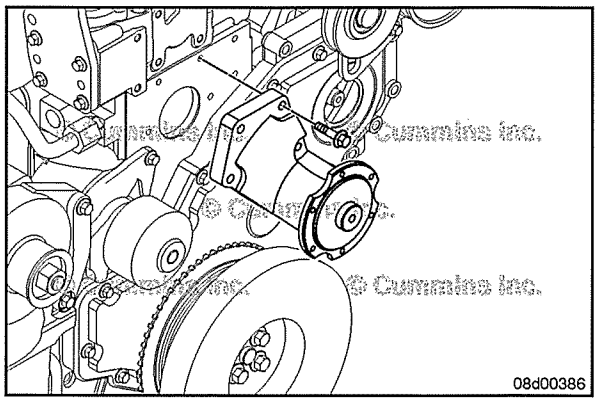
NOTE: Some fan hub assemblies can be rebuilt with new bearings and related components. Check for part availability before disassembling the fan hub.



Install

Install the fan hub and four capscrews.

Torque Value: 33 N•m [24 ft-lb]

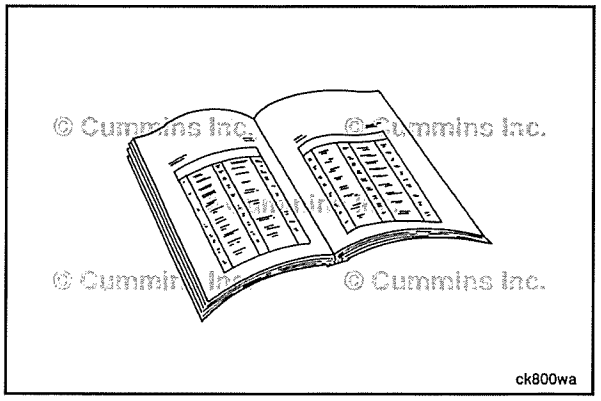


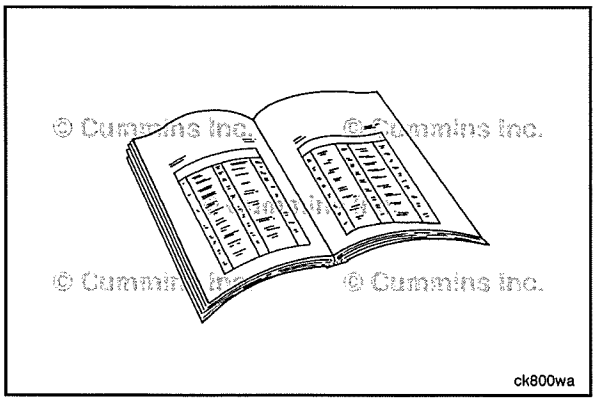
Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

- Install the fan pulley and spacer. Refer to Procedure 008-039 in Section 8.
- If removed, install the cooling fan. Refer to the OEM service manual.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Use the following procedure if equipped with Cummins® Electric Fan Clutch option. Refer to Procedure 008-026 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for proper operation.





Fan Spacer and Pulley (008-039)

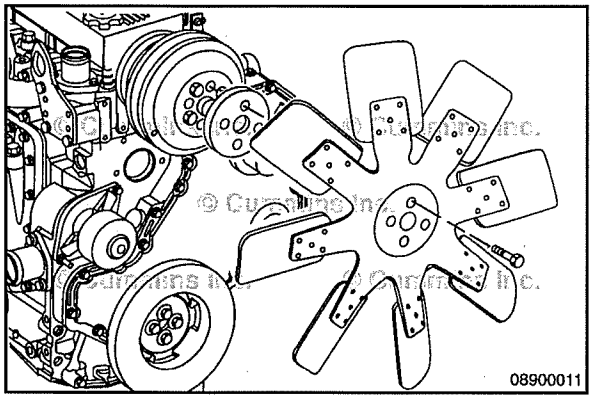
Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.

NOTE: Prior to removing the drive belt, loosen the fan pulley and cooling fan (if equipped) mounting capscrews.

- If equipped with Cummins® Electric Fan Clutch option. Refer to Procedure 008-026 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.

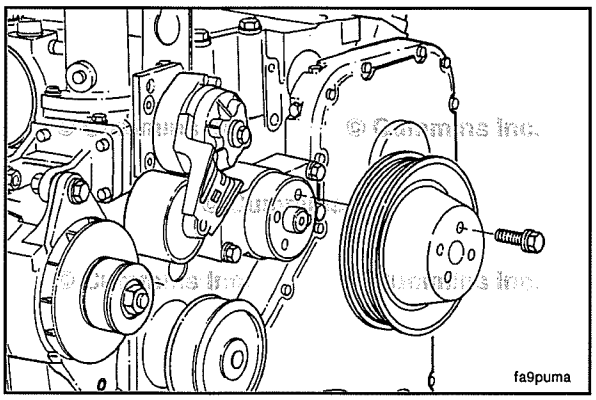


Remove

NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

If equipped, remove the cooling fan. Refer to the OEM service manual.

For engines equipped with an engine driven cooling fan, the fan holds the fan pulley and spacer in place. Remove the fan pulley and spacer.



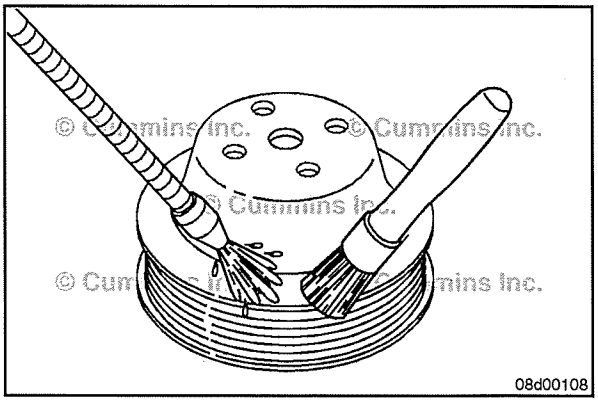
If the engine is **not** equipped with an engine driven cooling fan, remove the fan pulley mounting capscrews and fan pulley.

Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

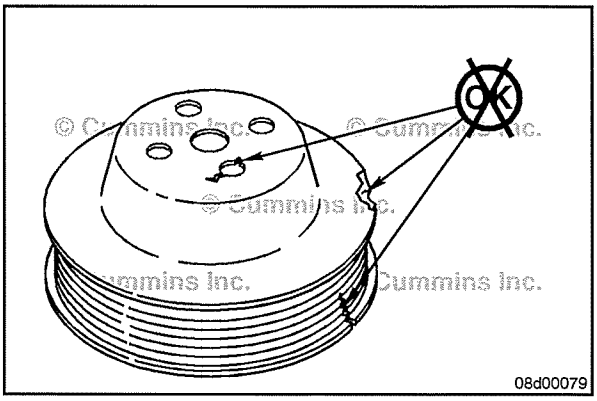
Clean the fan pulley and spacer with solvent and dry with compressed air.



Inspect the fan pulley for cracks near the bolt holes and for damage at the drive belt contact surface.

If damage is found on the fan pulley, the fan hub **must** also be inspected. Refer to Procedure 008-036 in Section 8.

Replace the pulley if any damage is found.



Install

NOTE: Use the tension of the drive belt to hold the cooling fan in place when tightening the mounting capscrews. Do **not** hold the fan blades to keep the cooling fan from rotating.

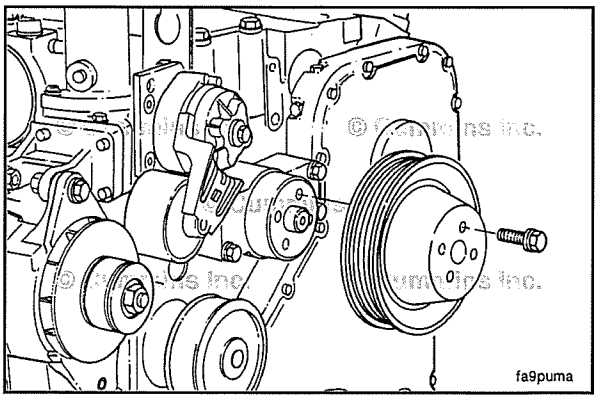
If the engine is **not** equipped with an engine driven cooling fan, install the fan pulley mounting capscrews and fan pulley.

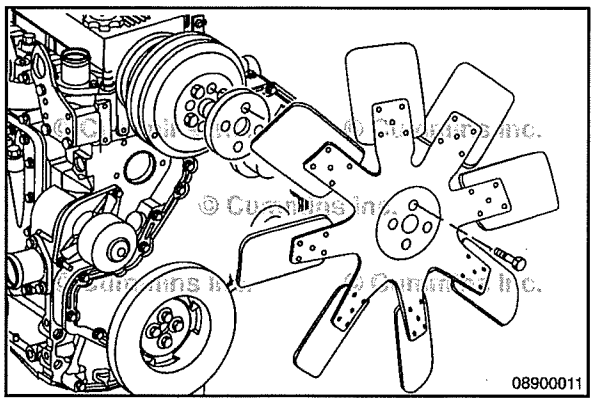
Do **not** tighten the mounting capscrews at this time. Tighten the mounting capscrews after the drive belt is installed.

Torque Value:
M6 10 N•m [89 in-lb]

Torque Value:
M10 43 N•m [32 ft-lb]

Torque Value:
M12 77 N•m [57 ft-lb]





NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

For engines equipped with an engine driven cooling fan, the fan holds the fan pulley and spacer in place. Install the fan pulley and spacer.

If removed, install the cooling fan. Refer to the OEM service manual.

NOTE: Use the tension of the drive belt to hold the cooling fan in place when tightening the mounting capscrews. Do **not** hold the fan blades to keep the cooling fan from rotating.

Do **not** tighten the mounting capscrews at this time. Tighten the mounting capscrews after the drive belt is installed.

Torque Value:
M6 10 N•m [89 in-lb]

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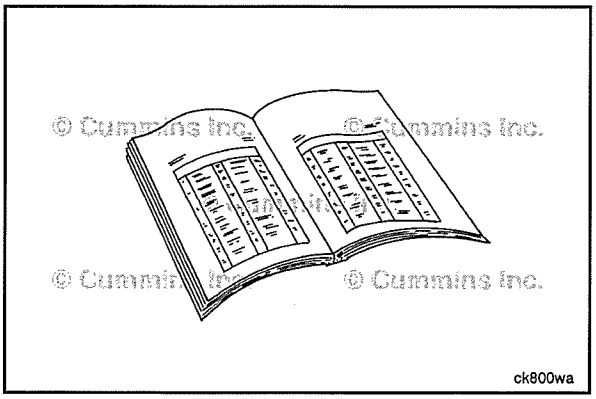
M10 43 N•m [32 ft-lb]

Torque Value:
M12 77 N•m [57 ft-lb]

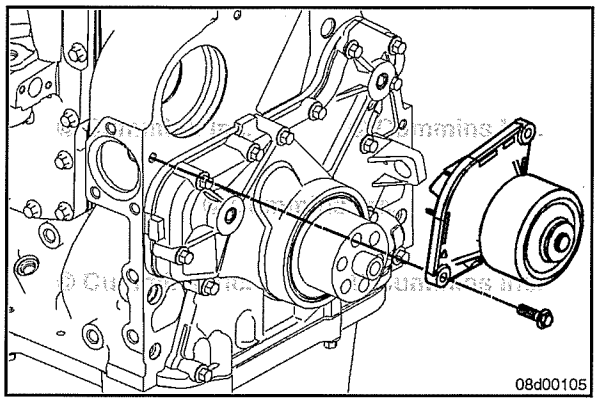


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: Tighten the fan pulley and cooling fan (if equipped) mounting capscrews.

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- If equipped with Cummins® Electric Fan Clutch option. Refer to Procedure 008-026 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for proper operation.



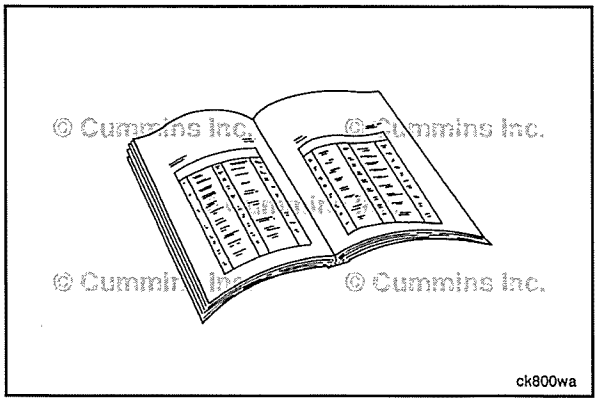
Water Pump (008-062)

General Information

NOTE: It is **not** practical to replace the components of the water pump; the water pump is serviced as an assembly.

The water pump is a belt-driven, centrifugal-type pump with the inlet and bypass as integral parts of the cylinder block.

Preparatory Steps



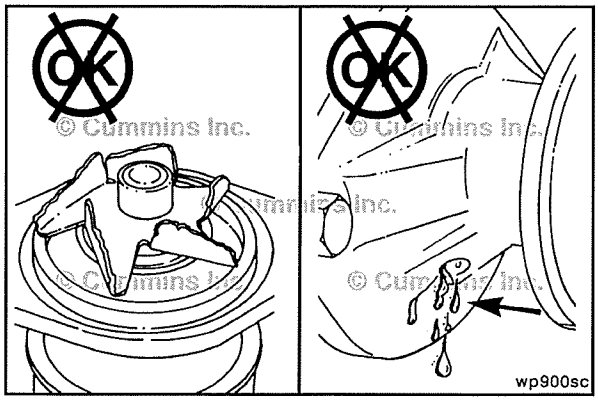
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- If required, remove the belt tensioner. Refer to Procedure 008-087 in Section 8.
- If required, remove the fan shroud assembly. Refer to the OEM service manual.

Initial Check



Inspect the water pump housing for cracks and or other damage.

Check the water pump seal weep hole. The water pump seal design requires a coolant film for lubrication and cooling. Therefore, it is normal to observe a minor chemical buildup or streaking at the weep hole.

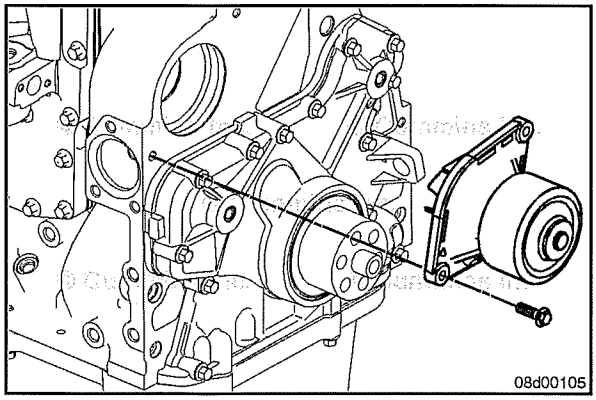
NOTE: A streak or chemical buildup at the weep hole is **not** justification for water pump replacement.

Use the following guidelines to determine if water pump replacement is necessary: Make sure the weep hole is open.

Clean off any coolant residue around the weep hole.

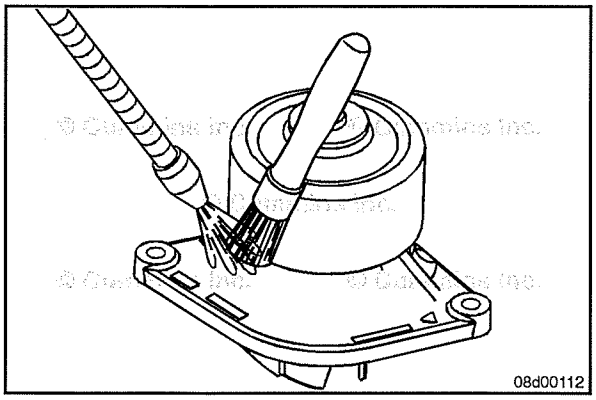
NOTE: A small screwdriver or a similar tool can be used to remove any debris.

If no leakage is observed from the weep hole under operating conditions, do **not** replace the water pump.



Remove

Remove the two mounting capscrews, water pump, and seal.



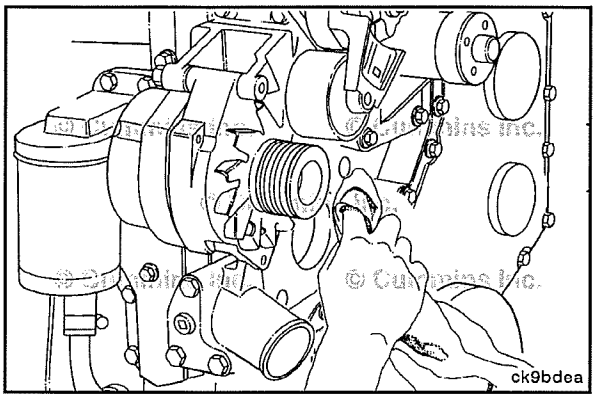
Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Compressed air should not be applied into the weep hole nor directly behind the impeller. Compressed air could potentially damage the water pump rotating seal.

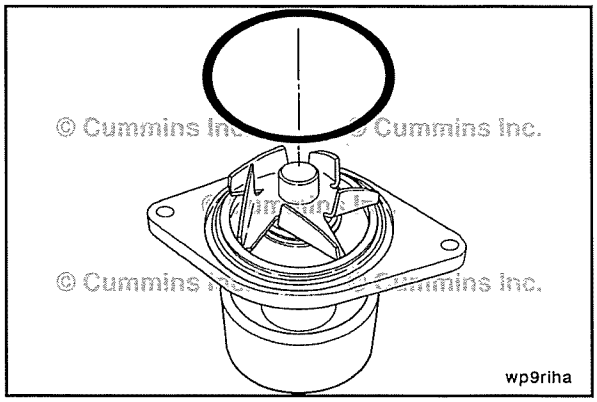
Clean the water pump with solvent. Dry with compressed air.



Clean the sealing surface on the cylinder block.

Clean the o-ring sealing surface on the water pump housing.

Inspect the sealing surface for damage. Replace the water pump if any damage is found.

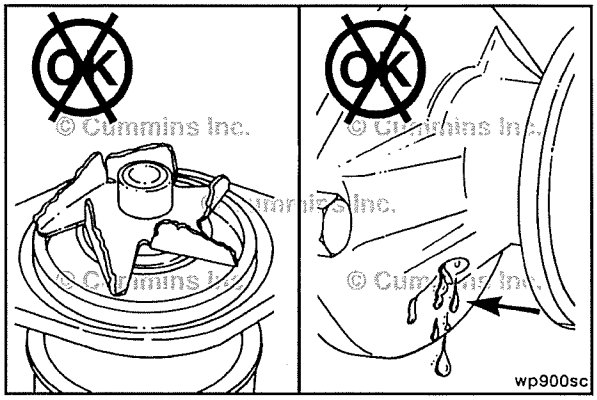


NOTE: If any damage to the impeller blades is found, make sure to inspect the cylinder block for damage.

Inspect the impeller for cracks, missing blades, slippage on the shaft, and other types of damage.

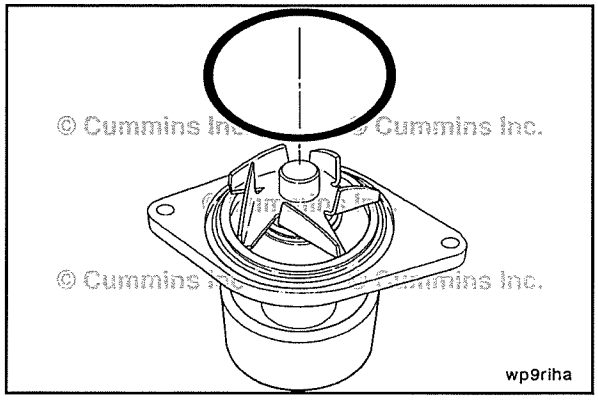
Inspect the water pump housing for damage and cracks.

Replace the water pump if any damage is found.



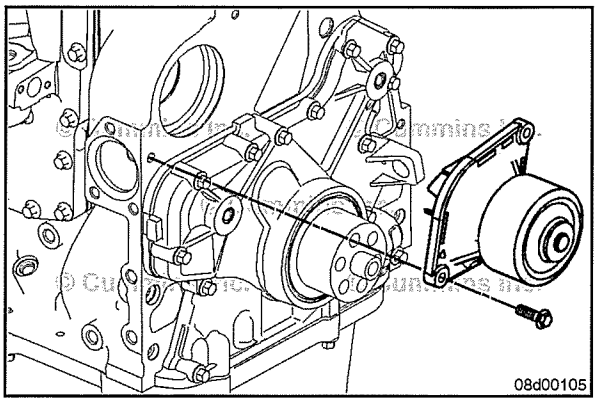
Install

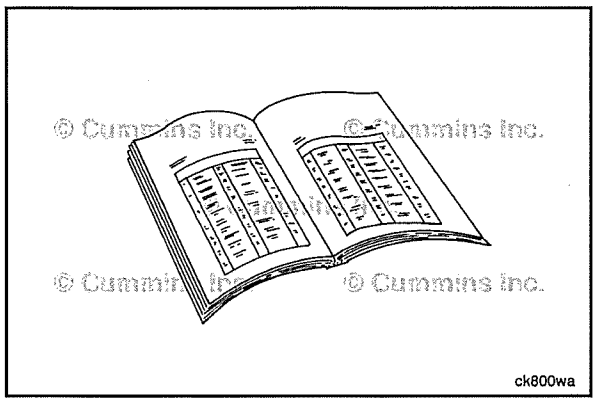
Install the new sealing ring into the pump groove.



Install the water pump (with seal) and mounting capscrews.

Torque Value: 30 N•m [22 ft-lb]





Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- If removed, install the belt tensioner. Refer to Procedure 008-087 in Section 8.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- If removed, install the fan shroud assembly. Refer to the OEM service manual.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Torque Converter Cooler (008-065)

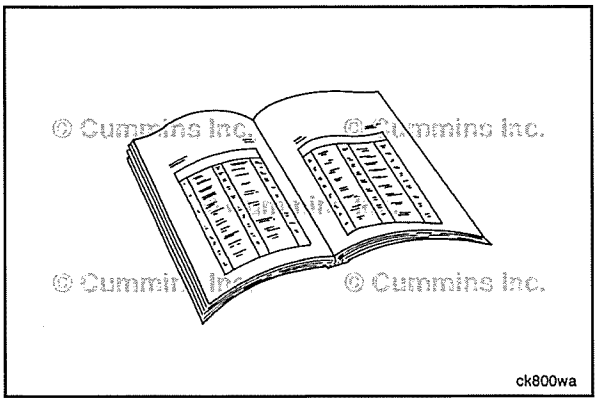
General Information

This procedure is for engines equipped with the torque converter cooler option.

Conventionally cooled engines with automatic transmissions typically use oil-to-water transmission torque converter coolers plumbed between the radiator and the engine water pump.

A torque converter cooling system with a remote bypass allows the torque converter to receive coolant flow when the thermostat is closed (engine cold, no flow through radiator).

Preparatory Steps



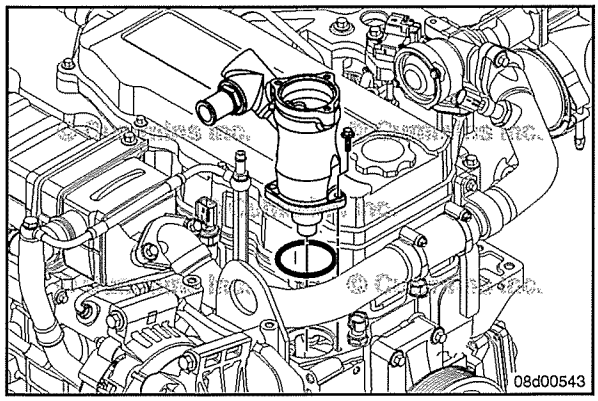
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the battery cables. Refer to the OEM service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the coolant thermostat. Refer to Procedure 008-013 in Section 8.
- Disconnect the OEM torque converter plumbing, as needed. Refer to the OEM service manual.

Remove



Remove the torque converter cooler capscrews.

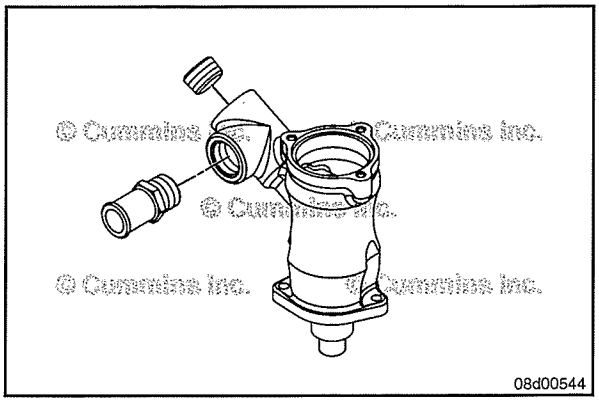
Remove the torque converter cooler.

Remove the torque converter cooler o-rings.

Remove the torque converter coolant return fitting from the water inlet connection or radiator return. The location and size of the fitting are OEM-dependent. Refer to the OEM service manual.

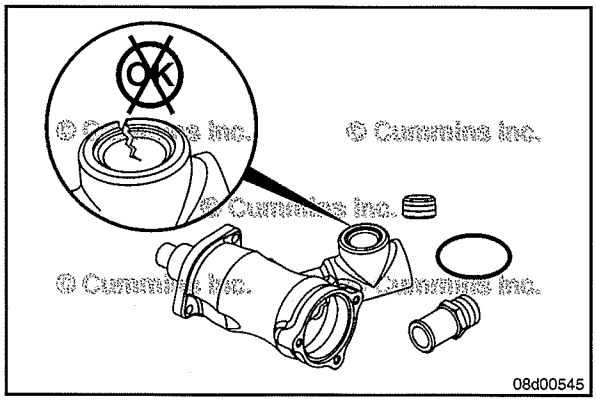
NOTE: Take note of the proper orientation and location of any 90 or 45 degree coolant line fittings before removal.

Disassemble



Remove the 3/4 NPTF fitting and plug from the torque converter coolant supply port on the torque converter cooler.

NOTE: Take note of the proper orientation and location of any 90 or 45 degree coolant line fittings. Depending on the OEM, the illustration may **not** display the proper orientation and location.



Clean and Inspect for Reuse

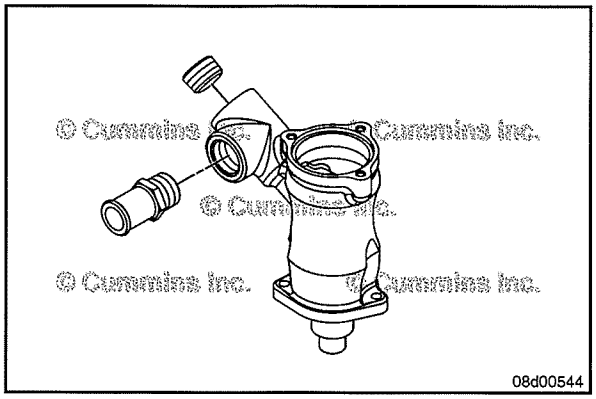
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the torque converter cooler, fittings, and o-rings with a cleaning solvent. Dry with compressed air.

Inspect the torque converter cooler, fittings, and o-rings for cracks, corrosion, or other damage.

If damaged, the part **must** be replaced.

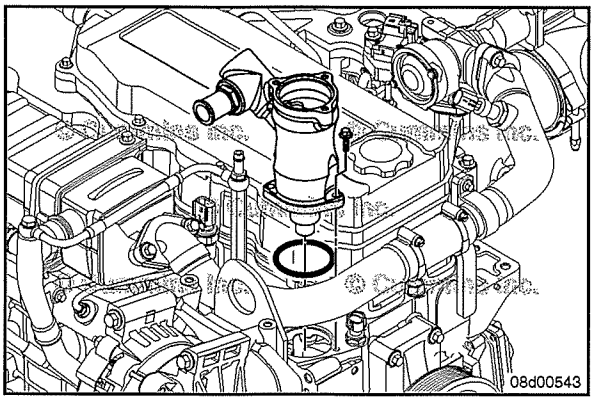


Assemble

Apply a film of pipe sealant, Part Number 3375066, or equivalent, to the threads of the fitting and plug.

Install the 3/4 NPTF fitting and plug into the torque converter coolant supply port on the torque converter cooler.

Torque Value: 75 N•m [55 ft-lb]



Install

Install the torque converter cooler and o-rings.

Install the torque converter cooler capscrews.

Torque Value: 10 N•m [89 in-lb]

Apply a film of pipe sealant, Part Number 3375066 or equivalent, to the threads of the torque converter coolant return fitting.

Install the torque converter coolant return fitting into the water inlet connection or radiator return. The location and size depend on the OEM. Refer to the OEM service manual.

Use the following procedure for torque values on various fitting sizes. Refer to Procedure 017-007 in Section 17.

NOTE: Make sure to properly orient any 90 or 45 degree coolant line fittings during installation and tightening.

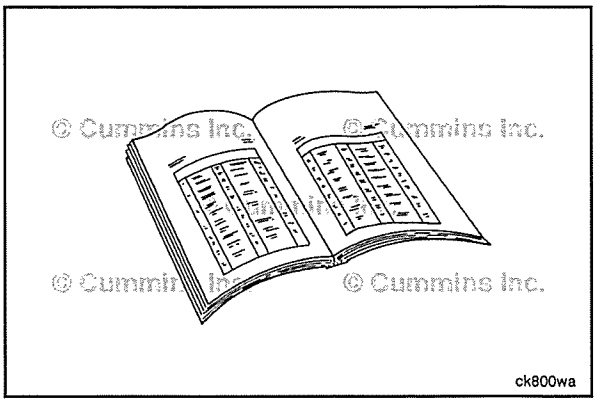
Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠
Always vent the engine during filling to remove air from the coolant system, or overheating can result.

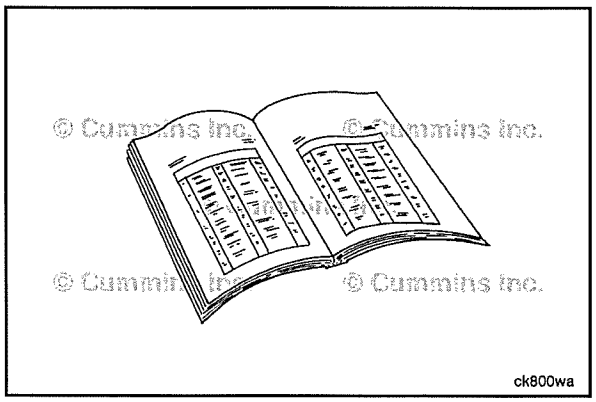
- Connect the OEM torque converter plumbing, as necessary. Refer to the OEM service manual.
- Install the coolant thermostat. Refer to Procedure 008-013 in Section 8.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine to check for leaks.



Water Inlet Connection (008-082)

General Information

NOTE: Due to the number of water inlet connection options, the following procedure has been commonized. The illustrations may **not** match the engine being serviced, but the procedures are the same.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

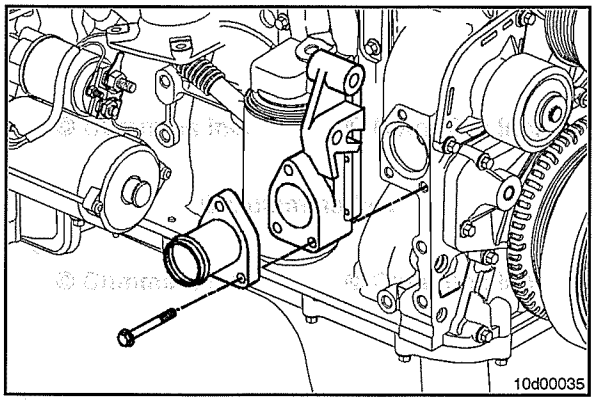
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the batteries. Refer to the original equipment (OEM) service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- If equipped, remove the air compressor coolant return line. Refer to Procedure 012-004 in Section 12.
- Remove exhaust gas recirculation (EGR) cooler coolant return line. Refer to Procedure 011-031 in Section 11.
- If required, remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- If required, remove the fan belt tensioner. Refer to Procedure 008-087 in Section 8.

NOTE: Some belt tensioners are mounted to the water inlet connection.

- Remove the lower radiator hose.
- If required, disconnect any OEM coolant hoses. Refer to the OEM service manual.
- If required, remove the alternator. Refer to Procedure 013-001 in Section 13.
- If required, remove the alternator mounting bracket. Refer to Procedure 013-003 in Section 13.



Remove

Remove the capscrews, water inlet connection, gasket, and rectangular sealing ring(s).

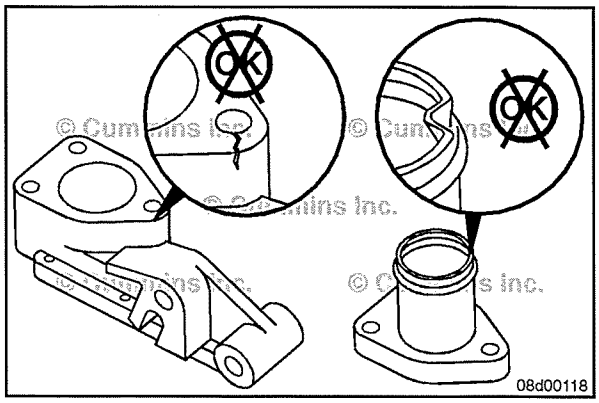
Clean and Inspect for Reuse

NOTE: If replacing the water inlet connection, it could be necessary to transfer coolant fitting(s) from the old water inlet connection to the new water inlet connection.

Clean the water inlet connection and cylinder block mounting surface.

Inspect the water inlet connection for damage.

Replace the water inlet connection if any damage is found.



Install

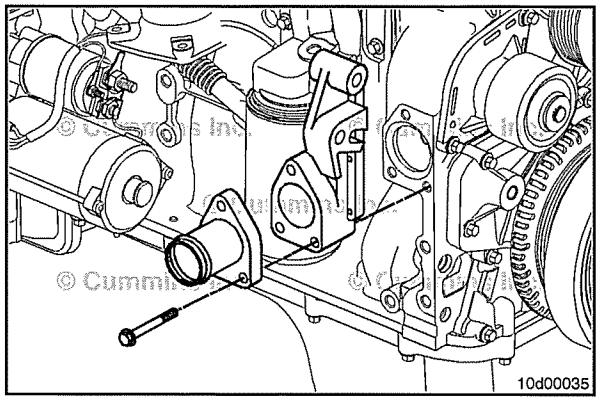
Install the capscrews, water inlet connection, gasket, and rectangular sealing ring(s).

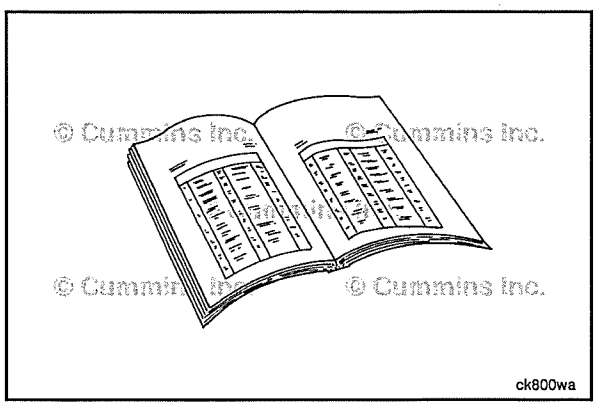
Align the roll pins against the front face of the cylinder block and tighten the capscrews.

NOTE: Use pipe plug sealant, Part Number 3375066, or equivalent, to install any OEM coolant fittings removed from the water inlet connection.

Torque Value:
M10 43 N•m [32 ft-lb]

Torque Value:
M12 80 N•m [59 ft-lb]



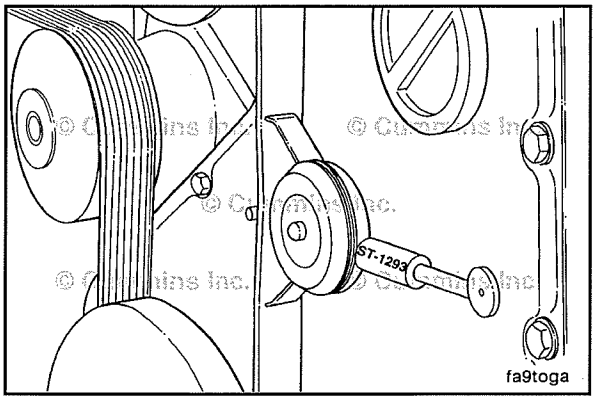


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Install the EGR cooler coolant return line. Refer to Procedure 011-031 in Section 11.
- If equipped, install the air compressor coolant return line. Refer to Procedure 012-004 in Section 12.
- If removed, install the fan belt tensioner. Refer to Procedure 008-087 in Section 8.
- If removed, install the cooling fan drive belt. Refer to Refer to Procedure 008-002 in Section 8.
- If removed, connect any OEM coolant hoses. Refer to OEM service manual.
- If removed, install the alternator. Refer to Procedure 013-001 in Section 13.
- If removed, install the alternator mounting bracket. Refer to Procedure 013-003 in Section 13.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks, alignment, and tension on the drive belt.



Cooling Fan Belt Tensioner (008-087)

Initial Check

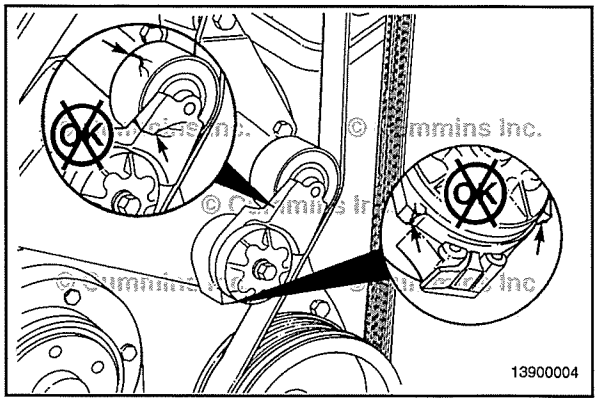
With the engine stopped and the belt installed, record the belt tension generated by the existing belt tensioner.

Use belt tensioner gauge, Part Number ST-1293, to measure the tension in the drive belt.

Belt Tension		
N		**lbf**
356	MIN	80
534	MAX	120

If the measurement is out of the specified range, replace **only** the belt and perform the tension test again. If a new belt has been installed and the measurement is still outside of the specified range, replace the belt tensioner.

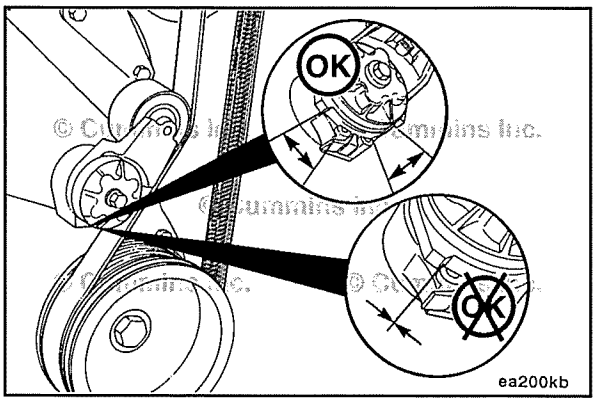
With the engine stopped, check the tensioner arm, pulley, and stops for cracks. If any cracks are found, the tensioner **must** be replaced.



With the belt installed, verify that neither tensioner arm stop is in contact with the spring case stop. If either of the stops is touching:

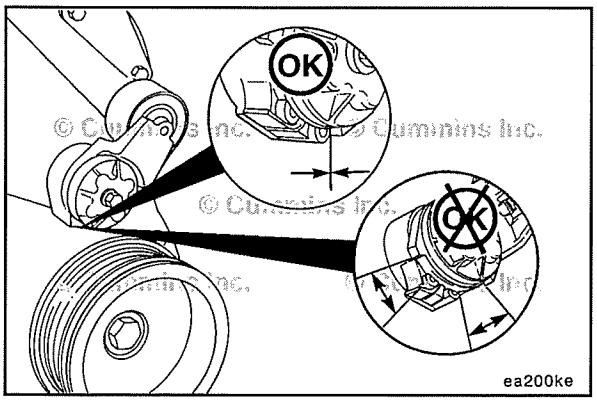
- Verify the correct belt part number is installed.
- If the correct belt is installed, replace the belt. Refer to Procedure 008-002 in Section 8.

After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, the tensioner **must** be replaced.



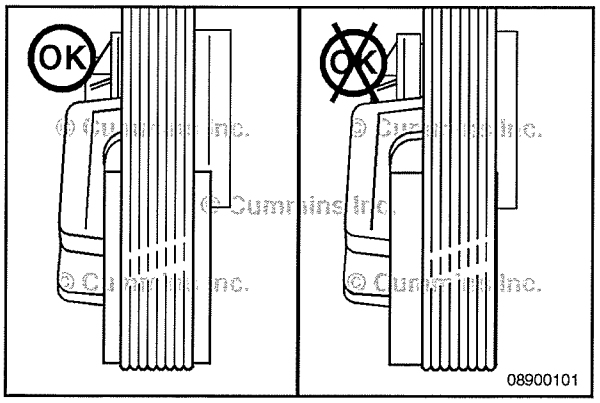
With the belt removed, verify that the tensioner arm stop is in contact with the spring case stop. If these two are **not** touching, the tensioner **must** be replaced.

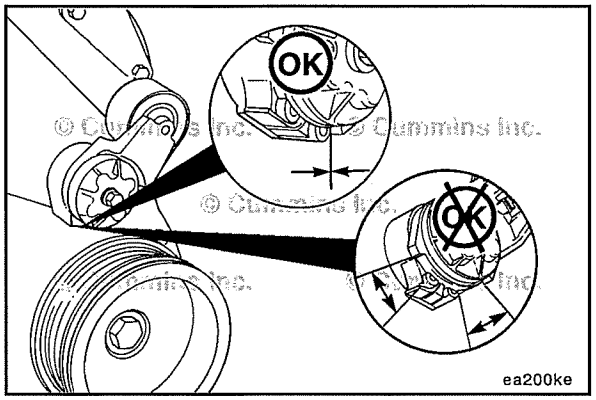
After replacing the belt, if the tensioner arm stop is still in contact with the spring case stop, the tensioner **must** be replaced.



Check the location of the drive belt on the belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley. Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-offs, or increase uneven tensioner bushing wear.

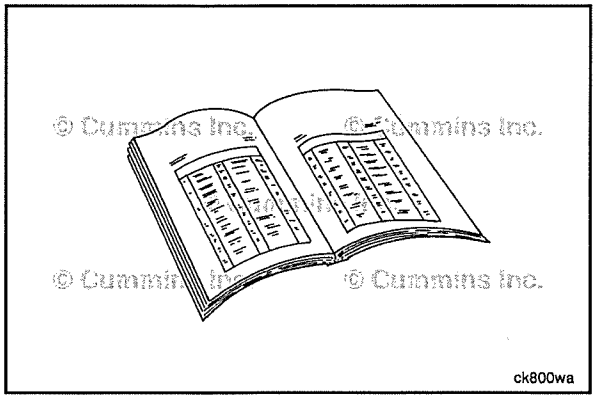
NOTE: Belt mis-alignment is **not always** a result of a malfunctioning or faulty belt tensioner. Make sure the adjacent pulleys and mounting brackets are aligned and mounted correctly. Refer to Procedure 008-002 in Section 8.





Remove the drive belt. Refer to Procedure 008-002 in Section 8.

With the belt removed, verify that the tensioner arm stop is in contact with the spring case stop. If they are **not** touching, the tensioner **must** be replaced.

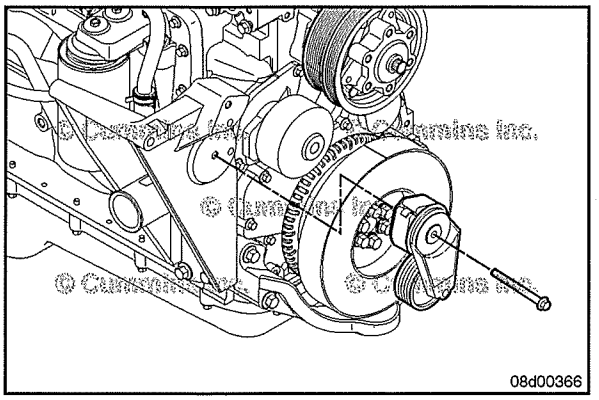


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

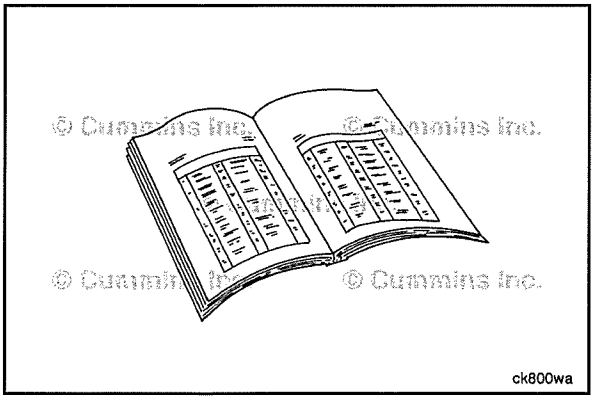
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.



Remove

Remove the capscrew and belt tensioner from the bracket.

NOTE: Most belt tensioners are mounted to the water inlet connection. Some belt tensioners are mounted to a separate mounting bracket and use internal fasteners for clearance.



Clean and Inspect for Reuse

Inspect the cooling fan drive belt for reuse. Refer to Procedure 008-002 in Section 8.

Measure the clearance between the tensioner spring case and the tensioner arm to verify tensioner wear-out and uneven bearing wear. If the clearance at measurement point 5 exceeds 3 mm [0.12 in] at any point, the tensioner is damaged and **must** be replaced as a complete assembly.

Tensioners generally show a larger clearance gap near the lower portion of the spring case, resulting in the upper portion rubbing against the tensioner arm.

1 Tensioner cap

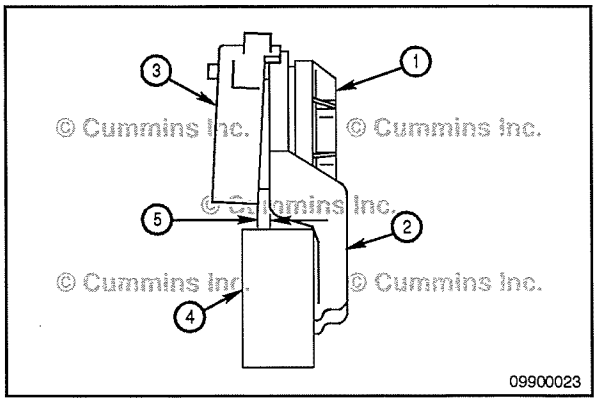
2 Tensioner arm

3 Spring case

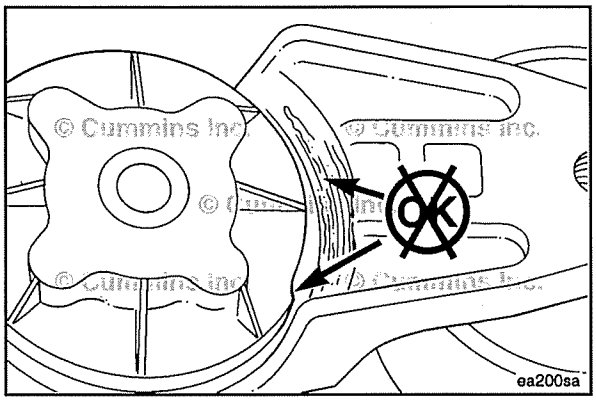
4 Tensioner pulley

5 Clearance gap.

NOTE: Always replace the belt when a tensioner is replaced. However, it is **not** always necessary to replace a tensioner when a belt is replaced.



Inspect the tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact, the pivot tube bushing has failed and the tensioner **must** be replaced.



Install

If removed, install the belt tensioner mounting bracket and mounting bracket capscrews.

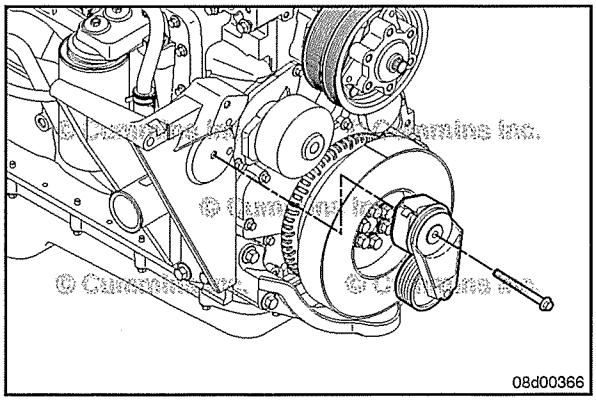
NOTE: Some belt tensioner mounting brackets use internal fasteners for clearance.

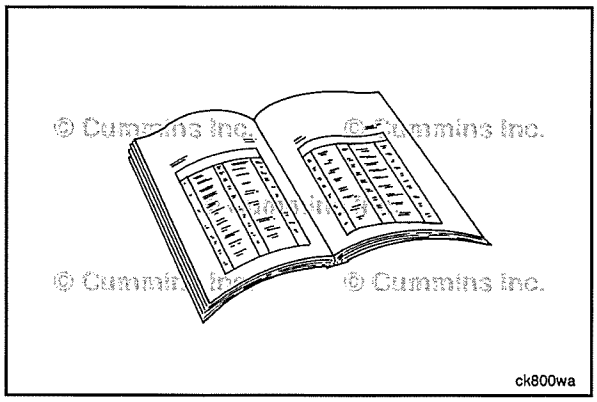
Torque Value: 24 N•m [212 in-lb]

Install the belt tensioner and capscrew.

Tighten the capscrew.

Torque Value: 43 N•m [32 ft-lb]



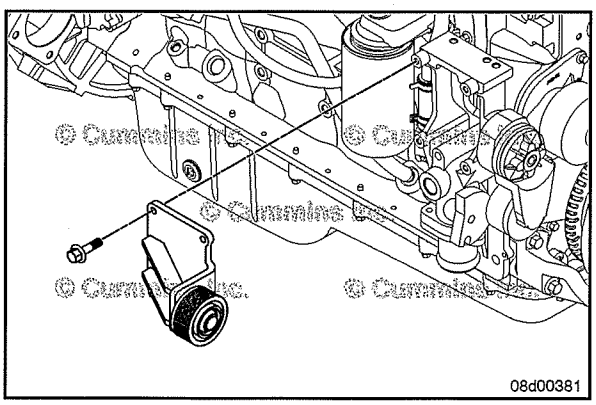


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

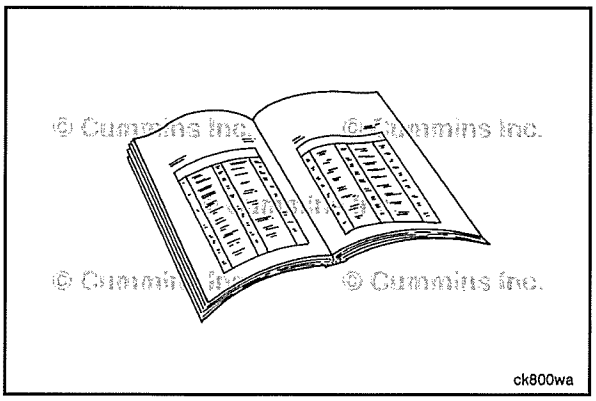
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Pulley, Fan Idler (008-111)

General Information

Some front accessory drive configurations require an idler pulley to support the drive belt. The location of the idler pulley will vary depending on the application and front accessory drive configuration.



Preparatory Steps

⚠WARNING⚠

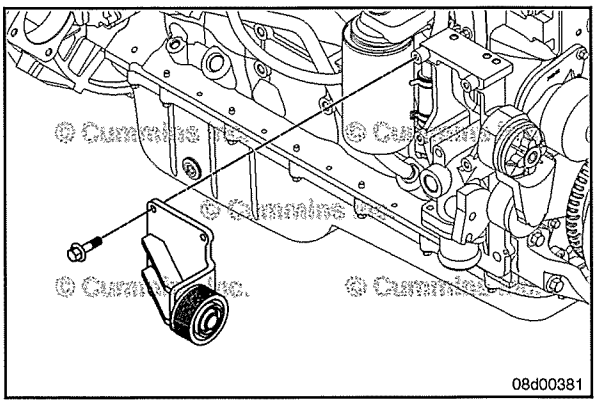
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- If required, remove the fan shroud assembly. Refer to the OEM service manual.

Remove

NOTE: If replacing the idler pulley, it is recommended that the idler pulley assembly be removed to make sure the dust shield is properly installed.

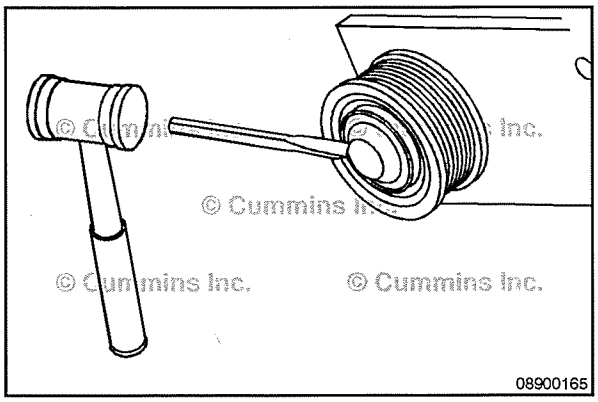
Remove the idler pulley support bracket mounting capscrews and remove the idler pulley assembly.



Disassemble

If the idler pulley mounting capscrew is covered by a dust shield, use a hammer and chisel to drive the dust shield out of the pulley. To ease removal, position the chisel on the side portion of the dust shield.

Discard the old dust shield. A new dust shield will be required upon installation.

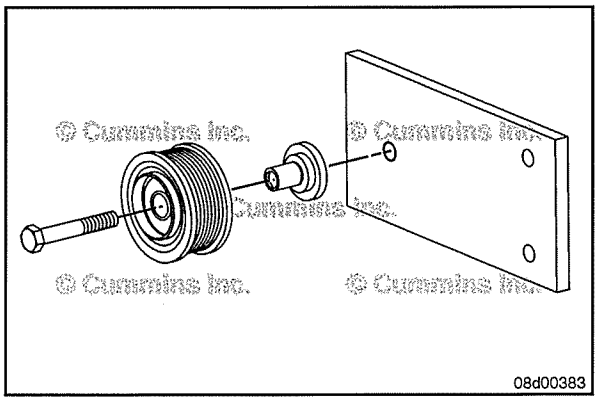


NOTE: For some idler pulley installations, the idler pulley shaft is a part of the idler pulley support bracket.

Remove the idler pulley mounting capscrew.

Remove the idler pulley and idler pulley shaft.

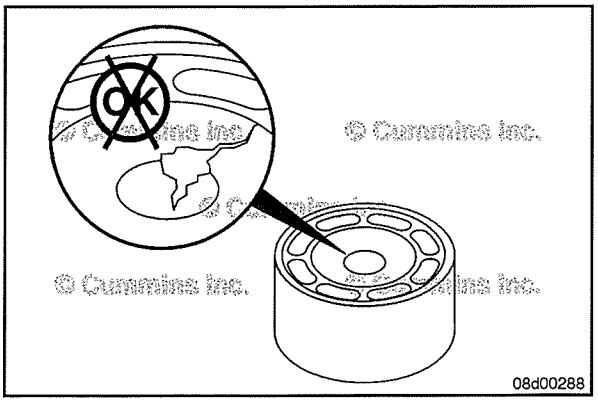
Observe the orientation of the idler pulley during removal. The pulley may **not** be symmetrical. The pulley **must** be oriented correctly during installation for proper belt alignment.

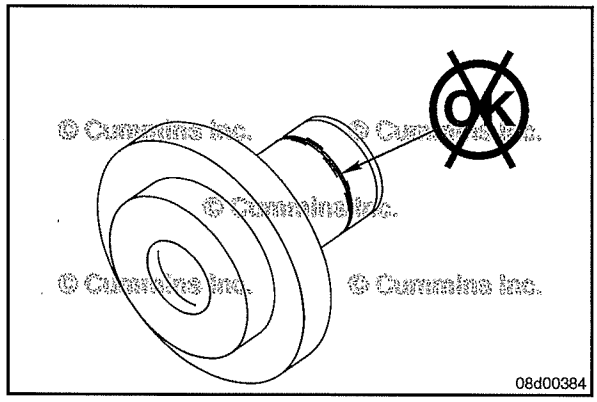


Clean and Inspect for Reuse

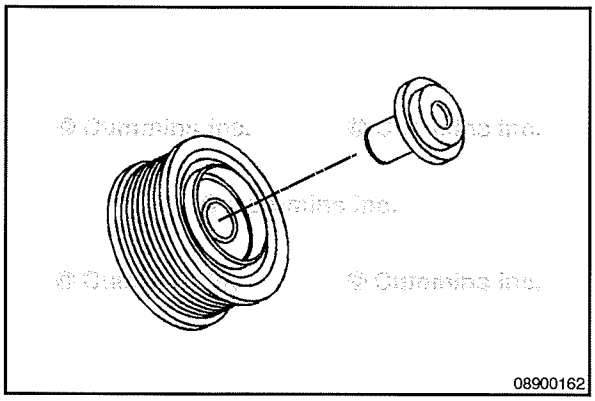
Inspect the idler pulley for nicks, cracks or any other type of damage. Spin the idler pulley to check for rough or noisy operation.

Replace the idler pulley if any damage is found.





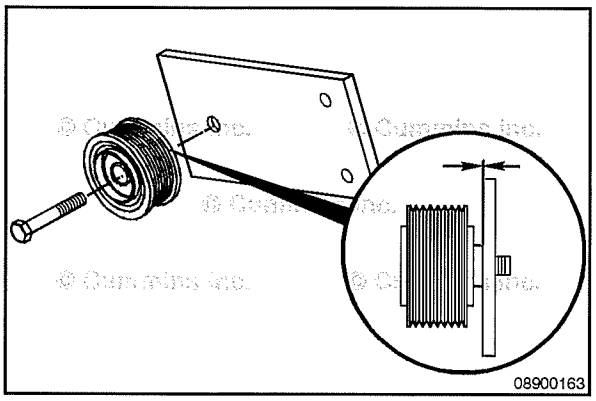
Inspect the idler pulley shaft for grooves or galling. Replace the shaft or support bracket if any damage is found.



Assemble

Install the idler pulley onto the idler shaft.

For idler pulley installations in which the idler pulley shaft is **not** part of the idler pulley support bracket, the pulley is symmetric, so the shaft can be assembled to either side of the pulley.

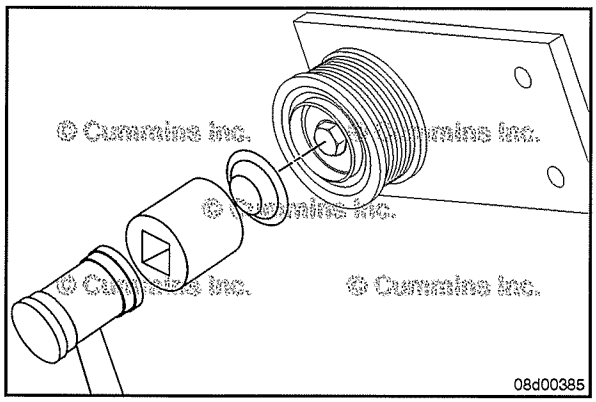


NOTE: For idler pulley installations in which the idler pulley shaft is **not** part of the idler pulley support bracket, the flanged side of the idler pulley shaft **must** set flush against the idler pulley support bracket.

For idler pulley installations in which the idler pulley shaft is **not** part of the idler pulley support bracket, align the idler pulley assembly with the mounting location on the idler pulley support bracket.

Install the idler pulley mounting capscrew and tighten.

Torque Value: 18 N•m [159 in-lb]



If the idler pulley mounting capscrew is covered by a dust shield, install a new dust shield.

The preferred method of installation is to use a press and socket that match the outside diameter of the dust shield.

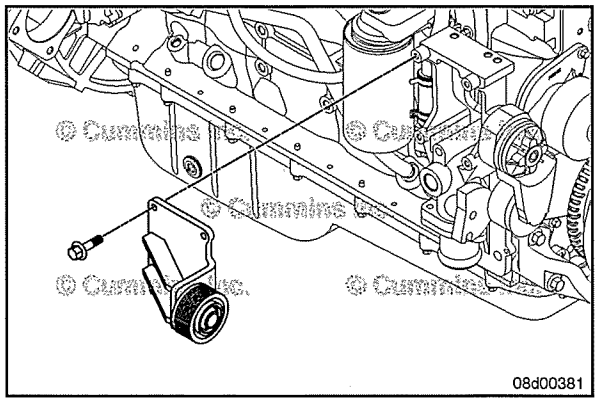
If a press is **not** available, use a socket that matches the outside diameter of the dust shield and drive the dust shield into the idler pulley with a hammer.

Install

Install the idler pulley assembly and idler pulley support bracket mounting capscrews

Tighten the capscrews.

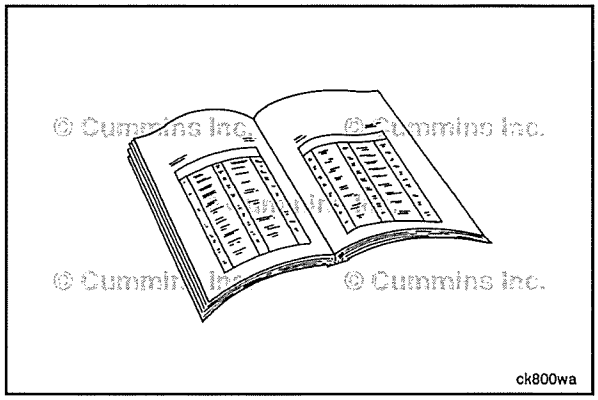
Torque Value: 18 N•m [159 in-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the fan drive belt. Refer to Procedure 008-002 in Section 8.
- If removed, install fan shroud assembly. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



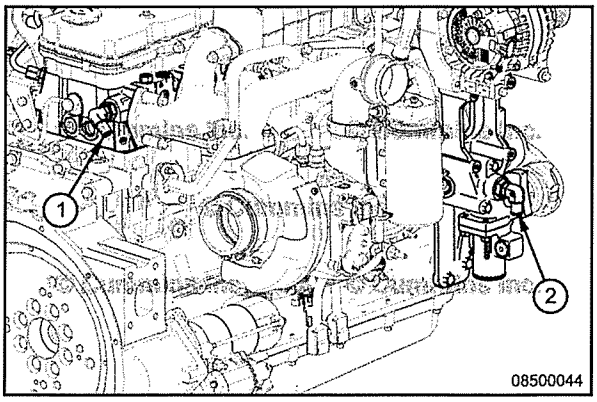
Coolant Plumbing (008-124)

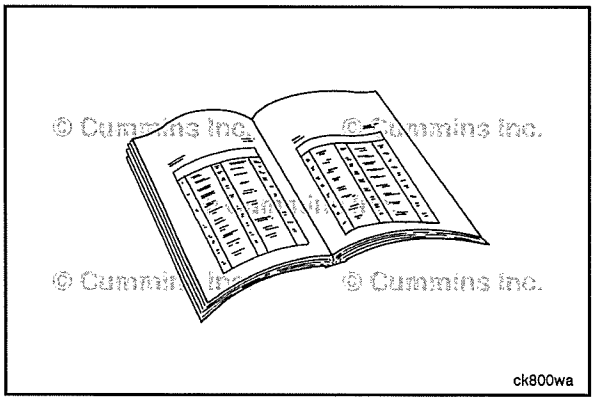
General Information

The purpose of this procedure is to explain how to install and remove the selective catalytic reduction (SCR) coolant fittings that fasten to the cylinder head and water inlet connection.

The location and size of these fasteners may vary by original equipment manufacturer (OEM). Refer to the OEM service manual for details.

Generally, the SCR coolant supply port (1) is located on the back of the cylinder head and the SCR coolant return port (2) is located at the water inlet connection.





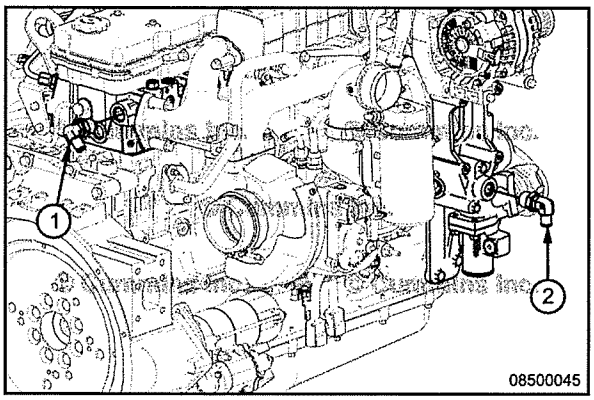
Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the OEM service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Disconnect the OEM SCR coolant plumbing, as needed.

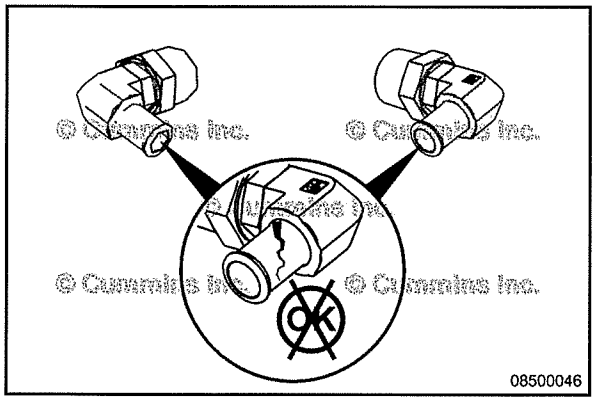


Remove

Remove the ¾-14 NPTF fitting from the back of the cylinder head SCR coolant supply port (1).

Remove the SCR coolant return fitting (2). The location and size of the fitting varies by OEM. Refer to the OEM service manual.

NOTE: Take note of the proper orientation and location of any 90 or 45 degree coolant line fittings before removal.



Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the fittings with cleaning solvent. Dry with compressed air.

Inspect the fittings for cracks, corrosion, or other damage.

If damaged, the part **must** be replaced.

Install

Apply a film of pipe sealant, Part Number 3375066 or equivalent, to the threads of the ¾-14 NPTF fitting.

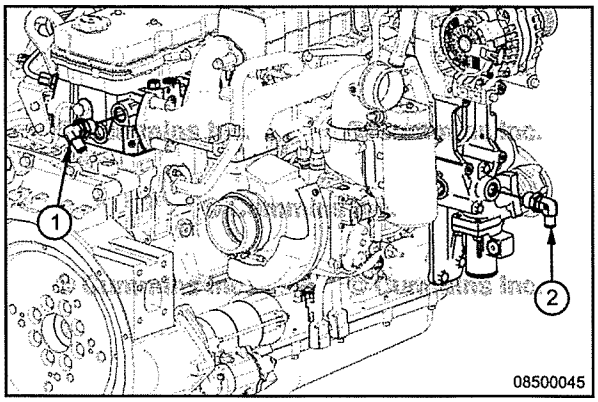
Install the ¾-14 NPTF fitting into cylinder head SCR coolant supply port (1).

Torque Value: 55 N•m [41 ft-lb]

Apply a film of pipe sealant, Part Number 3375066 or equivalent, to the threads of the SCR coolant return fitting (2).

Install the SCR coolant return fitting. The location and size vary by OEM. Refer to the OEM service manual.

Use the following procedure for torque values on various fitting sizes. Refer to Procedure 017-007 in Section 17.

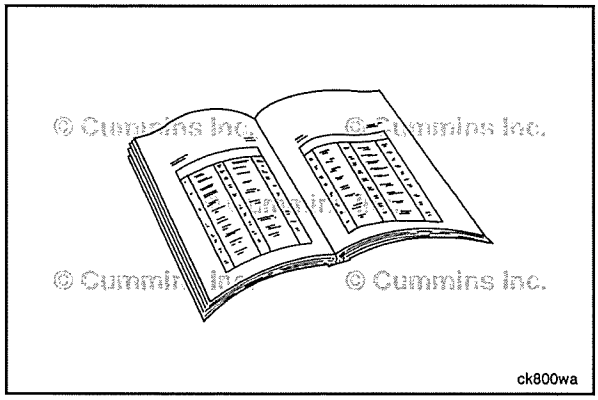


Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the OEM SCR coolant plumbing, as needed.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine to check for leaks.



Notes

Section 9 - Drive Units - Group 09

Section Contents

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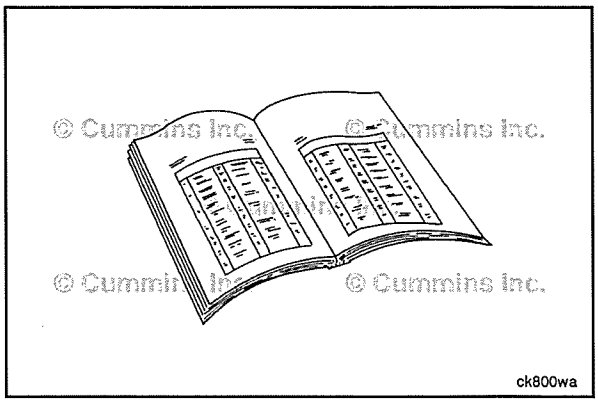
Accessory Drive (009-001)

Preparatory Steps



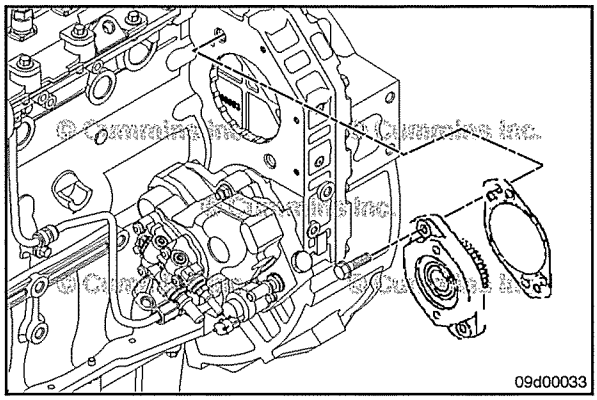
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the OEM service manual.
- Remove the driven accessory. Refer to the OEM service manual.

NOTE: Typically the driven accessory is a hydraulic pump.

- Remove the hydraulic pump. Refer to Procedure 009-016 in Section 9.

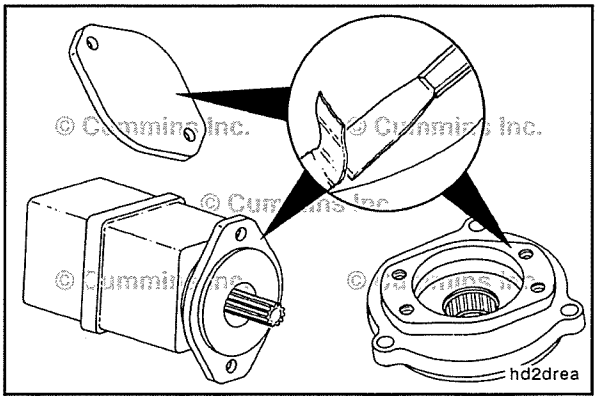
Remove



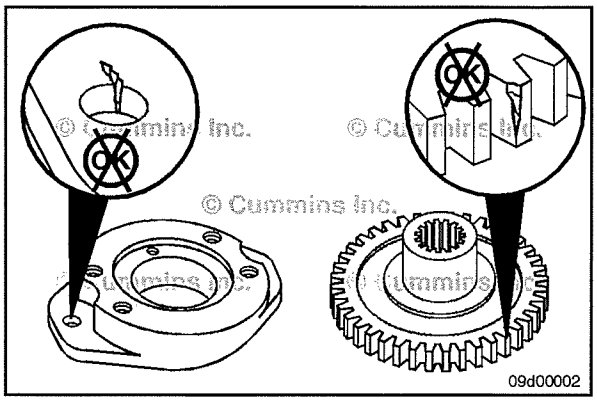
Remove the two capscrews securing the accessory drive to the rear gear housing.

Remove the accessory drive and gasket.

Clean and Inspect for Reuse



Remove any residual gasket material from the mounting surfaces of the accessory drive, driven accessory/ hydraulic pump, and, if equipped, the cover plate surface.



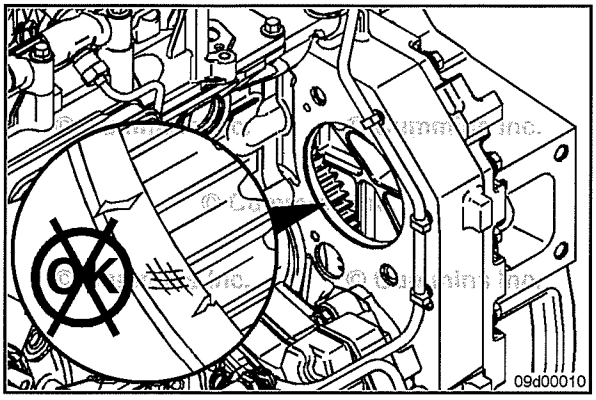
NOTE: Make sure the oil supply hole in the accessory drive housing is open and free of debris.

Inspect the accessory drive housing for cracks.

Inspect the accessory drive gear and shaft splines for cracks, broken teeth, and other damage.

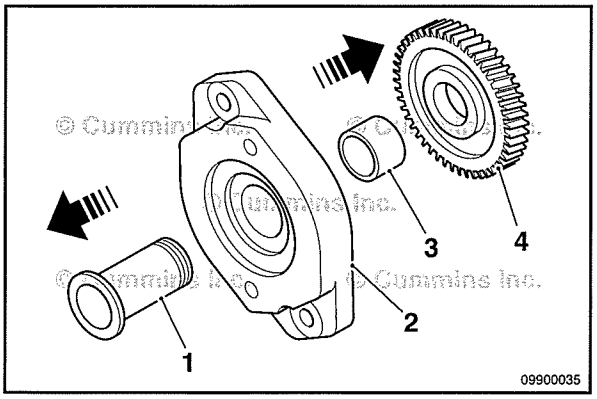
NOTE: If there is damage to the accessory drive gear teeth or there are signs of excessive heat, make sure to inspect the associated camshaft and fuel pump gears for damage. Measure camshaft gear backlash upon installation.

Replace any damaged components. See the Disassemble step of this procedure.



NOTE: Make sure the oil supply hole in the gear housing is open and free of debris.

Inspect the inside diameter of the drive gear bore for excessive wear or damage; replace if necessary.



Disassemble

If damage was found to a component of the accessory drive during the Clean and Inspect for Reuse step, the following components of the accessory drive, if damaged, can be replaced by disassembling the accessory drive.

- Accessory drive shaft
- Accessory drive housing
- Accessory drive bearing
- Accessory drive gear.

NOTE: Before disassembling the accessory drive, check to make sure the parts for the specific accessory drive being serviced are available. If **not**, replace the accessory drive as an assembly.

Use a hydraulic press and proper support to disassemble the accessory drive in the following order.

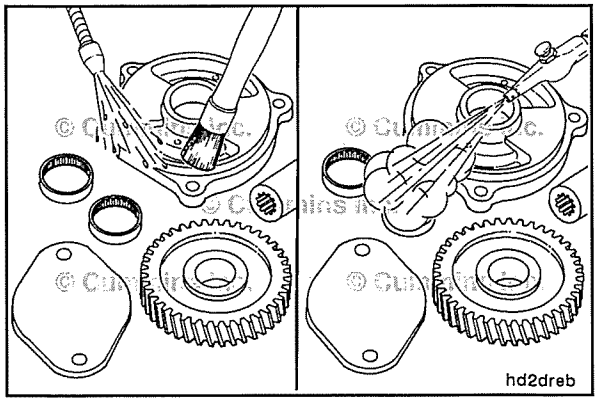
- Press the drive shaft from the drive gear and housing
- Press the bearing from the housing.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

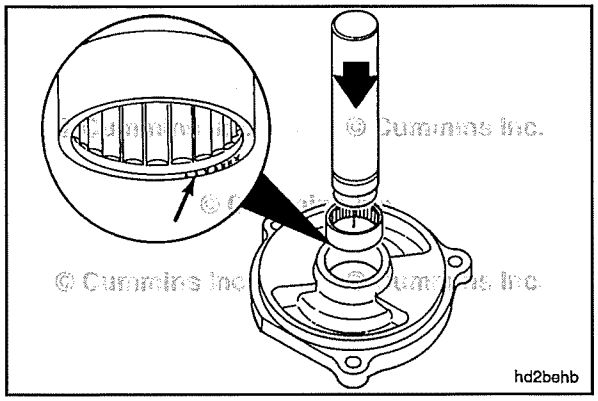
Clean the accessory drive components with solvent.

Dry with compressed air.



Inspect the bearing for binding, seizing, and excessive noise when spun.

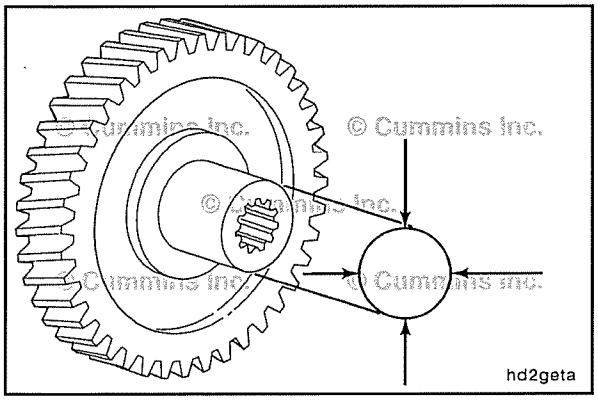
Replace if any damage is found.



Measure the inside diameter of the accessory drive gear bore.

Accessory Drive Gear Bore Inside Diameter (Accessory Drive Adapter)		
mm		**in**
38.920	MIN	1.5323
38.945	MAX	1.5333

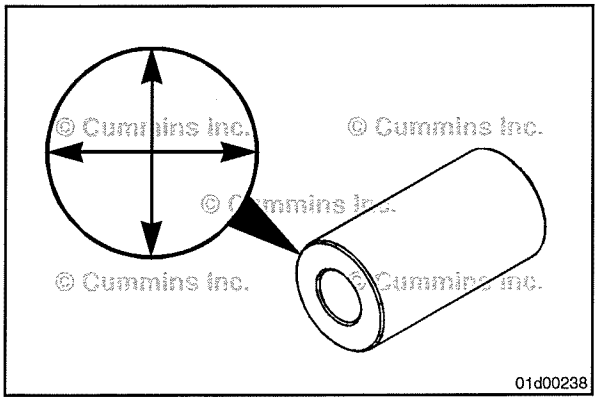
If out of specification, replace the accessory drive gear.

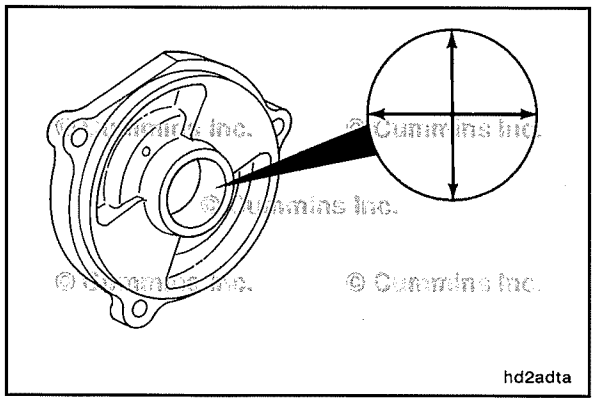


Measure the outside diameter of the accessory drive shaft at multiple locations along the shaft.

Accessory Drive Shaft Outside Diameter (Accessory Drive Adapter)		
mm		**in**
39.008	MIN	1.5357
39.020	MAX	1.5362

If out of specification, replace the accessory drive shaft.

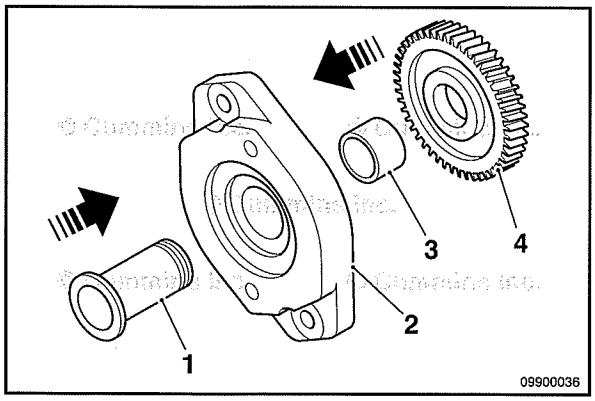




Measure the inside diameter of the bearing bore in the accessory drive adapter housing.

Bearing Bore Inside Diameter (Accessory Drive Adapter)		
mm		in
67.759	MIN	2.6755
67.983	MAX	2.6765

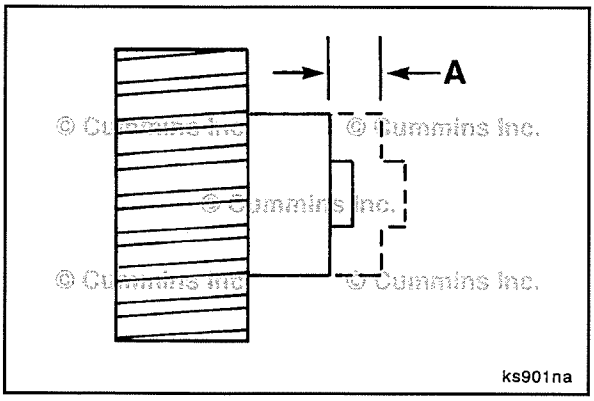
If out of specification, replace the housing.



Assemble

Use a hydraulic press and proper support to assemble the accessory drive in the following order:

- Press the accessory drive shaft into the bearing, while supporting the bearing inner race, until the drive shaft bottoms on the inner race.
- Press the outer race of the bearing, with drive shaft, into the accessory drive housing, until the outer race bottoms in the housing.
- Press the accessory drive gear onto the shaft while supporting the bottom of the drive shaft. Press until gear bottoms against inner bearing race.



Measure

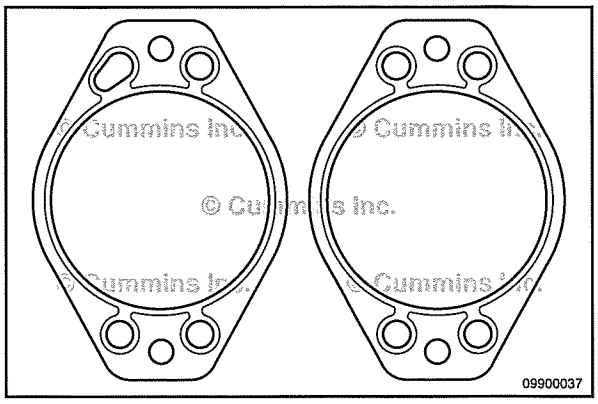
Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399 to check the accessory drive gear end clearance.

Accessory Drive Gear End Clearance		
mm		in
0.5	MIN	0.020

If the end clearance is out of specification:

- If just assembled, check if the drive gear and bearing were completely pressed onto the drive shaft
- If **not** previously disassembled, disassemble the accessory drive and inspect for damage. Replace as necessary
- Replace the accessory drive assembly.

Initial Check



NOTE: If oil supply to the accessory drive is **not** required and the gasket does **not** have oil passages, this check is **not** required. If the accessory drive uses o-rings for seals, this check is **not** required.

Prior to installing the accessory drive, identify which gasket is going to be installed so that, if necessary, the gasket can be properly oriented.

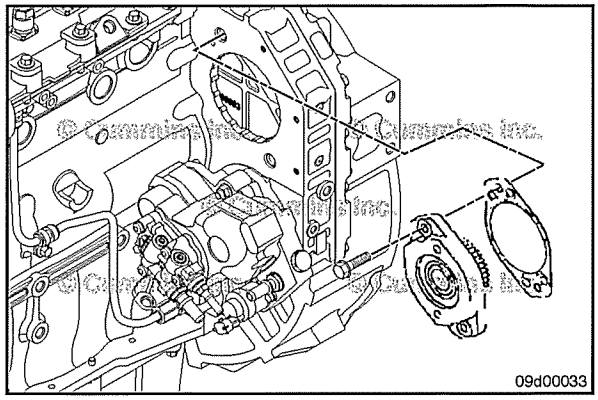
There are two types of accessory drive gasket:

- Three round oil supply passages and one elongated oil supply passage
- Four round oil supply passages.

It is preferred that, when installing the accessory drive, the gasket with the four round oil supply passages be used. The gasket can be installed in any orientation.

If **only** the gasket with the one elongated oil supply passage is available, install the gasket so that the elongated oil supply passage is **not** over the oil supply hole in the gear housing.

Install



⚠CAUTION⚠
Failure to line up the oil supply hole to the accessory drive properly will result in accessory drive damage.

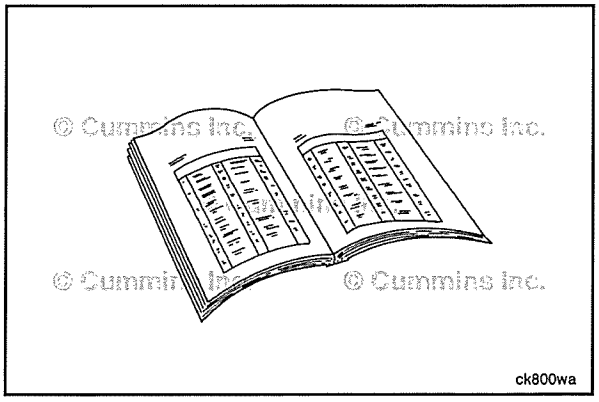
Install the accessory drive and new gasket.

NOTE: When installing the accessory drive and gasket, make sure the oil supply hole in the gear housing is lined up with the holes in the accessory drive and gasket. The accessory drive is marked for "Top" and "Bottom".

Install and tighten the two capscrews securing the accessory drive to the rear gear housing.

Torque Value: 62 N•m [46 ft-lb]

Finishing Steps

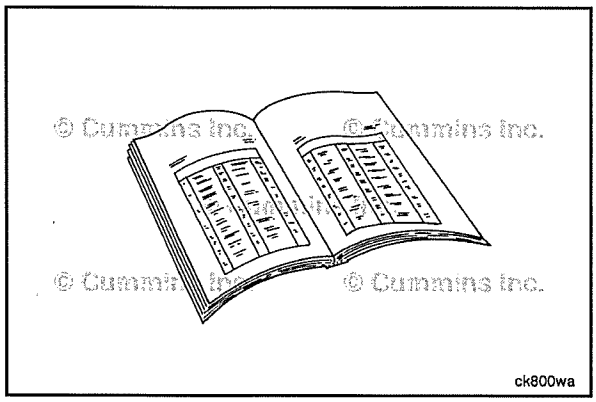


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the driven accessory. Refer to the OEM service manual.

NOTE: Typically the driven accessory is a hydraulic pump.

- Install the hydraulic pump. Refer to Procedure 009-016 in Section 9.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

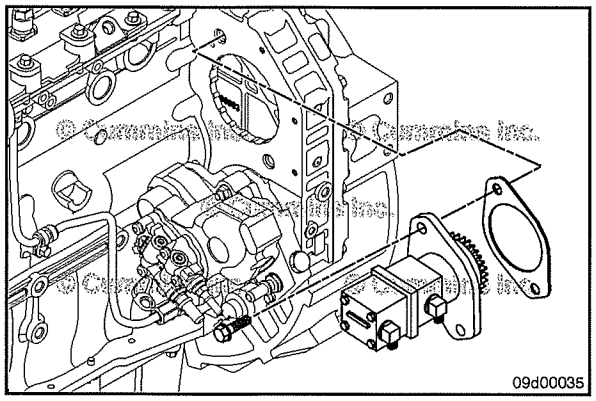


Hydraulic Pump Drive (009-016)

Preparatory Steps

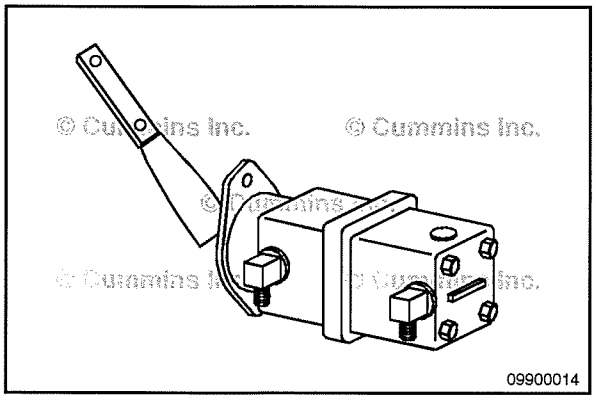
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the OEM service manual.



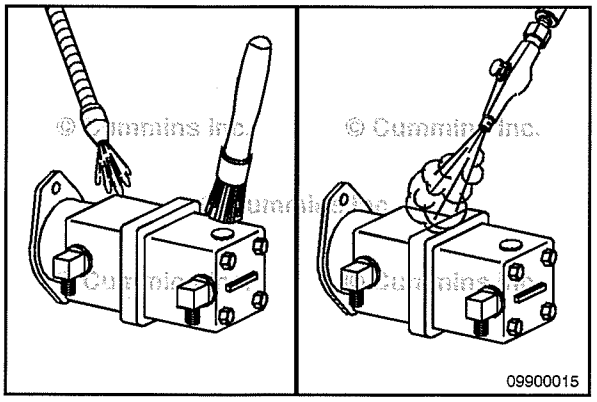
Remove

Remove the hydraulic pump and gear assembly. Refer to the OEM service manual for removal procedures.



Clean and Inspect for Reuse

Clean the gasket material from the hydraulic pump with a putty knife and a clean rag.



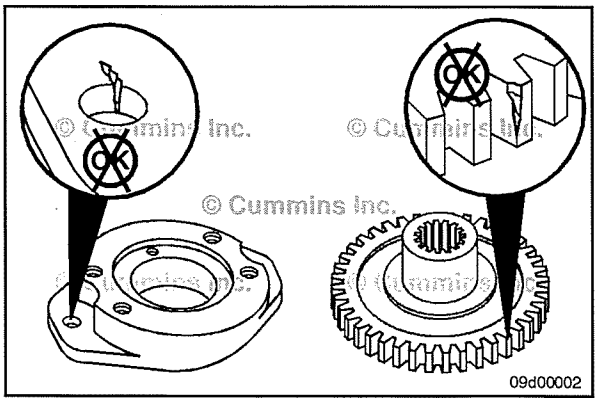
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

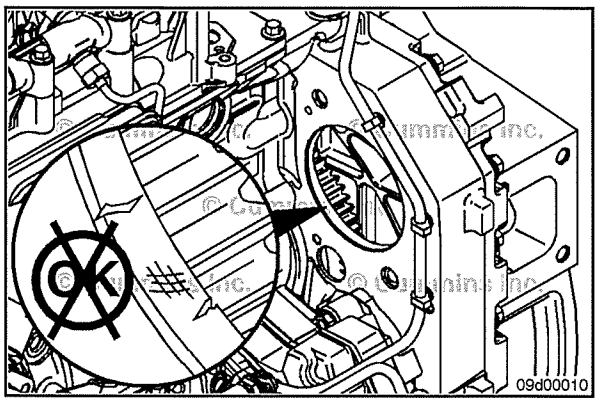
Clean the hydraulic pump gear with solvent.

Dry with compressed air.

Inspect the hydraulic pump drive gear for cracks, broken teeth, and other damage.



Inspect the inside diameter of the drive gear bore for excessive wear or damage; replace if necessary.

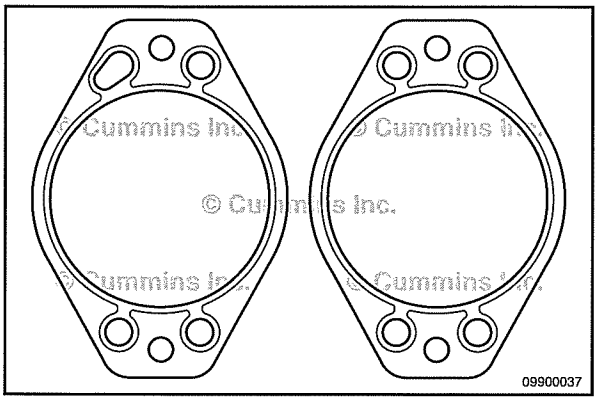


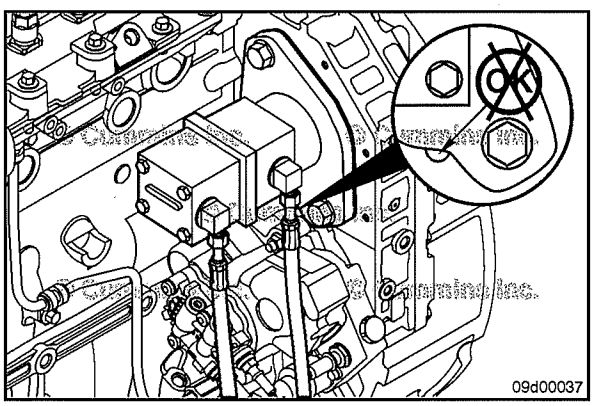
Install

Prior to installing the accessory drive, identify which style of gasket is going to be installed so that, if necessary, the gasket can be properly oriented. There are two types of accessory drive gaskets:

- Three round oil supply passages and one elongated oil supply passage.
- Four round oil supply passages.

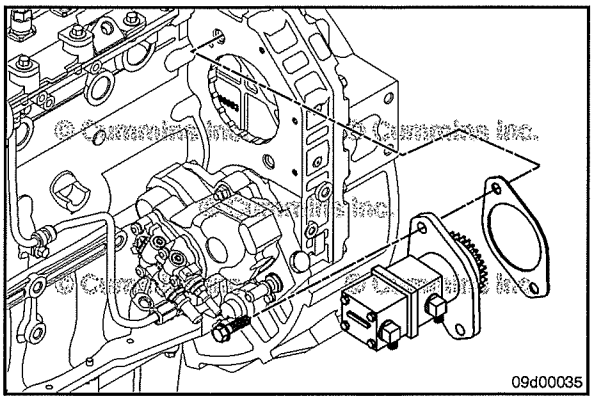
It is preferred that, when installing the accessory drive, the gasket with the 4 round oil supply passages be used. The gasket can be installed in any orientation. If **only** the gasket with the one elongated oil supply passage is available, install the gasket so that the elongated oil supply passage is **not** over the oil supply hole in the gear housing.





For hydraulic/power steering pumps mounted directly to the rear gear housing, verify that the pump has a full mounting flange.

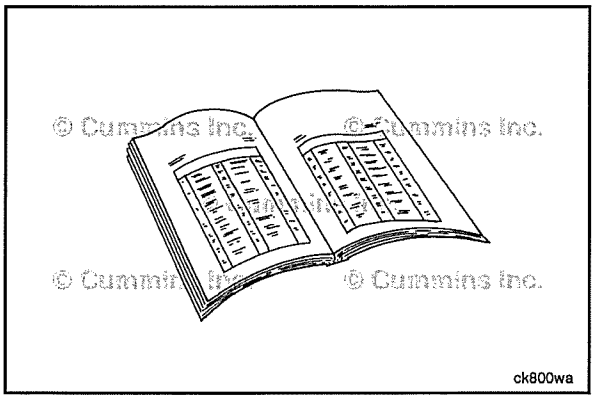
A hydraulic/power steering pump that has a notch in the mounting flange will **not** cover the oil supply port in the rear gear housing completely, when installed.



Use a new gasket and install the hydraulic pump and mounting capscrews.

Tighten the capscrews.

Torque Value: 62 N•m [46 ft-lb]

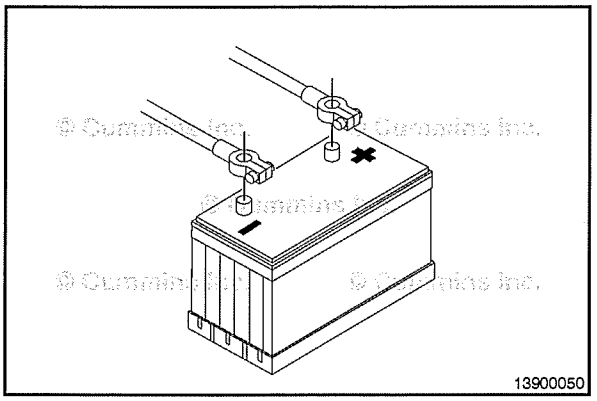


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Accessory Drive Cover (009-039)

Preparatory Steps

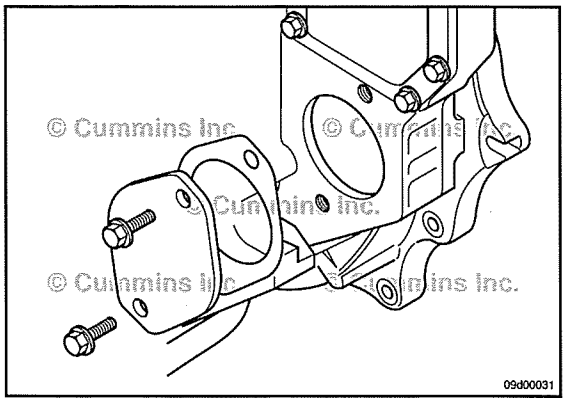
⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to OEM service manual.

Remove

Remove the accessory drive cover, mounting capscrews and gasket.



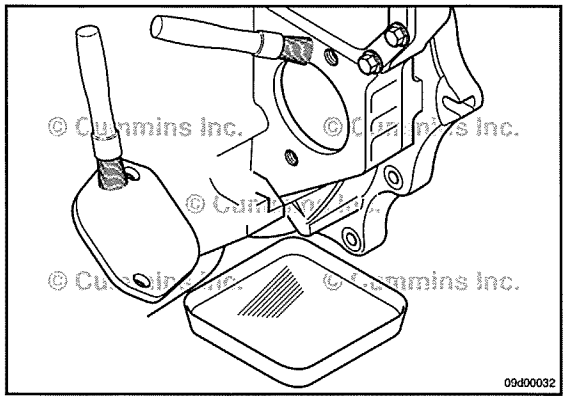
Clean

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the accessory drive cover and rear gear housing mounting surface with solvent.

Dry with compressed air.



Install

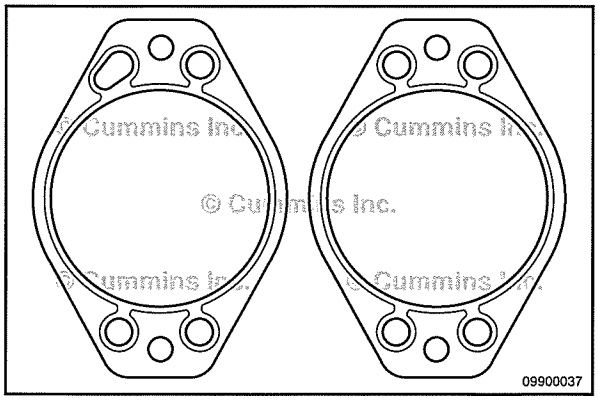
Prior to installing the accessory drive cover, identify which style of gasket is going to be installed so that, if necessary, the gasket can be properly oriented.

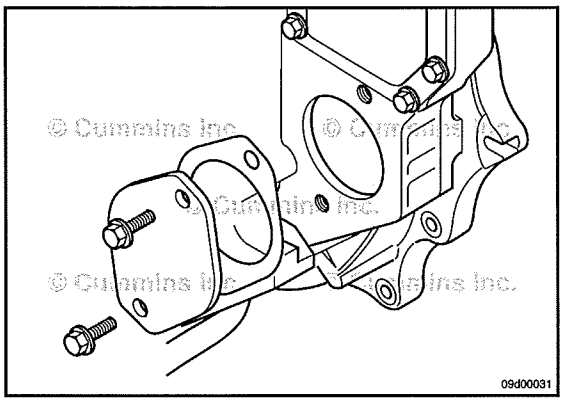
There are two types of accessory drive cover gaskets:

- Three round oil supply passages and one elongated oil supply passage
- Four round oil supply passages.

It is preferred that, when installing the accessory drive, the gasket with the four round oil supply passages be used. The gasket can be installed in any orientation.

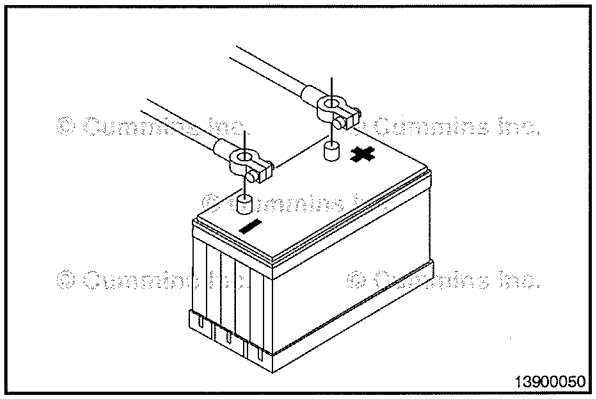
If **only** the gasket with the one elongated oil supply passage is available, install the gasket so that the elongated oil supply passage is **not** over the oil supply hole in the gear housing.





Install the accessory drive cover, gasket and mounting capscrews. Tighten the mounting capscrews.

Torque Value: 50 N•m [37 ft-lb]

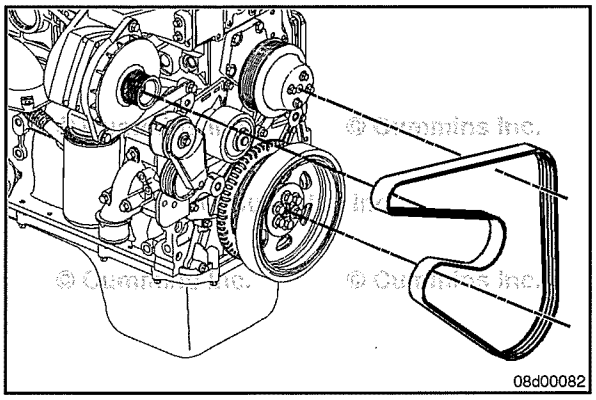


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

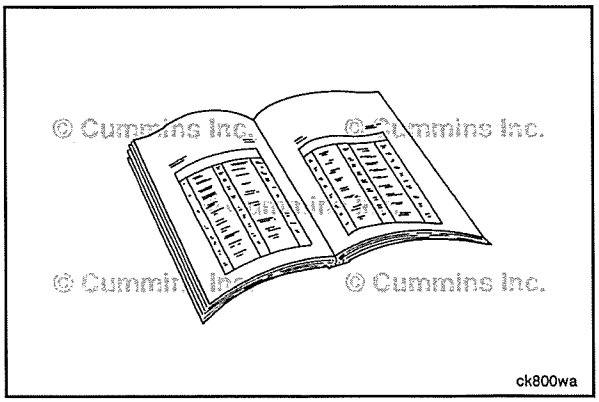


Drive Belt, Refrigerant Compressor (009-052)

General Information

Some refrigerant compressors use the cooling fan drive belt. Use the following procedure for information and instructions on these belts. Refer to Procedure 008-002 in Section 8.

Preparatory Steps

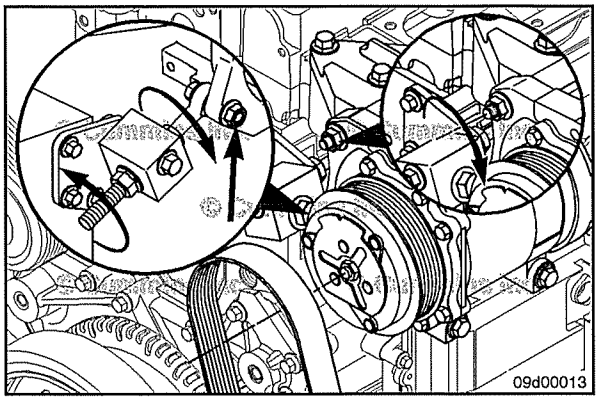


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

- Disconnect the battery cables. Refer to the OEM service manual.

Remove



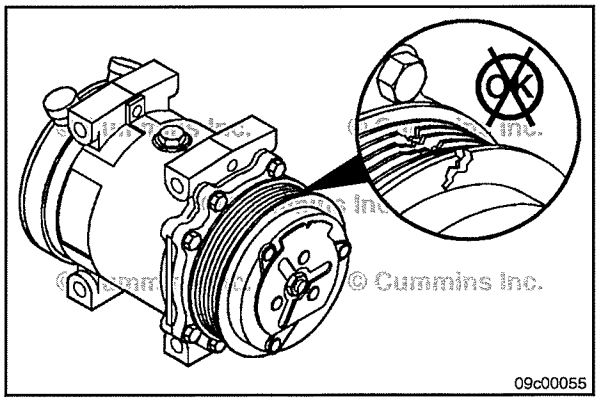
Loosen the pivot bolt.

Loosen the bolt that attaches the adjusting link to the compressor bracket.

Loosen the adjusting nuts on the adjusting link to remove tension from the belt.

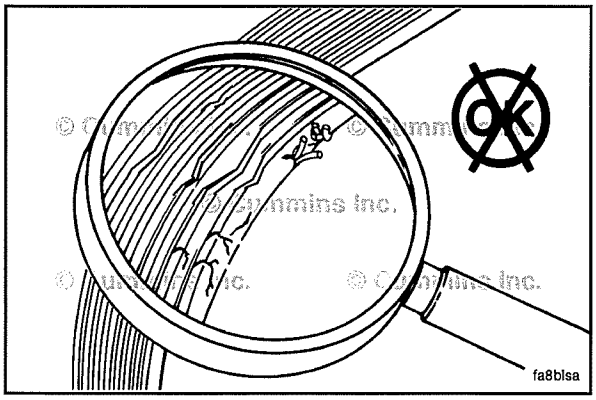
Remove the refrigerant compressor drive belt.

Inspect for Reuse



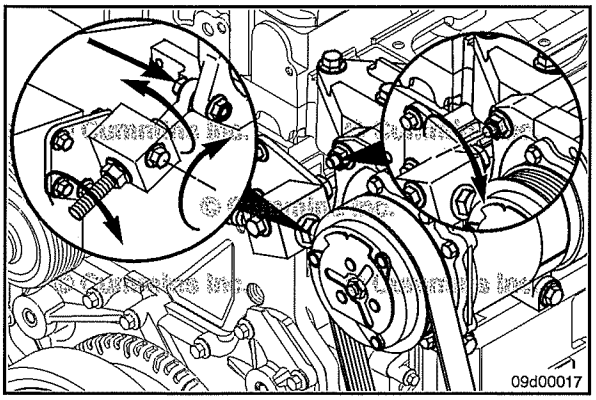
Inspect the refrigerant compressor pulley for cracks or broken grooves.

Replace the refrigerant compressor, if it is damaged.



Inspect the belt for cracks, glazing, tears, cuts, and excessive wear.

Replace the belt, if necessary.

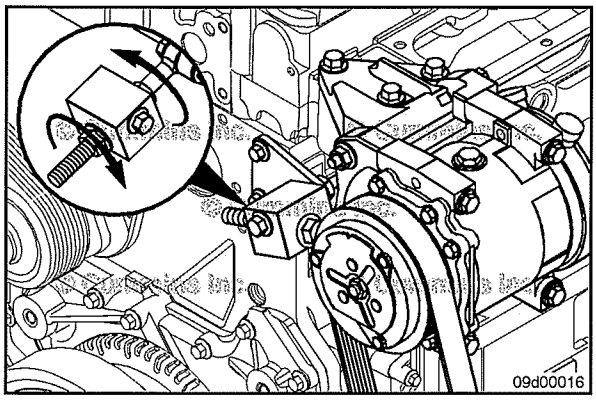


Install

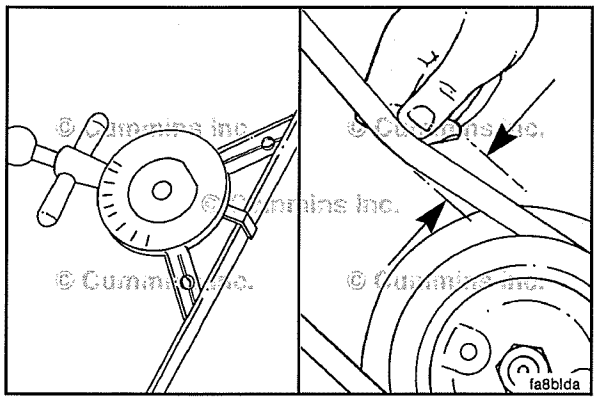
Tighten the pivot bolts and the adjusting link bolts hand-tight.

Tighten the bolt that attaches the adjusting link to the compressor bracket hand-tight.

Install the refrigerant compressor drive belt.



Use the adjusting nuts on the adjusting link to tighten the refrigerant compressor drive belt.



Use a belt gauge to measure the belt tension. Use the following procedure for the correct gauge and tension value for the belt width used. Refer to Procedure 018-005 in Section V.

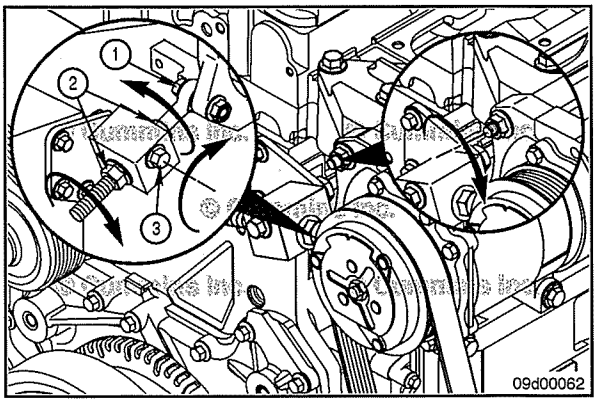
Belt Tension 534 N [120 lbf]

Tighten the pivot bolt, the adjusting link bolts, and the adjusting link to bracket mounting bolt.

Torque Value:
Pivot Bolt (1) 43 N•m [32 ft-lb]

Torque Value:
Adjusting Link Bolts (2) 77 N•m [57 ft-lb]

Torque Value:
Adjusting Link to Bracket Mounting Bolt (3) 43 N•m [32 ft-lb]

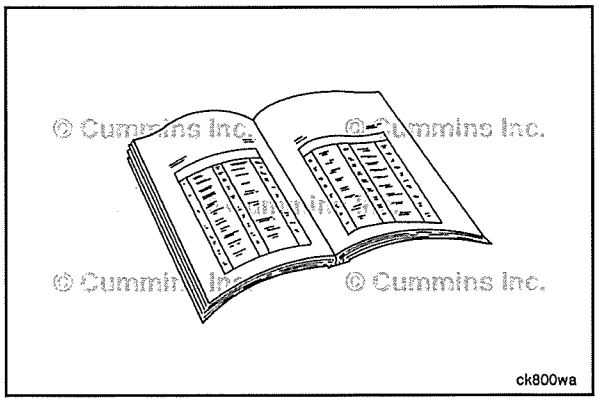


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for belt squeal. Excessive belt squeal indicates belt slippage.
- If belt squeal is present, check the belt tension.

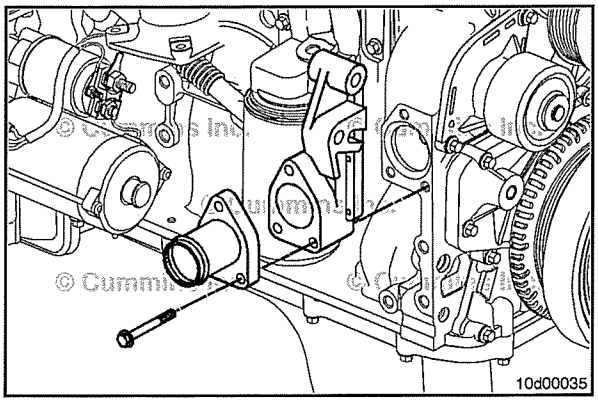


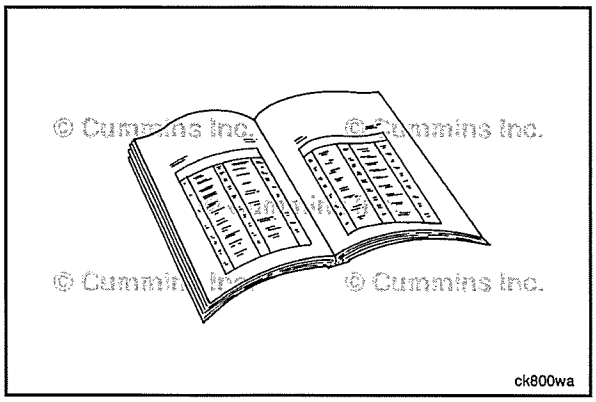
Refrigerant Compressor Mounting Bracket (009-055)

General Information

Some refrigerant compressor brackets are integral to the water inlet connection.

Refer to Procedure 008-082 in Section 8.

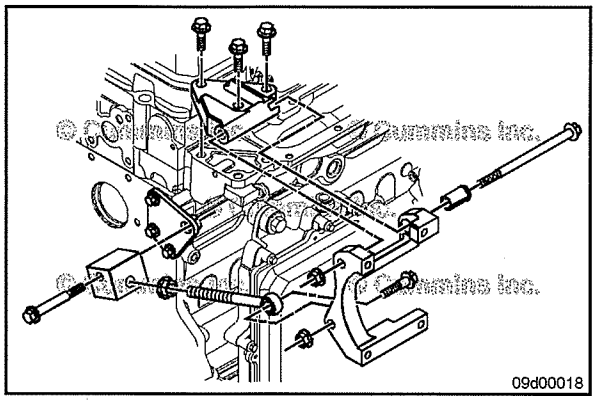




Preparatory Steps

⚠WARNING⚠
To protect the environment, liquid refrigerant systems must be properly emptied and filled using equipment that prevents the release of refrigerant gas into the atmosphere. Federal law requires capturing and recycling the refrigerant.

- Remove the refrigerant compressor belt. Refer to Procedure 009-052 in Section 9.
- Remove the refrigerant compressor. Refer to the original equipment manufacturer (OEM) service manual.



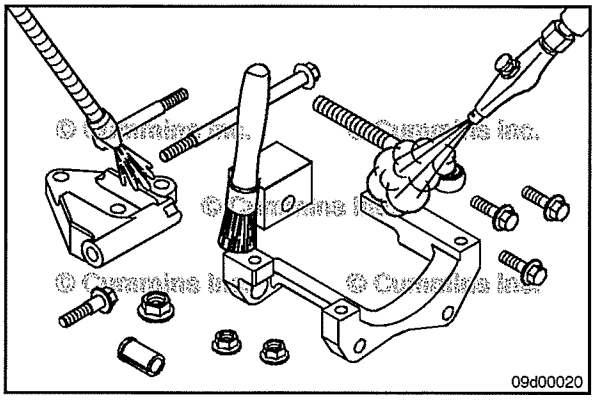
Remove

Remove the adjusting link bolts.

Remove the adjusting link.

Remove the pivot bolt and the refrigerant compressor support.

Remove the remaining capscrews and brackets.



Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

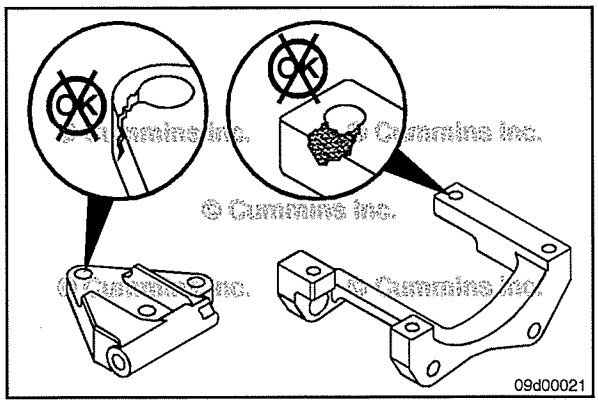
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the refrigerant compressor mounting brackets with solvent.

Dry with compressed air.

Inspect the refrigerant compressor mounting brackets.

Replace the refrigerant compressor mounting brackets, if cracked or otherwise damaged.



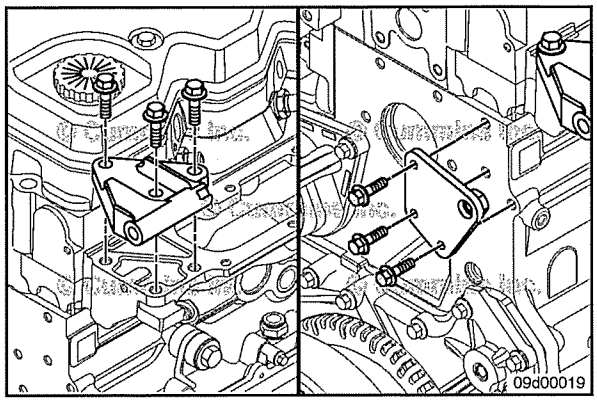
Install

Install the two mounting brackets and capscrews.

Tighten the capscrews.

Torque Value:
M8 23 N•m [204 in-lb]

Torque Value:
M10 43 N•m [32 ft-lb]



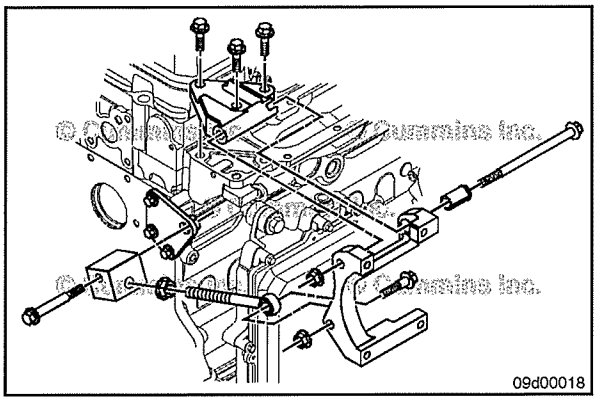
Install the refrigerant compressor support.

Install the pivot bolt hand-tight.

Install the adjusting link.

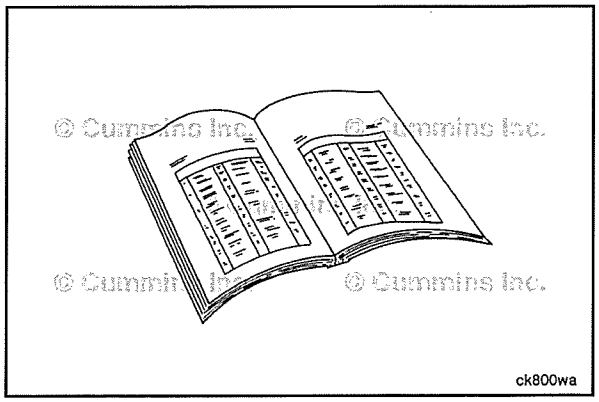
Install the adjusting link bolts hand-tight.

Tighten the adjusting link bolts and the pivot bolt after the refrigerant compressor is installed and the drive belt has been tensioned.



Finishing Steps

- Install the refrigerant compressor. Refer to the OEM service manual.
- Install the refrigerant compressor belt. Refer to Procedure 009-052 in Section 9.
- Operate the engine and check for leaks.



Notes

Section 10 - Air Intake System - Group 10

Section Contents

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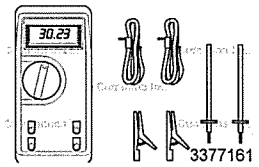
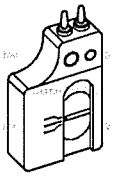
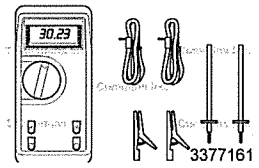
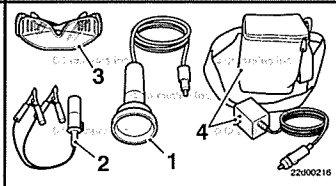
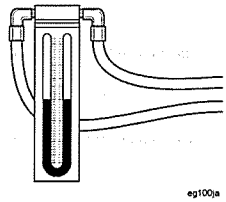
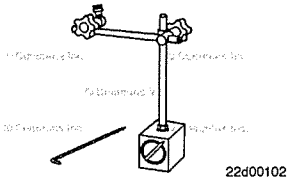
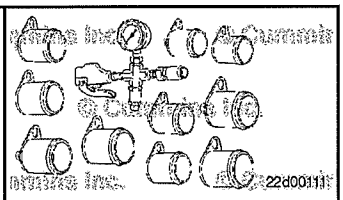
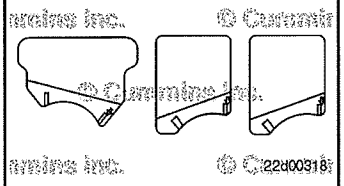
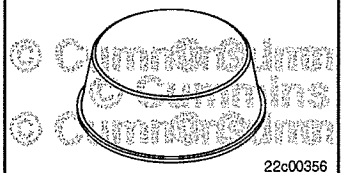
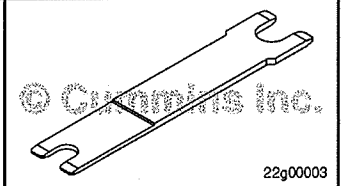
Service Tools

Air Intake System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164488, 3164489	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amperes). Part Number 3164488 - Standard Meter, Part Number 3164489 - Automotive Meter with built in temperature adapter and tachometer.	
3164499	**Digital Thermometer** Used to measure ambient air temperature. Use with digital multimeter, Part Number 3164488.	
3164498	**Bead Probe** Used with digital thermometer, Part Number 3164499.	
3163338	**Black Light Lamp (12-VDC)** Used with fluorescent tracer to locate coolant and/or oil leaks. Lamp operates off vehicle battery or portable rechargeable battery included in kit. Oil tracer, Part Number 3376891, coolant tracer, Part Number 3377438.	
ST-1111-3	**Manometer** Used to measure pressure and restriction 0 to 2.5 kPa [0 to 36 in H_2O] differential with more accuracy	
ST-537	**Magnetic Base Indicator Holder** Used in conjunction with dial indicator, Metric, Part Number 3824564. SAE, Part Number 4918289.	

Tool No.	Tool Description	Tool Illustration
3824556	**Charge-Air Cooler Tester** Used to pressure test charge-air coolers.	
4919281	**Turbocharger Actuator Inspection Gauge Kit** Used to determine if the variable geometry turbocharger has full travel of the sector gear.	
5298878	**Air Handling Clean Care Kit** Contains a variety of protective caps to prevent contamination of vehicle air handling plumbing during service procedures.	
2892393	**Quick Connect Connector Remover** Double ended tool used to release the size STC-06 and STC-08 quick connect fittings.	

Air Cleaner Element (010-014)

General Information

⚠CAUTION⚠

Only use the approved Cummins Filtration™ Direct Flow replacement filter elements to service the air cleaner. Use of improper filters can lead to engine damage.

NOTE: There are two different configurations in which the Direct Flow air cleaners can be serviced: a front service or a side service direction. Verify the configuration by reviewing the appropriate illustrations in this manual.

The Direct Flow air cleaner uses both a Primary and Secondary filter element for Industrial applications. The Direct Flow air cleaner has been designed for a maximum restriction at 635 mm H_20 [25 in H_20] of water, at which point the filter element(s) should be changed.

Measure

NOTE: The maximum restriction is reached when the vehicle is under full-load. The restriction indicator will hold the maximum restriction value read during operation, even after the engine is shut down.

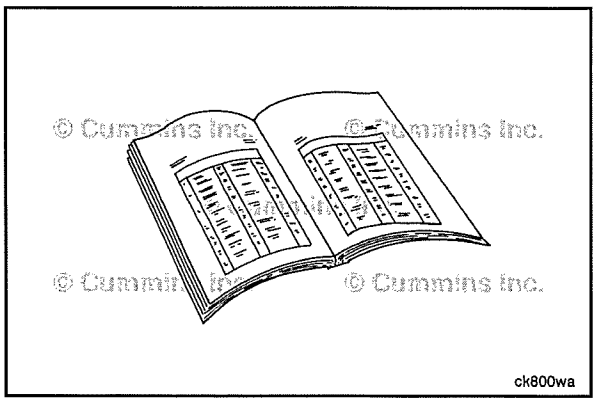
Restriction Indicator Check

Check the air cleaner restriction by the restriction indicator located on the outlet end of the air cleaner. A restriction indicator can be purchased separately if **not** present on the housing. The restriction indicator is located at the pressure tap on the outlet side of the housing.

Some restriction indicators are installed with an electronic switch that illuminates a lamp in the cab at full restriction of 635 mm H_20 [25 in H_20] of water.

Pressure/Vacuum Gauge Measure

If a restriction indicator is **not** present, attach a pressure gauge to the pressure port on the outlet side of the filter housing. Measure the vacuum during operating conditions at the maximum load.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

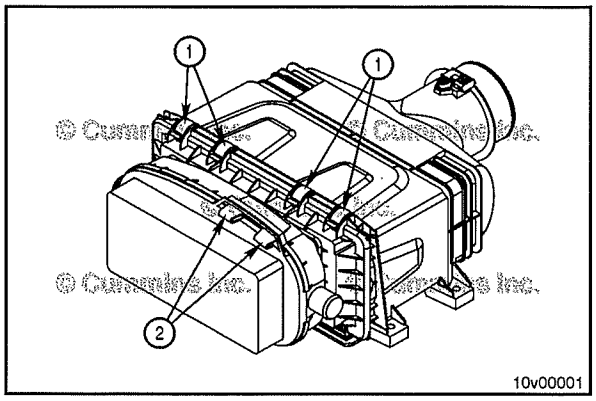
⚠WARNING⚠
Improper practices, carelessness, or ignoring the warnings can cause burns, cuts, mutilation, asphyxiation, or other personal injury or death.

△CAUTION△
Dirt or contaminants can be introduced into the system and engine if the surrounding areas are not cleaned, resulting in damage to the engine.

NOTE: It is **not** recommended to open the housing if a service event is **not** required.

NOTE: Before servicing any intake air system component, (such as the air cleaner, precleaner, hoses, ducting, etc.), clean the fittings, mounting hardware, and the area around the component to be removed.

- Shut the engine OFF.
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.



Remove

Front Service Filter Housing

Release the J-clamps to remove the pre-cleaner from the main filter housing. If present, the inlet ducting to the pre-cleaner could possibly need to be loosened or removed to remove the pre-cleaner from the housing. The pre-cleaner can be separated from the housing by sliding the mounting tabs out of the slots on the main housing.

1 Clip locations.

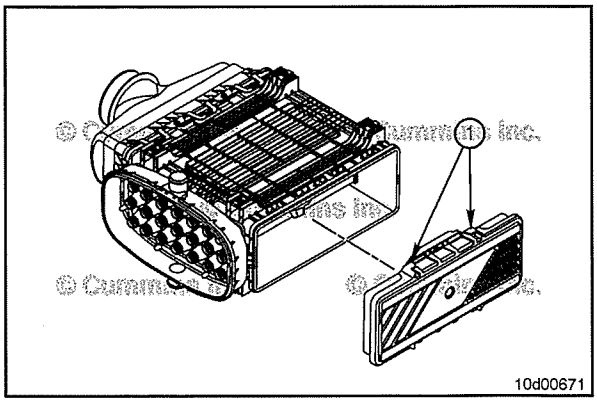
2 Tab locations.

Side Service Filter Housing

The inlet ducting does **not** need to be removed to service the filter elements. To access the filter elements, remove the service door by lifting on the plastic clips on both the top and bottom sides of the housing. The service door will be completely removed from the main housing.

1 Service door clip (both sides).

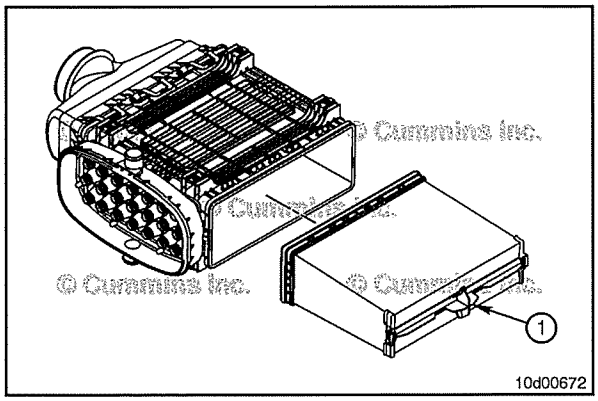
Make sure the gasket around the service door or pre-cleaner remains seated.



The Direct Flow primary filter element has a built-in handle for easy removal. Grasp the handle in the center of the element and pull the filter element outward.

1 Primary element removal handle.

Clean the inside of the housing with a damp rag to remove all loose dirt and dust.



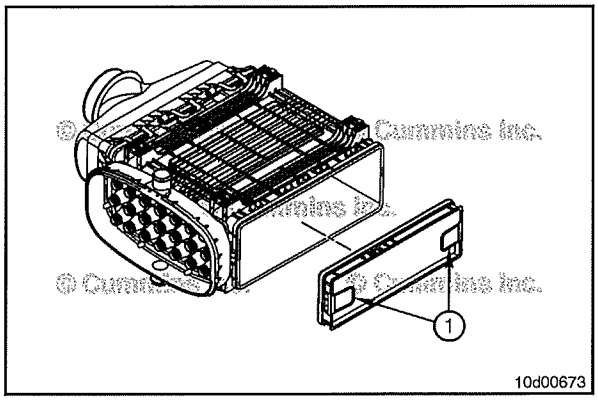
⚠CAUTION⚠
Use caution when removing the secondary element. Any loose debris can fall into the air intake plumbing leading directly to the engine. Clean the area around the secondary filter element and replace the secondary promptly to avoid engine contamination ingestion.

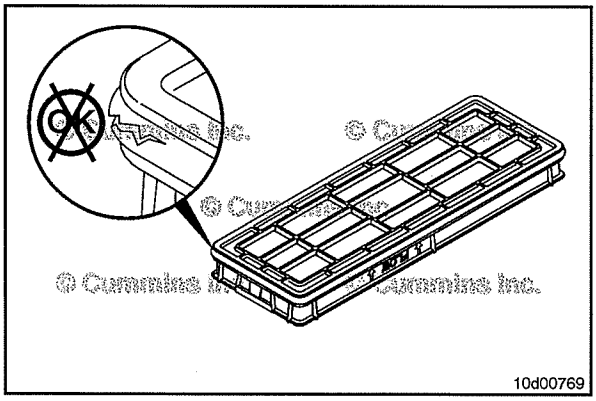
⚠CAUTION⚠
Do not attempt to clean the filter elements. Cleaning filter elements by impact or compressed air voids the warranty and can degrade or damage the filter media leading to malfunction.

NOTE: The secondary element should be changed every-other time the primary element is changed. Proper inspection of the secondary element is to be performed and the element is to be changed, if necessary.

The secondary element is removed by pulling on the plastic ring tab on the inside face of the filter element.

1 Secondary element removal ring tab.

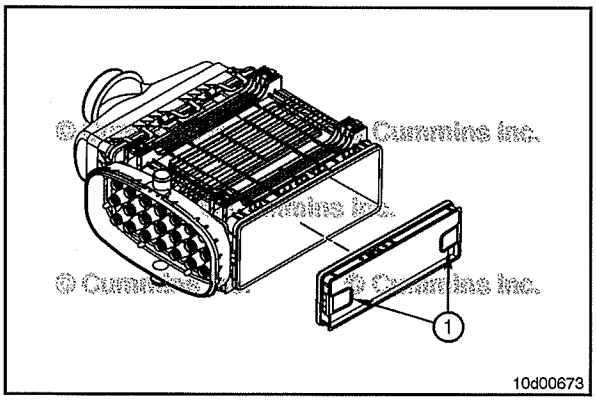




Inspect for Reuse

If the used filter element is to be used again, the following precautions must be taken:

- Inspect the gasket around the base of the filer element, if the gasket exhibits any damage, then change the entire filter element assembly.
- Inspect the filer media for any tears or excessive wear. Change the entire filter element assembly if the filter media is **not** intact. The media rows of the filter element may **not** appear straight and exhibit some amount of a wave pattern. This appearance is normal due to standard operation and does **not** require filter element replacement.



Install

⚠CAUTION⚠
Only use the approved Cummins Filtration™ aftermarket direct flow replacement filter elements to service the air cleaner. Use of improper filters can lead to engine damage.

⚠CAUTION⚠
Make sure any cloth or tools used during the removal process are not left in the filter housing (before installing the filter elements) or engine damage can occur.

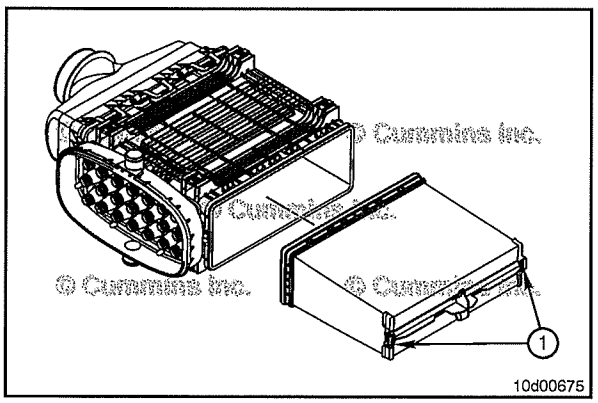
NOTE: The secondary element **must** be installed first if both the secondary and primary elements were removed.

Secondary Element

Insert the element so the orientation of the plastic removal ring is facing the inside of the housing and is accessible for the next service interval.

1 Secondary element removal ring tab should be visible.

Push the secondary element into the back of the housing so all surfaces are seated inside the housing. Apply pressure to all four corners to make sure the element is secure within the housing. The secondary filter element includes an o-ring that is glued to the filter element to provide an airtight seal.

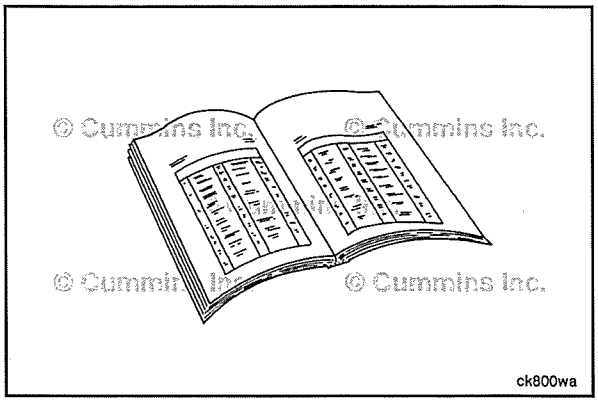


Primary Filter Element

Service Tip: Before installing a new primary filter element, use a marker to note on the element handle if a new secondary element should be installed at the next primary element service event.

Place a new primary filter element in the housing so the o-ring is toward the secondary element. Push the primary element into the housing so all surfaces are seated inside the housing. Apply pressure to the two tabs on the side of the primary element to make sure the element is secure within the housing. The tabs should seat against the center of the housing. The primary filter element also includes an o-ring that is glued to the filter element to provide an airtight seal.

Finishing Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: The service door or pre-cleaner assembly will **not** latch if the primary filter element is **not** fully seated into the housing.

NOTE: For the 127 mm x 381 mm x 204 mm [5 in x 15 in x 8 in] version, the pre-cleaner assembly has tabs on the opposite side that will interface with slots on the housing.

NOTE: The Direct Flow filter elements are completely disposable.

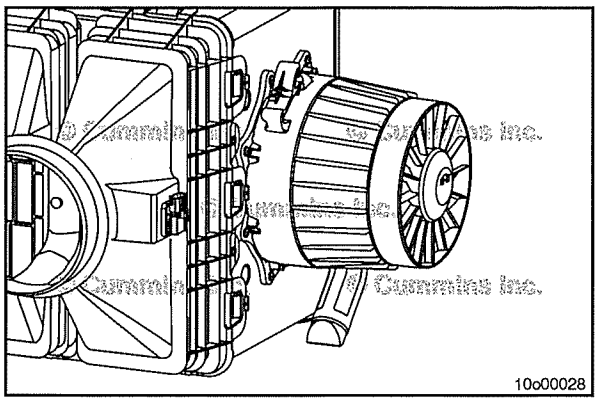
- Install the service door or pre-cleaner assembly by latching to the housing.
- Reset the restriction indicator by pushing the reset button.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and listen for a noise that could indicate an air leak. Use the following procedure to locate any air leaks in the air system. Refer to Procedure 010-024 in Section 10.

Air Cleaner Precleaner (010-015)

General Information

Air filtration precleaners are used to remove debris from the air stream in order to extend the life of the air filter elements. There are several types of precleaners that can be used, including, but **not** limited to:

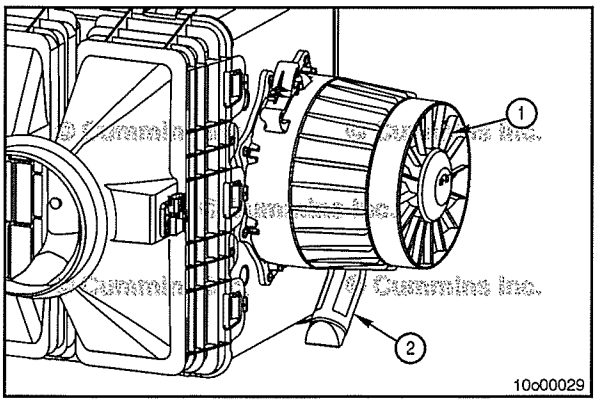
- Integrated precleaner with dust ejection valve
- Non-captive style precleaner
- Integrated precleaner with exhaust aspiration.

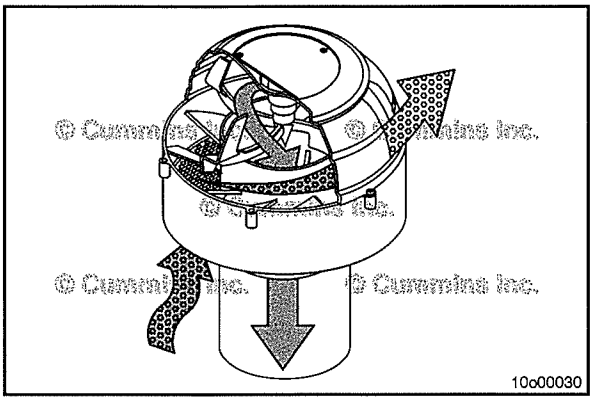


An integrated precleaner with a dust ejection valve removes debris from the intake air by using fins (1) to create centrifugal motion in the intake air stream.

The centrifugal motion causes debris to be forced to the outside of the precleaner, where it is then collected in the dust ejection valve (2).

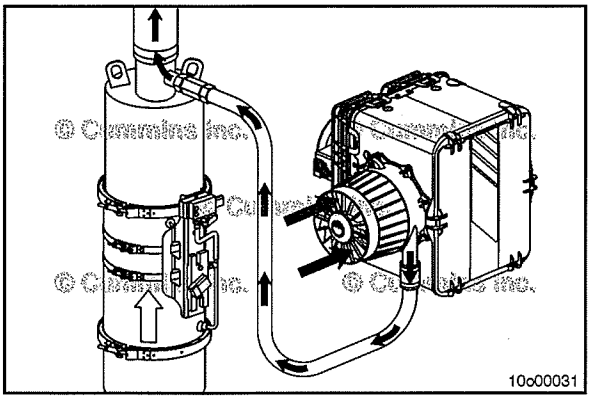
NOTE: If the dust ejection valve becomes full of debris, the precleaner will **not** function and the debris will remain in the air stream, which can lead to frequent air filter plugging or low air filter service life. Refer to Procedure 010-146 in Section 10.





Non-captive style precleaners work similarly to integrated precleaners by using centrifugal motion to force debris to the outside of the precleaner. However, instead of being collected in the dust ejection valve, the debris is immediately expelled back into the outside air.

NOTE: These precleaners are typically more costly than the integrated precleaner with dust ejection valve and can create higher intake restriction.

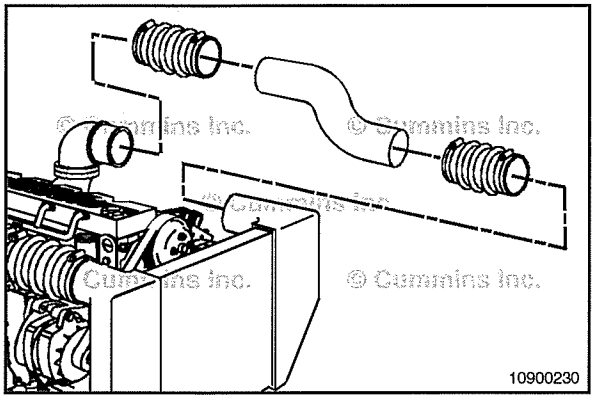


Integrated precleaning with exhaust aspiration is used for applications that are exposed to extremely dirty and dusty environments, such as agricultural equipment.

An exhaust aspirator uses exhaust flow to create suction. The suction tube from the aspirator is plumbed to the integrated precleaner and helps to separate debris out of the intake air. The debris is sucked from the precleaner through the suction tube and travels out through the exhaust.

A check valve **must** be used with an exhaust aspirator to prevent exhaust gases from traveling through the air cleaner in instances when the exhaust suction force is low.

NOTE: Vacuum leaks in the exhaust aspirator piping can reduce the ability of the air cleaner precleaner to remove debris from the intake air, which can lead to frequent air filter plugging or low air filter service life.



Air Crossover (010-019)

Remove

Loosen the hose clamps and position the crossover tube so it can be removed.

Remove the tube.

Install protective caps from the Air Handling Clean Care Kit, Part Number 5298878, on all open connection points including inlet to engine, charge-air cooler, and ends of crossover tube.

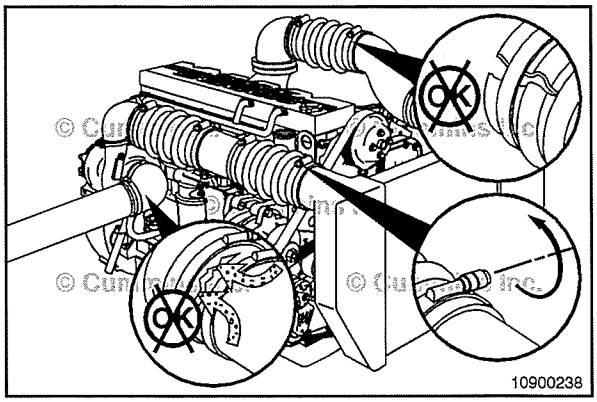
Inspect for Reuse

Check the crossover tube for cracks, holes, and worn sections.

Also check for poor sealing between the hose and tube.

Inspect the clamps for wear.

Replace damaged components with new hoses and clamps, if necessary.

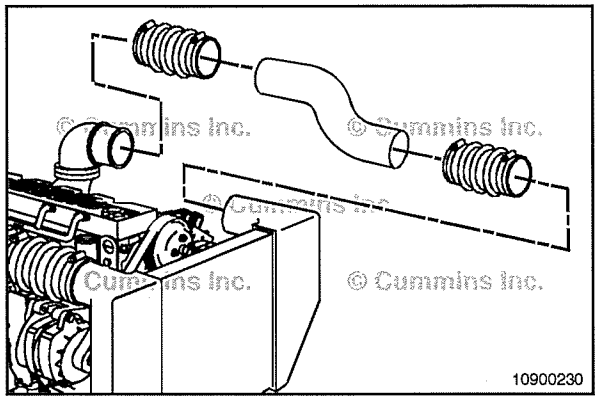


Install

Remove all protective caps from components.

Install the crossover tube hose and clamps in the reverse order of removal.

Tighten the clamps. Refer to the original equipment manufacturer (OEM) service manual for torque specifications.



Air Inlet Connection (010-022)

General Information

The air inlet connection connects the turbocharger air inlet to the original equipment manufacturer (OEM) air inlet piping.

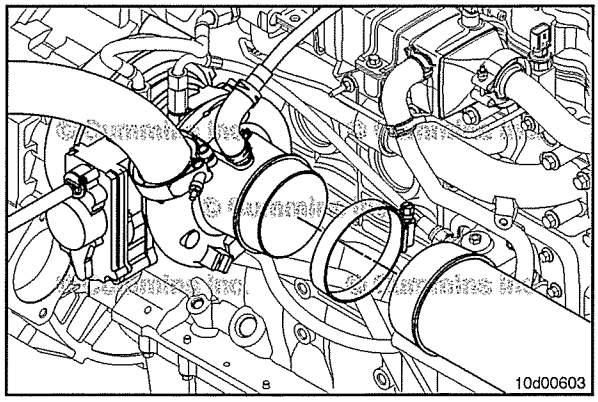
Remove

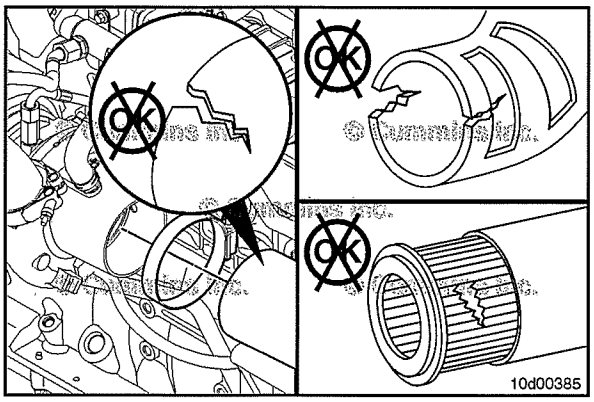
NOTE: Brush away all loose dirt from around the area or the air handling connections to avoid contamination of the interior of the engine.

Loosen the clamps which hold the air inlet connection to the turbocharger air inlet and the OEM air inlet piping.

Remove the air inlet connection. Take care not to get any dirt or debris inside the turbocharger.

Use protective caps from the Air Handling Clean Care Kit, Part Number 5298878, to cover both of the connection points.





Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

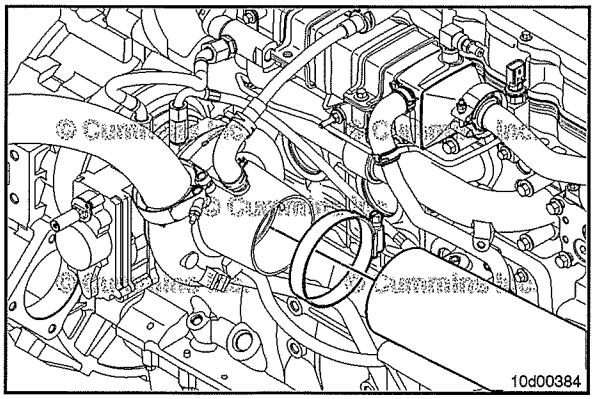
⚠WARNING⚠
Use skin and eye protection when handling caustic solutions to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the piping and connections with solvent or hot soapy water and dry with compressed air.

Check the piping and connections for cracks, holes, and worn sections.

If any damage is found, replace the damaged components.



Install

Remove the protective caps from the component.

Install the air inlet piping and connections.

Tighten the attaching clamps.

Torque Value: 8 N•m [71 in-lb]

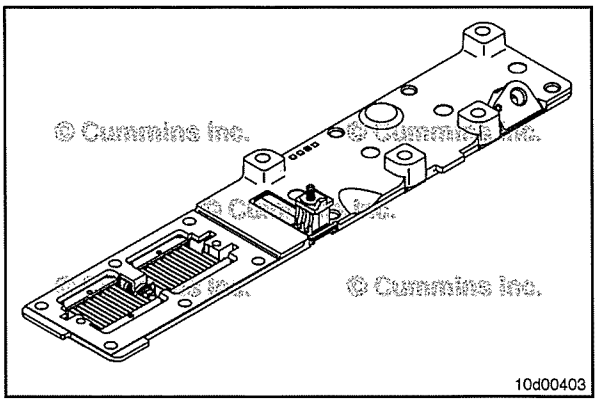
Finishing Steps

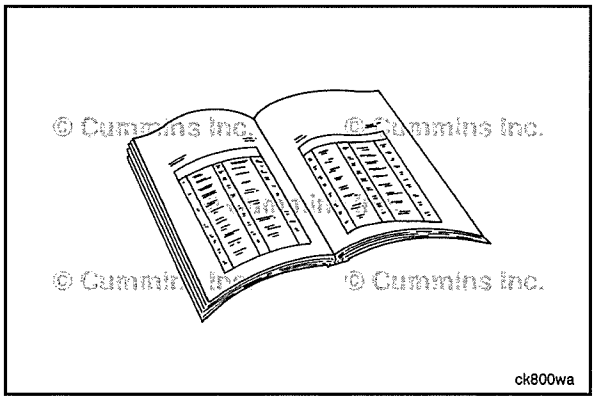
Operate the engine and check for leaks.

Air Intake Manifold (010-023)

Initial Check

Verify the cold starting aid is functioning properly. Refer to Procedure 010-029 in Section 10.





Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

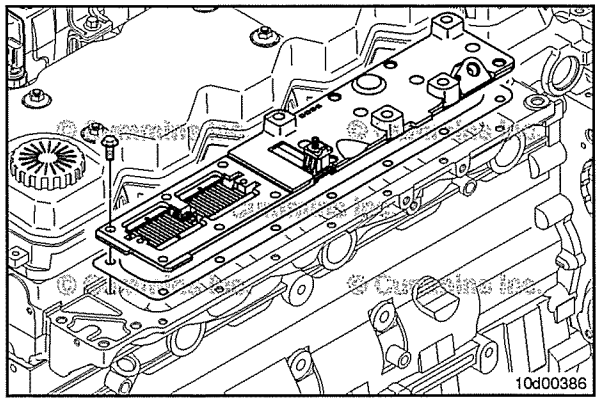
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Steam clean the area around the intake manifold to remove any loose dirt or debris. Dry with compressed air.
- Disconnect the electrical connection from the cold starting aid. Refer to the OEM service manual.
- Disconnect the electrical connections from the injector pass-through connectors. Refer to Procedure 019-043 in Section 19.
- Disconnect the electrical connections from the crankcase pressure sensor. Refer to Procedure 019-445 in Section 19.
- Disconnect the electrical connections from the exhaust gas recirculation (EGR) differential pressure sensor. Refer to Procedure 019-370 in Section 19.
- Remove the air crossover/charge-air piping from the air intake connection adapter. Refer to Procedure 010-019 in Section 10.
- Remove the air intake connection adapter, if required. Refer to Procedure 010-031 in Section 10.
- Remove the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the EGR valve. Refer to Procedure 011-022 in Section 11.
- Remove the air intake connection. Refer to Procedure 010-080 in Section 10.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the fuel rail. Refer to Procedure 006-060 in Section 6.
- Remove the intake manifold pressure/temperature sensor. Refer to Procedure 019-159 in Section 19.

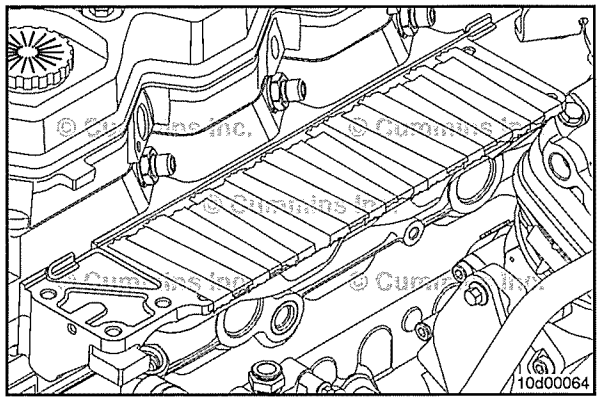
Remove

Remove the remaining capscrews holding the air intake manifold to the cylinder head.

Remove the intake manifold from the cylinder head, taking care **not** to drop any debris into the cylinder head.



Use heavy tape to cover the intake manifold opening in the cylinder head to prevent debris from entering the engine.

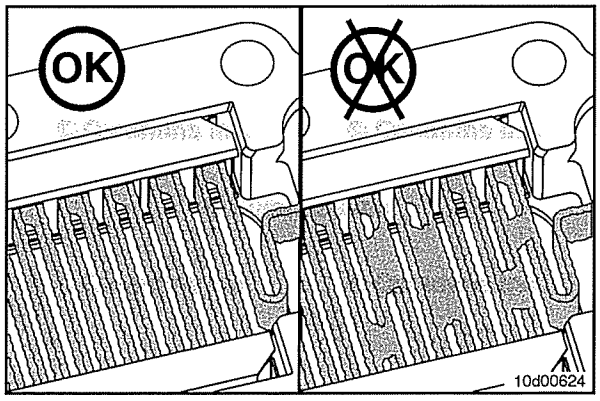


Clean and Inspect for Reuse

Inspect the air intake manifold heater for plugging or soot buildup. If plugged, check for the source; turbocharger, air compressor, temperature/pressure sensor, relay, or wiring harness.

Soot **only** covering individual elements is acceptable. Soot bridging the heating elements is **not** acceptable.

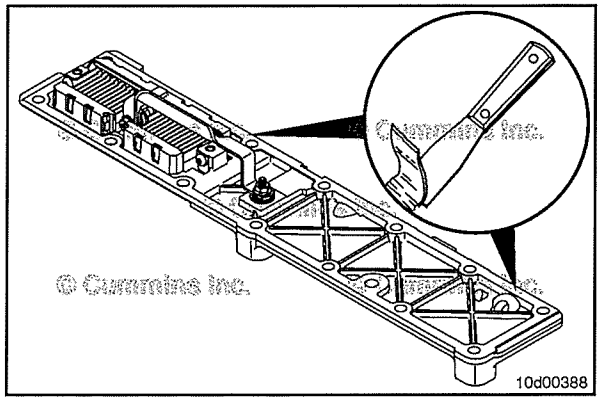
Replace the air intake manifold cold starting aid, if necessary.

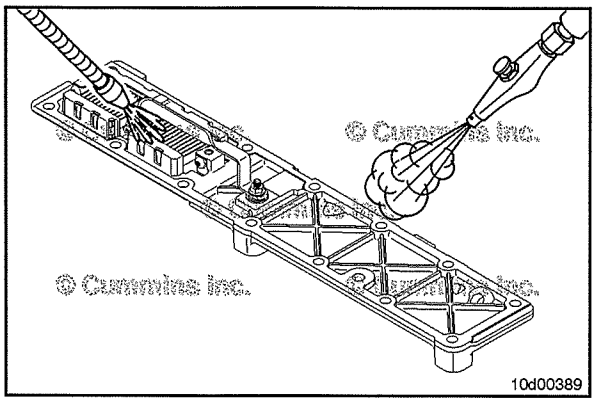


NOTE: The cold starting aid and air intake manifold will be coated with a thin layer of carbon. This carbon coating is normal.

NOTE: Some air intake manifolds have a corrosion resistant coating on the inside. Take care not to scratch or otherwise damage this coating.

Scrape the gasket surfaces with a gasket scraper on both the intake manifold and cylinder head, taking care **not** to drop any gasket material into the cylinder head.



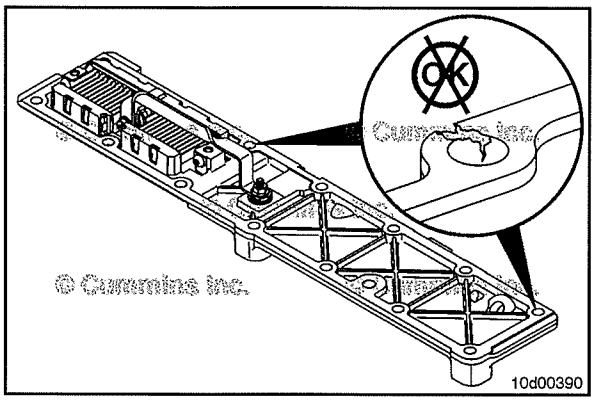


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the intake manifold and cold starting aid with solvent and dry with compressed air.

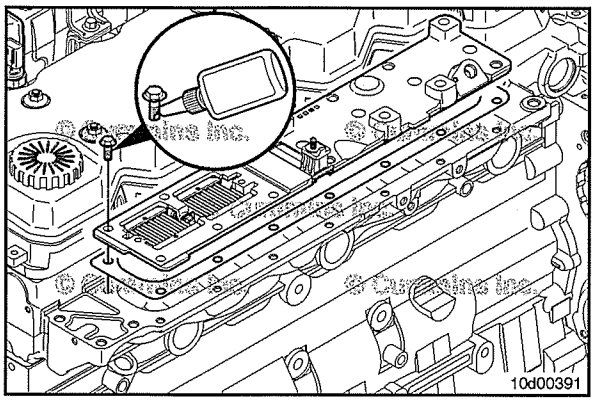
NOTE: Some of the engines equipped with EGR have a corrosion resistant green Teflon™ coating on the inside surfaces of the intake manifold. Soot buildup is common on these surfaces, and does **not** need to be cleaned off.



Inspect the air intake manifold for cracks, warping, or other damage.

Replace if necessary.

NOTE: If the air intake manifold needs to be replaced, there is no need to remove the cold starting aid and install it on the new manifold. The new manifold will be shipped with a new cold starting aid.



Install

If previously taped off, remove the tape from the cylinder head prior to installing the intake manifold.

If a new air intake manifold is being installed, verify that the correct voltage manifold is being installed. Both 12 volt and 24 volt versions exist.

Install the air intake manifold to the cylinder head with a new gasket.

If the capscrews are to be reused, lightly coat the threads with thread sealant, Part Number 3824040, to prevent boost leaks.

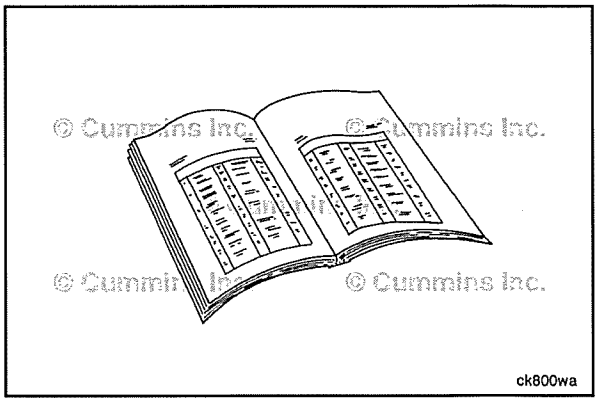
Tighten the capscrews in a criss-cross pattern, starting from the middle of the manifold.

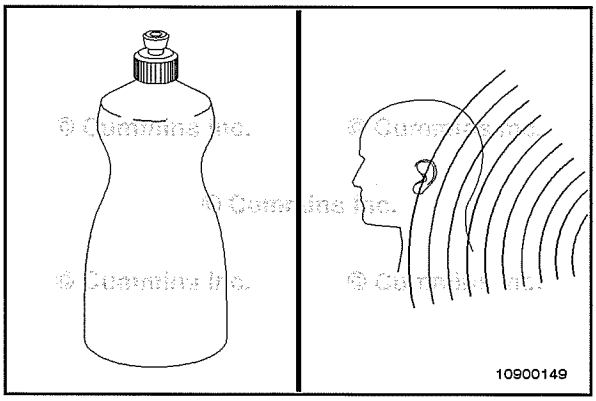
Torque Value: 24 N•m [212 in-lb]

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the combined intake manifold pressure/ temperature sensor. Refer to Procedure 019-159 in Section 19.
- Install the fuel rail. Refer to Procedure 006-060 in Section 6.
- Install the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the air intake connection. Refer to Procedure 010-080 in Section 10.
- Install the EGR valve. Refer to Procedure 011-022 in Section 11.
- Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Install the air intake connection adapter, if required. Refer to Procedure 010-031 in Section 10.
- Install the air crossover/charge air piping from the air intake connection adapter. Refer to Procedure 010-019 in Section 10.
- Connect the electrical connections to the injector pass-through connectors. Refer to Procedure 019-043 in Section 19.
- Connect the electrical connections to the crankcase pressure sensor. Refer to Procedure 019-445 in Section 19.
- Connect the electrical connections to the EGR differential pressure sensor. Refer to Procedure 019-370
- Connect the electrical connection to the cold starting aid and tighten. Refer to the OEM service manual.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Air Leaks, Air Intake and Exhaust Systems (010-024)

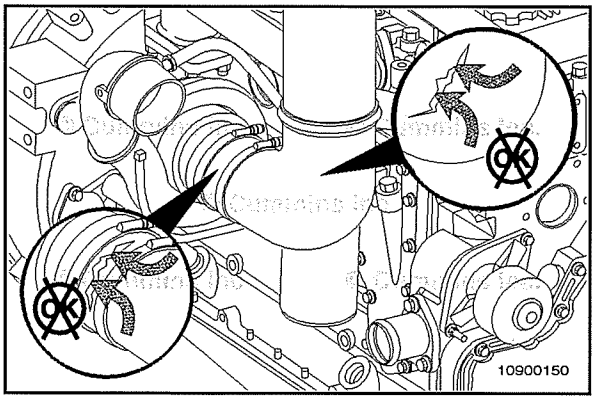
Initial Check

Leaks in the intake air system are most commonly identified by:

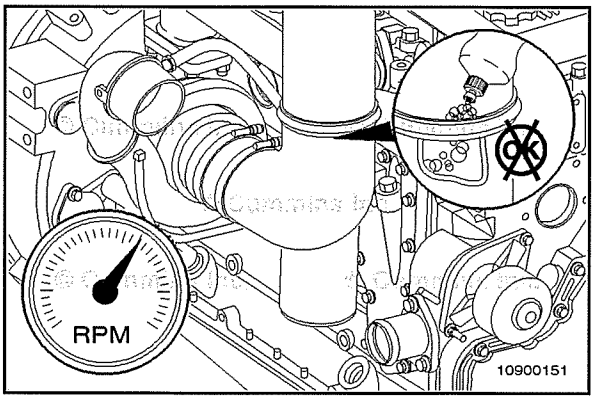
1 Inspection of piping for cracked or loose clamps.

2 Applying a solution of soapy water in the suspected area and inspecting for bubbles.

3 Listening for a high-pitched whining or sucking noise in the suspected area.



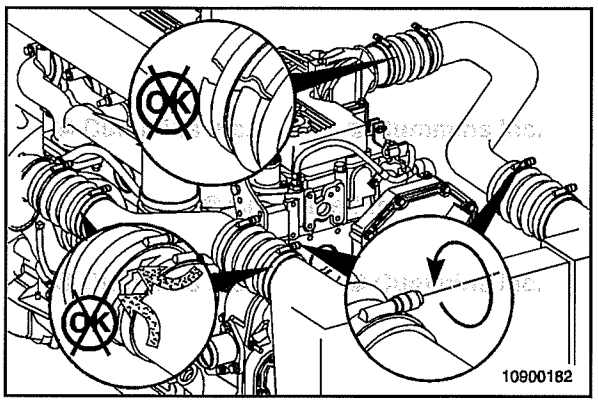
⚠CAUTION⚠
Engine intake air must be filtered to prevent dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.



Inspect the inlet air piping for cracked hoses and damaged or loose clamps.

Operate the engine at high idle, and use a solution of soapy water to spot intake air leaks.

If an air leak exists, the soap bubbles will be drawn in with the air.



Replace damaged pipes and tighten loose clamps to make sure the charge-air piping and hoses do **not** leak.

Torque Value: 10 N•m [89 in-lb]

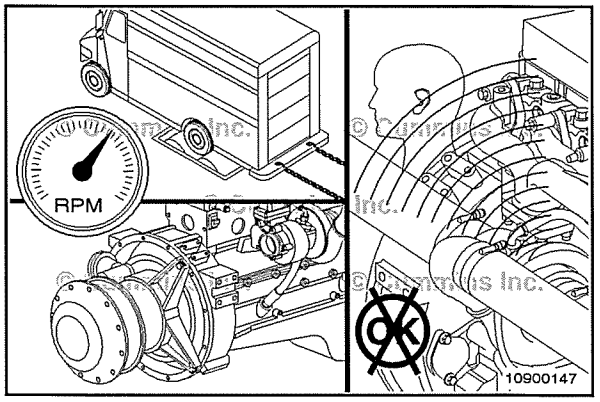
Check for corrosion of the inlet system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system.

Disassemble and clean as required.

Operate the engine at full throttle and rated rpm with maximum load.

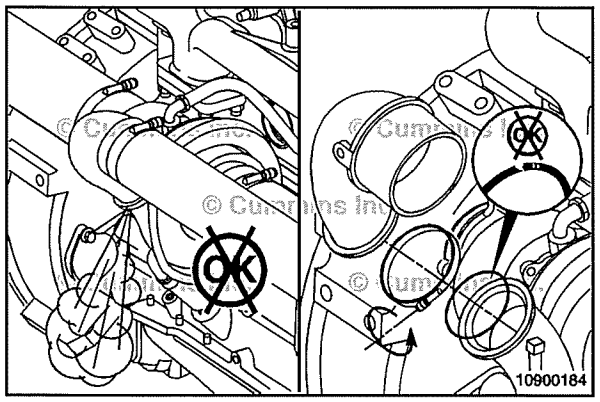
Listen for a high-pitched whistling sound from the turbocharger, nearby piping, and connections.

Apply a soapy water solution to sealing surfaces and inspect for bubbles. Bubbles can be easily detected.



Leaks can also be found at the turbocharger compressor outlet connection.

Inspect for damage, replace the sealing o-ring, and tighten loose clamps. Refer to Procedure 010-033 in Section 10.

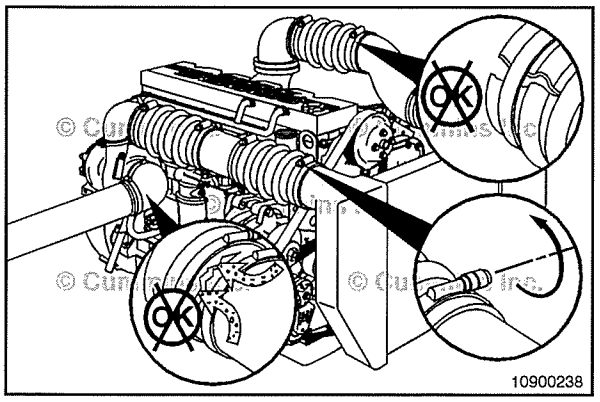


Charge-Air Cooler Tubing or Connecting Hoses:

Inspect the hose and tubing for damage. Refer to Procedure 010-019 in Section 10.

Tighten loose clamps.

See the equipment manufacturer's specifications for the correct torque value.



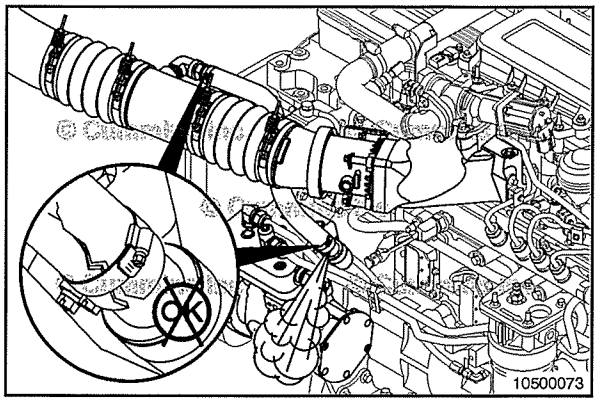
Air Compressor Plumbing:

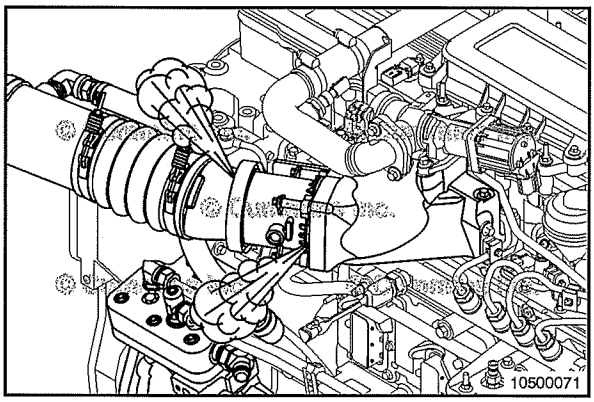
The air compressor is supplied with turbocharged air **only**.

Inspect the original equipment manufacturer (OEM) air supply hose, fittings, and clamps for damage.

Tighten loose clamps and fittings.

Replace the OEM air supply hose, fittings, or clamps, if necessary. Refer to the OEM service manual.



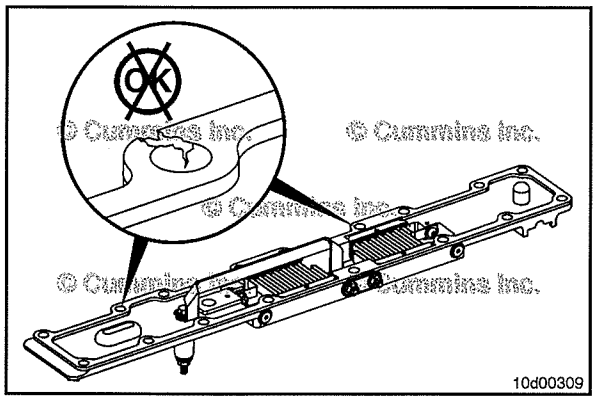


Air Intake Connection, Air Intake Connection Adapter:

Inspect for damage.

Replace the connection clamp, o-ring, or gasket, if necessary.

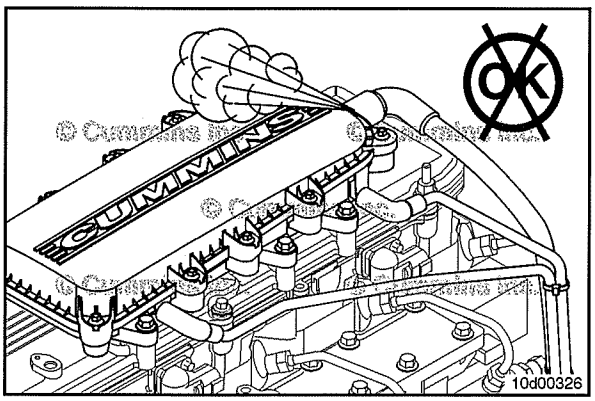
Refer to Procedure 010-131 in Section 10.



Intake Manifold:

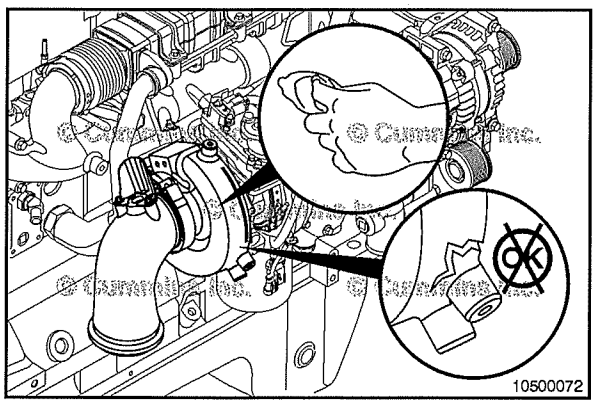
Inspect for damage.

If damage is found, replace the gasket if the engine was originally equipped with a gasket.



Open Crankcase Ventilation System:

Inspect for damage, tighten loose fittings and replace cracked or leaking hoses and piping.



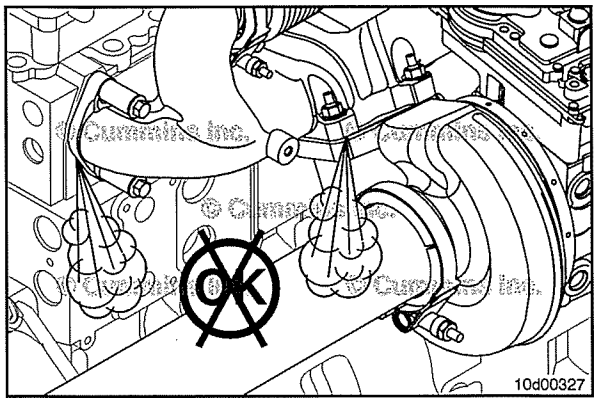
Compressor Housing:

Clean and inspect for cracks in the compressor housing.

Tighten the clamp, if loose.

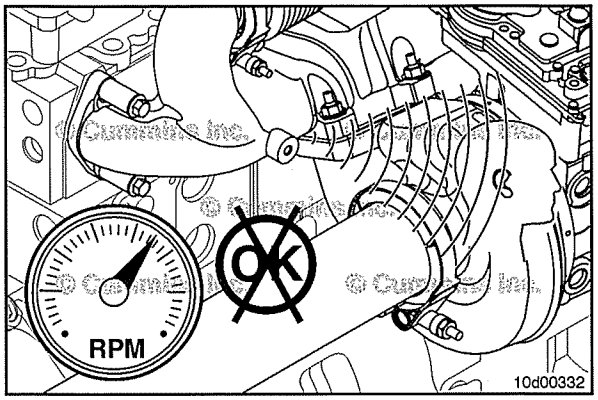
Exhaust System:

Leaks in the exhaust system will cause the turbocharger to operate at a lower speed, reducing the amount of air going to the cylinders during engine operation.



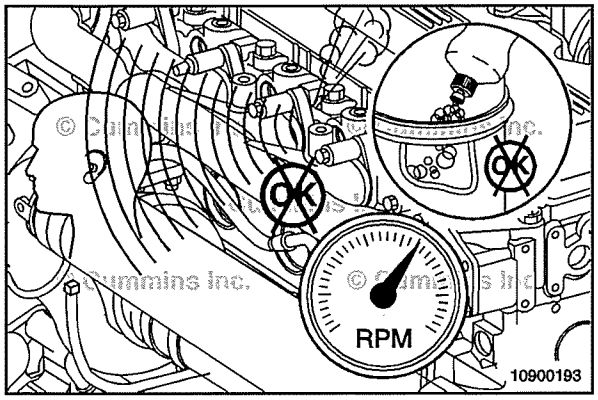
Operate the engine at full throttle and rated rpm with maximum load.

Leaks can be identified by noise, soapy water, or discoloration caused by the escaping hot gases.



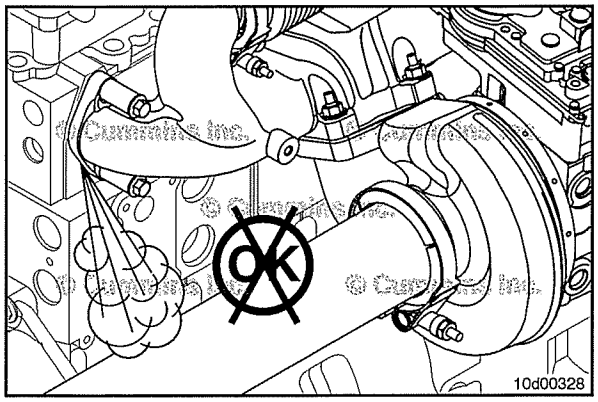
Operate the engine at full throttle and rated rpm with maximum load.

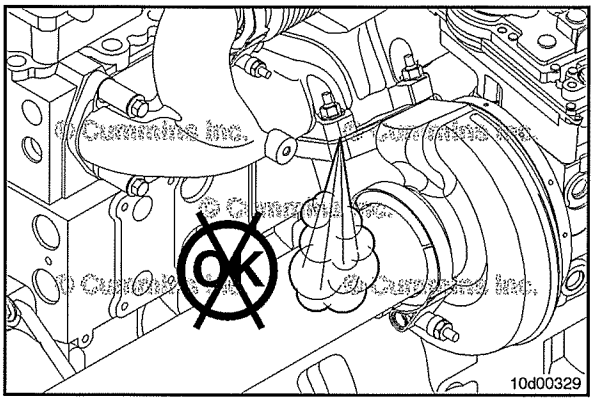
Listen and inspect again for leaks.



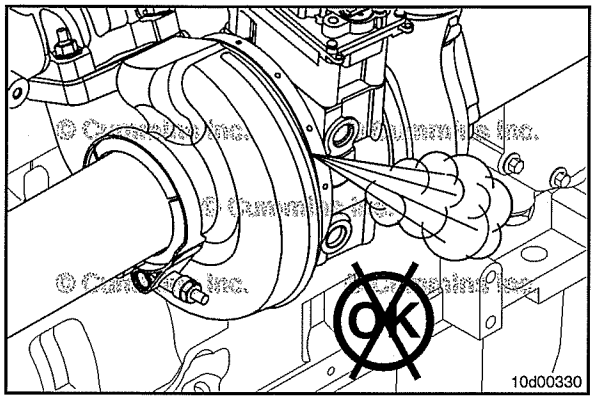
Leaks can be found at:

- Exhaust manifold gaskets

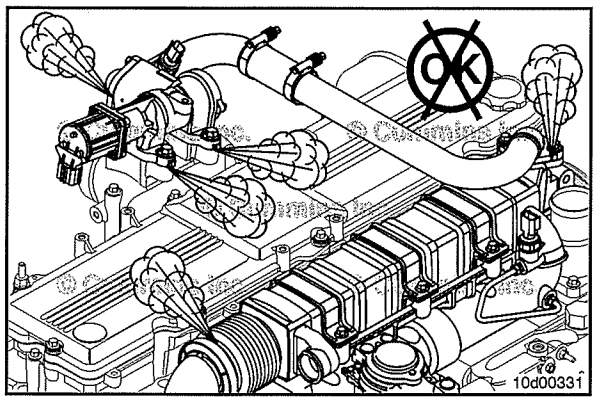




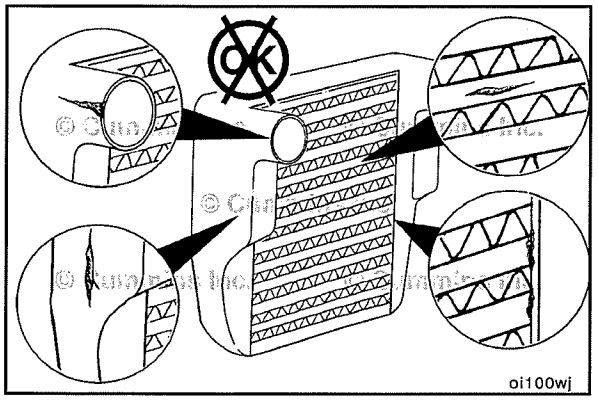
- Turbocharger mounting gaskets



- Turbine housing sealing surface



- Exhaust gas recirculation (EGR) component gaskets
- EGR cooler inlet gasket
- EGR cooler outlet gasket
- EGR valve inlet gasket
- EGR valve mounting gasket.



Charge-Air Cooler (010-027)

Initial Check

Inspect the charge air cooler for cracks, holes, and other damage.

Inspect the tubes, fins, and welds for tears, breaks, or other damage.

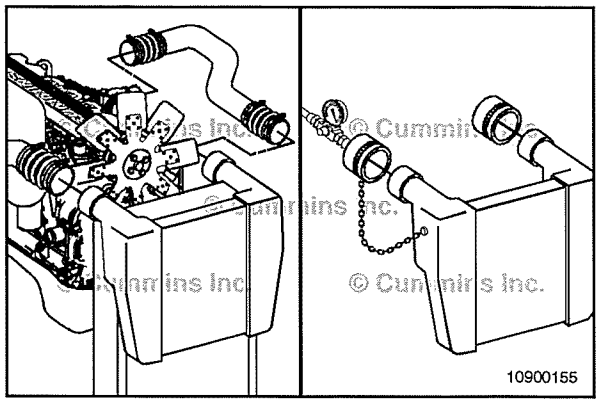
If any damage causes the charge air cooler to fail the air leak check, the charge air cooler **must** be replaced.

Inspect the charge air cooler plumbing for cracks and other damage.

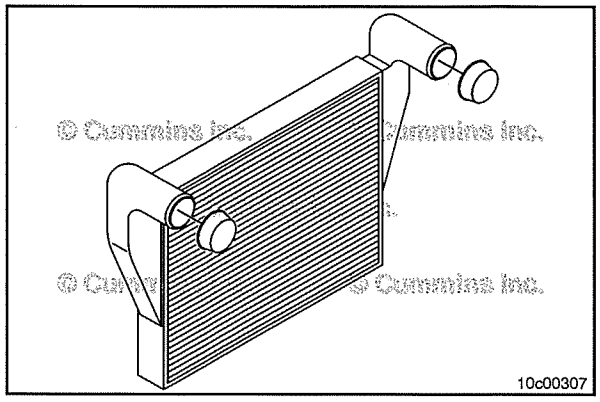
Leak Test

⚠WARNING⚠
To reduce the possibility of injury if either plug blows off during the test, secure safety chains on the test plugs to any convenient capscrew on the radiator assembly. This test must not be performed without securely fastened safety chains.

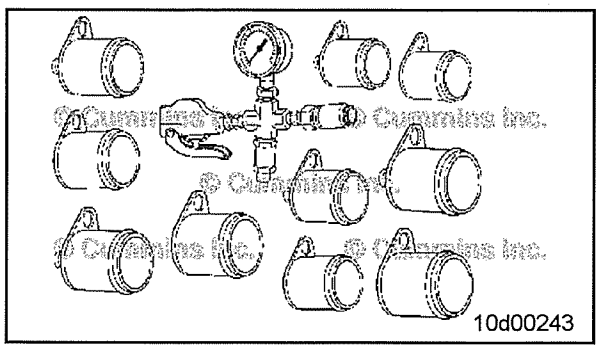
To check the charge air cooler for cracked tubes or header, remove the inlet and outlet hoses from the cooler. The charge air cooler does **not** have to be removed from the chassis.



Use protective caps from the Air Handling Clean Care Kit, Part Number 5298878, to cover the open points on the engine plumbing and charger-air cooler.



To perform the leak test, use tool, Part Number 3824556. Install the cap over the outlet side of the cooler. Install the gauge end of the tool with a regulated shop air supply line and a shutoff valve to the inlet side of the cooler.

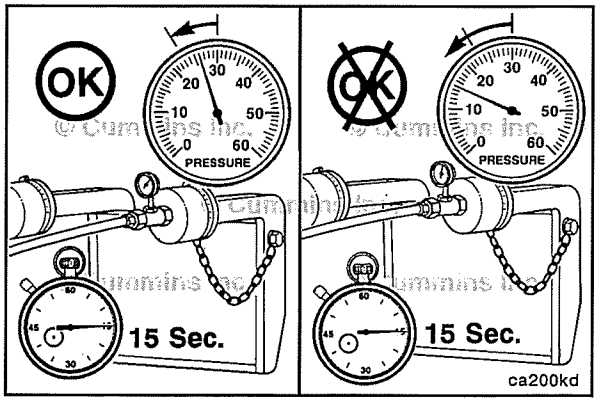


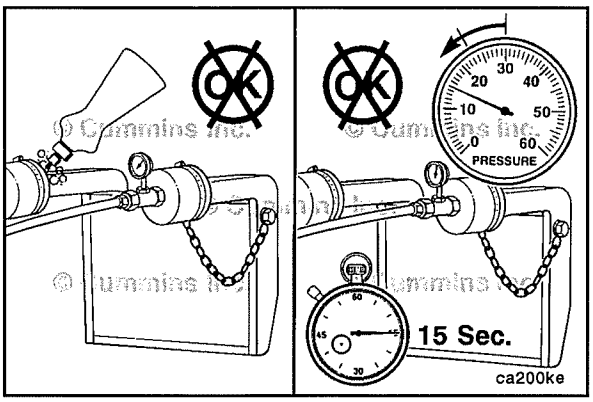
Apply air pressure to the cooler until the pressure gauge reads a steady 207 kPa [30 psi] of air pressure.

Shut off the airflow to the cooler and start a stopwatch at the same time. Record the leakage at 15 seconds.

If the pressure drop is 48 kPa [7 psi] or less in 15 seconds, the cooler is operational.

If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, check all connections again.

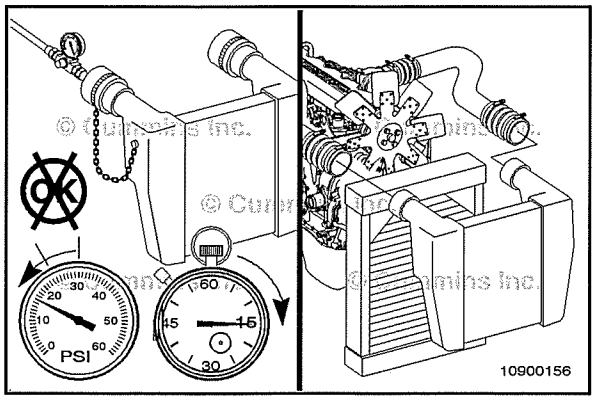




Determine if the pressure drop is caused by a leak in the charge air cooler or from a leaky connection. Use a spray bottle filled with soapy water, applied to all hose connections. Watch for bubbles to appear at the location of the leak.

If the pressure drop is caused by a leaky connection, repair the connection and repeat the test. If the leak is within the charge air cooler, repeat the test to verify the accuracy of the pressure drop measurement. Similar pressure drop readings **must** be obtained in at least three consecutive tests before the reading can be considered accurate.

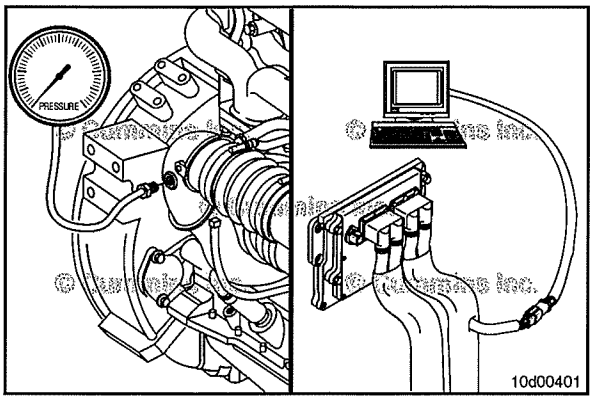
NOTE: If a charge-air cooler leak causes a pressure drop of more than 48 kPa [7 psi] in 15 seconds, it will appear as a major leak in a leak tank.



If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, the charge air cooler **must** be replaced.

Refer to the OEM service manual for replacement instructions.

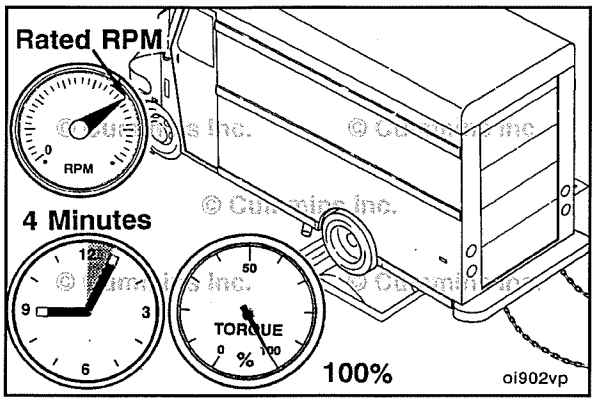
NOTE: Charge-air coolers are **not** designed to be 100-percent leak free. If the pressure drop is less than 48 kPa [7 psi] in 15 seconds, the charge air cooler does **not** need to be replaced.



Pressure Test

Use pressure gauge, Part Number 3823205, to record the air pressure at the inlet of the charge-air cooler. Install the pressure gauge in the 1/8 - inch fitting in the turbocharger compressor outlet elbow.

Monitor the intake manifold pressure sensor reading with INSITE™ electronic service tool, to record the air pressure at the outlet of the charge air cooler.

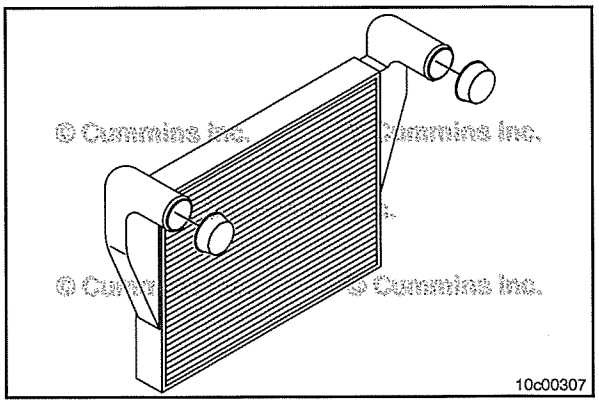


Operate the engine at rated rpm and load. Record the readings on the two gauges.

If the differential pressure is greater than 20.6 kPa [3 psi], check the charge air cooler and associated piping for plugging, restrictions, or damage.

Clean or replace, if necessary.

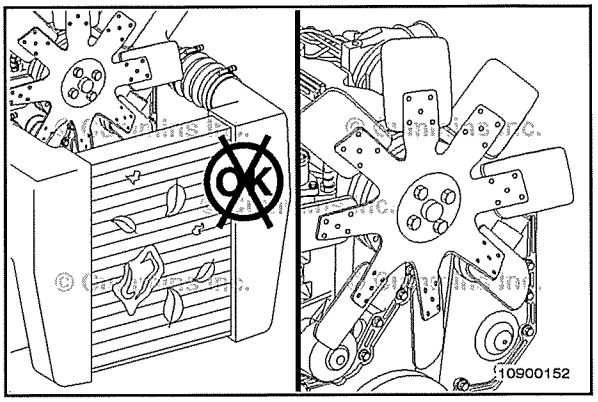
After the test is complete, cover the open points on the charge-air cooler with protective caps from the Air Handling Clean Care Kit, Part Number 5298878.



Temperature Differential Test

Inspect the charge-air cooler fins for obstructions to airflow. Remove obstructions such as a winterfront or debris. Manually lock the shutters in the open position, if equipped.

Lock the fan drive in the ON mode to prevent erratic test results. This can be done by installing a jumper wire across the temperature switch.



Use INSITE™ electronic service tool to monitor the intake manifold air temperature sensor and ambient air temperature sensor values.

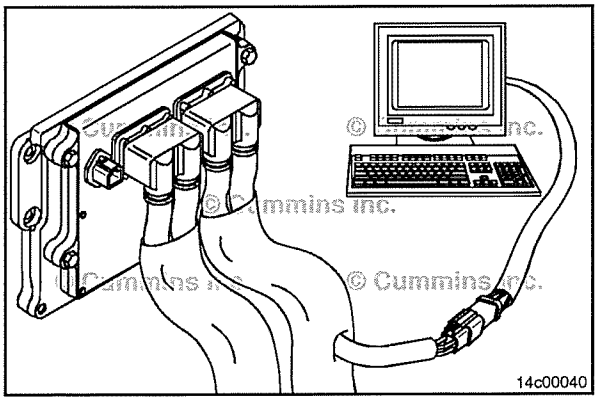
Perform a road test with the engine at peak power and a vehicle speed of 48 km/h [30 mph] or greater.

Record the intake manifold temperature and the ambient air temperature.

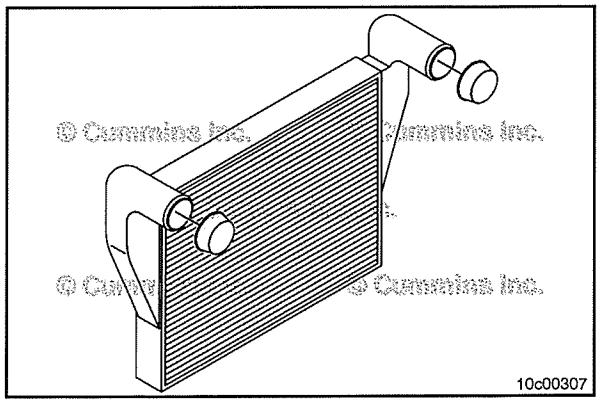
Calculate the differential temperature:

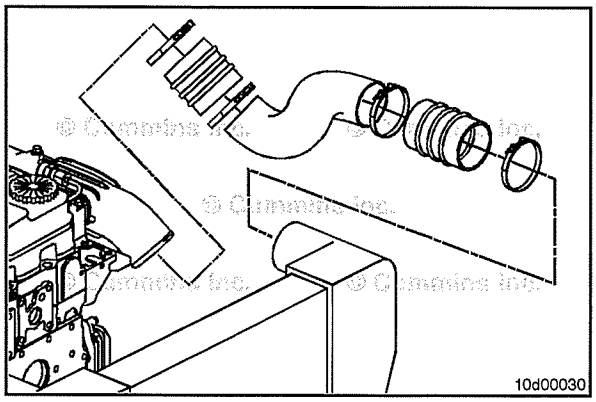
Intake manifold temperature - ambient air temperature = differential temperature.

- Maximum Differential Temperature = 21°C [38°F]



If the temperature differential is greater than the specifications, check the charge air cooler for dirt and debris on the fins and clean as necessary. If the problem still exists, check the charge air cooler for debris in the fins or between the charge air cooler and radiator. Confirm full-fan engagement.

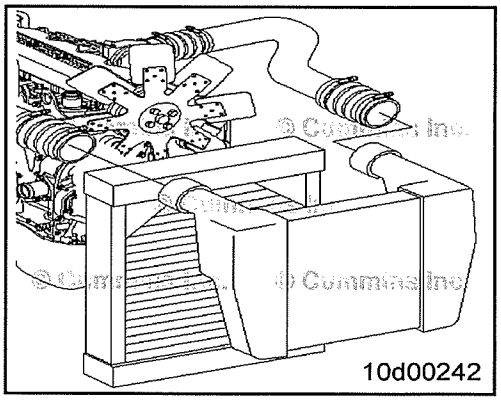




Preparatory Steps

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

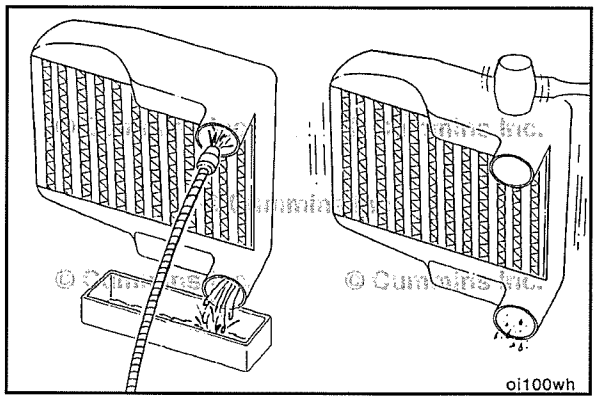
- Use compressed air to clean debris from the outside of the charge-air cooler.
- Remove the charge air cooler piping. Refer to Procedure 010-019 in Section 10.



Remove

Remove the charge-air cooler. Refer to the OEM service manual.

Use protective caps from the Air Handling Clean Care Kit, Part Number 5298878, to cover the open points on the engine plumbing and charge-air cooler.



Clean

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

△CAUTION△
Do not use caustic cleaners to clean the charge air cooler. Damage to the charge air cooler will result.

NOTE: If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the charge air cooler, the charge-air cooler **must** be cleaned.

Flush the charge-air cooler internally with solvent in the opposite direction of normal airflow. Shake the charge-air cooler and lightly tap on the end tanks with a rubber mallet to dislodge trapped debris. Continue flushing until all debris or oil is removed (i.e., the water runs clear).

NOTE: Make sure that the tubes are in an upright position when flushing.

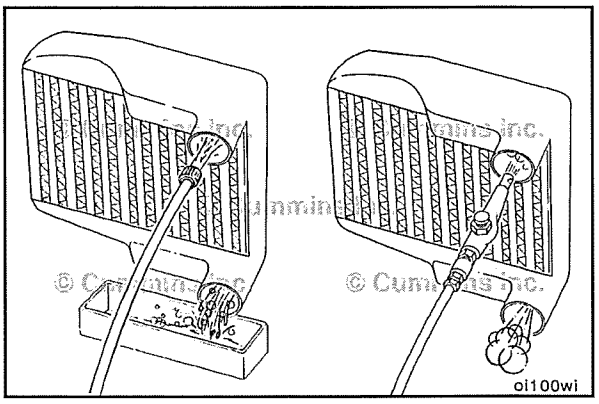
If the debris can **not** be totally removed from the charge-air cooler, the charge-air cooler **must** be replaced.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

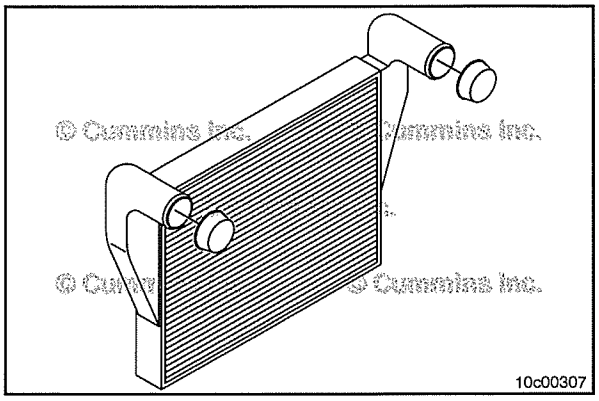
⚠CAUTION⚠
The charge air cooler must be rinsed, dried, and cleaned of solvent, oil, and debris, or engine damage will result.

After the charge air cooler has been thoroughly cleaned of all oil and debris with solvent, wash the charge air cooler internally with hot, soapy water to remove the remaining solvent. Rinse thoroughly with clean water.

Blow compressed air through the inside of the charge-air cooler in the opposite direction of normal airflow until the charge air cooler is dry internally.

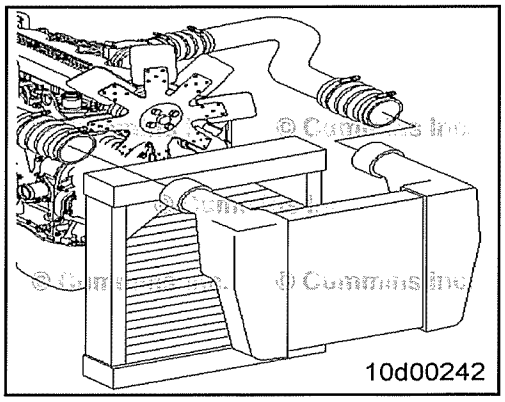


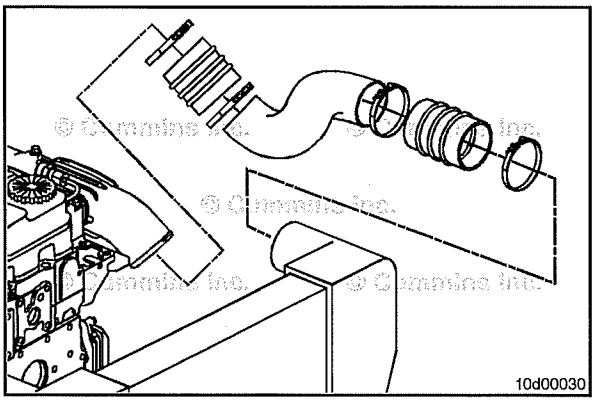
Use protective caps from the Air Handling Clean Care Kit, Part Number 5298878, to cover the open points on the charge-air cooler.



Install

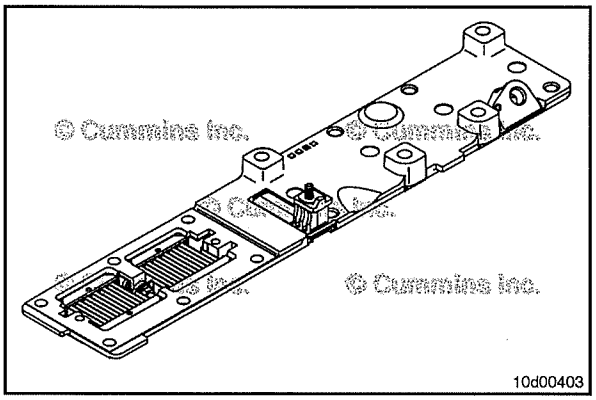
Install the charge air cooler. Refer to the OEM service manual.





Finishing Steps

- Install the charge air cooler piping. Refer to Procedure 010-019 in Section 10.
- Operate the engine and check for leaks.



Cold Starting Aid (010-029)

General Information

The cold starting aid is **not** a serviceable part. If the cold starting aid has cracked, broken, or melted elements, the entire air intake manifold **must** be replaced. Refer to Procedure 010-023 in Section 10.

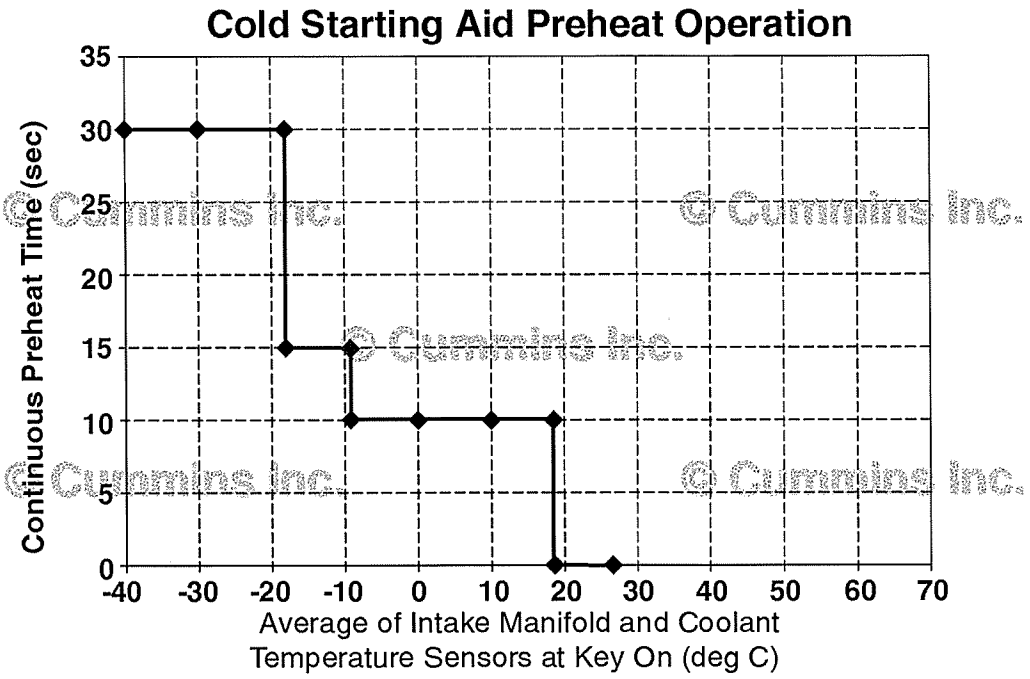


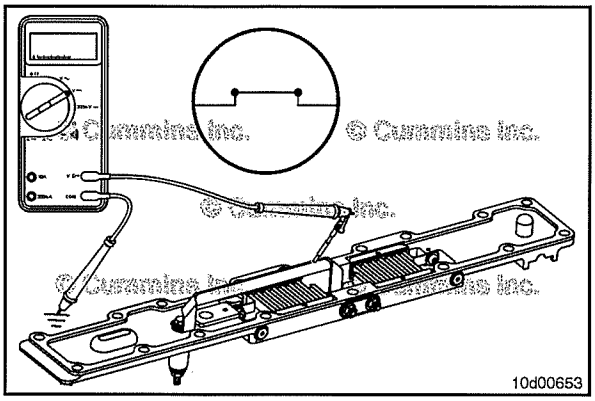
Figure 1, Preheat Time By Seconds

QSB preheat cycle information:

The cold starting aid can be employed prior to a cold start, which is termed “preheat”. A wait-to-start lamp is activated during preheat. Preheat time is determined as a function of the average of the intake manifold temperature sensor and the coolant temperature sensor at key ON, as shown in Figure 1.

QSB post-heat cycle information:

After a cold start, the cold starting aid could be activated during warm-up, which is termed “post-heat”. The post-heat schedule is determined by the average of the intake manifold temperature sensor and the coolant temperature sensor at key ON. Post-heat is deactivated at vehicle speeds greater than 30 kph [18.6 mph]. The cold starting aid post-heat operates for a minimum of 30 seconds if the average of the intake manifold temperature sensor and the coolant temperature sensor is below 49°C [120°F]. The post-heat operation is turned OFF if the temperature is above this threshold. The actual duration is calculated by the engine control module (ECM) and is a function of engine speed, the average of the intake manifold temperature sensor ,and the coolant temperature sensor and how quickly the engine warms.



Test

Verify the cold starting aid operation.

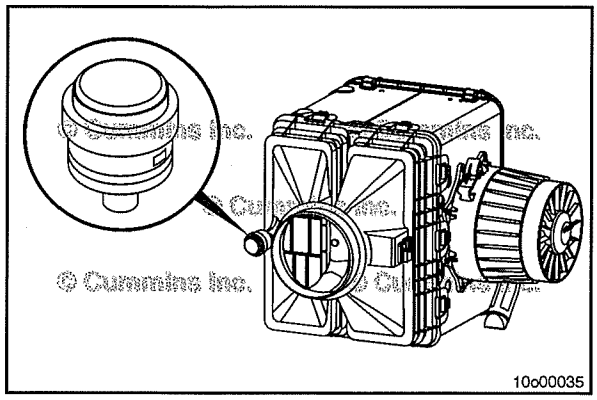
Use a voltmeter, Part Number 3164489, or equivalent, and connect the negative test lead to the block ground. Connect the positive test lead to the electrical connection of the cold starting aid.

Connect INSITE™ electronic service tool, from the list of ECM Diagnostic Tests select Grid Heater Override. Turn ON the cold starting aid for a few seconds, and note the voltage reading on the voltmeter, then turn it OFF again. The voltmeter **must** read within 1-VDC of battery voltage. If it does **not**, there is a malfunction with the wiring or the power jumper in the manifold.

Check the cold starting aid relay circuit. Refer to Procedure 019-408 in Section 19. Check the original equipment manufacturer (OEM) wiring and the cold starting aid relay functionality. Refer to the OEM service manual.

Repair the wiring as necessary.

If the electrical connection reads close to battery voltage, turn ON the cold starting aid using the grid heater override test. To check if the cold starting aid is heating, use an infared non-contact thermometer, Part Number 3164457. If the air intake manifold does **not** heat, it **must** be replaced.



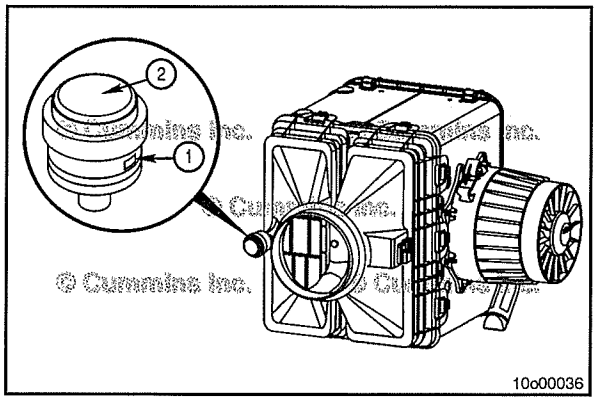
Air Intake Restriction (010-031)

General Information

Filter Restriction Indicator

A filter restriction indicator **must** be located on the direct Flow air cleaner to provide an indication of the proper time to replace the air filter(s).

A filter restriction indicator can be purchased separately, if one is **not** present on the housing. The restriction indicator is located at the pressure tap on the outlet side of the housing.

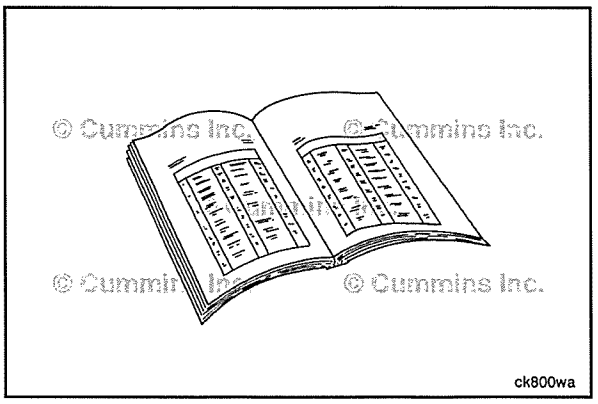


A mechanical filter restriction indicator is available to indicate excessive air restriction through the air filter(s). This instrument is mounted in the air cleaner outlet. The red flag (1) in the window gradually rises as the air filter loads with dirt. When the maximum air filter restriction is indicated the air filter **must** be replaced. After changing or replacing the air filter, reset the indicator by pushing the reset button (2).

Air Filter Restriction		
mm H_2O		in H_2O
635	MAX	25

Some restriction indicators are installed with an electronic switch that illuminates a lamp in the cab at full restriction, indicating that the air filters **must** be replaced.

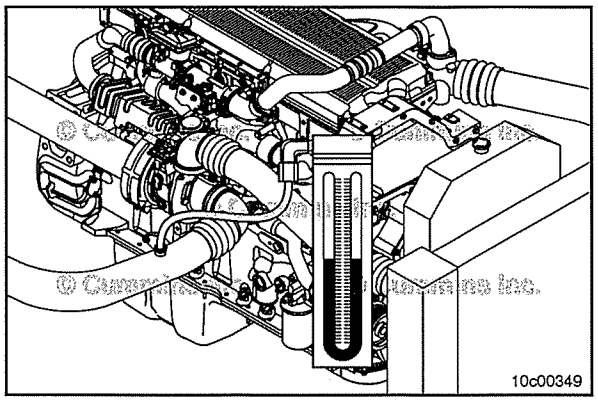
Refer to OEM service manual for information on resetting this type of indicator once the air filters have been changed.



Measure

Install a vacuum gauge or water manometer in the intake air piping.

NOTE: The gauge adapter **must** be installed at a 90-degree angle to the airflow in a straight section of pipe, 127 mm [5 in], before the turbocharger compressor inlet.

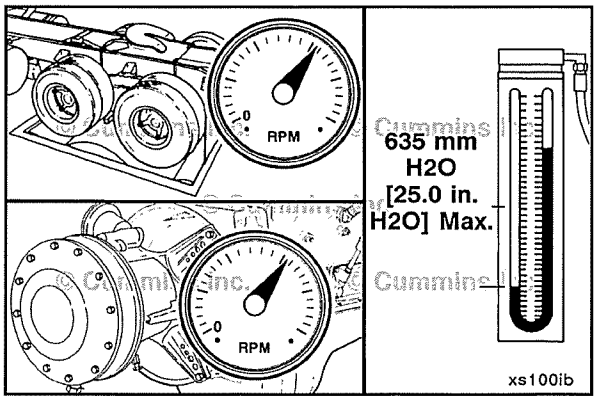


Operate the engine at full throttle and maximum horsepower rpm with maximum load.

Record the reading on the gauge or manometer.

Use the following procedure for the correct air filter restriction specification. Refer to Procedure 018-019 in Section V.

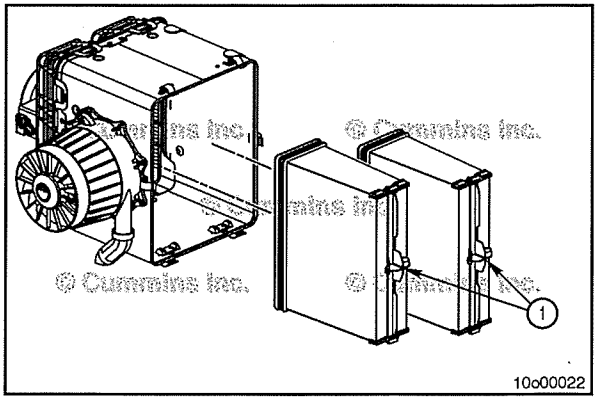
Air Filter Restriction		
mm H_2O		in H_2O
635	MAX	25

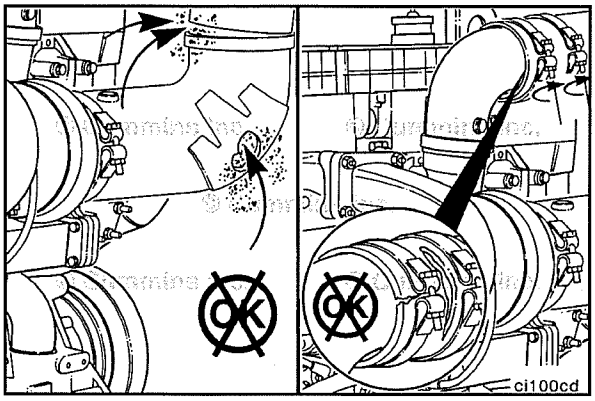


If the air filter restriction exceeds the specification, do the following:

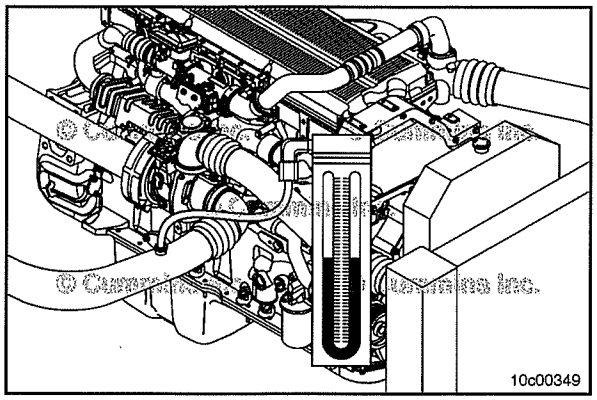
- Change the air filter element. Refer to Procedure 010-014 in Section 10.

NOTE: The air filter element change interval is based on air filter restriction, but the elements **must** be changed at least every 1500 hours or 1 year. The secondary air filter elements **must** be changed every-other time the primary air filter elements are changed. Proper inspection of the secondary air filter elements **must** be performed and the secondary elements changed, if necessary.

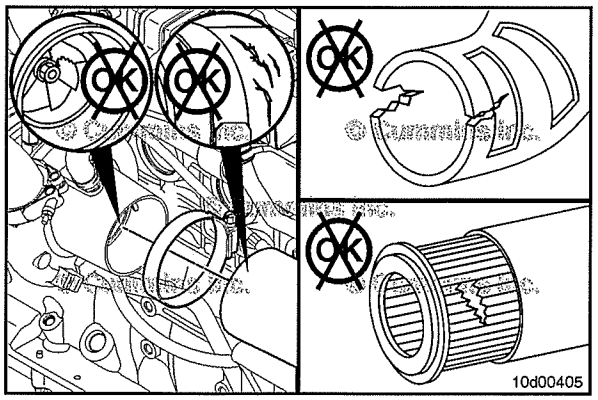




- Inspect the intake air piping for damage. Check for collapsed and dented piping or elbows, and loose connections. Refer to Procedure 010-024 in Section 10.



Remove the test equipment.



Turbocharger (010-033)

Initial Check

⚠CAUTION⚠
Do not operate the engine with the charge-air piping removed. The lack of boost pressure on the outlet side of the compressor outlet can cause progressive damage to the turbocharger.

Remove the intake pipe from the turbocharger. See the Remove section in this procedure.

Install protective caps from the Air Handling Clean Care Kit, Part Number 5298878, on all open connection points.

Inspect the turbocharger compressor impeller blades for damage.

Replace the turbocharger if damage is found. See the Remove and Install sections of this procedure.

If the compressor impeller is damaged, inspect the inlet piping and filter element for damage.

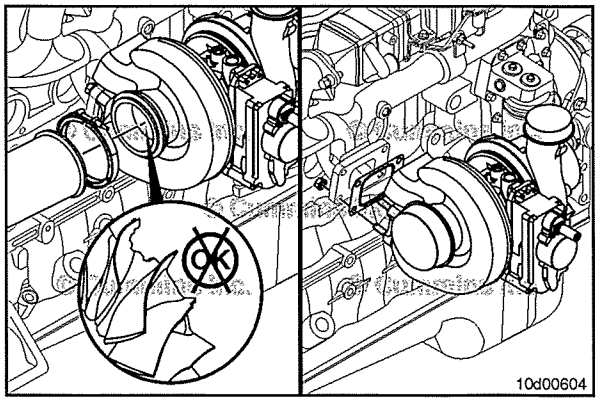
Repair any damage before operating the engine.

Remove the exhaust pipe from the turbocharger. See the Remove section in this procedure.

Install protective caps from the Air Handling Clean Care Kit, Part Number 5298878, on all open connection points.

Inspect the turbine wheel for damage.

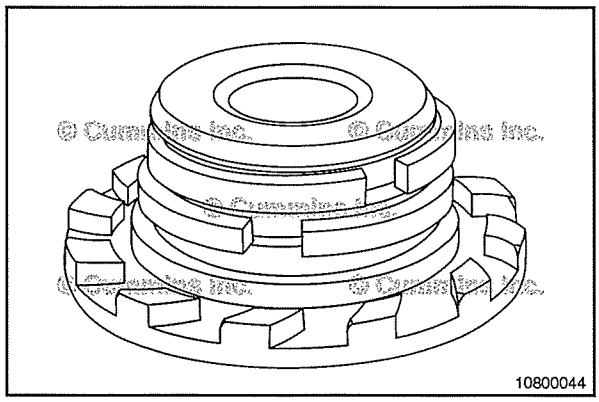
Replace the turbocharger if damage is found. See the Remove and Install sections of this procedure.

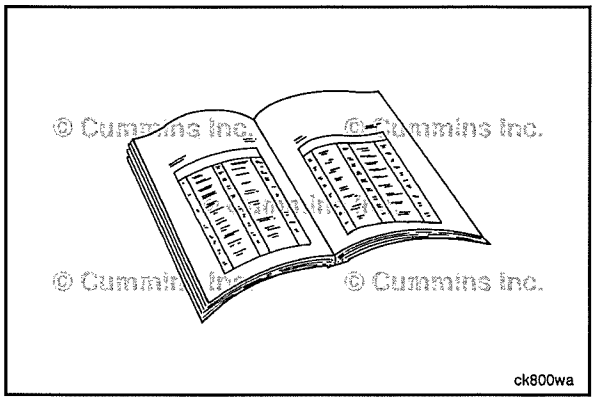


Oil leaks from the compressor (cold side) or turbine (hot side) seals do **not** always indicate a malfunction of the turbocharger oil seal. The oil seal is a piston-ring type seal, that is designed to function under a positive pressure differential between the turbine or compressor backwheel pressure (related to exhaust or boost pressure) and the turbocharger bearing housing pressure (related to crankcase pressure).

If the turbine or compressor backwheel pressure drops below the bearing housing pressure, oil can be forced past the seal and into the turbine or compressor housing of the turbocharger. If bearing wear/damage has **not** occurred (radial and axial end play is still in specification), the turbocharger itself will be undamaged. It can be cleaned and put back into service.

Reference the appropriate troubleshooting symptom tree to troubleshoot the turbocharger oil leak.





Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact with hot oil.

⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

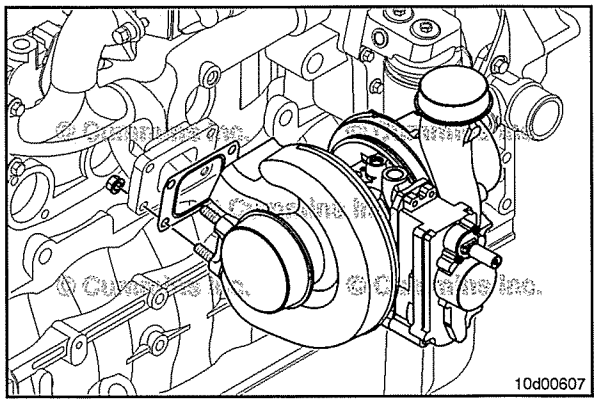
NOTE: Brush away all loose dirt from around the area of the air handling connections to avoid contamination of the interior of the engine.

NOTE: Take note of oil and coolant line orientation prior to removal and install in the same manner. Do **not** lift the turbocharger by the coolant return lines.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the oil supply line from the turbocharger. Refer to Procedure 010-046 in Section 10.
- Remove the oil drain line from the turbocharger. Refer to Procedure 010-045 in Section 10.
- Remove the turbocharger coolant lines. Refer to Procedure 010-041 in Section 10.

  NOTE: Be sure all turbocharger plumbing lines are **not** in contact with other lines or components.
- Disconnect the turbocharger actuator wiring harness by unlocking the tang and pushing down to release the tab.
- Disconnect the turbocharger speed sensor. Refer to Procedure 019-390 in Section 19.
- Remove the exhaust piping. Refer to the OEM service manual.
- Remove the turbocharger compressor air inlet and outlet connections. Refer to the OEM service manual.
- Remove the turbocharger compressor outlet connection. Refer to Procedure 010-132 in Section 10.
- Remove the turbocharger compressor air inlet connection. Refer to Procedure 010-132 in Section 10.

Remove



⚠WARNING⚠
This component or assembly weighs greater than 25kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift the component or assembly.

Remove the four turbocharger mounting nuts.

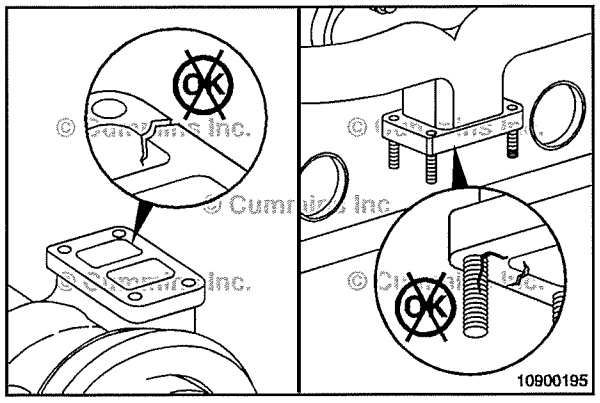
Care **must** be taken **not** to damage the turbocharger sensors or the turbocharger actuator coolant lines when removing the turbocharger from the engine.

Remove the turbocharger and gasket.

Cover the turbocharger exhaust inlet port with a protective cap from the Air Handling Clean Care Kit, Part Number 5298878. Cover the opening on the exhaust manifold with heavy tape.

If required, remove the turbocharger actuator. Refer to Procedure 010-134 in Section 10.

Clean and Inspect for Reuse



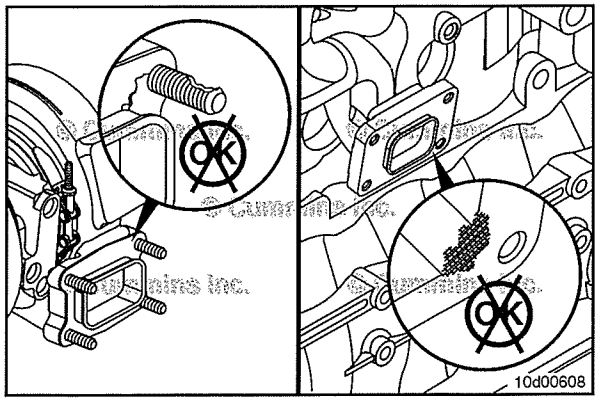
Clean the turbocharger and exhaust manifold gasket surfaces.

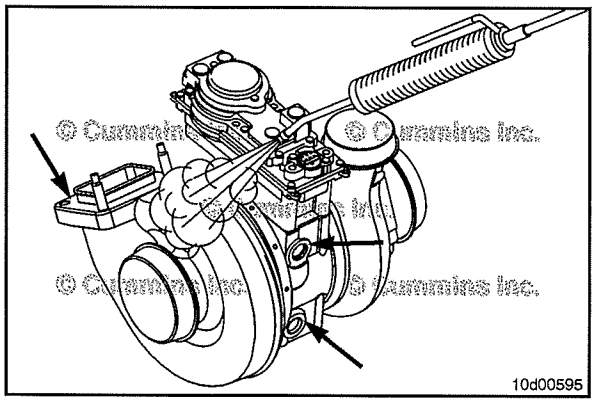
Inspect the turbocharger and exhaust manifold gasket surfaces and mounting studs for cracks and other damage.

Cracking of the turbine housing inlet flange may require turbocharger replacement.

Replace the turbocharger if any cracks or other damage is found in the mounting flange surface.

Replace the exhaust manifold if any cracks or other damage is found in the mounting flange surfaces. Refer to Procedure 011-007 in Section 11.





⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

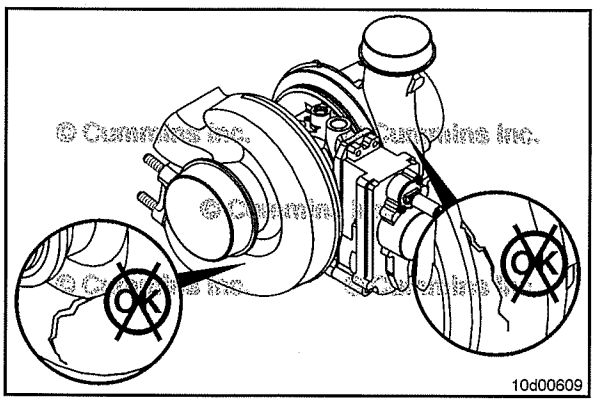
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove all carbon deposits and gasket material from the surfaces.

Use solvent or steam to clean the exterior of the turbocharger.

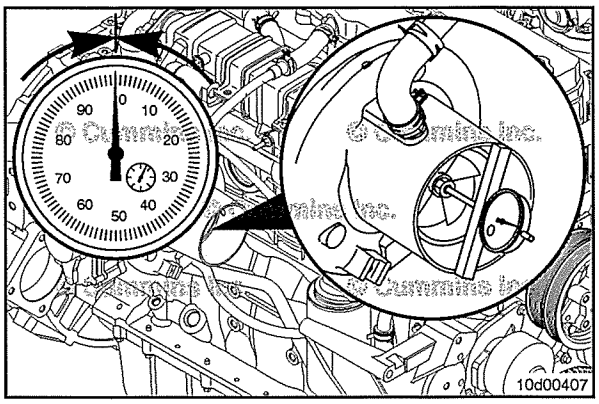
Dry with compressed air.



Inspect the turbine and compressor housings.

If cracks which go all the way through the outer walls are found, the turbocharger **must** be replaced.

Axial Clearance Check



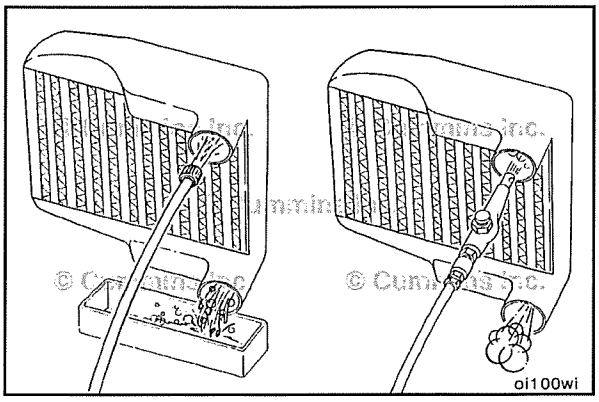
- Use dial depth gauge, Part Number ST-537.
- Push the rotor assembly away from the gauge.
- Set the gauge to zero.
- Push the rotor assembly toward the gauge and record the reading.

Axial Clearance (HE3xx Variable Geometry)		
mm		**in**
0.025	MIN	0.001
0.127	MAX	0.005

Replace the turbocharger if the clearance does **not** meet specifications. See the Remove and Install sections of this procedure.

Radial Clearance Check

- Check the radial movement of the rotor system by pushing the turbocharger compressor wheel toward the wall of the turbocharger compressor cover with light finger pressure. The turbocharger passes inspection if the wheel does **not** contact the compressor cover wall.
- Repeat the procedure on the turbine wheel.
- Replace the turbocharger if there is contact between the turbine wheel and turbine housing or compressor wheel and compressor housing. See the Remove and Install sections of this procedure.

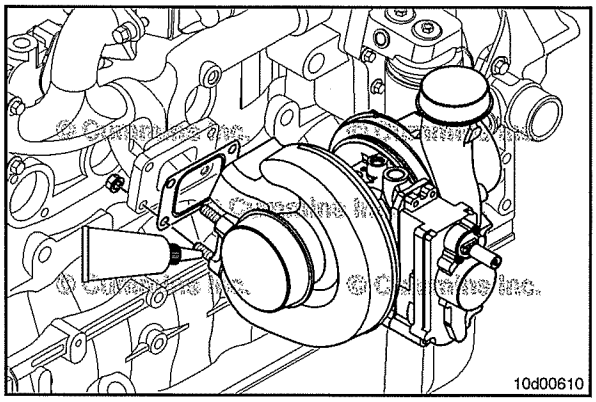


NOTE: If the engine experiences a turbocharger malfunction or any other occasion in which oil or debris is put into the charge-air system, the charge-air system **must** be inspected and cleaned. Refer to Procedure 010-027 in Section 10.

NOTE: If the engine experiences a turbocharger malfunction that resulted in coolant or oil entering the intake, the charge-air cooler system, as well as the exhaust gas recirculation (EGR) differential pressure cross drillings should be inspected and cleaned. Refer to Procedure 010-027 in Section 10. Refer to Procedure 010-080 in Section 10.

NOTE: If the engine experiences a turbocharger malfunction or any other occasion where oil is put into the exhaust, the aftertreatment components **must** be inspected. Inspect the aftertreatment diesel oxidation catalyst Refer to Procedure 011-049 in Section 11.

Inspect the aftertreatment selective catalytic reduction (SCR) catalyst. Refer to Procedure 011-036 in Section 11.



Install

⚠CAUTION⚠
Do not use a metal hammer on the compressor housing or damage can occur.

⚠CAUTION⚠
Do not pinch the turbocharger speed sensor with the V-band or compressor cover.

⚠CAUTION⚠
Do not remove the compressor cover to reduce the possibility of compressor wheel damage.

NOTE: Make sure to install the lines in the proper orientation.

NOTE: If installing a new turbocharger, orient the compressor housing to the same position as the turbocharger that was removed. Begin by taking note of the present turbocharger speed sensor and actuator jumper harness routing. Move the turbocharger speed sensor away from the bearing housing to the compressor housing joint. Orient the compressor housing by loosening the V-band clamp. Do **not** remove the V-band clamp or uninstall the compressor cover from the bearing housing. Reorient the compressor housing by lightly tapping the housing (**not** the compressor outlet flange) with a soft hammer. Retorque the V-band to 8 N•m [75 in-lb]. Reroute the turbocharger speed sensor and actuator jumper harness to the original rounting path. When finished, check to make sure the compressor wheel freely rotates and no clearance/rubbing issues are found. If the compressor wheel is rubbing the compressor housing, replace the turbocharger.

Torque Value: 8 N•m [75 in-lb]

Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.

Only remove clean care caps as the connections are being made.

Install a new gasket and install the turbocharger.

Use a new gasket and install the turbocharger.

Install and tighten the four mounting nuts.

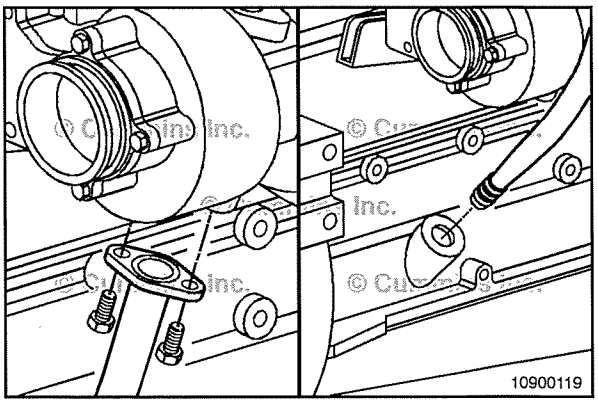
NOTE: The torque values given have been established using anti-seize compound as a lubricant.

Torque Value: 55 N•m [41 ft-lb]

If required, remove the turbocharger actuator. Refer to Procedure 010-134 in Section 10.

Prime

Install and tighten the turbocharger oil drain line. Refer to Procedure 010-045 in Section 10.

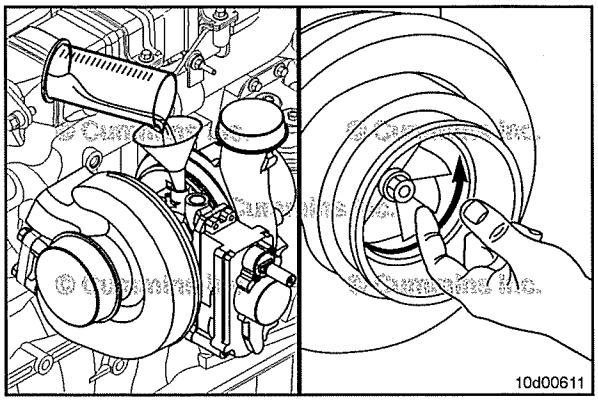


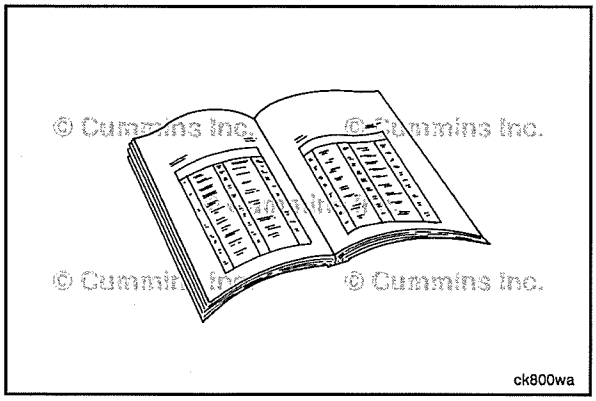
Lubricate the bearings by pouring 59 to 89 cc [2 to 3 oz] of clean 15W-40 engine oil in the turbocharger oil supply line fitting.

Rotate the turbine wheel to allow oil to enter the bearing housing.

NOTE: If too much oil is poured into the bearing housing, the oil may leak past the seals. This is **not** a malfunction since the seals are **not** dynamic and rely on exhaust gas and boost pressure to provide a proper seal.

Install the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.





Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- If equipped, install the turbocharger compressor air inlet connection. Refer to Procedure 010-022 in Section 10.
- If equipped, install the turbocharger compressor outlet connection. Refer to Procedure 010-132 in Section 10.
- Install the exhaust piping. Refer to the OEM service manual.
- Connect the turbocharger speed sensor. Refer to Procedure 019-390 in Section 19.
- Connect the turbocharger actuator wiring harness, making sure the tab locks and the locking tank slides into place.
- Install the turbocharger coolant lines. Refer to Procedure 010-041 in Section 10.
- Install the oil supply line to the turbocharger. Refer to Procedure 010-046 in Section 10.

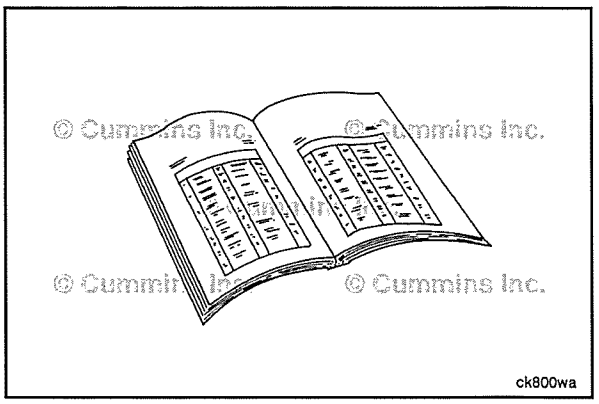
  NOTE: Be sure all turbocharger plumbing lines are **not** in contact with other lines or components.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Turbocharger Coolant Hoses (010-041)

General Information

The turbocharger coolant hose routing varies depending on the turbocharger mounting configuration. This procedure was written to be generic. **Not all** illustrations within this procedure will represent the application that is being worked on.

Preparatory Steps



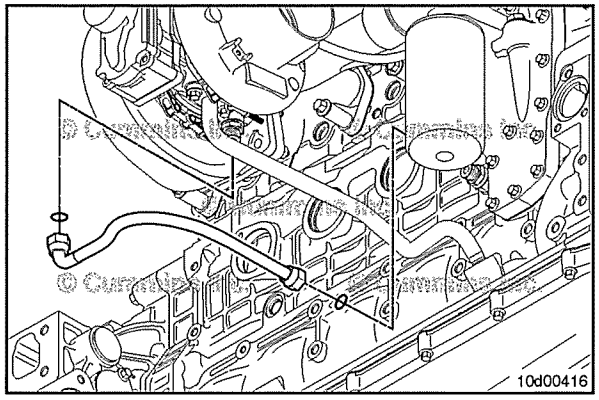
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.

Remove



NOTE: Take note of the oil and coolant line orientation prior to removal and install in the same manner.

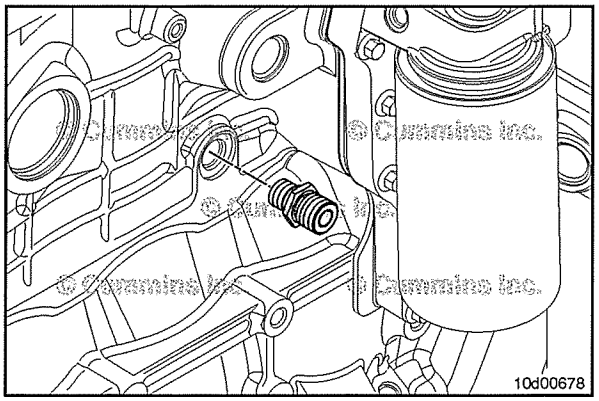
Disconnect the turbocharger coolant supply hose from the fitting in the cylinder block.

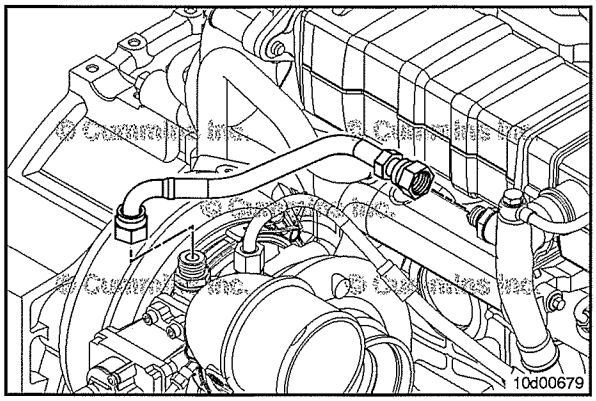
Disconnect the turbocharger coolant supply hose from the fitting in the turbocharger bearing housing or the variable geometry turbocharger (VGT) actuator housing.

Remove the turbocharger coolant supply hose.

NOTE: Use a second wrench to hold the coolant connection fittings at the cylinder block and the turbocharger bearing housing to prevent accidental loosening of the fittings. Hold the turbocharger coolant supply line while loosening, to prevent kinking the line.

Remove the turbocharger coolant supply hose fitting from the cylinder block.





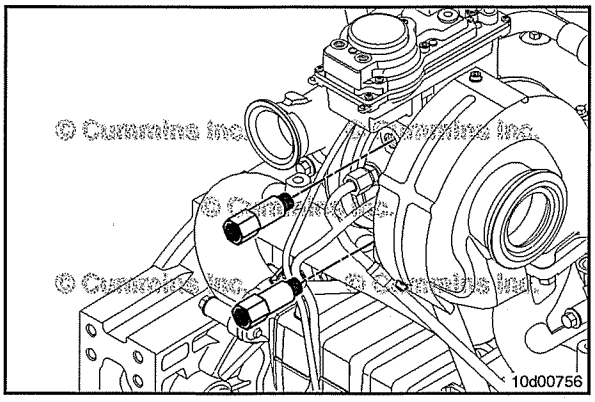
NOTE: On high mount exhaust configurations, remove the coolant vent line before removing the coolant return line. Also, remove the exhaust gas recirculation (EGR) cooler connection before removing the turbocharger so that the lines do **not** fall over or kink.

Disconnect the turbocharger coolant return hose from the fitting at the EGR cooler coolant inlet connection.

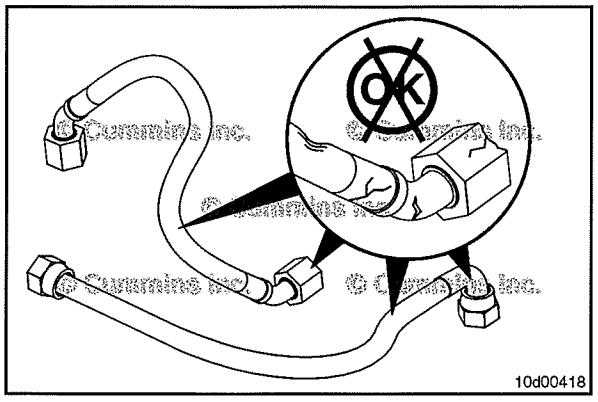
Disconnect the turbocharger coolant return hose from the fitting in the turbocharger bearing housing or the VGT actuator.

Remove the turbocharger coolant return hose.

NOTE: Use a second wrench to hold the coolant connection fittings at the turbocharger bearing housing, to prevent accidental loosening of the fittings Hold the turbocharger coolant return line while loosening to prevent kinking of the line.



Remove the turbocharger coolant hose fittings from the turbocharger bearing housing.



Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the coolant hoses with solvent and dry with compressed air.

A sealing washer is used on both sides of a banjo fitting.

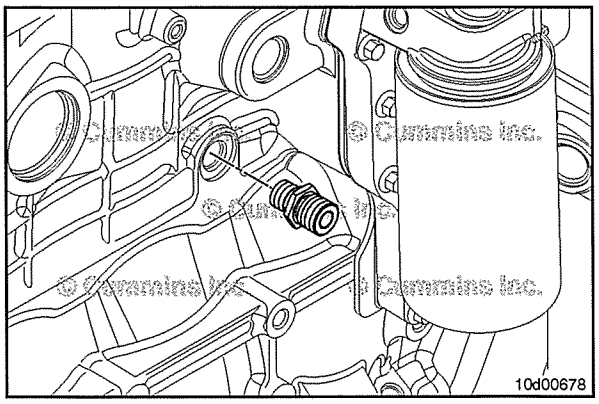
NOTE: New sealing washers **must** be installed when assembling banjo fittings.

Inspect the coolant hoses for cuts, cracks, leaks, or other damage. Replace as necessary.

Install

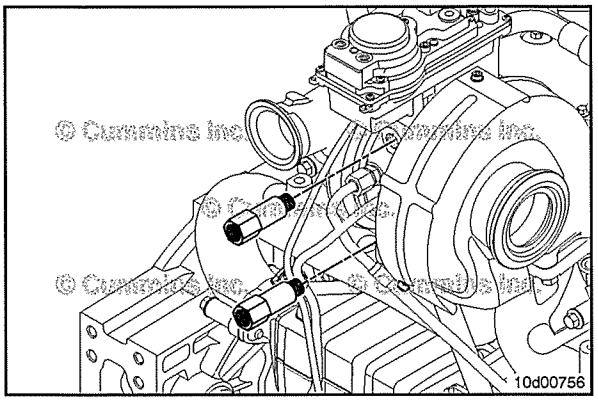
Install the turbocharger coolant supply hose fitting into the cylinder block.

Torque Value: 55 N•m [41 ft-lb]



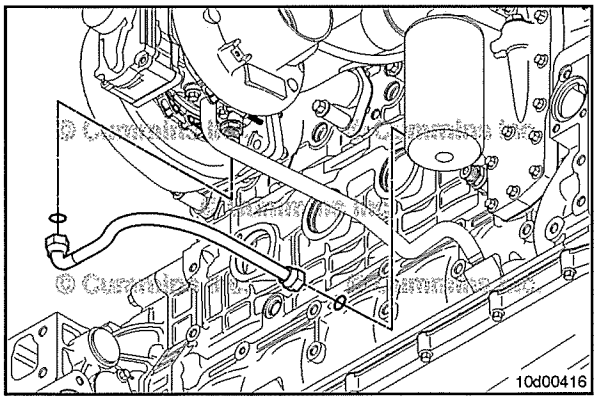
Install the turbocharger coolant hose fittings into the turbocharger bearing housing.

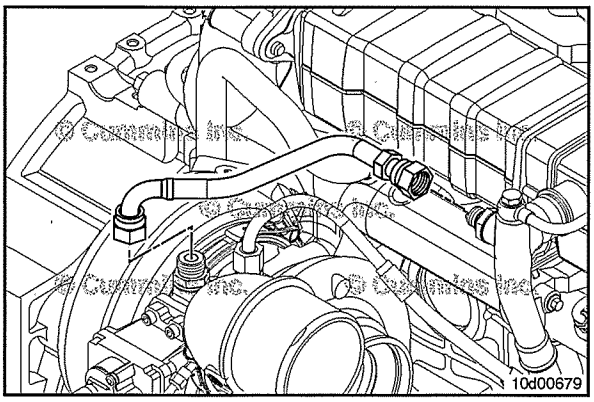
Torque Value: 35 N•m [26 ft-lb]



Install the turbocharger coolant supply hose onto the fittings in the cylinder block and the turbocharger bearing housing or VGT actuator.

Do **not** tighten the fittings at this time.





NOTE: On high mount exhaust configurations, the coolant return line **must** be aligned properly to reduce the possibility of vent line kinking when installed. The top of the return line **must** be horizontal.

Install the turbocharger coolant return hose onto the fittings on the EGR cooler coolant return and the turbocharger bearing housing or the VGT actuator.

Do **not** tighten the fittings at this time.

NOTE: Use a second wrench to hold the coolant connection fittings at the cylinder block, EGR cooler coolant return, and the turbocharger bearing housing or the VGT actuator, to prevent accidental overtightening of the fittings.

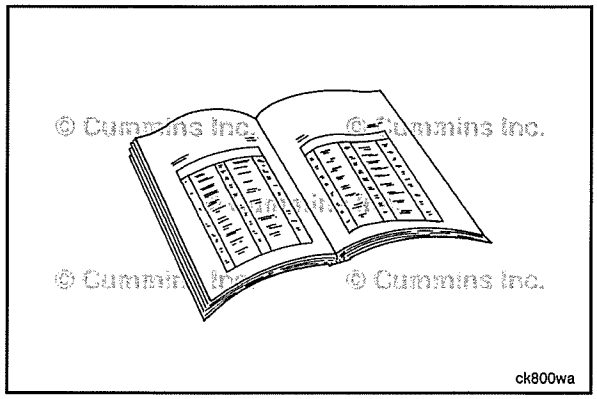
Tighten the supply and return hose fittings.

Torque Value:
Banjo fitting to bearing housing, when applicable 35 N•m [26 ft-lb]

Torque Value:
Banjo fitting to VGT actuator, when applicable 25 N•m [221 in-lb]

Torque Value:
Hose nut fitting to bearing housing, when applicable 35 N•m [26 ft-lb]

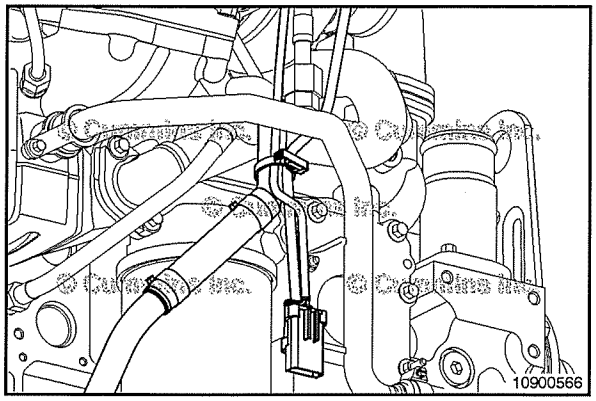
NOTE: Be sure all turbocharger plumbing lines are **not** in contact with other lines or components.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

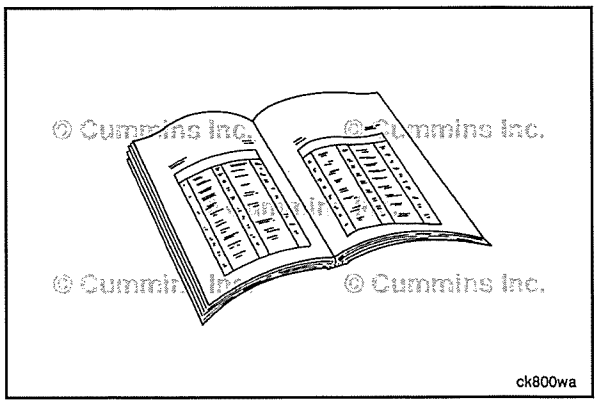


If zip ties were removed, zip tie the turbocharger actuator and turbocharger speed sensor harnesses to the same plumbing lines. The harnesses **must** route over the top of the compressor cover between the bearing housing and the compressor cover.

Turbocharger Oil Drain Line (010-045)

General Information

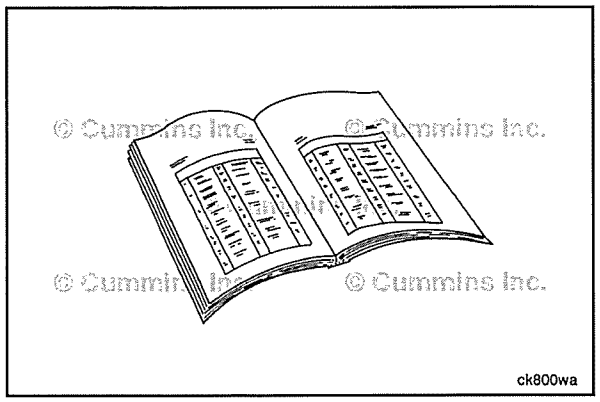
Some engines are equipped with a turbocharger dual oil drain line that uses both the front and rear block oil drain ports. This procedure covers both drain line configurations.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

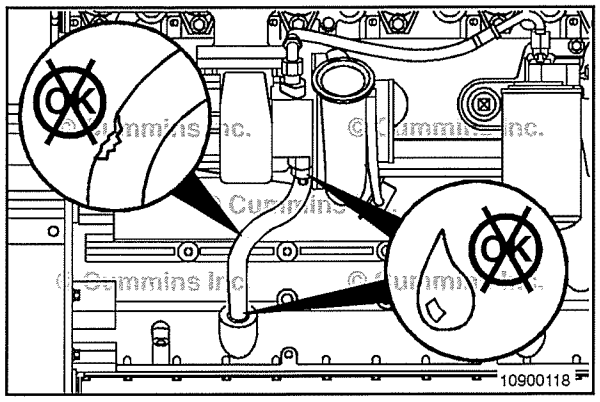
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.



Initial Check

Inspect the line for oil leaks or damage. Inspect all joining surfaces.

Repair or replace as necessary.



Remove

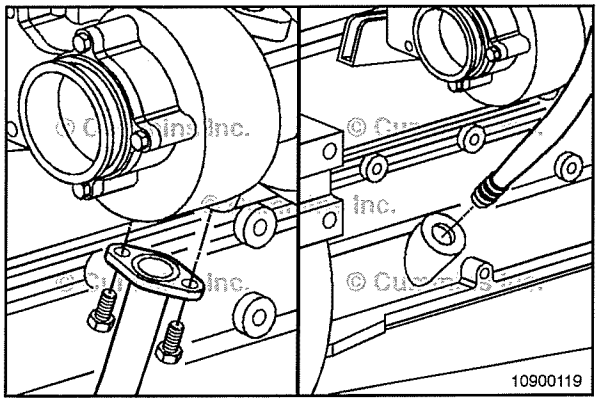
Clean around the area where the oil drain line inserts into the cylinder block with a clean cloth.

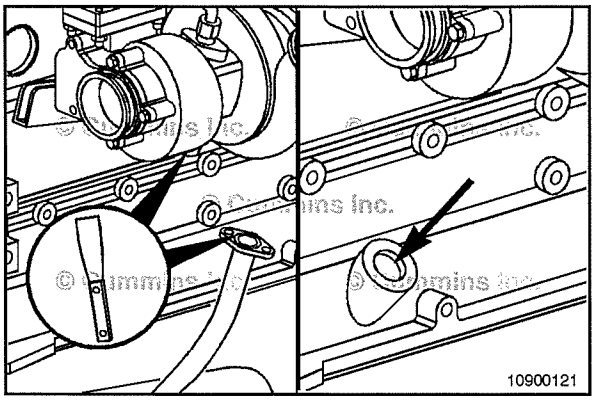
Remove the two capscrews that hold the oil drain line to the turbocharger.

Remove the oil drain line from the turbocharger and discard the gasket.

Pull the oil drain line out of the cylinder block.

NOTE: Do **not** bend or kink the rubber hose section, if equipped.

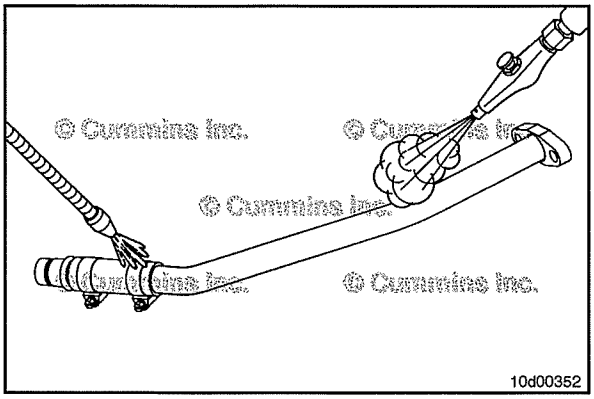




Clean and Inspect for Reuse

Clean the gasket sealing surfaces on the oil drain line and the turbocharger.

Clean the o-ring seating bore in the cylinder block, taking care **not** to drop any dirt and debris into the cylinder block.



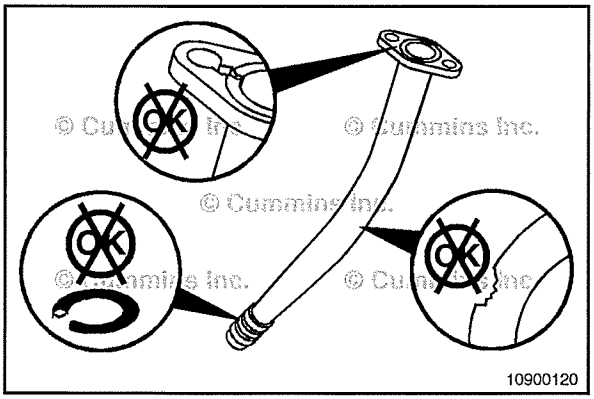
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the turbocharger oil drain line with solvent and dry with compressed air.

Inspect the oil drain line for any signs of coking or restriction.

Clean the inside of the oil drain line if it shows signs of oil coking or restriction.



Inspect all pieces of the drain line for signs of cracks, wear, or other damage. Replace the damaged part if these signs are present.

Inspect the drain line sealing o-rings for signs of cracks, wear, or fretting. Replace as necessary.

Install

Apply a thin film of clean engine oil to the drain line o-rings.

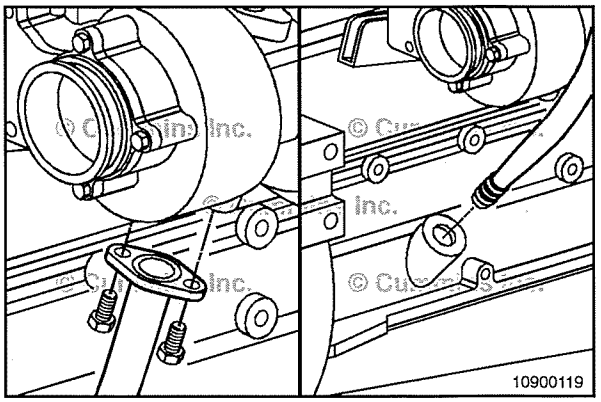
Push the drain line into the oil drain line boss. Make sure all o-rings are completely seated in their mating bores.

If equipped with the turbocharger dual oil drain line, insert both ends into the oil drain line bosses. Then mount the tube flange to the turbocharger bearing housing. Use a new gasket.

Install the oil drain line mounting capscrews and tighten.

Torque Value: 24 N•m [212 in-lb]

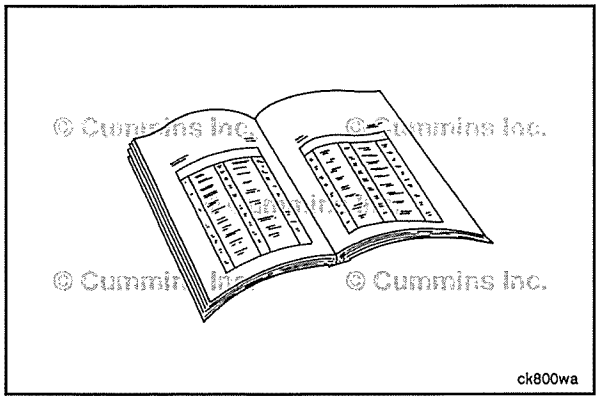
NOTE: Make sure **all** turbocharger plumbing lines are **not** in contact with other lines or componenets.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

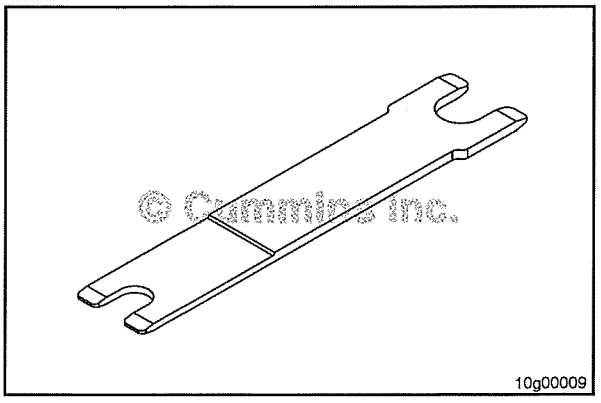
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Turbocharger Oil Supply Line (010-046)

General Information

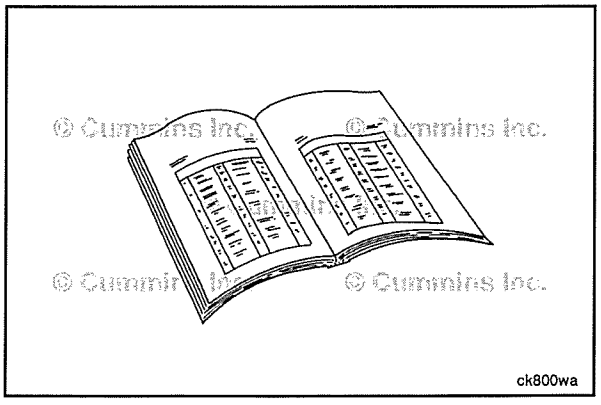
Some engines are equipped with a quick connect fitting at the lubricating oil cooler head. This fitting requires a Cummins® service tool or equivalent, to disassemble this fitting. If the tool is **not** available, then the fitting at the lubricating oil cooler head can be unscrewed from the oil filter head and removed or installed while still connected to the line.

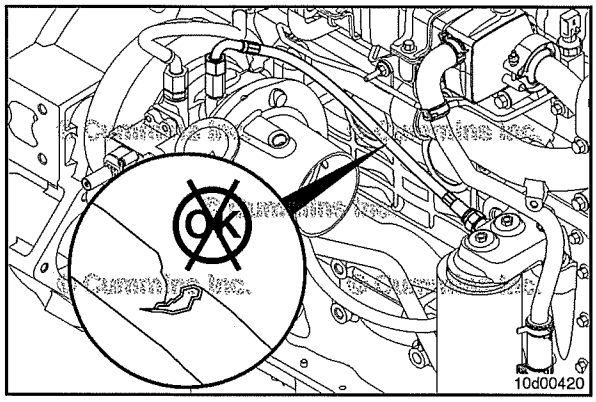


Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

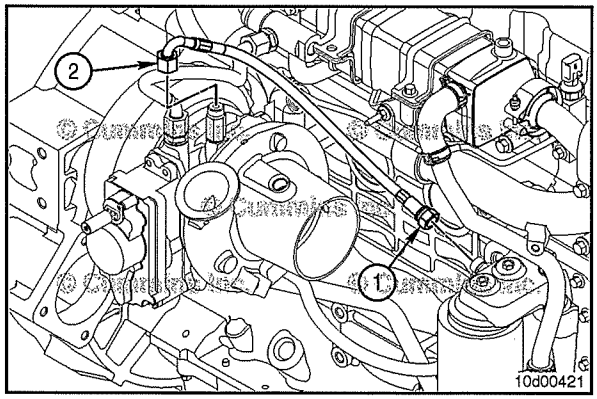
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.





Initial Check

Inspect the turbocharger oil supply line for oil leaks or damage. Replace as necessary.

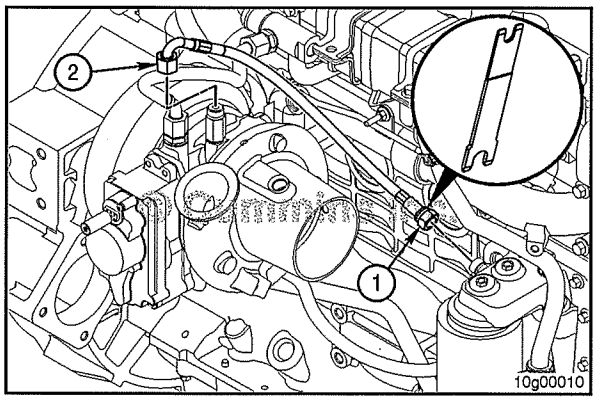


Remove

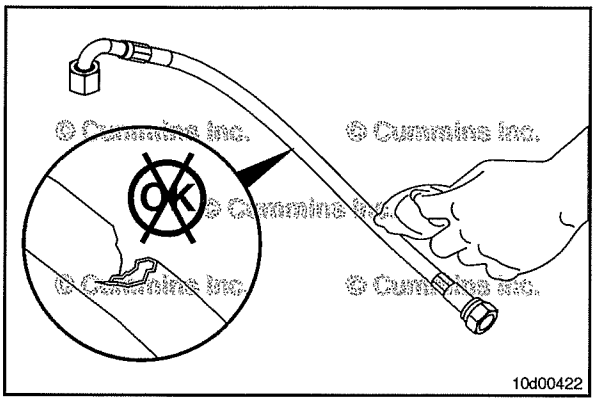
⚠CAUTION⚠
Do not bend the line more than is necessary and always remove both ends because the line can be damaged by excessive bending.

Remove the turbocharger oil supply line from the bearing housing (2) and from the oil filter head (1).

NOTE: Use a wrench to hold the fitting below the oil supply line on both the turbocharger bearing housing and oil filter head. This will prevent the fittings from loosening.



For engines equipped with the quick connect fitting at the oil filter head (1), use quick connect connector remover, Part Number 2892393. Insert the correct size end of the tool into the gap between the rubber boot and the line. Do **not** pry on the connection. Pull the line away from the fitting to release it. If the tool is **not** available, then unscrew the fitting in the lubricating oil cooler head and remove the fitting with the line still connected.



Inspect for Reuse

Clean the oil supply line with a clean, lint-free cloth. Take precautions to keep dirt and debris out of the oil supply line.

Inspect the line for cracks, wear, kinks, burns, and other damage.

For the lines equipped with the quick connect fitting, inspect the snap ring and o-ring inside the fitting and the line for cracks, wear, or other damage.

The rubber boot on the line can show some wear but should be replaced if it does **not** cover the fitting and will **not** prevent dirt intrusion.

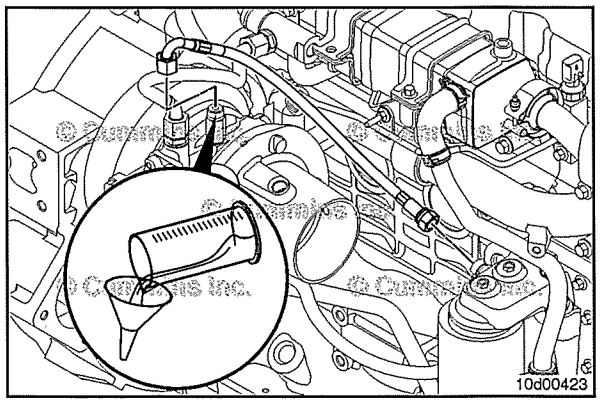
Replace the component if any damage is found.

Install

⚠CAUTION⚠
To reduce the possibility of chafing oil lines, maintain a 10 mm [0.39 in] minimum distance between the oil supply line and turbine housing or exhaust manifold. Maintain 5 mm [0.20 in] minimum distance between the oil supply line and any other component.

Fill the turbocharger oil inlet with clean 15W-40 engine oil.

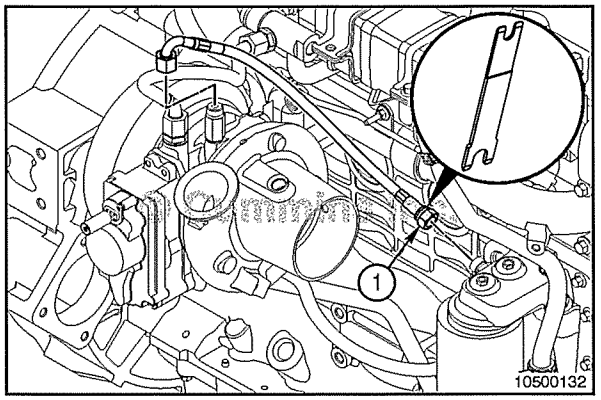
Install the oil supply line at the turbocharger bearing housing and the oil filter head, use new o-ring seals.



For engines equipped with the quick connect fitting (1), if the quick connect fitting was removed, install it to the lubricating oil cooler head.

Torque Value: 35 N•m [26 ft-lb]

Push the line onto the quick connect fitting until the snap ring inside the fitting clicks. Verify that the fitting is locked by pulling on the line.



⚠CAUTION⚠
To reduce the possibility of chafing oil lines, maintain a 10 mm [0.39 in] minimum distance between the oil supply line and turbine housing or exhaust manifold. Maintain 5 mm [0.20 in] minimum distance between the oil supply line and any other component.

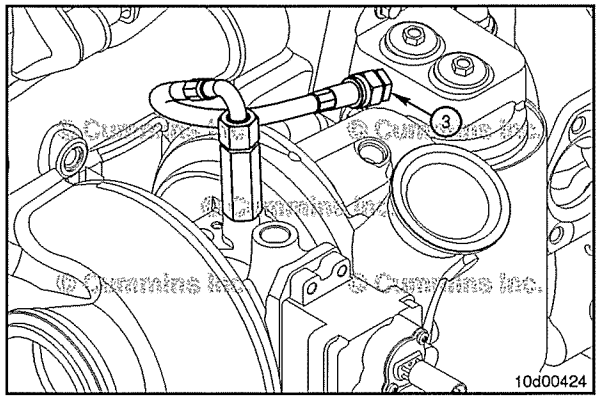
NOTE: Use a wrench to hold the fittings (3) below the oil supply line on both the turbocharger bearing housing and oil filter head. This will prevent the fittings from being overtightened.

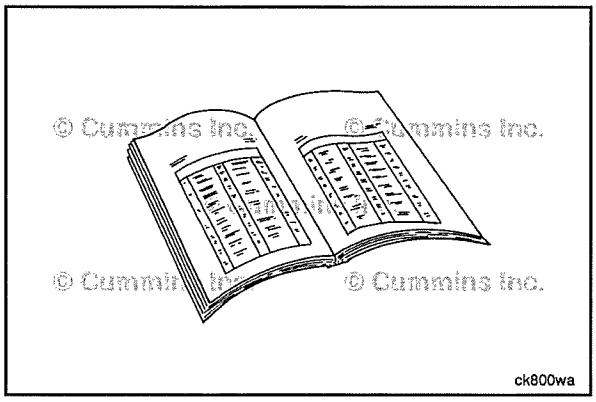
Tighten the oil supply line at the turbocharger bearing housing.

Torque Value:
Oil supply line 36 N•m [27 ft-lb]

Torque Value:
Banjo fitting to bearing housing (when applicable) 15 N•m [133 in-lb]

NOTE: Be sure all turbocharger plumbing lines are **not** in contact with other lines or components.





Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Turbocharger Heat Shield (010-076)

General Information

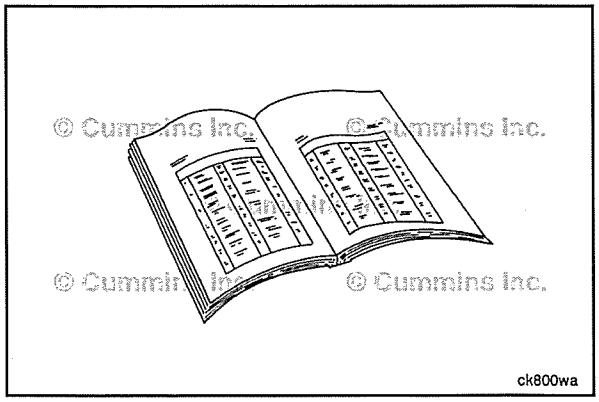
⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components.

⚠WARNING⚠
Improper practices, carelessness, or ignoring the warnings can cause burns, cuts, mutilation, asphyxiation, or other personal injury or death.

There are several turbocharger turbine housing mounted heat shield designs. The heat shield reduces heat exposure to chassis components from the turbocharger turbine housing.

Due to the number of turbocharger mounting configurations and heat shield designs, this procedure has been written to be generic. The Remove and Install sections are common, regardless of the style of heat shield used.

Preparatory Steps

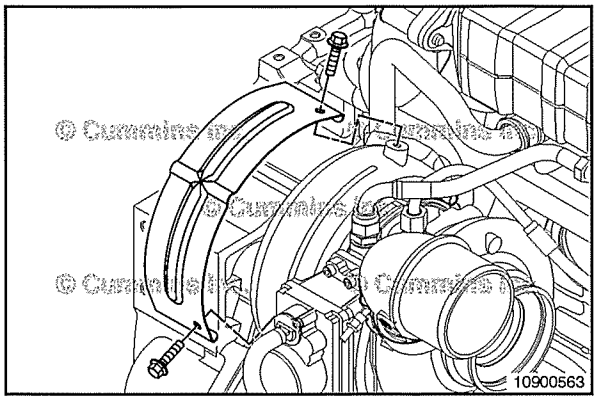


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

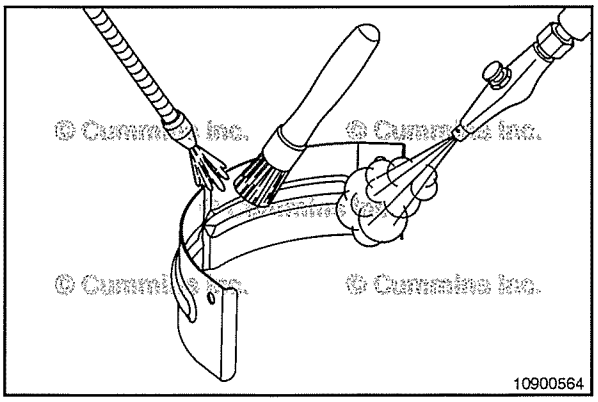
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.

Remove



Remove the capscrews securing the turbocharger heat shield to the turbocharger turbine housing.

Clean and Inspect for Reuse



⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

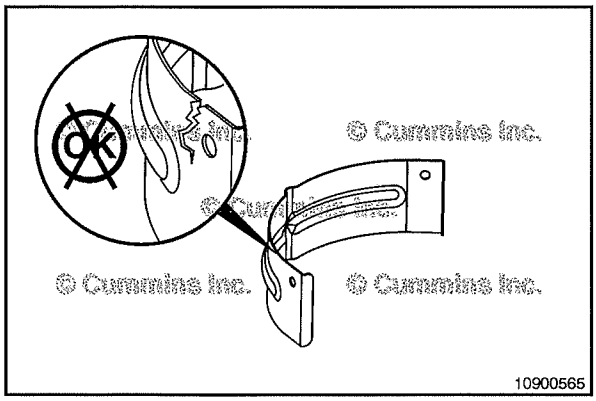
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

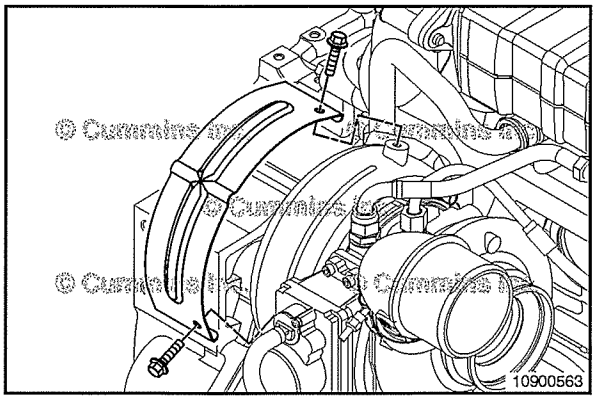
Use solvent or steam to clean the turbocharger heat shield.

Dry with compressed air.



Inspect the turbocharger heat shield.

If cracks or other damage is found, replace the turbocharger heat shield.



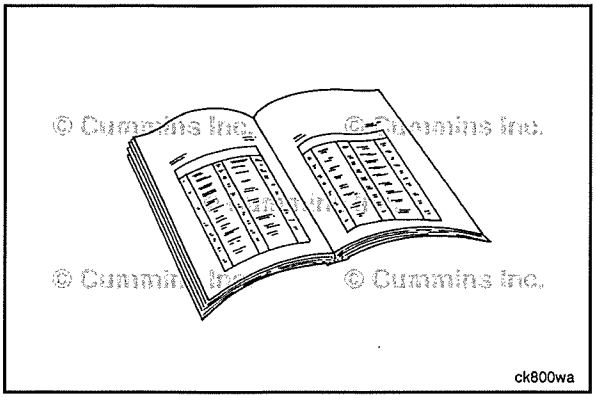
Install

Place a light coating of high-temperature anti-seize compound, Part Number 3824732 or equivalent, on the retaining capscrews prior to installation.

Install the turbocharger heat shield.

Tighten the capscrews.

Torque Value: 25 N•m [221 in-lb]

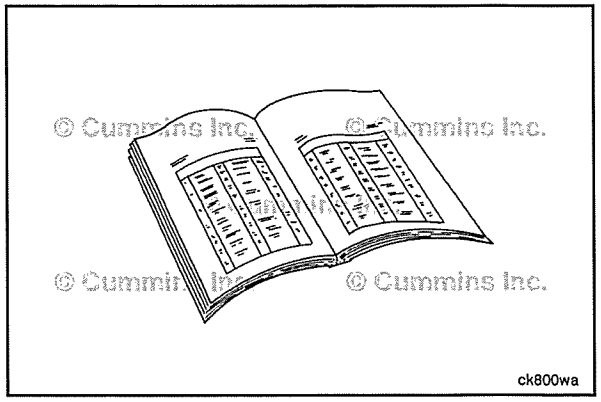


Finishing Steps

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for loose components.

Air Intake Connection (010-080)

Preparatory Steps



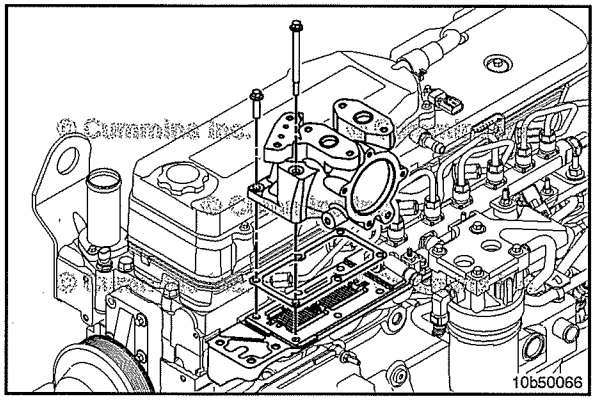
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: Brush away all loose dirt around the area of the air handling connections to avoid contamination of the interior of the engine.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Cover all open connections with protective caps from the Air Handling Clean Care Kit, Part Number 5298878.
- Disconnect the air crossover tube from the air intake connection adapter. Refer to Procedure 010-019 in Section 10.
- Disconnect the exhaust gas recirculation (EGR) connection tube from the EGR valve. Refer to Procedure 011-025 in Section 11.
- Disconnect the electrical connection from the EGR valve.
- Remove the EGR valve. Refer to Procedure 011-022 in Section 11.
- Disconnect the electrical connection from the EGR temperature sensor. Refer to Procedure 019-378 in Section 19.
- Disconnect the electrical connection from the EGR differential pressure sensor. Refer to Procedure 019-370 in Section 19.
- Remove the two wiring harness P-clips from the air intake connection and move the wiring harness out of the way.

NOTE: The following components can be left assembled onto the air intake connection. If removing the air intake connection as part of another repair.

- Remove the air intake connection adapter. Refer to Procedure 010-131 in Section 10.
- Remove EGR differential pressure sensor. Refer to Procedure 019-370 in Section 19.



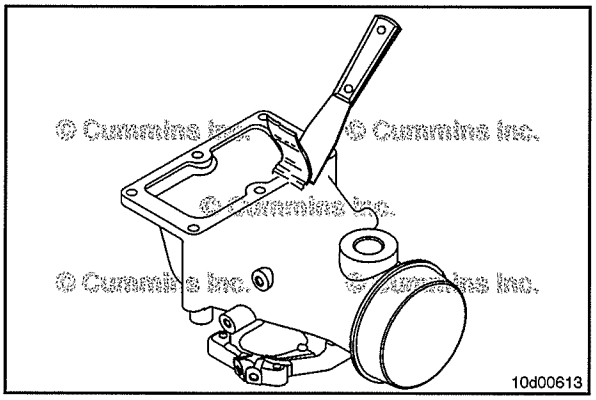
Remove

Remove the six mounting capscrews, air intake connection, and gasket.

Cover all open connections with protective caps from the Air Handling Clean Care Kit, Part Number 5298878.

Use heavy tape to cover the intake manifold opening to prevent debris from entering the engine.

NOTE: If the engine experiences a turbocharger failure or any other occasion in which oil, debris, or coolant is put into the charge-air system, the EGR differential pressure sensor flow ports **must** be cleaned.

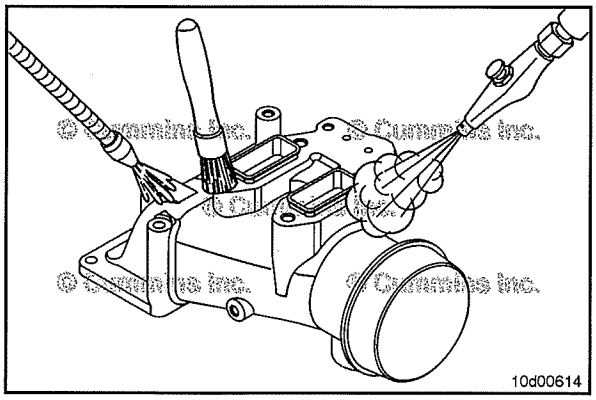


Clean and Inspect for Reuse

Remove the old gasket material from the intake connection and intake manifold cover sealing surface.

NOTE: Use caution while cleaning. Do **not** scratch, score, or remove the protective corrosion-resistant coating on the inside of the air intake connection.

NOTE: Discoloration at the EGR differential pressure sensor mounting surface is normal and does **not** warrant replacement of the intake connection.



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

NOTE: Use a nylon brush when cleaning cross drillings and exhaust gas entrance ports. Do **not** use hard-wired brushes, as the exhaust gas entrance ports are very sensitive measurement devices and should **not** be scratched. Make sure all carbon is removed from the ports as this could affect engine operation.

Saturate the inside of the air intake connection, the EGR differential pressure sensor flow ports, and cross-drillings with safety solvent.

NOTE: Use **only** cleaning solvent intended for use on aluminum components and a non-abrasive brush.

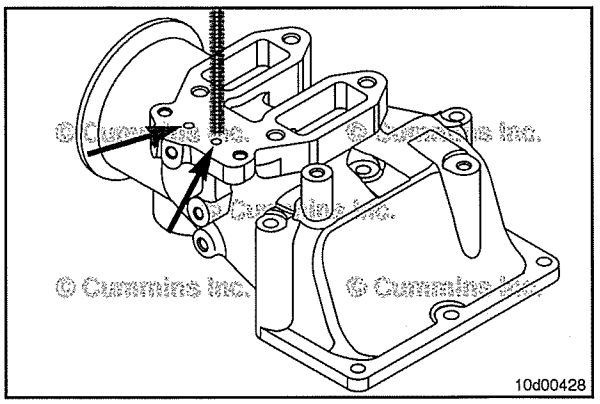
Clean the EGR differential pressure sensor flow ports with a pipe cleaner or similar device. Inspect the cross-drillings for soot blockage. If any of the EGR differential pressure sensor flow ports are blocked, be sure to clean the ports completely prior to installing the air intake connection.

Remove the pipe plugs to clean the EGR differential pressure sensor cross-drillings. After cleaning the cross-drillings, install the pipe plugs. Use thread sealant, Part Number 3375066, or equivalent, to prevent any leaks.

Torque Value: 10 N•m [89 in-lb]

Remove the tape or cloth from the intake manifold. Inspect the intake manifold cover, cold starting aid, and air intake connection sealing surfaces for cracks or other damage. Replace any damaged components. Refer to Procedure 010-023 in Section 19.

NOTE: If the engine experiences a turbocharger malfunction or any other occasion in which oil, debris, or coolant is put into the charge-air system, the EGR differential pressure sensor flow ports **must** be cleaned.

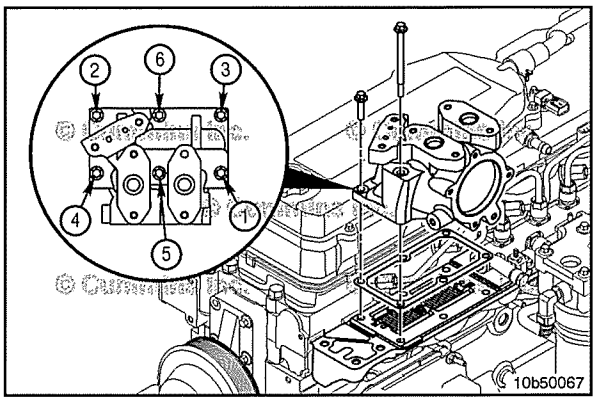


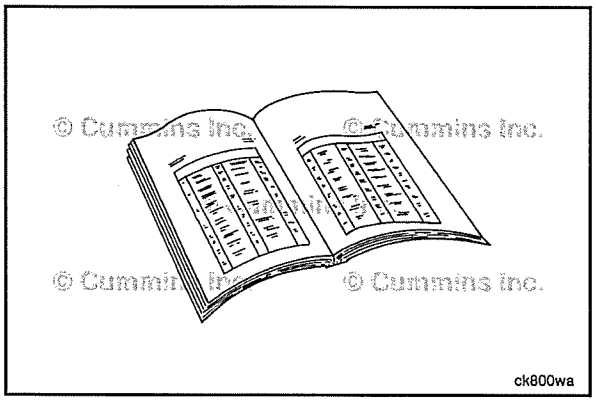
Install

Install the new air intake connection, new gasket, and air intake connection.

Install and tighten the capscrews in the sequence shown.

Torque Value: 24 N•m [212 in-lb]





Finishing Steps

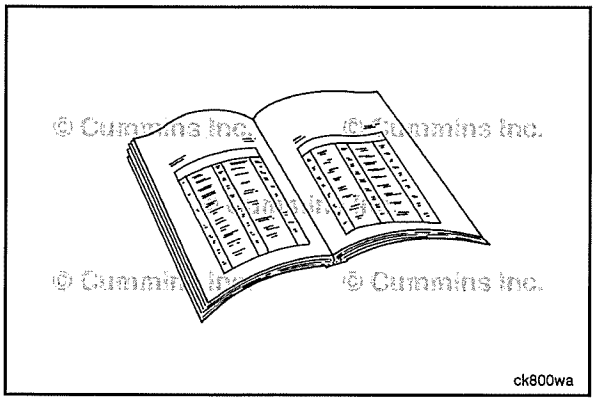
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- If removed, install the air intake connection adapter. Refer to Procedure 010-131 in Section 10.
- If removed, install the EGR valve to the air intake connection. Refer to Procedure 011-022 in Section 11.
- If removed, install the EGR differential pressure sensor. Refer to Procedure 019-370 in Section 19.
- Connect the electrical connection to the EGR differential pressure sensor. Refer to Procedure 019-370 in Section 19.
- Connect the electrical connection to the EGR valve and EGR temperature sensor. Refer to Procedure 019-378 in Section 19.
- Install the two wiring harness p-clips to the air intake connection.
- Connect the air crossover tube to the air intake connection adapter. Refer to Procedure 010-019 in Section 10.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Air Intake Connection Adapter (010-131)

General Information

The air intake connection adapter refers to the part of the air intake system upstream of the air intake connection. The Cummins® engines covered in this manual use an air intake connection adapter attached to the air intake connection by a v-band clamp.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

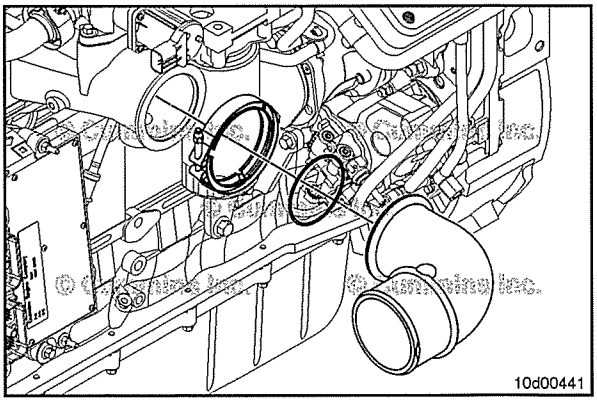
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the charge air piping between the air intake connection adapter and the outlet of the charge air cooler. Refer to Procedure 010-019 in Section 10.

Remove

Remove the v-band connection holding the air intake connection adapter to the air intake connection.

Remove the air intake connection adapter and o-ring seal.

Use protective caps from the Air Handling Clean Care Kit, Part Number 5298878, to cover both connection points.



Clean and Inspect for Reuse

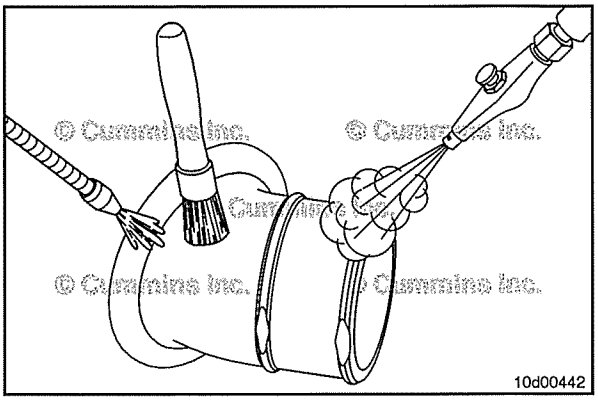
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the air intake connection adapter with solvent and dry with compressed air.

Inspect the air intake connection adapter, seal, and clamps for damage, cuts, cracks, holes, or worn sections.

Replace damaged components if necessary.

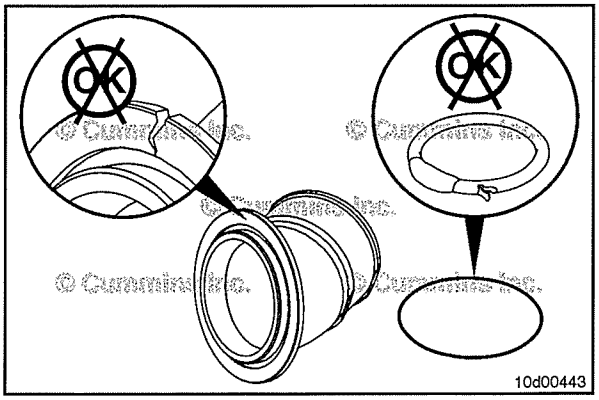


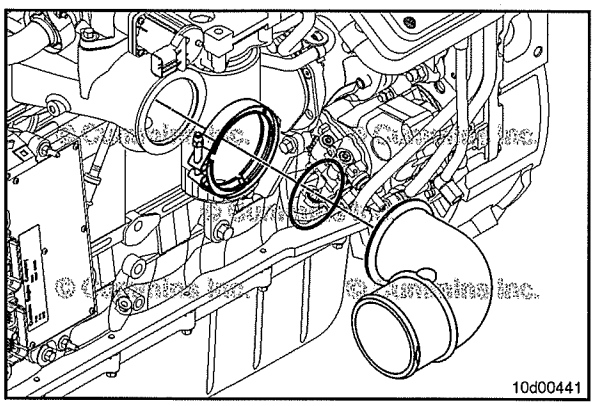
Inspect the sealing surfaces for signs of damage.

Inspect the o-ring seal for cuts or wear.

Inspect the v-band clamp for signs of damage or overextension.

Replace damaged components as necessary.





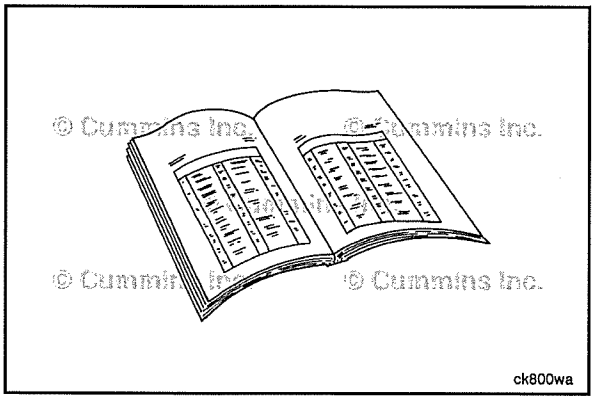
Install

Install the o-ring seal in the groove of the air intake connection adapter.

Install the air intake connection adapter. Make sure the o-ring seal stays in the groove.

Install and tighten the v-clamp.

Torque Value: 10 N•m [89 in-lb]



Finishing Steps

⚠WARNING⚠

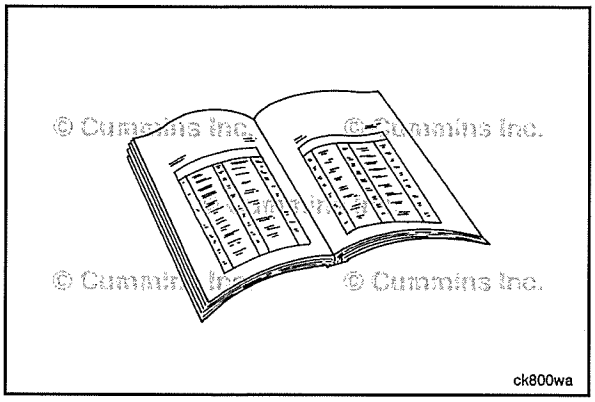
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the air cross over piping. Refer to Procedure 010-019 in Section 10.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for air leaks.

Turbocharger Compressor Outlet Connection (010-132)

General Information

This procedure includes instructions on removal, cleaning/inspection, and installation of the turbocharger compressor outlet connection. There are many different styles of outlet connection on the ISB/QSB/ISBe series engines, and the pictures contained in this procedure will **not** exactly represent the actual hardware on the engine being serviced. However, the procedures for removal, cleaning/inspection, and installation of each different turbocharger compressor outlet connection are identical.



Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

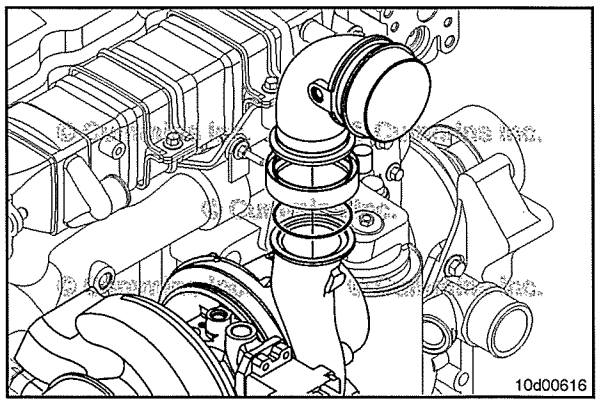
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the outside of the turbocharger compressor outlet connection with a clean cloth, making sure to remove all dirt which could fall into the intake when the charge air piping is removed.
- Disconnect the charge air piping and connections from the turbocharger compressor outlet connection. Refer to Procedure 010-019 in Section 10.

Remove

Loosen the clamp holding the turbocharger compressor outlet connection to the turbocharger.

Remove the turbocharger compressor outlet connection and seal, taking care **not** to drop the seal or any foreign matter into the turbocharger.

Use protective caps from the Air Handling Clean Care Kit, Part Number 5298878, to cover both connection points.



Clean and Inspect for Reuse

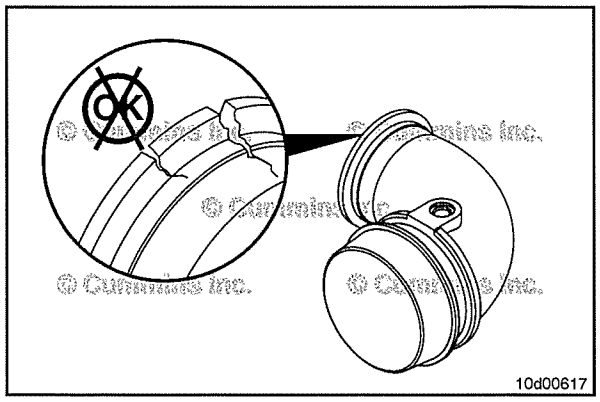
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Clean the turbocharger compressor outlet connection with solvent and dry with compressed air.

Inspect the turbocharger compressor outlet connection for cracks, damage, or abnormal wear. Replace as necessary.

Discard the o-ring seal, it is **not** serviceable.



Install

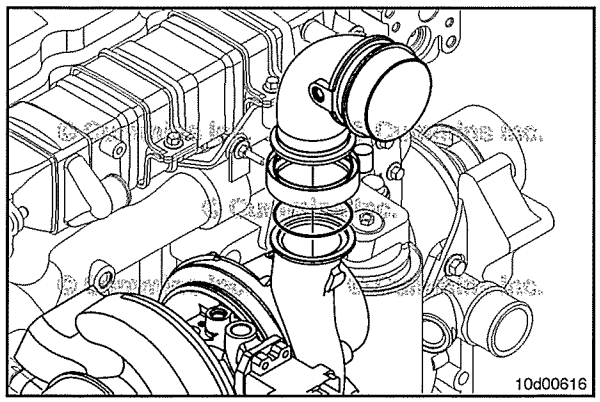
Install the turbocharger compressor outlet connection and o-ring seal.

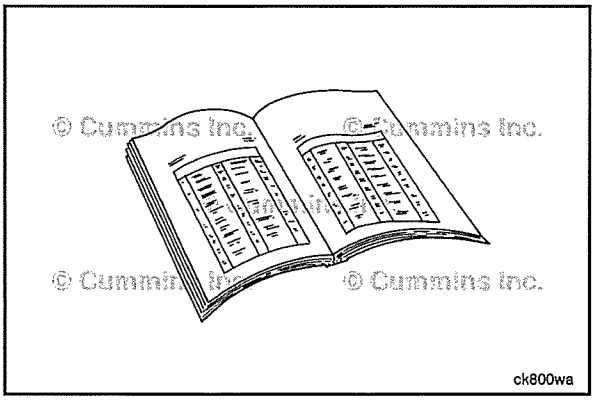
Use a new o-ring seal.

Make sure to remove the protective caps.

Install the clamp and tighten.

Torque Value: 10 N•m [89 in-lb]

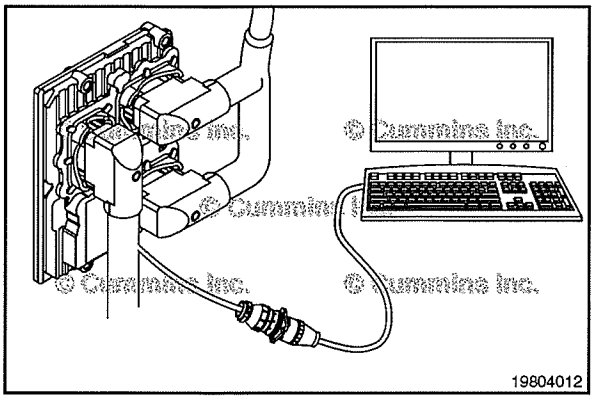




Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the charge air piping to the turbocharger compressor outlet connection. Refer to Procedure 010-019 in Section 10.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine at rated speed, use soapy water to check for leaks at the turbocharger compressor outlet connection joints.

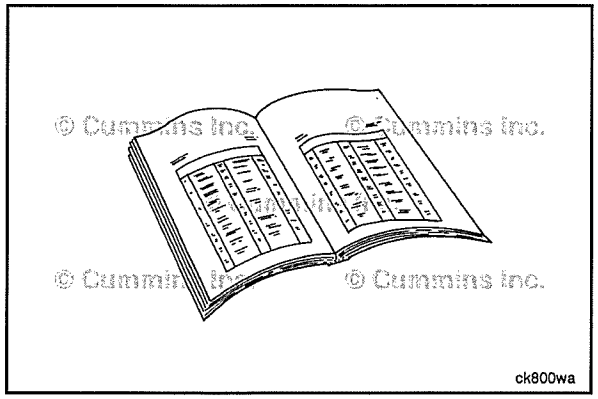


Variable Geometry Turbocharger Actuator, Electric (010-134)

General Information

△CAUTION△
The starting motor wiring could electrically interfere with the variable geometry turbocharger (VGT) wiring harness. The starting motor wiring must be at least 300 mm [12 in] away from the actuator and harness.

This procedure provides service information for the electronically controlled variable geometry turbocharger actuator. Take careful note of the procedure steps to avoid improper installation of the turbocharger actuator. Installation or replacement of the actuator requires the use of INSITE™ electronic service tool.



Preparatory Steps

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

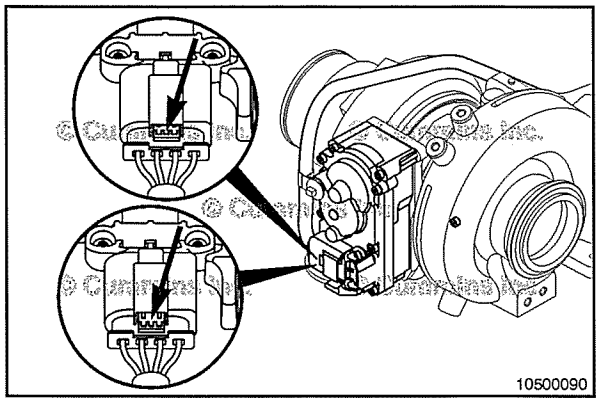
- Clean the area around the turbocharger actuator and dry with compressed air.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the turbocharger coolant hoses. Refer to Procedure 010-041 in Section 10.

Remove

⚠CAUTION⚠
Make sure the coolant has been drained before the actuator is removed. If the coolant is not completely drained, the actuator can be damaged.

NOTE: Before attempting to disconnect the wiring harness from the turbocharger. Clean the connector of any dirt or debris to reduce the possibility of damage to the connector.

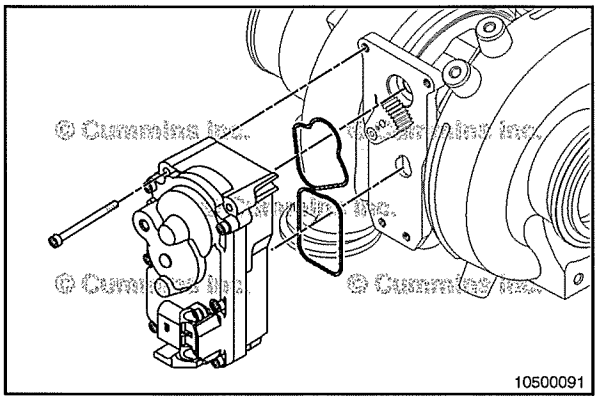
Disconnect the wiring harness from the turbocharger actuator by pushing down and out on the locking tab. The locking tab should click, indicating it is unlocked. Continue to push down and out on the locking tab while pulling the connector to remove it from the turbocharger actuator.



Remove the turbocharger actuator mounting capscrews and discard the capscrews.

Remove the actuator.

Remove and discard the turbocharger actuator sealing gaskets.



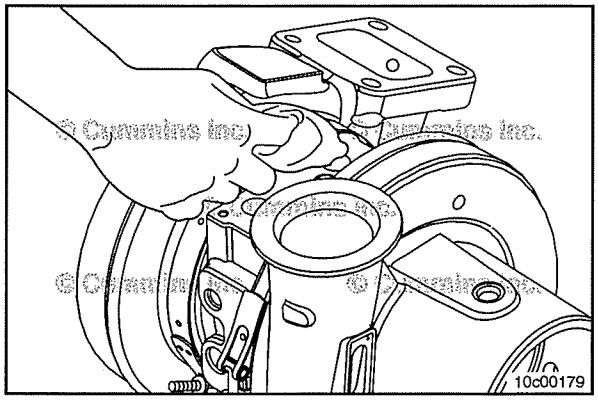
Clean and Inspect for Reuse

Install protective caps from Air Handling Clean Care Kit, Part Number 5298878, on all open connection points.

Use a clean cloth to wipe around the surface where the turbocharger actuator seals to the turbocharger.

NOTE: Take care **not** to drop any dirt or debris into the turbocharger.

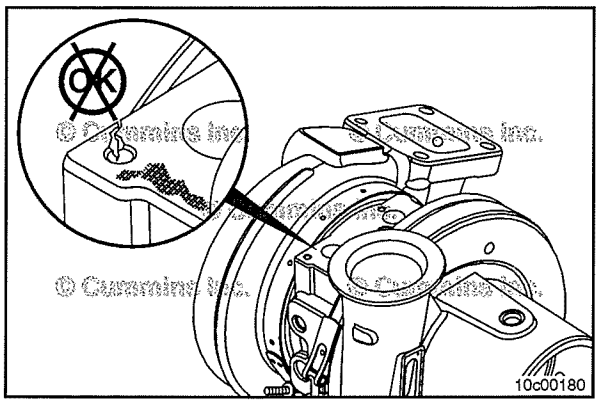
Inspect the sealing surfaces and the rubber sealing gasket for signs of leaks, cracks, or other damage.

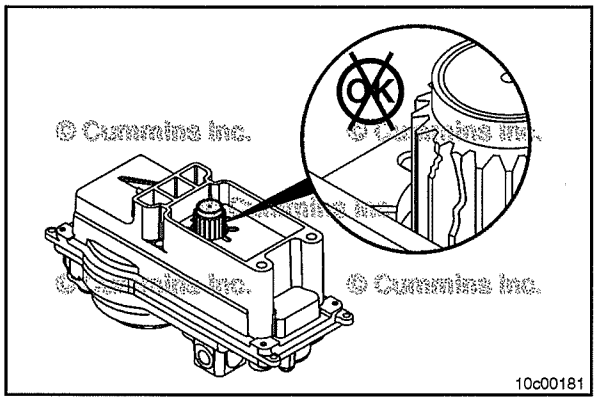


If the sealing surface of the turbocharger is damaged and causing a leak, the turbocharger **must** be replaced. Do **not** continue with this procedure. Refer to Procedure 010-033 in Section 10.

If the sealing surface of the actuator is causing a leak, replace **only** the actuator.

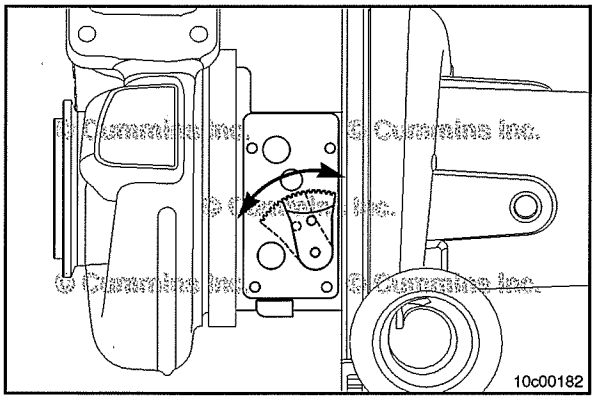
NOTE: It may be common to see oil leaking from around the sector gear shaft. This is **not** considered a malfunction or damage.





Inspect the pinion gear on the actuator for excessive wear or damaged teeth.

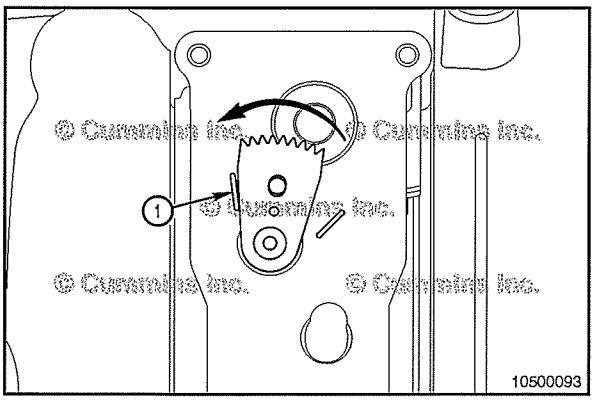
Replace the actuator if the pinion gear teeth are worn or damaged.



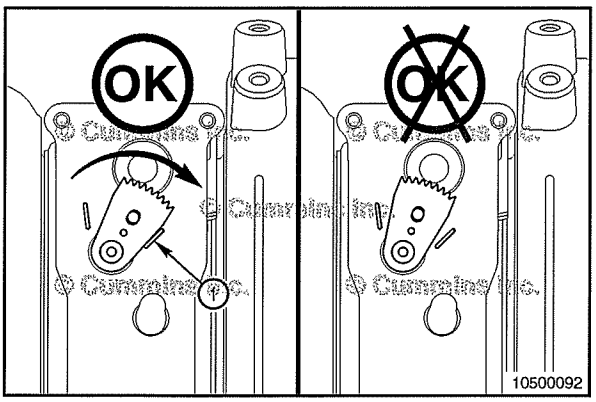
Inspect the sector gear on the turbocharger for excessive wear, damaged teeth, or a broken shaft.

Grasp the sector gear by hand and move it through its operational range.

NOTE: It may take considerable force to move the sector gear. If it can be moved by hand, this is considered acceptable. Do **not** use any hand tools.



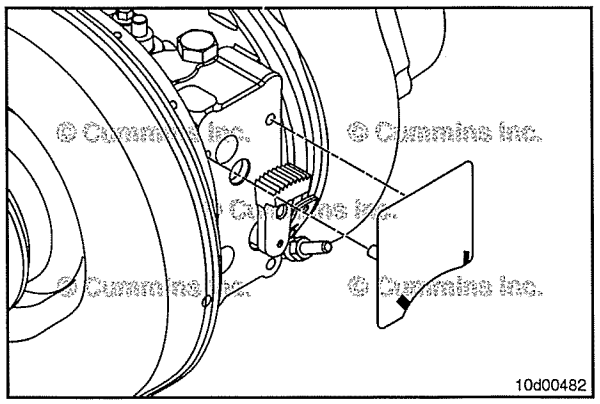
Rotate the sector gear **counterclockwise** (1) toward the turbocharger compressor cover. The edge of the sector gear **must** touch the engraved bearing housing hash mark.



Rotate the sector gear **clockwise** (1) toward the turbocharger turbine housing. The edge of the sector gear **must** touch the engraved bearing housing hash mark.

If the sector gear does **not** go through its entire range of motion, or if the sector gear is seized, it is necessary to replace the entire turbocharger assembly. Do **not** continue with this procedure. Refer to Procedure 010-033 in Section 10.

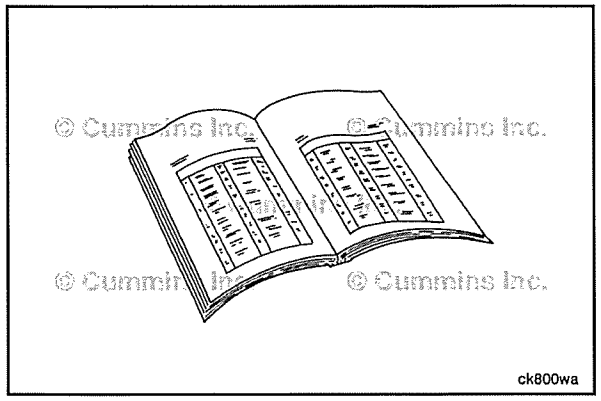
Alternately, the HE300Ve sector gear travel gauge from the Turbocharger Actuator Inspection Gauge Kit, Part Number 4919281, can be used to check the sector gear for range of motion.To install the sector gear travel gauge, carefully bend the gauge and slide the thin section under the sector gear. If necessary, pull the sector gear out by hand to allow more clearance for the gauge. Verify that the three alignment bosses are fully engaged in the bearing housing.



Install

NOTE: New turbocharger actuators are sold with a calibration code installed. Downloading a new calibration code into the turbocharger actuator should **only** be required if Fault Code 4956 or 4957 is active after installing a new turbocharger actuator, or if directed by a Campaign, Temporary Repair Practice, or warrantable repair.

If the turbocharger actuator requires a calibration code to be downloaded, use the following procedure. Refer to Procedure 010-150 in Section 10.



NOTE: Following these installation instructions in order is very important.

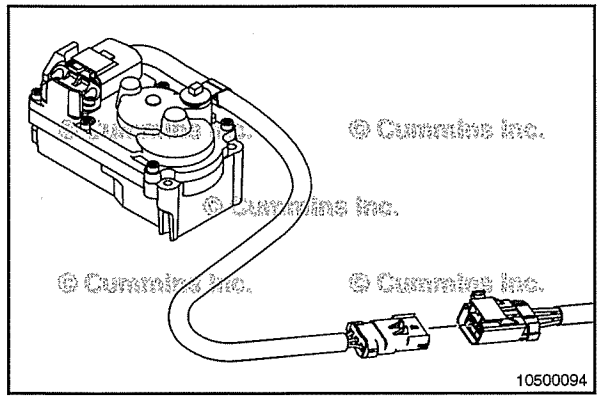
- Continue through the entire turbocharger actuator installation procedure before attempting to troubleshoot any other fault codes.
- Verify that the turbocharger actuator is removed from the turbocharger bearing housing.
- Verify that the turbocharger actuator electrical connector is disconnected from the engine wiring harness.
- Turn the keyswitch ON. Connect INSITE™ electronic service tool and wait 60 seconds.

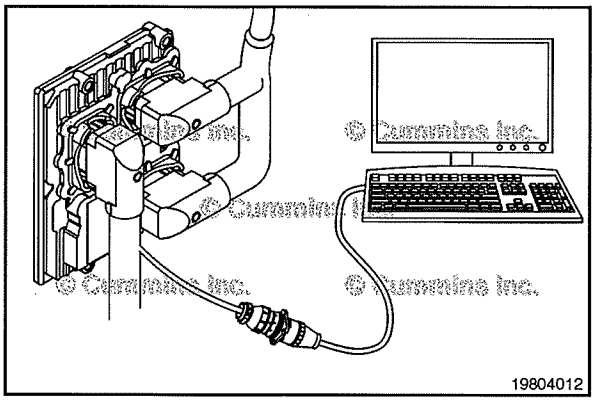
  NOTE: It is important that the keyswitch remain in the ON position throughout both the Install and Calibrate procedures unless otherwise directed.
- Connect the turbocharger actuator electrical connector to the engine wiring harness.

If Fault Code 2634 becomes active, disconnect the turbocharger actuator connector from the engine wiring harness with the keyswitch ON. Connect the turbocharger actuator electrical connector. Fault Code 2634 will go inactive.

It is normal and expected to have Fault Code 2449 active when a new turbocharger actuator is connected to the engine, because it is **not** calibrated to the turbocharger.

Continue through the engine turbocharger actuator installation procedure before attempting to troubleshoot any other fault codes.





In INSITE™ electronic service tool, go to the ECM Diagnostic Tests screen.

From the list, select VGT Electronic Actuator Installation and Calibration, and click on the "next" button.

NOTE: The VGT Electronic Actuator Installation and Calibration is **not** a diagnostic test. It is the procedure to properly install and calibrate the turbocharger actuator. Running this procedure improperly can result in additional fault codes and/or damage to the turbocharger or actuator.

INSITE™ electronic service tool "INSTALL ACTUATOR" command **must only** be run with the actuator **not** mounted to the turbocharger.

Locate the column labeled "Value" and left click on the down arrow. Select INSTALL ACTUATOR and select START.

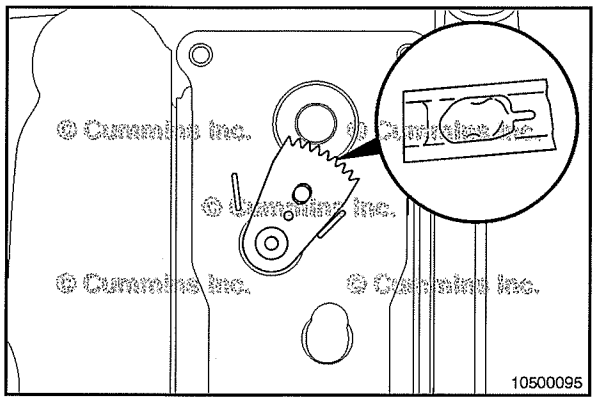
NOTE: The pinion gear on the turbocharger actuator will **not** move during this step.

INSITE™ electronic service tool will indicate when this step is complete.

Fault Code 2449 will be active at this point in the procedure. Continue through the turbocharger actuator procedure before troubleshooting any fault codes.

If at any point, INSITE™ electronic service tool status message indicates the procedure was stopped or failed, leave the key ON and cycle the power to the actuator by disconnecting it from the harness and reconnecting.

If cycling power to the actuator does **not** work, unplug the actuator, turn the keyswitch OFF for 30 seconds, and restart INSITE™ electronic service tool. Then start over, beginning with the actuator "INSTALL" step.



Rotate the sector gear clockwise by hand toward the turbocharger turbine housing. Make sure the edge of the sector gear is rotated all the way toward the hash mark on the bearing housing. Do **not** move the sector gear after this point.

Coat the teeth on the sector gear with the high-temperature grease packet supplied in the installation kit.

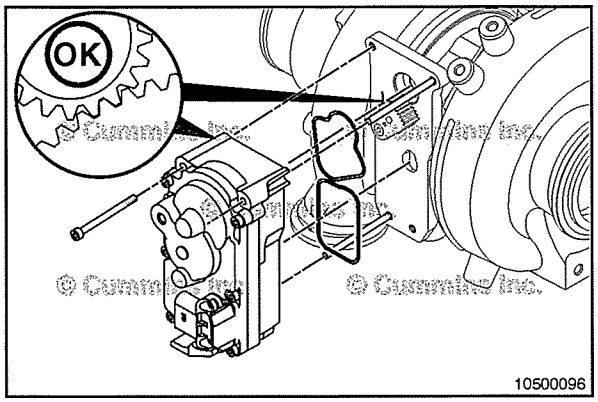
NOTE: It is critical for smooth reliable operation of the actuator to use the full amount of the Holset® supplied high-temperature grease.

⚠CAUTION⚠
Do not attempt to force the actuator onto the bearing housing by using the capscrews. Misalignment can cause damage to the actuator or turbocharger.

Install two new sealing o-rings on the turbocharger actuator. Make sure to use the new capscrews available in the Turbocharger actuator Mounting Kit.

Insert the threaded guide pins into the diagonally opposite fastener holes in the bearing housing and locate the actuator onto the guide pins. Slide the actuator into position, making sure the gear spigot and shroud locate into the mating holes in the bearing housing face. Insert the long and short actuator socket head capscrews in the remaining fastener holes and hand-tighten.

The actuator pinion gear and the turbocharger sector gear **must** engage smoothly. If they do **not** engage smoothly, verify the sector gear through-hole and the bearing housing blind hole are aligned.

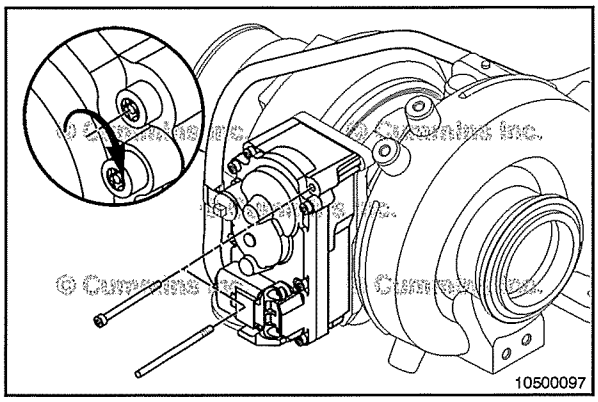


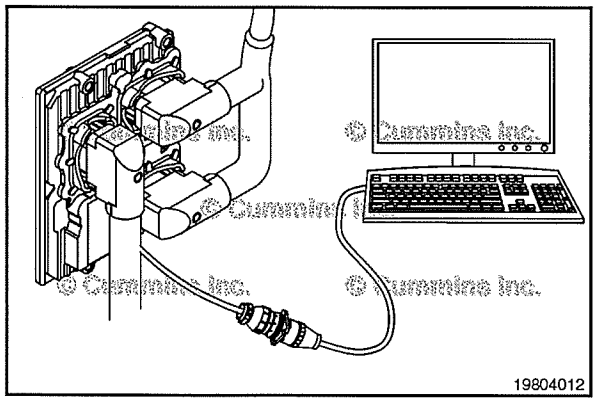
With the actuator aligned on the bearing housing, replace the guide pins with the actuator capscrews. Install the remaining two capscrews.

Tighten the four capscrews in a criss-cross pattern in two steps.

Torque Value:

Step 1	3 N•m	[27 in-lb]
Step 2	11 N•m	[97 in-lb]





Calibrate

The turbocharger actuator **must** be calibrated to the turbocharger. This step **must** be performed to make sure of proper turbocharger operation.

In INSITE™ electronic service tool screen labeled "VGT Electric Actuator Install and Calibrate", locate the column labeled "Value" and left click on the down arrow. Select "CALIBRATE ACTUATOR".

The INSITE™ electronic service tool "CALIBRATE ACTUATOR" command **must only** be run with the actuator mounted to the turbocharger.

Follow the instructions on the screen to calibrate the turbocharger actuator to the turbocharger. INSITE™ electronic service tool will indicate when this step is complete.

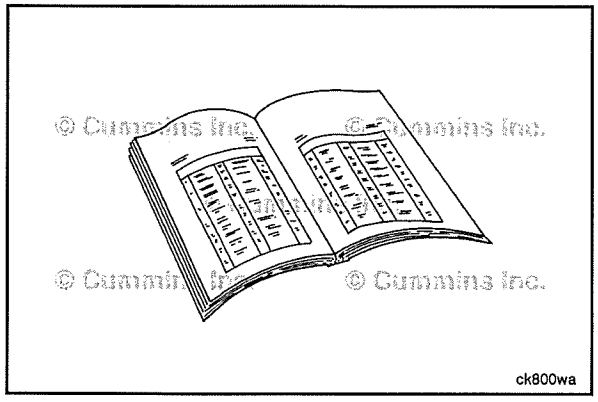
If INSITE™ electronic service tool status message indicates the procedure was stopped or failed, turn the keyswitch OFF for 30 seconds, then turn the keyswitch ON. Then start over, beginning with the "INSTALL ACTUATOR" instructions.

If the "CALIBRATE ACTUATOR" step does **not** pass, restart with the Install section.

It is normal to have an active Fault Code 2387 at this point.

Turn the keyswitch to the OFF position for 30 seconds. Turn the keyswitch ON and refresh the fault code screen. All turbocharger actuator fault codes should be inactive. Use INSITE™ electronic service tool to clear all fault codes.

Make sure all turbocharger fault codes are inactive and cleared before adding coolant to the engine.



Finishing Steps

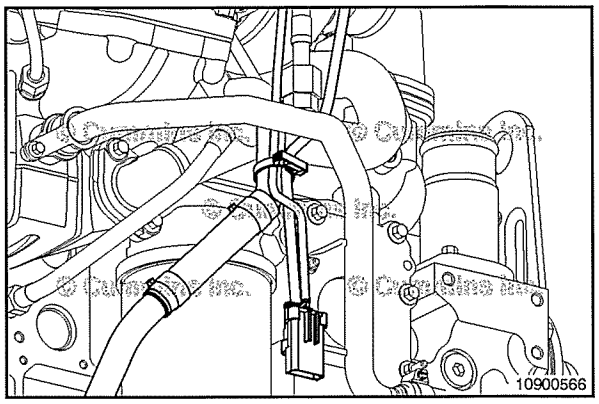
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Install the turbocharger coolant hoses. Refer to Procedure 010-041 in Section 10.

  NOTE: Be sure all turbocharger plumbing lines are **not** in contact with other lines or components.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Operate the engine to make sure the turbocharger actuator operates correctly and all turbocharger actuator fault codes are inactive.
- Check the engine for leaks.

⚠CAUTION⚠
The starting motor wiring can electrically interfere with the VGT pigtail and wiring harness. The starting motor wiring must be at least 300 mm [12 in] away from the actuator and harness.

If zip ties were removed, zip tie the turbocharger actuator and turbocharger speed sensor harnesses to the the oil drain line. The harnesses **must** route over the top of the compressor cover in between the bearing housing and compressor cover.



Air Intake System Diagnostics (010-139)

General Information

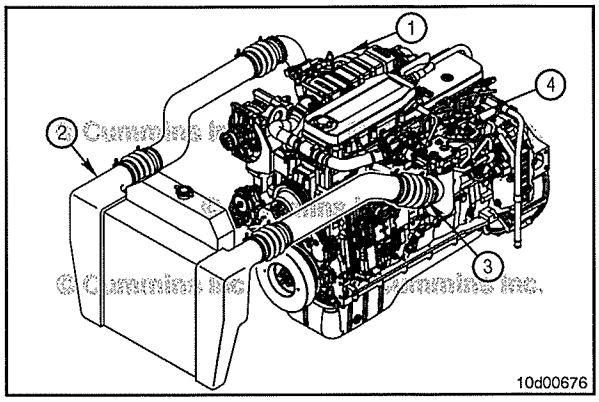
This engine uses exhaust gas recirculation (EGR) in the intake air system. Every component of the EGR system (EGR cooler, air transfer tube, etc.) up to the EGR connection is considered part of the exhaust system.

Before diagnostics of the air intake system begins, there are a few items that should be checked:

- Check for fault codes and refer to the appropriate troubleshooting trees
- Make sure all intake pipe couplers are connected properly
- Inspect the intake piping for any physical damage or cracks
- Inspect the engine air filter for inlet restriction, contamination, or other damage. Refer to the original equipment manufacturer (OEM) service manual.

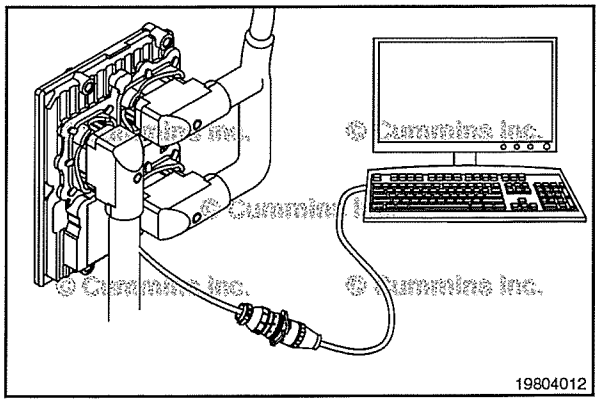
This procedure lists various symptoms and respective components to check, listed in the order of easy to difficult to inspect. If there are no clear symptoms, or more than one, follow the diagnostics in order until the complaint has been resolved.

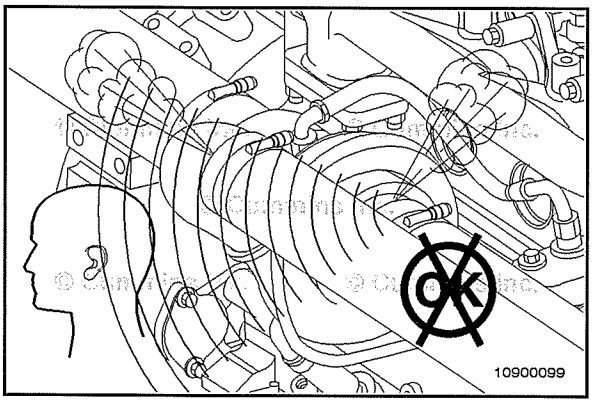
NOTE: The exhaust system components are covered in the Exhaust Systems - Overview. Refer to Procedure 011-999 in Section F.



Make sure the compressor intake and intake manifold temperature and pressure sensors are working properly. Use the following procedures for functionality checks for the intake manifold pressure/temperature sensor. Refer to Procedure 019-159 in Section 19.

Use the following procedures for functionality checks for the turbocharger compressor intake pressure/temperature sensor. Refer to Procedure 019-466 in Section 19.



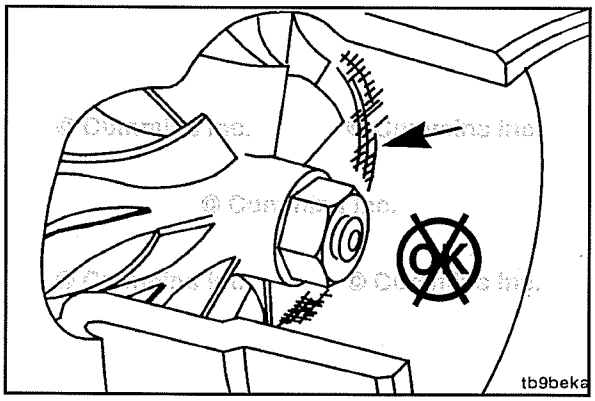


Leaks in the air system intake and/or exhaust components can produce excessive engine noise.

A leaking noise usually sounds like a high-pitched whining or sucking.

Check for leaks in the intake and exhaust system.

Check to make sure all hose clamps are tight. Refer to Procedure 010-024 in Section 10.



Malfunctioning Turbocharger

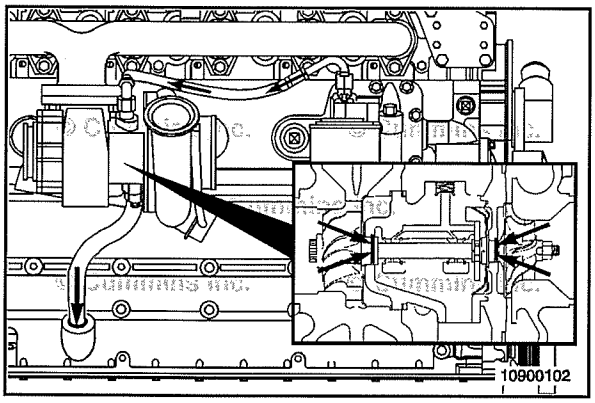
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Use skin and eye protection when handling caustic solutions to reduce the possibility of personal injury.

A malfunction of the internal components of the turbocharger can reduce its effectiveness. A bearing malfunction can produce friction, which will slow the speed of the rotor assembly. Worn bearings can also allow the blades of the rotor assembly to rub the housing, reducing the rotor assembly speed.

Lower pitched sounds or rattles, at slower engine speeds, can indicate that debris is in the system or that the rotor assembly is touching the housings. If there is a complaint for noise, low power, engine response, or oil consumption, verify the conditions under which the complaint occurred. Refer to Procedure 010-033 in Section 10.



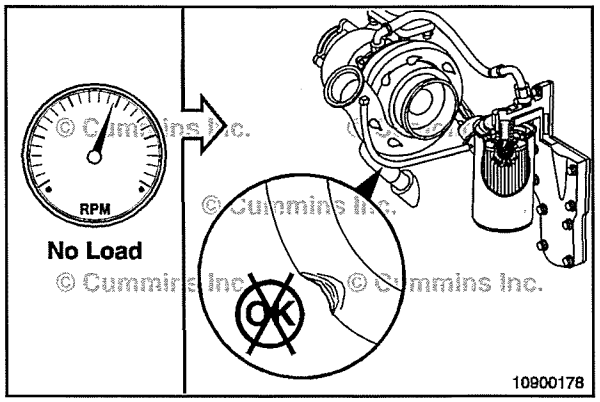
Seal rings are used on each end of the rotor assembly. The primary function of the seals is to prevent exhaust gases and compressed air from entering the turbocharger housing. Lubricating oil leakage from the seals is rare, but it can occur.

NOTE: Excessive crankcase pressure will not allow the oil to drain from the turbocharger. This will load the bearing housing and allow lubricating oil to leak past the seal rings and into the intake and exhaust of the engine.

If turbine seal leakage into the exhaust occurs on engines with an aftertreatment system, the aftertreatment system **must** be inspected for reuse.

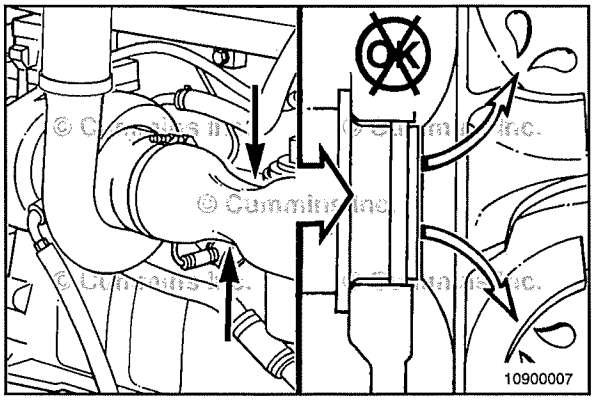
NOTE: If the engine experiences a turbocharger failure or any other occasion in which oil, debris, or coolant is put into the charge-air system, the EGR differential pressure sensor flow ports **must** be cleaned.

A restricted or damaged lubricating oil return line will cause the turbocharger housing to be pressurized, causing lubricating oil to migrate past the seal rings on both the intake and exhaust side of the turbocharger.



Additionally, high intake or exhaust restrictions can cause a vacuum between the compressor and the turbocharger housing, resulting in lubricating oil leaking past the seal rings at the compressor (intake) side.

NOTE: If this occurs, it is necessary to flush the charge-air cooler to clean the oil from the intake system. Clean the intake manifold. Refer to Procedure 010-023 in Section 10. Clean the charge-air cooler. Refer to Procedure 010-027 in Section 10. Clean the EGR differential pressure sensor flow ports. Refer to Procedure 010-080 in Section 10.



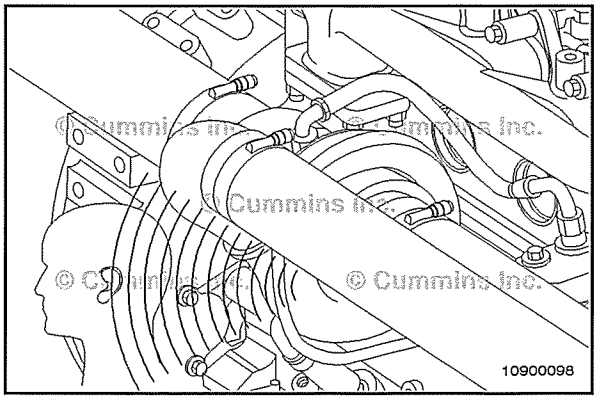
Turbocharger Noise

It is normal for the turbocharger to emit a whining sound that varies in intensity, depending on turbine wheel speed.

The sound is caused by the very high rotational speed of the rotor assembly and the method used to balance the rotor assembly during manufacturing.

Because the engine uses a variable geometry turbocharger, which allows for control of the turbine wheel speed independent of engine load and speed, the sound may **not** be the loudest at rated engine speed and load.

Depending on engine requirements for exhaust temperatures and exhaust pressure, the sound may be most noticeable around idle speed conditions or slightly above.

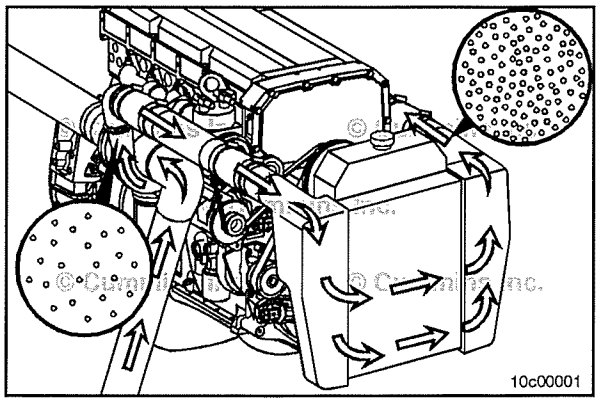


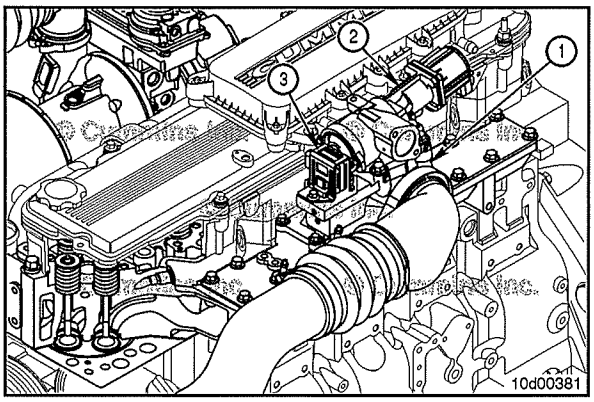
Charge Air Cooled Engines

The charge-air cooler makes sure that the proper intake air density is achieved. External damage to the fins or excessive restriction or pressure losses can affect its performance and reduce engine performance.

Use the following procedure for inspection of the charge-air cooler. Refer to Procedure 010-027 in Section 10.

NOTE: The long-term integrity of the charge-air cooling system is the responsibility of the vehicle and component manufacturers.





Air Intake System

NOTE: The style of the air intake connection (1) can vary, depending on the application. Although the air intake connection may appear different, the function is the same.

The air intake connection is a critical element in combining the EGR flow and the fresh intake air of the engine.

The EGR valve (2) is mounted to the top of the air intake connection.

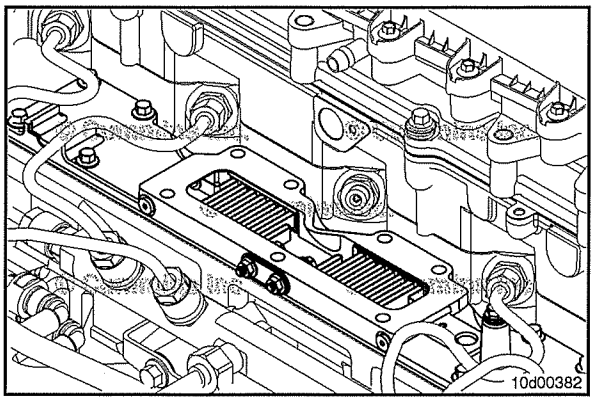
The purpose of the EGR valve is to control the amount of EGR flow into the air intake connection.

The amount of EGR flow is calculated by measuring the pressure differential across the exhaust gas entrance port in the air intake connection, just below the EGR valve outlet. A differential pressure sensor (3) mounted on top of the intake connection reads the pressure on each side of the exhaust gas entrance port through internal drillings in the air intake connection.

Soot in the exhaust gas entrance ports can affect the pressure readings which, in turn, will affect the calculated EGR flow. This can result in an improperly commanded EGR valve position. The air intake connection also acts as the intake air source for engines equipped with turbocharged air compressors. An air compressor inlet tube connects the air compressor to the air intake connection.

Inspect and clean the intake air connection, if necessary. Refer to Procedure 010-080 in Section 10.

Use the following procedure for troubleshooting the exhaust system diagnostics related to the EGR system. Refer to Procedure 011-056 in Section 11.



Air Intake Manifold/Cold Starting Aid

The ON/OFF operation of the intake air heater is controlled by the engine control module (ECM).

The ECM controls a single OEM supplied relay which provides power for the intake air heater when commanded. A symptom of a malfunctioning cold starting aid is a hard start in cold ambient temperatures and/or white smoke on engine startup. A plugged intake air heater element can also result in low power.

Use the following procedure for verifying the cold starting aid function. Refer to Procedure 010-029 in Section 10.

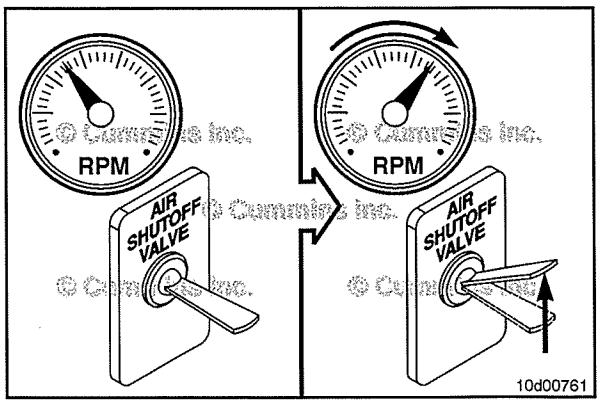
NOTE: The cold starting aid is **not** a serviceable part. If the cold starting aid has cracked, broken, or melted elements, the engine air intake manifold **must** be replaced. Refer to Procedure 010-023 in Section 10.

Air Shutoff Valve (010-143)

Preparatory Steps

⚠WARNING⚠
Be sure the valve is in the closed position before removal to reduce the possibility of personal injury.

- Activate the air shutoff valve before service to be sure it is in the closed position.
- Disconnect the charge-air piping connected to the air shutoff valve. Refer to the original equipment manufacturer (OEM) service manual.



Remove

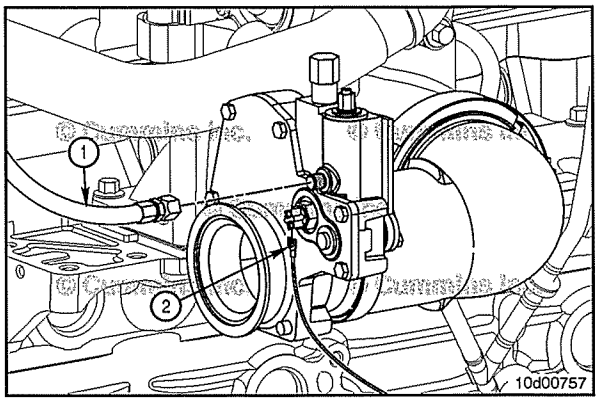
Be sure the keyswitch is in the OFF position.

Disconnect the air line (1) from the air shutoff valve.

Cover or mask the end of the air line to prevent contamination.

Disconnect the electrical connector (2) from the air shutoff valve.

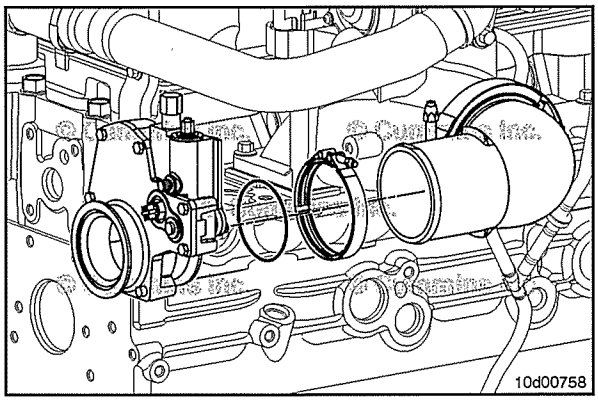
Remove the air shutoff valve support bracket from the shutoff valve, if applicable.



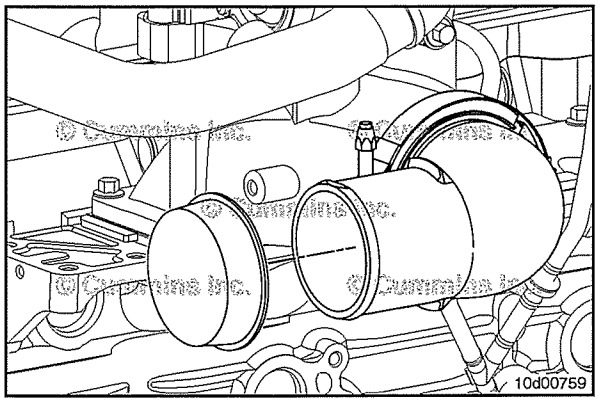
Be sure to completely loosen the v-band clamp from the charge-air piping. Be sure to support the valve while loosening.

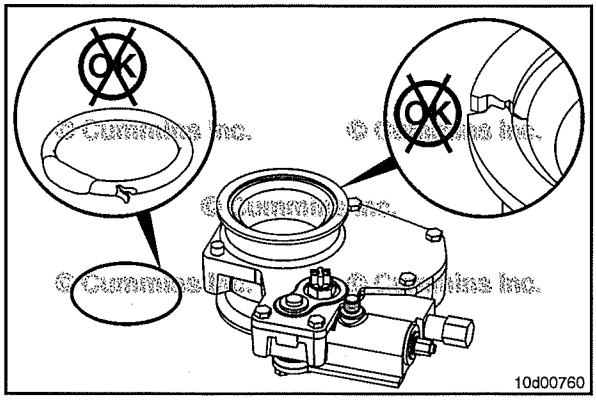
Remove the clamp, o-ring, and shutoff valve from the air intake manifold.

The charge-air cooler o-rings can be used again. Do **not** damage the o-rings when removing the valve or when setting the assembly aside during repair.



Cover all openings on the air intake connection and cylinder head with caps and heavy tape from the Air Handling Clean Care Kit, Part Number 5298878.





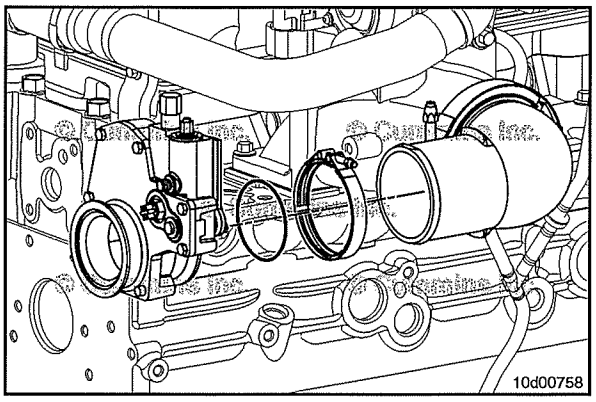
Inspect for Reuse

Inspect the o-rings for cuts, tears, wear, or other damage.

Replace the o-rings if necessary.

Inspect the air shutoff valve for cracks or other damage.

Replace the air shutoff valve if necessary.



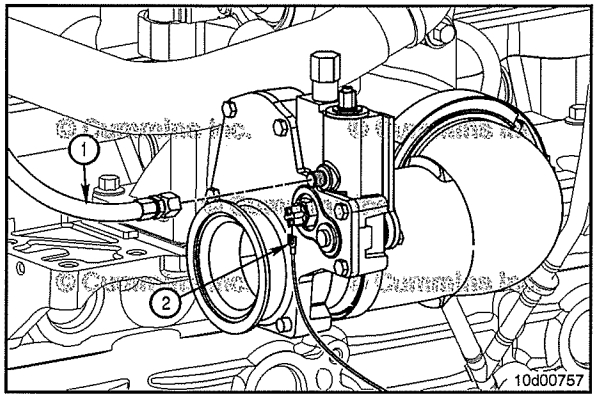
Install

Install the air shutoff valve onto the air intake manifold. Orient the valve with the reset lever toward the rear of the engine.

Connect the charge-air piping onto the shutoff valve. Be sure to support the valve and align it as such that the valve will **not** contact any OEM components.

Tighten the v-band clamps.

Torque Value: 8 N•m [71 in-lb]



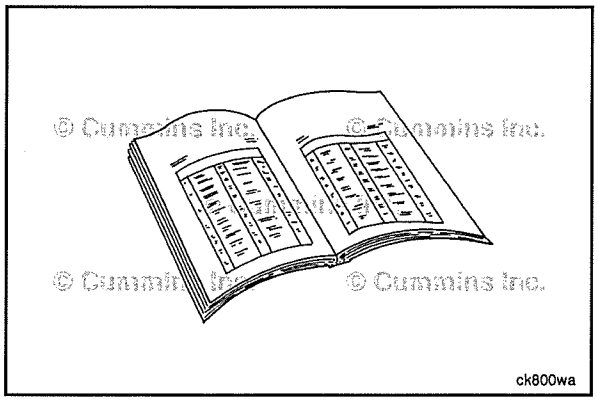
Install the air shutoff valve support bracket, if applicable.

Torque Value:
Support Bracket Capscrew 24 N•m [212 in-lb]

Torque Value:
Support Bracket Nut 20 N•m [177 in-lb]

Install the air line (1) to the air shutoff valve.

Connect the electrical connector (2) to the air shutoff valve.



Finishing Steps

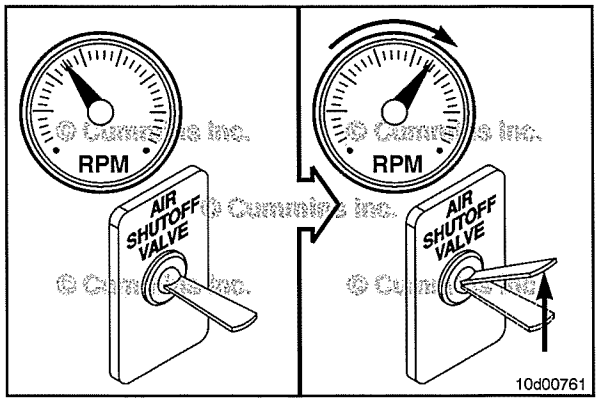
- Install the charge-air piping to the air shutoff valve. Refer to the OEM service manual.
- Reset the air shutoff valve.
- Operate the engine to check for leaks.

Test

Move and hold the air shutoff valve test switch to the active position and apply the throttle to raise the engine rpm.

The air shutoff valve is functioning properly if the engine shuts down.

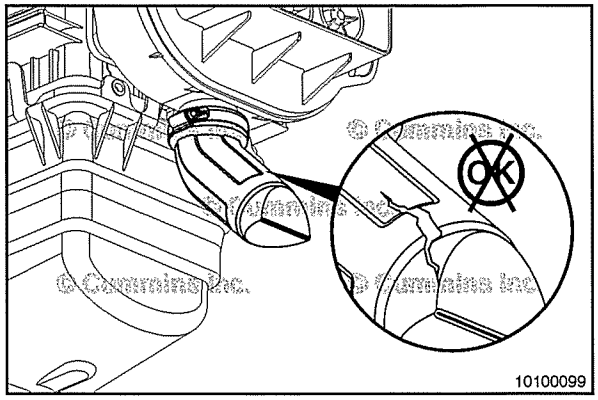
After the air shutoff valve activates, turn the keyswitch to the OFF position and push the reset lever on the valve to reset the valve. **Only** hand pressure should be used to reset the valve.



Dust Ejection Valve (010-146)

Maintenance Check

Inspect the dust ejection valve for cuts and tears. Replace the valve if damage is found.



General Information

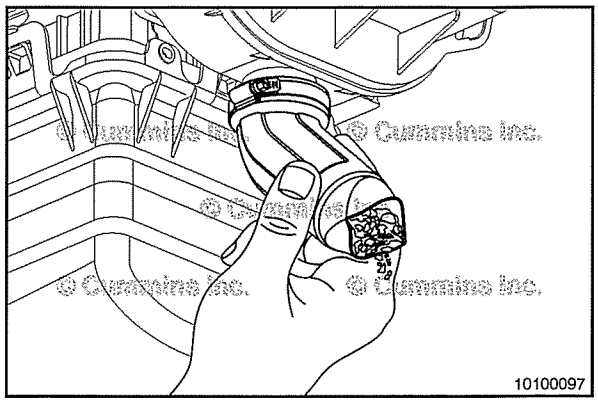
The dust ejection valve is a thin flexible rubber boot located at the bottom of the pre-cleaner on the air cleaner assembly. It is used to accumulate and remove dust ejected from the pre-cleaner.

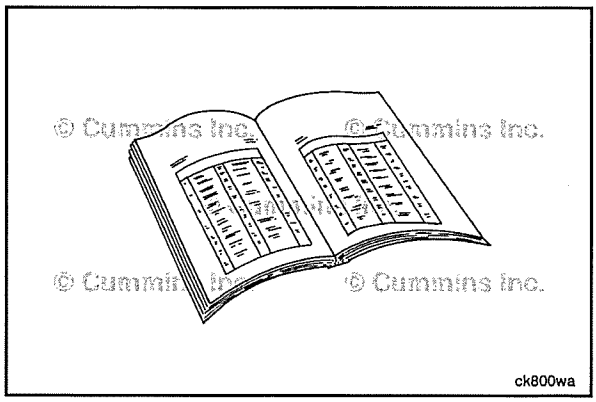
If an application is equipped with a pre-cleaner exhaust aspirator, a dust ejection valve will **not** be present, as the aspirator takes place of the dust ejection valve.

Do **not** operate the engine without a dust ejection valve or exhaust aspirator. The pre-cleaner efficiency will be greatly reduced and may result in shortened filter element life.

Clean

Purge the dust ejection valve of dust by squeezing the valve until it opens. This may have to be performed multiple times depending on the severity of dust or debris found in the valve. If debris is **not** able to be purged from the valve, remove the valve and clean out by hand. Reference the Remove section of this procedure.

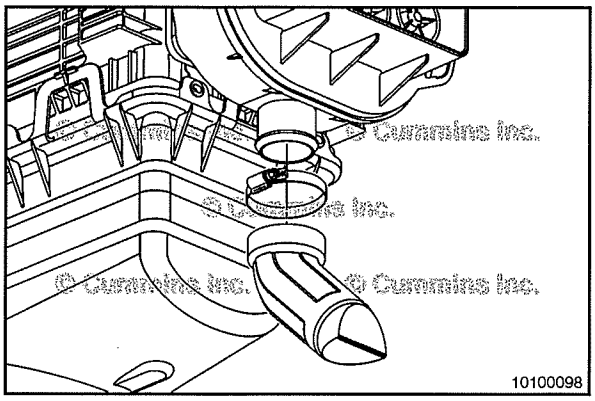




Preparatory Steps

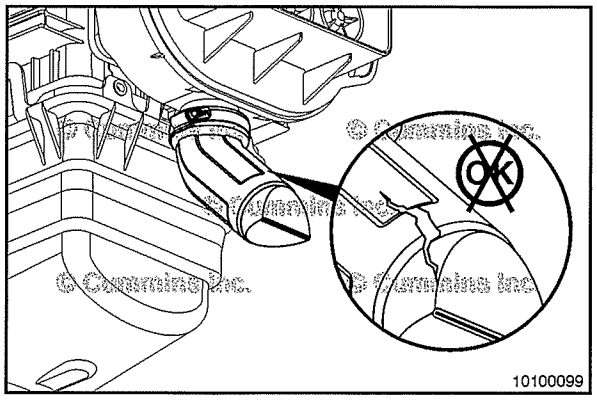
NOTE: Before servicing any intake air system component, (such as the air cleaner, pre-cleaner, hoses, ducting, etc.), clean the fittings, mounting hardware, and the area around the component to be removed.

- Shut the engine OFF.



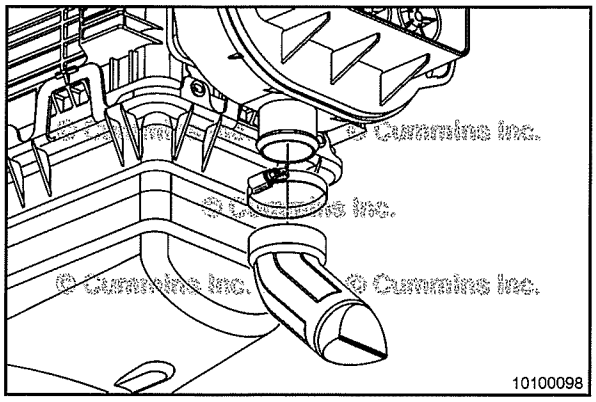
Remove

Remove the dust ejection valve from the pre-cleaner by loosening the hose clamp, if present, then rotating and pulling downward on the dust ejection tube.



Inspect for Reuse

Inspect the dust ejection valve for cuts and tears. Replace the valve if damage is found.



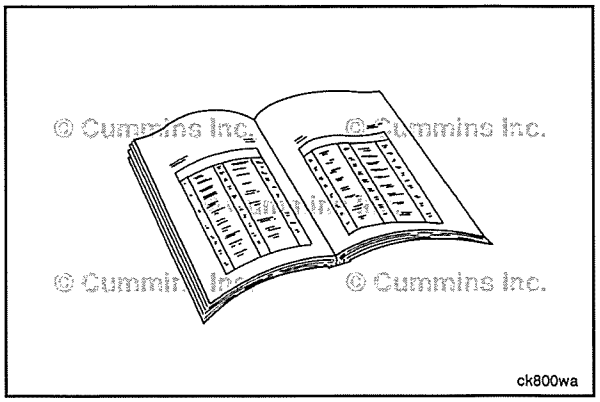
Install

Install the dust ejection valve on the pre-cleaner by attaching the hose clamp, if present. Tighten the hose clamp.

Torque Value: 5 N•m [44 in-lb]

Finishing Steps

- Start the engine.
- Check for leaks.



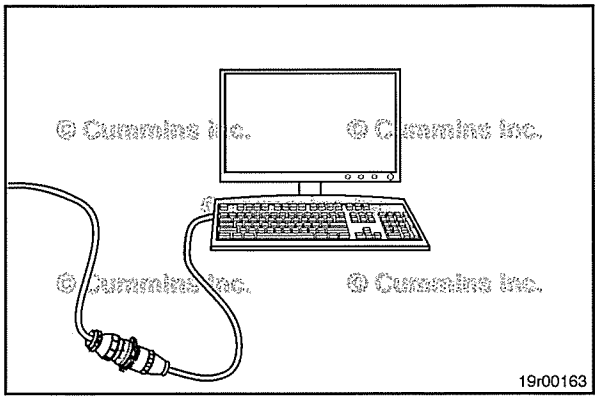
Turbocharger Actuator Calibration Code (010-150)

General Information

NOTE: Downloading a calibration code into the turbocharger actuator is **only** required if directed by a Campaign, Temporary Repair Practice, or warrantable repair.

Turbocharger actuator calibration code downloads can be performed with INSITE™ electronic service tool.

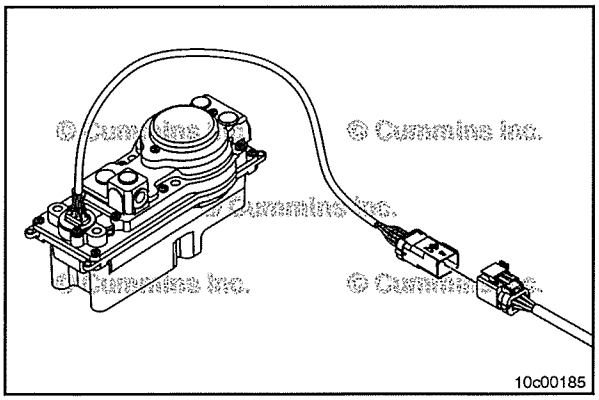
INSITE™ electronic service tool connects to the turbocharger actuator through the engine control module (ECM) by using the J1939 data link.



The turbocharger actuator calibration code download can be performed with the actuator installed or removed from the turbocharger when installing a new actuator. If performing a calibration code download into an existing actuator do not remove the actuator.

The "Install" and "Calibrate" sections **must** be performed after the calibration code download process if the actuator is not yet installed onto the turbocharger. Refer to Procedure 010-134 in Section 10.

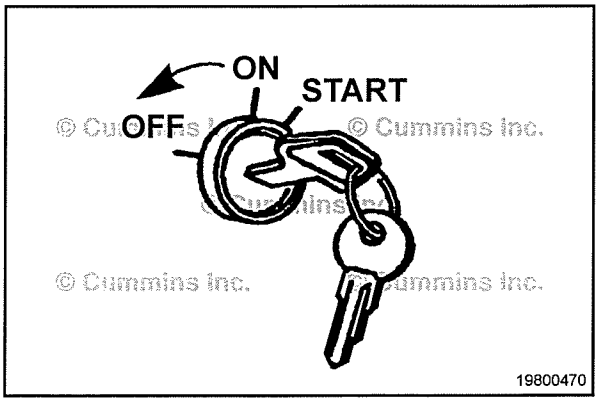
If the turbocharger actuator is **not** removed during the calibration code download, no further steps are required.

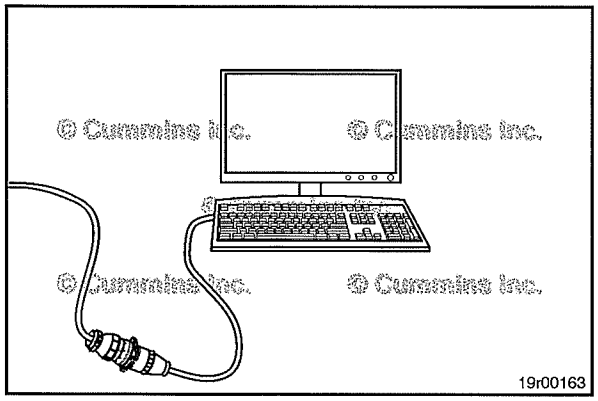


Initial Check

The turbocharger actuator calibration code download process occurs with the keyswitch turned ON. **Always** follow the instructions on the service tool screens.

NOTE: If the tool will **not** communicate with the keyswitch in the ON position, cycle the keyswitch and try again.





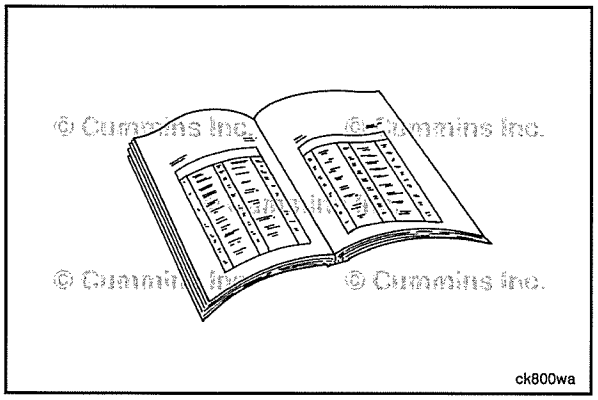
Install

NOTE: Although either the engine-mounted service tool connector or the vehicle-mounted service tool connector can be used for the software installation, Cummins Inc. recommends that the engine-mounted service tool connector be used for the software installation process, whenever possible.

Connect the INSITE™ electronic service tool to the J1939 data link, located on the engine or in the vehicle cab.

Follow the steps in INSITE™ electronic service tool screens to complete the turbocharger actuator calibration code download.

Once completed, use INSITE™ electronic service tool to clear all fault codes. Turn the keyswitch OFF for 30 seconds. Turn the keyswitch ON and check for fault codes.



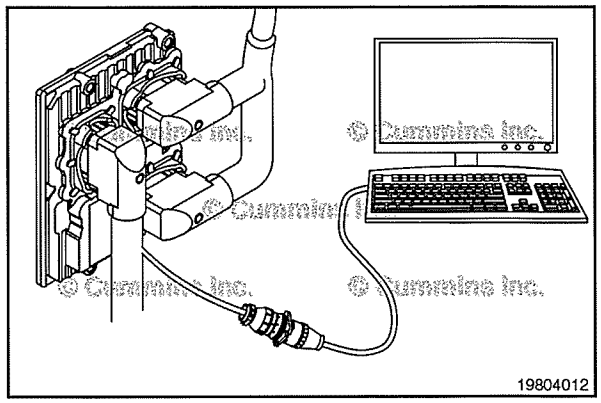
Finishing Steps

NOTE: If the connection is lost during the download process, it can result in Fault Code 2636. If this occurs, the turbocharger actuator calibration process **must** be performed a second time to clear Fault Code 2636.

- See the Help Section of INSITE™ electronic service tool for detailed turbocharger actuator calibration code download procedures.
- If necessary, complete the variable geometry turbocharger actuator installation. Refer to Procedure 010-134 in Section 10.
- Use INSITE™ electronic service tool to clear all inactive fault codes.

Variable Geometry Turbocharger Hysteresis Test (010-152)

General Information



Conditions necessary to perform the Variable Geometry Turbocharger Hysteresis Test:

- Engine OFF
- Keyswitch ON
- Turbocharger and actuator installed on engine
- Coolant temperature greater than 10°C [50°F]
- Battery voltage greater than 11.5 VDC
- No active turbocharger fault codes
- INSITE™ electronic service tool connected
- Compare the engine control module (ECM) code and revision number in the ECM to the calibration revision listed in the ECM calibration revision history for applicable changes related to the "Variable Geometry Turbocharger Hysteresis Test". If the ECM does **not** contain this revision or higher, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

The INSITE™ electronic service tool "Variable Geometry Turbocharger Hysteresis Test" **must only** be performed with the actuator mounted to the turbocharger.

In INSITE™ electronic service tool screen labeled "Variable Geometry Turbocharger Hysteresis Test", locate the button labeled "Start".

Follow the instructions on the screen to test the turbocharger. INSITE™ electronic service tool will indicate when the test has completed.

If INSITE™ electronic service tool status message indicates the procedure was stopped or had an error, turn the keyswitch OFF for 30 seconds, then turn the keyswitch ON. Verify that all conditions above are met, and perform the test again.

If the "Variable Geometry Turbocharger Hysteresis Test" results in an output of "Fail", the turbocharger is **not** reusable. Refer to Procedure 010-033 in Section 10.

If the "Variable Geometry Turbocharger Hysteresis Test" results in an output of "Pass", this indicates that the sector gear movement is acceptable and the actuator should **not** be removed.

Notes

Section 11 - Exhaust System - Group 11

Section Contents

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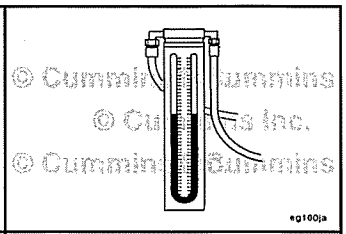
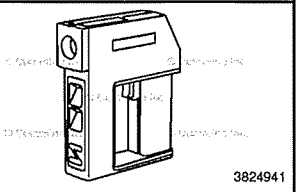
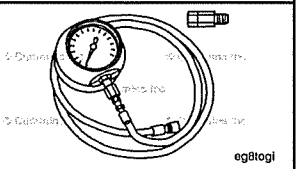
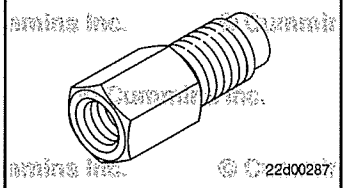
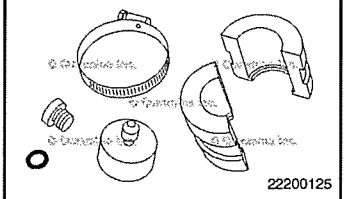
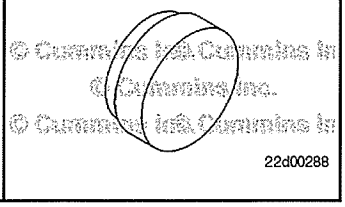
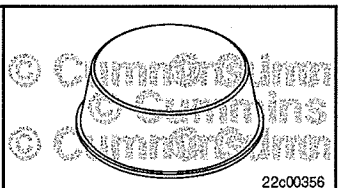
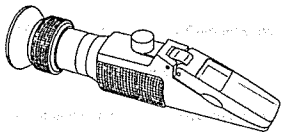
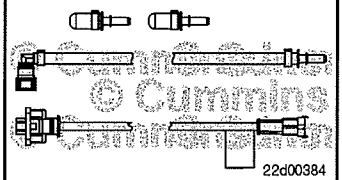
Service Tools

Exhaust System

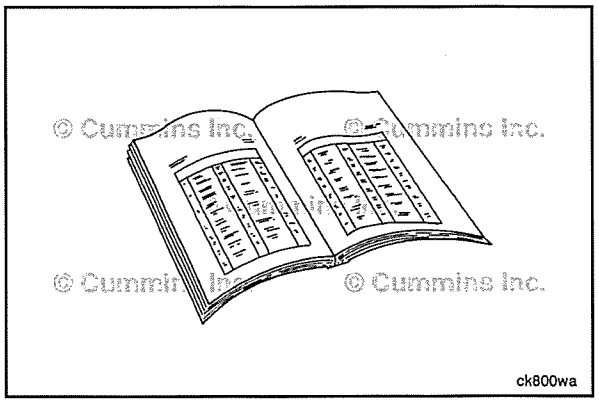
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-1111-3	**Manometer** Used to measure exhaust restriction.	
3164487	**Infrared Thermometer** Used to measure the surface temperature of exhaust components.	
ST-1273	**Pressure Gauge** Used to measure inches of mercury (in Hg) pressure.	
4918576	**Exhaust Restriction/Pressure Adapter** Used to convert aftertreatment temperature sensor ports to 1/8" NPT pipe thread so that service tool ST-1273 can be used to measure exhaust pressure.	
4918625	**Exhaust Gas Recirculation (EGR) Cooler Leak Check Kit** Used to pressure test the EGR cooler.	
4918709	**Exhaust Manifold Seal Installer** Used to install the exhaust manifold seal.	

Tool No.	Tool Description	Tool Illustration
4919508	**Air Handling Clean Care Kit** Contains a variety of caps to prevent contamination of vehicle air handling plumbing during service procedures.	
4919554	**Diesel Exhaust Fluid Refractometer** Used for measuring the concentration of diesel exhaust fluid.	
4919573	**Aftertreatment Diesel Exhaust Fluid Dosing Valve Extension Kit** Used to supply diesel exhaust fluid into the exhaust flow.	

Exhaust Manifold, Dry (011-007)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

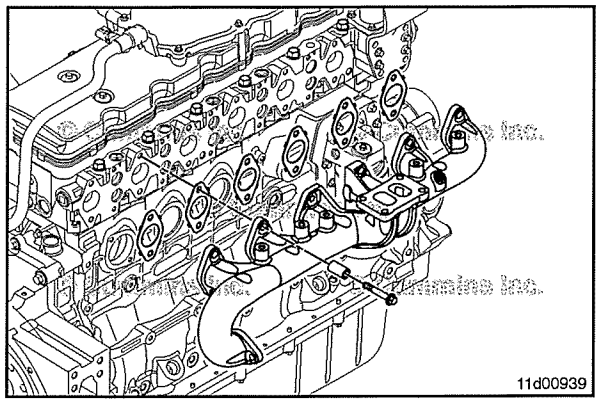
⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

NOTE: Brush away all dirt from the around the area of the air handling connections to avoid contamination of the interior of the engine.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the turbocharger. Refer to Procedure 010-033 in Section 10.
- Remove the exhaust gas recirculation (EGR) cooler coolant lines. Refer to Procedure 011-031 in Section 11.
- Remove the EGR connection tubes. Refer to Procedure 011-025 in Section 11.
- Remove the EGR cooler. Refer to Procedure 011-019 in Section 11.
- Remove the exhaust gas pressure sensor tube. Refer to Procedure 011-027 in Section 11.

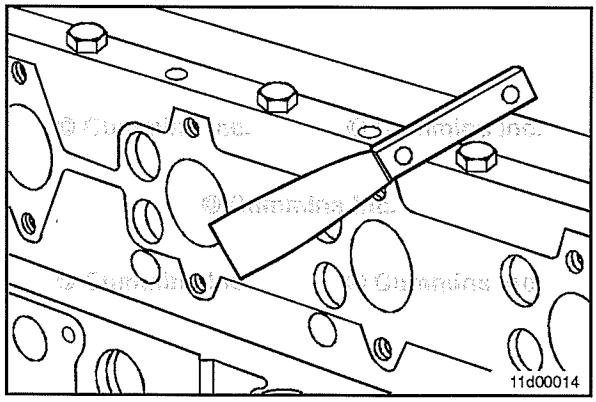
Remove



Remove the twelve exhaust manifold mounting capscrews and spacers.

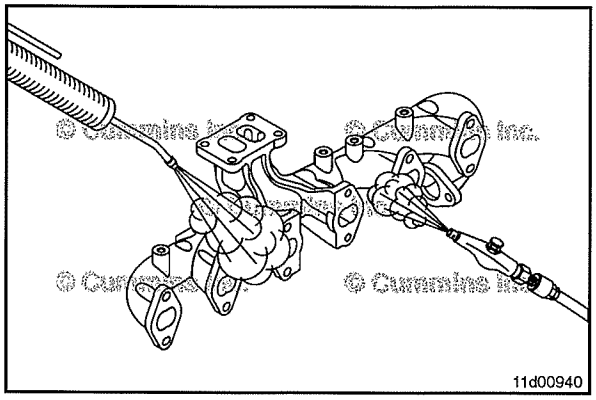
Remove the exhaust manifold.

Cover open points in the exhaust manifold and cylinder head with heavy tape, if the repair is being delayed.



Clean and Inspect for Reuse

Clean the sealing surfaces of the cylinder head and the exhaust manifold with a gasket scraper or a wire brush. Take caution to keep all debris out of the cylinder head.

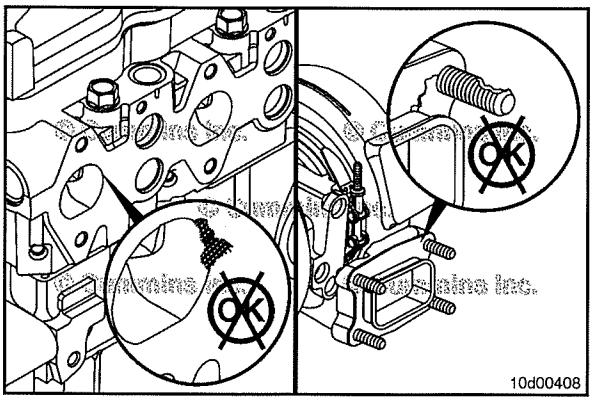


⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

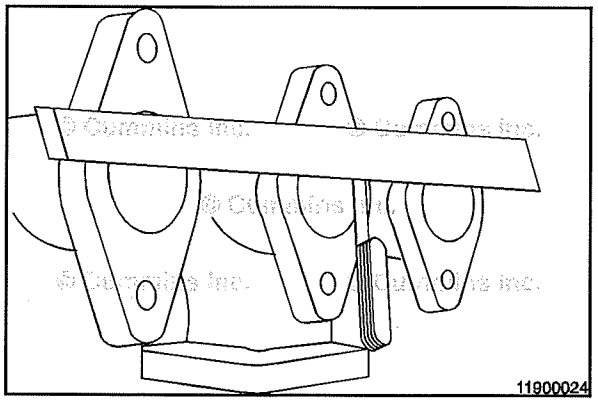
Steam clean the exhaust manifold.

Dry with compressed air.



Inspect the cylinder head bosses and turbocharger mounting studs for damage. Repair or replace as necessary.

NOTE: If the exhaust manifold is damaged, check for charge-air leaks. A charge-air leak can cause progressive damage to the exhaust manifold. Refer to Procedure 010-024 in Section 10.



For one and two piece manifolds:

Use a precision straightedge, Part Number 4918219 or equivalent, to check the manifold mounting surfaces for flatness. Lay the straightedge on edge across all ports and measure the flatness with a feeler gauge.

Exhaust Manifold Flatness

mm		in
0.20	MAX	0.008

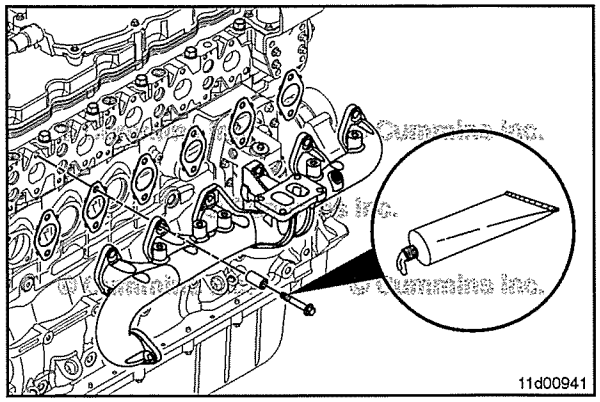
If any port measures out of specification, replace the exhaust manifold.

NOTE: For multi-piece manifolds, each section must be verified to be flat independently. If either section is found to be out of specification, replace both sections of the manifold.

Install

Apply high-temperature anti-seize compound to the exhaust manifold capscrew threads.

Install the exhaust manifold, new gaskets, spacers, and capscrews.

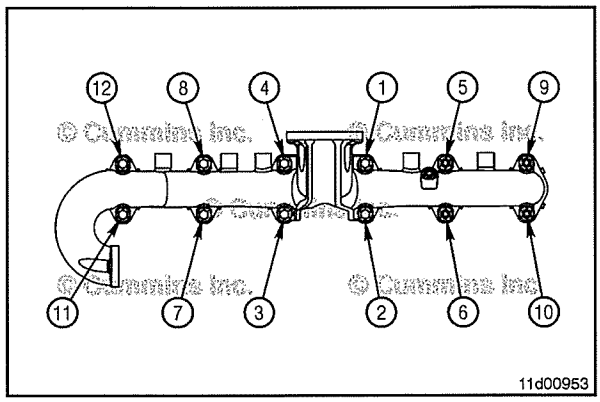


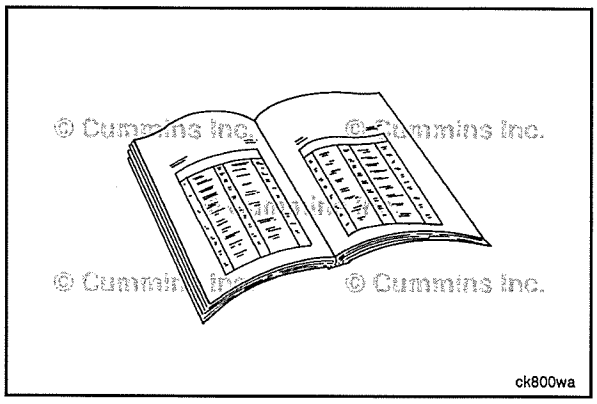
NOTE: To aid in alignment of the exhaust manifold, two capscrew passages have a smaller diameter than the other passages. The location of these varies with manifold configuration. The capscrews in the smaller passages can be tightened first, with the remaining capscrews tightened in a sequence starting from the inside of the manifold and working toward the outside.

Follow the tightening sequence shown in the illustration.

Tighten the exhaust manifold mounting capscrews.

Torque Value: 53 N•m [39 ft-lb]



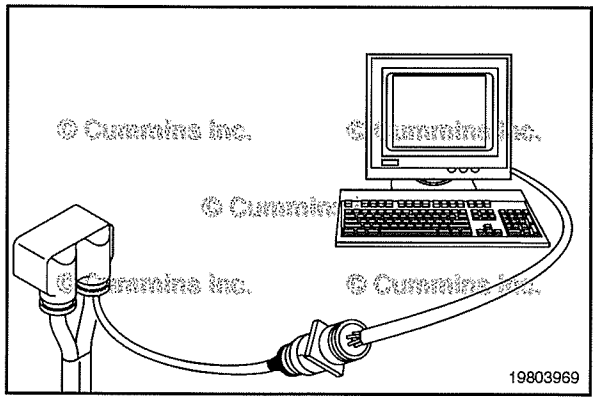


Finishing Steps

NOTE: If the two piece manifold was installed with the sealant, remove excess sealant that has been pushed out of the joint. Allow the exhaust manifold sealant to set up for at least four hours before operating the engine.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- If equipped, install the exhaust manifold heat shield.
- Install the exhaust gas pressure sensor tube. Refer to Procedure 011-027 in Section 11.
- Install the EGR cooler. Refer to Procedure 011-019 in Section 11.
- Install the EGR connection tubes. Refer to Procedure 011-025 in Section 11.
- Install the EGR cooler coolant lines. Refer to Procedure 011-031 in Section 11.
- Install the turbocharger. Refer to Procedure 010-033 in Section 10.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

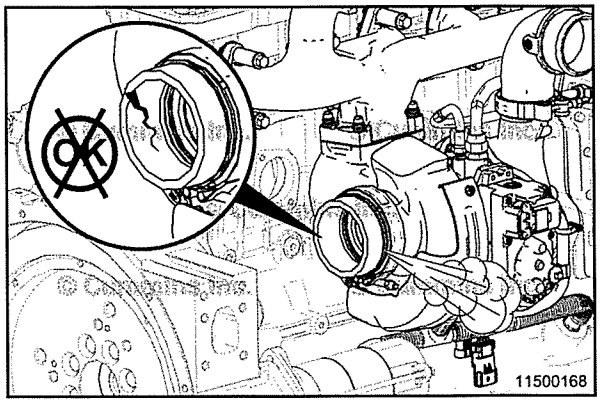


Exhaust Restriction (011-009)

Initial Check

Use INSITE™ electronic service tool to check for fault codes. If any are present, follow the troubleshooting steps as outlined in the corresponding fault code troubleshooting procedure.

Inspect the exhaust tubing for damage or leaks.



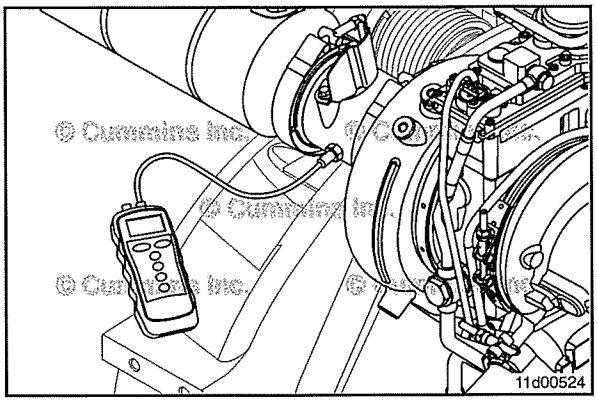
Measure

If equipped, remove the pressure tap plug located in exhaust tubing.

If equipped, remove the pressure tap plug located in the exhaust tubing.

Install the service tool module Part Number 3164491 with digital multimeter, Part Number 3164488 or equivalent, into the pressure tap location.

NOTE: Install at least 30.5 cm [12 in] of metal tubing between the pressure tap and gauge to prevent inaccurate readings and damage.

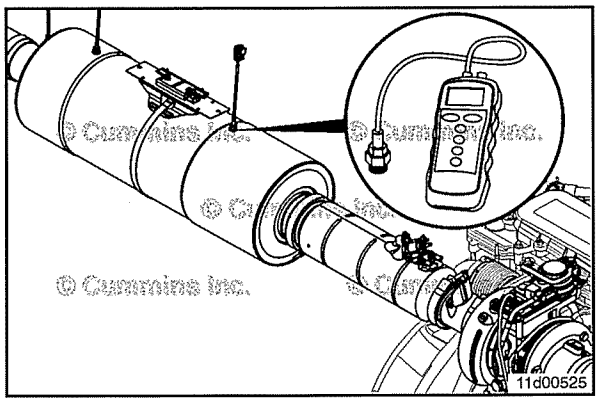


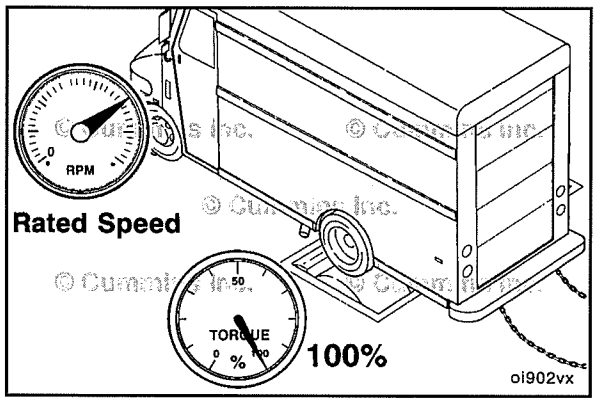
If the exhaust tubing is **not** equipped with a pressure tap, remove the first exhaust gas temperature sensor in the aftertreatment system. Refer to Procedure 019-449 in Section 19.

Install adapter fitting Part Number 4918576 in the port.

Install service tool module Part Number 3164491 with digital multimeter, Part Number 3164488 or equivalent, into the pressure tap location.

NOTE: Install at least 30.5 cm [12 in] of metal tubing between the pressure tap and gauge to prevent inaccurate readings and damage.





Start the engine and bring to operating temperature (above 70°C [158°F]).

Operate at rated speed and load. Record the exhaust restriction. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 018-020 in Section V. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 018-020 in Section V.

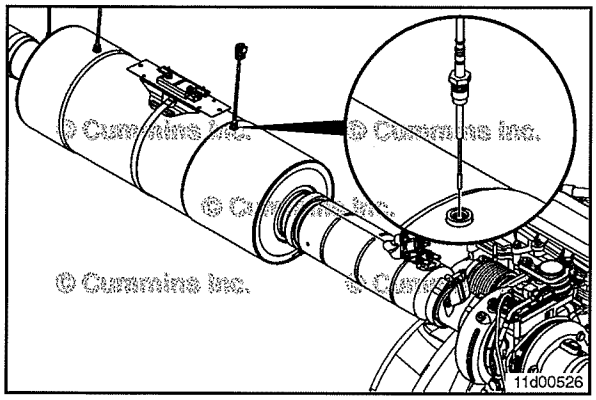
If the exhaust restriction exceeds the specification:

1 Inspect exhaust for damage. Refer to the original equipment manufacturer (OEM) service manual.

2 Check for fault codes related to the aftertreatment system.

3 Check for a damaged decomposition tube. Refer to Procedure 011-062 in Section 11.

- Check for DEF build-up in the exhaust pipe between the decomposition outlet and SCR catalyst inlet. Refer to Procedure 011-036 in Section 11.



Install the pressure plug or aftertreatment exhaust gas temperature sensor with high-temperature anti-seize. Refer to Procedure 019-449 in Section 19.

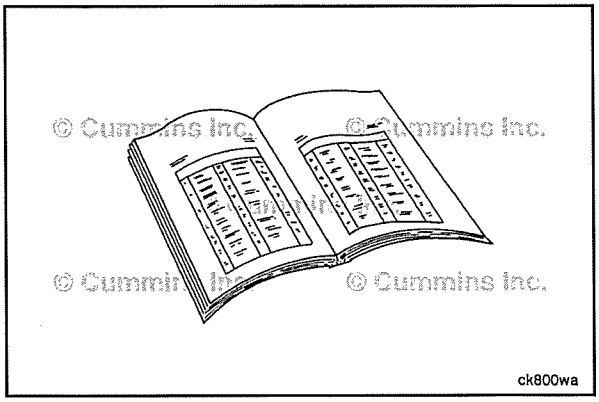
NOTE: Clear any inactive fault codes with INSITE™ electronic service tool once the testing is completed.

EGR Cooler (011-019)

General Information

The illustrations in this procedure may **not** exactly match the engine being serviced. The procedure is the same, regardless of the style of the exhaust gas recirculation (EGR) cooler.

Preparatory Steps

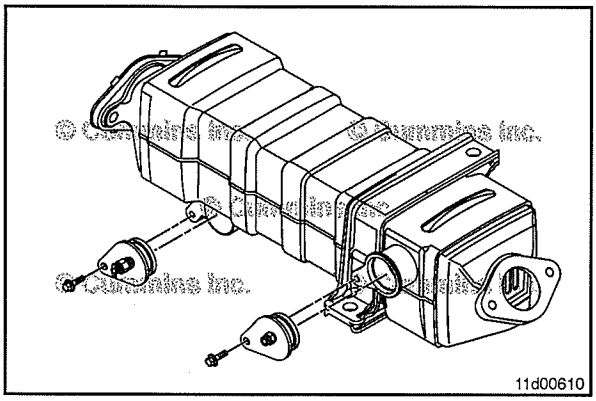


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: Brush away any dirt from the area around the air handling connections to avoid contamination of the interior of the engine.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-018 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-018 in Section 8.
- Remove the EGR connection tube. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-025 in Section 11. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-025 in Section 11.
- Disconnect the EGR cooler coolant supply and return lines. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-031 in Section 11. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-031 in Section 11.
- Disconnect the coolant vent line. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-017 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-017 in Section 8.
- On some applications, it may be necessary to remove the turbocharger coolant return hoses. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 010-041 in Section 10. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 010-041 in Section 10.
- Check the function of the engine coolant level sensor. Refer to Procedure 019-017 in Section 19.



Pressure Test

NOTE: The engine **must** be within 3°C or 5°F of ambient temperature to perform the test.

NOTE: Moisture in the EGR cooler or EGR connection tubes does **not** indicate a malfunctioning EGR cooler. The EGR cooler **must** be pressure tested before being replaced.

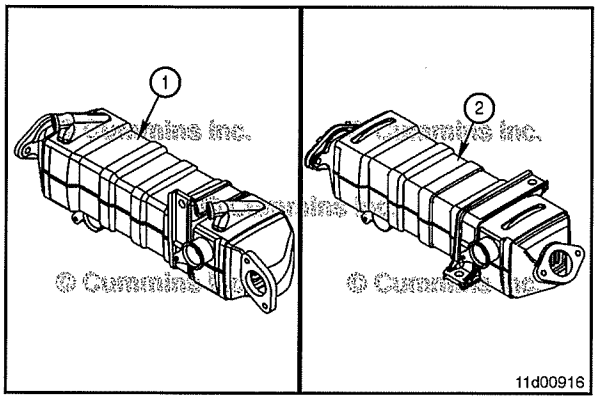
Cap off the coolant inlet by installing the Cummins® plug, Part Number 4919206, supplied in the Cummins® EGR Cooler Pressure Test Kit, Part Number 4919203.

Use the Cummins® test plug retainer, Part Number 4919204, and Cummins® capscrew, Part Number 3600815, to secure the leak test plug to the EGR cooler.

Cap off the coolant outlet by installing the Cummins® plug, Part Number 4919207, supplied in the Cummins® EGR Cooler Pressure Test Kit, Part Number 4919203.

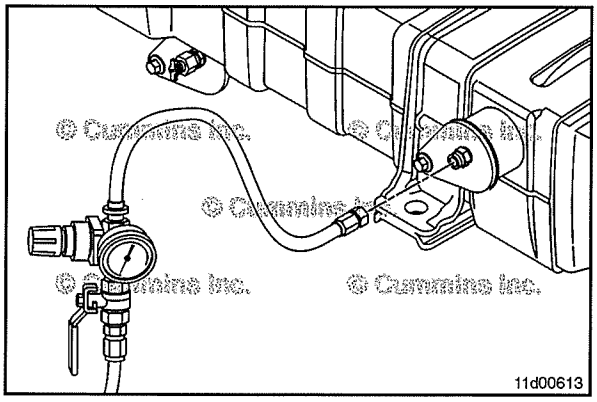
Use the Cummins® test plug retainer, Part Number 4919204, and Cummins® capscrew, Part Number 3600815, to secure the leak test plug to the EGR cooler.

Make sure the o-ring is lubricated with Cummins® P-80 lubricant, Part Number 3824878, to prevent rolling and damaging the o-ring during installation.



NOTE: The low-mount EGR cooler (1) is configured with two coolant vent ports. The high-mount EGR cooler (2) does **not** have a coolant vent port.

Plug the EGR cooler vent ports by installing the Cummins® straight thread plugs, Part Number 3678923.



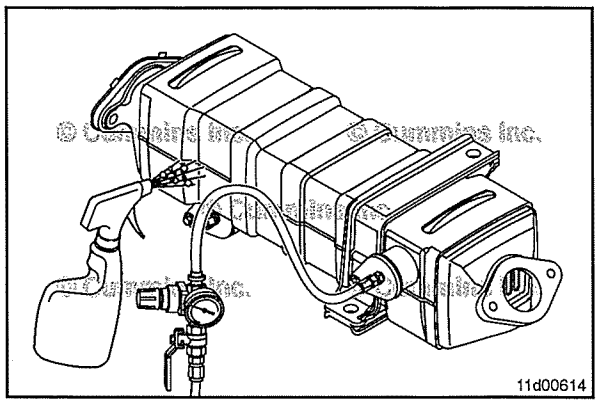
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: Air pressure regulator kit, Part Number 3164231, or equivalent, is suitable for use during this step.

Install the air pressure regulator and hose assembly onto the test fitting on the coolant inlet of the EGR cooler.

Install a ball type shutoff valve onto the inlet side of the air pressure regulator to allow the air supply to be shut OFF during testing.

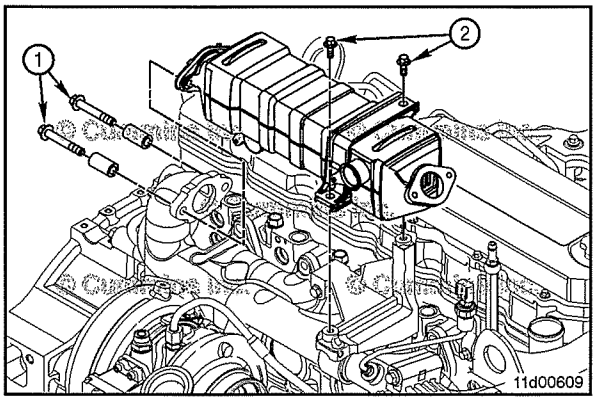
- Make sure the air pressure regulator and ball type valve are closed. Connect a compressed air supply to the pressure regulator.
- Apply 483 kPa [70 psi] of air pressure to the EGR cooler.
- Inspect for air escaping the EGR cooler assembly as a result of loose lines and fittings by spraying the exterior of the EGR cooler and all lines and fittings with a mixture of mild soap and water.
- Shut the air supply OFF to the regulator by using the ball valve and disconnect the compressed air supply.
- Record the time at which the air supply was shut off and the air pressure shown on the air pressure regulator gauge.
- Periodically check the fittings for air leaks using a mixture of soap and water. If there are any air leaks found during the test, fix the leak and start the test over.
- Measure and record the air pressure after 20 minutes.
- If there is no pressure drop, the cooler is reusable.
- If the measured pressure drop is greater than 138 kPa [20 psi], replace the EGR cooler.
- If the measured pressure drop is 138 kPa [20 psi] or less, check all of the fittings for air leaks to make sure that no air leaks are found on the test equipment and test again.
- If the measured pressure drop is greater than 3.45 kPa [0.5 psi] on the second test and there are no air leaks found on the test equipment, replace the EGR cooler.



If the EGR cooler is **not** usable, check the following items:

- Pressure check the cooling system for leaks. Leaks can be in the OEM coolant plumbing as well as on the engine which can cause EGR cooler malfunction. Verify there are no issues with the cooling system (coolant leaks, water pump damage, fan drive damage, or similar. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-020 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-020 in Section 8.
- Inspect the turbocharger turbine housing for signs of coolant deposits. Coolant deposits can typically be identified as dried white deposits coating the insides of the housings. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 010-033 in Section 10. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 010-033 in Section 10.
- Inspect the EGR valve inlet for signs of coolant deposits. Clean if coolant is found. Refer to Procedure 011-022 in Section 11.
- Inspect the air intake connection for coolant. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 010-080 in Section 10. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 010-080 in Section 10.
- Replace the crankcase breather element. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 003-021 in Section 3. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 003-021 in Section 3.
- If there is coolant contamination in the engine lubricating oil, change the engine lubricating oil. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 007-037 in Section 7. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 007-037 in Section 7. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 007-013 in Section 7. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 007-013 in Section 7.

If the EGR cooler is reusable, remove the parts supplied in the service kit and proceed to the Clean and Inspect for Reuse section of this procedure.



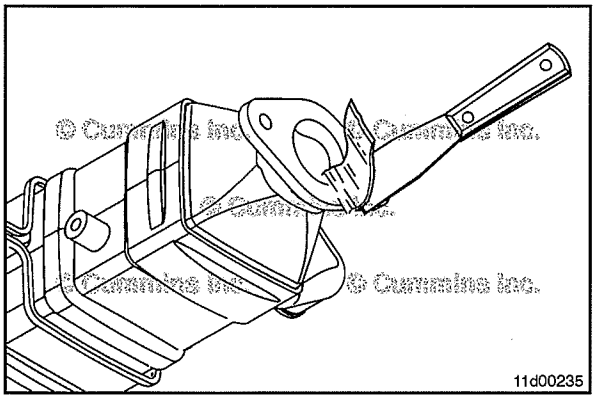
Remove

Remove the EGR cooler exhaust manifold capscrews and spacers (1) and the EGR cooler mounting capscrews (2).

Remove the EGR cooler assembly.

Remove and discard gaskets.

Cover open connections with protective caps from the Cummins® Air Handling Clean Care Kit, Part Number 4919498.



Clean and Inspect for Reuse

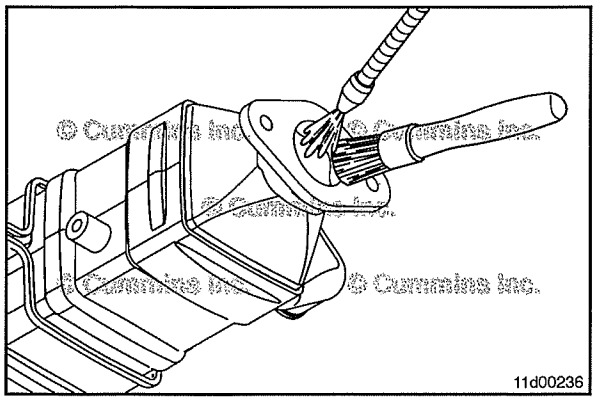
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Prior to cleaning, inspect the EGR cooler for internal leaks. If the EGR cooler is leaking internally, there could be coolant or signs of coolant (light colored deposits) in the EGR cooler.

Also, if the EGR cooler is leaking internally, there could be small amounts of soot in the coolant that has been drained from the vehicle.

Inspect the EGR cooler for signs of external leaks or cracks.

Scrape any gasket material from the EGR cooler inlet and outlet flanges with a gasket scraper.



⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Use skin and eye protection when handling caustic solutions to reduce the possibility of personal injury.

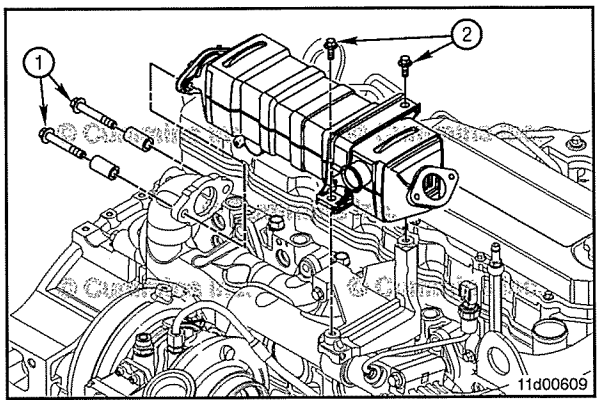
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use safety solvent to clean the soot from the inside of the EGR cooler.

Use compressed air to dry the inside of the EGR cooler.

If any solvents or cleaners entered the coolant side of the EGR cooler, use clean water to flush the coolant side of the cooler to prevent these solvents or cleaners from entering the coolant.

Install



NOTE: Following these installation instructions in order is very important.

Install the EGR cooler to the EGR cooler bracket.

Install the EGR cooler with a new gasket between the EGR cooler and the exhaust manifold.

Install the capscrews and spacers, hand-tight **only**, that connect the EGR cooler to the exhaust manifold.

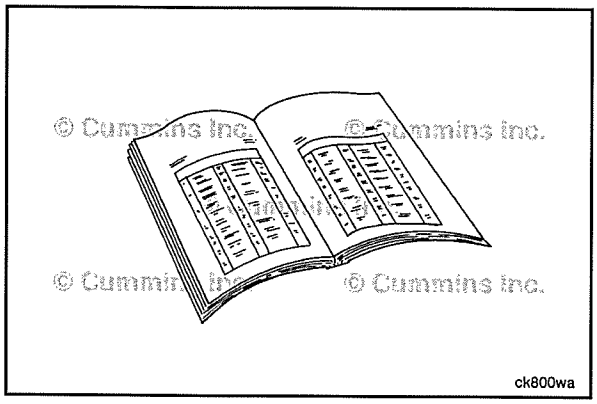
Install the EGR cooler to mounting bracket capscrews, hand-tight **only**.

Tighten the exhaust manifold capscrews (1) first.

Torque Value: 43 N•m [32 ft-lb]

Tighten the EGR cooler to mounting bracket capscrews (2).

Torque Value: 24 N•m [212 in-lb]



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

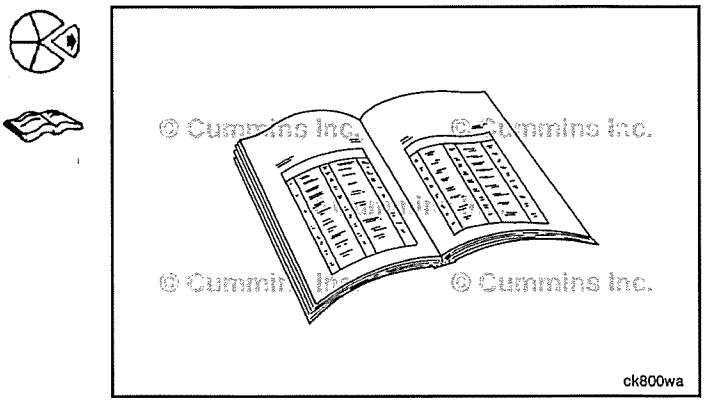
- Connect the EGR cooler coolant supply and return lines. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-031 in Section 11. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-031 in Section 11.
- Install the turbocharger coolant hoses, if removed. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 010-041 in Section 10. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 010-041 in Section 10.
- Install the EGR connection tube. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-025 in Section 11. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-025 in Section 11.
- Connect the coolant vent line. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-017 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-017 in Section 8.
- Fill the engine with coolant. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-018 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

If a malfunction resulted in oil, excessive fuel, or excessive black smoke entering the exhaust system, the aftertreatment system **must** be inspected. Reference the Reuse guidelines in the following procedure. Refer to Procedure 011-049 in Section 11.

If a malfunction resulted in coolant entering the exhaust system, the aftertreatment diesel oxidation catalyst can be recovered. Refer to Procedure 014-015 in Section 14.

EGR Valve (011-022)

Preparatory Steps

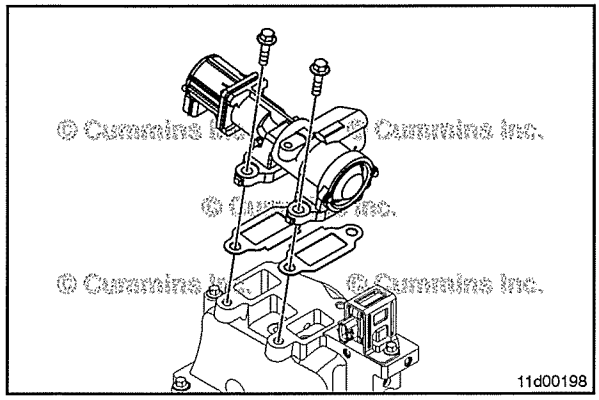


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: Brush away all loose dirt from the around the area of the air handling connections to avoid contamination of the interior of the engine.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the exhaust gas recirculation (EGR) connection tube from the EGR valve. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-025 in Section 11. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-025 in Section 11.
- Disconnect the electrical connection from the EGR valve.

Remove

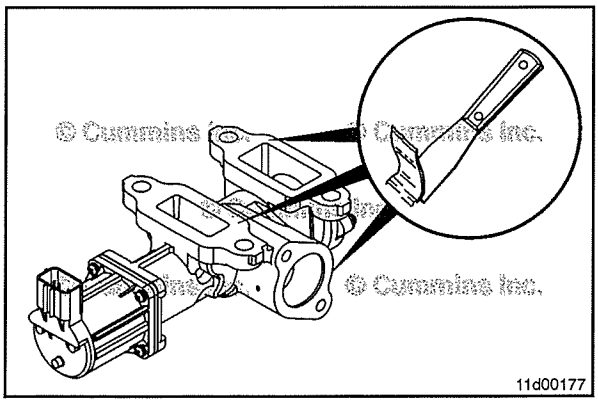


Clean the area around the EGR valve with a clean cloth to help prevent debris from entering the air intake system when the EGR valve is removed.

Remove the four capscrews holding the EGR valve to the air intake connection and remove the EGR valve.

Use protective caps from the Air Handling Clean Care Kit, Part Number 4919498, or equivalent, or heavy tape to cover any open connections to prevent debris from entering the system.

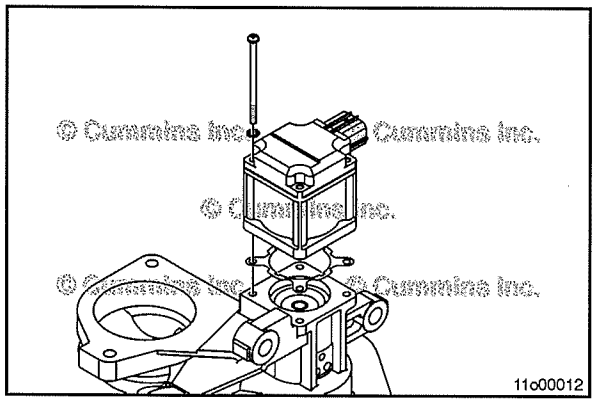
Clean and Inspect for Reuse



Clean the EGR valve and air intake connection mounting surfaces of gasket material. Take care to keep any debris out of the air intake system.

NOTE: A light coating of carbon is common on the inside of the EGR valve, and does **not** need to be removed.

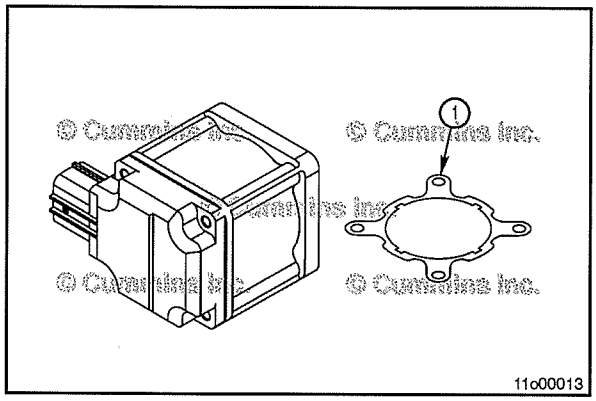
NOTE: The EGR valve can have a corrosion resistant coating on the inner surfaces. Do **not** scratch or remove this coating.



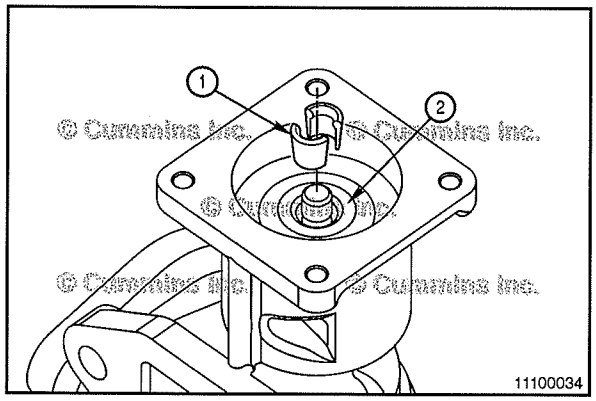
Remove the four capscrews that hold the EGR valve motor to the EGR valve base.

Remove the EGR valve motor. Take care to keep the shim with the motor.

NOTE: Note the orientation of the electrical connector with respect to the valve body. A witness mark on the outside of the motor case and valve body can be used to document the orientation. This orientation must be the same upon assembly.

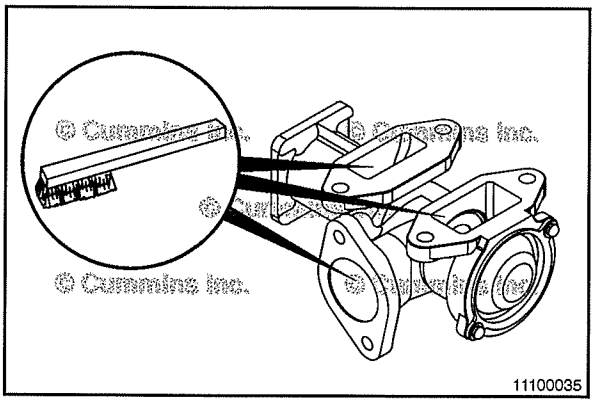


NOTE: The shim (1) is specific to the valve and can **not** be replaced. If the shim is lost or damaged, replace the EGR valve.



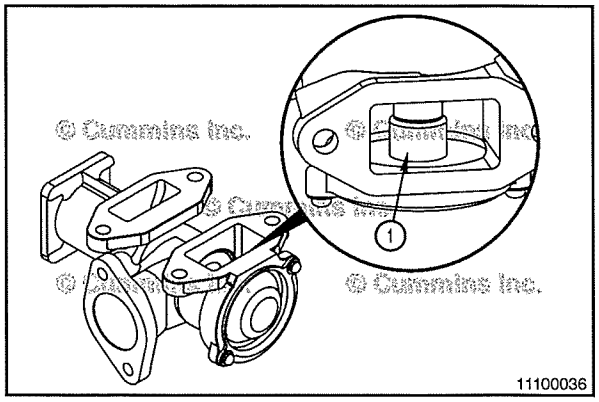
Use two fingers to press down the valve spring retainer (1) to unlock the two valve keepers (2). If the valve keepers will **not** release using finger pressure, locate a 5/8" deep socket to the spring retainer (1). Gently tap on the socket with a small hammer to release the keepers, then use two fingers and press for keeper removal.

NOTE: The spring, spring keepers, and spring retainer can **not** be replaced. If the spring, spring keepers, or spring retainer are lost or damaged, replace the EGR valve.



Clean the accumulated soot from the EGR valve inlet port and outlet ports with a nylon bristle and/or wire brush. Some deposits may need to be scraped out with a pick or scraping tool. Remove as much material as possible before applying any cleaner, without damaging the poppet sealing surfaces and the anti-corrosion finish, inside the EGR valve body.

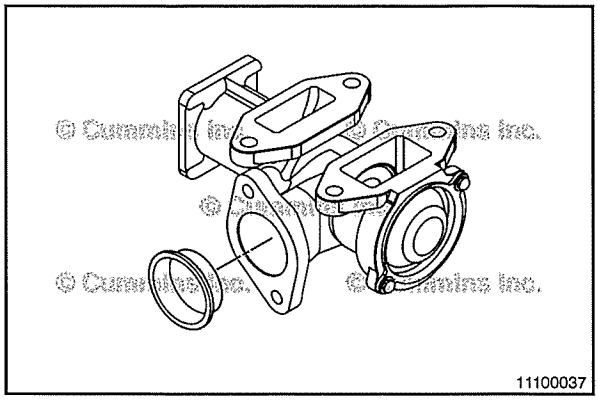
Clear the area around the soot guard (1) in the outlet port with a 90 degree bent pick. Clear any deposit material all the way around the front and the back of the soot guard. Make sure that there is no deposit material on or around the soot guard that could hold the poppet shaft open.



⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Spray carburetor cleaner into the EGR valve outlet ports to soak the inner surfaces. Use Clean Care Kit, Part Number 4919501, available in the ISB CM2150 and CM2250 Clean Care Kit, Part Number 4919498, to seal the EGR valve inlet. Fill the EGR valve cavity with carburetor cleaner. Soak for 5 minutes. Work the poppet shaft back and forth and turn it while the poppets are in contact with the valve seats (closed position) to help clean the valve. After 5 minutes, drain and properly dispose of the excess cleaner.

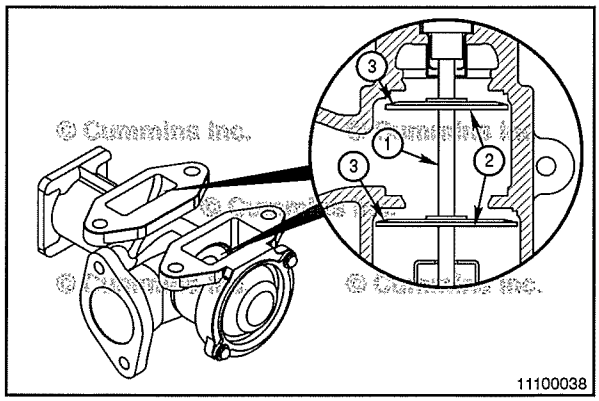
NOTE: Carburetor cleaner is the most effective solvent for this procedure. Do **not** substitute any other cleaning solvent.

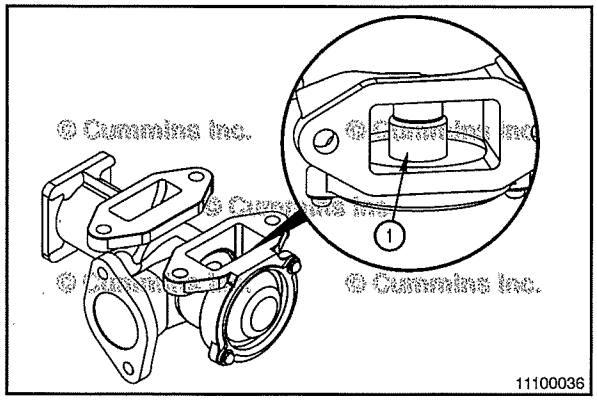


The EGR valve shaft stem (1) is comprised of two valve faces (2) on two valve seats (3). Use a small nylon or brass wire brush to lightly brush away loose soot from the stem (1), valve seat (3), and from the valve seat on the EGR valve housing. Take care **not** to damage the poppet sealing surfaces.

Spray additional carburetor cleaner as needed to clean the sealing surfaces.

NOTE: Carburetor cleaner is the most effective solvent for this procedure. Do **not** substitute any other cleaning solvent.

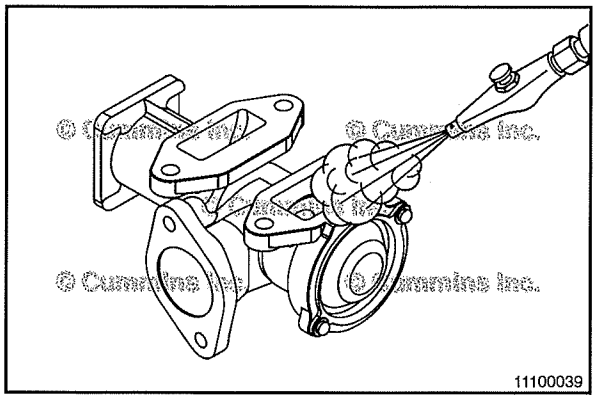




The soot guard (1) is comprised of outer and inner cylinders which must be able to close with a small gap at the bottom. Use a small nylon or brass wire brush to brush away deposits from the soot guard. Deposits can be on the back side of the soot guard causing the valve **not** to close fully.

Spray additional carburetor cleaner as needed to clean the sealing surfaces.

NOTE: Carburetor cleaner is the most effective solvent for this procedure. Do **not** substitute any other cleaning solvent.



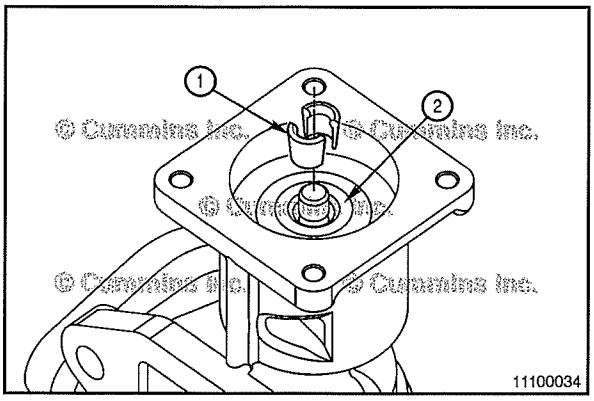
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury

Drain any remaining carburetor cleaner from the EGR valve and properly dispose of the liquid.

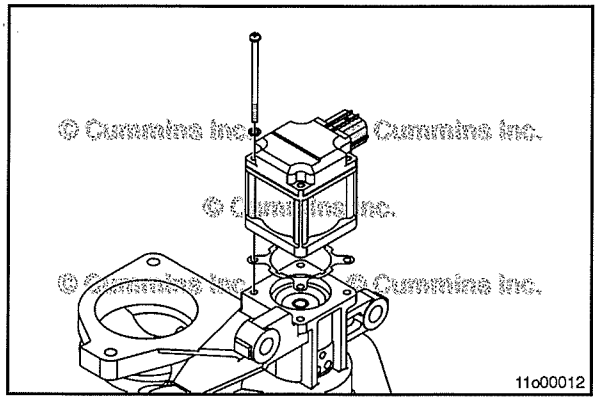
Use compressed air to dry the inside of the EGR valve.

Repeat the cleaning steps, if necessary.

NOTE: An effectively cleaned valve will close with a metal sound when the poppet shaft is closed. A soft thud is an indication that deposits are still holding the EGR valve partially open.



Install the spring, spring retainer, and spring keepers.



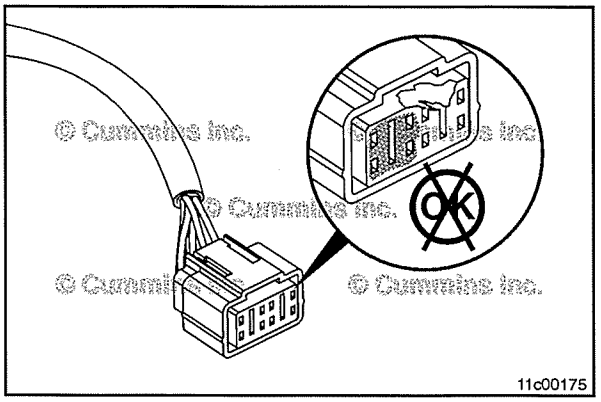
Install the EGR valve motor, shim, and four capscrews to the base.

Torque Value:
EGR Motor Capscrews 2.5 N•m [22 in-lb]

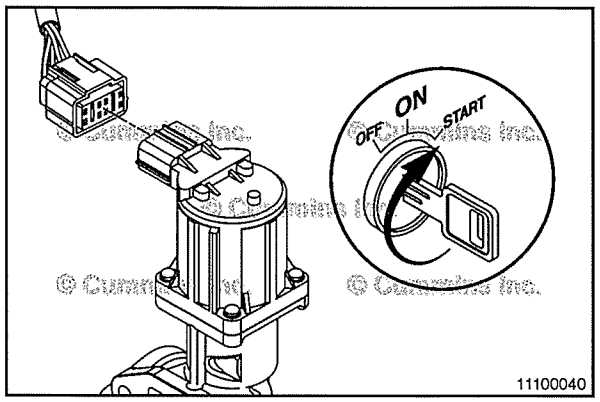
NOTE: The EGR valve motor electrical connector **must** be oriented in the same direction as it was when originally installed.

Inspect the engine wiring harness EGR valve actuator connector for corrosion, worn receptables, or other damage.

Replace the engine wiring harness EGR valve connector if corrosion, worn receptacles, or other damage is found.



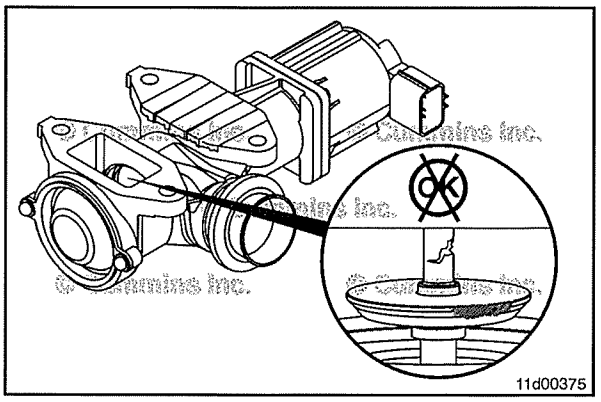
After cleaning the EGR valve, connect the electrical connector to the EGR valve and turn the ignition key ON. Do **not** start the engine. Check for active Fault Code 1896. If Fault Code 1896 persists after cleaning, replace the EGR valve.



Inspect the EGR valve seats and stem for galling, pitting, cracks, or excessive corrosion.

NOTE: Soot and condensation leaking from the weep hole on the EGR valve is considered normal and does **not** mean that the EGR valve needs to be replaced.

If the EGR valve shows signs of internal damage, replace the EGR valve assembly.

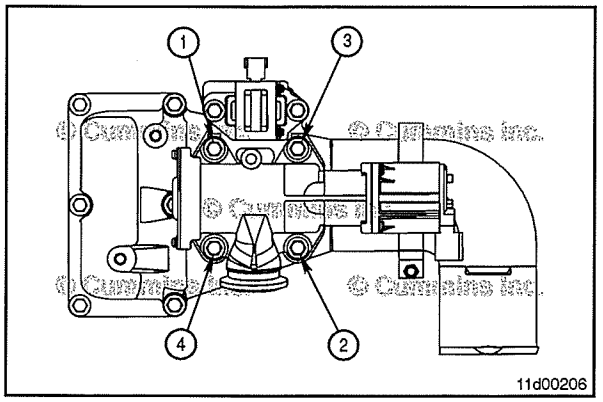


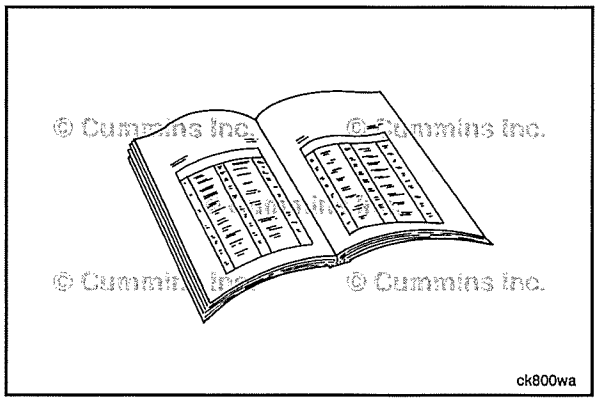
Install

Install the EGR valve, with new mounting gaskets, onto the air intake connection.

Install the four capscrews holding the EGR valve to the air intake connection hand tight to minimize assembly stresses on the EGR connection tube. Tighten in a criss-cross pattern.

Torque Value: 24 N•m [212 in-lb]

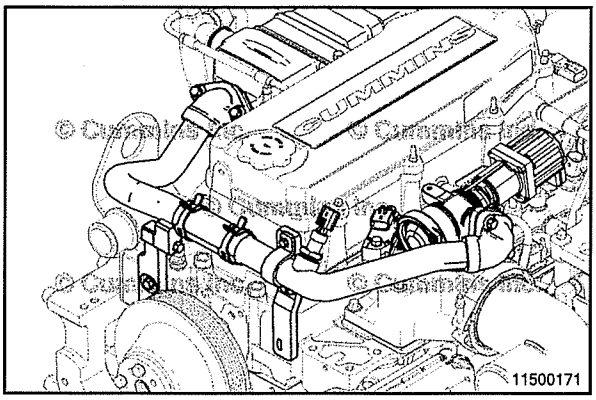




Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the EGR connection tube to the EGR valve. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-025 in Section 11. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-025 in Section 11.
- Connect the engine harness to the EGR valve.
- If a malfunction resulted in coolant, oil, excessive fuel or excessive black smoke entering the exhaust system, the aftertreatment system **must** be inspected. Refer to Procedure 014-015 in section 14.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

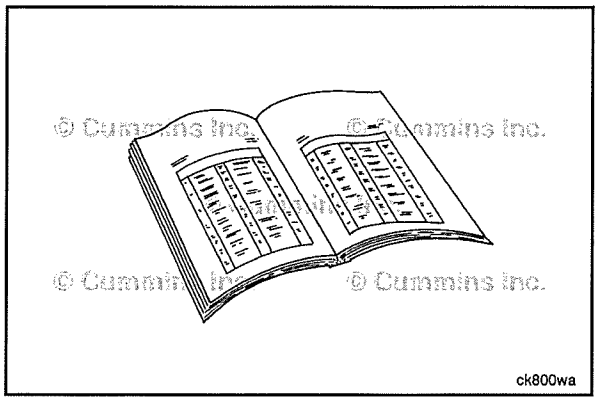


EGR Connection Tubes (011-025)

General Information

The exhaust gas recirculation (EGR) connection tube is the tube that connects the EGR valve to the EGR cooler.

The illustrations in this procedure may **not** exactly match the engine being serviced. The procedure is the same, however, regardless of the style of the EGR connection tube.



Preparatory Steps

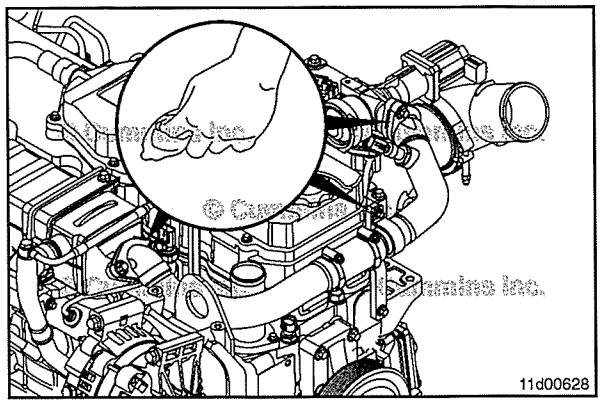
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the engine harness from the EGR temperature sensor.

NOTE: If the EGR connection tube requires replacement or extensive cleaning, remove the EGR temperature sensor. Refer to Procedure 019-378 in Section 19.

Remove

Clean around the flanges of the EGR connection tube with a clean cloth.



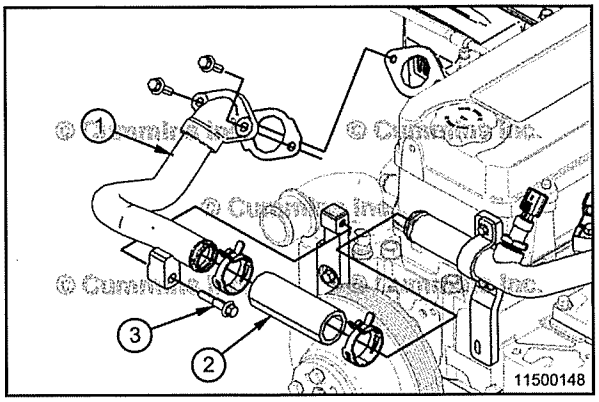
⚠CAUTION⚠
Do not twist or bend the EGR connection tube during removal or installation, or damage to the hose can result.

To remove the cooler-side EGR connection tube (1):

- Remove the hose clamps and crossover hose (2) from the EGR connection tubes.
- Remove the capscrews that attach the support brace (3) to the tube.
- Remove the capscrews and EGR connection tube (1) from the EGR cooler.

Use caution to keep debris from falling into the EGR cooler and the EGR valve when removing the EGR connection tube.

Cover all open EGR connections with protective caps from the Air Handling Clean Care Kit, Part Number 4919498.



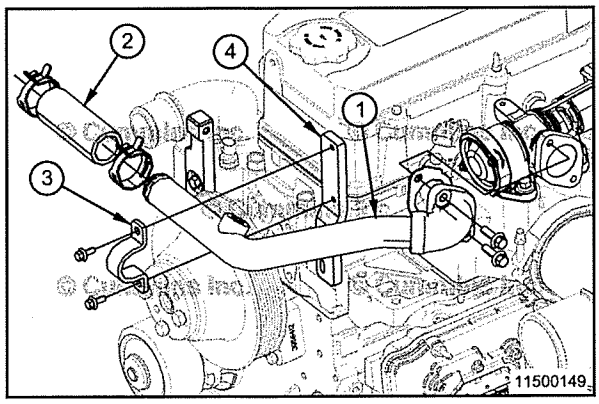
⚠CAUTION⚠
Do not twist or bend the EGR connection tube during removal or installation, or damage to the hose can result.

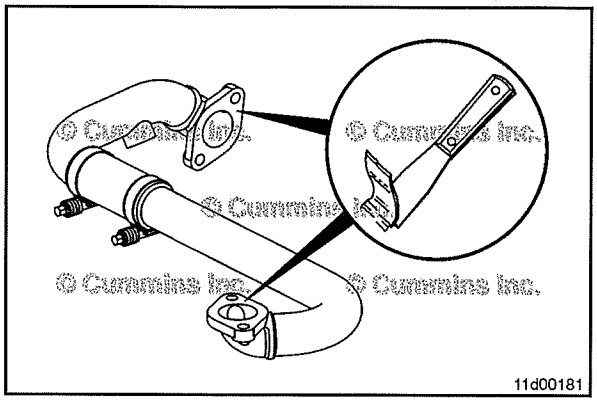
To remove the valve-side EGR connection tube (1):

- Remove the hose clamps and crossover hose (2) from the EGR connection tube.
- Remove the capscrews and clamp (3) that attach the support brace (4) to the tube.
- Remove the capscrews and EGR connection tube (1) from the EGR valve.

Use caution to keep debris from falling into the EGR cooler and the EGR valve when removing the EGR connection tube.

Cover all open EGR connections with protective caps from the Air Handling Clean Care Kit, Part Number 5298878.





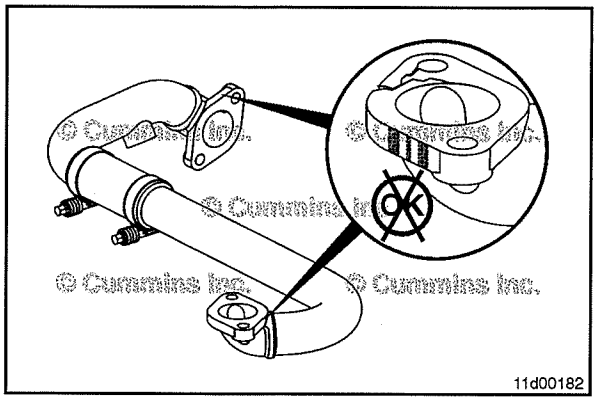
Clean and Inspect for Reuse

Scrape the gasket surfaces of the EGR connection tube, as well as the EGR valve and the EGR cooler, free of gasket material.

Use caution **not** to drop any foreign material into the EGR cooler and EGR valve.

NOTE: It is common for the EGR components to have a buildup of carbon on their inside surfaces. This buildup is normal and does **not** need to be removed.

NOTE: If the EGR connection tube will be off the engine for a prolonged period to time, tape over the opening in the EGR cooler and the EGR valve to prevent debris from entering the EGR and air intake system.

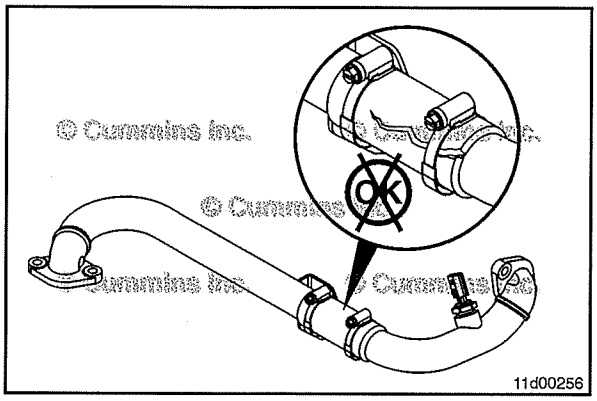


Inspect the EGR connection tube of cracks, distortion, corrosion, or soot streaking on the outside of the connection tube, indicating an EGR leak.

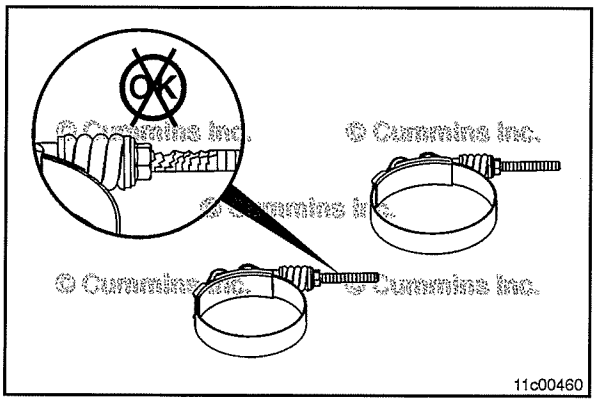
Inspect for signs of coolant in the EGR connection tube.

If signs of coolant are found in the EGR connection tube, inspect the EGR cooler for leaks. Refer to Procedure 011-019 in Section 11.

Replace the EGR connection tube if any cracks or other damage is found.



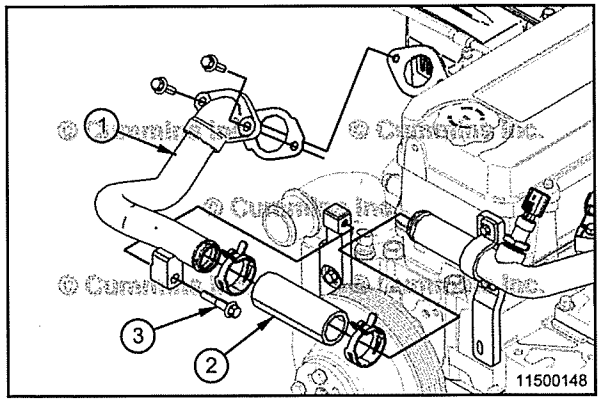
Inspect the interior and exterior of the hose connecting the two pieces of the EGR connection tube for damage. Replace if any damage is found.



Inspect the hose clamps for signs of over-extension. The clamp **must not** be bent or damaged.

Replace the hose clamps if damage is found.

Install



⚠CAUTION⚠
Do not twist or bend the EGR connection tube during removal or installation, or damage to the hose can result.

Install the EGR connection tube using new gaskets.

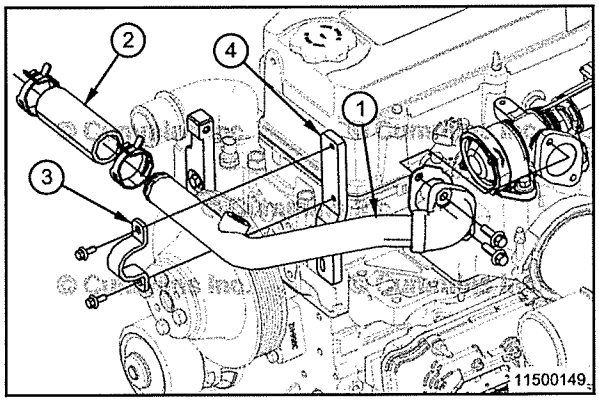
To install the cooler-side EGR connection tube (1):

- Install the mounting capscrews and EGR connection tube (1) to the EGR cooler hand-tight.
- If removed, install the support brace mounting capscrews (3) to the EGR tube (1) and cylinder head hand-tight.
- Install the hose clamp and crossover hose (2) to the EGR connection tube.
- Check for correct alignment at all locations.
- Tighten the capscrews at the EGR cooler outlet (1).

Torque Value: 24 N•m [212 in-lb]

- Tighten the capscrew at the support brace (3).

Torque Value: 24 N•m [212 in-lb]



⚠CAUTION⚠
Do not twist or bend the EGR connection tube during removal or installation, or damage to the hose can result.

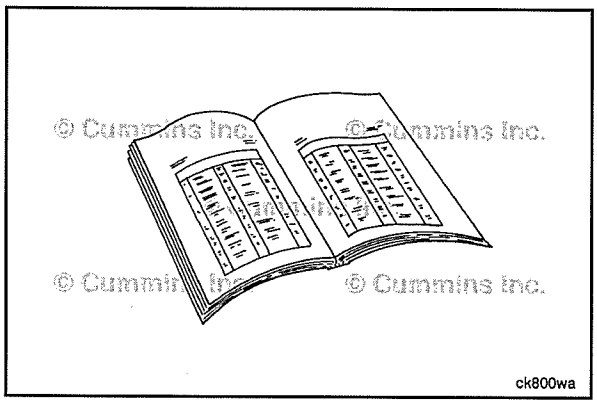
To install the valve-side EGR connection tube (1):

- If removed, install the capscrews and clamp (3) that attach the support brace (4) to the tube hand-tight.
- Install the crossover hose (2), EGR connection tube (1), and hose clamps to the EGR connection tubes.
- Install the mounting capscrews and EGR connection tube (1) to the EGR valve hand-tight.
- Check for correct alignment at all locations.
- Tighten the capscrews at the support brace (4) and clamp (3) on the EGR tube (1).

Torque Value: 24 N•m [212 in-lb]

- Tighten the capscrews at the EGR valve inlet.

Torque Value: 10 N•m [89 in-lb]

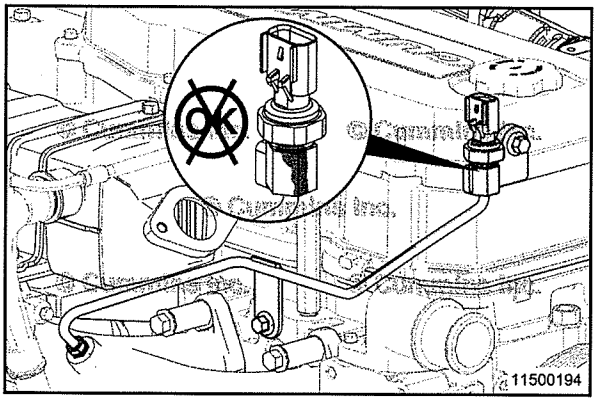


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the engine harness to the EGR temperature sensor. Refer to Procedure 019-378 in Section 19.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

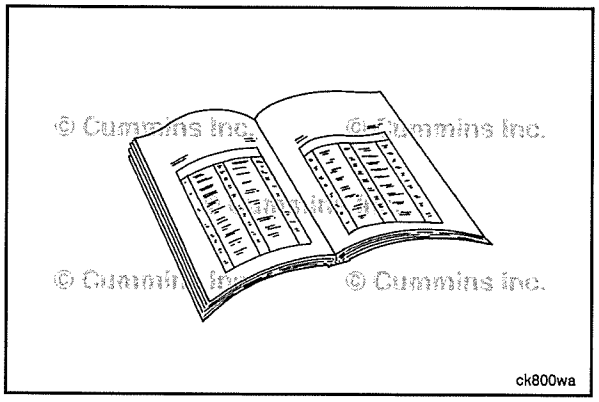


Exhaust Gas Pressure Sensor Tube (011-027)

Initial Check

Inspect the ports on the exhaust manifold and the exhaust pressure sensor for signs of leaks or damage. Leaks can be identified by soot streaks.

If leaks are found, tighten the fittings again. If the fittings are **not** loose, replace the exhaust gas pressure sensor tube.



Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

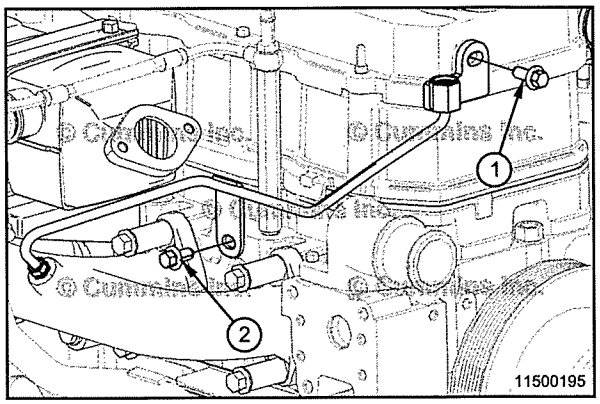
NOTE: Do **not** peel apart the adhesive of the tube to remove.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the electrical connector from the exhaust pressure sensor and remove the exhaust pressure sensor. Refer to Procedure 019-376 in Section 19.

Remove

Remove the mounting fastener securing the exhaust gas pressure sensor tube support brace to the breather cover (1).

Remove the mounting fastener securing the exhaust gas pressure sensor tube to the cylinder head (2).

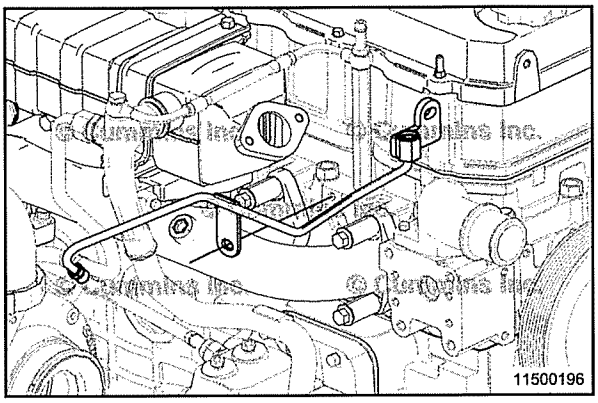


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use compressed air to clean around the fitting where the exhaust gas pressure sensor tube connects to the exhaust manifold.

Disconnect the exhaust gas pressure sensor tube from the exhaust manifold.

Remove the exhaust gas pressure sensor tube.



Clean and Inspect for Reuse

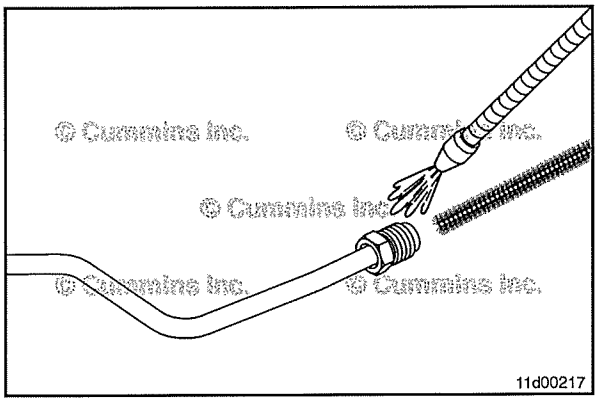
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

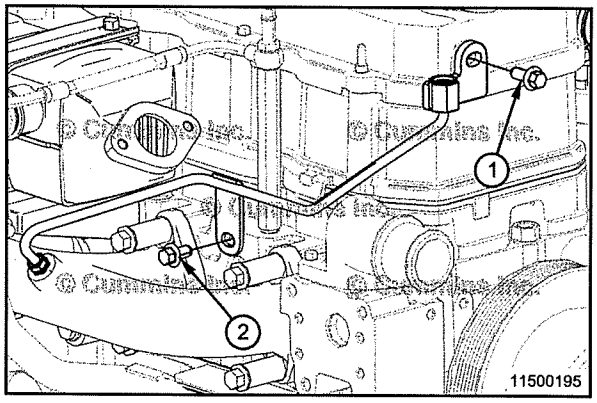
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Clean the exhaust gas pressure sensor tube with solvent and dry with compressed air.

Inspect the tube for signs of leakage, damaged sealing areas, or plugging with soot.

If the tube is plugged with soot, use solvent and a pipe cleaner, or similar device, to remove the soot blockages in the tube.

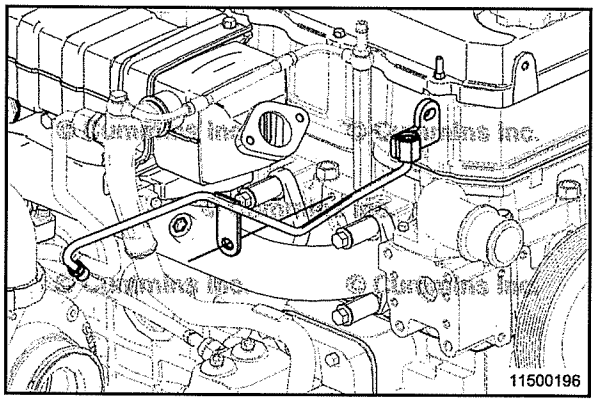




Install

NOTE: Install a light coating of high temperature anti-seize compound to the threads of the exhaust gas pressure sensor tube prior to installation.

Install the exhaust gas pressure sensor tube to the port on the exhaust manifold.



Install the mounting fastener securing the exhaust pressure sensor tube support bracket to the breather cover and tighten hand tight.

Install the mounting fastener securing the exhaust pressure sensor tube to the cylinder head and tighten.

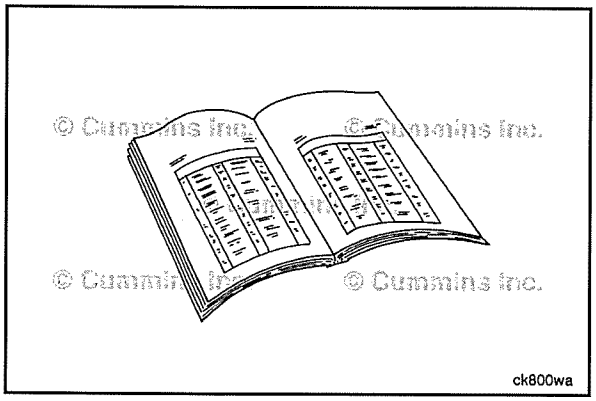
Torque Value: 24 N•m [212 in-lb]

Tighten the exhaust gas pressure sensor tube support bracket.

Torque Value: 24 N•m [212 in-lb]

Tighten the exhaust gas pressure sensor tube fitting to the cylinder head.

Torque Value: 18 N•m [159 in-lb]



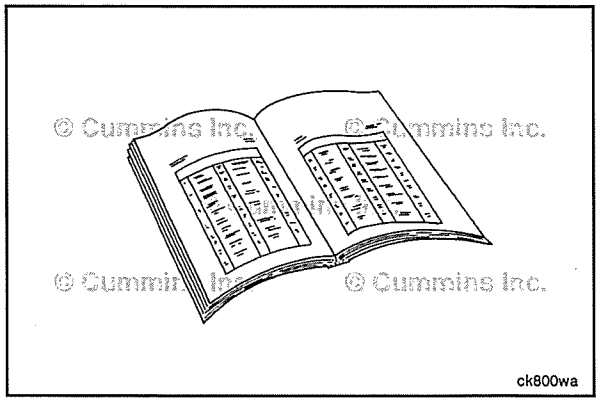
Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the exhaust pressure sensor and connect the electrical connector to the exhaust pressure sensor. Refer to Procedure 019-376 in Section 19.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

EGR Cooler Mounting Bracket (011-029)



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

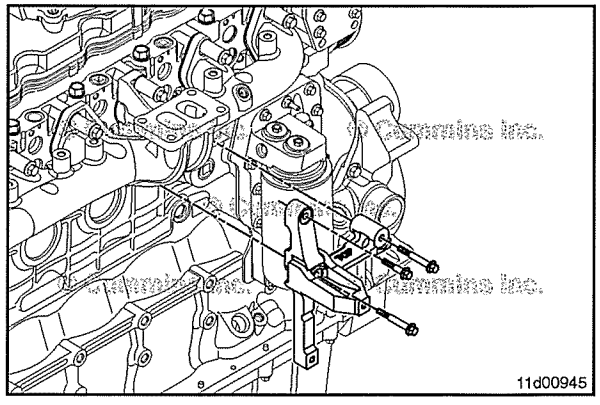
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

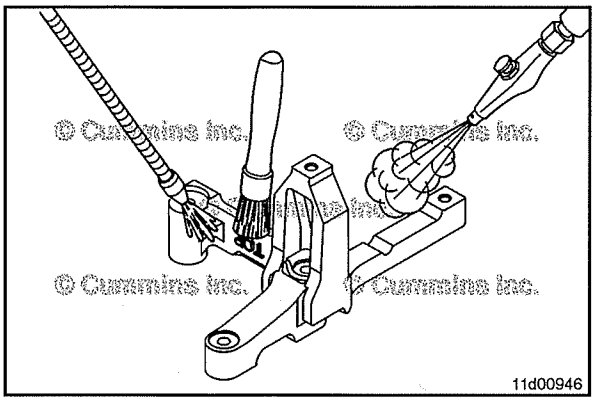
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the exhaust gas recirculation (EGR) connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the EGR cooler coolant lines. Refer to Procedure 011-031 in Section 11.
- Remove the EGR cooler. Refer to Procedure 011-019 in Section 11.
- If required, remove the exhaust pressure sensor tube. Refer to Procedure 011-027 in Section 11.
- If required, remove the turbocharger. Refer to Procedure 010-033 in Section 10.
- If required, remove the exhaust manifold. Refer to Procedure 011-007 in Section 11.

Remove

Remove the three capscrews that attach the EGR cooler bracket to the cylinder head.

Remove the EGR cooler bracket.



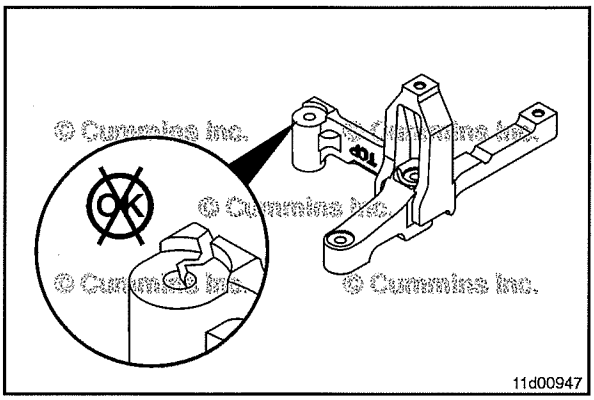


Clean and Inspect for Reuse

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

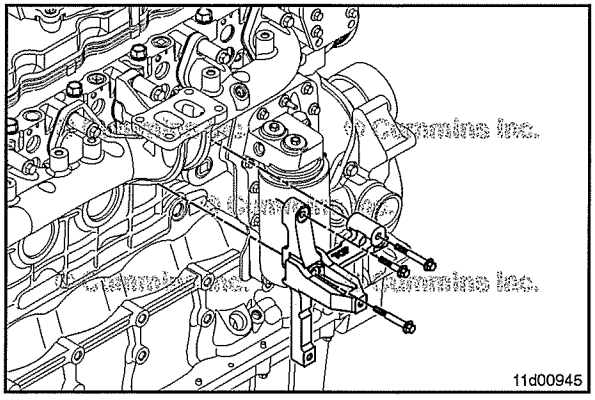
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Clean the EGR cooler bracket with solvent and dry with compressed air.



Inspect the EGR cooler bracket for cracks or other damage.

Replace the EGR cooler bracket if damaged.



Install

Install the EGR cooler bracket to the cylinder head.

Tighten the capscrews.

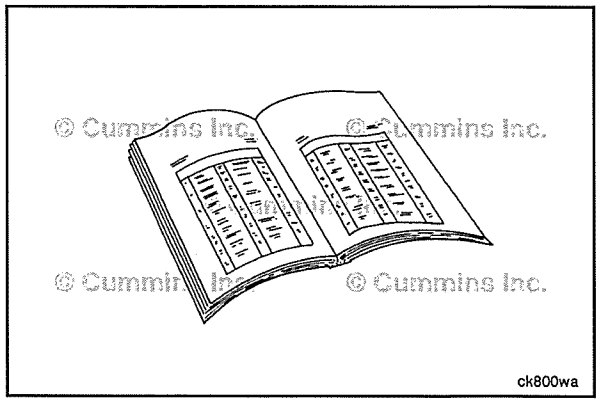
Torque Value: 24 N•m [212 in-lb]

Finishing Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- If removed, install the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- If removed, install the turbocharger. Refer to Procedure 010-033 in Section 10.
- If removed, install the exhaust pressure sensor tube. Refer to Procedure 011-027 in Section 11.
- Install the EGR cooler. Refer to Procedure 011-019 in Section 11.
- Install the EGR cooler coolant lines. Refer to Procedure 011-031 in Section 11.
- Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



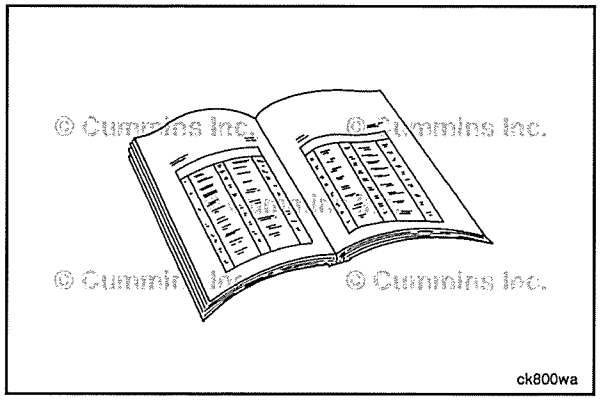
EGR Cooler Coolant Lines (011-031)

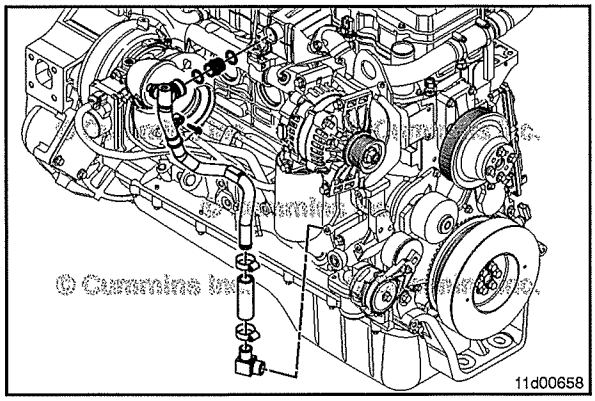
Preparatory Steps


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Engines with high mount exhaust gas recirculation (EGR) coolers, remove the coolant vent lines. Refer to Procedure 008-017 in Section 8.
- Engines with low mount EGR coolers, disconnect the turbocharger coolant hose from the EGR cooler, coolant return line. Refer to Procedure 010-041 in Section 10.





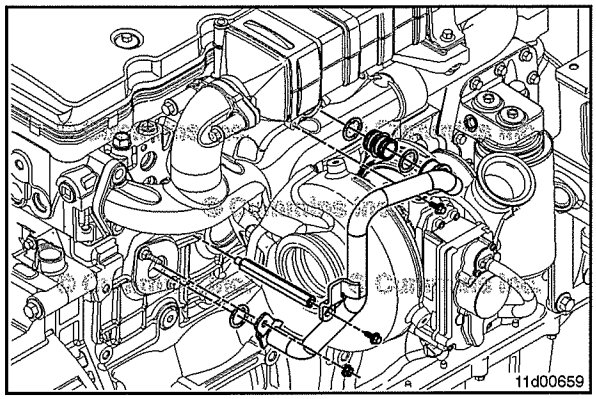
Remove

High Mount

NOTE: Discard and replace all o-ring seals.

EGR Cooler Coolant Return Line

- Remove the nut from the studded capscrew on the oil cooler housing.
- Remove the capscrew attaching the EGR cooler coolant return line to the EGR cooler mounting bracket.
- Remove the hose clamps from the EGR cooler coolant return line.
- Remove the EGR cooler coolant return line.
- Remove the EGR cooler coolant return hose.
- Remove the EGR cooler coolant line transfer tube between the EGR cooler and EGR cooler coolant return line.
- If necessary, remove the EGR cooler return fitting from the water inlet connection.



NOTE: Discard and replace all o-ring seals.

EGR Cooler Coolant Supply Line

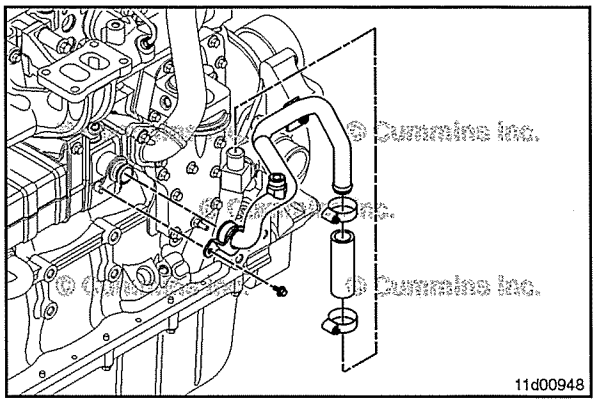
- Remove the capscrew attaching the EGR cooler coolant supply line to the EGR cooler.
- Remove the nut from the studded capscrew attached to the water transfer connection on the cylinder block.
- Remove the capscrew attaching the EGR cooler coolant supply line to the line support and remove the line. The cooler coolant supply line support can then be removed, if needed.
- Remove the EGR cooler coolant supply line.
- Remove the EGR cooler coolant transfer tube between the EGR cooler and EGR cooler coolant supply line.
- If necessary, remove the two capscrews holding the EGR cooler coolant supply line transfer connection to the cylinder block and remove the transfer connection.

Low Mount

NOTE: Discard and replace all o-ring seals.

EGR Cooler Coolant Return Line

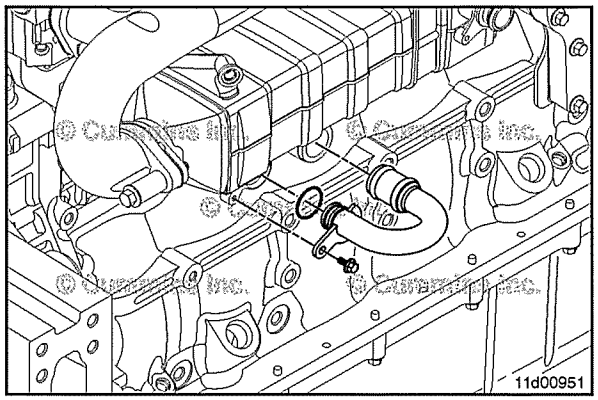
- Remove the nut from the studded capscrew on the oil cooler housing.
- Remove the capscrew attaching the EGR cooler coolant return line to the EGR cooler.
- Remove the hose clamps from the EGR cooler coolant return line.
- Remove the EGR cooler coolant return line.
- Remove the EGR cooler coolant return hose.
- Remove the EGR cooler coolant transfer tube between the EGR cooler and EGR cooler coolant return line.
- If necessary, remove the EGR cooler return fitting from the water inlet connection.



NOTE: Discard and replace all o-ring seals.

EGR Cooler Coolant Supply Line

- Remove the capscrew attaching the EGR cooler coolant supply line to the EGR cooler.
- Remove the hose clamps from the EGR cooler coolant supply line.
- Remove the EGR cooler coolant supply line.
- Remove the EGR cooler coolant supply hose.
- If necessary, remove the two capscrews holding the EGR cooler coolant supply line transfer connection to the cylinder block, and remove the transfer connection.



Clean and Inspect for Reuse

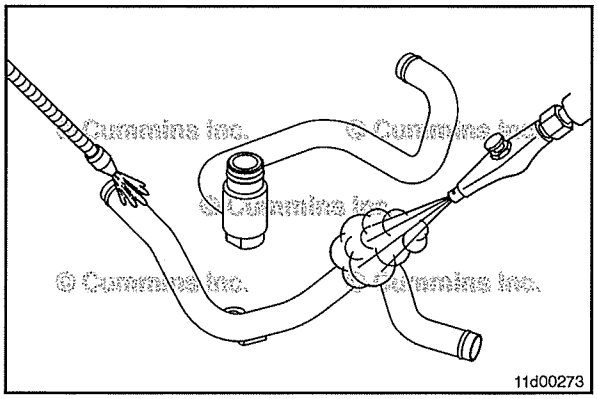
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

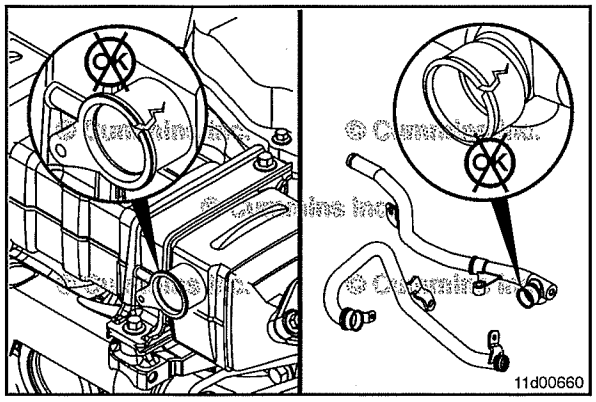
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the tubes with solvent and dry with compressed air.

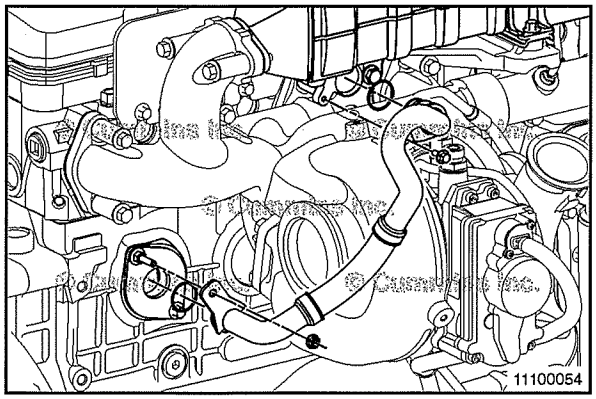
Inspect the tubes and hoses for cracks, leaks, or distortion. Replace as necessary.

Inspect the hose clamps for damage or distortion. Replace as necessary.





Inspect the EGR cooler line bores in the EGR cooler, as well as the EGR cooler coolant line/connection tube sealing areas for signs of distortion, cracks or other damage. Replace as necessary.



Install

High Mount

EGR Cooler Coolant Supply Line

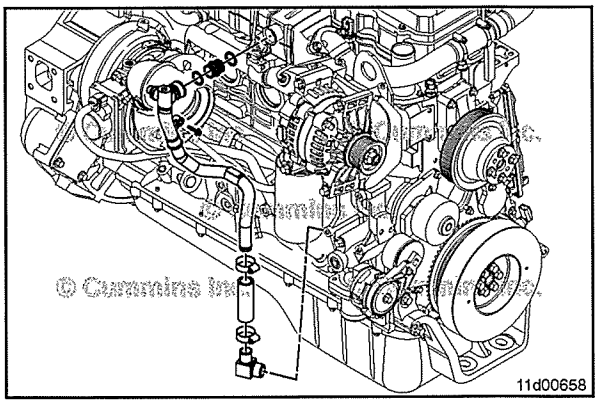
- Install the EGR cooler coolant supply line onto the EGR cooler coolant inlet and the water transfer connection on the cylinder block fitting.
- Install the capscrew attaching the EGR cooler coolant supply line to the water transfer connection on the cylinder block fitting.
- Install the capscrew attaching the EGR cooler coolant supply line to the EGR cooler coolant inlet.
- Tighten the capscrew attaching the EGR cooler coolant supply line to the water transfer connection on the cylinder block fitting.

Torque Value: 24 N•m [212 in-lb]

- Tighten the capscrew attaching the EGR cooler coolant supply line to the EGR cooler.

Torque Value: 10 N•m [89 in-lb]

EGR Cooler Coolant Return Line



- Install the EGR cooler coolant transfer tube into the EGR cooler coolant outlet. Use assembly lubricant, Part Number 3824878, to aid in installation.
- If removed, install the EGR cooler return fitting into the coolant supply connection. The threads of this fitting **must** be coated with pipe thread sealant.
- Install the EGR cooler coolant return hose. Use assembly lubricant, Part Number 3824878, to aid in installation.
- Install the EGR cooler coolant return line.
- Install the hose clamps to the EGR cooler coolant return hose connections.
- Tighten the clamps.

Torque Value: 5 N•m [44 in-lb]

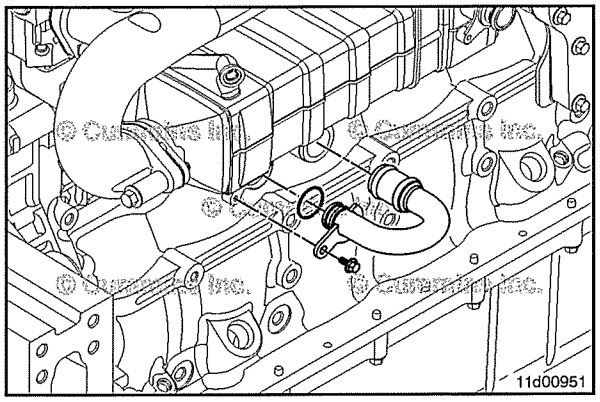
- Install the nut to the studded capscrew on the lubricating oil cooler housing.
- Tighten the nut.

Torque Value: 10 N•m [89 in-lb]

- Install the capscrew attaching the EGR cooler coolant return line to the EGR cooler mounting bracket.
- Tighten the capscrew.

Torque Value: 10 N•m [89 in-lb]

Low Mount
EGR Cooler Coolant Supply Line



- If removed, install the cooler supply line transfer connection to the cylinder block.
- Install the two capscrews. Tighten the capscrews.

Torque Value: 24 N•m [212 in-lb]

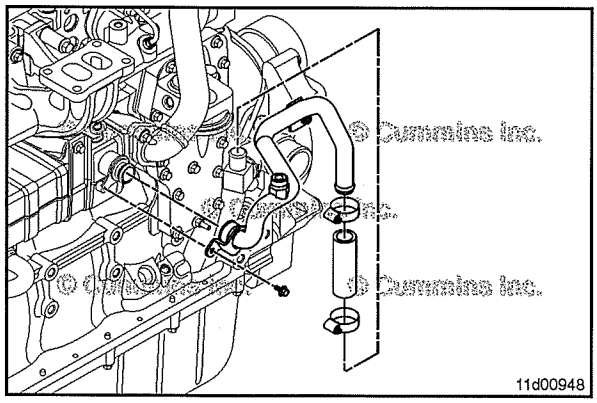
- Install the EGR cooler coolant supply hose to the engine block fitting. Use assembly lubricant, Part Number 3824878, to aid in installation.
- Install the EGR cooler coolant supply line tube to the coolant.
- Install the capscrew attaching the EGR cooler coolant supply line to the EGR cooler.
- Tighten the capscrew.

NOTE: Allow the tube brace to sit flush on the EGR cooler inlet bore.

Torque Value: 10 N•m [89 in-lb]

- Install the hose clamps to the EGR cooler coolant supply hose connections.
- Tighten the hose clamps.

Torque Value: 5 N•m [44 in-lb]



EGR Cooler Coolant Return Line

- Install the EGR cooler coolant transfer tube into the EGR cooler coolant outlet. Use assembly lubricant, Part Number 3824878, to aid in installation.
- If removed, install the EGR cooler return fitting into the coolant supply connection. The threads of this fitting **must** be coated with pipe thread sealant.
- Install the EGR cooler coolant return hose. Use assembly lubricant, Part Number 3824878, to aid in installation.
- Install the EGR cooler coolant return line.
- Install the hose clamps to the EGR cooler coolant return line connections.
- Tighten the hose clamps.

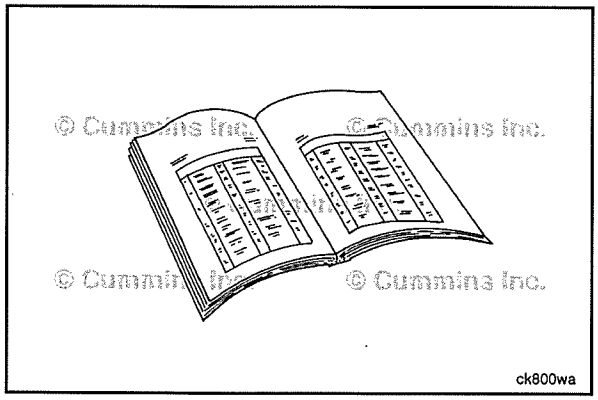
Torque Value: 5 N•m [44 in-lb]

- Install the capscrew attaching the EGR cooler coolant return line to the EGR cooler.
- Tighten the capscrew.

Torque Value: 10 N•m [89 in-lb]

- Install the nut to the studded capscrew on the lubricating oil cooler housing.
- Tighten the nut.

Torque Value: 10 N•m [89 in-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Engines with low mount EGR coolers, install the turbocharger coolant hose to the EGR cooler coolant return line. Refer to Procedure 010-041 in Section 10.
- Engines with high mount EGR coolers, install the coolant vent lines. Refer to Procedure 008-017 in Section 8.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Heat Shield (011-032)

General Information

⚠WARNING⚠

The exhaust and exhaust components can remain hot after the engine is shut down. To reduce the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

⚠CAUTION⚠

Wear goggles and protective clothing to reduce the possibility of personal injury.

Heat shields reduce heat exposure to various components from the exhaust and exhaust gas recirculation (EGR) components.

In the following information, there are examples of the different heat shields found on MidRange Cummins® engines.

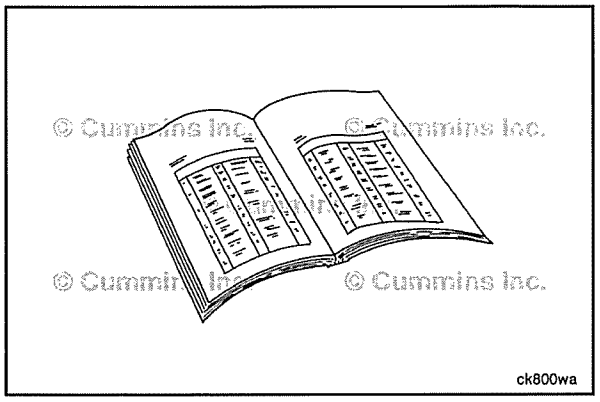
Due to the various heat shield mounting locations, this procedure has been written to be generic. The Remove and Install sections are common regardless of the style of heat shield used.

Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

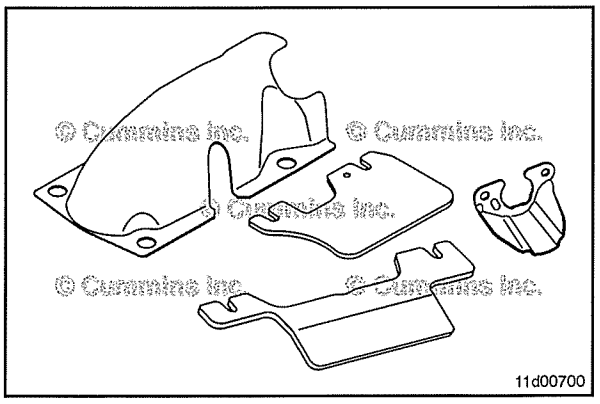
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- The turbocharger turbine housing heat shield is **not** covered in this procedure. Refer to Procedure 010-076 in Section 10.

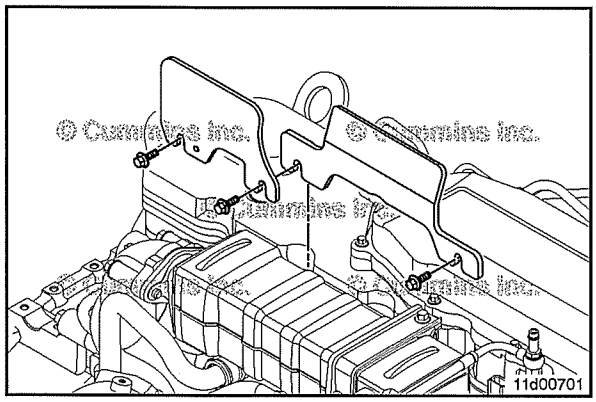


Remove

The mono-nitrogen oxides (NOx) sensor module/ crankcase breather/rocker cover heat shield is mounted on the rocker housing.

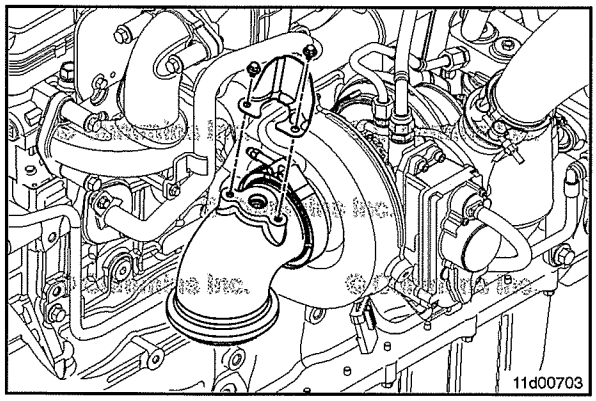
The shield provides attachment points for the NOx sensor wiring.





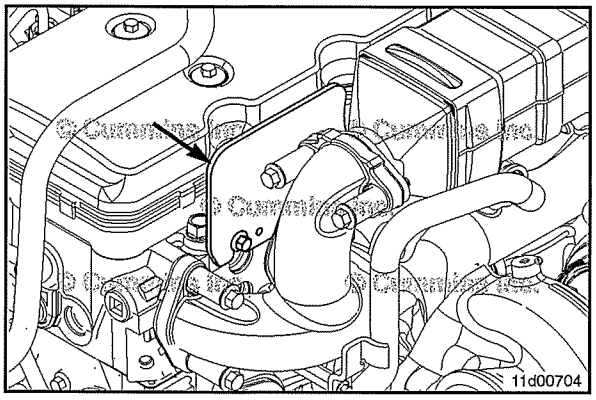
The rocker cover/crankcase breather heat shield is used on some industrial models and is mounted to the rocker housing.

Remove the heat shield(s).



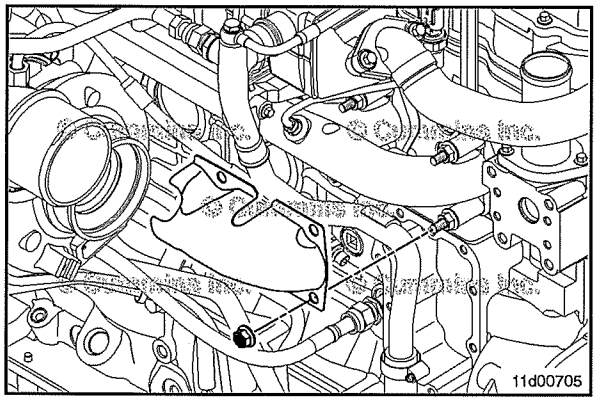
The aftertreatment intake NOx sensor heat shield is **not** applicable or required for all OEMs. When used, it is mounted to the exhaust outlet connection.

Remove the heat shield.



The rocker cover heat shield is mounted to the cylinder head.

Remove the heat shield.



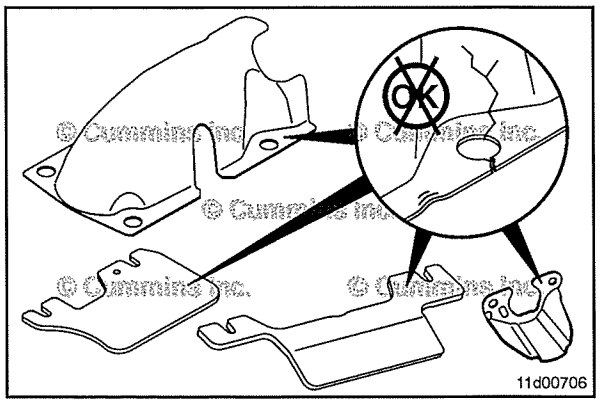
The exhaust manifold heat shield is mounted to the end of the exhaust manifold capscrews and can be found on either end of the manifold, depending on the exhaust/ turbocharger configuration.

Remove the heat shield.

Clean and Inspect for Reuse

Inspect the heat shield for cracks or other damage.

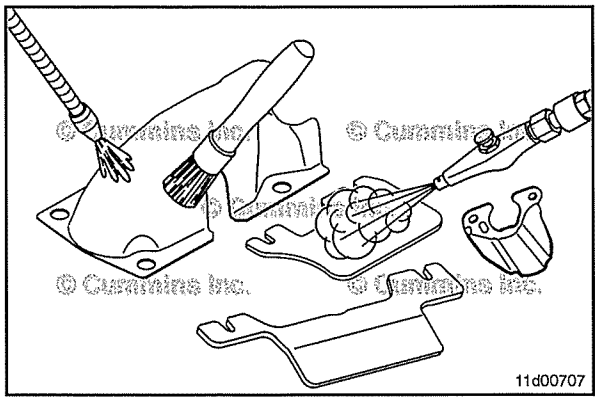
Replace the heat shield if any damage is found.



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the heat shield in a hot, soapy water solution or steam clean if desired.

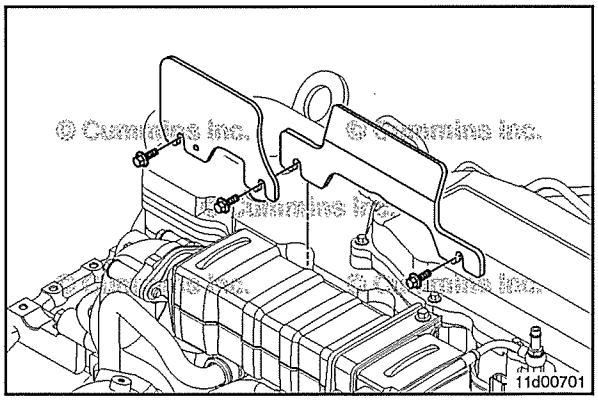
Dry with compressed air.



Install

Install all applicable heat shields.

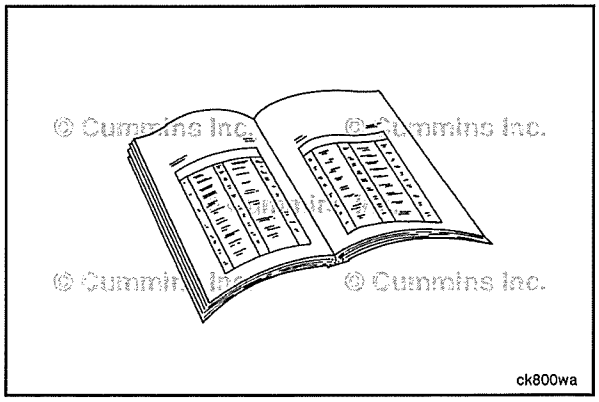
Use the following procedure for torque values. Refer to Procedure 018-009 in section V.

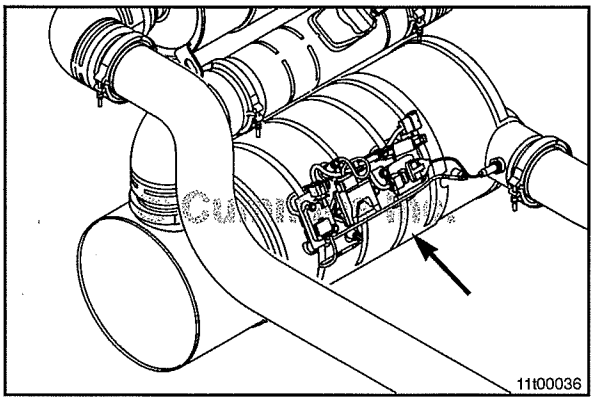


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.





Aftertreatment Selective Catalytic Reduction (SCR) Catalyst (011-036)

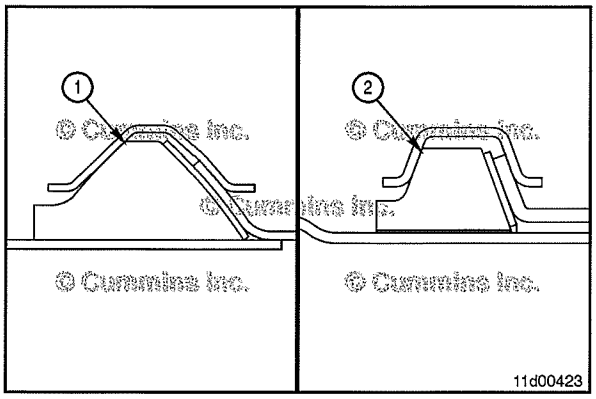
General Information

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair. Make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components.

△CAUTION△
The catalyst elements contained in the aftertreatment system are made of brittle material. Do not drop or strike the side of the aftertreatment system, as damage to the catalyst element can result.

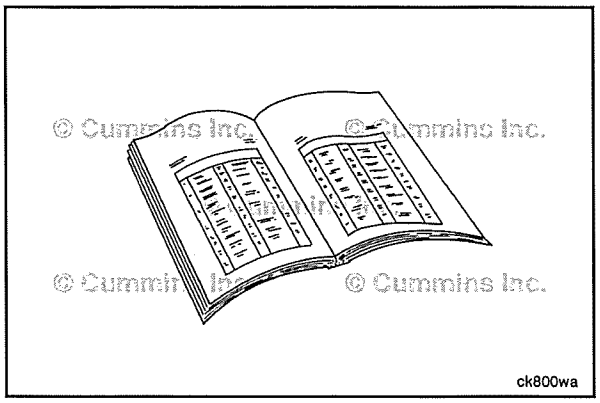
Due to the number of varying exhaust aftertreatment applications, this procedure has been written to be generic. **Not** all illustrations within this procedure will represent the application being serviced.

Different vehicles will require different aftertreatment configurations. Some of the aftertreatment selective catalytic reduction (SCR) catalysts may have elbows clamped to them.



A variation in vehicle aftertreatment configuration will cause the aftertreatment SCR catalyst to have different flanges. The clamps and gaskets on either end of the aftertreatment SCR catalyst may be different from one another. There are two types of flanged joints, spherical Marmon and full Marman. The spherical Marmon (1) joints allow a small amount of misalignment and have a rounded cross section. The full Marmon (2) joints are completely rigid and have a more edgy profile.

Preparatory Steps

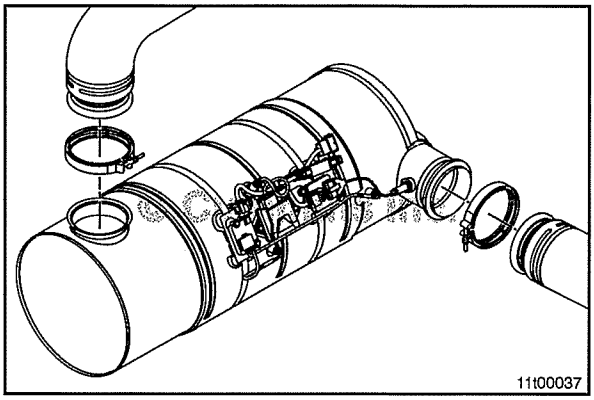


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
During selective catalytic reduction (SCR) system cleaning, exhaust gas temperature can reach 800°C [1500°F], and exhaust system surface temperature can exceed 700°C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area with compressed air to remove any loose debris.
- Draw an orientation reference line across each of the V-band and Torca™ clamps on either end of the aftertreatment SCR canister. This will aid in lining up the clamps and canister to their original orientation during installation.
- Remove the aftertreatment outlet mono-nitrogen oxides (NOx) sensor probe to prevent damage to the sensor. Refer to Procedure 019-451 in Section 19.
- Disconnect the aftertreatment interface harness from the OEM wiring harness connection.



Remove

⚠WARNING⚠

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

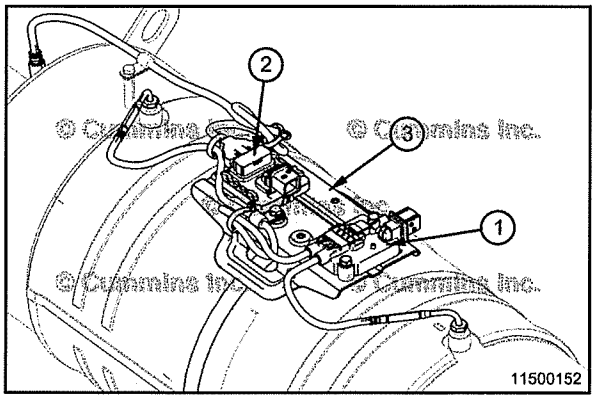
Support the aftertreatment decomposition tube to prevent it from being freely suspended after the aftertreatment SCR catalyst is removed. If supporting it is not an available option, remove the aftertreatment diesel exhaust fluid (DEF) decomposition tube. Refer to Procedure 011-062 in Section 11.

Support the aftertreatment SCR catalyst with a lowering jack.

Remove the clamps on either end of the aftertreatment SCR catalyst.

Remove the exhaust hangers that support the aftertreatment SCR catalyst and slowly remove the canister from the vehicle.

Discard the gasket from the V-band joint.



Disassemble

If the aftertreatment SCR catalyst is being replaced, complete the following procedures to remove the key parts of the aftertreatment SCR catalyst.

Disconnect and remove the aftertreatment temperature sensor assembly (1). Refer to Procedure 019-449 in Section 19.

Remove the aftertreatment outlet NOx sensor module and probe assembly (2). Refer to Procedure 019-451 in Section 19.

Remove the aftertreatment SCR catalyst temperature sensor interface module mounting bracket (3). Refer to Procedure 011-076 in Section 11.

Clean and Inspect for Reuse

⚠CAUTION⚠
Do not use a metallic object to clean the aftertreatment SCR catalyst. This will scratch the surface of the aftertreatment SCR catalyst which may cause future excessive DEF deposits.

Inspect the aftertreatment SCR catalyst for cracks or puncture holes, especially around the weld areas.

Replace the aftertreatment SCR catalyst if damaged.

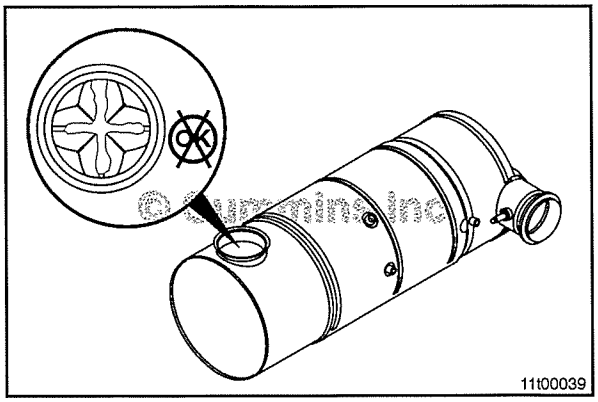
Inspect the aftertreatment SCR catalyst inlet for DEF deposits.

If buildups are present, carefully scrape the buildup with a non-metallic object to clean the majority of the buildup from the catalyst.

NOTE: Do **not** use a mechanical device to remove DEF deposits from the aftertreatment. SCR catalyst.

NOTE: Do **not** use a pressure washer to remove DEF deposits from the aftertreatment SCR catalyst.

NOTE: If crystallization buildup was present after installation, complete a stationary SCR/exhaust system cleaning to make sure that any of the remaining DEF crystallization has been removed from the aftertreatment SCR catalyst.

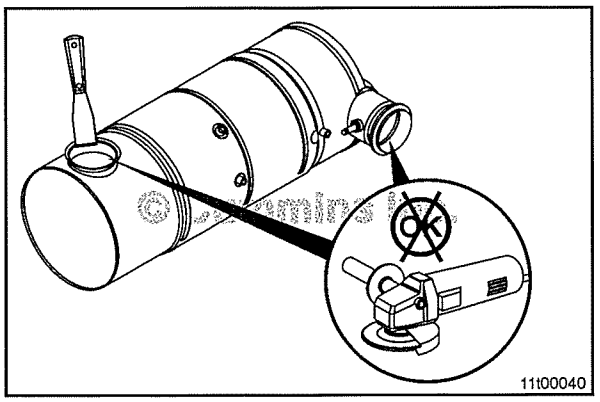


Inspect the exhaust flanges for corrosion or other damage.

Use a putty knife to remove any residual gasket material from the flanges on the aftertreatment SCR catalyst.

Avoid dropping fragments of gasket material into the aftertreatment SCR catalyst.

Do **not** grind on the flange surface, as this can damage the flange and cause the connection to leak.

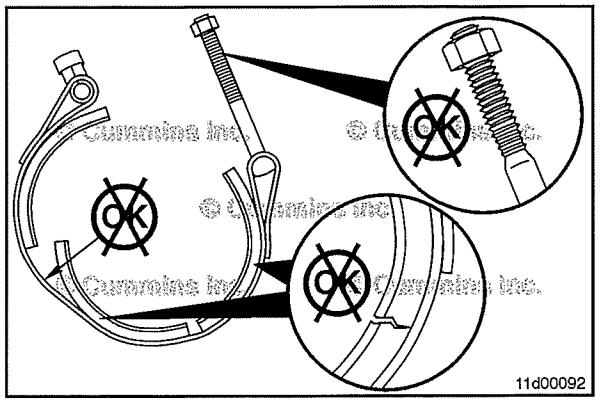


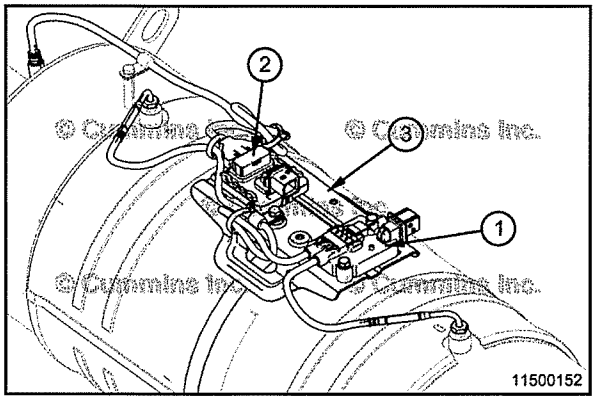
Inspect the V-band clamps and mounting straps for signs of over-extension.

The band **must not** be bent or damaged.

Inspect the V-band clamp and mounting strap threads for damage.

Replace the V-band clamp or mounting strap if damage is found.



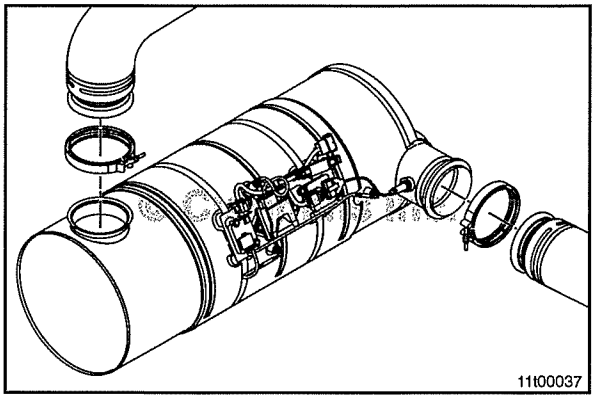


Assemble

Install the aftertreatment SCR catalyst temperature sensor interface module mounting bracket (3). Refer to Procedure 011-076 in Section 19.

Install the aftertreatment outlet NOx sensor module (2) on the aftertreatment SCR catalyst temperature sensor interface module mounting bracket. Refer to Procedure 019-451 in Section 19.

Install the aftertreatment temperature sensor assembly (1). Refer to Procedure 019-449 in Section 19.



Install

⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

△CAUTION△
Do not use an air tool to tighten the V-band clamp. An air tool will damage the threads.

Place the aftertreatment SCR catalyst on the vehicle. Use the exhaust hangers to support the canister.

Align the catalyst in the same orientation as marked previously.

NOTE: Horizontal aftertreatment SCR catalysts incorporate a water drain hole in the outlet section of the canister. If a new horizontal aftertreatment SCR catalyst is being installed, make sure the drain hole is located toward the bottom of the installation, within ±10 degrees of the vertical axis.

NOTE: Where applicable, install and tighten the full Marmon clamps before the spherical Marmon to account for misalignment in the aftertreatment system.

Apply a coat of anti-seize compound, Part Number 3824879 or equivalent, on the threads of the V-band clamp. Put a new gasket on the V-band connection of the aftertreatment SCR catalyst and install opposite of removal. Tighten the V-band and Torca™ clamps.

Tighten the V-Band and Torca™ clamps.

Torque Value:
V-band Clamp 14 N•m [124 in-lb]

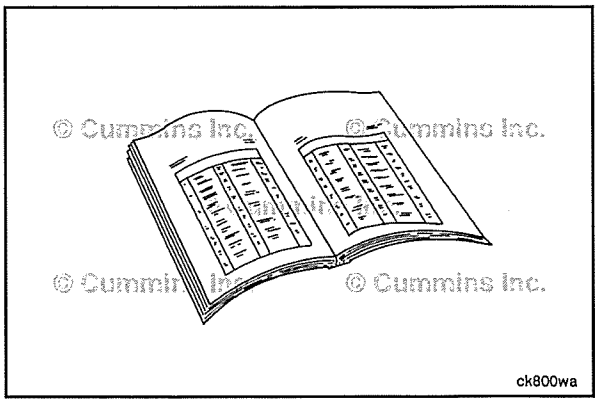
Torque Value:
Torca™ Clamp 55 N•m [41 ft-lb]

Connect the OEM wiring to the aftertreatment interface harness.

Install the aftertreatment outlet NOx sensor probe. Refer to Procedure 019-451 in Section 19.

Tighten the exhaust hangers. Refer to the OEM service manual.

Finishing Steps

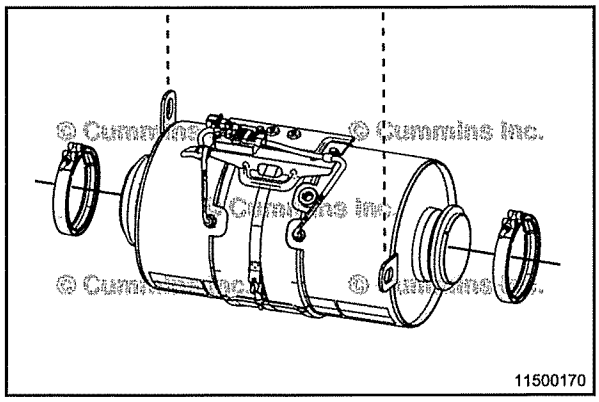


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Start the engine and check the system for leaks.
- Use INSITE™ electronic service too to check for active fault codes.
- If buildups were present, complete a stationary SCR/ exhaust system cleaning to make sure that any of the remaining DEF crystallization has been removed from the aftertreatment SCR catalyst.
- Continue to monitor for leaks at the exhaust joints.

Aftertreatment Diesel Oxidation Catalyst (011-049)

General Information

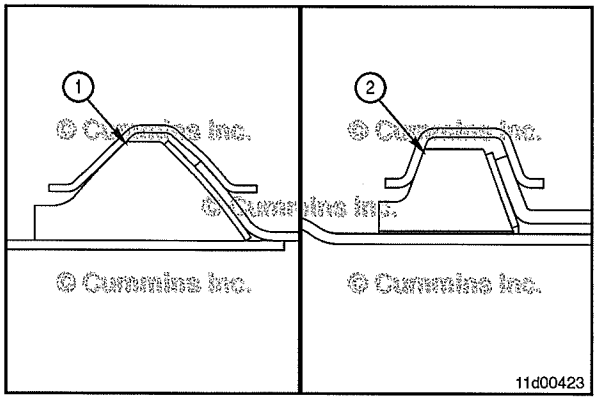


△CAUTION△
The aftertreatment diesel oxidation catalyst elements contained in the aftertreatment system are made of brittle material. Do not drop or strike the side of the aftertreatment system as damage to the aftertreatment diesel oxidation catalyst element can result.

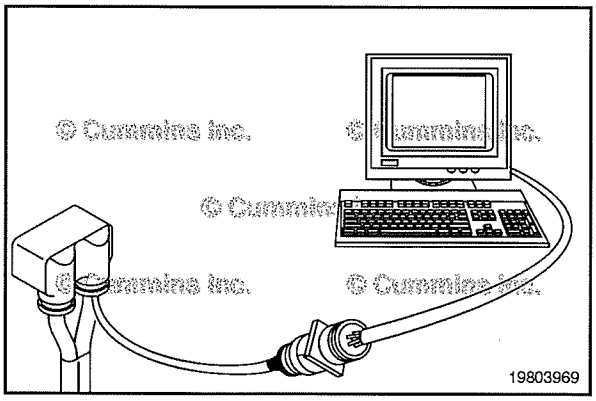
△CAUTION△
Do not steam clean the inlet of the diesel oxidation catalyst (DOC) as damage to the aftertreatment DOC can result.

Due to number of exhaust aftertreatment applications, this procedure is generic. **Not** all illustrations within this procedure will represent all applications.

NOTE: If the aftertreatment diesel oxidation catalyst (DOC) is being replaced due to progressive damage from engine oil or fuel, clean the tailpipe from the turbocharger outlet to the aftertreatment DOC.



A variation in vehicle aftertreatment configuration will cause the aftertreatment DOC to have different flanges. The clamps and gaskets on either end of the aftertreatment DOC may be different from one another. There are two types of flanged joints, spherical Marmon and full Marmon. The spherical Marmon (1) joints allow a small amount of misalignment and have a rounded cross section. The full Marmon (2) joints are completely rigid and have a more edgy profile.



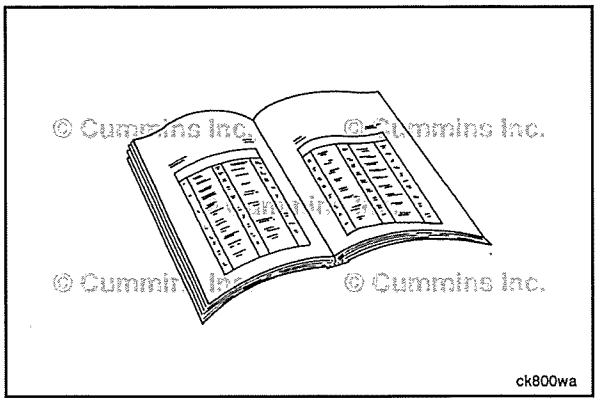
Test

⚠CAUTION⚠
If an engine progressive damage malfunction has sent fuel or oil to the DOC, do not perform an SCR/ exhaust system cleaning until the aftertreatment DOC is inspected.

To test the DOC, use INSITE™ electronic service tool to perform the SCR Performance Test. The efficiency of the DOC will be tested, in addition to the aftertreatment system.

If a malfunction in the catalyst system is detected, fault codes will become active during the test. Follow the appropriate fault code troubleshooting tree.

Preparatory Steps



⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

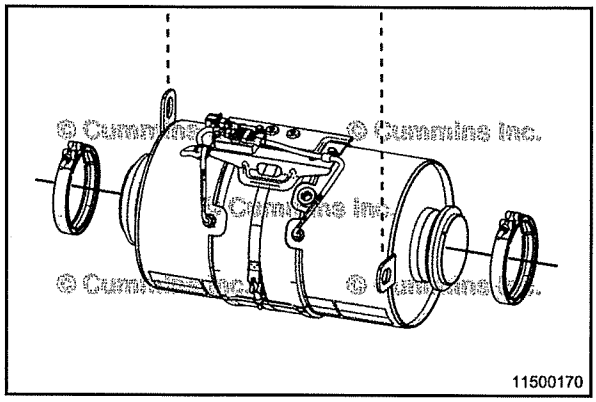
⚠WARNING⚠

During Selective Catalytic Reduction (SCR) system cleaning, exhaust gas temperature can reach 800°C [1500°F], and exhaust system surface temperature can exceed 700°C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

⚠CAUTION⚠

Aftertreatment DOC can remain hot for a long time after the engine has stopped.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area with compressed air to remove any loose debris.
- Draw an orientation reference line across each of the V-band clamps on either end of the aftertreatment DOC canister. This will aid in lining up the clamps and canister to their original orientation during installation.
- Remove the aftertreatment inlet mono-nitrogen oxides (NOx) sensor probe to prevent damage to the sensor. Refer to Procedure 019-463 in Section 19.
- Disconnect the OEM wiring harness from the aftertreatment interface harness.
- Support or remove the aftertreatment diesel exhaust fluid decomposition tube. Refer to Procedure 011-062 in Section 11.



Remove

⚠WARNING⚠
The component or assembly weighs greater than 23 kg [50 lbs]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

△CAUTION△
The aftertreatment DOC elements contained in the aftertreatment system are made of brittle material. Do not drop or strike the side of the aftertreatment system as damage to the aftertreatment DOC element can result.

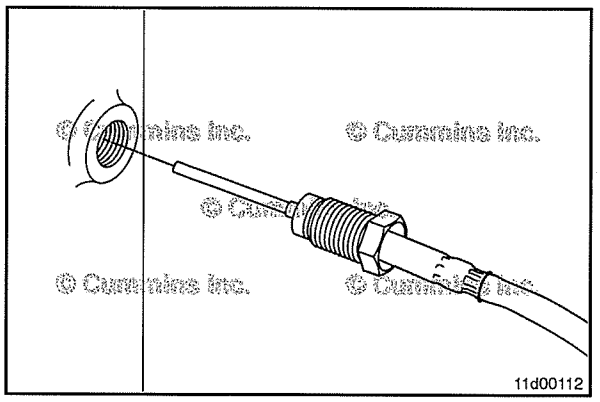
△CAUTION△
Do not use an air tool to remove the V-band clamp nut. An air tool will damage the threads. Apply thread lubricant to the V-band clamp threads prior to nut removal.

Support the aftertreatment DOC with a lowering jack.

Remove the clamps on either end of the aftertreatment DOC.

Remove the exhaust hangers that support the aftertreatment DOC and slowly remove the canister from the vehicle.

Remove and discard the gaskets.



Disassemble

If the DOC is being replaced, remove the aftertreatment DOC temperature sensor assembly. Refer to Procedure 019-449 in Section 19.

Clean and Inspect for Reuse



⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠CAUTION⚠
Do not use a grinder or abrasive air tool to remove residual gasket material, as this can damage the flange and cause the connection to leak.

⚠CAUTION⚠
Do not steam clean the inlet of the DOC as damage to the aftertreatment DOC can result.

Remove any residual gasket material from the flanges on the aftertreatment DOC with a putty knife.

NOTE: Avoid dropping fragments of gasket material into the aftertreatment DOC.

Inspect the exhaust gas temperature sensor boss threads for damage.

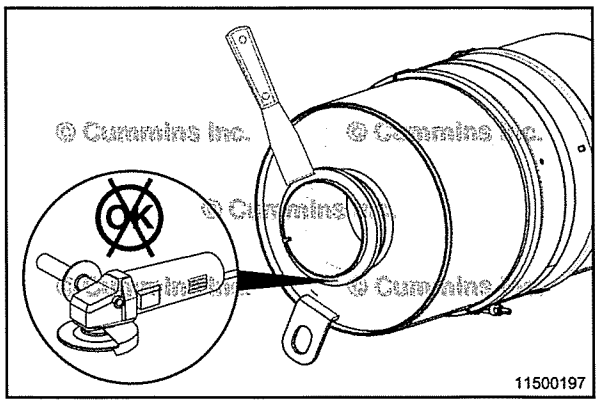
If thread damage is found on the exhaust gas temperature sensor boss threads, a helicoil **must** be used for repair.

NOTE: If the aftertreatment DOC is being inspected due to progressive damage that introduced engine oil or excessive fuel into the exhaust, inspect the tailpipe from the turbocharger outlet to the aftertreatment DOC.

If a trail of coolant can be seen exiting the turbocharger outlet, the DOC can be recovered without removing it for inspection. Refer to Procedure 014-015 in Section 14.

If a trail of coolant can be seen exiting the turbocharger outlet, the tailpipe between the turbocharger outlet and aftertreatment DOC **must** be cleaned. Refer to the OEM service manual.

If a trail of engine oil or fuel can be seen exiting the turbocharger outlet, steam clean the tailpipe between the turbocharger and the aftertreatment DOC. Refer to the OEM service manual.

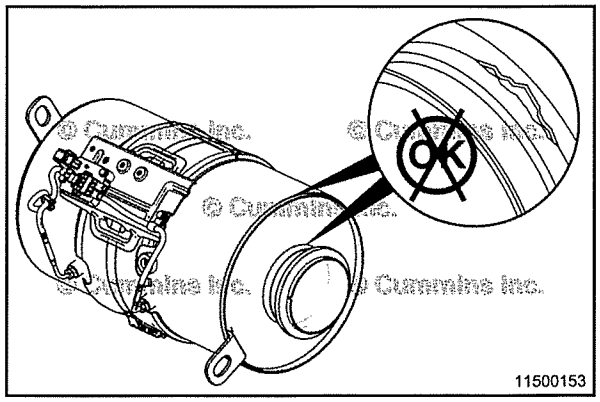


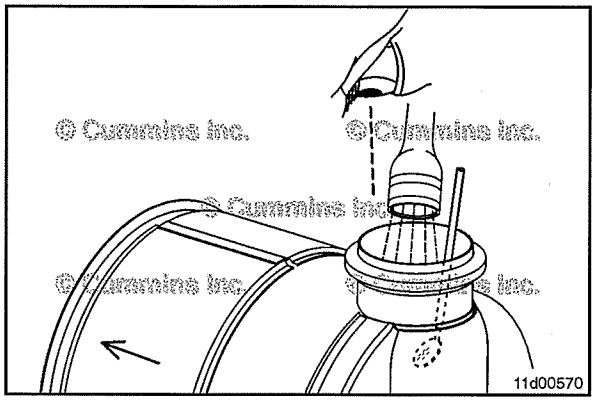
If the aftertreatment DOC section has shifted, moved, or is loose inside the canister, replace the aftertreatment DOC.


Inspect the aftertreatment DOC for cracks or puncture holes, especially around the weld areas.

Inspect the aftertreatment DOC insulation for damage.

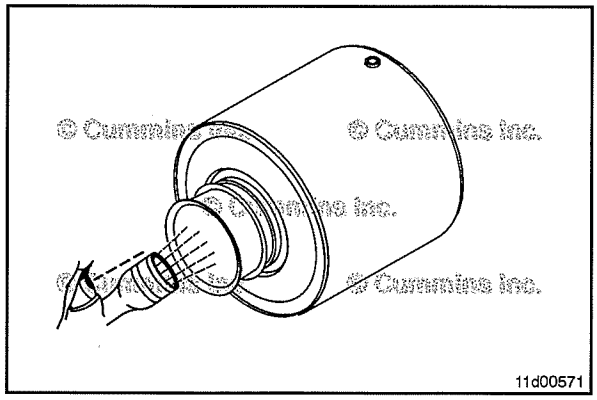
Replace the aftertreatment DOC if it is damaged.





For side-in configurations:

Place an inspection mirror into the inlet of the DOC and shine a flashlight on the mirror to inspect the cells of the inlet face.

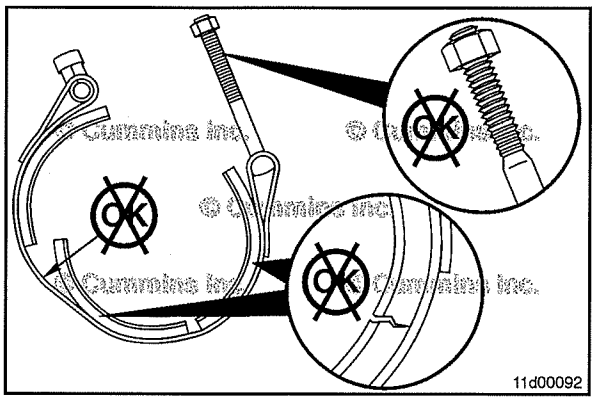


For end-in configurations:

Use a flashlight to inspect the inlet face of the DOC.

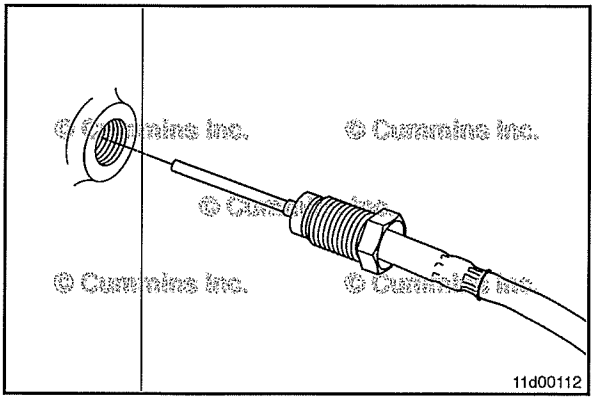
If oil contamination is observed during inspection, inspect the engine system. See the appropriate troubleshooting symptom tree in Section TS.

If coolant contamination is observed, the DOC can be recovered. Refer to Procedure 014-015 in Section 14.



Inspect the V-band clamps and aftertreatment DOC mounting straps for signs of overextension. The V-band **must not** be bent or otherwise damaged.

Replace the V-band clamps or aftertreatment DOC mounting straps if damage is found.



Assemble

Install the exhaust gas temperature sensor probes, if removed. Refer to Procedure 019-449 in Section 19.

Install

⚠WARNING⚠
The component or assembly weighs greater than 23 kg [50 lbs]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

⚠CAUTION⚠
Do not use an air tool to tighten the V-band clamp. An air tool will damage the threads.

Install new gaskets on the inlet and outlet of the exhaust gas aftertreatment DOC.

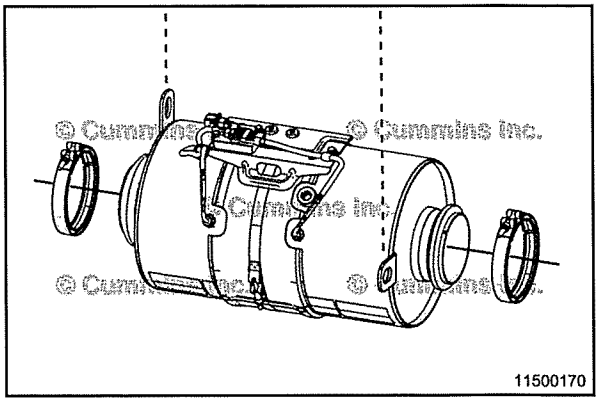
Apply a coat of anti-seize compound on the threads of the V-band clamps.

Install the aftertreatment DOC.

Tighten the V-band clamp used to secure the inlet of the aftertreatment DOC to the exhaust pipes.

Torque Value: 13.5 N•m [120 in-lb]

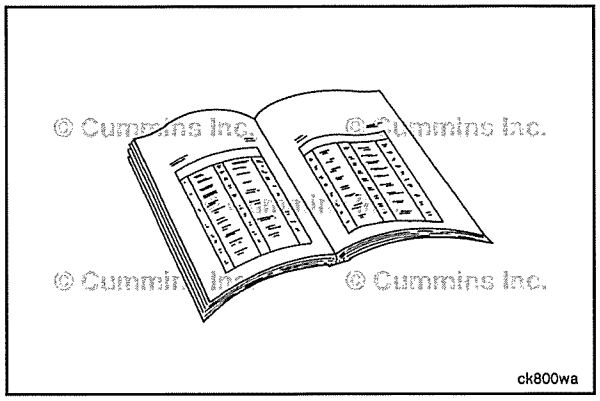
If necessary, install any additional mounting hardware that was used to secure the aftertreatment DOC to the vehicle.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the aftertreatment DEF decomposition tube, if removed. Refer to Procedure 011-062 in Section 11.
- Connect the OEM wiring harness to the aftertreatment interface harness.
- Install the aftertreatment inlet NOx sensor probe. Refer to Procedure 019-463 in Section 19.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for fault codes and exhaust leaks.

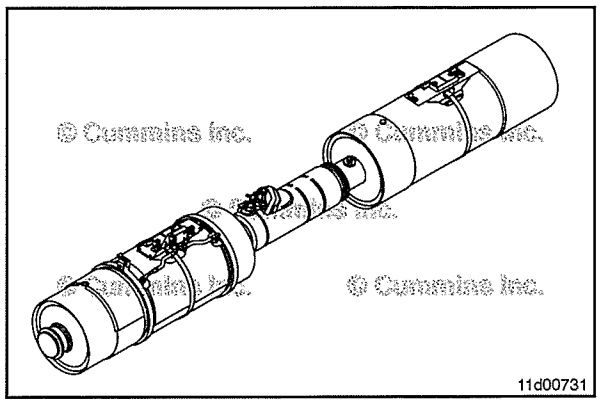


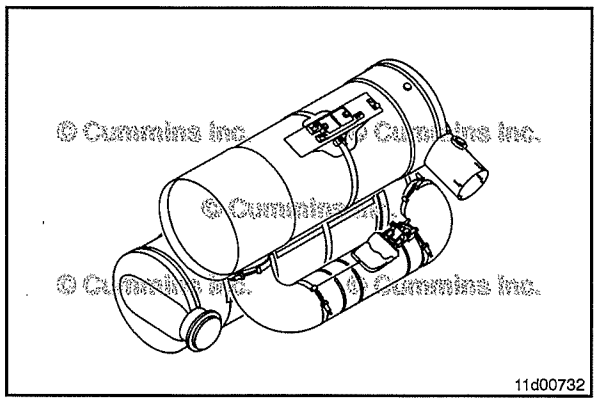
Aftertreatment System (011-050)

General Information

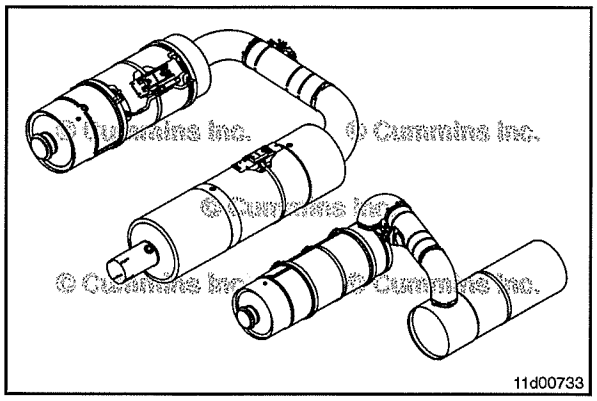
The aftertreatment system configuration will vary depending on the vehicle type and/or manufacturer. Some of the more common aftertreatment configurations are:

- Inline Horizontal - the selective catalytic reduction (SCR) assembly is aligned with and directly behind the diesel oxidation catalyst (DOC).

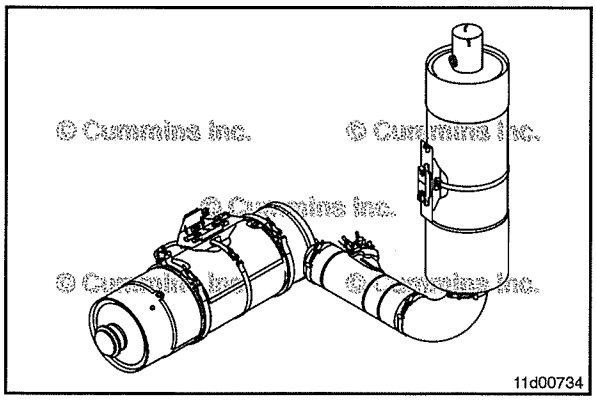




- Switchback - the DOC and SCR assembly are side-by-side so that the aftertreatment system can fit in a small area such as underneath the side steps of the vehicle.



- Horizontal - the DOC and SCR assemblies are on opposite sides of the chassis.
- Crossover - the DOC and SCR assemblies are on opposite sides of the chassis.



- Horizontal to Vertical - the DOC assembly is horizontal and then transitions to a vertical SCR assembly.

NOTE: The illustration is depicting some common arrangements.

For some aftertreatment systems, if required, the entire aftertreatment system can be removed as a complete assembly. Refer to the OEM service manual.

In many cases the aftertreatment system **must** be removed component by component. See the appropriate procedures in the section for removal and installation information.

Use the following procedure for more detailed information about the aftertreatment system. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-999 in Section F. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-999 in Section F.

Exhaust System Diagnostics (011-056)

General Information

The following procedure contains troubleshooting steps and information regarding the aftertreatment system.

Leaks in the exhaust system can cause exhaust odor or white smoke.

Inspect the exhaust piping for leaks, cracks, and loose connections. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 010-024 in Section 10. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 010-024 in Section 10.

Tighten the exhaust clamps, if necessary. Refer to the original equipment manufacturer (OEM) service manual for the correct torque value.

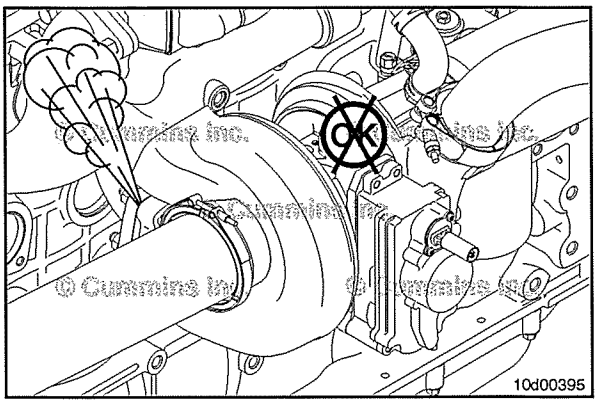
It may be necessary to perform a manual (non-mission) selective catalytic reduction (SCR)/exhaust system cleaning to locate exhaust leaks. Refer to Procedure 014-015 in Section 14.

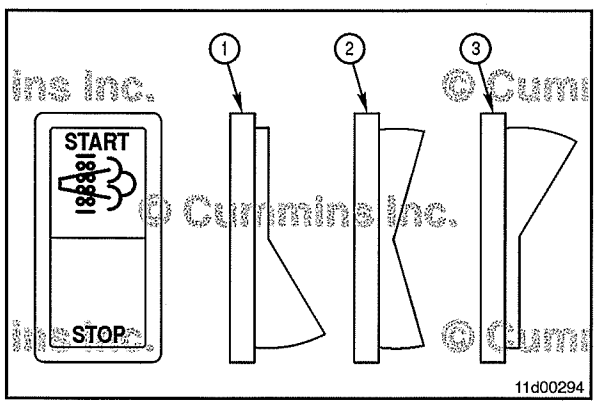
NOTE: The start and permit switches, as well as the SCR/exhaust system cleaning lamp, are common with other Cummins system utilizing a diesel particulate filter. Some OEMs, documentation, and tools may reference these as Aftertreatent Diesel Particulate Filter Regeneration or Aftertreatment Regeneration parameters.

The ambient temperature affects the length of time it will take to perform a manual (non-mission) SCR/exhaust system cleaning, because the engine **must** work harder to increase the exhaust temperatures to the appropriate levels in cold ambient temperatures.

In cold ambient temperatures (approximately -18°C [0°F] or colder), manual (non-mission) SCR/exhaust system cleaning may take longer to complete. In extremely cold ambient temperatures, manual (non-mission) SCR/exhaust system cleaning may **not** complete.

In these cases, it may be necessary to warm the engine to operating temperature before starting the manual (non-mission) SCR/exhaust system cleaning, or to move the vehicle/equipment to a location with higher ambient temperatures.





The vehicle/equipment manufacturer has installed a start switch to control the SCR/exhaust system cleaning function. Some manufacturers have also installed a permit switch.

The start switch (called the SCR System Cleaning Start Switch in INSITE™ electronic service tool) is used to start a manual (non-mission) SCR/exhaust system cleaning. The vehicle/equipment manufacturer may also reference this switch as a "manual SCR/exhaust system cleaning switch", "start switch", "non-mission SCR/exhaust system cleaning switch", or "SCR system cleaning switch".

The permit switch (called the SCR System Cleaning Permit Switch in INSITE™ electronic service tool) is used to allow the operator to disable active SCR/exhaust system cleaning, if necessary. The vehicle/equipment manufacturer may also reference this switch as an "inhibit switch", "stop switch", or "disable switch".

Either the start or the permit switch can be hardwired to the engine control module (ECM), or multiplexed over J1939 multiplexing.

If the start switch is hardwired, it shares an ECM pin with the diagnostic switch. When the switch is turned ON and the engine is OFF, the ECM interprets this signal as the diagnostic switch. When the switch is turned ON and the engine is operating, the ECM interprets this signal as the start switch.

If the start switch is J1939-multiplexed, the signal for this switch is broadcast over the J1939 data link.

A J1939-multiplexed start switch signal has priority over a hardwired start switch signal. Therefore, if the start switch is enabled over J1939, the hardwired signal is ignored by the engine ECM.

The default setting for the start switch is OFF. If the start switch is enabled in INSITE™ electronic service tool, but no switch is installed (either hardwired or J1939-multiplexed), the switch status will remain OFF.

The position of the start switch can be monitored with INSITE™ electronic service tool in the data monitor/logger screen.

A J1939-multiplexed permit switch signal has priority over a hardwired start switch signal, so if the permit switch is enabled over J1939, the hardwired signal is ignored by the engine ECM. If the permit switch is multiplexed, and therefore enabled, in the J1939 section of Features and Parameters in INSITE electronic service tool, it **must** also be enabled in the aftertreatment section of Features and Parameters in INSITE electronic service tool. If it is **not**, SCR/exhaust system cleaning will be inhibited.

The position of the permit switch can be monitored with INSITE™ electronic service tool in the Data Monitor/Logger screen:

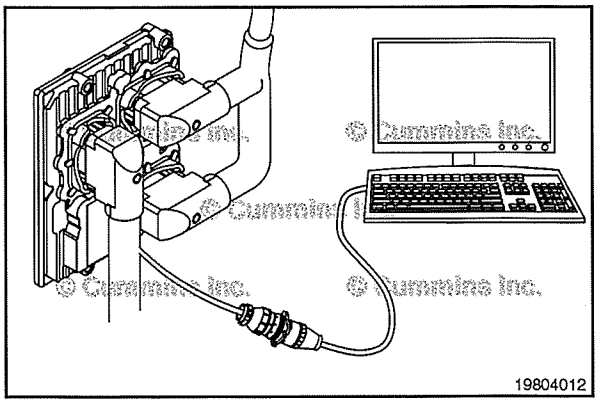
- When the permit switch is ON, active SCR/exhaust system cleaning is allowed.
- When the permit switch is OFF, active SCR/exhaust system cleaning is **not** allowed.

NOTE: If there is no permit switch installed and the permit switch is disabled in the J1939 section and aftertreatment sections of Features and Parameters in INSITE™ electronic service tool, the permit switch status in the Data Monitor/Logger screen will show the permit switch is OFF, but active SCR/exhaust system cleaning will be allowed.

The default setting for the permit switch is ON. If the permit switch is enabled in INSITE™ electronic service tool, but no switch is installed (either hardwired or J1939-multiplexed), the switch status will remain ON.

If the vehicle/equipment is operated for an extended period of time with the permit switch OFF, fault codes for the aftertreatment diagnostics may result.

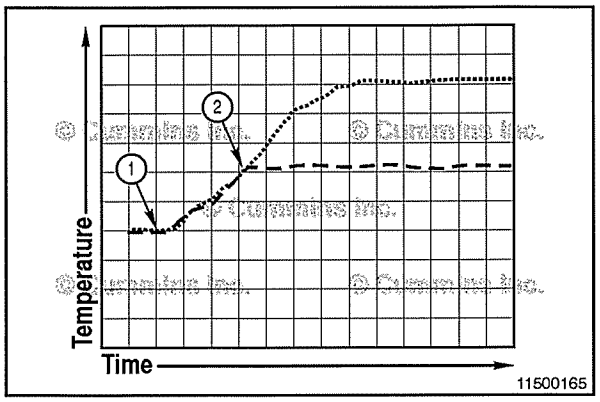
If the aftertreatment exhaust gas temperature sensors are **not** connected properly, or if the wiring in the harness between the engine and aftertreatment is **not** correct, the engine may experience frequent SCR/exhaust system cleaning lamp illuminations, or manual (non-mission) SCR/exhaust system cleaning that do **not** complete.



The aftertreatment sensors link to the ECM over J1939. See the appropriate fault code troubleshooting manual to diagnose and troubleshoot fault codes.

- QSB6.7 CM2350 B105 Fault Code Troubleshooting Manual, Bulletin 4332777.
- QSL9 CM2350 L102 Fault Code Troubleshooting Manual, Bulletin 4332795.

When performing a manual (non-mission) SCR/exhaust system cleaning, monitor the exhaust temperatures in the aftertreatment system to determine why a manual (non-mission) SCR/exhaust system cleaning will **not** complete.



Possible causes for manual (non-mission) SCR/exhaust system cleanings that will **not** complete include:

- A plugged aftertreatment diesel oxidation catalyst (DOC)
- A malfunctioning turbocharger
- Exhaust leaks between the engine and the aftertreatment system
- Very low ambient temperatures (less than -18°C [0°F]).

A normal manual (non-mission) SCR/exhaust system cleaning will follow the pattern shown.

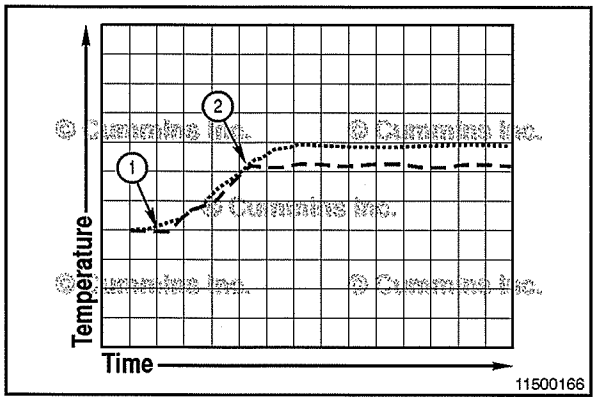
- The dashed line is for the aftertreatment DOC inlet temperature sensor.
- The dotted line is for the aftertreatment DOC outlet temperature sensor.

When the manual (non-mission) SCR/exhaust system cleaning begins (1), both temperatures should be approximately the same, and should increase at the same rate.

Aftertreatment injection begins when all three temperatures reach approximately 250°C [482°F] (2).

Once aftertreatment injection begins, the aftertreatment DOC inlet temperature may vary slightly, but will typically remain between 225 and 399°C [437 and 750°F].

The aftertreatment DOC outlet temperature will increase to approximately 482 to 649°C [900 to 1200°F]. The temperatures may vary during the manual (non-mission) SCR/exhaust system cleaning as the amount of fuel injected during aftertreatment injection is changed to maintain a constant temperature.



This graph illustrates a manual (non-mission) SCR/ exhaust system cleaning where the inlet of the aftertreatment DOC is blocked.

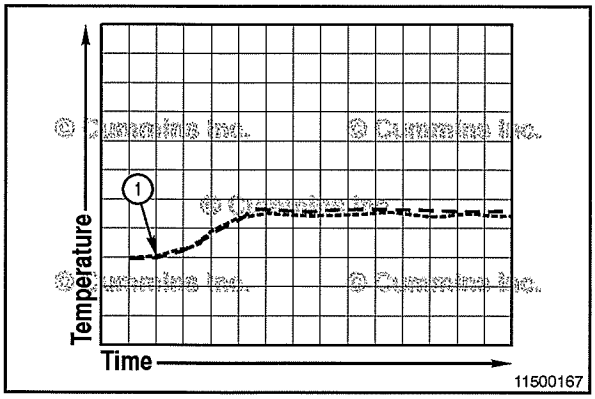
- The dashed line is for the aftertreatment DOC inlet temperature sensor.
- The dotted line is for the aftertreatment DOC outlet temperature sensor.

In this condition, the engine speed will increase to the manual (non-mission) SCR/exhaust system cleaning speed of 1000 to 1100 rpm.

Raising the aftertreatment temperature to the aftertreatment injection temperature may take longer to complete than normal if the inlet to the aftertreatment DOC is plugged, restricting some of the exhaust flow.

Once aftertreatment injection begins (2), the aftertreatment DOC inlet and outlet temperatures will differ greatly due to the plugged aftertreatment DOC being unable to oxidize the injected fuel. It is possible that white smoke would be present from the vehicle/equipment tailpipe in this condition.

The possible cause of this condition is a plugged aftertreatment diesel oxidation catalyst. Use the following procedure to inspect the aftertreatment diesel oxidation catalyst. Refer to Procedure 011-049 in Section 11.



This graph illustrates a manual (non-mission) SCR/ exhaust system cleaning where the engine can **not** build enough heat to start aftertreatment injection.

- The dashed line is for the aftertreatment DOC inlet temperature sensor.
- The dotted line is for the aftertreatment DOC outlet temperature sensor.

The engine speed will likely increase to the manual (non-mission) SCR/exhaust system cleaning speed of 1000 to 1100 rpm, but because the aftertreatment temperatures do **not** increase enough to start aftertreatment injection, the manual (non-mission) SCR/exhaust system cleaning will **not** complete.

Possible causes of this issue include:

- Low ambient temperatures. Move the vehicle/ equipment to a location with higher ambient temperatures.
- A malfunctioning turbocharger. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 010-134 in Section 10. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 010-134 in Section 10.

Test

NOTE: This section of the procedure provides information for testing the diesel exhaust fluid (DEF) concentration.

⚠WARNING⚠
It is unlawful to tamper with or remove any component of the aftertreatment system. It is also unlawful to use a DEF that does not meet the specifications provided or to operate the vehicle/ equipment without DEF.

⚠WARNING⚠
The DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

⚠CAUTION⚠
Never add water or any other fluid besides what is specified to the DEF tank. The aftertreatment system may be damaged.

The correct concentration of DEF is critical to the engine and aftertreatment system for correct performance.

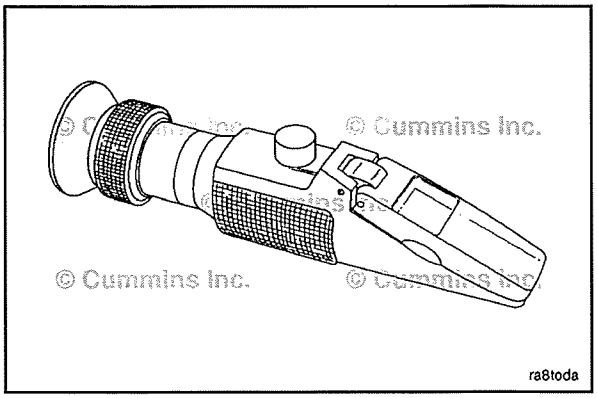
Cummins Inc. is **not** responsible for malfunctions or damage resulting from what Cummins Inc. determines to be abuse or neglect. This includes, but is **not** limited to: operation without correctly specified DEF, lack of maintenance of the aftertreatment system, improper storage or shutdown practices, or unauthorized modifications of the engine and aftertreatment system. Cummins Inc. is also **not** responsible for malfunctions caused by incorrect DEF, water, dirt, or other contaminants in the DEF. Use the Cummins® DEF refractometer, Part Number 4919554, to test the concentration of the DEF. Follow the instructions provided with the service tool.

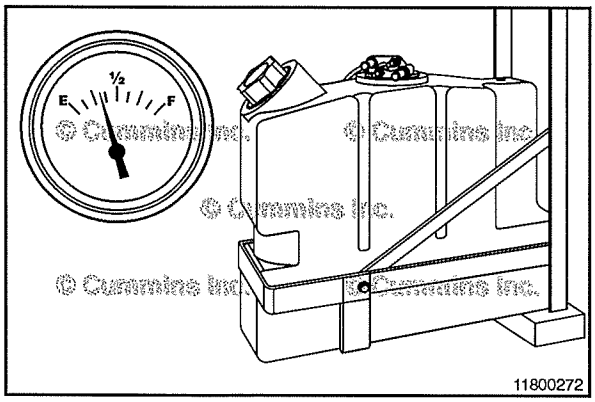
The concentration of the DEF **must** be 32.5 ± 0.7 percent.

If the DEF concentration does **not** meet this specification, drain the DEF tank, flush the tank with distilled water, and fill the tank with new and/or known good DEF. Check the DEF concentration.

Concentration of the DEF should be checked when:

- The vehicle has been stored for an extended period of time.
- It is suspected that water has been added to the DEF tank.
- It is suspected that water has evaporated from the DEF tank.
- The DEF filler cap has been removed from the tank for any extended period of time.





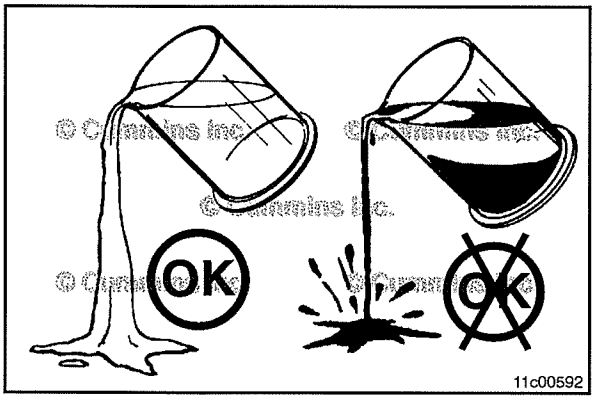
Contamination/Incorrect Fluid

DEF can become contaminated by the following situations:

- If equipped, the aftertreatment DEF tank coolant heating system malfunctions, allowing coolant to mix with the DEF.
- The aftertreatment DEF tank cap is missing or damaged, or the tank vent malfunctions.
- The aftertreatment DEF tank is filled with the incorrect fluid.

In the event that the DEF becomes contaminated, inspect the DEF to determine the most likely source.

Obtain a sample from the DEF tank and pour the sample into an appropriate container. Make sure to get a sample from the highest fluid level.

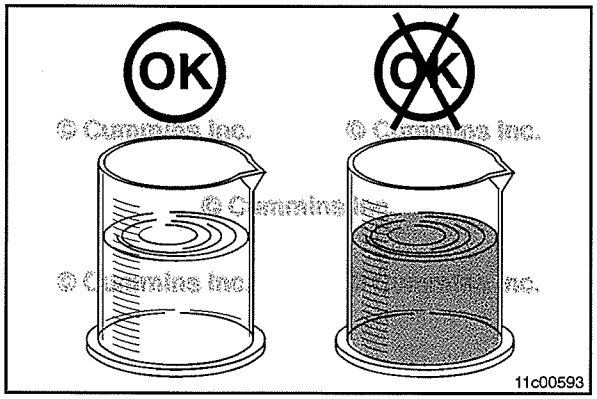


Petroleum based liquids, such as, but not limited to:

- Diesel fuel
- Hydraulic fluid
- Brake fluid.

Because DEF is largely composed of water, petroleum based liquids will separate from the DEF and rise to the top. Look for separation of the fluids, as well as characteristic smells.

If the DEF is contaminated, follow the steps detailed later in this procedure.



DEF can become contaminated by non-petroleum based liquids, such as, but not limited to:

- Water
- Coolant
- Windshield washer fluid.

If water has been added, the DEF will remain clear. As a result, the DEF will become diluted, reducing the concentration level.

NOTE: If **only** water has been added to the DEF tank, drain the DEF tank, flush with distilled water, and fill the tank with new and/or known good DEF. Check the DEF concentration after completing the refill. Follow the instructions in the Test section of this procedure.

For other non-petroleum based liquids that may have been added to the DEF, typically those fluids have coloring and will mix with DEF. If the DEF has a color tint to it, look for other fluids used on the vehicle that may match, such as coolant or windshield washer fluid.

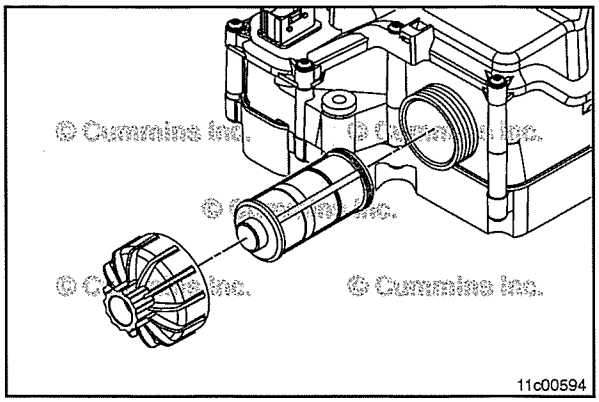
If the DEF is contaminated, follow the steps detailed later in this procedure.

NOTE: Use INSITE™ electronic service tool to view and troubleshoot any fault codes that occur during the following steps. Use the QSB6.7 CM2350 B105 Fault Code Troubleshooting Manual, Bulletin 4332777, or the QSL9 CM2350 L102 Fault Code Troubleshooting Manual, Bulletin 4332795. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 205-001 in Section L. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 205-001 in Section L.

If the DEF has been contaminated, remove the aftertreatment DEF dosing unit filter. Refer to Procedure 011-060 in Section 11. Inspect the filter for signs that the contaminated fluid went through the dosing system.

If the contaminated fluid did **not** go through the dosing system, drain the DEF tank and flush with distilled water. Replace any filters in the DEF tank. Refer to the OEM service manual for specific information on servicing the DEF tank.

After the DEF tank has been cleaned, fill the tank with new and/or known good DEF. Check the DEF concentration after completing the refill. Follow the instructions in the Test section of this procedure.



NOTE: Any discarded contaminated fluids and/or parts **must** be disposed of according to local area ordinances.

If the contaminated fluid did go through the dosing system:

1 Drain the DEF tank, flush with distilled water, and replace any filters in the DEF tank. Refer to the OEM service manual for specific information on servicing the DEF tank.

2 Replace the aftertreatment DEF dosing unit filter. Refer to Procedure 011-060 in Section 11.

3 Remove all of the aftertreatment DEF lines and flush with distilled water. Refer to the OEM service manual on the handling of contaminants in the aftertreatment DEF lines. Install the aftertreatment DEF lines.

4 Fill the aftertreatment DEF tank with distilled water.

5 Perform the INSITE™ electronic service tool DEF Doser Pump Override Test. Repeat the test until the distilled water runs clear.

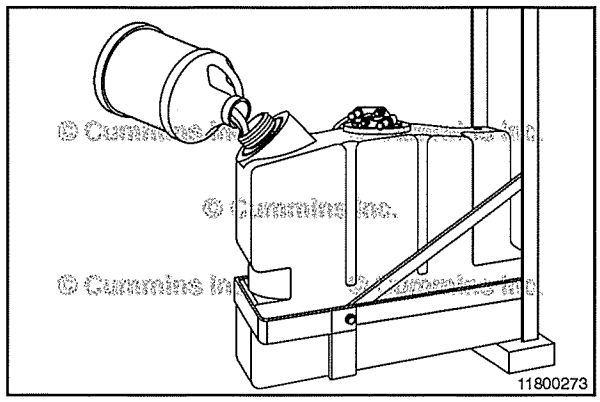
6 Drain the distilled water from the DEF tank and refill with new and/or known good DEF. Check the DEF concentration. Follow the instructions in the Test section of this procedure.

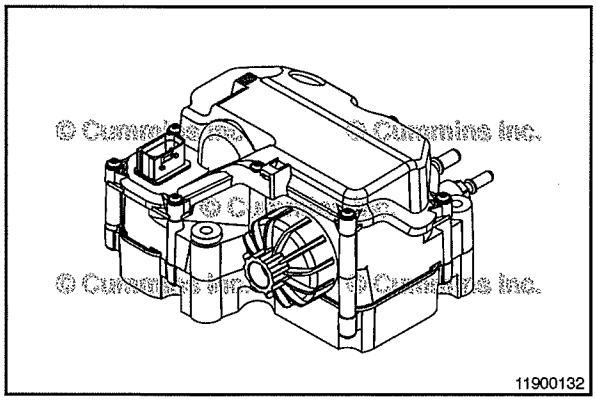
7 Replace the aftertreatment DEF dosing unit filter again. Refer to Procedure 011-060 in Section 11.

8 Perform the INSITE™ electronic service tool DEF Doser Pump Override Test. Test the performance and spray pattern of the aftertreatment DEF dosing valve.

- Perform a manual (non-mission) SCR/exhaust system cleaning. Refer to Procedure 014-015 in Section 14.

10 Test the vehicle for 30 minutes to verify system operation.





Aftertreatment Diesel Exhaust Fluid Dosing Unit (011-058)

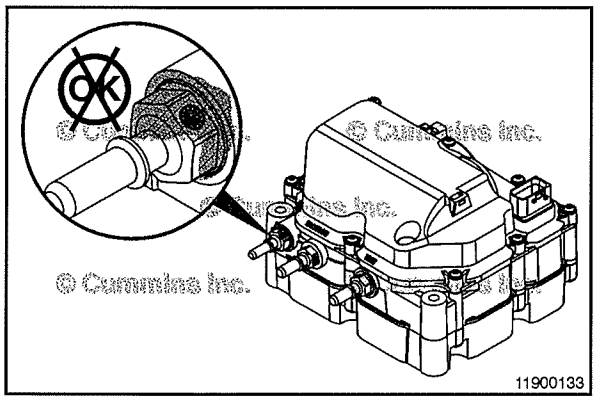
General Information

The aftertreatment diesel exhaust fluid (DEF) dosing unit draws DEF from the aftertreatment DEF tank, pressurizes the DEF, and delivers the DEF to the aftertreatment DEF dosing valve. Any unused DEF is then routed back to the aftertreatment DEF tank. Reference the following procedure for further information on the aftertreatment DEF dosing system. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-999 in Section F. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-999 in Section F.

Use the following procedure for information on handling incorrect or contaminated diesel exhaust fluid. Refer to Procedure 011-056 in Section 11.

NOTE: There are 12 volt and 24 volt versions of the DEF dosing unit. The voltage rating is stamped into the housing of the aftertreatment DEF dosing unit, next to the electrical connection. The aftertreatment DEF dosing unit can also be distinguished by the connector. If the face of the electrical connector on the electrical harness is gray, it is a 24 volt unit. If it is black, it is 12 volt unit. The electrical connectors are keyed differently and are **not** interchangeable.

NOTE: The aftertreatment DEF dosing unit has a serviceable filter. Refer to Procedure 011-060 in Section 11.



Initial Check

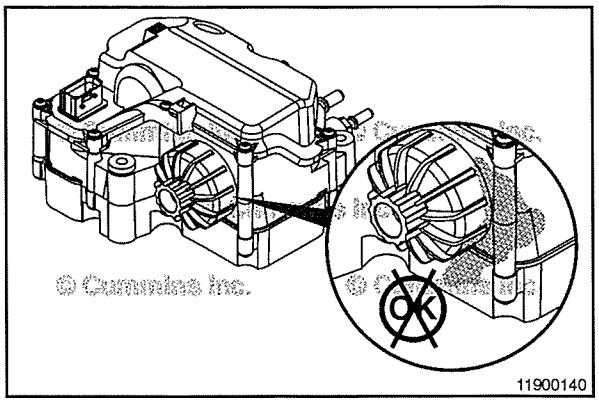
NOTE: Do **not** disconnect the vehicle batteries until the DEF dosing system has completed the purge cycle. Before beginning to remove and/or disconnect any components, wait at least five minutes after the keyswitch is turned OFF for the aftertreatment DEF dosing system to purge the DEF from the system. The purge cycle is an automatic process and does **not** require an intervention to occur. The aftertreatment DEF dosing unit will issue an audible pumping noise during the purging process.

Check the DEF lines to and from the dosing unit for signs of leakage. DEF forms a white deposit around leaky fittings.

If white deposits are found, inspect the DEF line connection fittings for damage. Refer to the original equipment manufacturer (OEM) service manual.

Check around the aftertreatment DEF dosing unit filter cap for white deposits.

Reference the Clean and Inspect for Reuse section of this procedure if leaks are visible from the aftertreatment DEF dosing unit line connectors or the filter cap.



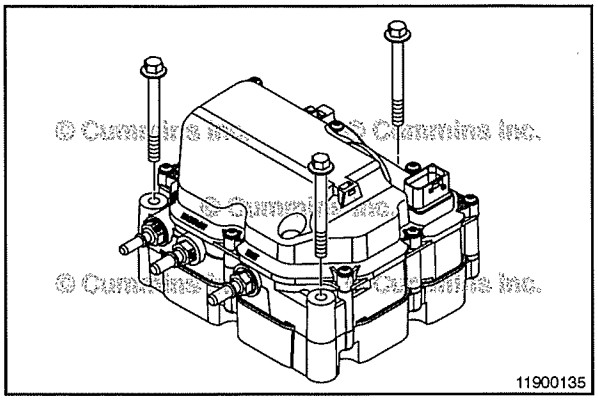
Test

Non Air Flush

NOTE: Make sure to prevent DEF from contaminating the electrical connector.

Remove the aftertreatment DEF dosing unit.

Thoroughly clean the aftertreatment DEF dosing unit.



NOTE: Remove the connector carefully to prevent debris from entering the inlet connector cavity.

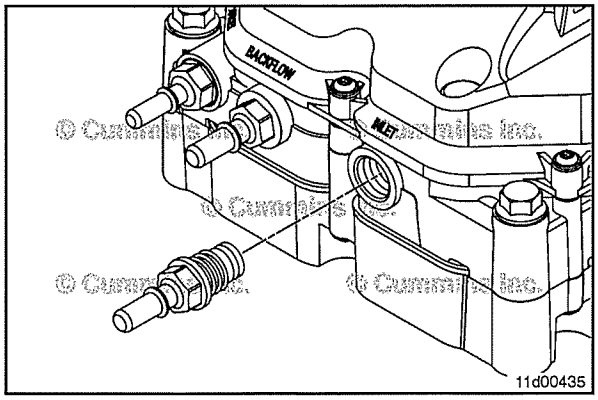
NOTE: Make sure the o-ring is attached to the connector and is **not** stuck inside the DEF dosing unit.

Remove the DEF inlet connector.

Discard the DEF inlet connector.

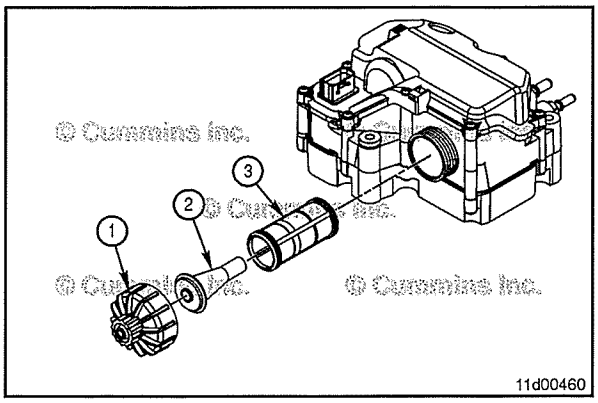
Install a new inlet connector. Lubricant is **not** required.

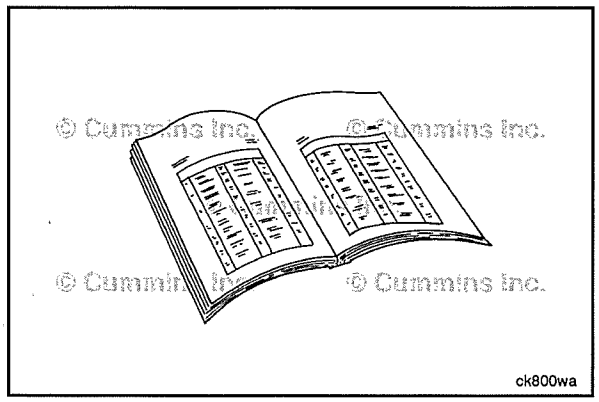
Torque Value: 4.5 N•m [40 in-lb]



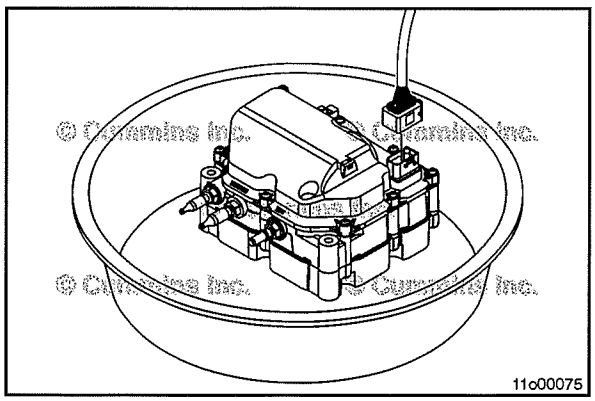
Remove the aftertreatment DEF dosing unit filter element. Refer to Procedure 011-060 in Section 11.

Do **not** install the new filter or install the DEF filter cap at this time.





If **not** completed, clean the DEF tank thoroughly and fill with certified DEF. Refer to the OEM service manual.

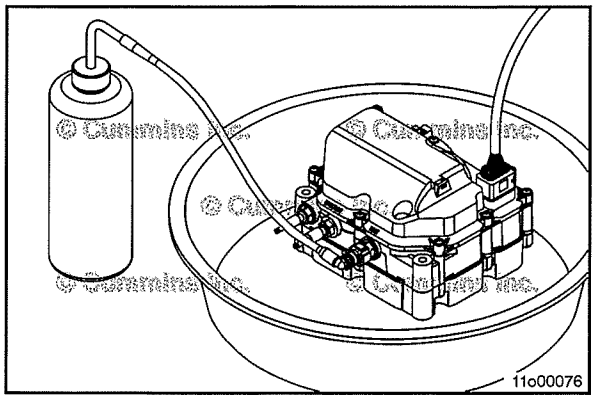


⚠CAUTION⚠
Make sure to support the aftertreatment DEF dosing unit so the unit is not suspended by the electrical connector.

NOTE: Make sure the electrical connections are clean and dry before installing.

Connect the 12-pin electrical connector on the aftertreatment DEF dosing unit.

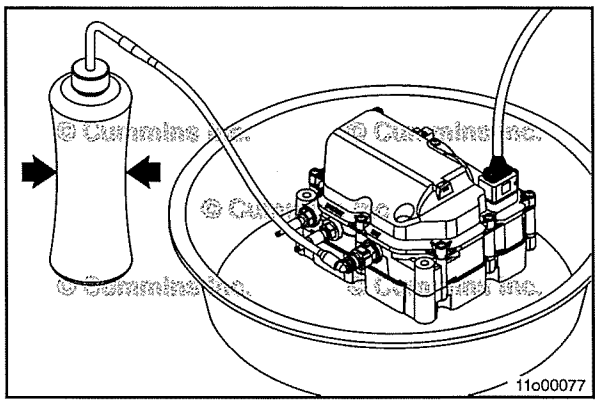
Position a collection container under the aftertreatment DEF dosing unit.



NOTE: Use distilled water if available, and make sure the filled fluid doser cleaner bottle is free of debris.

Fill the fluid doser cleaner bottle from the Fluid Doser Cleaner Kit, Part Number 5298533, with clean water and connect it to the aftertreatment DEF dosing unit inlet line connector.

Use INSITE™ electronic service tool DEF Doser Pump Override Test, found under ECM Diagnostic Tests, to flush clean water through the aftertreatment DEF dosing unit. Refer to Procedure 011-063 in Section 11.



Follow the on-screen instructions to perform the test.

NOTE: Only the fluid doser cleaner bottle and the 12-pin electrical connector are to be connected to the aftertreatment DEF dosing unit during this time.

Start the DEF Doser Pump Override Test.

Squeeze the fluid doser cleaner bottle gently to push water into the aftertreatment DEF dosing unit. The water will flow out from the DEF filter cap cavity.

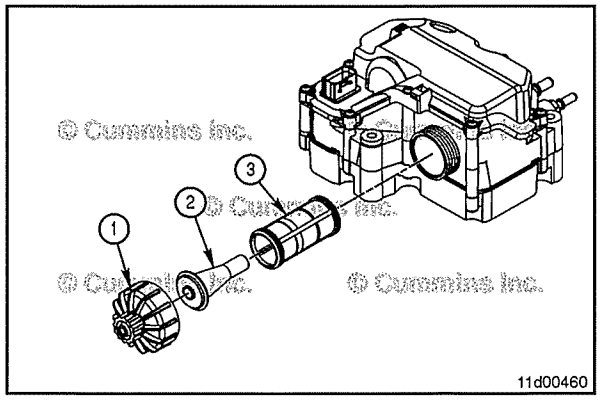
Repeat the procedure until the DEF dosing unit begins drawing fluid from the fluid doser cleaner bottle on its own.

The fluid doser cleaner bottle will start to collapse as the dosing unit starts drawing the fluid on its own. Once the aftertreatment DEF dosing unit is drawing fluid from the fluid doser cleaner bottle on its own, press the stop button on INSITE™ electronic service tool to stop the test.

NOTE: If the DEF dosing unit does **not** begin drawing fluid after three full bottles, then replace the DEF dosing unit.

Install a new aftertreatment DEF dosing unit filter element. Refer to Procedure 011-060 in Section 11.

NOTE: Lubrication of the DEF filter o-rings is **not** required.



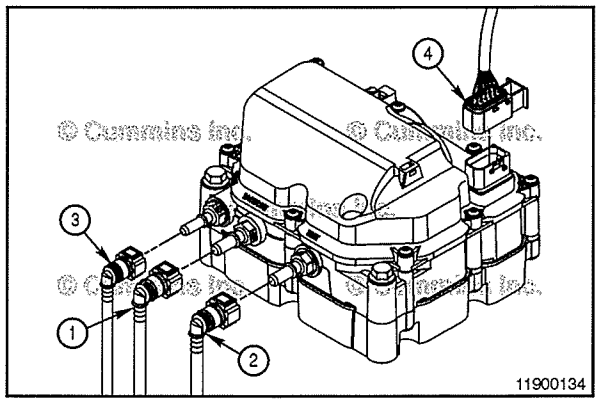
1 Slide the DEF filter equalizing element into the DEF filter cartridge.

2 Insert the assembly into the aftertreatement DEF dosing unit.

3 Install and tighten the cap.

Torque Value: 20 N•m [177 in-lb]

Connect the DEF lines to the aftertreatment DEF dosing unit in the following order to reduce the possibility of contamination of the electrical connector.



1 Backflow - DEF return to the DEF tank.

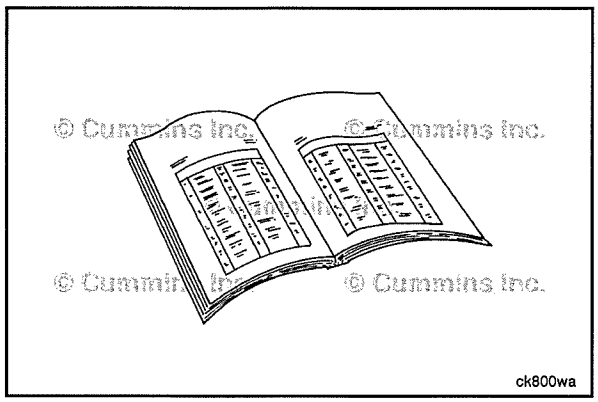
2 Inlet - DEF supply to the aftertreatment DEF dosing unit.

3 Outlet - DEF supply to the aftertreatment DEF dosing valve.

The DEF lines will snap when locked into place.

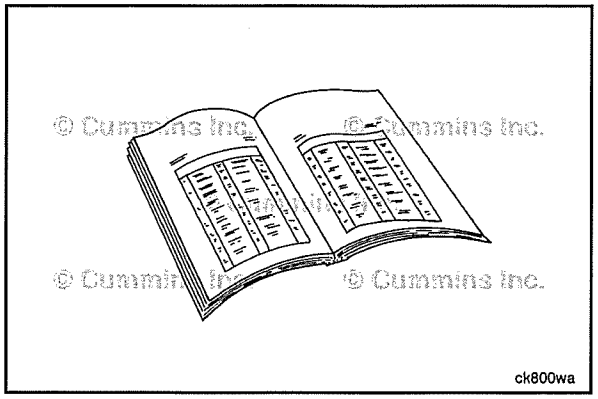
Lightly tug on the connectors to make sure they are secured.

NOTE: Do **not** mount the aftertreatment DEF dosing unit to the OEM mounting bracket at this time.



Perform the Aftertreatment DEF Dosing Unit Override Test to verify operation. Refer to Procedure 011-063 in Section 11.

If the measured volume of the aftertreatment DEF dosing unit is within specification, install the DEF dosing unit.



Preparatory Steps

⚠WARNING⚠
DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
The DEF line connecting the aftertreatment DEF dosing unit tank to the aftertreatment DEF dosing unit is under low pressure and should not be disconnected while the engine is running or before the system has completed the purge process after engine shutdown. Disconnecting the DEF line while under low pressure could cause DEF to spray.

NOTE: Do **not** disconnect the vehicle batteries until the DEF dosing system has completed the purge cycle. Before beginning to remove and/or disconnect any components, wait at least 5 minutes after the keyswitch is turned OFF for the aftertreatment DEF dosing system to purge the DEF from the system. The purge cycle is an automatic process and does **not** require an intervention to occur. The aftertreatment DEF dosing unit will issue an audible pumping noise during the purging process.

NOTE: Do **not** pressure wash or steam clean this unit. Use compressed air to remove **any** loose debris.

- Disconnect the batteries. Refer to the OEM service manual.

NOTE: The DEF lines are connected to the dosing unit by quick release fittings that could vary among vehicle manufacturers. Refer to the OEM service manual for the detailed removal process.

- Label and mark each DEF line and its mating connector for the aftertreatment dosing unit. If the lines are connected incorrectly, the system will **not** function properly and will light a fault lamp.
- Disconnect the DEF lines and electrical connector in the following order to reduce the possibility of accidental DEF contamination of the electrical connector:

1 Backflow: DEF return to the DEF tank.

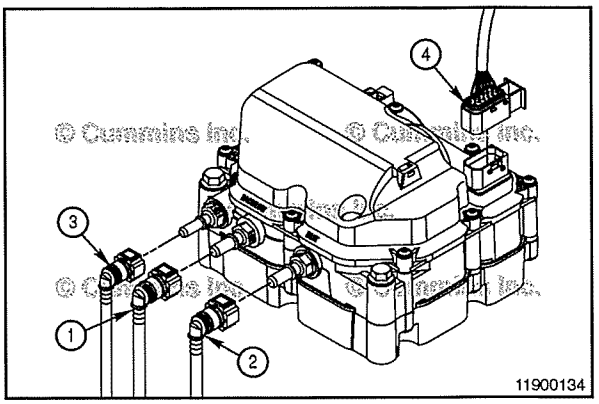
2 Inlet: DEF supply to the aftertreatment DEF dosing unit.

3 Outlet: DEF supply to the aftertreatment DEF dosing valve.

4 12-pin electrical connector.

The 12-pin electrical connector can be removed by sliding the yellow portion of the connector outward. The connector will then begin to rise and disconnect from the DEF supply module.

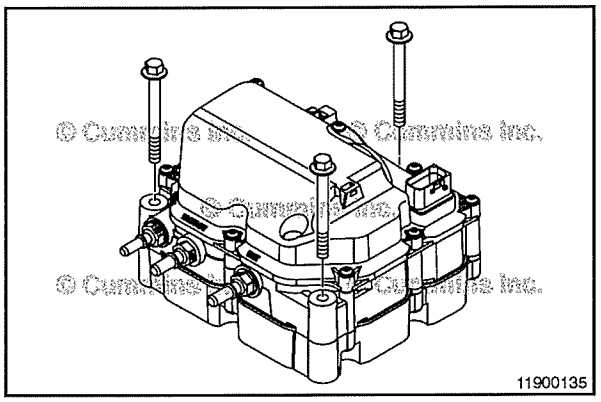
- Cap the DEF and electrical connectors of the aftertreatment DEF dosing unit to prevent contamination and DEF leakage.



Remove

Remove the three mounting capscrews.

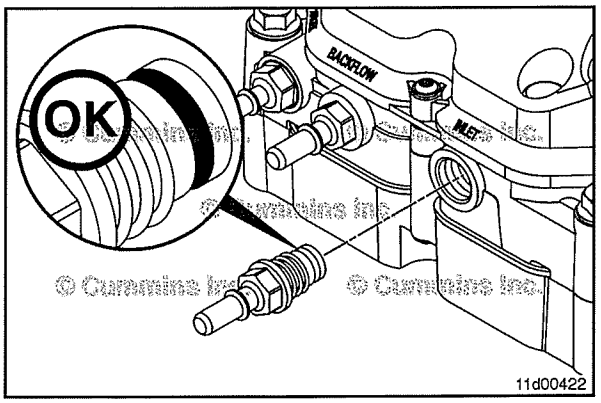
Remove the aftertreatment DEF dosing unit.

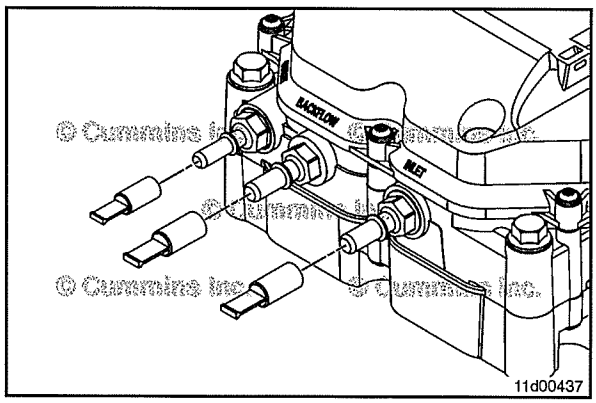


Disassemble

NOTE: The aftertreatment DEF dosing unit should **only** be disassembled if a symptom has been identified that indicates further investigation is required.

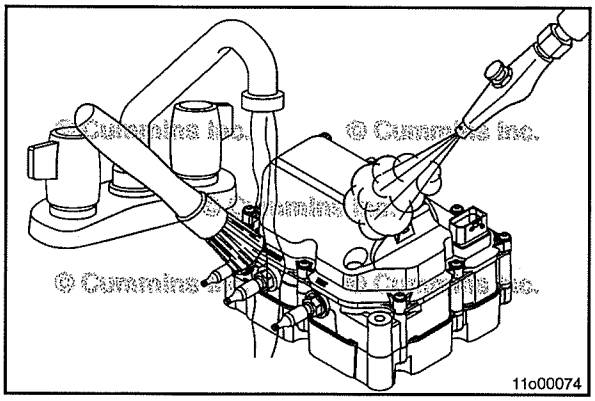
Remove the DEF connector(s). Make sure the o-ring(s) are attached to the connector(s) and are **not** stuck inside the DEF dosing unit.





Clean and Inspect for Reuse

Install the protective caps from the Fluid Doser Cleaner Kit, Part Number 5298533, on the fluid connector(s) and the electrical connector on the aftertreatment DEF dosing unit.



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: This unit is not serviceable. Do not open the case. Return the unit to a Cummins® Authorized Repair Location.

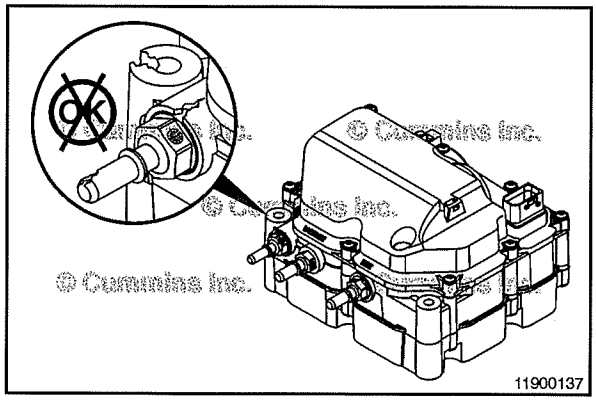
Do **not** immerse the unit in any kind of solution.

Do **not** wash with any detergents.

Clean the aftertreatment DEF dosing unit using **only** warm water and a soft bristled brush.

Thoroughly clean the areas surrounding the backflow connector, inlet connector, outlet connector, and main filter cap.

NOTE: Make sure that the protective caps remain on the DEFdosing unit electrical connection, backflow, inlet, and outlet connectors to prevent contamination.



NOTE: If damage or corrosion is found, also inspect the DEF line connection. Refer to the OEM service manual.

Inspect the outside of the unit. If there are any cracks or other damage to the exterior of the case or electrical connectors, replace the dosing unit.

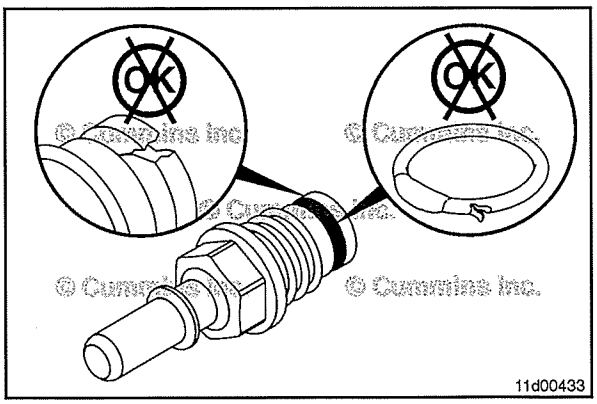
If there are any cracks or other damage to the DEF quick disconnect connectors, replace the DEF quick disconnect connectors.

Use the following procedure if the aftertreatment DEF dosing unit filter cap is damaged. Refer to Procedure 011-060 in Section 11.

Inspect the DEF line connection ports for cracks or pitting.

If the aftertreatment DEF dosing unit connectors were removed, inspect for cracks and broken o-rings.

Replace the aftertreatment DEF dosing unit connectors or o-rings, if damaged.

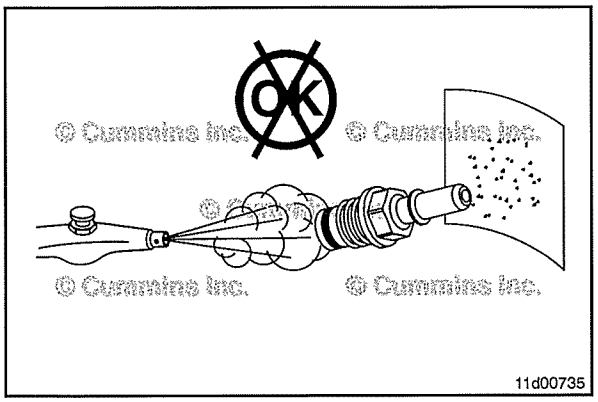


The inlet connector and the backflow connector on the aftertreatment DEF dosing unit have an incorporated non-serviceable filter screen.

Use a rubber tipped air gun and blow though the connector as shown, onto a piece of white paper.

Inspect for debris on the paper. Debris indicates a clogged connector.

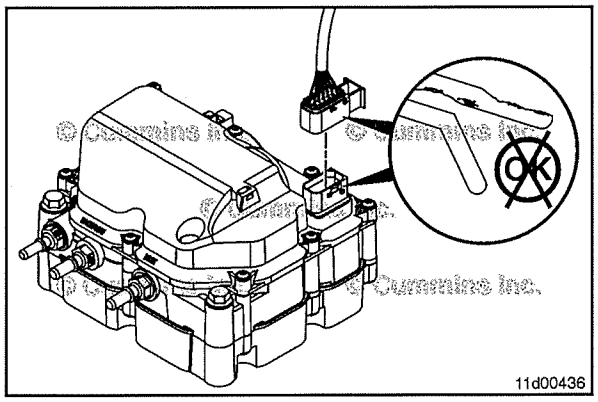
If debris is found in the inlet connector of the aftertreatment dosing valve, inspect the aftertreatment DEF tank filter. Refer to the OEM service manual.



Inspect the electrical connection of the aftertreatment DEF dosing unit for signs of corrosion and debris buildup.

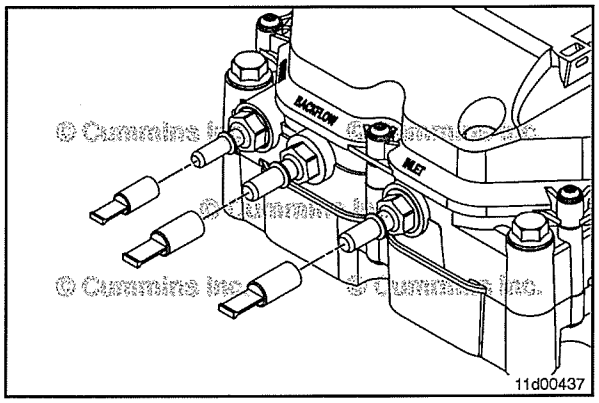
If the pins are heavily corroded or damaged, replace the aftertreatment dosing unit.

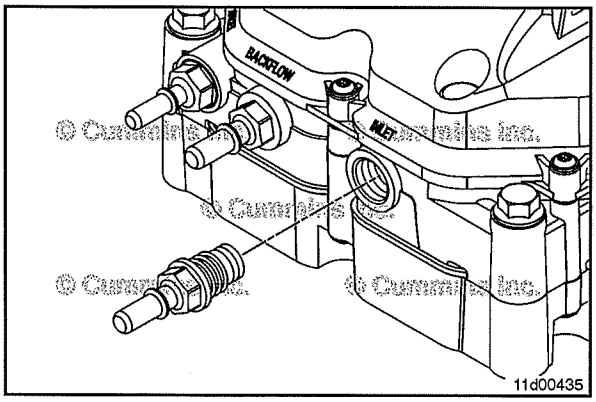
If the electrical connector on the aftertreatment DEF dosing unit is damaged, also inspect the 12-pin electrical connector wiring harness. Refer to the OEM service manual.



If replacing the aftertreatment DEF dosing unit, make sure to transfer the protective caps from the replacement aftertreatment DEF dosing unit to the old aftertreatment DEF dosing unit prior to placing it in the core return box.

Fill out any requested information: engine serial number (ESN), mileage, vehicle identification number (VIN), etc.



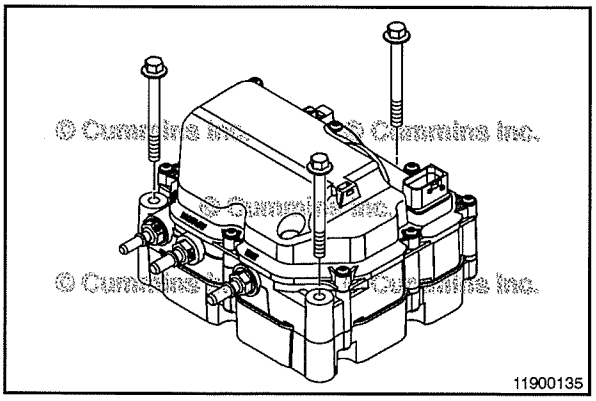


Assemble

NOTE: The backflow, inlet, and outlet connectors are **not** interchangeable and can **only** be installed one way due to thread and length restraints.

Install the connector. Lubricant is **not** required.

Torque Value: 4 N•m [35 in-lb]



Install

NOTE: Make sure the aftertreatment DEF dosing unit remains free from **any** contamination during installation to the vehicle. To reduce the possibility of false DEF leak reports, use a clean, damp cloth to wipe away **any** DEF that spilled during the repair process.

NOTE: Do **not** interchange 12 volt and 24 volt aftertreatment DEFdosing units.

Attach the aftertreatment DEF dosing unit to the OEM mounting bracket and secure it with the three capscrews.

Torque Value: 20 N•m [177 in-lb]

- Remove the caps from the electrical and DEF connectors.
- Install the electrical connector first. DEF will cause the electrical connector pins to corrode.
- The 12-pin electrical connector (4) can be installed by sliding the yellow portion of the connector inward. The connector will lower and lock onto the aftertreatment DEF dosing unit.
- Connect the DEF lines to the aftertreatment DEF dosing unit in the following order to reduce the possibility of contamination of the electrical connector. The DEF lines will snap when locked into place.

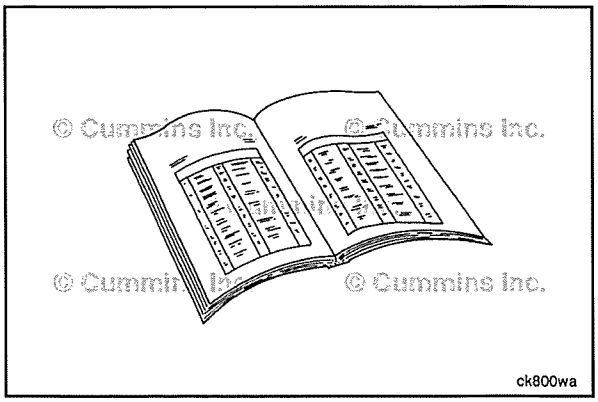
1 Backflow: DEF return to the DEF tank

2 Inlet: DEF supply to the aftertreatment DEF dosing unit

3 Outlet: DEF supply to the aftertreatment DEF dosing valve.

Lightly tug in the connectors to make sure they are secured.

Finishing Steps



⚠WARNING⚠

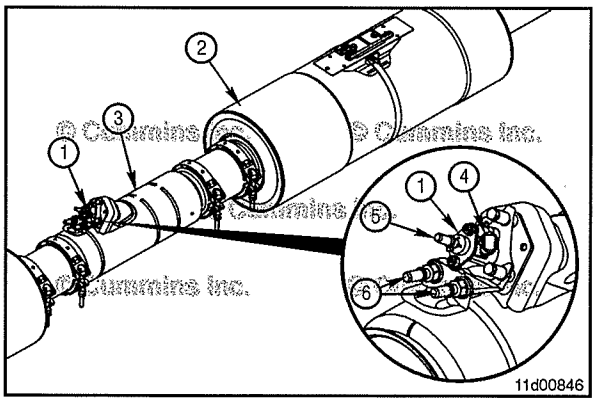
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠

Do not use the flow test portion of INSITE™ electronic service tool DEF Doser Pump Override Test to check the system for leaks. This will spray DEF into the exhaust system which is at too low a temperature to evaporate, resulting in deposit formations in the exhaust system.

NOTE: The aftertreatment DEF dosing system will **not** prime itself until the correct selective catalyst reduction temperatures are reached. To verify the system is correctly installed and has no leaks, induce a stationary regeneration or conditioning to raise the selective catalyst reduction system temperature. The dosing system status can be viewed in INSITE™ electronic service tool to confirm that the aftertreatment DEF dosing unit has reached a prime state.

- Connect the batteries. Refer to OEM service manual.
- Operate the engine and check for leaks.



Aftertreatment Diesel Exhaust Fluid Dosing Valve (011-059)

General Information

⚠CAUTION⚠

Use care when handling and/or disconnecting the DEF line from the aftertreatment DEF dosing valve. The DEF supply connector of the aftertreatment DEF dosing valve can be easily damaged.

The aftertreatment diesel exhaust fluid (DEF) dosing valve (1) is used to spray DEF into the exhaust flow prior to the intake of the selective catalytic reduction (SCR) catalyst (2). The aftertreatment DEF dosing valve is located on the decomposition tube (3), mounted on a flange with three capscrews.

NOTE: The same aftertreatment DEF dosing valve is used for 12 volt and 24 volt systems.

There are four primary connections at the aftertreatment DEF dosing valve:

(4) A 2-pin electrical connection, which connects the aftertreatment DEF dosing valve to the engine control module (ECM).

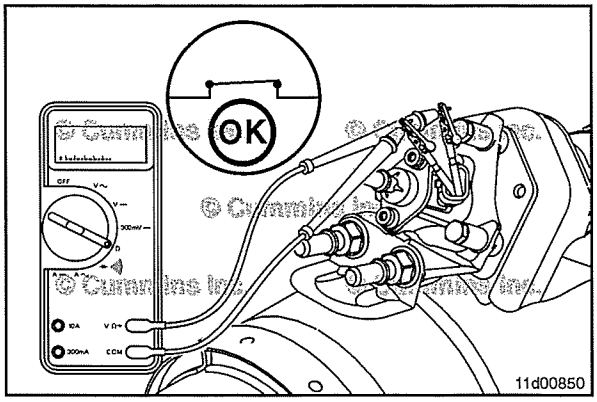
(5) A DEF supply line, which connects the aftertreatment DEF dosing valve to the aftertreatment DEF dosing unit.

(6) The coolant supply and return connections are interchangeable. They connect the aftertreatment DEF dosing valve to the engine cooling system.

For further information on the operation of the aftertreatment DEF dosing valve, reference the following procedure. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-999 in Section F. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-999 in Section F.

For information on handling incorrect or contaminated DEF, reference the following procedure. Refer to Procedure 011-056 in Section 11.

Measure



Resistance Check

Use a multimeter to check the resistance of the aftertreatment DEF dosing valve.

NOTE: Repair connector, Part Number 3164098 or equivalent, can be used as a test lead.

Resistance Specification: 11 to 18 ohms.

NOTE: The resistance **must** be measured at room temperature (approximately 25°C [77°F]).

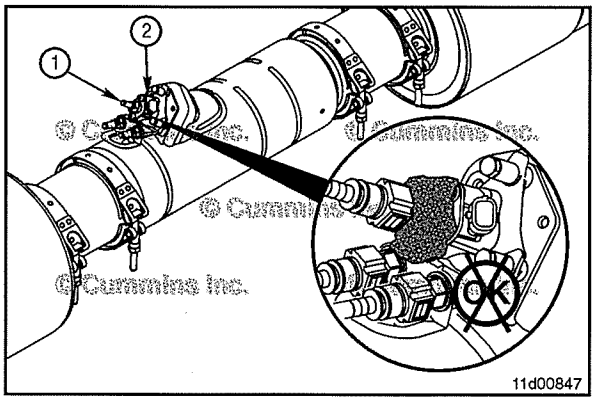
If the measured value is **not** within specifications, replace the aftertreatment DEF dosing valve.

If the measured resistance is out of specification, the aftertreatment DEF dosing valve may have been overheated.

Inspect the outside of the aftertreatment DEF dosing valve for signs of discoloration from excessive heat.

Inspect for inadequate or lack of coolant flow to the aftertreatment DEF dosing valve. Verify there are no leaks, blockages, or restrictions in the coolant supply and return lines between the engine and the aftertreatment DEF dosing valve.

To check the coolant passages internal to the aftertreatment DEF dosing valve, reference the Clean and Inspect for Reuse section of this procedure.



Initial Check

⚠WARNING⚠
During Selective Catalytic Reduction (SCR) system cleaning, exhaust gas temperature can reach 800°C [1500°F], and exhaust system surface temperature can exceed 700°C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

⚠CAUTION⚠
Do not use the flow test portion of INSITE™ electronic service tool Diesel Exhaust Fluid Doser Pump Override Test to check the system for leaks. This will spray DEF into the exhaust system at temperatures to low to evaporate, resulting in deposit formations in the exhaust system.

NOTE: DEF deposits could possibly be left over from a previous DEF spill or repair. Verify active leaks before replacing any components.

Inspect the area around the DEF line connection location at the aftertreatment DEF dosing valve.

Inspect for signs of leaks and/or white deposits.

A DEF leak in this area may come from:

1. The connection between the DEF line and the aftertreatment DEF dosing valve.

NOTE: Do **not** remove the DEF dosing valve (1) from the assembly (2). It is **not** a serviceable part.

2. The DEF dosing valve joints between the valve and the valve assembly body.

Due to deposit buildups possibly masking the source of the leak, it may be necessary to remove the deposits and clean the area with warm water.

NOTE: The aftertreatment DEF dosing system will **not** prime until the correct SCR temperatures are reached.

Test drive the vehicle for a minimum of 15 minutes to get the SCR system up to temperature. Check the area again for the source of the leak.

Once the source of the DEF leaks and/or deposits are identified, reference the Clean and Inspect for Reuse section of this procedure.

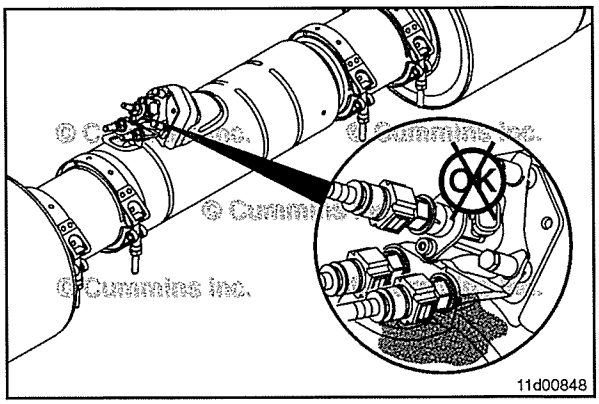
Inspect the dosing valve body and coolant fittings at the aftertreatment DEF dosing valve.

Inspect for signs of leaks and/or deposits.

If the aftertreatment DEF dosing valve is suspected to be leaking coolant and the source of the coolant leak can **not** be identified, pressurize the cooling system. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-020 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-020 in Section 8.

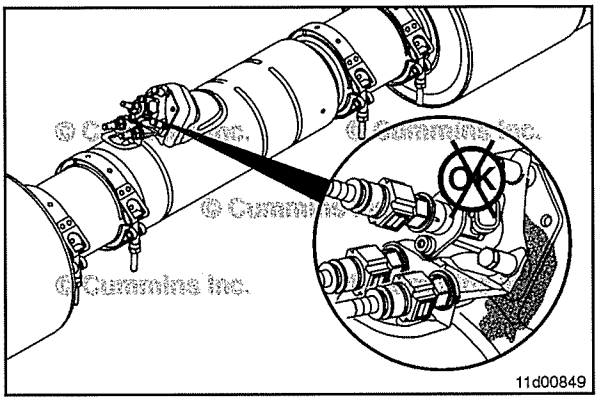
If leaks and/or deposits are identified, reference the Clean and Inspect for Reuse section of this procedure after the connections are removed.

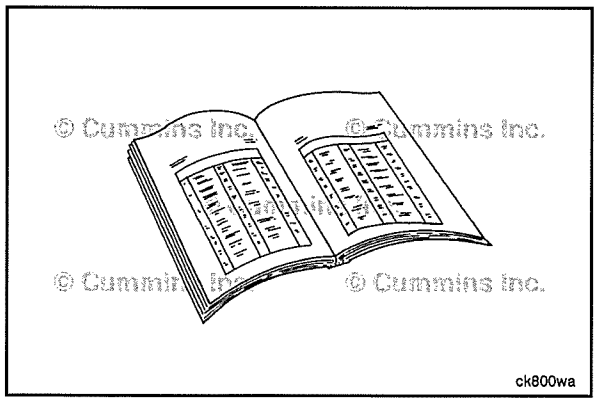
Service Tip: If removal of the coolant fittings and/or heat shield is necessary, remove/loosen the coolant fitting prior to removing the aftertreatment DEF dosing valve. Reference the Preparatory Steps and Disassemble sections of this procedure.



Inspect the body and around the base of the aftertreatment DEF dosing valve. Check for signs of exhaust leaks and white deposits.

If leaks and/or deposits are identified, reference the Clean and Inspect for Reuse section of this procedure.





Preparatory Steps

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

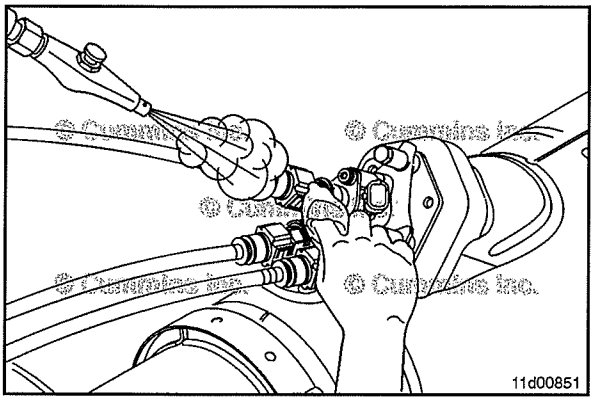
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
The DEF line connecting the aftertreatment DEF dosing unit to the aftertreatment DEF dosing valve is under low pressure and should not be disconnected while the engine is running or before the system has completed the purge process after engine shutdown. Disconnecting the DEF line while under low pressure could cause DEF to spray.

NOTE: Do **not** disconnect the vehicle batteries until the DEF dosing system has completed the purge cycle. Before beginning to remove and/or disconnect any components, wait at least 5 minutes after the keyswitch is turned OFF for the aftertreatment DEF dosing system to purge the DEF from the system. The purge cycle is an automatic process and does **not** require intervention to occur. The aftertreatment DEF dosing unit will create an audible pumping noise during the purging process.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.



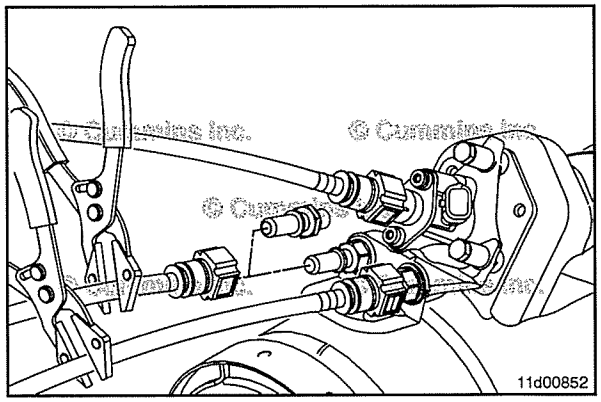
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use compressed air to remove any debris from around the aftertreatment DEF dosing valve and connections.

Remove any debris trapped in the gaps between the aftertreatment DEF dosing valve and the aftertreatment decomposition tube, so that debris does **not** fall into the aftertreatment decomposition tube upon removal of the aftertreatment DEF dosing valve.

If there are any white deposits on the DEF line connection, remove them by wiping with a clean shop towel soaked in warm water.

Do **not** drain the cooling system. Use one of the following two methods to prevent draining the cooling system when the aftertreatment DEF dosing valve coolant lines are disconnected.



Use the following instructions for method number 1.

NOTE: Prior to pursuing this method, inspect the aftertreatment DEF dosing valve coolant lines to make sure they are flexible hose material that will **not** be damaged when using the coolant hose pinch-off pliers.

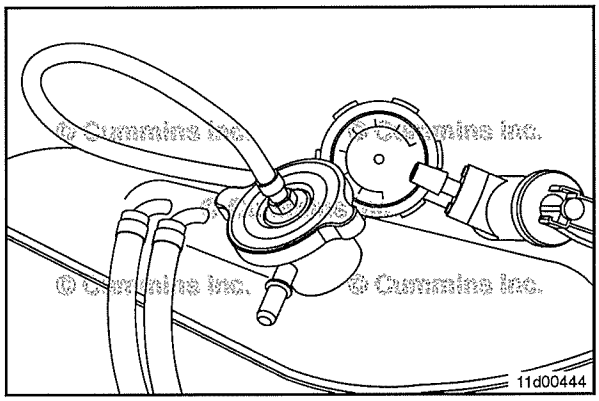
Use a pair of coolant hose pinch-off pliers. Clamp both of the aftertreatment DEF dosing valve coolant lines.

Place a container under the aftertreatment DEF dosing valve. A small quantity of coolant may drain from the coolant lines when disconnected.

NOTE: The coolant supply/return and DEF lines are supplied by the OEM. The removal of these lines may vary by OEM. The fittings on the aftertreatment DEF dosing valve are set up for quick disconnect style fittings.

Disconnect the coolant lines. Refer to the OEM service manual.

Insert coolant line plugs, Part Number 4919576, into the disconnected coolant lines. The coolant hose pinch-off pliers can be removed.



Use the following instructions for method number 2.

Determine the appropriate radiator/coolant expansion tank cap adapter for the vehicle being serviced. The list of available caps and applications can be found in Section 14 of the Service Products Catalog.

Install the adapter on the radiator/coolant expansion tank. Connect an automotive hand held vacuum pump and apply 76 mmHg [3 inHg] of vacuum.

NOTE: Depending on the cooling system configuration, more vacuum may be required to keep the cooling system in balance, especially on systems where there is a significant height difference between the aftertreatment DEF dosing valve and the radiator/coolant expansion tank fill location.

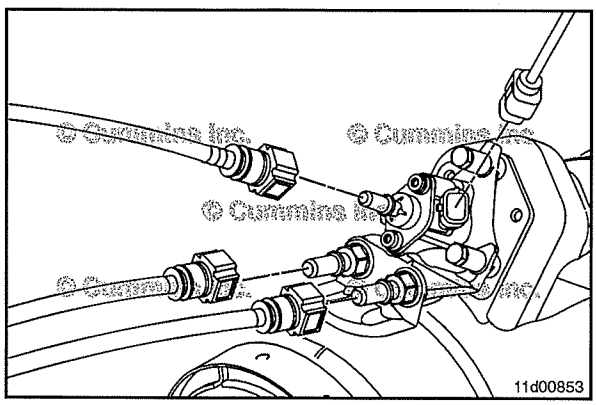
NOTE: The coolant supply and DEF lines are supplied by the OEM. The removal of these lines may vary by OEM. The fittings on the aftertreatment DEF dosing valve are set up for quick disconnect style fittings.

Place a container under the aftertreatment DEF dosing valve. A small quantity of coolant may drain from the coolant lines when disconnected.

Disconnect the coolant lines. Refer to the OEM service manual.

Insert coolant line plugs, Part Number 4919576 or equivalent, into each of the disconnected coolant lines.

The vacuum pump can be removed.



ΔCAUTIONΔ

Care should be taken when handling and/or disconnecting the DEF line from the aftertreatment DEF dosing valve. The DEF supply line connector of the aftertreatment DEF dosing valve can be easily damaged.

Disconnect the connections at the aftertreatment DEF dosing valve in the following order:

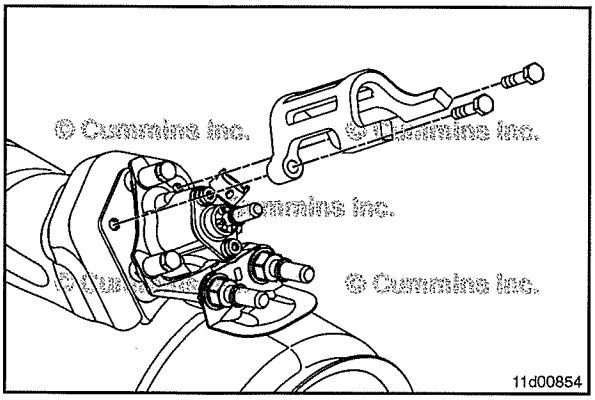
Place a small plastic container under the aftertreatment DEF dosing valve to catch any residual DEF prior to disconnecting the DEF supply line.

(1) Disconnect the DEF line. Refer to the OEM service manual.

NOTE: Protect the coolant and DEF ports with plastic caps to prevent entrance of dirt and debris.

Press the tab on the electrical connector and pull to disconnect the 2-pin electrical connector.

After the electrical connection is disconnected, cover the connection on the aftertreatment DEF dosing valve with electrical tape to prevent DEF from getting into the electrical connection.



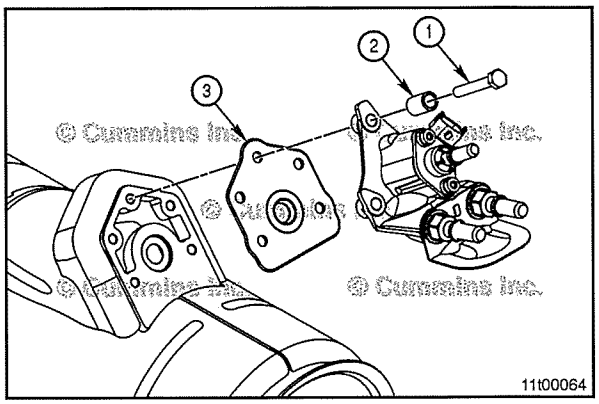
Remove

In some applications an aftertreatment DEF dosing valve guard can be installed around the dosing valve.

Remove the capscrews.

Remove the guard.

⚠CAUTION⚠
Do not set the aftertreatment DEF dosing valve down on the spray area of the aftertreatment DEF dosing valve. Damage can occur.



Remove the capscrews (1) and spacers (2) that mount the aftertreatment DEF dosing valve to the decomposition tube.

Remove the aftertreatment DEF dosing valve.

Remove the insulated gasket (3).

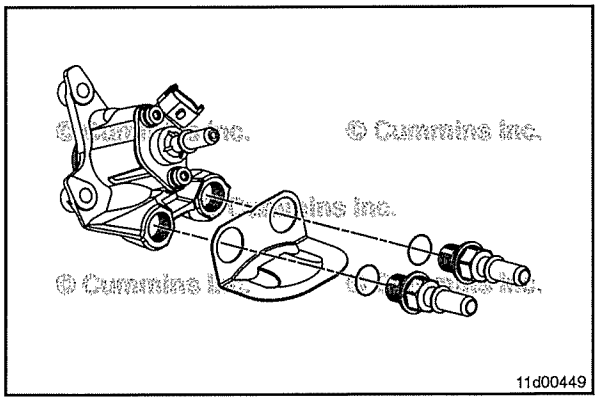
Remove the thermal isolator (4). The isolator can become brittle and adhere to either the aftertreatment decomposition tube or aftertreatment DEF dosing valve. Do **not** drop isolator material into the aftertreatment decomposition tube when removing. Apply water to the isolator to soften its composition. Use a pick and a shop vacuum to properly remove the isolator, if necessary.

Discard the gaskets and isolator.

NOTE: A small amount of DEF deposits is normal if observed on the aftertreatment DEF dosing valve face and around the isolator of the aftertreatment DEF dosing valve.

NOTE: Plug the aftertreatment DEF lines to reduce the possibility of debris entering the system.

Disassemble

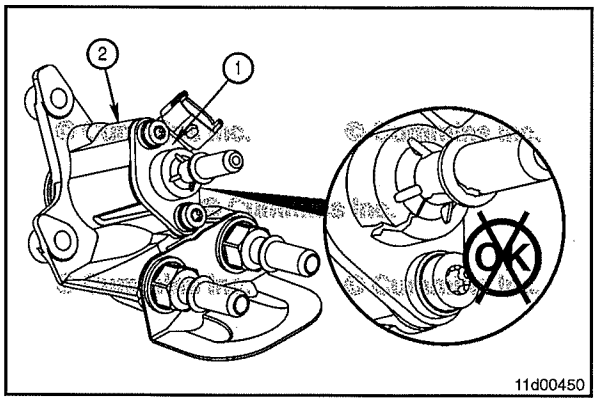


NOTE: The aftertreatment DEF dosing valve should **only** be disassembled if a symptom has been identified that indicates further investigation is required.

Remove the two coolant fittings from the aftertreatment DEF dosing valve.

Remove the o-rings from the coolant fittings and discard.

Remove the heat shield.



Clean and Inspect for Reuse

NOTE: Do **not** remove the DEF dosing valve (1) from the assembly (2). It is **not** a serviceable part.

If leaks/deposits are found at the DEF dosing valve joints between the valve and the valve assembly body during the Initial Check section of this procedure, replace the aftertreatment DEF dosing valve.

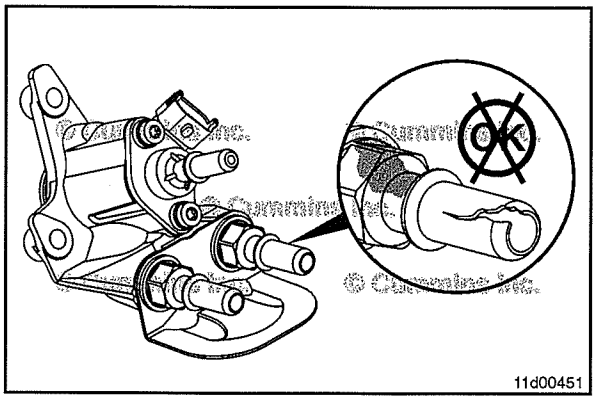
If leaks/deposits are found at the DEF line connection during the Initial Check section of this procedure, inspect the DEF line connection port for cracks or pitting.

NOTE: If damage/corrosion is found, also inspect the DEF line connection. Refer to the OEM service manual.

Inspect the electrical connection and pins for damage/ corrosion. Refer to Procedure 019-361 in Section 19.

NOTE: If damage/corrosion is found, inspect the electrical connector and pins on the vehicle harness. Refer to the OEM service manual.

Replace the aftertreatment DEF dosing valve if damage is found.



NOTE: The heat shield and coolant fittings are serviceable items of the aftertreatment DEF dosing valve.

If leaks/deposits are found at the coolant line connections during the Initial Check section of this procedure, inspect the coolant fittings for cracks and signs of corrosion and/ or pitting.

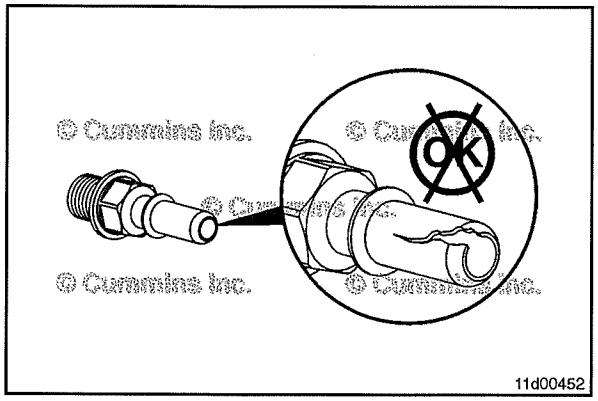
If corrosion is found, the coolant may be contaminated and/or the concentration incorrect. Check the coolant. For specifications, refer to Service Bulletin, Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.

NOTE: If damage/corrosion is found, inspect the coolant line connector(s). Refer to the OEM service manual.

Inspect the base of the coolant fittings.

Inspect the heat shield for cracks or heavy corrosion.

Replace as required. Reference the Disassemble section of this procedure.



If the coolant fittings were removed from the aftertreatment DEF dosing valve assembly, inspect the threads and o-ring sealing surfaces of the following for pitting and corrosion:

- Coolant fittings
- Coolant ports in the aftertreatment DEF dosing valve assembly.

Clean with an abrasive pad, Part Number 3823258 or equivalent, and a clean cloth.

If the pitting and/or corrosion can **not** be removed with the abrasive pad, replace the component.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacture's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠CAUTION⚠
Do not submerge the aftertreatment DEF dosing valve in solvent or water. Damage to the aftertreatment DEF dosing valve will result.

NOTE: If **not** already removed, remove the coolant fittings from the aftertreatment DEF dosing valve. Reference the Disassemble section of this procedure.

Clean the aftertreatment DEF dosing valve coolant passages with a safety solvent. Use a pipe cleaner to clean the passageways.

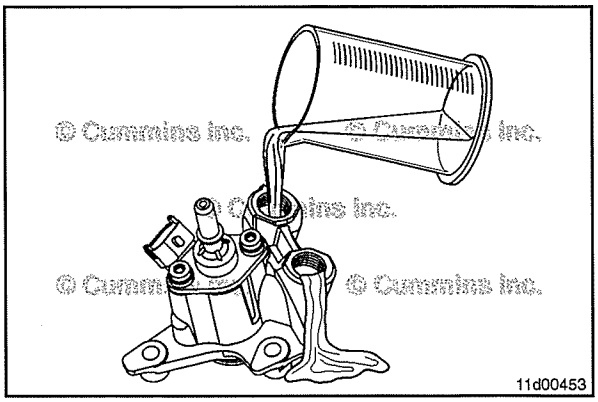
Do **not** spill solvent on the dosing valve.

With the aftertreatment DEF dosing valve positioned so the coolant ports are pointing upward, pour safety solvent in one coolant port until the safety solvent begins to flow out of the opposite port.

Tip the aftertreatment DEF dosing valve so the safety solvent flows out of the port **not** filled. Verify that the safety solvent flows out of this port as one continuous stream.

If safety solvent does **not** flow as one continuous stream, the coolant passage may still be restricted or blocked. Repeat the cleaning process again and inspect. If there is no change, replace the aftertreatment DEF dosing valve.

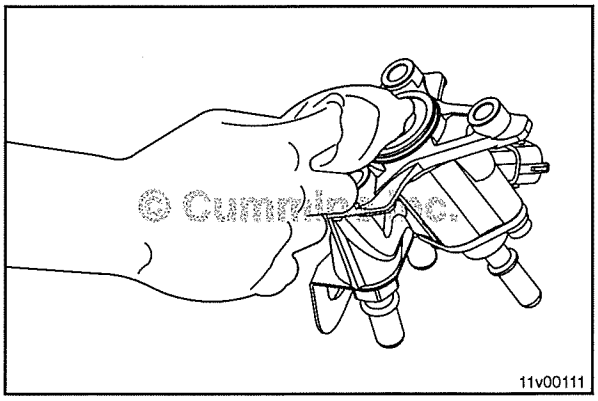
Dry with compressed air.

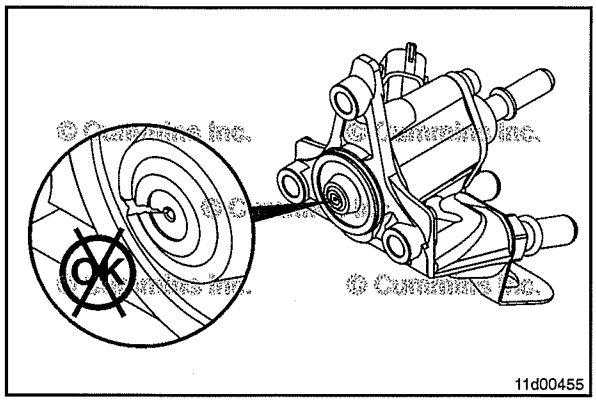


⚠CAUTION⚠
Use only a brass brush to clean the tip of the aftertreatment DEF dosing valve. The use of a wire wheel will cause permanent damage to the aftertreatment DEF dosing valve.

Use a brass brush and warm distilled water to clean the bottom and the tip of the aftertreatment DEF dosing valve.

Wipe any debris away with a clean shop towel soaked in distilled water.

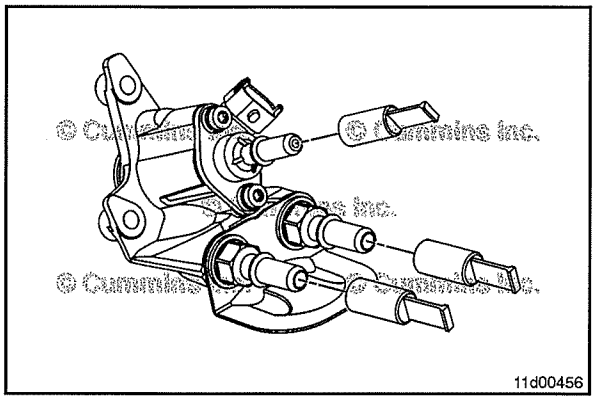




Inspect the dosing valve tip for cracks or other damage. Replace if damage is found.

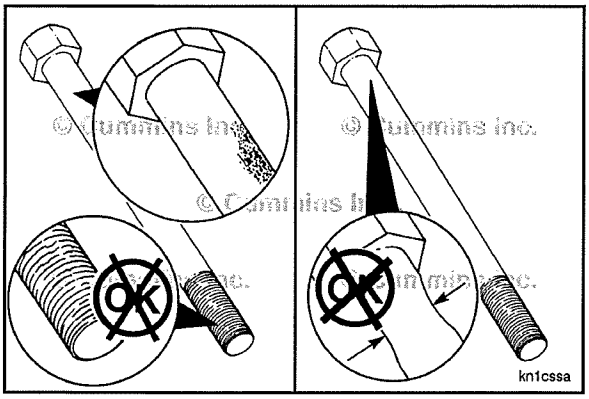
If leaks/deposits are found at the base of the aftertreatment DEF dosing valve during the Initial Check section of this procedure, inspect the following:

- The bottom of the aftertreatment DEF dosing valve around the gasket sealing surface for signs of heavy corrosion, pitting and/or surface damage. Replace the aftertreatment DEF dosing valve if damage is found.
- The aftertreatment DEF dosing valve mounting surface on the decomposition tube. Refer to Procedure 011-062 in Section 11.



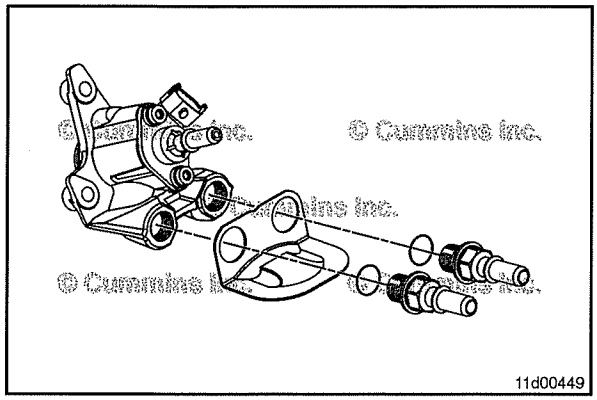
If replacing the aftertreatment DEF dosing valve, make sure to transfer the protective caps from the replacement aftertreatment DEF dosing valve to the old aftertreatment DEF dosing valve prior to putting it in the core return box.

Make sure to fill out any requested information (engine serial number (ESN), mileage, and vehicle identification number (VIN)).



Inspect the capscrews for damaged threads, corroded surfaces, or a reduced shank diameter (due to capscrew stretching).

Replace if damage is found.



Assemble

Install new o-rings onto the two coolant fittings. Lubricate the o-rings with assembly lubricant, Part Number 3163086 or equivalent.

Install the heat shield.

Install the coolant fittings onto the aftertreatment DEF dosing valve.

Tighten the coolant fittings.

Torque Value: 6 N•m [53 in-lb]

Service Tip: If removal of the coolant fittings and/or heat shield was necessary, install the coolant fittings after installing the aftertreatment DEF dosing valve. Reference the Install section of this procedure.

Install

Remove any protective caps.

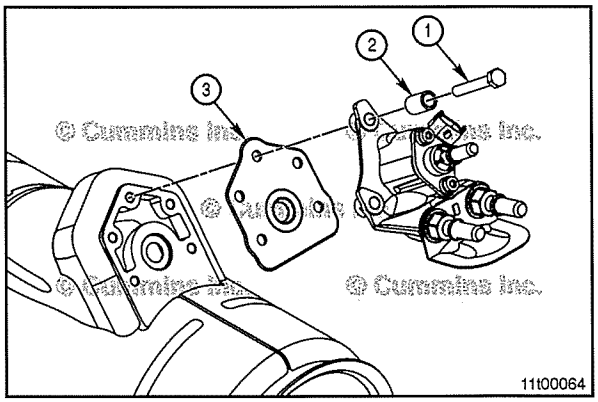
Make sure the aftertreatment DEF dosing valve spray port is free of gasket material and other debris.

Apply a coat of high temperature anti-seize compound to the threads of the aftertreatment DEF dosing valve mounting capscrews.

Install the insulated gasket (3) with the metallic side facing the aftertreatment DEF dosing valve. The insulated gasket can be held to the aftertreatment DEF dosing valve by inserting the capscrews (1) and spacers (2) into the square holes on the gasket to aid in alignment and installation.

NOTE: If the aftertreatment decomposition tube has been loosened or removed during the repair, confirm its orientation before installing the DEF dosing valve. Refer to Procedure 011-062 in Section 11.

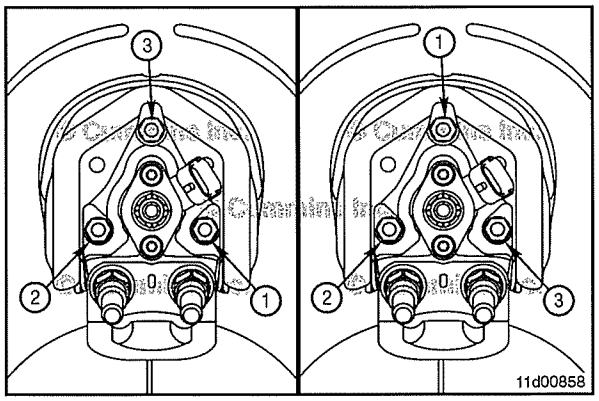
Install the aftertreatment DEF dosing valve onto the decomposition tube.



Tighten the capscrews by hand at first until the gasket is seated properly in the aftertreatment decomposition tube flange. Use the sequence shown in the left illustration.

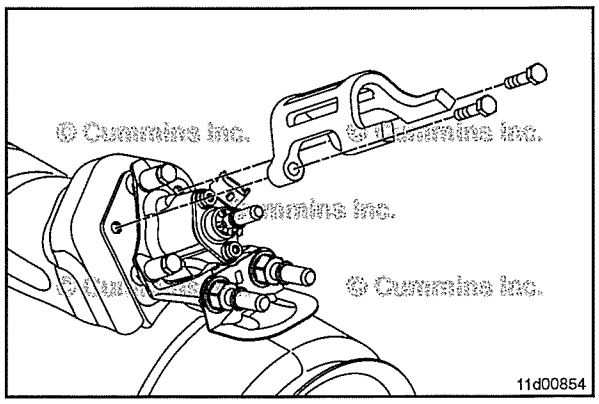
Tighten the capscrews in the sequence shown in the right illustration.

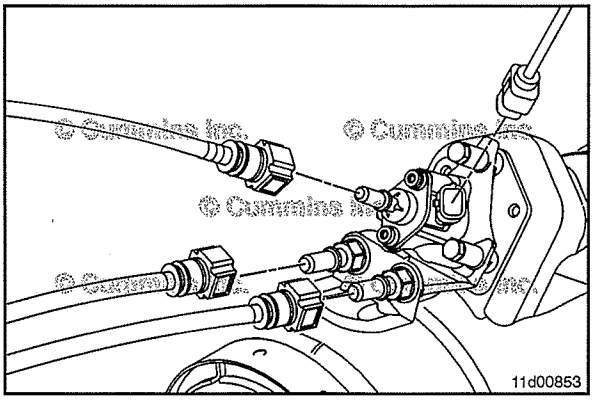
Torque Value: 9 N•m [80 in-lb]



Install the aftertreatment DEF dosing valve guard, if removed, and tighten the capscrews.

Torque Value: 9 N•m [80 in-lb]





Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△CAUTION△
Do not use the flow test portion of INSITE™ electronic service tool Diesel Exhaust Fluid Doser Pump Override Test to check the system for leaks. This will spray DEF into the exhaust system at temperatures too low to evaporate, resulting in deposit formations in the exhaust system.

NOTE: Remove any protective caps and/or covers from the electrical, coolant, and DEF ports just prior to making the connection.

Make the connections at the aftertreatment DEF dosing valve in the following order:

(1) The 2 pin electrical connector.

NOTE: The coolant supply and DEF lines are supplied by the OEM. The installation of the lines may vary by OEM. The fittings on the aftertreatment DEF dosing valve are set up for quick disconnect style fittings.

(2) Use the same method as used in the Preparatory Steps section to prevent draining the cooling system when the aftertreatment DEF dosing valve coolant lines are disconnected.

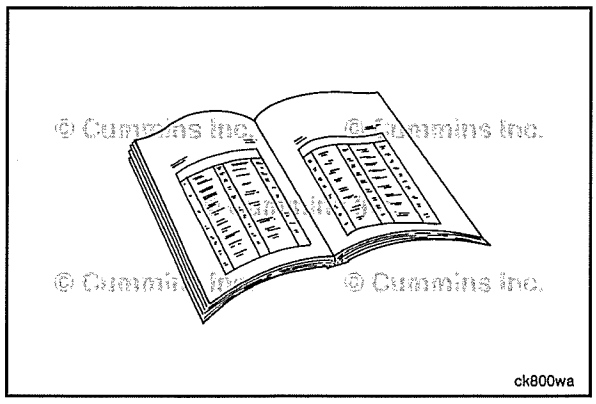
Remove the coolant line plugs, Part Number 4919576, from each of the disconnected coolant lines.

Connect the coolant supply and return lines. Refer to the OEM service manual.

Remove all tools used.

(3) Connect the DEF line. Refer to the OEM service manual.

Once all connections are made, give each a slight pull to make sure they are securely installed.



- If any coolant was spilled, check the coolant level. Fill as required. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-018 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.

NOTE: The aftertreatment DEF dosing system will not prime until the correct SCR temperatures are reached. To verify that the system is correctly installed and has no leaks, induce a stationary SCR/exhaust system cleaning to get the SCR system up to temperature.

- Operate the engine and check for leaks.

Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter (011-060)

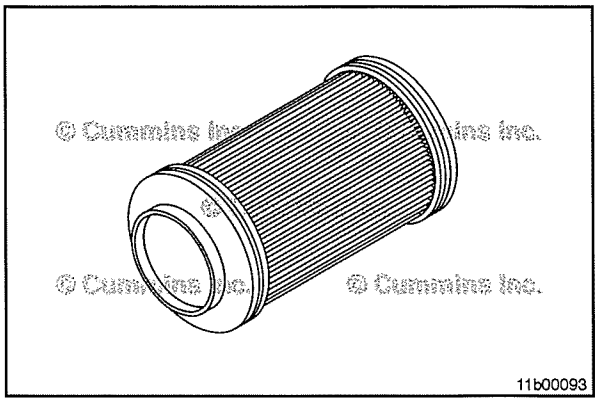
General Information

The diesel exhaust fluid (DEF) dosing unit filter is designed to prevent foreign objects that may be suspended in the DEF from entering the dosing system.

Debris can cause permanent damage and premature failure to either the aftertreatment DEF dosing unit or the aftertreatment DEF dosing valve. The aftertreatment DEF dosing unit filter is a maintenance item.

For handling incorrect or contaminated DEF, contact a Cummins® Authorized Repair Location.

Use the following procedure for handling incorrect or contaminated DEF. Refer to Procedure 011-056 in Section 11.

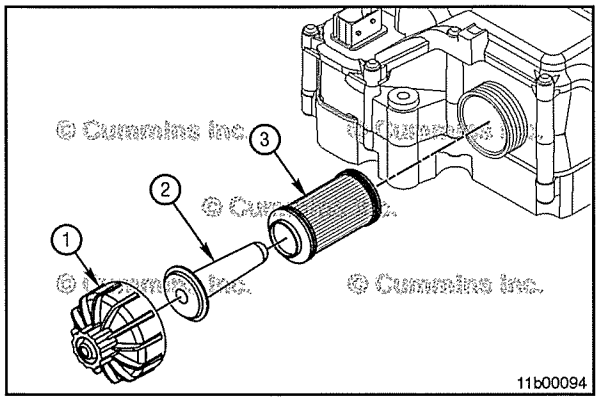


The aftertreatment DEF dosing unit filter consists of the following components:

1 Aftertreatment DEF dosing unit filter cap

2 Aftertreatment DEF dosing unit filter equalizing element

3 Aftertreatment DEF dosing unit filter element.



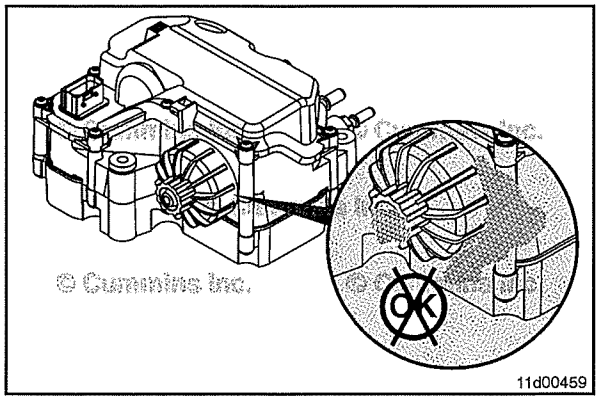
Initial Check

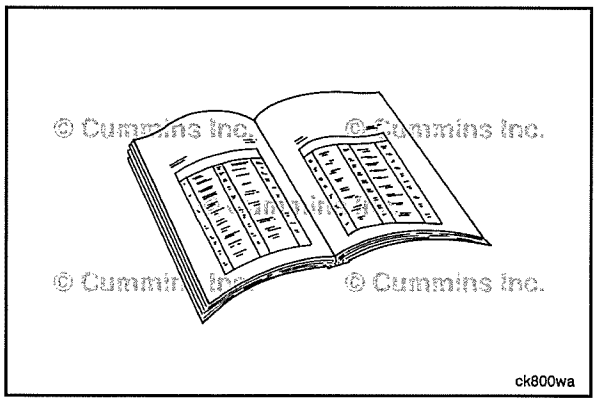
Locate the aftertreatment DEF dosing unit on the vehicle and notice the dome-shaped filter cap.

NOTE: The location of the aftertreatment DEF dosing unit varies on vehicles. Locate the DEF tank and follow the DEF lines to the aftertreatment DEF unit.

Inspect the area around the seal and vent of the aftertreatment DEF dosing unit filter cap for signs of leakage.

DEF leaks leave a white deposit. If deposits are found, see the Clean and Inspect for Reuse section in this procedure.





Preparatory Steps

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
The diesel exhaust fluid (DEF) line connecting the aftertreatment DEF dosing unit to the aftertreatment DEF dosing valve is under low pressure and should not be disconnected while the engine is running or before the system has completed the purge process after engine shutdown. Disconnecting the DEF line while under low pressure could cause DEF to spray.

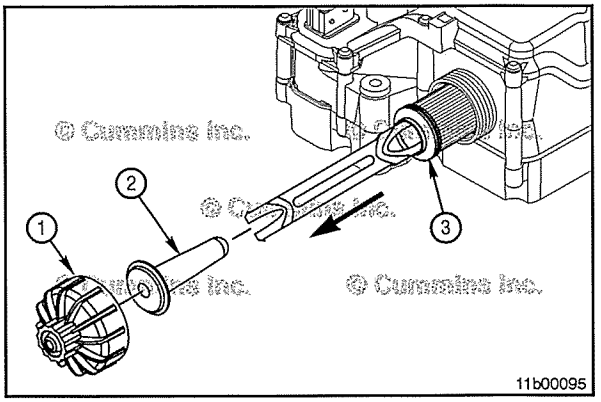
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: Do **not** disconnect the vehicle batteries until the DEF dosing system has completed the purge cycle. Before beginning to remove and/or disconnect any components, wait at least five minutes after the keyswitch is turned OFF for the aftertreatment DEF dosing system to purge the DEF from the system. The purge cycle is an automatic process and does **not** require intervention to occur. The aftertreatment DEF dosing unit will create an audible pumping noise during the purging process

NOTE: Do **not** power wash or steam clean this unit. Use compressed air to remove any loose debris.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.

Remove



NOTE: There may be residual DEF in the filter housing. A collection container placed below the DEF filter cap is recommended.

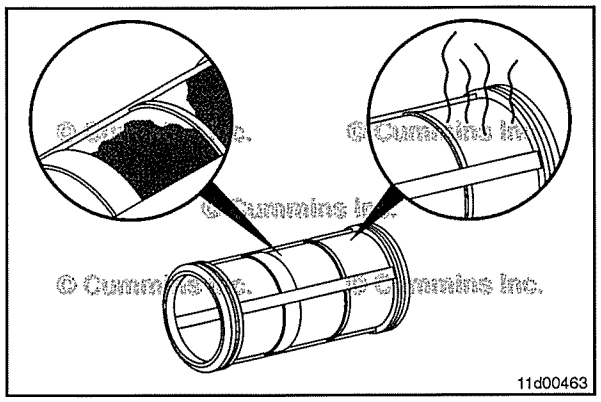
Unscrew the DEF filter cap (1). A 27 mm wrench can be used on the cap to aid in removal.

Remove the aftertreatment DEF filter equalizing element (2).

Remove the old aftertreatment DEF dosing unit filter element (3). A disposable service tool is included with the filter to aid in filter removal. Use the appropriate end of the tool, depending on the color of the plastic on the filter. When inserting the tool, a "click" sound can be heard which indicates proper engagement with the filter.

NOTE: If the filter element and equalizing element are removed from the aftertreatment DEF dosing unit, they **must** be discarded and replaced; regardless of condition.

Clean and Inspect for Reuse



If there is the possibility that contaminated DEF has gone through the DEF dosing system, check the DEF filter prior to discarding the filter.

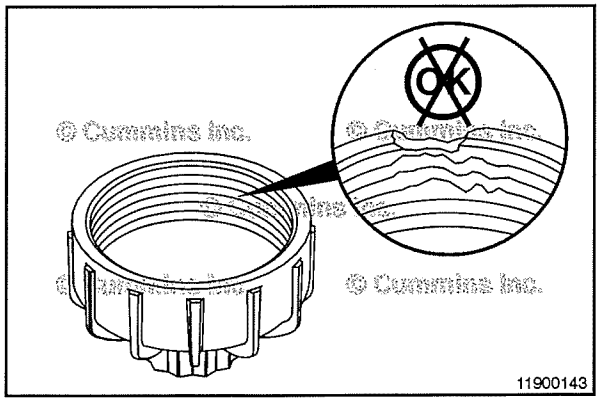
Check the diesel exhaust filter for evidence of contaminated DEF. Use visual and aroma characteristics of the filter to determine if contaminated fluid has passed through the dosing system.

Use the following procedure for further information on contaminated DEF. Refer to Procedure 011-056 in Section 11.

Inspect the diesel exhaust filter for debris. If debris is evident, also check:

- DEF tank pick up screen. Refer to the OEM service manual.
- The aftertreatment DEF dosing unit inlet connector. Refer to Procedure 011-058 in Section 11.

Discard the filter element and equalizing element.



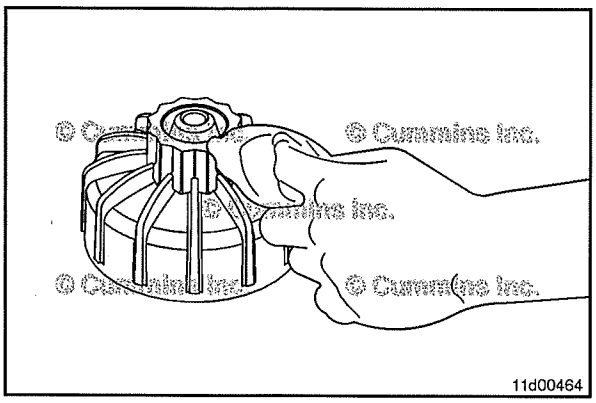
Inspect the aftertreatment DEF dosing unit filter cap for cracks or holes that could create a DEF leak path.

Check the condition of the threads on the aftertreatment DEF dosing unit cap.

If the threads are damaged, replace the aftertreatment DEF dosing unit filter cap.

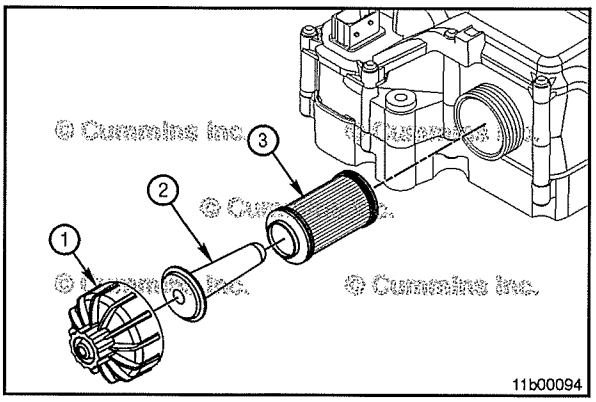
Inspect the aftertreatment DEF dosing unit threads. This is especially important if the aftertreatment DEF dosing unit cap was damaged.

If the aftertreatment DEF dosing unit threads are damaged, replace the entire aftertreatment DEF dosing unit.



NOTE: Never operate the vehicle with the DEF cap removed.

Clean the aftertreatment DEF dosing unit cap and threads on the dosing unit with warm water and a clean cloth.



Install

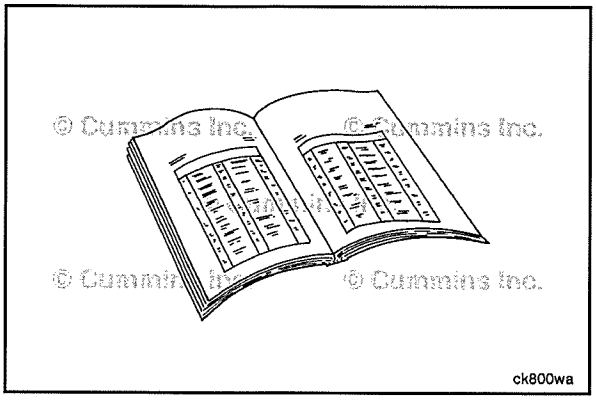
NOTE: Lubrication of the DEF filter o-rings is **not** required.

Slide the DEF filter equalizing element (2) into the DEF filter cartridge (3).

Insert the assembly into the aftertreatment DEF dosing unit.

Install and tighten the cap (1). A 27 mm wrench can be used to install and tighten the filter cap.

Torque Value: 20 N•m [177 in-lb]



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠

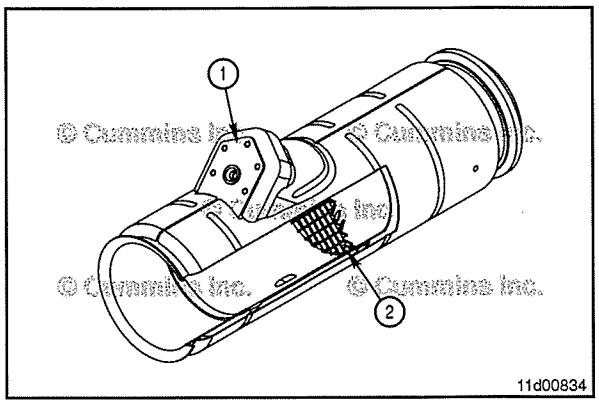
Do not use the flow test portion of the INSITE™ electronic service tool Diesel Exhaust Fluid Doser Pump Override Test to check the system for leaks. This will spray DEF into the exhaust system at temperatures too low to evaporate, resulting in deposit formations in the exhaust system.

NOTE: The aftertreatment DEF dosing system will **not** prime until the correct Selective Catalytic Reduction (SCR) temperatures are reached. To verify that there are no DEF leaks, test drive the vehicle for a minimum of 15 minutes to get the SCR system up to temperature.

- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Aftertreatment Decomposition Tube (011-062)

General Information



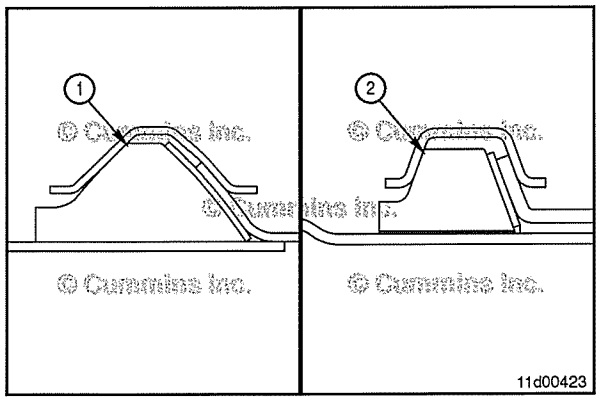
The decomposition tube is the section of exhaust pipe between the aftertreatment diesel oxidation catalyst (DOC) and aftertreatment selective catalytic reduction (SCR) catalyst. The aftertreatment decomposition tube is designed to help atomize and mix the diesel exhaust fluid (DEF) being sprayed into the exhaust stream for complete mono-nitrogen oxides (NOx) conversion.

The aftertreatment decomposition tube is composed of two important areas.

1 The aftertreatment DEF dosing valve mount: the position at which the aftertreatment DEF dosing valve is mounted and allowed to spray DEF into the exhaust stream.

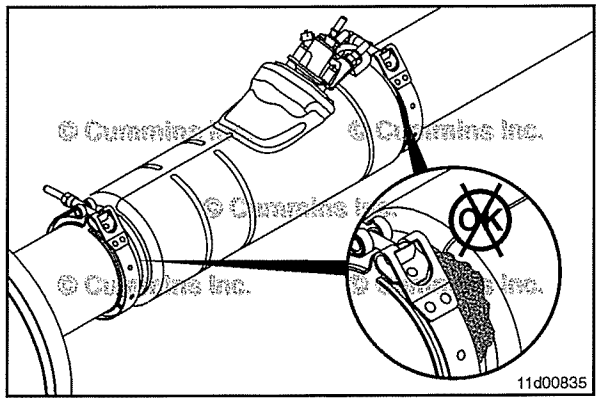
2 The aftertreatment decomposition tube mixer: creates a swirl pattern exhaust stream to help mix the DEF and engine exhaust.

Different vehicles will require different aftertreatment configurations. Some of the aftertreatment decomposition tubes may have elbows clamped to either end of the tube.

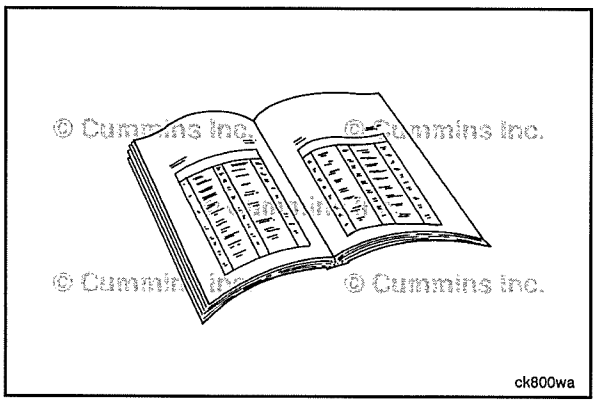


Different flanges are available to accommodate variations in vehicle aftertreatment configurations. The clamps and gaskets on either end of the aftertreatment decomposition tube may be different from one another. There are two types of flanged joints, spherical and full. The spherical (1) joints allow a small amount of misalignment and have a rounded cross section. The full (2) joints are completely rigid and have a more edgy profile.

Initial Check



Inspect all the joints for any signs of leaks. Leaking DEF will leave white deposits. If a DEF leak is found, reference the Clean and Inspect for Reuse section of this procedure.



Preparatory Steps

⚠WARNING⚠
During regeneration, exhaust gas temperature can reach 800°C [1500°F], and exhaust system surface temperature can exceed 700°C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

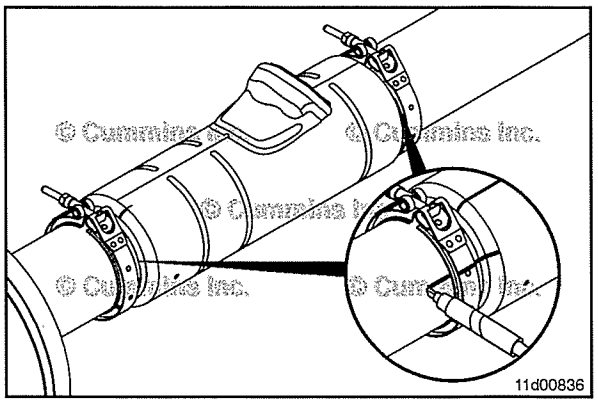
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
The aftertreatment DEF dosing valve is a fragile item. Use great care when handling this part. Avoid putting stresses on the fluid connectors, as damage to the component may result.

NOTE: It is acceptable to remove the aftertreatment dosing valve without removing the DEF and coolant lines. Support the aftertreatment DEF dosing valve. Do **not** let it suspend freely. It may damage the fluid connectors and lines.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area with shop air. Remove any debris from the aftertreatment decomposition tube.
- If applicable, remove the aftertreatment DEF dosing valve guard from the aftertreatment decomposition tube. Refer to Procedure 011-059 in Section 11.
- Remove the aftertreatment DEF dosing valve from the aftertreatment decomposition tube. Refer to Procedure 011-059 in Section 11.

Remove



⚠CAUTION⚠
Do not use an air tool to remove the V-band clamp nut. An air tool will damage the threads. Apply thread lubricant to the V-band clamp threads prior to nut removal.

NOTE: Before removing the aftertreatment decomposition tube, note the location and orientation of the aftertreatment decomposition tube and related components. Apply identifying markings to aid in installation.

NOTE: In some applications the aftertreatment decomposition tube may be welded to the aftertreatment SCR or aftertreatment elbow.

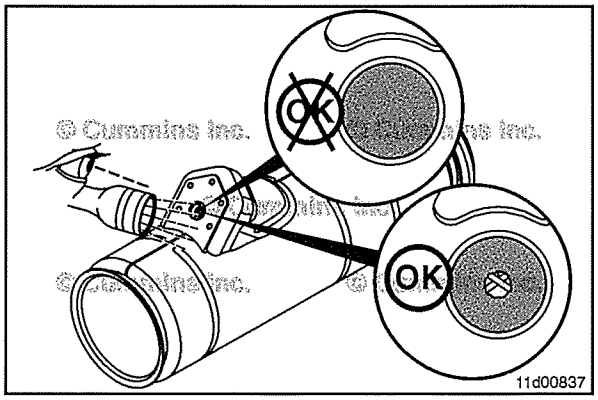
NOTE: Depending on the exhaust configuration, it may be necessary to loosen exhaust hangers or remove additional elbows and exhaust piping securing the rest of the aftertreatment before removing the aftertreatment decomposition tube.

Remove the exhaust clamps from both ends of the aftertreatment decomposition tube.

Remove the aftertreatment decomposition tube.

Discard the gaskets.

Clean and Inspect for Reuse

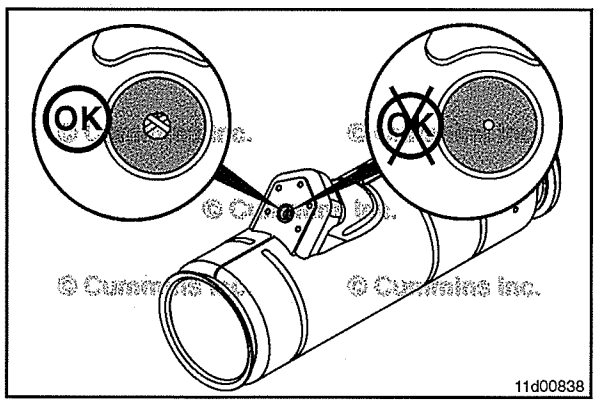


NOTE: If troubleshooting a fault code that has a step that indicates to check the aftertreatment decomposition for DEF deposits, clean the aftertreatment decomposition tube of DEF deposits, regardless of the inspection criteria in the steps below.

Inspect the aftertreatment DEF dosing valve spray port in the aftertreatment decomposition tube for DEF deposits.

If the DEF spray port is completely blocked by DEF deposits, clean the aftertreatment decomposition tube according to the cleaning steps later in this procedure.

If the aftertreatment DEF dosing valve spray port is blocked with DEF deposits, there may be issues with the aftertreatment dosing valve. Refer to Procedure 011-059 in Section 11.



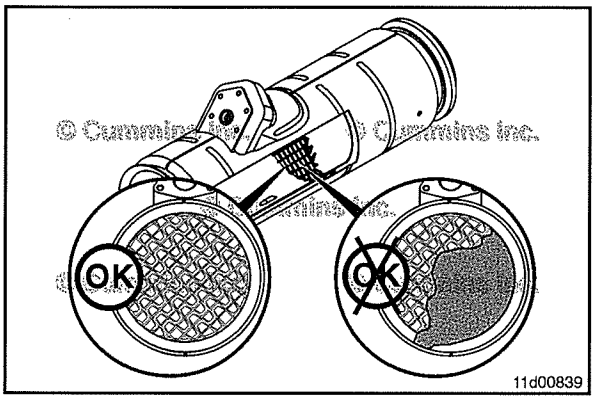
Inspect the aftertreament DEF dosing valve spray chamber in the aftertreatment decomposition tube. If there is a DEF deposit protruding into the main decomposition tube area that has a free flow path for a pressurized DEF stream and there are no active fault codes, no action is required.

NOTE: Use a light source when looking into the aftertreatment decomposition tube to inspect for a free flow path for a pressurized DEF stream.

It is **not** uncommon to see three holes in a DEF deposit. This is a formation of the three injection holes on the nozzle of the aftertreatment DEF dosing valve.

If there is a DEF deposit that is protruding into the main decomposition tube area that is restricting the free flow path for a pressurized DEF stream, clean the aftertreatment decomposition tube according to the cleaning steps later in this procedure.

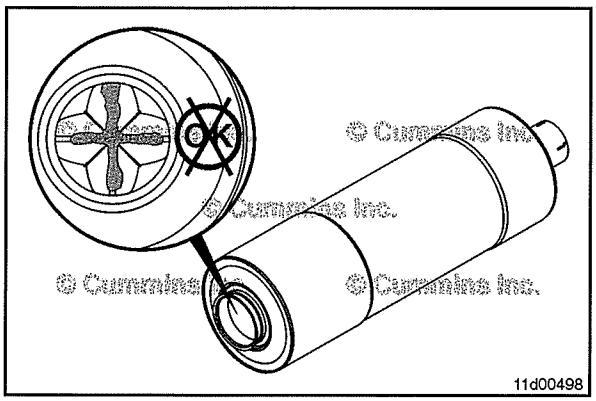
If the aftertreatment DEF dosing valve spray chamber is blocked with DEF deposits, there may be issues with the aftertreatment dosing valve. Refer to Procedure 011-059 in Section 11.



Inspect the aftertreatment decomposition tube main area around the mixer. If the mixer area is less than 50 percent blocked by DEF deposits, no action is necessary.

If the DEF deposits in the mixer area are blocking more than 50 percent of the aftertreatment decomposition tube, regardless if any related active fault codes are present, the aftertreatment decomposition tube **must** be cleaned. Reference the cleaning steps below.

If the DEF deposits in the mixer area are blocking more than 50 percent of the aftertreatment decomposition tube, there may be issues with the aftertreatment dosing valve. Refer to Procedure 011-059 in Section 11.



Inspect the intake of the aftertreatment SCR catalyst for DEF deposits. Refer to Procedure 011-036 in Section 11.

Inspect the outlet of the DOC for DEF deposits. Refer to Procedure 011-049 in Section 11.

Inspect any additional elbows or exhaust pipes connected to the aftertreatment decomposition tube for DEF deposits. Reference the cleaning steps below.

⚠CAUTION⚠

Do not use a metallic object to clean the aftertreatment decomposition tube. This will scratch the surface of the aftertreatment decomposition tube which may cause future excessive diesel exhaust fluid deposits.

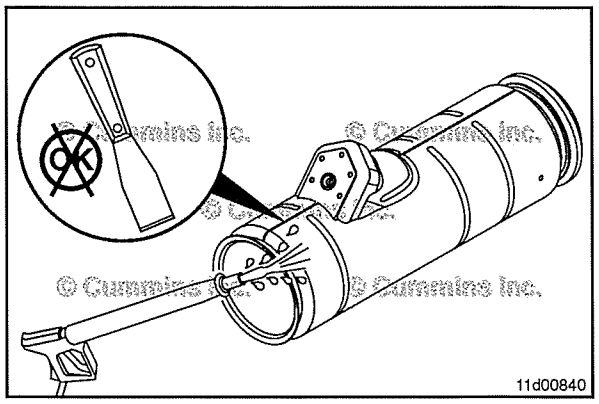
If DEF deposits are present, carefully scrape with a non-metallic object to remove the majority of the DEF deposits.

Use a pressure washer to dissolve the remaining DEF deposits.

NOTE: It is acceptable to have a small amount of DEF deposits remaining in the mixer area after the cleaning steps. The remaining DEF deposits can be removed by performing a stationary regeneration. Reference the Finishing Steps below.

Use **only** water to remove deposits.

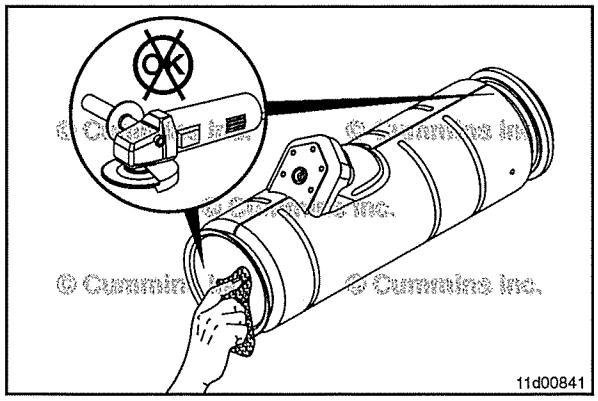
Do **not** submerge the aftertreatment decomposition tube in water or solvents which can saturate the insulation.



Inspect the exhaust flanges for corrosion or other damage.

Use an abrasive pad to remove any residual gasket material from the flanges on the aftertreatment decomposition tube.

Do **not** grind on the flange surface. This can damage the flange and cause the connection to leak.

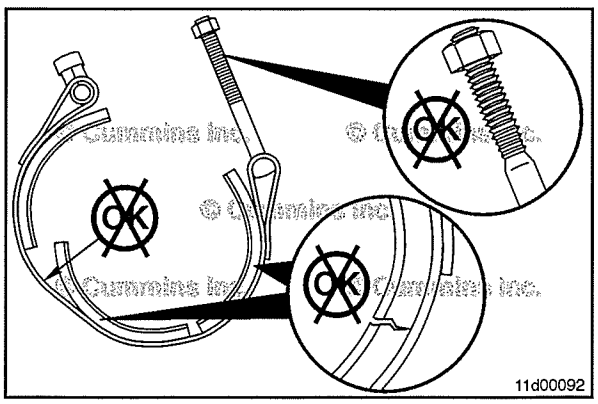


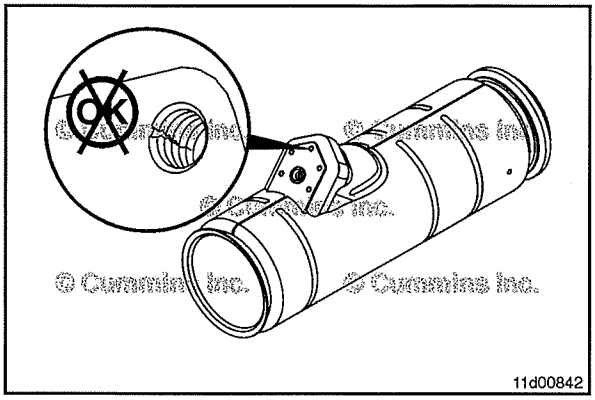
Inspect the V-band clamps and mounting straps for signs of over-extension.

The band **must not** be bent or damaged.

Inspect the V-band clamp and mounting strap threads for damage.

Replace the V-band clamp or mounting strap if damage is found.





⚠CAUTION⚠
Do not use a metallic object to clean the aftertreatment decomposition tube dosing valve mounting area. Damage to the gasket/isolator sealing surface area can result.

Inspect the aftertreatment DEF dosing valve mounting area.

Inspect for old gasket/isolator material or corrosion.

Clean with an abrasive pad.

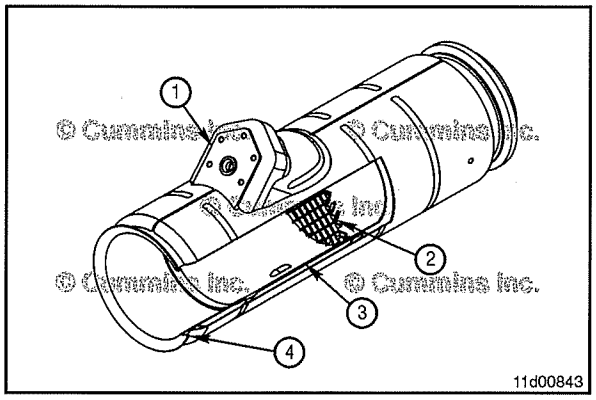
Check the threaded capscrew holes for damaged threads.

If the capscrew holes are damaged, the aftertreatment decomposition tube can be repaired.

Inner coil threads, M6 X 1, can be used to repair any damaged threads.

Use **only** the wire type coil inserts because the amount of material around the threaded capscrew hole is limited.

Follow the manufacturer's recommended guidelines to install the coiled threaded insert.



NOTE: The aftertreatment decomposition tube should be smooth and free from scratches and other damage.

If the aftertreatment decomposition tube has **any** structural defects or material degradation, replace the aftertreatment decomposition tube.

NOTE: Surface corrosion such as rust on the inside of the aftertreatment decomposition tube can possibly be observed. Do **not** replace the aftertreatment decomposition tube for this condition.

Check the following areas:

1 Aftertreatment dosing valve mount

2 Mixer

3 Insulation

4 Welded joints.

Install

⚠CAUTION⚠
Do not use an air tool to tighten the V-band clamp. An air tool will damage the threads.

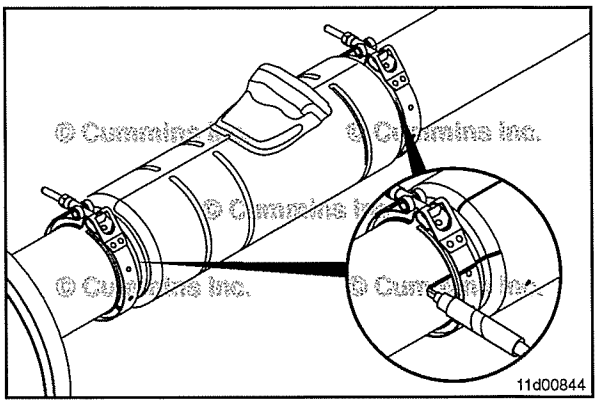
Install the aftertreatment decomposition tube with new gaskets. If other parts of the aftertreatment were adjusted in the removal process of the aftertreatment decomposition tube, slide them back into position.

Align the aftertreatment decomposition tube. Use the identification marks that were made before removal. If marks are **not** available, reference the next step for appropriate orientation of the aftertreatment decomposition tube.

Apply a coat of anti-seize compound on the threads of the V-band clamps.

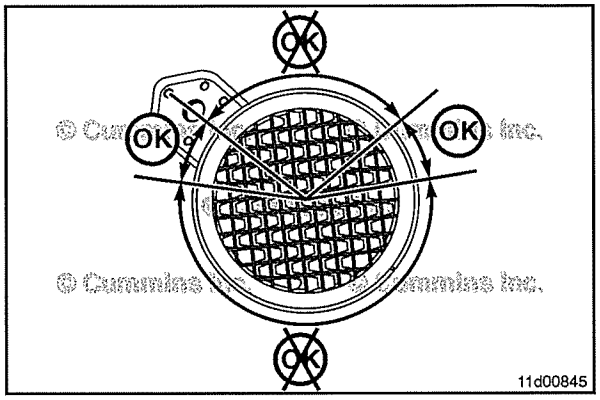
Install the clamps.

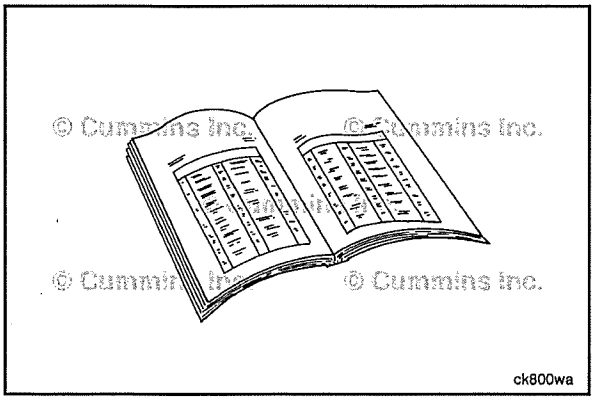
Torque Value: 14 N•m [124 in-lb]



Verify the aftertreatment decomposition tube is installed in the same orientation as it was before removal.

As viewed from the inlet/outlet of the aftertreatment decomposition tube, the aftertreatment DEF dosing valve mount should be placed between ± 45 degrees and ± 85 degrees.



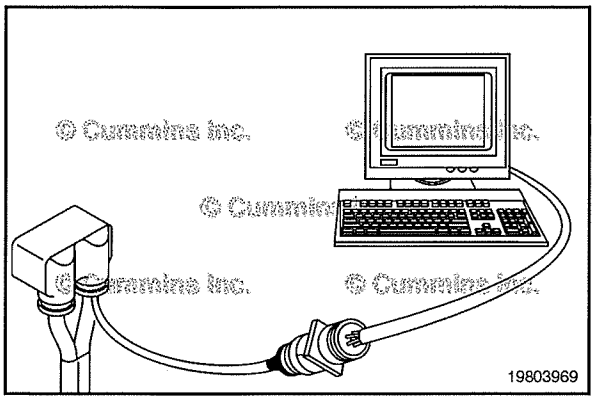


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Tighten any aftertreatment hangers that could possibly have been loosened in the removal process. Refer to the OEM service manual.
- Install the aftertreatment DEF dosing valve. Refer to Procedure 011-059 in Section 11.
- If applicable, install the aftertreatment DEF dosing valve guard. Refer to Procedure 011-059 in Section 11.
- Connect the battery cables. Refer to the OEM service manual.
- Start the engine and check for exhaust leaks.

NOTE: If DEF deposits were present, and cleaning of the aftertreatment decomposition tube was required, complete a stationary aftertreatment regeneration through the Aftertreatment Regeneration Test in INSITE™ electronic service tool to make sure that the remaining DEF deposits haves been removed from the aftertreatment system. Continue to monitor for leaks at the exhaust joints.



Aftertreatment Diesel Exhaust Fluid Dosing Unit Override Test (011-063)

General Information

Perform a dosing cycle to check the:

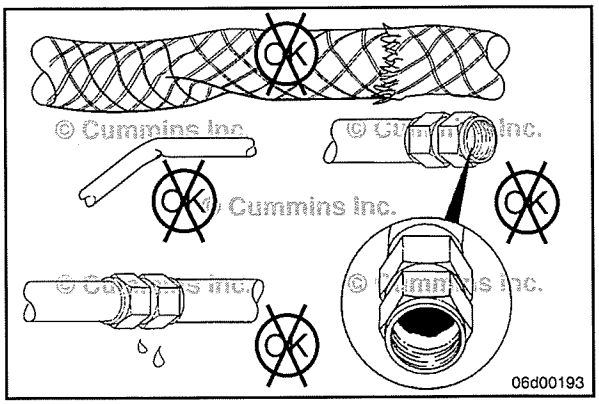
- Aftertreatment diesel exhaust fluid (DEF) dosing valve spray characteristics
- Amount of DEF to be delivered in a specified time (6 minutes).

The test can be accessed through INSITE™ electronic service tool under engine control module (ECM) Diagnostic Tests. Follow the on-screen instructions to perform the test.

Initial Check

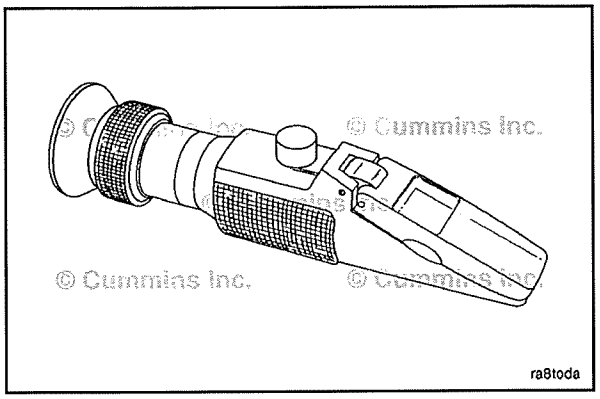
Check for any leaks, blockages, or restrictions in the DEF line between the aftertreatment DEF dosing unit and the aftertreatment DEF dosing valve.

Repair as necessary. Refer to the original equipment manufacturer (OEM) service manual.



Check for an adequate amount of DEF in the DEF tank prior to starting this test.

Check the concentration and quality of the DEF. Refer to Procedure 011-056 in Section 11.

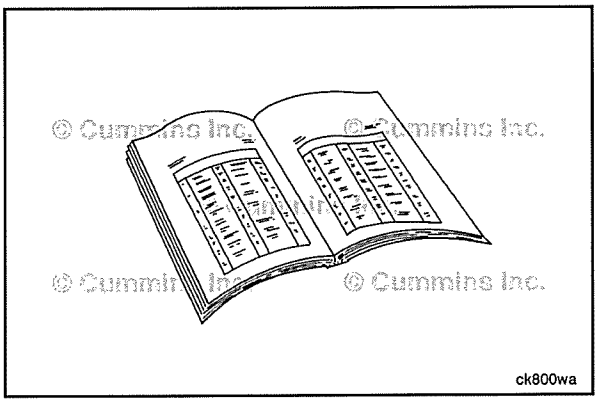


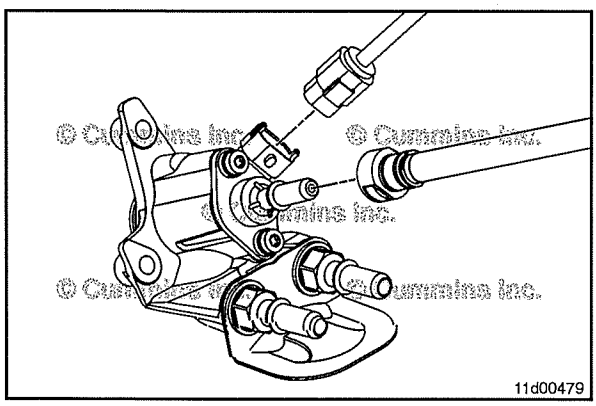
Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: Low battery voltage can cause the dosing volume to be low. Check the batteries. Refer to the OEM service manual.

- Disconnect the batteries. Refer to the OEM service manual.
- Remove the aftertreatment DEF dosing valve. Refer to Procedure 011-059 in Section 11.





Setup

⚠CAUTION⚠
Care should be taken when handling and/or disconnecting the DEF line from the aftertreatment DEF dosing valve. The intake connection of the aftertreatment DEF dosing valve is plastic and can be easily damaged.

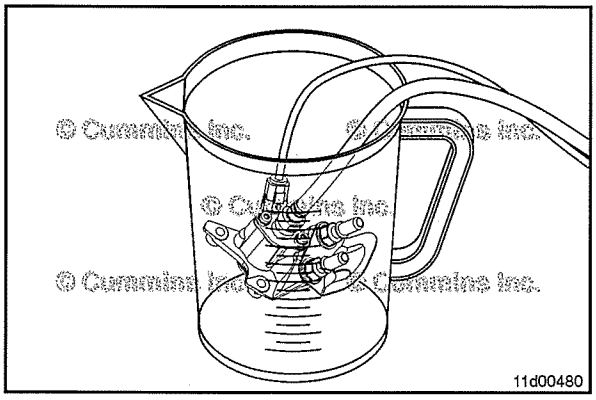
⚠CAUTION⚠
Do not connect a 12-VDC or 24-VDC supply to the aftertreatment DEF dosing valve as this will cause permanent damage.

Connect the electrical and DEF lines. Refer to Procedure 011-059 in Section 11.

NOTE: The coolant plumbing does **not** need to be connected for this test.

NOTE: There may **not** be enough length for the existing electrical and/or DEF line to allow the aftertreatment DEF dosing valve to be placed in the container. Use service tool kit, Part Number 4919573, or equivalent, which contains:

- Wiring harness extension, Part Number 4919575
- DEF extension line, Part Number 4919574
- Coolant line plug, Part Number 4919576.



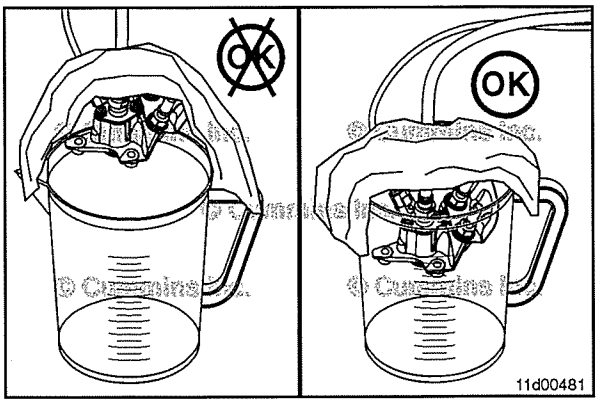
NOTE: It may be easier to capture the DEF in a clean container and transfer the DEF to the measuring device for the final measurement.

Obtain a clear plastic container (large enough to hold the aftertreatment DEF dosing valve) and a graduated beaker, Part Number 4919139, or equivalent. A measuring cup that is marked in milliliters (ml) or ounces (oz) can also be used.

The measuring device **must** be capable of measuring between 0 ml [0.0 oz] and 500 ml [17.0 oz] in 5 ml [0.34 oz] increments

Place the aftertreatment DEF dosing valve into the container.

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

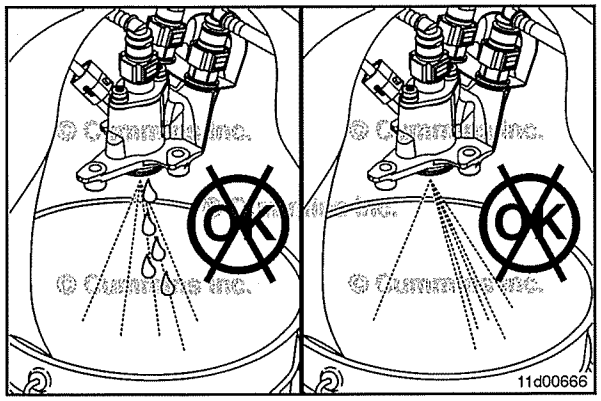


NOTE: When the test is started, the dosing system will first prime. During this process the aftertreatment DEF dosing valve will open intermittently to purge air from the system. In doing so, some DEF will be sprayed from the tip. This is a normal operating characteristic.

When the test is being performed, the aftertreatment DEF dosing valve will spray a very fine mist of DEF. To prevent fine mist from escaping into the air and to make sure of an accurate measurement, place a clean shop towel or cover over the valve and container.

When the test begins, briefly monitor the spray pattern of the DEF exiting the aftertreatment DEF dosing valve. Check for:

- Signs of larger drops and/or dripping DEF from the tip
- Spray pattern that is **not** symmetrical (sprays more to one side).



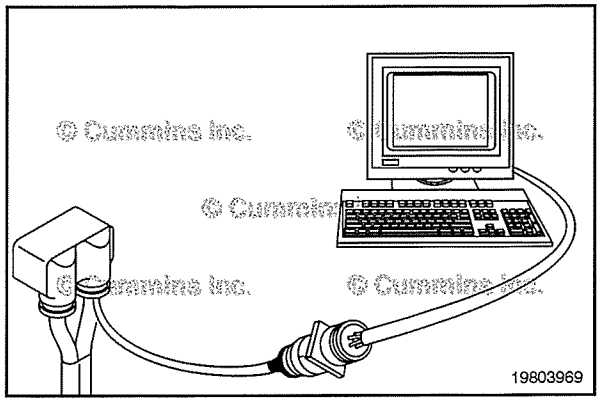
If either of these symptoms is noted, stop the test and inspect the aftertreatment DEF dosing valve tip. Refer to Procedure 011-059 in Section 11.

After cleaning, perform the test again and monitor the spray pattern. If the problem persists, replace the aftertreatment DEF dosing valve. Refer to Procedure 011-059 in Section 11.

NOTE: If a leak at the DEF dosing valve tip is suspected, then the Aftertreatment Diesel Exhaust Fluid System Leak Test may be used to confirm the symptom. Refer to Procedure 011-080 in Section 11.

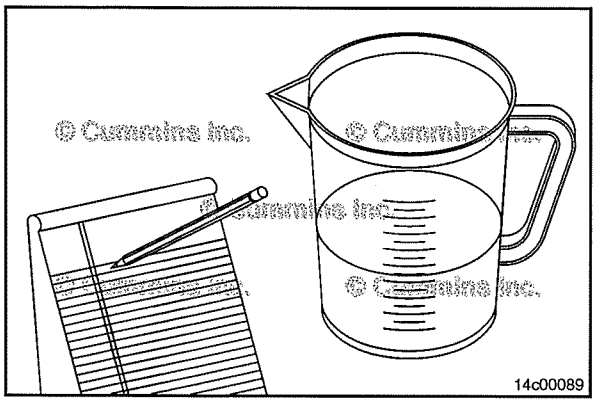
Flow Test

NOTE: Prior to performing this test, if **not** already directed by a fault code troubleshooting tree, view and troubleshoot any fault codes with INSITE™ electronic service tool. Reference the QSB6.7 CM2350 B105 Troubleshooting Fault Code Manual, Bulletin 4332777.



- Turn the keyswitch ON.
- Connect INSITE™ electronic service tool.
- Locate the Diesel Exhaust Fluid Doser Pump Override Test under ECM Diagnostic Tests.
- Follow the on-screen instructions to perform the test.

INSITE™ electronic service tool will start the test and will inject the DEF for 6 minutes. INSITE™ electronic service tool will automatically disable the injector at the end of the test. If the test needs to be stopped before finishing, click the STOP button.



After the test is complete (test runs for 6 minutes), measure the amount of DEF sprayed into the container. Pour the DEF into the graduated beaker, Part Number 4919139, or equivalent.

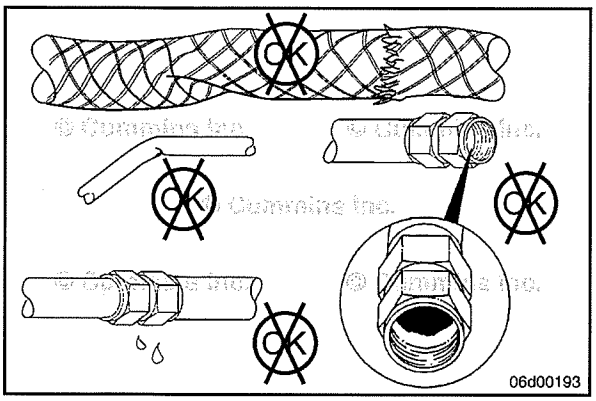
Perform the test three times. The amount of DEF measured for each test **must** be within specification.

Aftertreatment DEF Dosing Valve Volume Specifications

ml		fl-oz
85	MIN	2.9
115	MAX	3.9

NOTE: Do **not** pour the DEF back into the DEF tank. Dispose of the DEF in accordance with local environmental regulations.

NOTE: Inspect the collected sample of DEF for signs of debris or contamination.



NOTE: Low battery voltage can cause the dosing volume to be low. Check the batteries. Refer to the OEM service manual. View and troubleshoot any fault codes with INSITE™ electronic service tool. Reference the QSB6.7 CM2350 B105 Troubleshooting Fault Code Manual, Bulletin 4332777.

If the amount of DEF is **not** within specification, check for leaks, blockages, or restrictions in the DEF line between the aftertreatment DEF dosing unit and the aftertreatment DEF dosing valve. Use the following as a guide if the amount of DEF is still **not** within specification for one or more of the three tests:

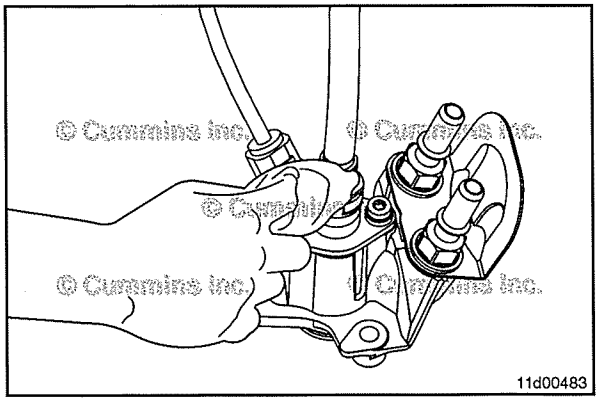
- Clean the DEF dosing valve if one or more of the test results is below 85 ml [2.9 oz]
- Replace the DEF dosing valve if one or more of the test results is above 115 ml [3.9 oz]
- Replace the DEF dosing valve if the test results vary with both below-specification and above-specification conditions. This could be an erratic valve with intermittent malfunction and **must** be replaced. Refer to Procedure 011-059 in Section 11.

NOTE: The aftertreatment DEF dosing valve may have been plugged by debris. Inspect the aftertreatment DEF dosing unit filter for signs of contamination and debris prior to installing the new aftertreatment DEF dosing valve. Refer to Procedure 011-060 in Section 11.

⚠CAUTION⚠
Do not submerge the aftertreatment DEF dosing valve in solvent or water. Damage to the aftertreatment DEF dosing valve will result.

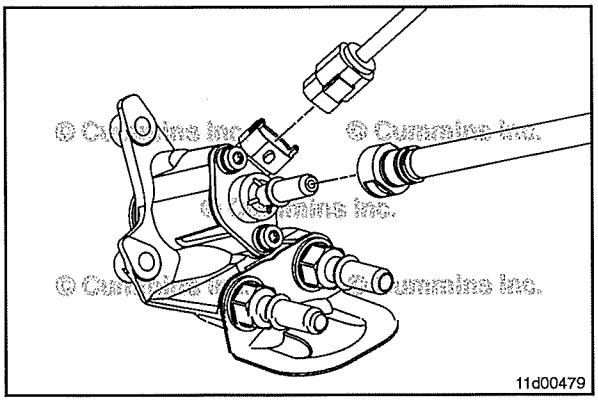
After the test is complete, a light coating of DEF will cover the aftertreatment DEF dosing valve, DEF line, and electrical line.

Prior to disconnecting anything, use a clean shop towel soaked in warm water to wipe the coating of DEF from the components.



NOTE: Clean any service tools used for this test with warm distilled water before storage.

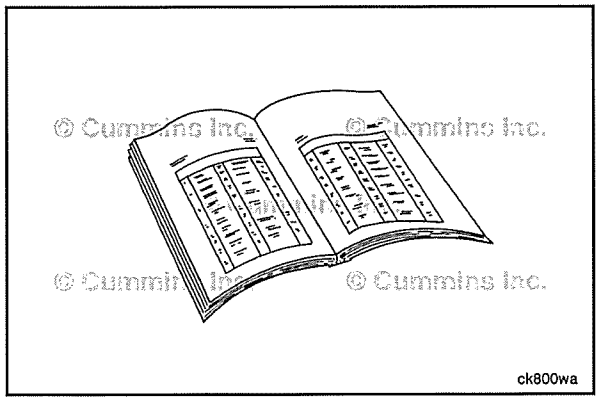
Disconnect the electrical and DEF lines. Refer to Procedure 011-059 in Section 11. If used, remove the service tool extensions.

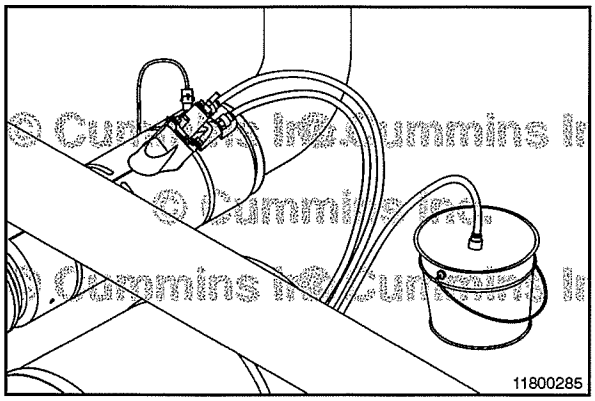


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the aftertreatment DEF dosing valve. Refer to Procedure 011-059 in Section 11.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Air in the Diesel Exhaust Fluid (011-075)

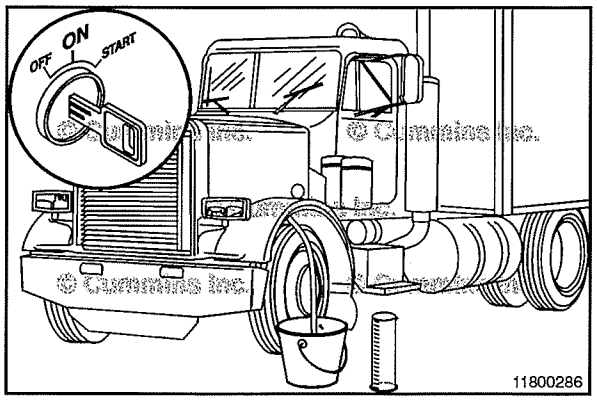
Setup

⚠CAUTION⚠
Care should be taken when handling and/or disconnecting the diesel exhaust fluid line from the aftertreatment diesel exhaust fluid dosing valve. The intake of the aftertreatment diesel exhaust fluid dosing valve is plastic and can be easily damaged.

Remove the aftertreatment diesel exhaust fluid dosing valve supply line from the aftertreatment diesel exhaust fluid dosing valve.

Install the diesel exhaust fluid extension line, Part Number 4919574, from the Aftertreatment Diesel Exhaust Fluid (DEF) Doser Shutoff Valve Test Kit, Part Number 4919573.

Obtain a container suitable for collection of the diesel exhaust fluid that exits the aftertreatment diesel exhaust fluid dosing valve supply line. A 3.8 liter [1 gal] bucket is recommended.



Measure

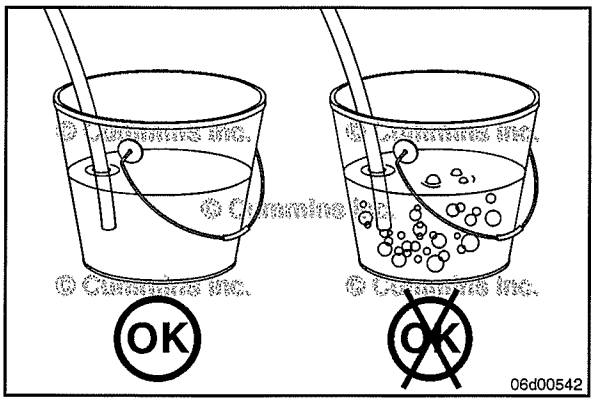
Route the outlet of the diesel exhaust fluid extension line into the collection container.

Turn the keyswitch to the ON position and connect INSITE™ electronic service tool.

Select the Diesel Exhaust Fluid Doser Pump Override test under the ECM Diagnostic Tests menu.

This test will attempt to prime the dosing system. During this test, diesel exhaust fluid will be drawn from the tank and pumped through the diesel exhaust fluid extension line.

NOTE: Once the test is initiated it will continue to pump diesel exhaust fluid, even when attempting to stop the test with INSITE™ electronic service tool. To stop the test, it is necessary to turn the keyswitch to the OFF position.



Observe the diesel exhaust fluid flow exiting the diesel exhaust fluid extension line while the Override Test is running.

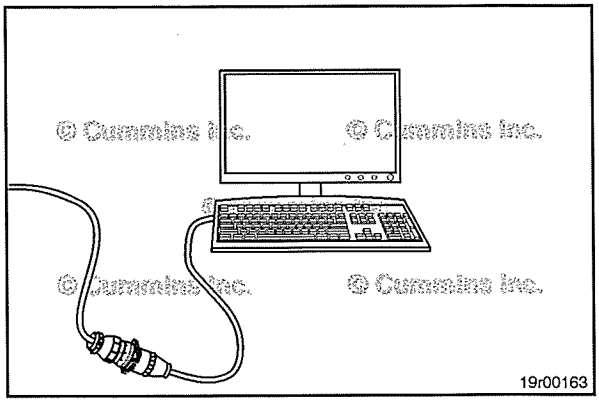
Bubbles are an indication of a leak that allows air to enter the dosing system. If bubbles are present, check the following components for damage or leaks:

- Aftertreatment diesel exhaust fluid dosing unit fittings
- Aftertreatment diesel exhaust fluid dosing unit supply line
- Aftertreatment diesel exhaust fluid tank assembly
- Aftertreatment diesel exhaust fluid tank fittings.

Repair or replace any damaged components.

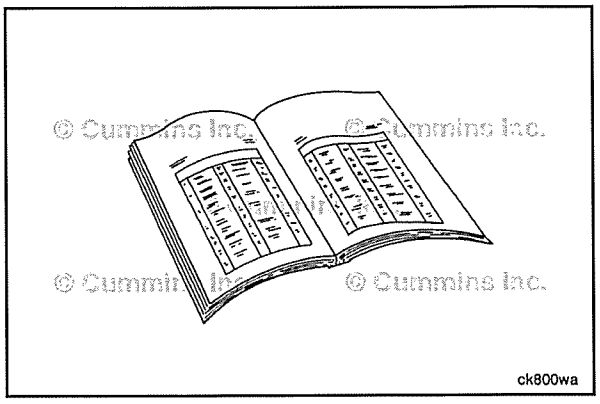
Turn the keyswitch to the OFF position to end the test.

NOTE: If this test is run for an extended period of time, Fault Code 1682 will become active. Limit the test time to 5 minutes or less.



Finishing Steps

- Remove the aftertreatment diesel exhaust fluid extension line.
- Connect that aftertreatment diesel exhaust fluid dosing valve supply line.
- Discard the collected diesel exhaust fluid. Dispose of the collected diesel exhaust fluid in accordance with local environmental regulations.
- Operate the engine and check for leaks.



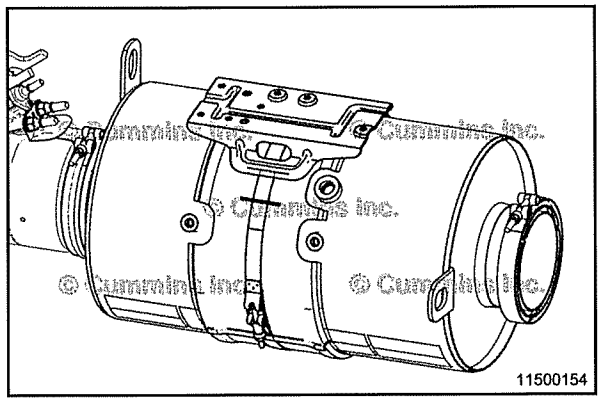
Aftertreatment SCR Catalyst Temperature Sensor Interface Module Mounting Bracket (011-076)

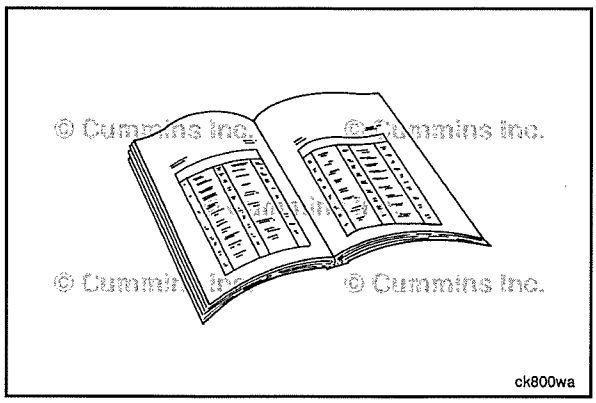
General Information

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To reduce the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair. Make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

△CAUTION△
The catalyst elements contained in the aftertreatment system are made of brittle material. Do not drop or strike the side of the aftertreatment system, as damage to the catalyst element can result.

NOTE: Due to the number of different exhaust aftertreatment applications, this procedure has been written to be generic. **Not** all illustrations within this procedure will represent the application being serviced.





Preparatory Steps

⚠WARNING⚠

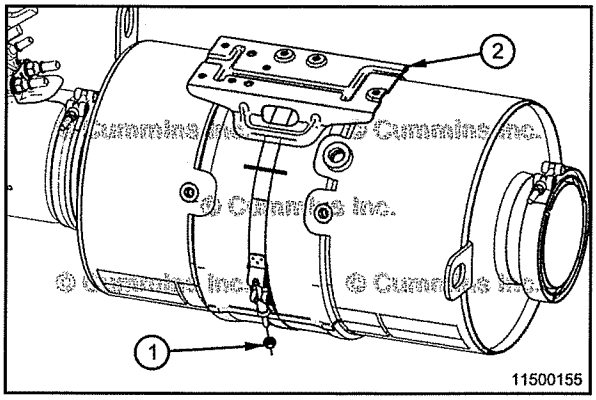
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠

The aftertreatment diesel particulate filter and catalyst can remain hot for long periods of time after the engine has stopped.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Mark the orientation and location of the bracket before it is removed to aid installation.
- Disconnect the aftertreatment interface harness from the OEM wiring harness connection.
- Remove the mono-nitrogen oxides (NOx) sensor probe from the aftertreatment catalyst body. Refer to Procedure 019-451 in Section 19.
- Remove the aftertreatment temperature sensor probes from the aftertreatment catalyst body. Refer to Procedure 019-449 in Section 19.

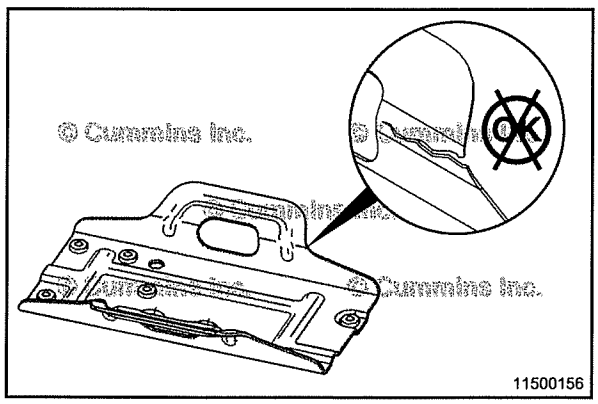
NOTE: The aftertreatment temperature sensor interface module **must** be oriented in the same location when it is installed. Pay special attention to this orientation.



Remove

Remove the nut (1) on the aftertreatment temperature sensor interface module mounting bracket strap.

Remove the aftertreatment temperature sensor interface module mounting bracket (2) from the catalyst body.



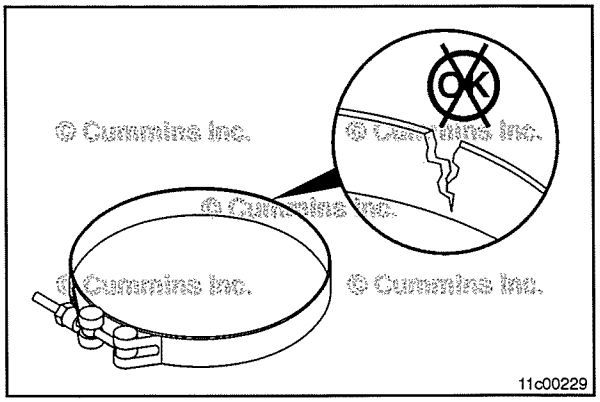
Clean and Inspect for Reuse

Inspect the aftertreatment temperature sensor interface module mounting bracket for cracks, damaged threads, or broken studs.

Replace the aftertreatment temperature sensor interface module mounting bracket if damaged.

Inspect the aftertreatment temperature sensor interface module mounting bracket strap for cracks, damaged threads, or bends.

Replace the aftertreatment temperature sensor interface module mounting bracket strap if it is damaged.



Install

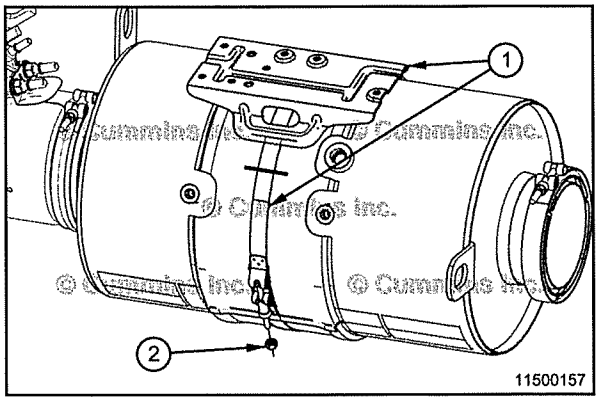
NOTE: Make sure the aftertreatment catalyst is oriented so the aftertreatment catalyst temperature sensor interface module mounting bracket is installed in the same orientation noted during removal.

Install the aftertreatment temperature sensor interface module mounting bracket (1) and strap. Be sure to align the mounting bracket using the reference mark that was made during removal.

Apply a coating of anti-seize compound, Part Number 3824879 or equivalent, to the threads of the aftertreatment temperature sensor interface module mounting bracket strap.

Tighten the nut (2) on the aftertreatment temperature sensor interface module mounting bracket strap.

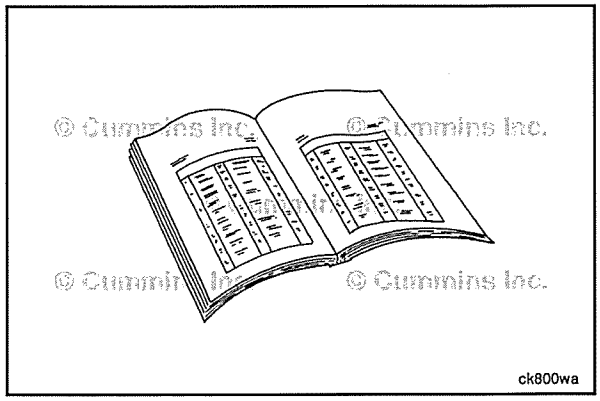
Torque Value: 7 N•m [62 in-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

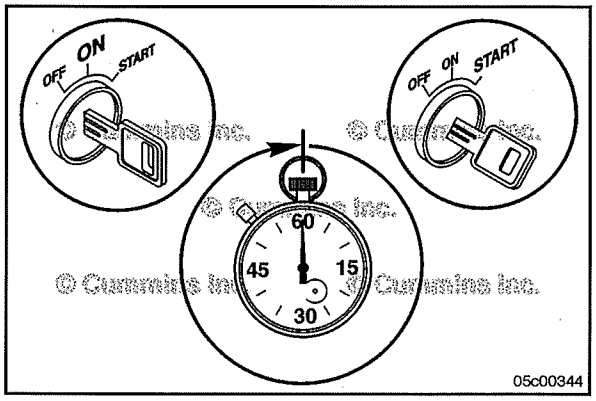
- Install the aftertreatment temperature sensor probes into the catalyst body. Refer to Procedure 019-449 in Section 19.
- Install the NOx sensor probe. Refer to Procedure 019-451 in Section 19.
- Connect the aftertreatment interface harness to the OEM wiring harness connection.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for proper operation.



Aftertreatment Diesel Exhaust Fluid System Leak Test (011-080)

General Information

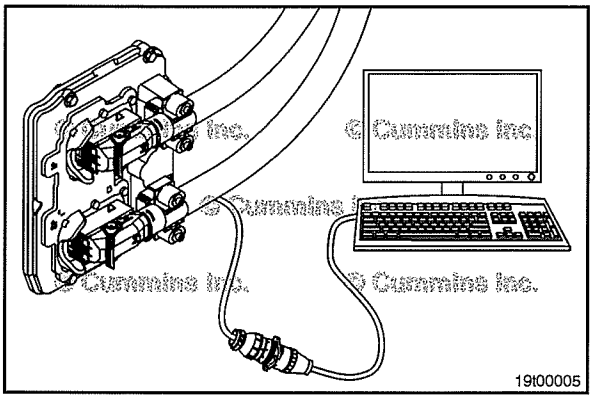
If the aftertreatment diesel exhaust fluid (DEF) dosing system has been serviced or repaired, it will be necessary to prime the DEF dosing system, in order to check for proper operation.



Setup

NOTE: It may be necessary to allow the aftertreatment system time to cool, to allow for accessibility to check for leaking components.

- Make sure the DEF tank is full of DEF. Refer to the original equipment manufacturer (OEM) service manual.
- Make sure the DEF is **not** frozen. If the DEF is frozen, it will be necessary to run the engine to allow the system to thaw.
- Make sure all DEF dosing system lines are properly connected to the DEF tank, DEF dosing unit, and DEF dosing valve. Refer to the OEM service manual.
- Connect INSITE™ electronic service tool.

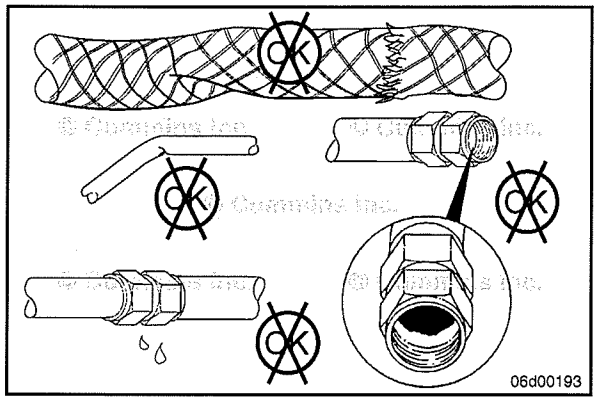


Prime

With the keyswitch ON and the engine **not** running, select the Aftertreatment Diesel Exhaust Fluid System Leak Test found under the ECM diagnostics test menu in INSITE™ electronic service tool.

This test will cause the DEF dosing unit to draw DEF from the tank and pressurize it in the DEF dosing valve supply line. During this test, the dosing unit will continuously run and all unused DEF will return to the tank. An audible pumping noise will be noticeable during the test.

During the initialization of this test, a note will pop up on the screen, indicating that the system has reached a prime state.



Inspect

NOTE: If the system is unable to prime due to leaks, it will be necessary to turn the keyswitch OFF in order to stop the dosing unit. The dosing unit can **not** be stopped using INSITE™ electronic service tool.

While the test is running, inspect all DEF lines, fittings, and connections for external leaks. Refer to Procedure 011-058 in Section 11 or Refer to Procedure 011-059 in Section 11 and/or the OEM service manual.

Repair and replace any leaking component(s). Refer to Procedure 011-058 in Section 11 or Refer to Procedure 011-059 in Section 11 and/or the OEM service manual.

NOTE: If the system fails to prime a key cycle will be required before attempting to run the aftertreatment diesel exhast fluid system leak test again.

NOTE: The aftertreatment DEF system leak test can **only** be attempted twice consecutively. A key cycle will be required before attempting to run the aftertreatment DEF system leak test again after two attempts.

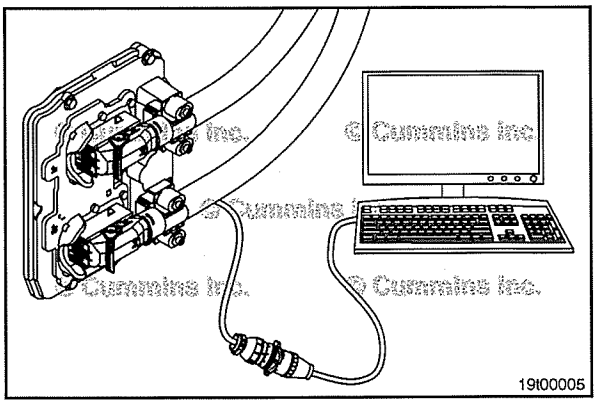
If the system is able to successfully prime, a pop-up message will appear in INSITE™ electronic service tool to notify the technician.

Upon completion of inspecting the lines, fittings, and connections for leaks, press the STOP button in INSITE™ electronic service tool. The dosing unit will then purge the system of DEF. An audible purging noise will be noticeable.

If the test is not STOPPED using INSITE™ electronic service tool, it will continue to pump for 20 minutes and then automatically purge the system of DEF.

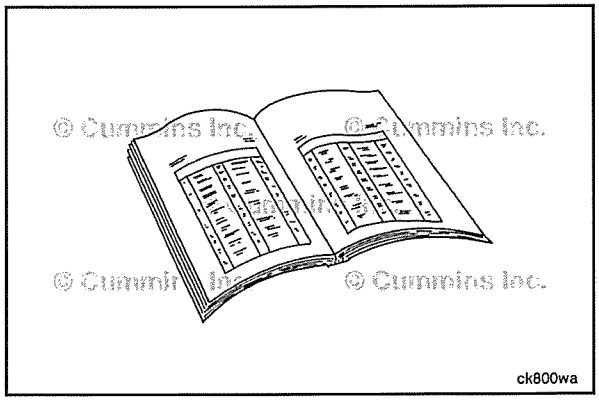
If the system can **not** build pressure, it will attempt to prime multiple times before flagging a fault code.

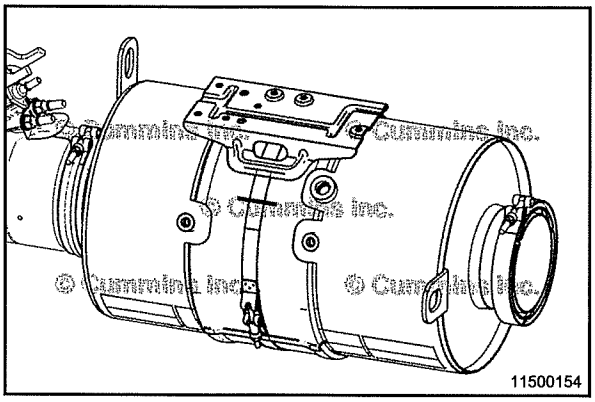
If any fault codes occur while running this test, reference the appropriate fault code troubleshooting tree.



Finishing Steps

- During the test, a small quantity of DEF is sprayed into the aftertreatment decomposition tube. After completion of the test, it is necessary to run the engine at high idle for 5 minutes in order to prevent DEF deposits from forming in the aftertreatment decomposition tube.
- Check for fault codes.





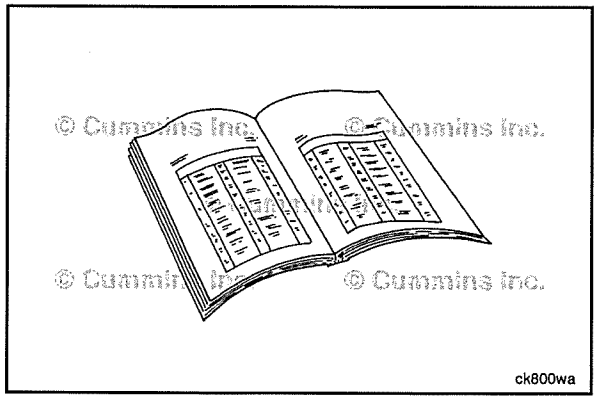
Aftertreatment Diesel Oxidation Catalyst Temperature Sensor Module Mounting Bracket (011-095)

General Information

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To reduce the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair. Make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

△CAUTION△
The catalyst elements contained in the aftertreatment system are made of brittle material. Do not drop or strike the side of the aftertreatment system, as damage to the catalyst element can result.

NOTE: Due to the number of different exhaust aftertreatment applications, this procedure has been written to be generic. **Not** all illustrations within this procedure will represent the application being serviced.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△CAUTION△
The aftertreatment diesel particulate filter and catalyst can remain hot for long periods of time after the engine has stopped.

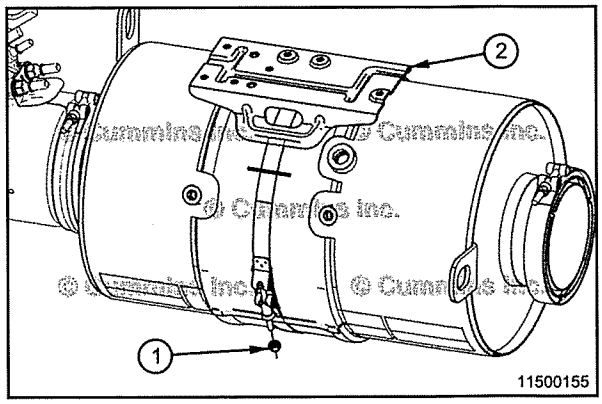
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Mark the orientation and location of the bracket before it is removed to aid installation.
- Disconnect the aftertreatment interface harness from the OEM wiring harness connection.
- Remove the mono-nitrogen oxides (NOx) sensor probe from the aftertreatment catalyst body. Refer to Procedure 019-463 in Section 19.
- Remove the aftertreatment temperature sensor probes from the aftertreatment catalyst body. Refer to Procedure 019-449 in Section 19.

NOTE: The aftertreatment temperature sensor interface module **must** be oriented in the same location when it is installed. Pay special attention to this orientation.

Remove

Remove the nut (1) on the aftertreatment temperature sensor interface module mounting bracket strap.

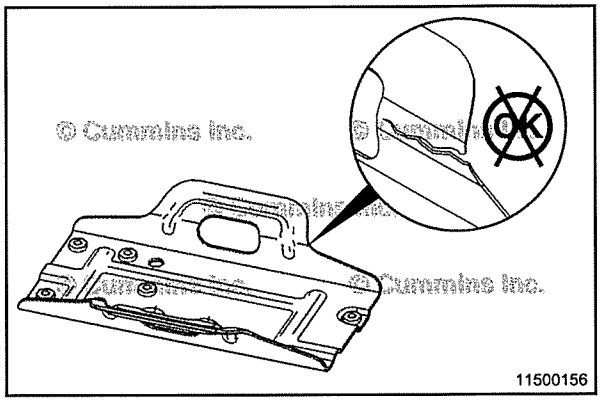
Remove the aftertreatment temperature sensor interface module mounting bracket (2) from the catalyst body.



Clean and Inspect for Reuse

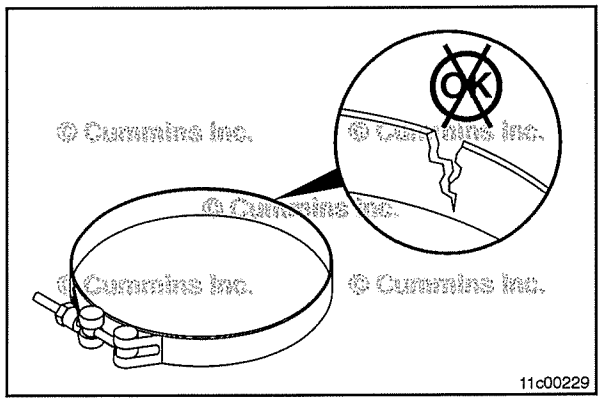
Inspect the aftertreatment temperature sensor interface module mounting bracket for cracks, damaged threads, or broken studs.

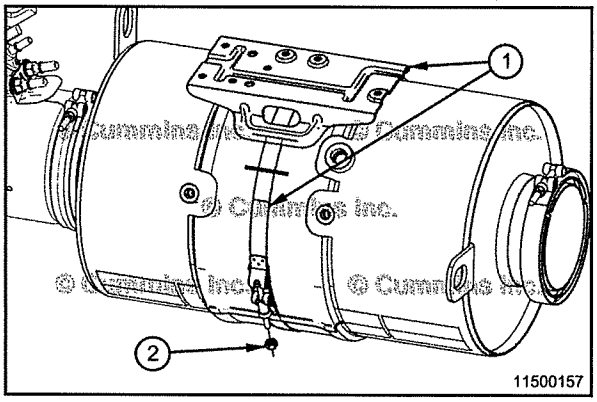
Replace the aftertreatment temperature sensor interface module mounting bracket if damaged.



Inspect the aftertreatment temperature sensor interface module mounting bracket strap for cracks, damaged threads, or bends.

Replace the aftertreatment temperature sensor interface module mounting bracket strap if it is damaged.





Install

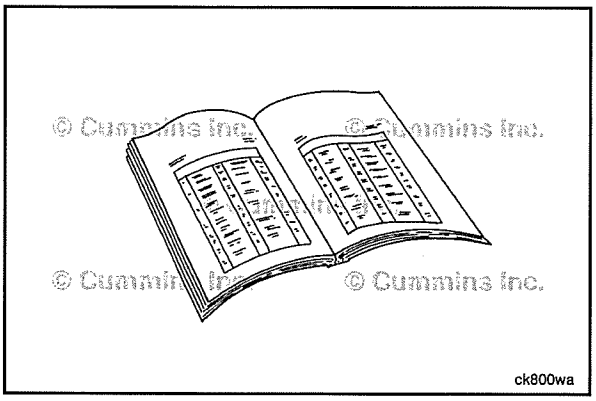
NOTE: Make sure the aftertreatment catalyst is oriented so the aftertreatment catalyst temperature sensor interface module mounting bracket is installed in the same orientation noted during removal.

Install the aftertreatment temperature sensor interface module mounting bracket (1) and strap. Be sure to align the mounting bracket using the reference mark that was made during removal.

Apply a coating of anti-seize compound, Part Number 3824879 or equivalent, to the threads of the aftertreatment temperature sensor interface module mounting bracket strap.

Tighten the nut (2) on the aftertreatment temperature sensor interface module mounting bracket strap.

Torque Value: 7 N•m [62 in-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the aftertreatment temperature sensor probes into the catalyst body. Refer to Procedure 019-449 in Section 19.
- Install the NOx sensor probe. Refer to Procedure 019-463 in Section 19.
- Connect the aftertreatment interface harness to the OEM wiring harness connection.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for proper operation.

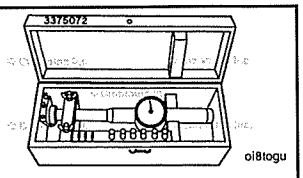
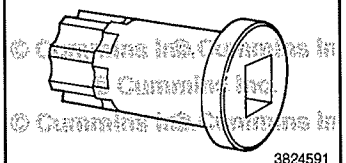
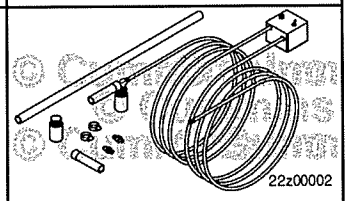
Section 12 - Compressed Air System - Group 12

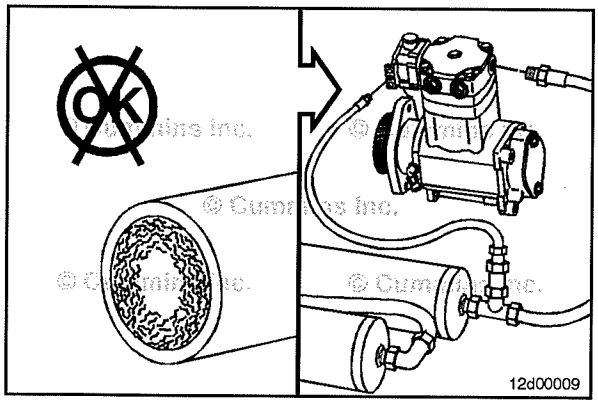
Section Contents

Service Tools

Compressed Air System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3376619	**Dial Bore Gauge** Used to measure the cylinder bores.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
2892280	**Air Compressor Cleaning Kit** Used to clean and remove internal carbon deposits and other foreign material from Wabco™ air compressor cylinder heads.	



Air Compressor Carbon Buildup (012-003)

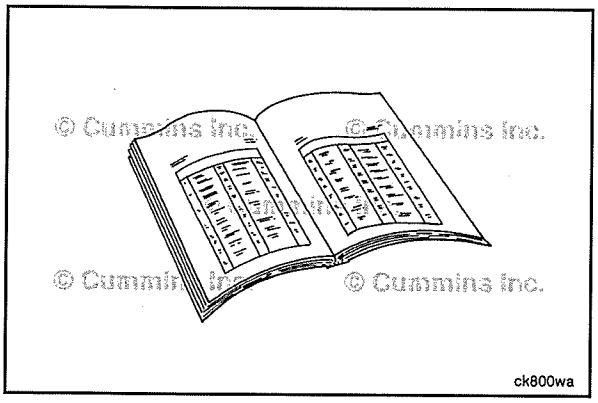
General Information

The key factor that determines the reliability and durability of an air compressor in an application is the amount of time the air compressor is supplying air during the vehicle/machine operation known as the duty cycle of the air compressor.

Air compressors are **not** designed to pump continuously and generate a lot of heat when pumping. The heat is dissipated during the time the compressor is **not** pumping (called the unloaded operation).

Compressed air system maintenance/servicing can help minimize the air compressor duty cycle and optimize the reliability and durability of the air compressor.

This includes checking the air compressor exhaust port, discharge line, and fittings for carbon buildup at regular intervals. See the Owners and/or Operation and Maintenance Manuals for the engine being serviced.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

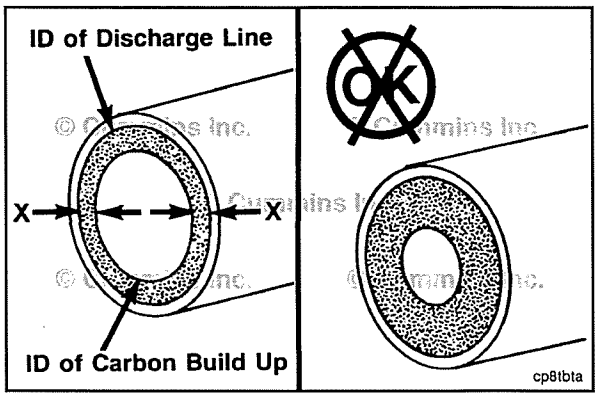
⚠WARNING⚠
Air discharge lines can be very hot. Make sure the lines are cool before touching to reduce the possibly of personal injury.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the vehicle air system. Refer to the OEM service manual.
- Disconnect the air compressor discharge line. Refer to Procedure 012-015 in Section 12.

Initial Check

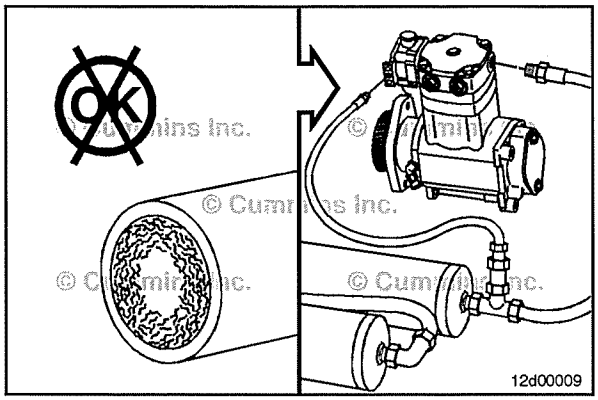
Measure the total carbon buildup thickness inside the air discharge line, as illustrated.

NOTE: The carbon buildup thickness **must not** exceed 1.6 mm [1/16 in].

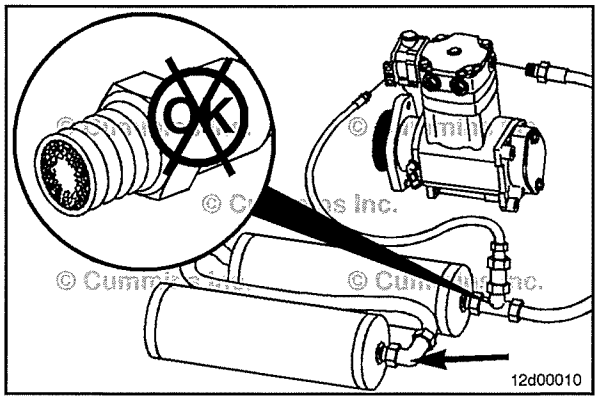


⚠WARNING⚠
The air discharge line must be capable of withstanding extreme heat and pressure to reduce the possibility of personal injury and property damage. Refer to manufacturer's specifications.

If the total carbon buildup thickness exceeds specification, remove and clean, or replace the air discharge line. Refer to the OEM service manual.



Continue to check for carbon buildup in the air discharge line connections up to the first connection, or wet tank. Clean and replace any lines and fittings with carbon buildups greater than 1.6 mm [1/16 in]. Refer to the OEM service manual.

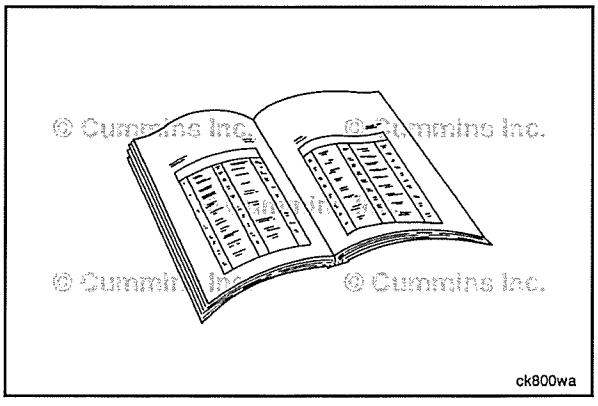


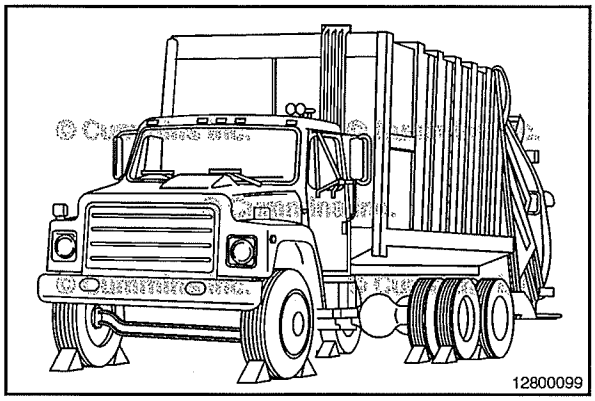
Clean

Use the Air Compressor Cleaning Kit, Part Number 2892280, to clean and remove internal carbon deposits and other foreign material from the air compressor cylinder head.

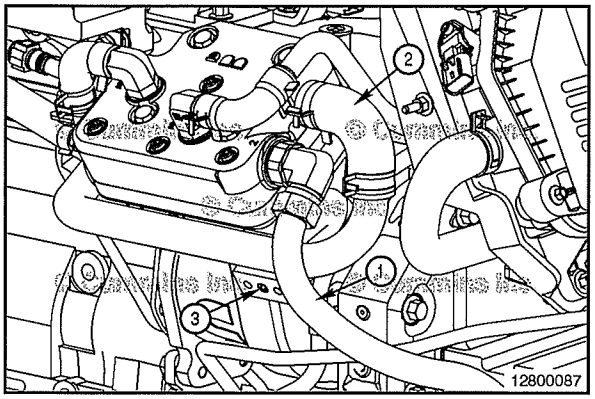
The items below are **not** included in the air compressor cleaning kit, Part Number 2892280, but are required to perform the repair.

- Regulated shop air 621 kPa [90 psi]
- Automatic transmission fluid
- Shop rags
- 19 liter [5 gal] bucket
- INSITE™ electronic service tool.

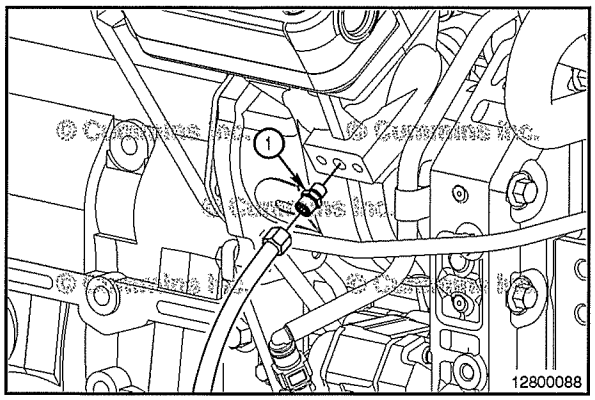




Park vehicle on a level surface and in an area where it is safe to idle for an extended period of time. Chock the vehicle wheels, and completely drain the vehicle air system.



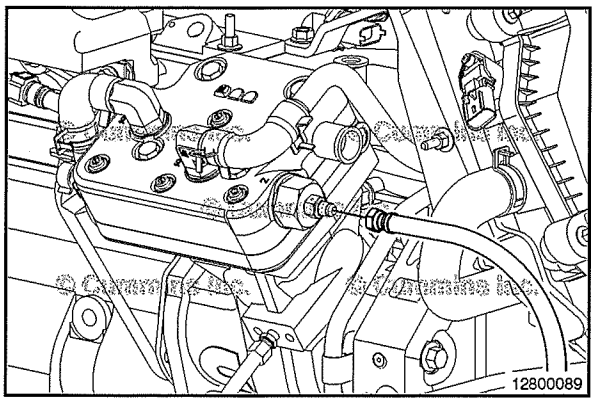
Remove the air compressor discharge line (1), air compressor intake line (2), and air governor signal line (3) at the air compressor.



Install and tighten the M10 connector (1) into the unloader port of the air compressor housing.

Install and tighten the unloader control valve hose to the M10 connector installed into the air compressor housing.

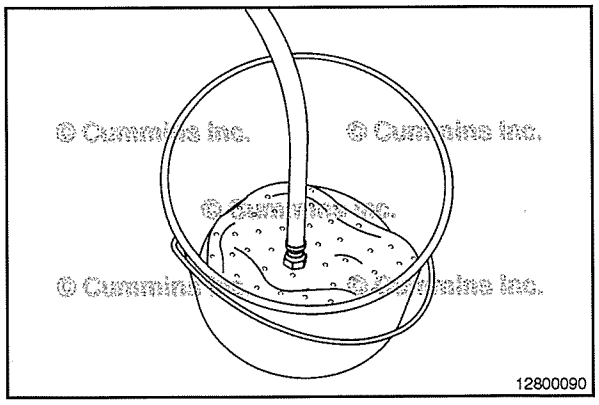
NOTE: Some air compressors have two unloader ports in the air compressor housing. Make sure that one of the ports is plugged with an appropriate pipe plug.



△CAUTION△
While cleaning the air compressor cylinder head, do not install the original intake or discharge plumbing. Only use the intake and discharge lines and fitting supplied with the air compressor cleaning kit during this procedure.

Install the discharge line and clamp from kit, Part Number 2892280, onto the discharge port fitting on the air compressor cylinder head.

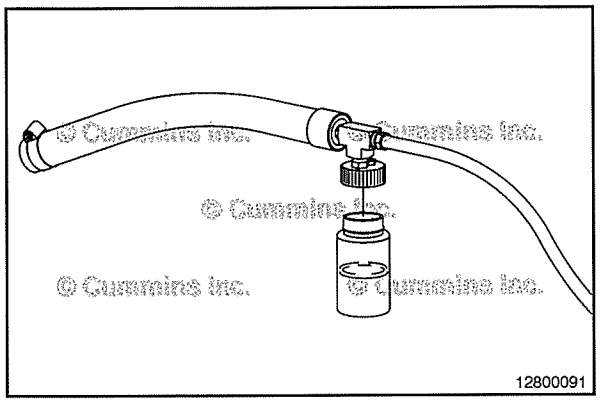
Place the discharge line into a 19 liter [5 gal] bucket and cover with several oil absorption pads.



Pour 89 ml [3 oz] of automatic transmission fluid into the dispensing bottle.

Install the dispensing bottle onto the dispensing hose assembly.

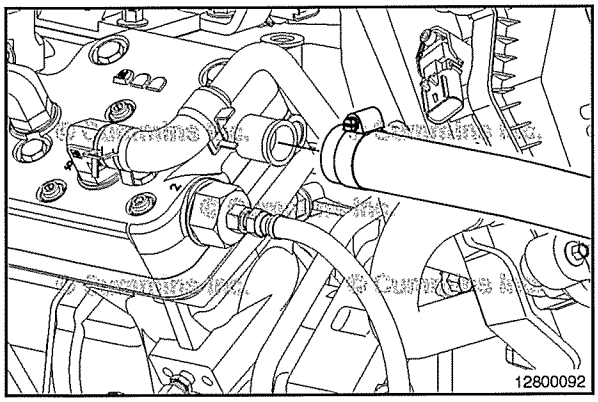
NOTE: For best results, use Dexron III automatic transmission fluid, or equivalent.



Install and tighten the dispensing hose assembly and clamp to the intake port of the air compressor cylinder head.

Connect the regulated shop air at 621 kPa [90 psi] to the air compressor cleaner.

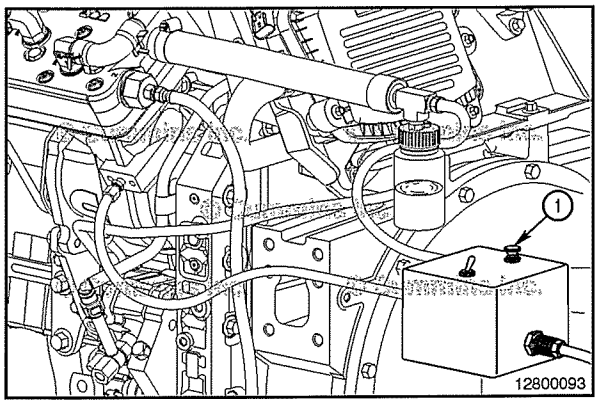
NOTE: The next three steps will happen quickly. For best results, read the remaining instructions prior to continuing with the cleaning procedure. Do **not** cycle the unloader until all 89 ml [3 oz] of automatic transmission fluid have been applied.

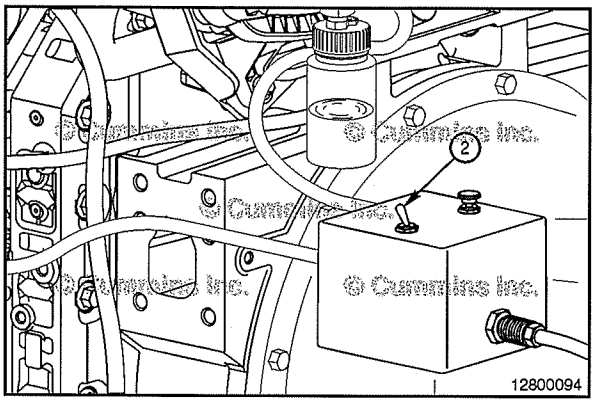


Start the engine, and let it idle for 1 minute.

The air compressor may draw in the automatic transmission fluid naturally (no forced air applied). If the fluid is **not** pulled from the dispensing bottle, press and hold the "Clean" button (1) on the air compressor cleaner until all 89 ml [3 oz] of automatic transmission fluid have been dispensed.

Shut the engine OFF.

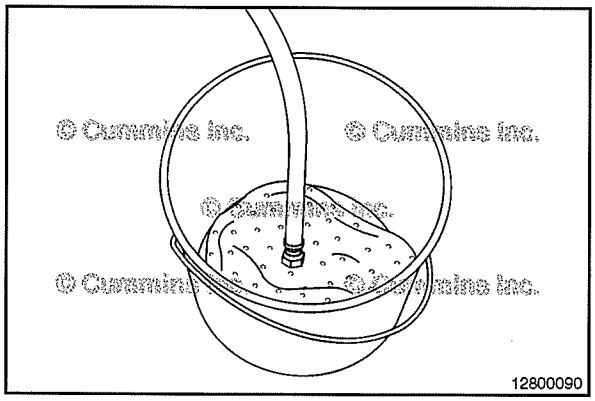




Pour 89 ml [3 oz] of automatic transmission fluid into the dispensing bottle and install back onto the dispensing hose assembly.

Toggle the "Unloader" switch (2) on to apply air pressure to the unloader signal port.

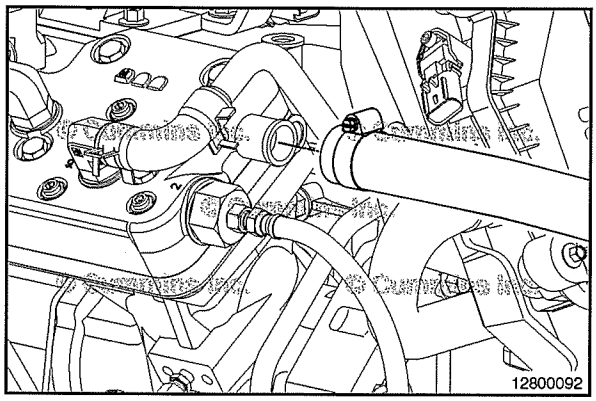
Do **not** relieve pressure at the unloader valve at this time.



Start the engine.

Immediately depress and hold the "Clean" button on the air compressor cleaner until all 89 ml [3 oz] of automatic transmission fluid have been dispensed. Continue to hold the "Clean" button down for an additional 10 to 20 seconds.

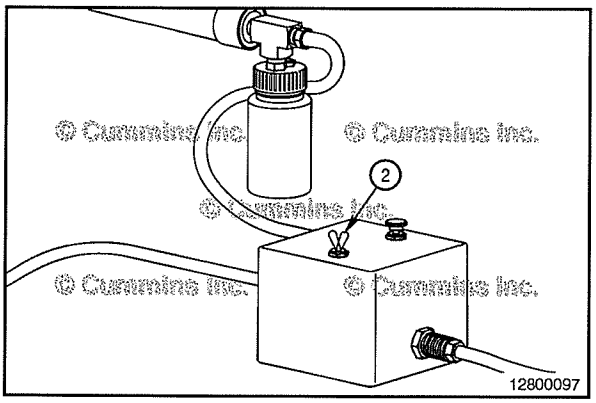
NOTE: A heavy mist of automatic transmission fluid should be coming from the discharge hose.



Shut the engine OFF.

Remove the discharge hose assembly from the air compressor cylinder head intake port.

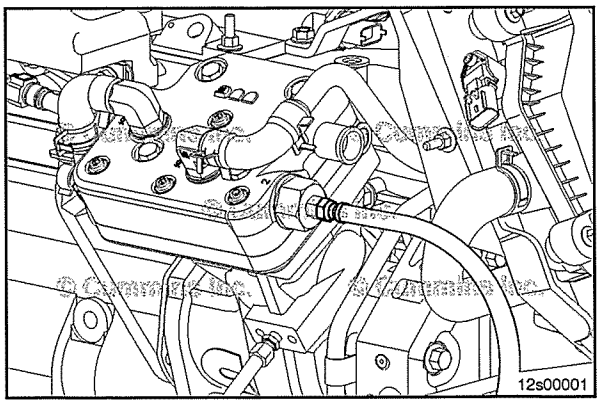
Start the engine.



Continuously cycle the "Unloader" switch on the air compressor cleaner for up to 25 cycles.

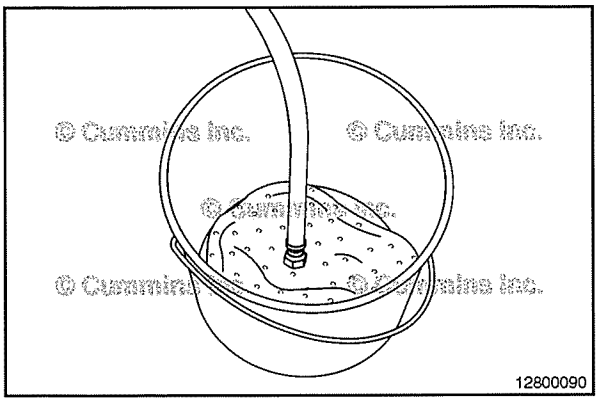
NOTE: When the air compressor cylinder head has been adequately cleaned, there should be an audible difference between loaded and unloaded states of the air compressor. Installation of a 1.5 meter [5 ft] length of rubber hose over the intake port may help to audibly identify when the unloader is functioning properly.

Verify constant suction at the air compressor cylinder head intake port when the air compressor is loaded (unloader switch OFF), and fluctuating air flow when unloaded (unloader switch ON). If constant suction is **not** present in a loaded state, repeat the cleaning process one additional time.



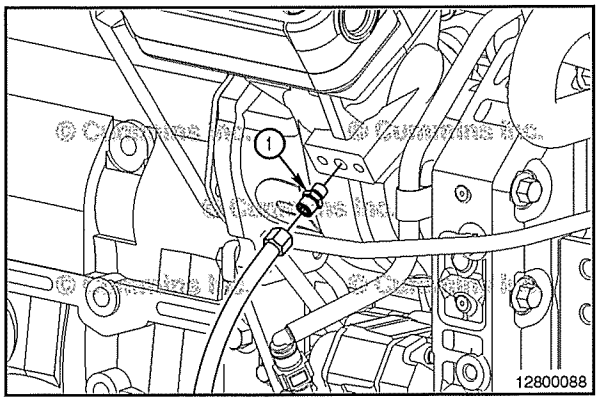
⚠CAUTION⚠
Operating the air compressor with no filter in place at the intake port may allow dust or debris to enter the air compressor. A rubber hose should be placed over the intake port and routed to an area free of air born dust and debris.

With the discharge hose still installed, relieve the pressure at the unloader port (switch OFF), and operate the engine at high idle for 3 - 5 minutes to remove any excess automatic transmission fluid.



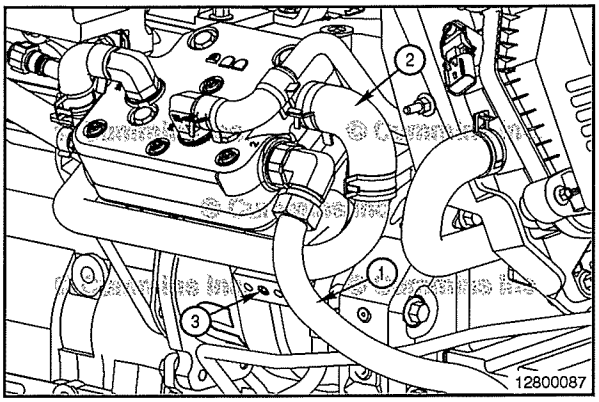
Allow engine to return to low idle. Shut the engine OFF.

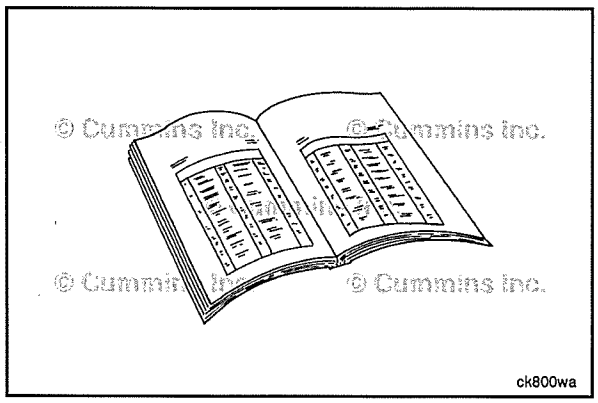
Remove the unloader control valve hose and M10 connector (1).



Install the vehicle air governor and/or signal line (3) and air inlet (2) and outlet (1) connections on the air compressor.

Operate the engine and verify the air compressor is functioning properly.



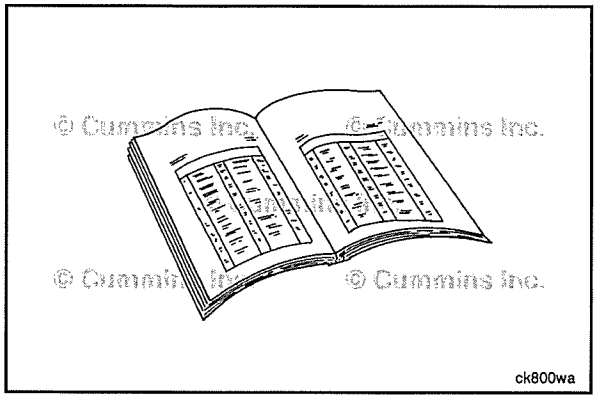


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Connect the air compressor discharge line. Refer to Procedure 012-015 in Section 12.
- Connect the battery cables. Refer to the OEM service manual.
- Fill the vehicle's air system. Refer to the OEM service manual.
- Operate the engine and check for air leaks.



Air Compressor Coolant Lines (012-004)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Some applications may require removal of the starter. Refer to Procedure 013-020 in Section 13.

Remove

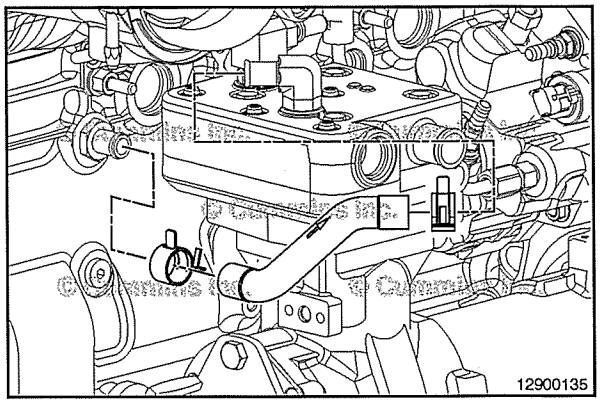
NOTE: The illustrations show a high mount air compressor. The procedure is the same for low mount air compressors.

Remove any p-clips and/or mounting fasteners securing the air compressor coolant lines.

Remove the hose clamps securing the air compressor coolant lines.

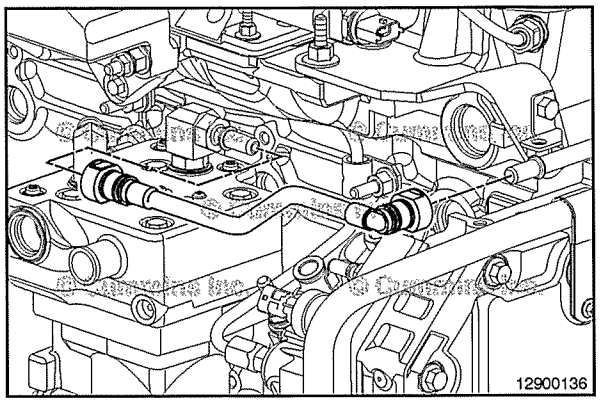
For the air compressor coolant supply line, disconnect the line from the cylinder block and then from the air compressor cylinder head.

Remove the air compressor coolant supply line.

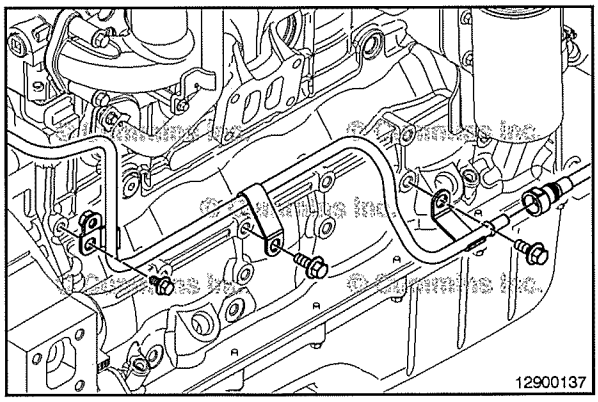


The air compressor coolant return line is composed of three sections.

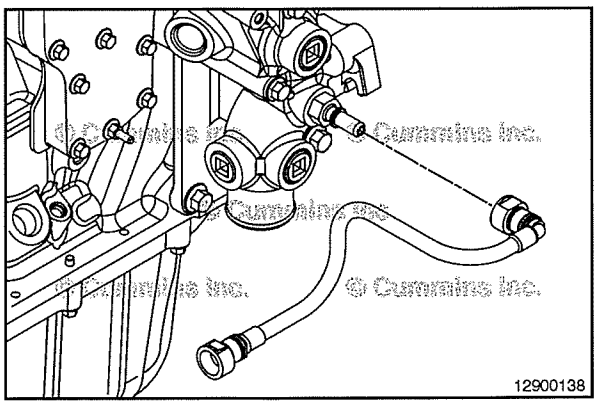
Disconnect the section closest to the air compressor from the air compressor cylinder head and from the middle section of line. These are quick connect fittings.

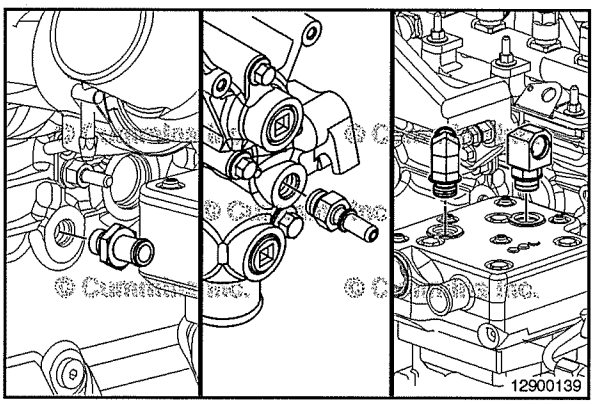


Disconnect the middle section from the last section. This is a quick connect fitting.



Disconnect the last section closest to the water inlet connection. This is a quick connect fitting.



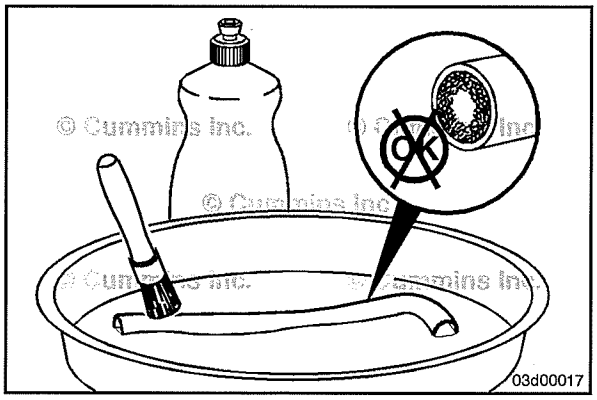


Disassemble

NOTE: Note the location of all fitting(s) before removal to aid in assembly.

Remove the coolant supply and return fitting(s) from the following:

- Cylinder block
- Water inlet connection
- Air compressor cylinder head.



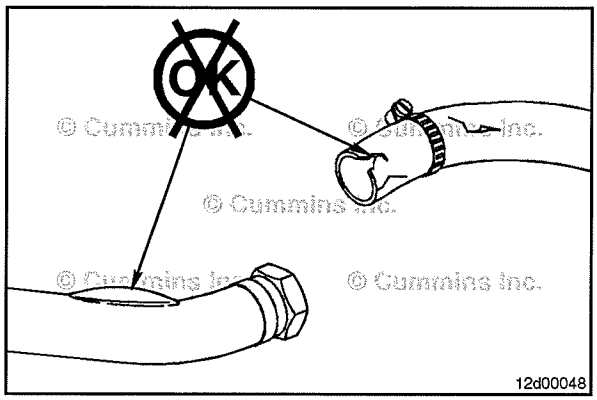
Clean and Inspect for Reuse

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the air compressor coolant lines with a strong detergent solution.

Dry the air compressor coolant lines with compressed air.

Inspect the air compressor coolant lines for any internal restrictions. Replace the coolant lines if any restrictions are found.



Inspect the coolant hoses for splits, cracks, hardening, or other damage.

Inspect metal coolant lines for kinks, corrosion, or cracks.

Inspect the quick connect fittings for corrosion, cracks, or other damage.

Replace the component if any damage is found.

Assemble

NOTE: When installing any 90 degree air compressor coolant line fittings, make sure to properly orient the fitting before and while tightening.

NOTE: Apply a film of sealant, Part Number 3375066 or equivalent, to all fittings with pipe threads.

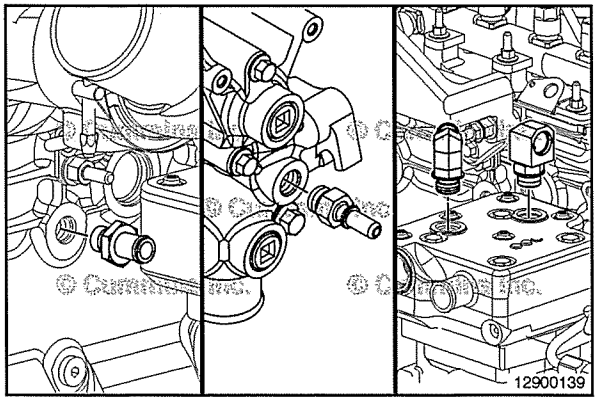
NOTE: Apply a film of clean 15W-40 engine lubricating oil to all fittings with straight threads and an o-ring seal.

Install the coolant supply lines fitting(s) into the appropriate location and tighten:

Torque Value:
Cylinder Block Fitting 18 N•m [159 in-lb]

Torque Value:
Water Inlet Connection Fitting 20 N•m [177 in-lb]

Torque Value:
Air Compressor Cylinder Head Fitting 24 N•m [212 in-lb]

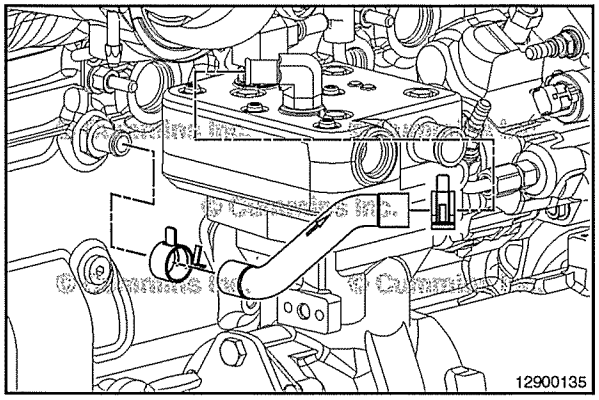


Install

Install the air compressor coolant supply line.

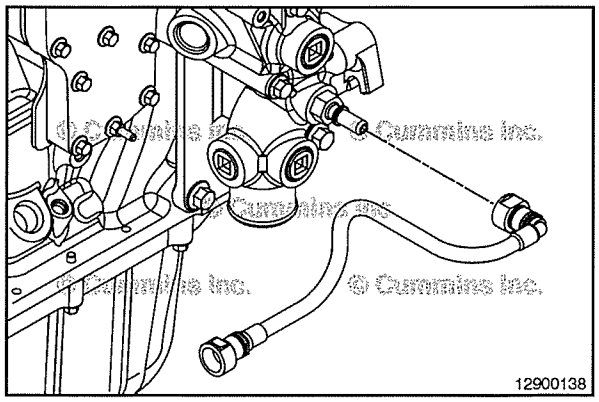
For the air compressor coolant supply line, connect the line to the cylinderblock and then to the air compressor cylinder head.

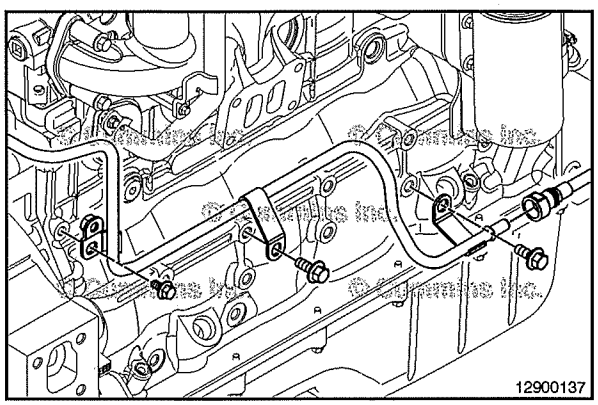
Install and secure the hose clamps.



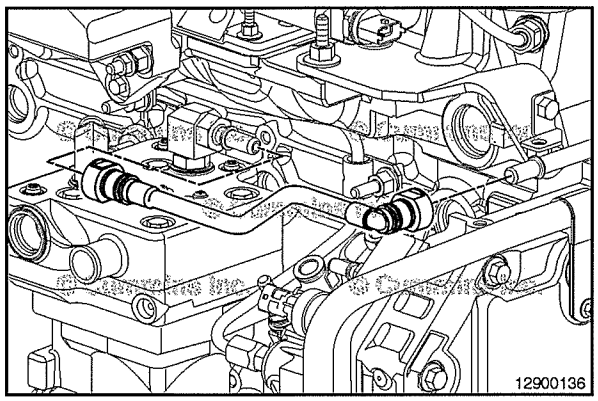
The air compressor coolant return line is composed of three sections.

Install the section closest to the water inlet connection. This is a quick connect fitting.





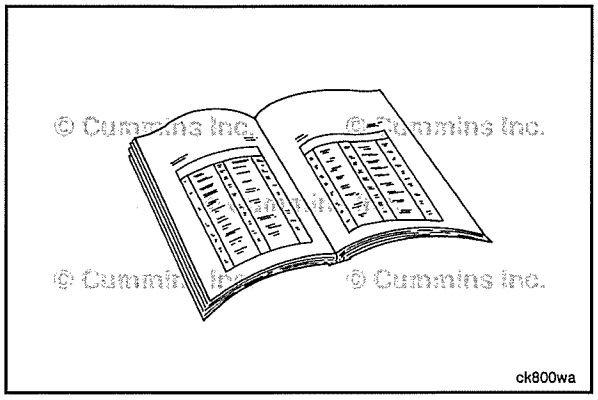
Install the middle section onto the section closest to the water inlet connection. This is a quick connect fitting.



Install the section closest to the air compressor into the air compressor cylinder head and into the middle section of line. These are quick connect fittings.

Install any p-clips and/or mounting fasteners securing the air compressor coolant lines.

See the following procedure for torque values on M8, M10, and M12 fasteners. Refer to Procedure 018-009 in Section V.



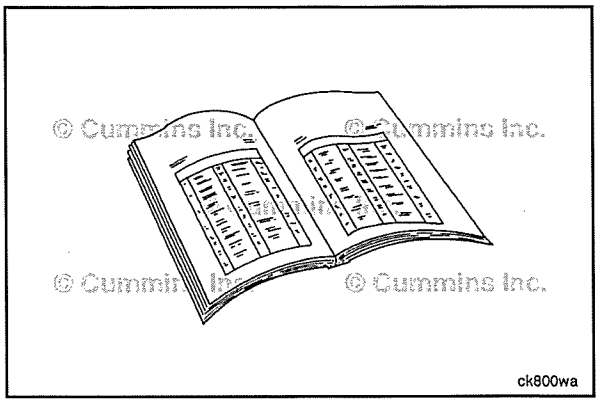
Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Some applications may require installation of the starter. Refer to Procedure 013-020 in Section 13.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Air Compressor Cylinder Head, Single Cylinder (012-007)



Preparatory Steps

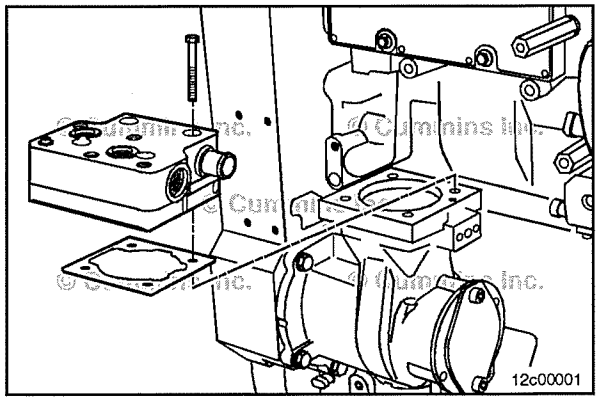
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the air governor or air governor signal line, if necessary. Refer to the OEM service manual.
- Remove the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- Remove the air inlet and outlet connection from the air compressor.

Remove

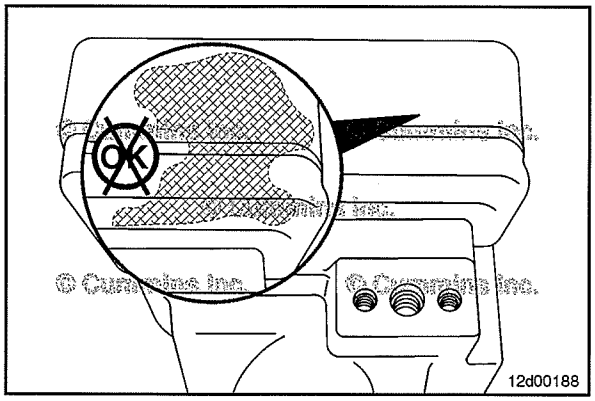


Remove the four 8-mm capscrews.

Do **not** remove the three M6 internal hex capscrews at this time.

Remove the head and gasket.

NOTE: Due to an interference with the fuel pump on some applications, it can be difficult to remove all four mounting capscrews completely from the air compressor cylinder head while the air compressor is still mounted to the engine. To remove the cylinder head, completely remove the front two capscrews and completely loosen the rear two capscrews. Simultaneously lift the left rear capscrew and cylinder head to unseat the locating dowel from the air compressor housing. Slowly rotate the head **counterclockwise**, using the right rear locating dowel as a pivot point, until enough clearance is available to lift the cylinder head off of the air compressor.

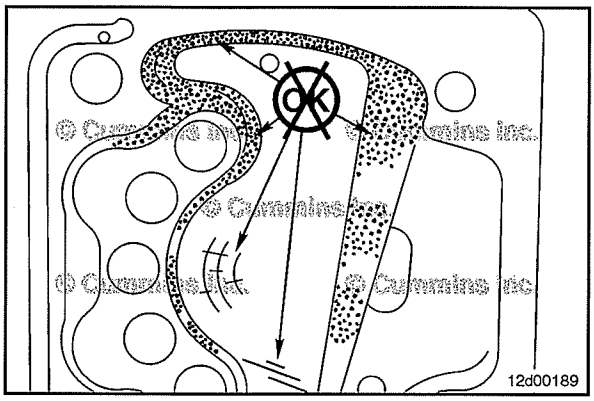


Clean and Inspect for Reuse

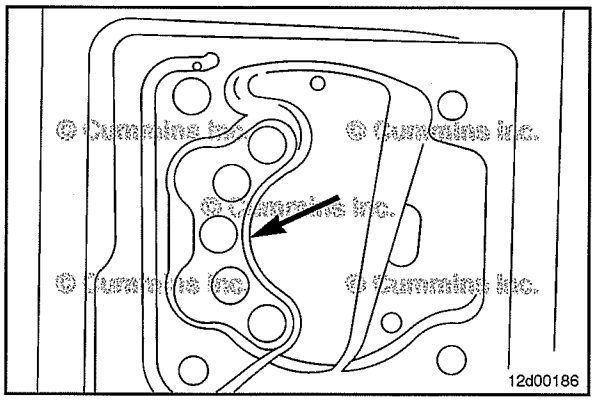
NOTE: The below clean and inspect steps are **only** to be completed if the air compressor cylinder head was removed as part of another repair. The air compressor cylinder head does **not** need to be removed if the unloader and valve assembly are determined to be stuck/ seized. Refer to Procedure 012-003 in Section 12.

Inspect the cylinder head for signs of an external coolant leak. A large coolant leak from the air compressor cylinder head will have blistered/removed paint and/or have a white deposit build up.

If a large coolant leak is observed, the head should be rebuilt with a gasket kit. Reference the Cylinder Head Gasket Kit in the Install section of this procedure.



Inspect the unloader valve plate and cylinder head for deep scratching or scoring. If the cylinder head is scratched or scored deeply, it **must** be replaced.



Verify that the unloader piston is in the proper orientation and operates properly. If, upon inspection, the unloader piston and plate are stuck open, exposing any area of the relief chamber, carefully remove the unloader plate from the unloader piston pinions.

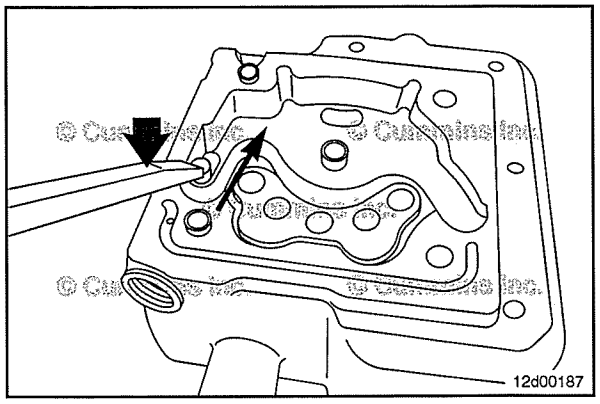
NOTE: The unloader piston and plate **must always** default to the fully closed position.

Place a few drops of automatic transmission fluid into the unloader piston bore. Coat the front and back side of the piston with fluid.

Use a stiff wooden handle to apply pressure to the unloader valve against the spring. Slide the unloader piston through the full range of rearward travel. When the spring is fully compressed, quickly let the pressure off, allowing the spring to drive the piston back to its closed state. Repeat cycling the unloader piston in this manner 5 to 10 times.

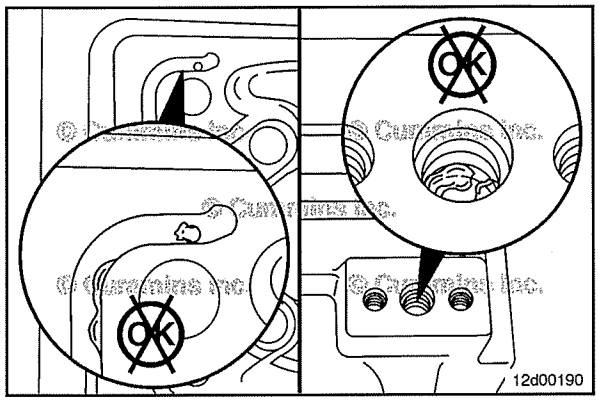
If the unloader piston continues to demonstrate any resistance to movement, or slow response while returning to the default closed position, the cylinder head **must** be replaced.

NOTE: The above steps can be completed without removing the air compressor cylinder head from the air compressor by using the Air Compressor Cleaning Kit, Part Number 2882280. Refer to Procedure 012-003 in Section 12.

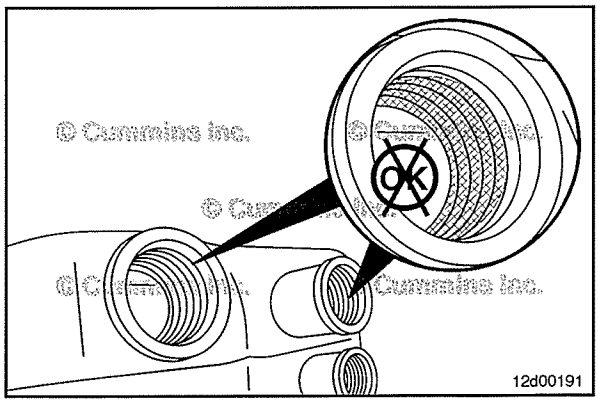


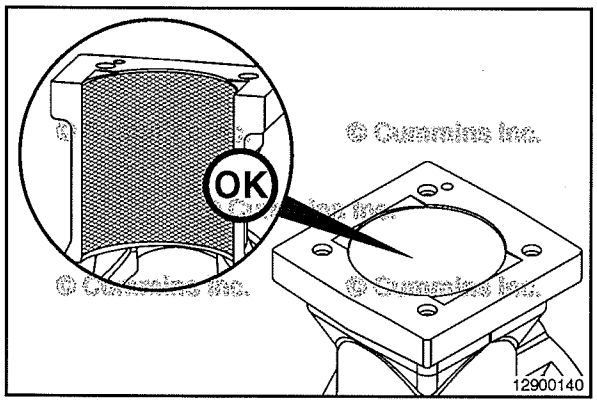
Inspect the unloader channel and governor supply port, as well as the unloader piston, for signs of rust.

NOTE: Rust present in the unloader channel and/or governor feed port indicates either the air dryer has malfunctioned, or improper draining of the vehicle air tanks. Use the following procedure to check the air governor for proper operation. Refer to Procedure 012-016 in Section 12. Refer to the OEM service manual for troubleshooting the air dryer, as well as proper maintenance intervals for the vehicle compressed air tanks.

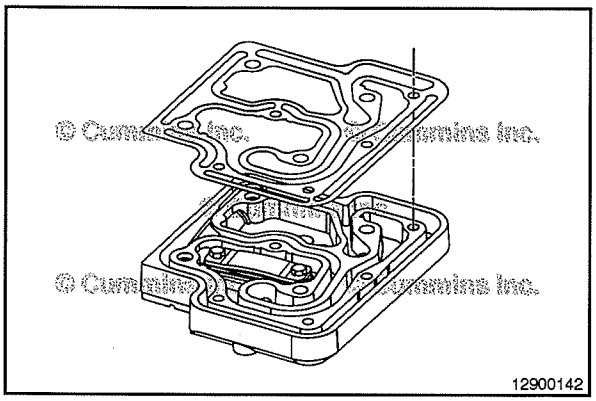


Inspect the intake and discharge ports for heavy carbon buildup. Use the following procedure for proper reuse guidelines. Refer to Procedure 012-003 in Section 12.





While the air compressor cylinder head is removed, inspect the rotating components and the cylinder bore of the air compressor for damage. Refer to Procedure 012-014 in Section 12.



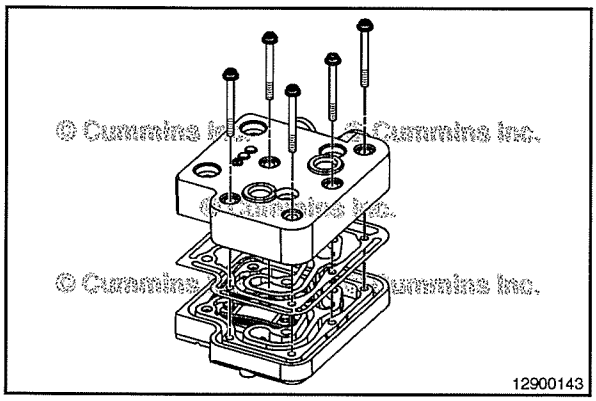
Disassemble

Air compressor cylinder heads can be rebuilt with new gaskets if air or coolant leaks are detected.

Disassemble the cylinder head by removing the five internal hex capscrews.

Separate the cylinder head.

Remove and discard the old gasket.

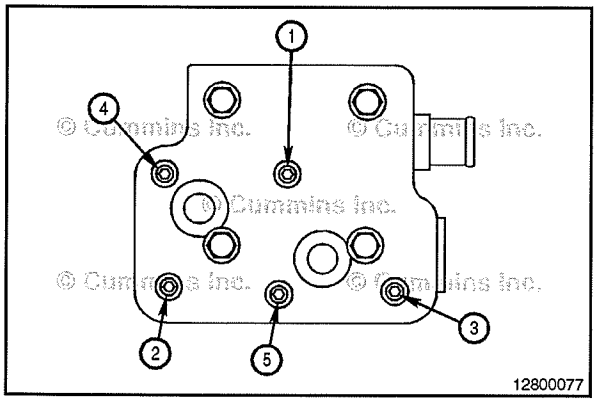


Inspect the sealing surface on both the upper and lower sections of the cylinder head for damage.

Replace the exhaust valve if there is coolant related failure, or it is suspected that it is **not** sealing.

Do **not** reuse the exhaust valve capscrews.

Clean and inspect sealing surface.



Assemble

Place the new exhaust valve with the flat surface down.

Torque Value:

Step 1	5 N•m	[44 in-lb]
Step 2	10 N•m	[89 in-lb]

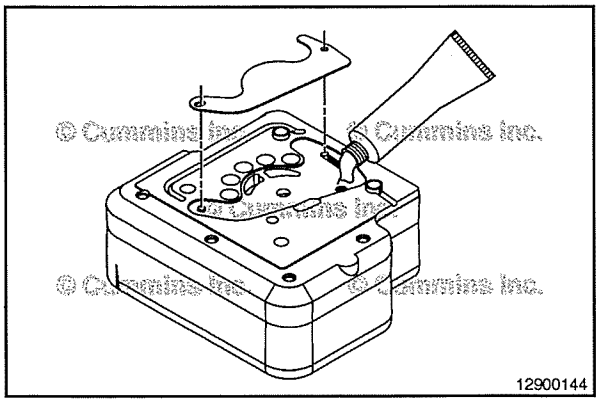
Carefully place a new gasket on the lower section of the cylinder head.

Place the upper section of the cylinder head and insert five internal hex capscrews, and finger tighten.

NOTE: If installing a new air compressor cylinder head assembly, the following steps should **not** be performed. New cylinder head assemblies are already assembled per the instructions below. Skip to placement of the cylinder head assembly onto the air compressor housing.

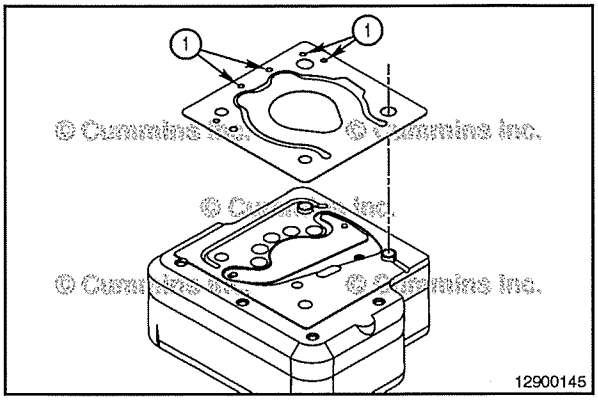
Apply a light coating of assembly lubricant, Part Number 3163087 or equivalent, to the unloader plate recess of the cylinder head.

Place the unloader plate onto the unloader piston pinion, as well as the stationary pinion, and press the unloader plate into the assembly lubricant.



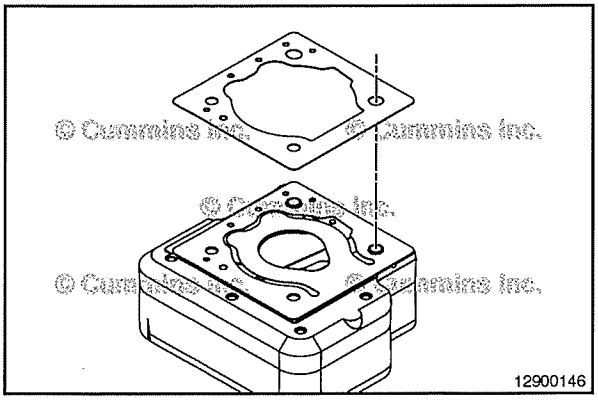
Install the air compressor intake valve.

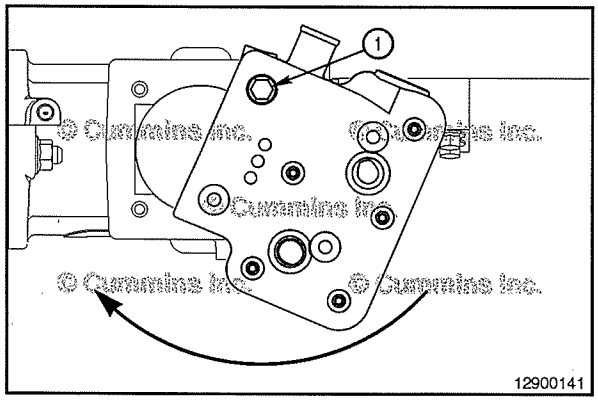
Make sure the intake valve is oriented so the unloader channel of the cylinder head is exposed by four holes (1).



Install the sealing gasket in a similar manner.

Make sure to orient the gasket so the four holes are **not** blocked by the sealing gasket.





Install

NOTE: A new gasket kit **must** be used each time the air compressor cylinder head is removed and installed. Do **not** reuse the cylinder head mounting capscrews.

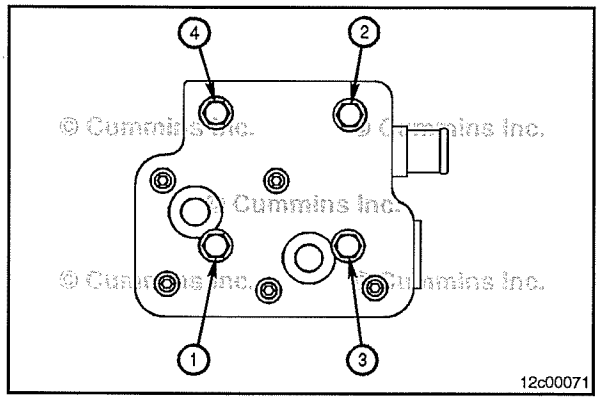
NOTE: Due to an interference with the fuel pump on some applications, following a specific installation sequence of the air compressor cylinder head and mounting capscrews will make installation possible with the air compressor still installed on the engine.

Before placing the cylinder head on the air compressor housing, insert the rear right capscrew (1) through the mounting hole. Place the cylinder head on the air compressor housing such that the right rear locating dowel and mounting capscrew engage the mounting hole in the air compressor housing.

Insert the rear left capscrew through the cylinder head mounting hole. Rotate the cylinder head clockwise into position, using the rear right capscrew and locating dowel as a pivot. Once the cylinder head has been properly set onto the air compressor housing, insert the front two capscrews.

Install the cylinder head and gasket.

Install the four 8-mm capscrews.

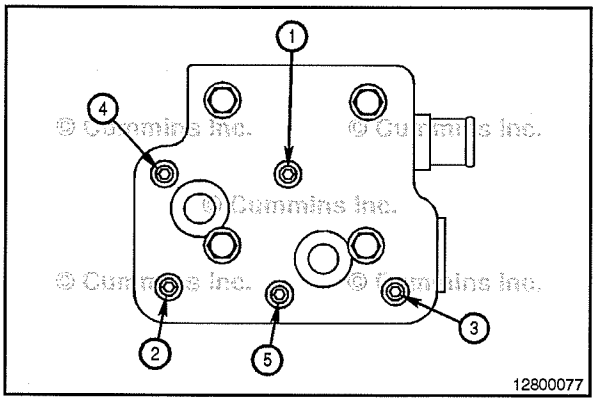


Tighten the capscrews in the sequence shown. Use the torque plus angle method.

Torque Value:

Step 1	25 N•m	[221 in-lb]
Step 2	Rotate capscrews 90 degrees	

NOTE: If a new head assembly is being installed, the five small head cover bolts **must** be tightened.



If a new head assembly is being installed, tighten the five small head cover capscrews in the sequence shown.

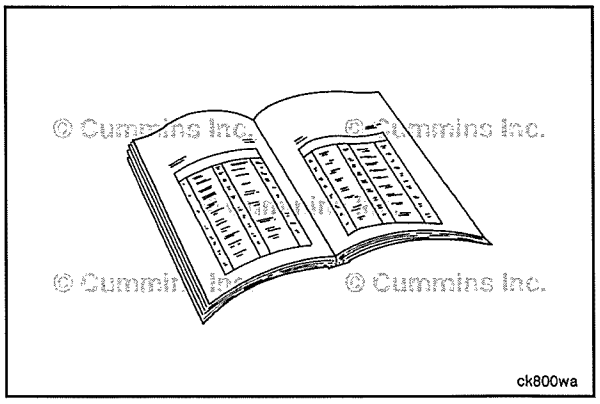
Torque Value:

Step 1	6 N•m	[53 in-lb]
Step 2	Rotate 90 degrees.	

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the air inlet and outlet connections from the air compressor.
- Install the air governor or air governor signal line, if necessary. Refer to the OEM service manual.
- Install the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

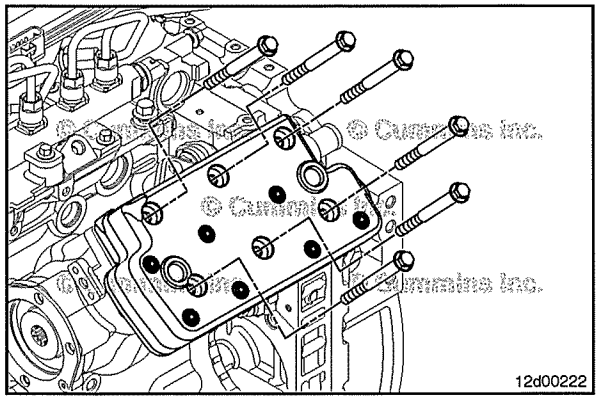


Air Compressor Cylinder Head, Two Cylinder (012-008)

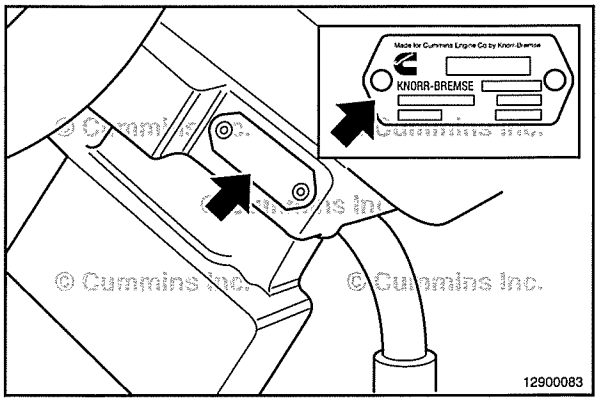
General Information

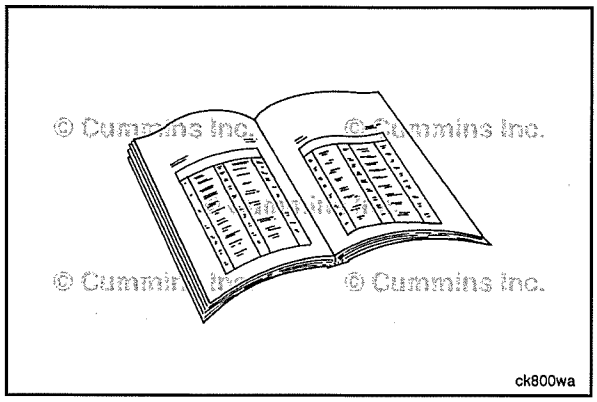
Before removing the cylinder head of the air compressor, **always** check to make sure parts are available for the type of air compressor being serviced. If parts are **not** available, it will be necessary to replace the entire air compressor. Refer to Procedure 012-014 in Section 12.

NOTE: The following procedure has been written to cover different air compressor configurations. For some applications and mounting configurations, it can be necessary to remove the air compressor in order to remove the air compressor cylinder head.



Cummins® engines are equipped with a variety of air compressors. This procedure will cover the removal, cleaning, inspection, and installation of the Wabco™ air compressors.





Preparatory Steps

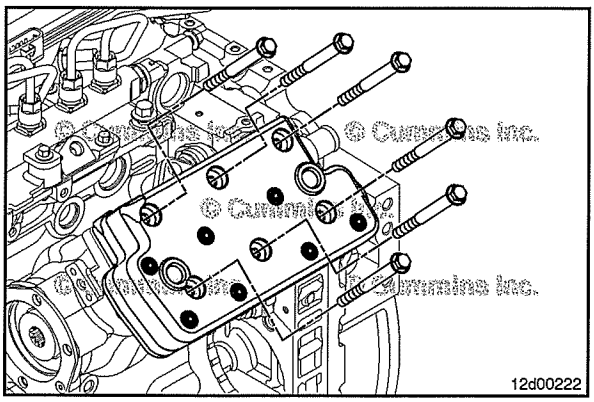
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the vehicle air system. Refer to the OEM service manual.
- Use steam to clean the air compressor. Dry with compressed air.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the coolant lines from the air compressor. Refer to Procedure 012-004 in Section 12.
- Remove the air inlet tube. Refer to Procedure 012-109 in Section 12.
- Remove the air discharge line. Refer to Procedure 012-015 in Section 12.



Remove

NOTE: The head and valve plate are indexible; marking the parts is recommended to make sure they are assembled in the proper orientation.

Remove and discard the cylinder head capscrews.

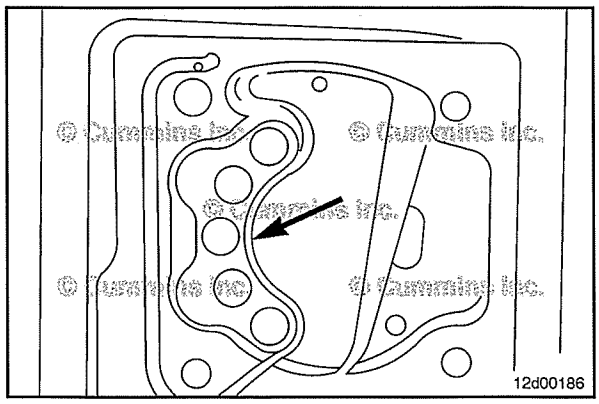
NOTE: The cylinder head capscrews **must not** be used again.

Remove the cylinder head and valve assemblies.

Inspect for Reuse

NOTE: The unloader piston and plate should **always** default to the fully closed position.

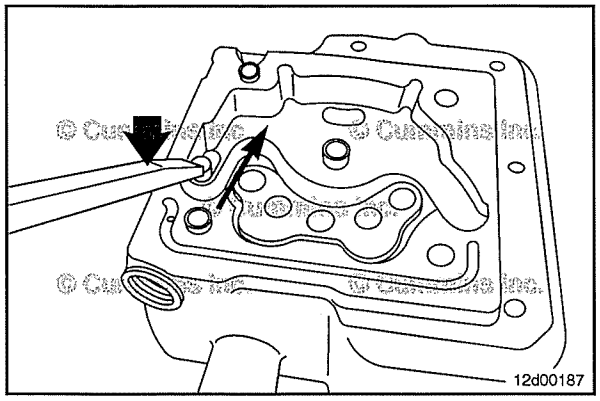
Verify that the unloader piston is in the proper orientation and operates properly. If upon inspection, the unloader piston and plate are stuck open, exposing any area of the relief chamber, the cylinder head **must** be replaced.



Carefully remove the unloader plate from the unloader piston pinions.

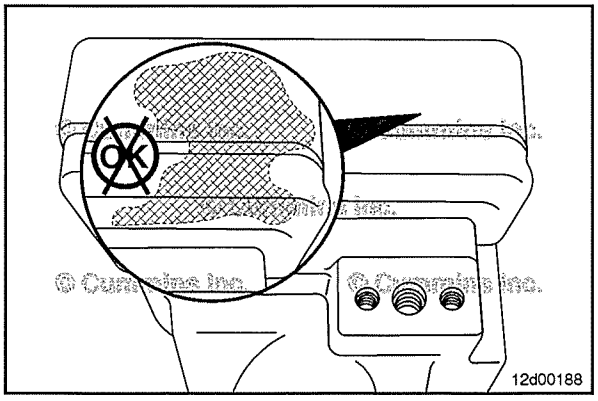
Use a stiff wooden handle to apply pressure to the unloader valve against the spring. Slide the unloader piston through its full range of rearward travel. When the spring is fully depressed, quickly let the pressure off, allowing the spring to drive the piston back to its closed state.

If the unloader piston demonstrates any resistance to movement, or slow response while returning to the default closed position, the cylinder head **must** be replaced.



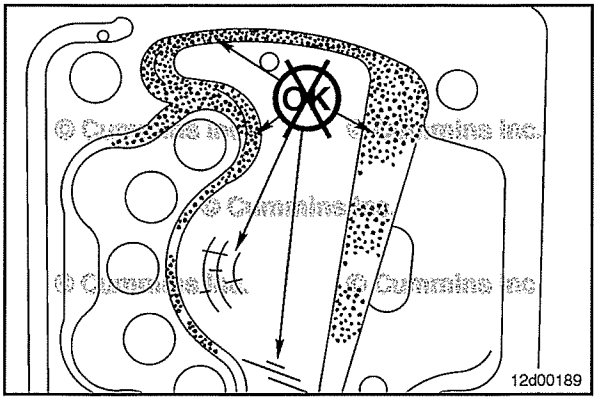
Inspect the cylinder head for:

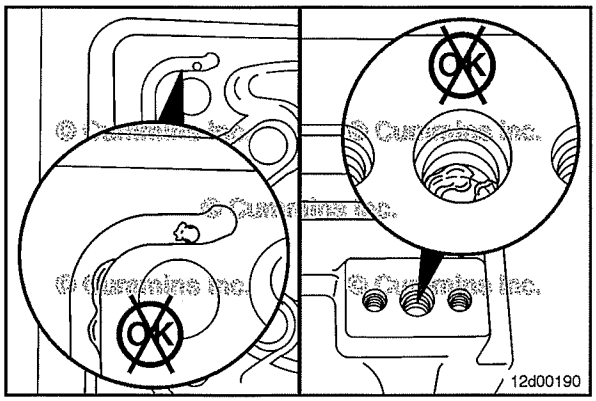
- Discoloration due to overheating
- Discoloration due to an external coolant leak.



Inspect the unloader valve plate and piston for:

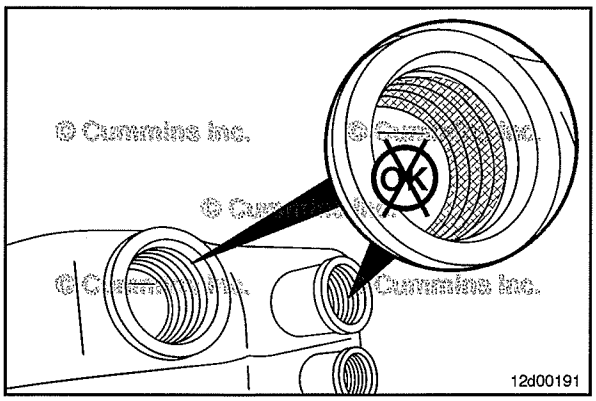
- Heavy carbon buildup
- Deep scratching or scoring.





Inspect the unloader channel and governor supply port, as well as the unloader piston, for signs of rust.

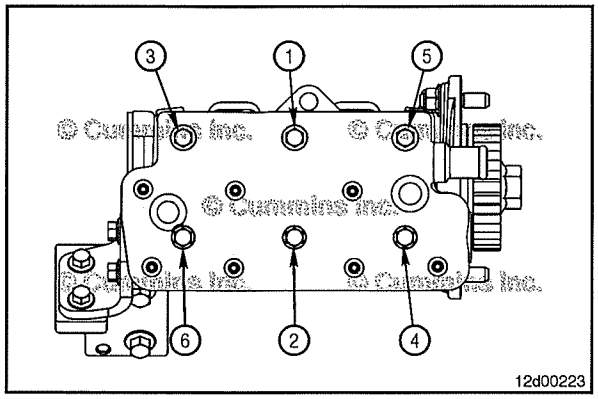
Rust present in the unloader channel and/or governor feed port indicates that either the air dryer has malfunctioned, or improper draining of the vehicle air tanks. Use the following procedure and check for proper operation. Refer to Procedure 012-016 in Section 12. Refer to the OEM service manual for troubleshooting the air dryer, as well as proper maintenance intervals for the vehicle compressed air tanks.



Inspect the intake and discharge ports, and unloader piston assembly for heavy carbon buildup.

If any of the above conditions are present, replace the air compressor cylinder head.

While the air compressor cylinder head is removed, inspect the rotating components and the cylinder bore of the air compressor for damage. Refer to Procedure 012-014 in Section 12.



Install

Use a new gasket and capscrews to assemble the air compressor.

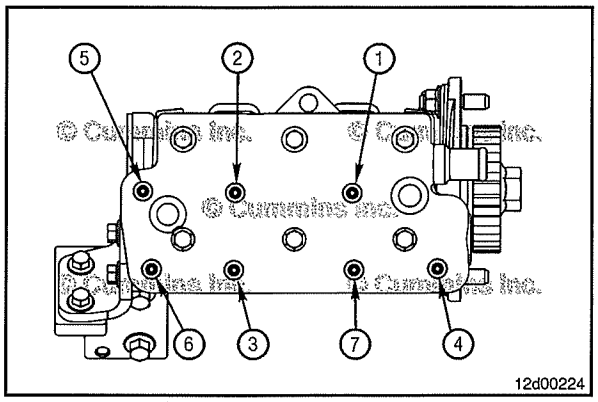
Install the gasket and air compressor cylinder head to the air compressor body.

Tighten the capscrews in the sequence shown. Use the torque plus angle method.

Torque Value:

Capscrews 1 - 6		
Step 1	25 N•m	[221 in-lb]
Step 2	Rotate capscrews 1 - 2: 150 degrees	
Step 3	Rotate capscrews 3 - 6: 120 degrees	

NOTE: If a new head assembly is being installed, the seven small head cover bolts **must** be tightened.

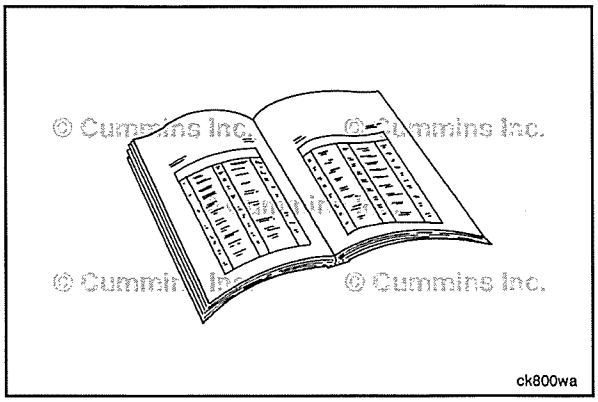


If a new air compressor cylinder head assembly is being installed, tighten the seven small head cover bolts in the sequence shown. Use the torque plus angle method.

Torque Value:

Capscrews 1 - 7		
Step 1	6 N•m	[53 in-lb]
Step 2	Rotate 135 degrees.	

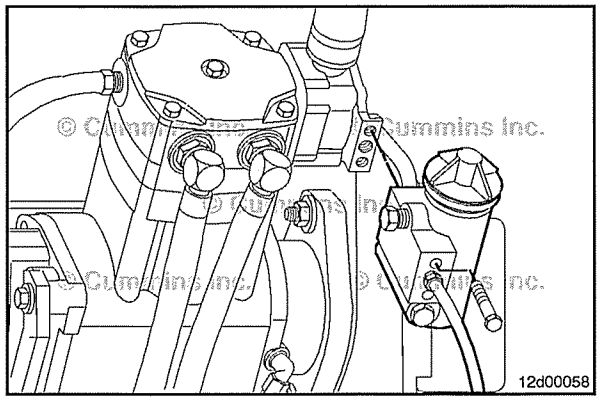
Finishing Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the coolant lines from the air compressor. Refer to Procedure 012-004 in Section 12.
- Install the air inlet tube. Refer to Procedure 012-109 in Section 12.
- Install the air discharge line. Refer to Procedure 012-015 in Section 12.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Air Compressor Unloader and Valve Assembly (012-013)



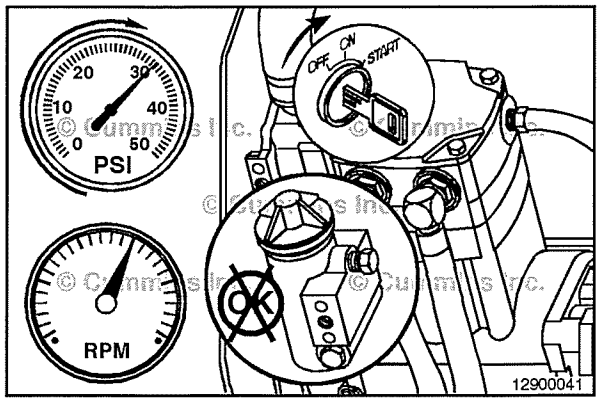
Initial Check

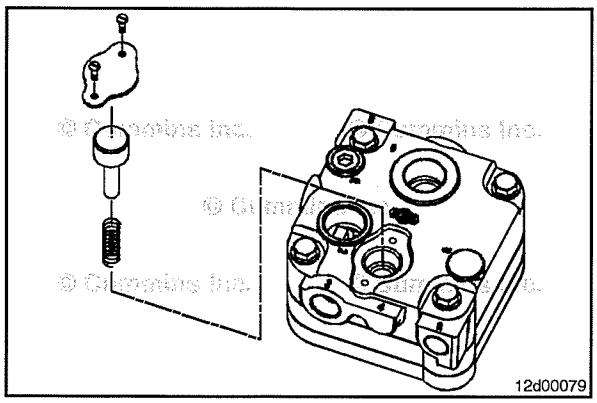
⚠WARNING⚠
Air pressure must be released from system before removing the air governor. The governor can be under pressure and cause personal injury.

Remove the air governor or air governor hose from the air compressor unloader body.

Operate the engine to activate the air compressor.

If the air compressor is **not** pumping, the unloader valve is malfunctioning and **must** be repaired or replaced.





Remove

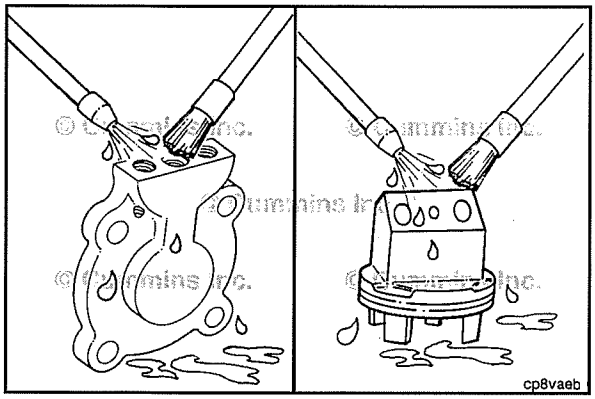
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
The unloader body is installed with spring tension. Use care when removing to reduce the possibility of personal injury. Always wear protective eye wear.

Open the wet tank drain cock and release compressed air from the system.

Remove the air compressor unloader valve cover plate capscrews.

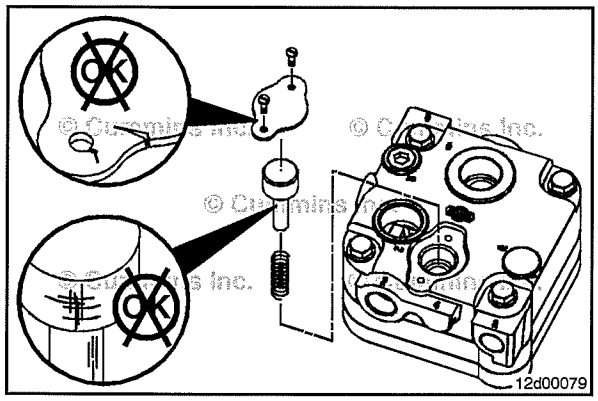
Withdraw the unloader valve assembly.



Clean and Inspect for Reuse

⚠CAUTION⚠
Do not use caustic cleaners. Damage to the compressor parts can occur.

Remove all carbon and varnish from the unloader valve cap body.



Inspect the unloader valve assembly for reuse or replace with a service kit. Refer to the manufacturer's specifications.

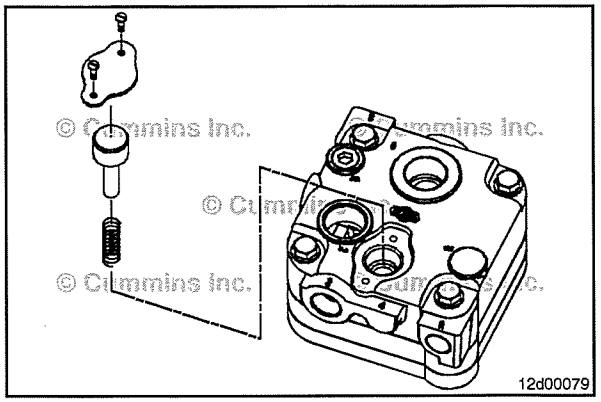
Install

⚠WARNING⚠
Wear appropriate eye and face protection when working with compressed air systems. Flying debris and dirt can cause bodily injury.

⚠WARNING⚠
The unloader body is installed with spring tension. Use care when removing to reduce the possibility of personal injury. Always wear protective eye wear.

Install the unloader kit assembly and cover plate and tighten the capscrews in accordance with the manufacturer's instructions.

Operate the engine and check for correct air compressor operation, air, and fluid leaks.



Air Compressor (012-014)

Pressure Test

⚠WARNING⚠
The external pressure tank used must meet SAE J10 and FMVSS121 standards, and have a safety pressure relief valve which opens between [150 to 175 psi]. Failure to use the proper pressure vessel and plumbing can result in property damage and serious personal injury.

Air Compressor Diagnostic Test

1 Park vehicle on a level surface and in an area where it is safe to idle for an extended period of time. Chock the vehicle wheels or use an appropriate anti-roll device to stabilize the vehicle.

2 Drain the vehicle air system.

3 Remove the air discharge hose and air governor signal hose from the air compressor.

4 Plumb an air discharge hose from the air compressor into an external pressure tank. The external pressure tank **must** be equipped with a 1034 kPa [150 psi] pressure gauge and 1034 kPa [150 psi] pressure relief valve. Make sure that the ditting are installed with appropriate thread sealant and do **not** leak.

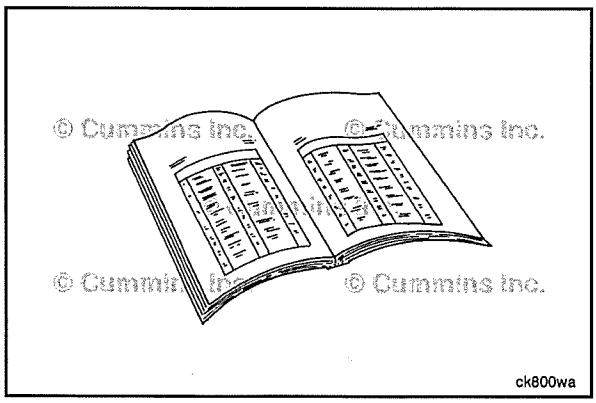
Start the engine and operate at idle engine speed.

NOTE: Once the external pressure tank pressure reaches 862 kPa [125 psi], shut the engine OFF. Depending on the size of the external tank and the diameter/length of the discharge hose being used, the buildup time will vary.

For example, a single cylinder (318 cc) compressor filled an 42 liters [11 gal] tank to 862 kPa [125 psi] using a (#10 x 6 ft length) discharge hose in 90 seconds. This was considered in specification for this setup.

Verify that the air compressor will build pressure in the external tank. If air pressure successfully builds to 862 kPa [125 psi], the air compressor functions properly. Remove the external air discharge hose from the air compressor and install the vehicle air discharge hose and air governor signal hose to the compressor. Refer back to the symptom tree being utilized to inspect the rest of the air system components for leaks and proper operation.

If the air compressor fails to build to 862 kPa [125 psi], the air compressor is malfunctioning and the cylinder head needs to be repaired based on the marking scribed on the head. Refer to Procedure 012-003 in Section 12.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Wear safety glasses or a face shield, as well as protective clothing, to prevent personal injury when using a steam cleaner or high-pressure water.

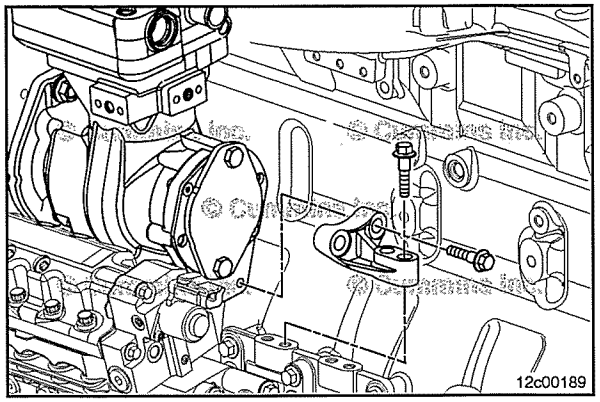
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the vehicle air system. Refer to the OEM service manual.
- Use steam to clean the air compressor and mounting area. Dry with compressed air.
- If equipped, remove the hydraulic pump. Refer to Procedure 009-016 in Section 9 or the OEM service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- If the air compressor is mounted, remove the air governor. Refer to the OEM service manual.
- Remove the air inlet tube. Refer to Procedure 012-109 in Section 12.

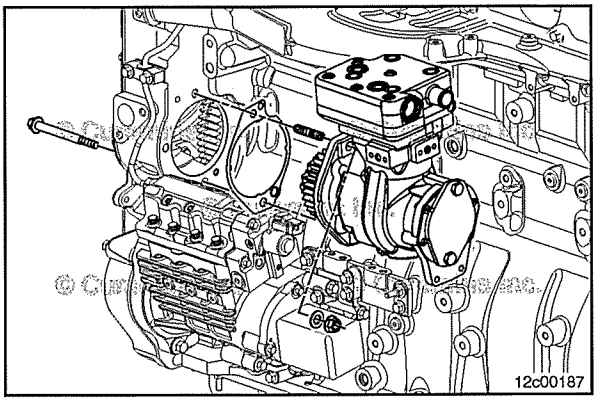
Remove

Remove the air compressor support bracket and capscrews.



Remove the mounting nut, capscrew, and air compressor.

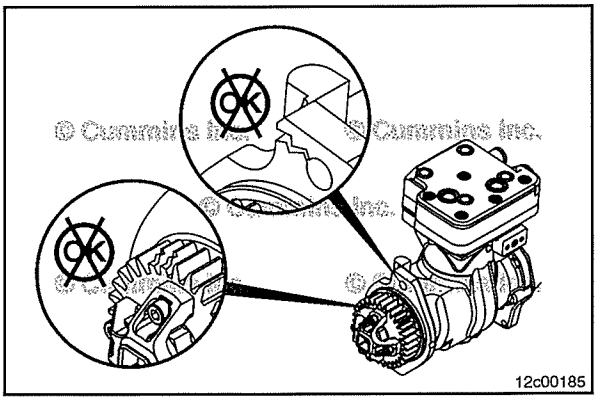
Discard the gasket.



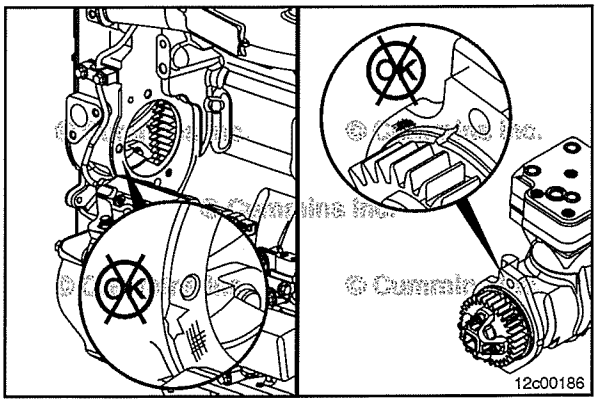
Clean and Inspect for Reuse

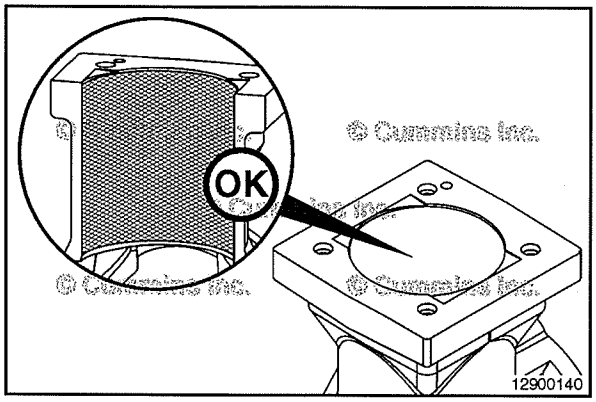
Inspect the air compressor housing for cracks or other damage.

Inspect the air compressor drive gear for cracks or other damage.



Make sure the gasket surfaces of the front gear housing and the air compressor are clean and **not** damaged.



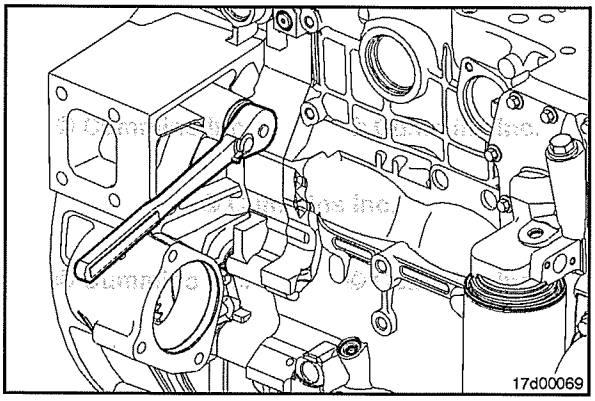


Remove the air compressor cylinder head if it is **not** already removed. Refer to Procedure 012-007 in Section 12.

Inspect the inside circumference for vertical scratches deep enough to be felt with a fingernail.

If a fingernail catches in the scratch, the air compressor **must** be replaced.

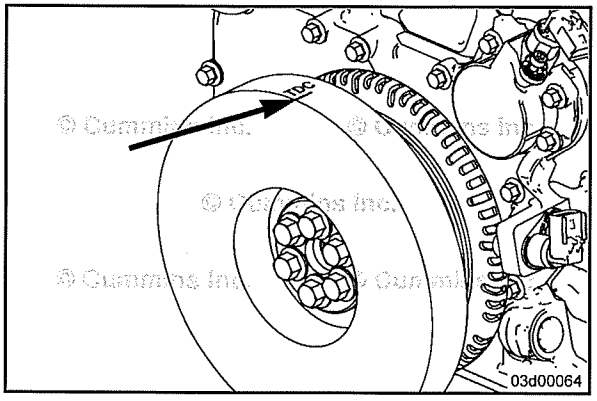
Inspect the inside circumference for scuffing, scoring, or polishing.



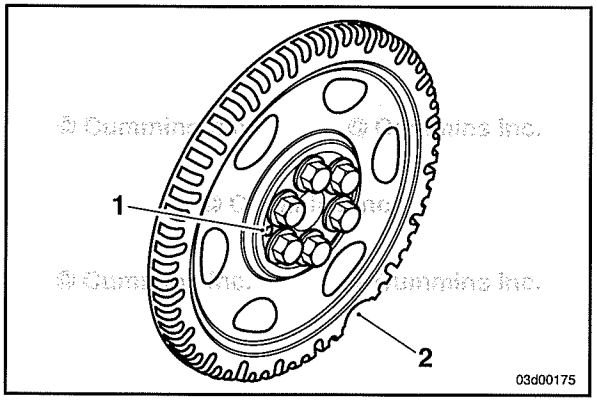
Time

NOTE: To make sure the air compressor does **not** contribute to engine vibrations when installed, the air compressor **must** be properly timed to the engine.

Use the barring tool, Part Number 3824591 or equivalent, to rotate the crankshaft until the number 1 is at top dead center (TDC).



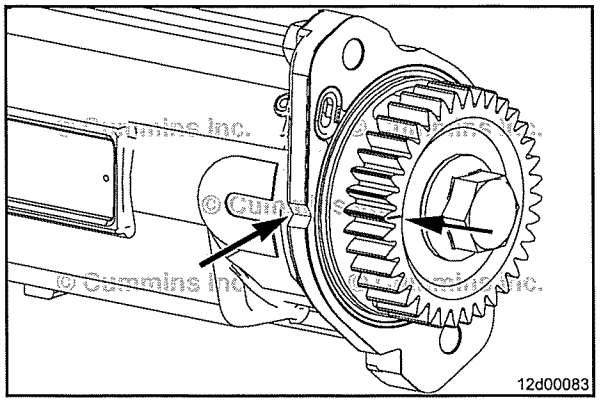
Align the vibration damper so that the TDC indicator on the vibration damper is at the 12-o'clock position.



NOTE: If no TDC mark is present on either the vibration damper or the crankshaft speed indicator ring, align the large gap in the crankshaft speed indicator ring to the 5-o'clock position (2). The dowel pin can also be visible in the 9-o'clock position (1).

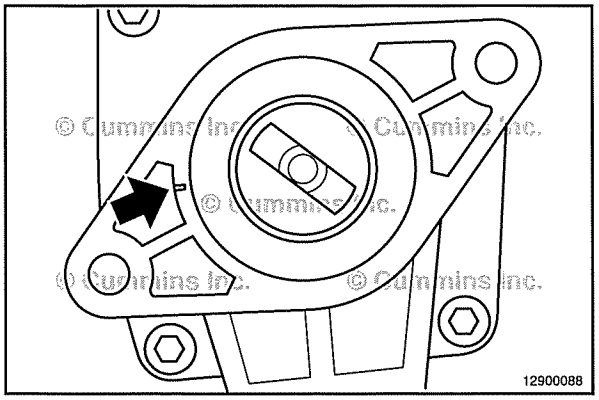
Wabco™ Air Compressors

Set the timing mark on the air compressor gear to the 9-o'clock position when looking at the gear. It **must** point at the casting depression on the side of the air compressor mounting flange.



Knorr-Bremse™ Air Compressors

Set the air compressor to TDC by aligning the two timing marks on the rear of the compressor and on the rear drive.



Install

Wabco™ Air Compressors

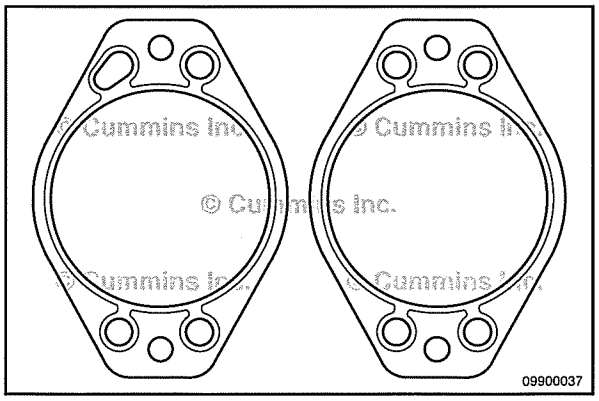
For Wabco™ air compressors use the following procedure:

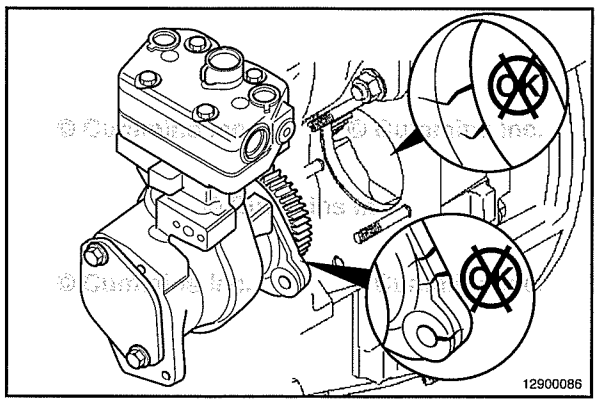
Prior to installing the air compressor, identify which gasket is going to be installed so that, if necessary, the gasket can be properly oriented.

The are two types of accessory drive cover gaskets:

- Three round oil supply passages and one elongated oil supply passage
- Four round oil supply passages

It is preferred that, when installing the air compressor, the gasket with the four round oil supply passages be used. The gasket can be installed in any orientation. If **only** the gasket with the one elongated oil supply passage is available, install the gasket so that the elongated oil supply passage is **not** over the oil supply port in the rear gear housing.





⚠CAUTION⚠
The air compressor gasket must sit flat against the gear housing without any interference to prevent air compressor failure.

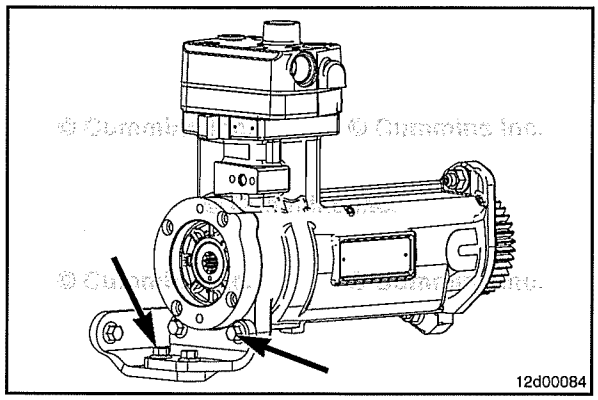
⚠CAUTION⚠
Air compressor failure can result if the oil feed hole is not aligned with the oil passage in the gear housing or if the wrong gasket is used.

NOTE: Rotate the engine slightly before or after TDC, if necessary, to properly engage the compressor drive gear with the camshaft gear.

With the engine set at TDC, install the air compressor and a new gasket onto the rear gear housing, engaging the air compressor drive gear with the camshaft gear.

Install the air compressor mounting fasteners and tighten.

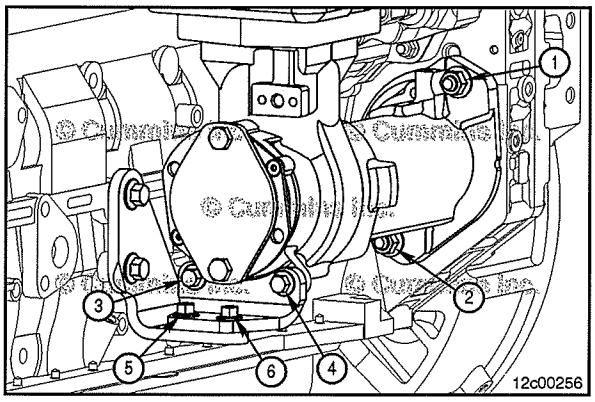
Install the air compressor mounting fasteners and finger tighten the capscrews.



Install the air compressor support bracket.

Install the air compressor support bracket to cylinder block mounting bracket mounting capscrews and finger-tighten.

Install the air compressor support bracket mounting capscrews and finger-tighten.

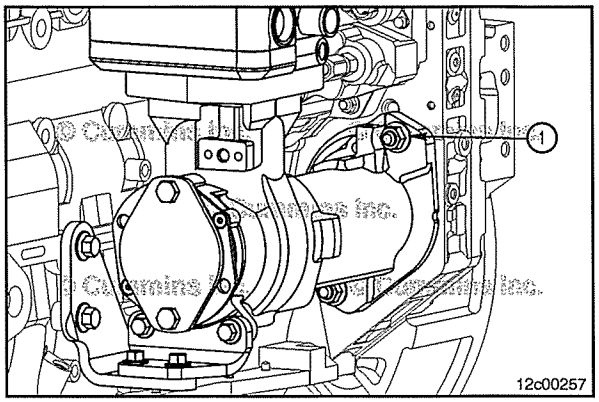


NOTE: For low mount designs, it is important to make sure of appropriate positioning of the air compressor relative to the engine block in order to minimize gear lash. This will help minimize noise from the gear train during normal engine operation.

Loosen the six air compressor mounting capscrews.

Push the air compressor assembly as close to the engine block as possible and tighten the upper mounting capscrew (1).

Torque Value: 77 N•m [57 ft-lb]

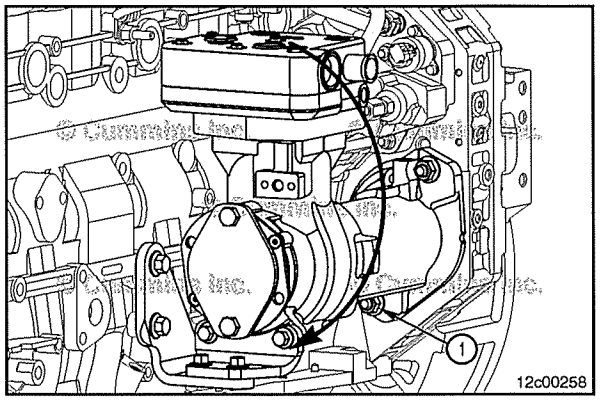


Using the upper mounting capscrew as a pivot point, rotate the air compressor assembly in the **clockwise** direction when viewed from the front of the engine.

NOTE: This action should slightly move the bottom of the air compressor assembly towards the engine block.

Tighten the lower mounting capscrew (1).

Torque Value: 77 N•m [57 ft-lb]



⚠CAUTION⚠
Air compressor failure can result if any of the mating surfaces are not touching prior to tightening.

Verify the air compressor support bracket is contacting the cylinder block support bracket. Adjust the brackets as necessary. If necessary, loosen the cylinder block support bracket to align the components.

Tighten the air compressor support bracket mounting capscrews (1).

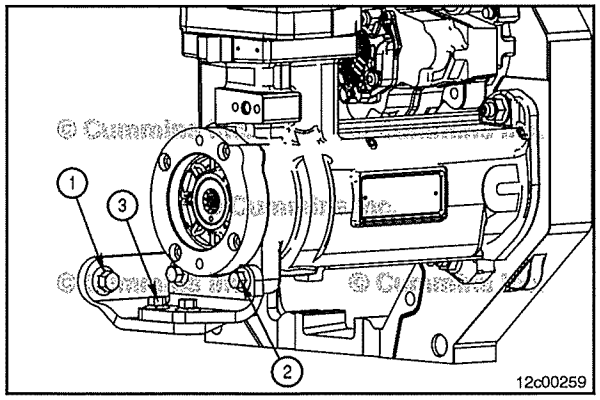
If loosened, tighten the cylinder block support bracket cylinder block mounting capscrews (2).

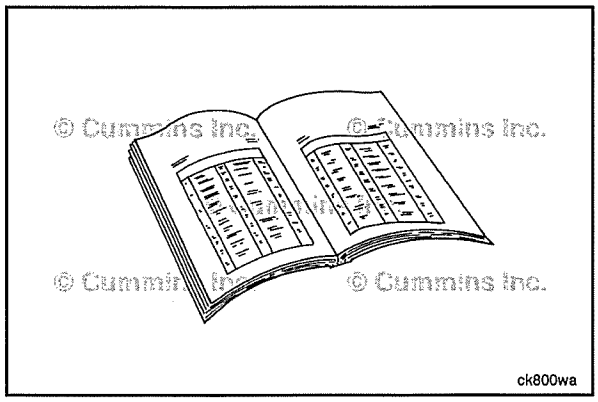
Tighten the compressor support bracket to the cylinder block support bracket mounting capscrews (3).

Torque Value:
M8 24 N•m [212 in-lb]

Torque Value:
M10 43 N•m [32 ft-lb]

Torque Value:
M12 77 N•m [57 ft-lb]



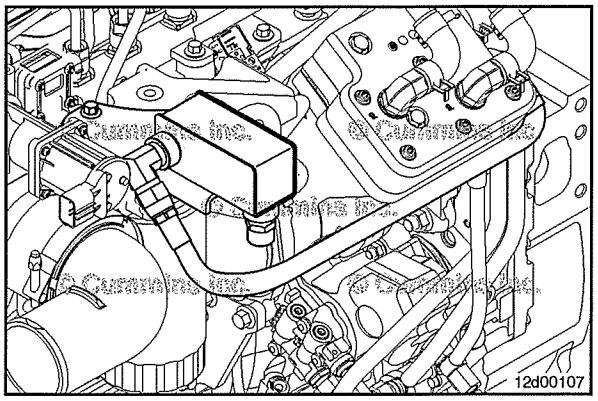


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- If equipped, install the hydraulic pump. Refer to Procedure 009-016 in Section 9 or the OEM service manual.
- Install the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- If removed, install the air governor. Refer to the OEM service manual.
- Install the air inlet tube. Refer to Procedure 012-109 in Section 12.
- Connect the air discharge line. Refer to Procedure 012-015 in Section 12.
- Install the air connections to the air compressor. Refer to Procedure 012-109 in Section 12.
- Fill the engine coolant, if applicable. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Air Compressor Discharge Lines (012-015)

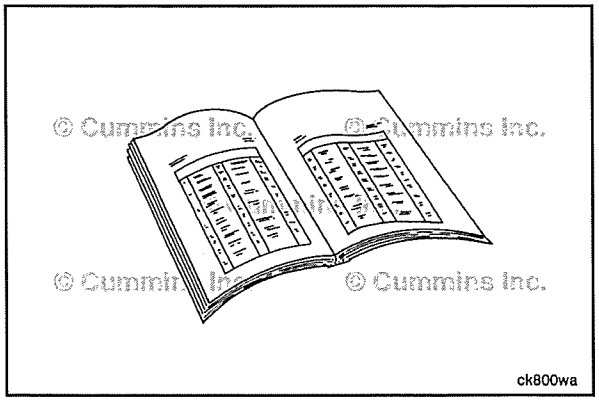
General Information

The air discharge line is supplied and connected directly to the engine's air compressor by the vehicles original equipment manufacturer (OEM).

For some applications, a noise reduction tank or “ping” tank has been installed on the engine to reduce air compressor pumping noise. If the engine is equipped with a “ping” tank, the OEM would connect the air discharge line to the “ping” tank and not directly to the air compressor.

The procedure covers the removal and installation of the noise reduction tank or “ping” tank and related components **only**.

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Air discharge lines can be very hot. Make sure the lines are cool before touching to reduce the possibility of personal injury.

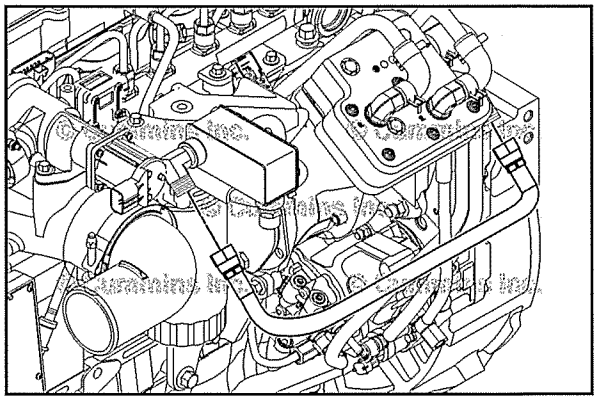
- Disconnect the battery cables. Refer to the OEM service manual.
- Drain the vehicle air system. Refer to the OEM service manual.
- Disconnect the air compressor discharge line. Refer to the OEM service manual.

Remove

NOTE: Apply a counter-torque to the air compressor discharge fitting when loosening the discharge line.

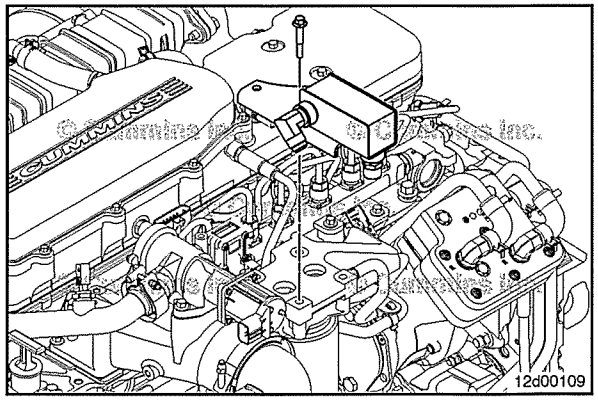
Disconnect the air compressor discharge line between the air compressor and the “ping” tank.

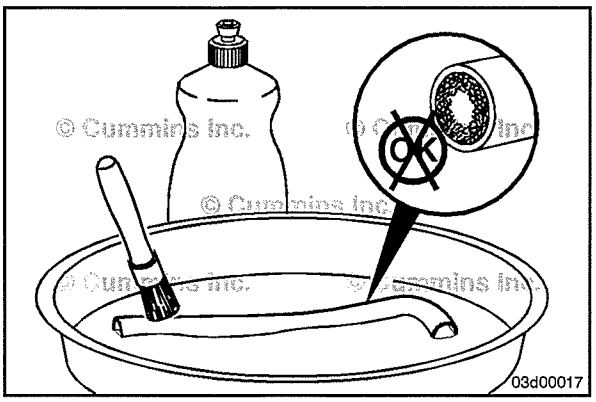
Remove the discharge line.



Remove the three “ping” tank to fuel filter bracket mounting capscrews.

Remove the “ping” tank.





Clean and Inspect for Reuse

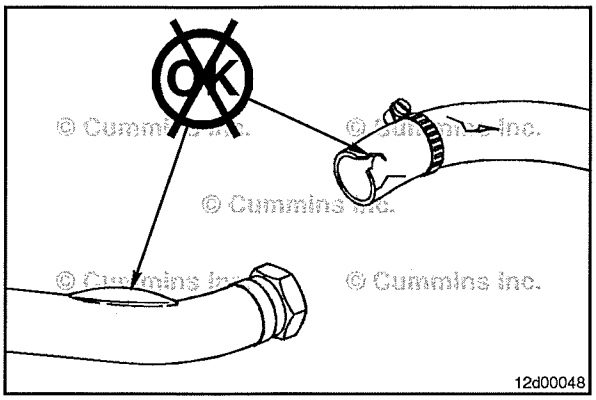
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: For the OEM installed discharge line inspection of carbon buildup. Refer to Procedure 012-003 in Section 12.

Clean the air compressor discharge line and "ping" tank with a strong solution of detergent.

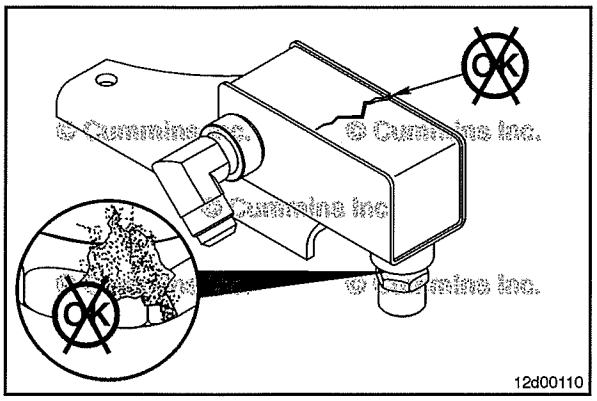
Dry air compressor discharge line and "ping" tank with compressed air.

Inspect the air compressor discharge line and "ping" tank for any internal restrictions. Replace the component if any restrictions are found.



Inspect the air compressor discharge line for splits, cracks, hardening, or other damage.

Replace the component if any damage is found.



Inspect the "ping" tank for corrosion or cracks.

Replace the component, if any damage is found.

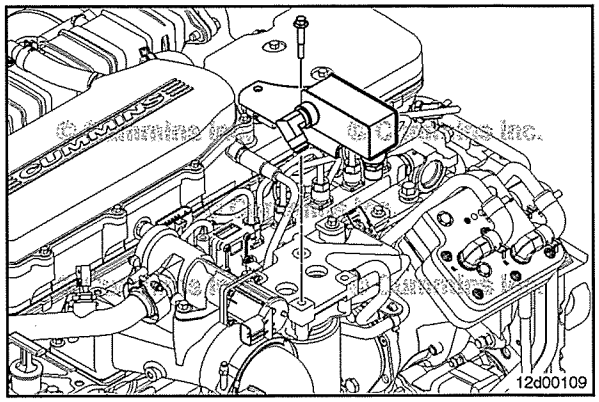
Install

Install the "ping" tank.

Install the three "ping" tank to fuel filter bracket mounting capscrews.

Tighten and mounting capscrews.

Torque Value: 24 N•m [212 in-lb]

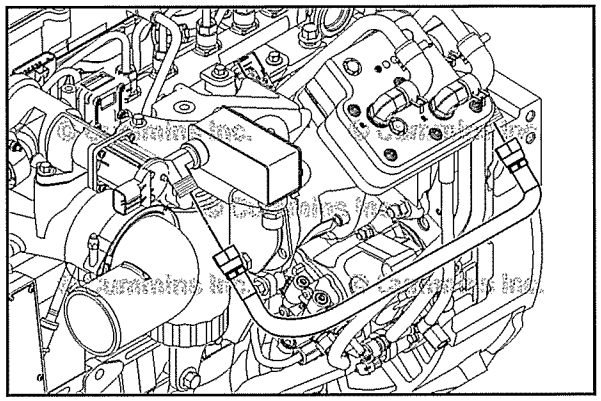


NOTE: Apply a counter-torque to the air compressor discharge fitting when tightening the discharge line.

Install the air compressor to "ping" tank discharge line.

Connect the air compressor discharge line between the air compressor and the "ping" tank.

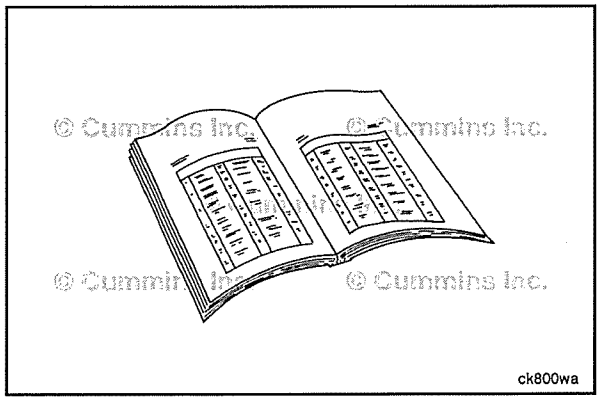
Tighten the air compressor discharge line fittings.

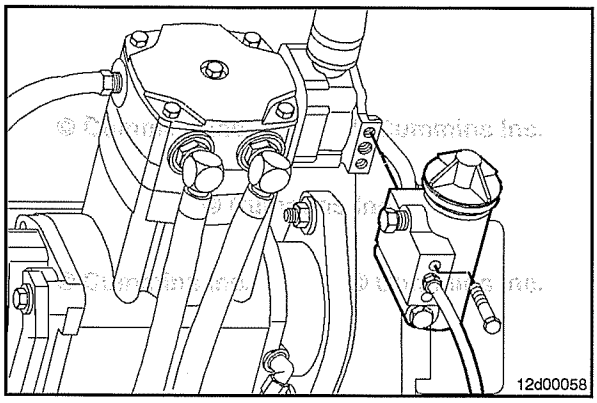


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the air compressor discharge line. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Air Governor (012-016)

General Information

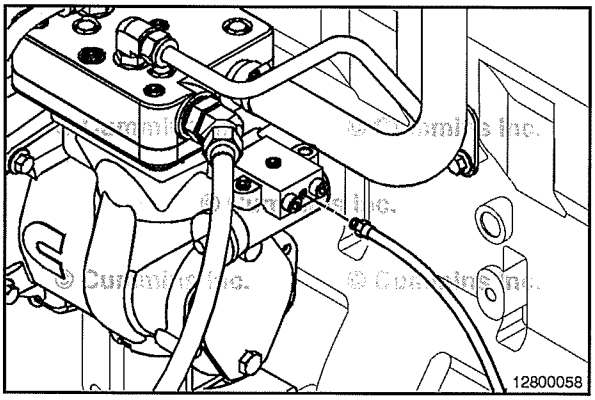
The air compressor governor location can vary. The air governor can be air compressor mounted or chassis mounted.

For air compressor governor specifications, removal, and installation procedures, refer to the original equipment manufacturer (OEM) service information.

Cummins Inc. requires that the air governor setting is in the following range:

Air Governor Setting

kPa		psi
724	MIN	105
1000	MAX	145



Pressure Test

If the air pressure is being governed at either a higher or lower pressure than the equipment manufacturer's specification, connect a regulated shop air pressure line to the air compressor governor air signal port.

NOTE: Be positive the gauge is accurate and the supply lines and fittings are in good condition before performing any air pressure checks. Use a master gauge of known accuracy to check the air pressure gauge.

NOTE: When performing the test, be sure the air system pressure does **not** exceed the manufacturer's maximum allowable pressure.

- Inspect the governor control lines for restrictions.
- Drain the air system and install a gauge of known accuracy onto the unloader port of the air governor.
- Start the engine and apply the brakes to initiate air compressor pumping. Note the governor cut-out pressure (pressure at which the compressor stops pumping).
- Apply the brakes until the compressor starts to pump. Note the cut-in pressure.

NOTE: Zero pressure in the governor unloader line will allow the compressor to start pumping.

- Apply the brakes until the compressor starts to pump. Note the time it takes for the governor unloader port to go from system pressure to 0 kPa [0 psi]. The cycle should take less than 2 seconds.
- Repeat steps three through five for a total of 3 runs.

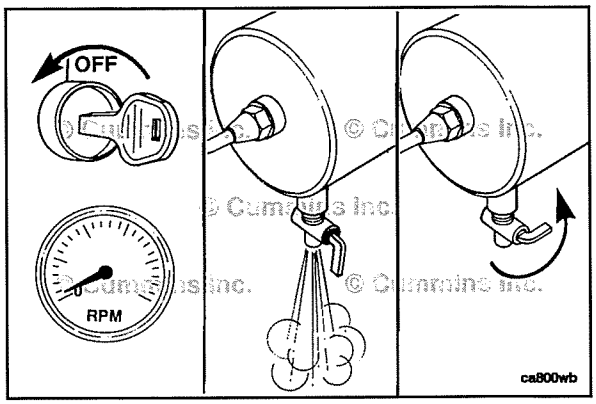
Air Leaks, Compressed Air System (012-019)

Initial Check

⚠WARNING⚠
Wear appropriate eye and face protection when releasing air pressure from the compressed air system. Flying debris and dirt can cause personal injury.

Shut the engine OFF.

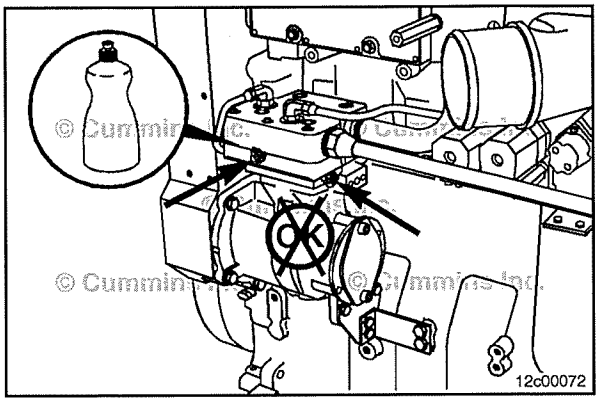
Open the drain cock on the wet air tank to release air pressure from the system. Close the draincock after the pressure is released.



Operate the engine to activate the air compressor.

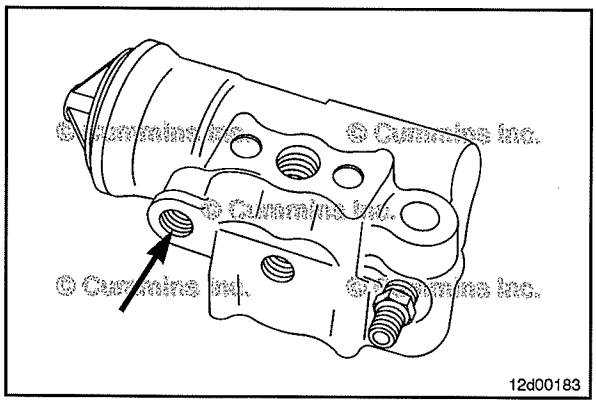
With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to check for air leaks in the following areas:

- Air compressor head gasket
- Air compressor cover gasket
- Hose and fitting leaks
- Air inlet and outlet fittings
- Wet tank fittings
- Service tank fitting
- Ping tank fittings
- Air governor fittings
- Air dryer fittings
- Air compressor muffler fittings, if applicable
- Air dryer purge assembly.

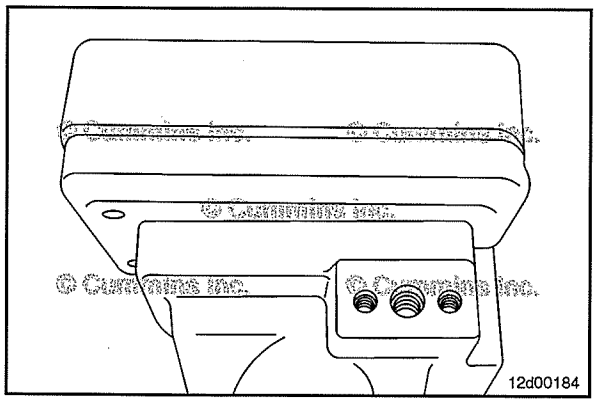


If air leaks are found on the air compressor, verify that the air compressor head and cover bolts are torqued properly. Use the following procedure for proper torque values. Refer to Procedure 012-007 in Section 12. Make sure all hoses and fittings are tight. Replace if necessary.

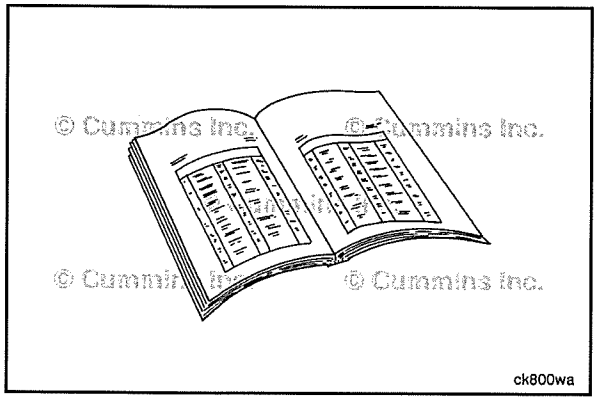
If leaks are found on any of the other system component fittings, verify the fittings are tight. Refer to the original equipment manufacturer (OEM) service manual for torque specifications.



The air governor vent port **must not** be plugged. This port **must** be vented to the atmosphere. When the vent port is plugged, it will cause the intake and exhaust valve within the air compressor cylinder head to malfunction.



Some air compressors have provisions for alternate governor plumbing location(s). Verify that the alternate governor plumbing location(s) are plugged if **not** in use.



Air Compressor (Oil Carryover) (012-020)

Inspect for Reuse

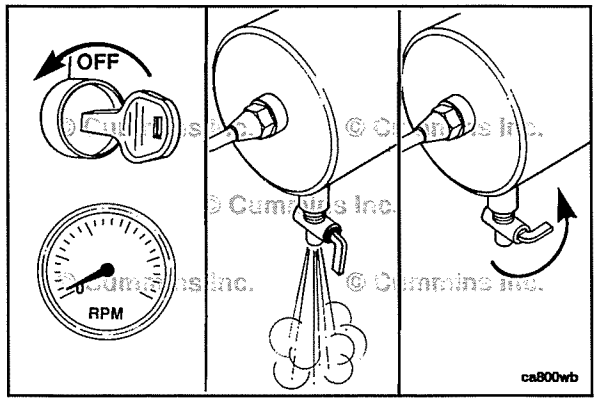
Perform this test in conjunction with troubleshooting the air compressor pumping oil into the air system.

NOTE: Small oil deposits at the air dryer purge valve are normal. The air compressor is lubricated with engine oil, and small amounts of carryover are to be expected. Oil carryover is more common on naturally aspirated air compressors. Oil or moisture can be expected at any purge or drain valves up to and including the air dryer, which will include ping tanks and/or cooling or condesation tanks. If there is no oil or condensation found at the tanks after the air dryer, then the air dryer is working correctly and sized adequately.

⚠WARNING⚠
The air discharge line and other equipment will become hot during the course of the test. To prevent burns, use protective gloves when touching heated surfaces.

Operate the engine until the coolant temperature reaches normal operating temperature. Once the coolant has reached operating temperature, shut the engine down and completely drain the vehicle air system.

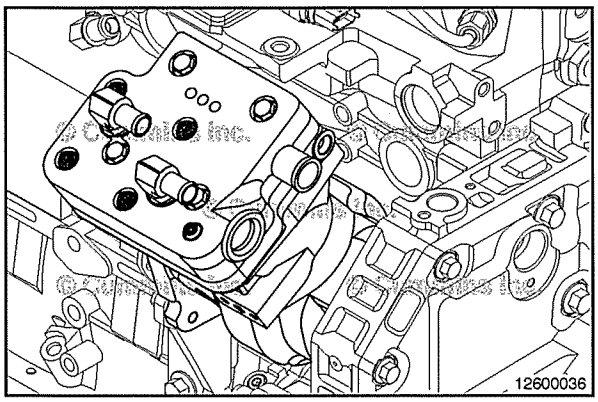
NOTE: Failure to warm the engine adequately can result in false test results.



⚠WARNING⚠
The discharge from the air compressor will be hot, possibly contain oil vapors, and will be noisy. Make sure there is adequate ventilation and hearing protection is worn, particularly if the type of vehicle requires the test be conducted in an enclosed environment.

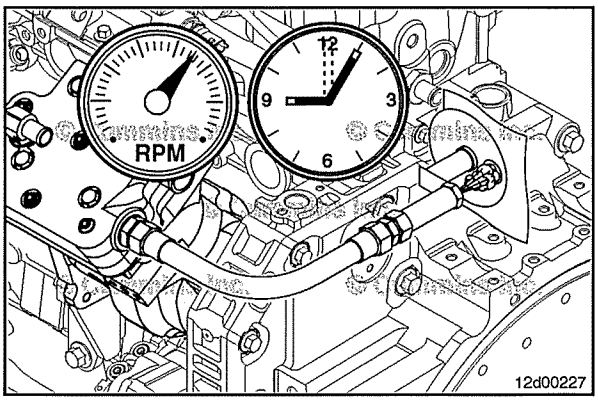
Disconnect the discharge pipe from the air compressor cylinder head.

Disconnect the air inlet plumbing at the air compressor cylinder head.



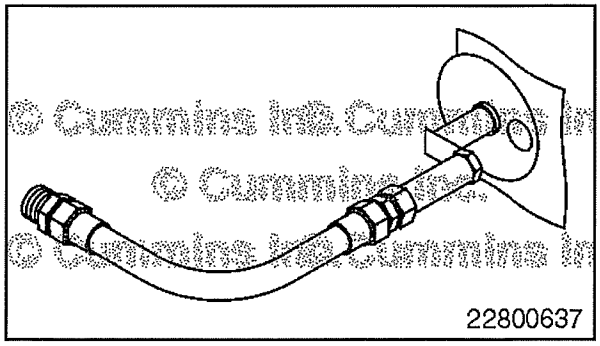
Connect the oil carryover test tool, Part Number 4918883, to the air compressor cylinder head discharge port.

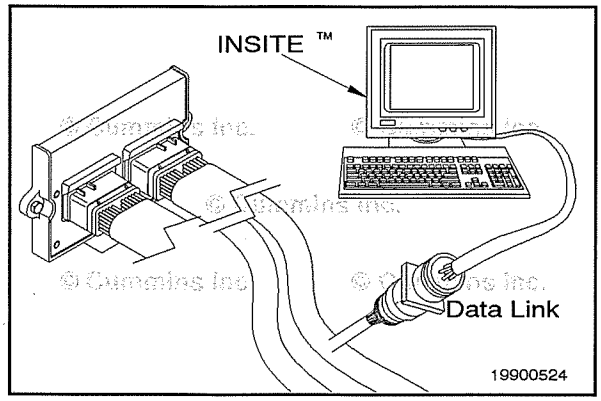
NOTE: If the application presents restricted access to the air compressor, a high temperature flexible hose (minimum 15 mm [0.6 in] inside diameter) can be connected directly to the discharge port of the compressor in order to carry out the test outside the engine compartment. Be sure to have a 90 degree bend near the end of the flexible hose during testing.



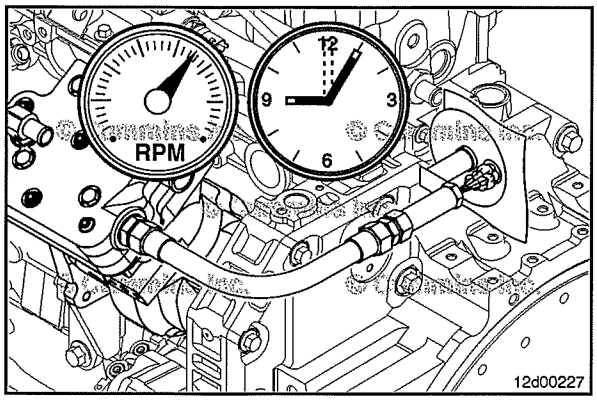
Install the test paper into the service tool, Part Number 4918883. Make sure it is held at a right angle to and in line with the flow of compressed air, at a distance **not** to exceed 100 mm [3.9 in] from the end of the compressor discharge pipe or flexible hose, if fitted.

The test paper can be standard clean copier paper, typically 80 grams/sq meter. It **must** be mounted in the air compressor discharge line tool, leaving a 70 mm [2.76 in] diameter circle of the paper exposed. The outline of the circle in the mask **must** be drawn onto the test paper to later aid in comparison.





NOTE: It may be necessary to use INSITE™ electronic service tool to increase the maximum engine speed, without vehicle speed sensor (VSS), to 2100 rpm.

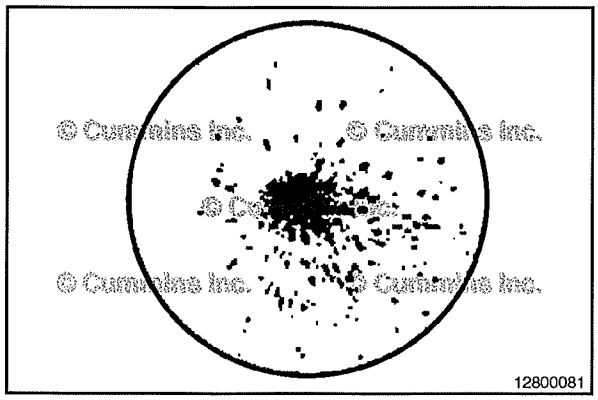


To perform the test, start the engine and run at high idle. Leave the test paper in the airflow for exactly 5 minutes. Remove the test paper, or rotate the tool mask exposing a new circular test area.

Repeat this test until three comparable circular test areas are generated.

Shut the engine down.

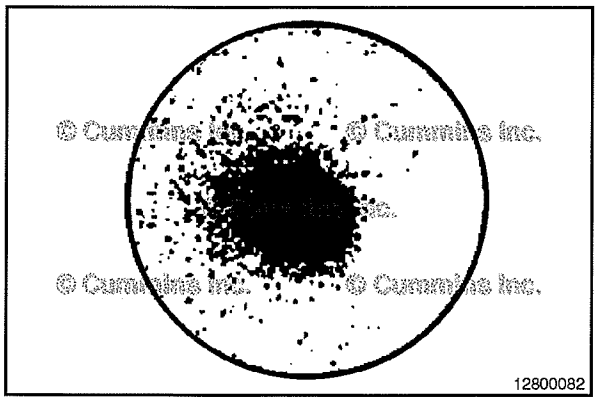
NOTE: If the maximum engine speed, without VSS, was adjusted in the previous step, change it back to the original value upon completion of the test.



NOTE: Compare the test results with the reference results shown below.

Time Air Compressor Has Been In Service (Months/ Years):

- Less Than 6 Months - Compressor in good condition
- 6 Months to 2 Years - Compressor in good condition
- Greater Than 2 Years - Compressor in good condition.

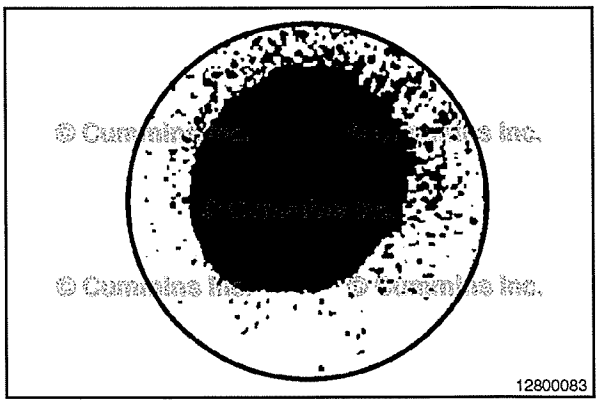


Time Air Compressor Has Been In Service (Months/ Years):

- Less Than 6 Months - Compressor needs to be replaced
- 6 Months to 2 Years - Compressor in acceptable condition
- Greater Than 2 Years - Compressor in good condition.

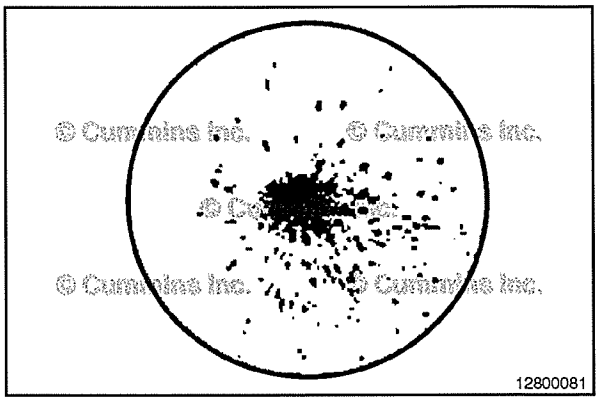
Time Air Compressor Has Been In Service (Months/ Years):

- Less Than 6 Months - Compressor needs to be replaced
- 6 Months to 2 Years - Compressor needs to be replaced
- Greater Than 2 Years - Compressor needs to be replaced.



NOTE: This step **must** be completed if the compressor assembly is replaced as a result of this test and is requested to be returned via the CORE, or enhanced parts return (EPR) return process.

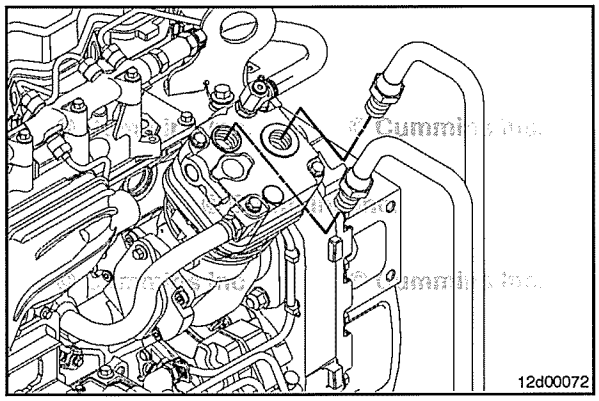
If the compressor is deemed failed and needs to be replaced, please place the test paper, with results of Oil Carryover Test, in a sealable plastic bag, seal to prevent oil contamination, and include with the failed compressor.



Air Compressor Inlet Tube (012-109)

General Information

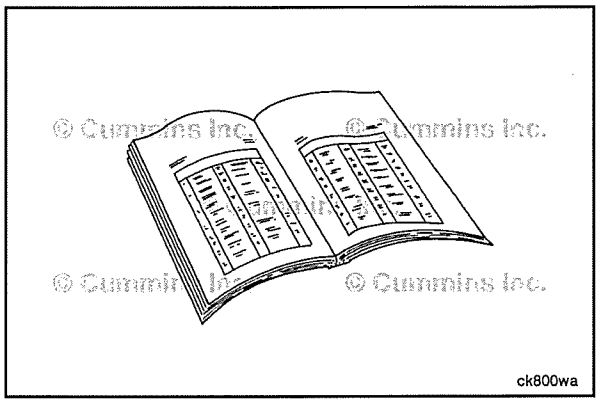
A turbocharged air compressor receives intake air from the intake of the engine. This means the compressor intake air is the same pressure as the air intake manifold of the engine.

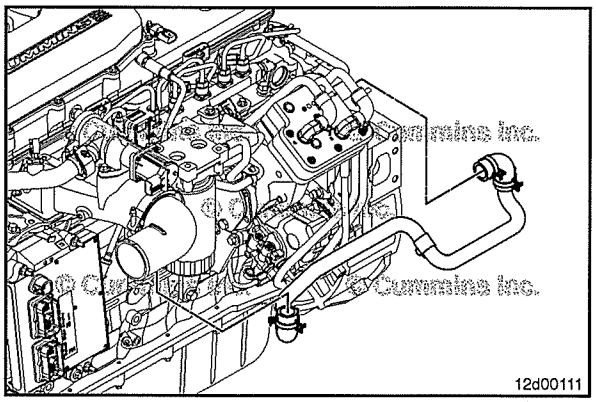


Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.





Remove

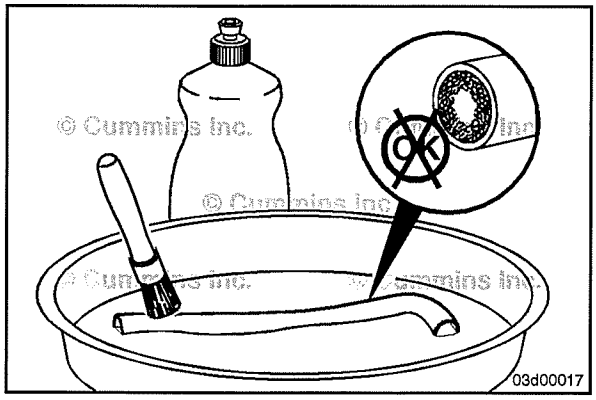
NOTE: The illustration shows a high mount air compressor. The procedure is the same for low mount air compressors.

Remove any P-clips and/or mounting fasteners securing the air compressor inlet tube.

Remove the hose clamps securing the air compressor inlet tube.

Disconnect the inlet tube from the charge-air cooler piping and then from the air compressor cylinder head.

Remove the air compressor inlet tube.



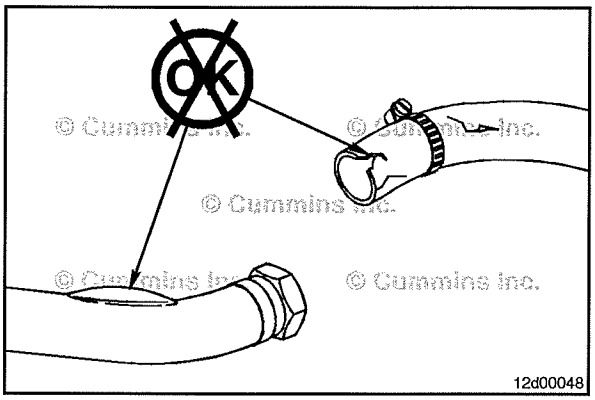
Clean and Inspect for Reuse

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the air compressor inlet tube with a strong solution of detergent.

Dry the air compressor inlet tube with compressed air.

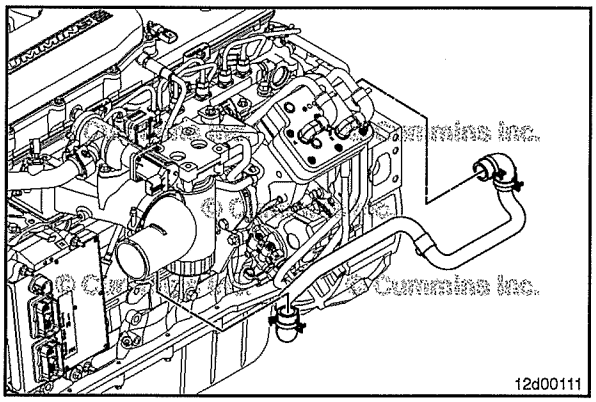
Inspect the air compressor inlet tube for any internal restrictions. Replace the inlet tube if any restrictions are found.



Inspect the inlet tube hoses for splits, cracks, hardening, or other damage.

Inspect metal inlet tubes for kinks, corrosion, or cracks.

Replace the component, if any damage is found.



Install

Install the air compressor inlet tube.

Connect the inlet tube to the charge-air cooler piping and then to the air compressor cylinder head.

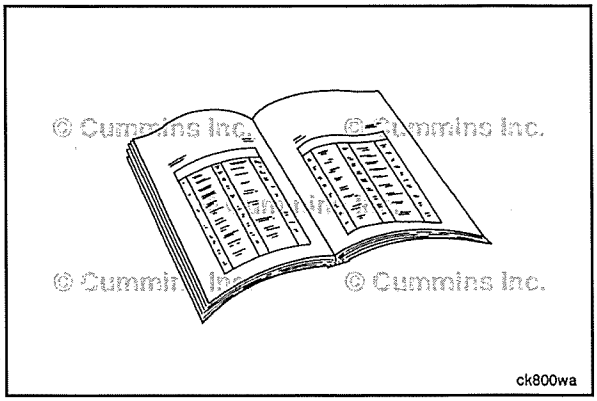
Install any P-clips and/or mounting fasteners securing the air compressor inlet tube.

Install and secure the hose clamps.

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to OEM service manual.
- Operate the engine and check for leaks.



Notes

Section 13 - Electrical Equipment - Group 13

Section Contents

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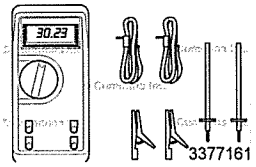
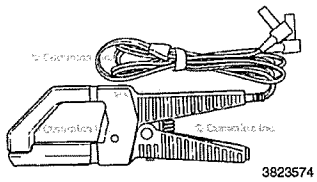
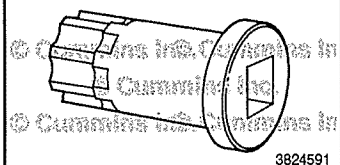
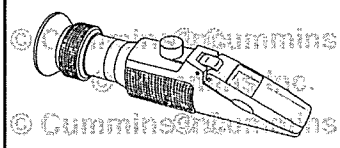
Service Tools

Electrical Equipment

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164488 or 3164489	**Digital Multimeter** Used to measure electrical circuits: Voltage (VDC), resistance (ohms), and current (amperes). Standard meter, Part Number 3164488. Automotive meter, Part Number 3164489, with built in temperature adapter and tachometer.	
3164490	**Clamp-on Current Probe** Used to measure DC currents from 1 to 1000 amperes or AC currents from 1 to 1000 amperes.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
CC-2800	**Refractometer** The Fleetguard® refractometer is used to check the charge condition of a conventional battery.	

Alternator (013-001)

General Information

Due to the number of different alternator brands and configurations, the following procedure has been generalized to cover the most common configurations. Consult the alternator manufacturer for any information that is **not** covered in this procedure.

Typical Delco™ Alternator Wiring System

Indicator (I) Terminal

The main function of the indicator (I) terminal is to indicate if the alternator is working correctly. Typically, an indicator light is wired to this terminal. If the alternator is **not** charging properly, the light turns on. Another function of the indicator (I) terminal is that it can be used to supply up to 1 ampere of output at system voltage.

Lamp (L) Terminal

Similar to the I terminal, the L terminal is used to indicate if the alternator is working correctly. The difference between the L terminal and the I terminal is that the L terminal is a current sink **only** and can **not** be used to reduce turn on speed.

Relay (R) Terminal

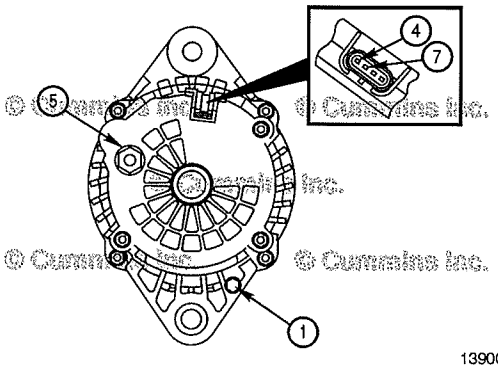
The function of the relay (R) terminal varies. It can supply up to 4 amperes of output at one-half nominal alternator voltage to power items such as a tachometer or an hour meter.

One-Wire System

This is the simplest of the wiring systems because the **only** wires connected to the alternator are at the battery (BAT) and ground terminals. (See the illustrations below.) Connecting to the R terminal, L terminal, and I terminal is optional.

Three-Wire System

This system requires more wiring because it has a battery (BAT) terminal, R terminal, two blade terminals identified as number 1 and number 2, and a ground terminal. Typically, in the three-wire system, the number 1 blade terminal serves as the I terminal. (See the illustrations below.) The advantage of the three-wire system is that it provides the same features as the one-wire system, plus remote sense. By connecting the number 2 blade terminal to the battery's positive (+) terminal, the voltage is both sensed and regulated at the battery, instead of at the alternator. This eliminates the potential for voltage losses in the wiring from the alternator to the battery.



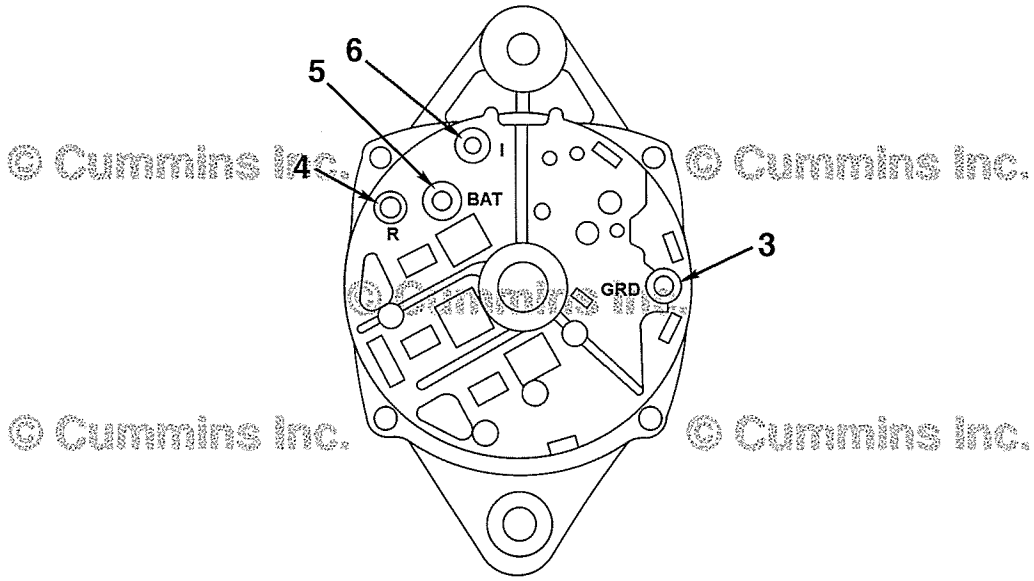
13900200

One Wire System, Typical Alternator (Delco-Remy™) with Combined Metri-Pack™ Connector

One Wire System, Typical Alternator (Delco-Remy™) with Combined Metri-Pack™ Connector		
1	GRD*	Ground
4	R*	Charge indicator, automatic lockout system, tachometer**
5	BAT	Battery
7	L	Lamp Terminal

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of alternator rpm.



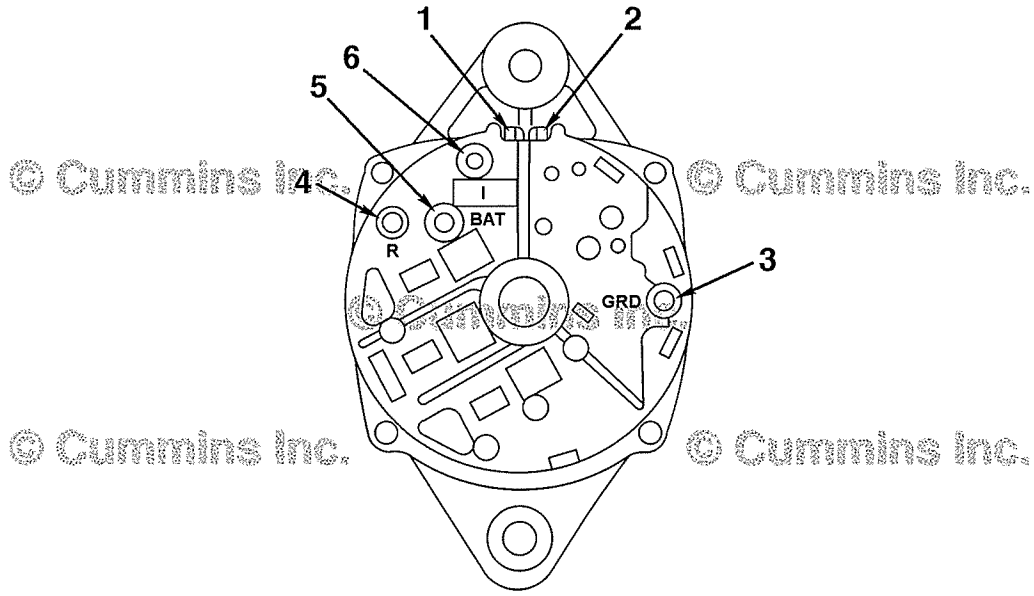
13900134

One Wire System, Typical Alternator (Delco-Remy™

One Wire System, Typical Alternator (Delco-Remy™)		
3	GRD*	Ground
4	R*	Charge indicator, automatic lockout system, tachometer**
5	BAT	Battery
6	I*	Indicator light

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of alternator rpm.



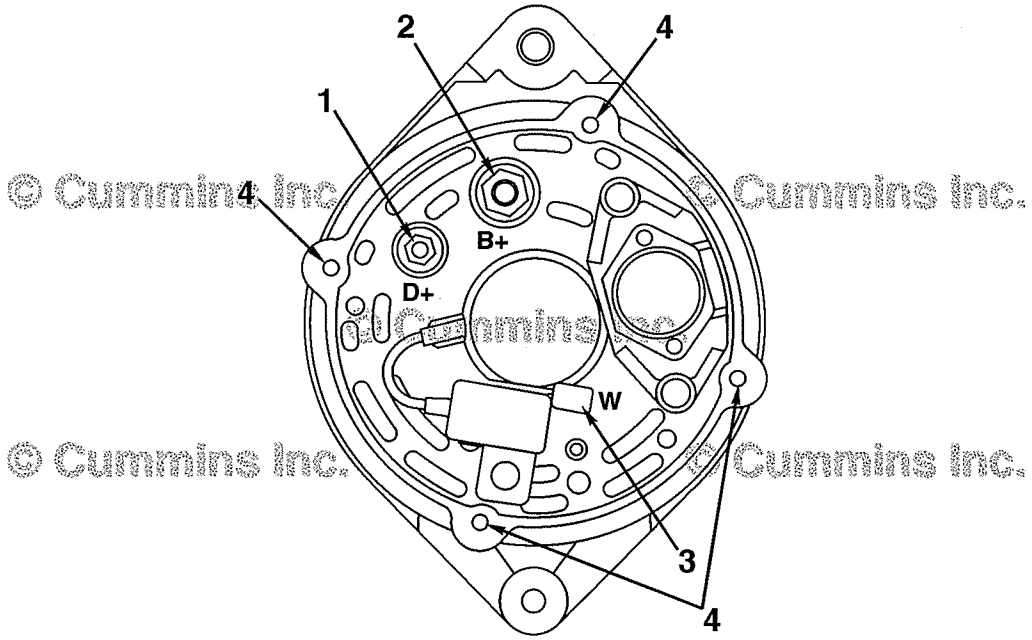
13900135

Three Wire System, Typical Alternator (Delco-Remy™)

Three Wire System, Typical Alternator (Delco-Remy™)		
Key	**Terminal**	**Connected To**
1	Blade number 1*	Indicator light
2	Blade number 2	Voltage sense
3	GRD*	Ground
4	R*	Charge indicator, automatic lockout system, tachometer**
5	BAT	Battery
6	I*	Indicator light

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of alternator rpm.



Typical Alternator (Bosch™ K1)

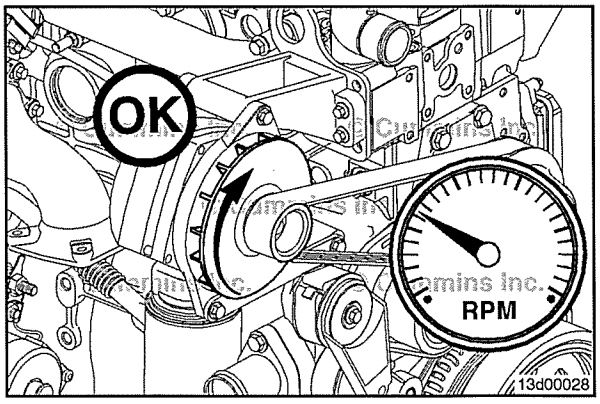
Typical Bosch™ K1 Wiring System		
Key	**Terminal**	**Connected to**
1	D+	Electrical charging system status light
2	B+	Positive battery
3	W	Tachometer
4	—	Ground/assembly

Initial Check

Check the drive belt and alternator pulley to be sure the alternator is rotating properly.

If any problems exist, check the following:

- If the drive belt is slipping on the alternator pulley. Refer to Procedure 008-002 in Section 8.
- Use the following procedure to inspect the belt tensioner. Refer to Procedure 008-087 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8. Check if the alternator pulley is loose on the shaft. If loose, remove the pulley and inspect for damage. Refer to Procedure 013-006 in Section 13.
- If the alternator will **not** rotate or does **not** rotate freely, the alternator **must** be replaced. See the Remove and Install sections of this procedure.

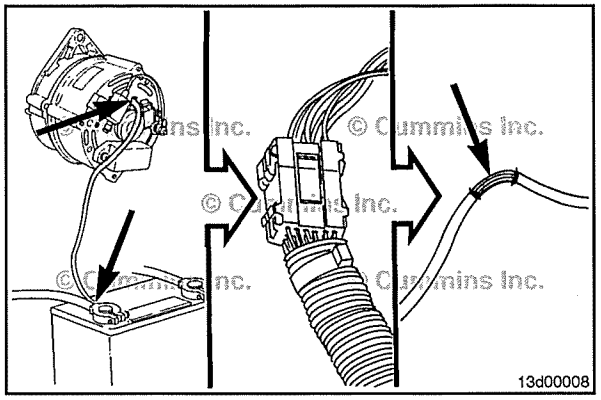


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

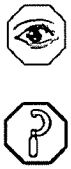
Check the battery and all wiring connections.

Inspect the wiring for damage.

Check all connections for tightness and cleanliness. This includes the slip connectors at the alternator and engine compartment bulkhead, and the connections at the battery.



Test



NOTE: Any multimeter reading of zero voltage indicates an open circuit.

Check for open circuits.

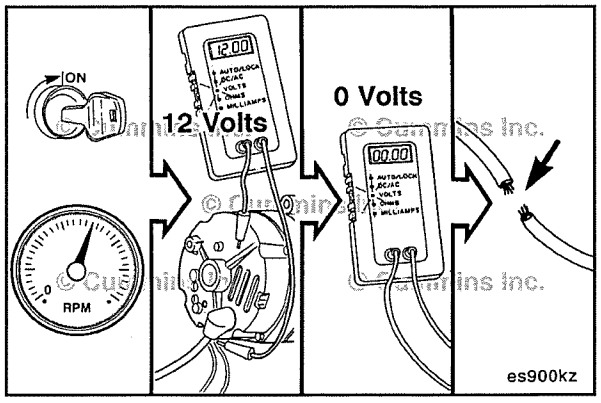
Turn the keyswitch to the ON position.

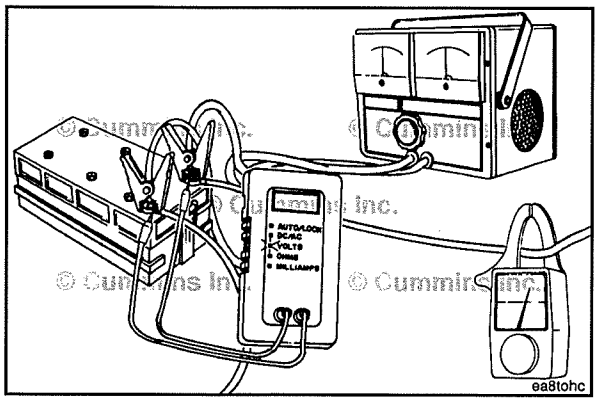
Connect a multimeter, Part Number 3164488 or 3164489, to the following locations:

Delco™ Alternators

- Alternator "BAT" terminal to ground
- Alternator blade terminal "number 1" to ground
- Alternator blade terminal "number 2" to ground.

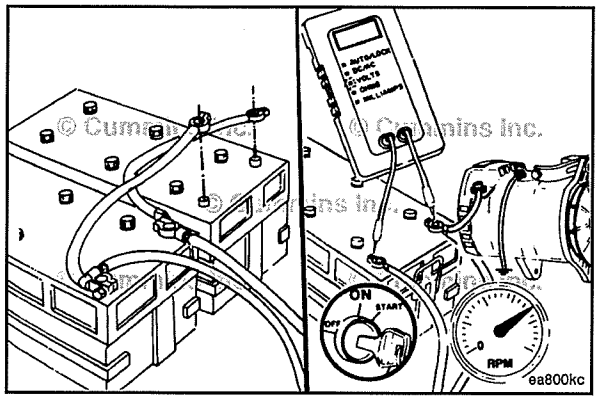
Locate and repair the open circuit.





Connect a carbon-pile load (battery/alternator tester) across the batteries in one of the battery boxes.

Clamp an induction pickup-type ampere-hour meter around the battery cable; or use the digital multimeter, Part Number 3164488 or 3164489, with the clamp-on current probe, Part Number 3164490.

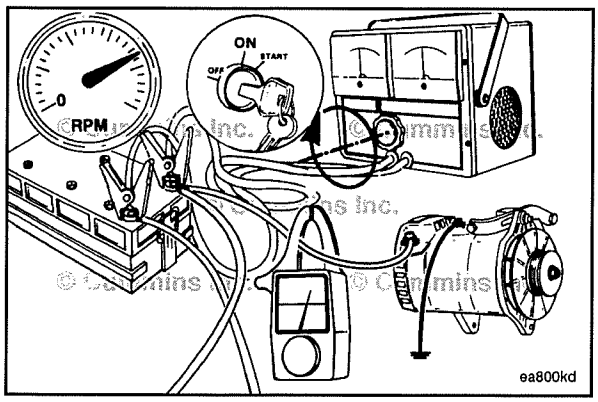


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

Disconnect any cables that lead to any other battery boxes in the circuit, negative (-) cables first.

Operate the engine at high idle; and measure the alternator voltage output to the batteries with digital multimeter, Part Number 3164488 or 3164489. Refer to the OEM service manual.



Operate the engine at high idle and adjust the carbon-pile load-testing equipment to apply the maximum rated amperage load to the alternator. Refer to the OEM service manual.

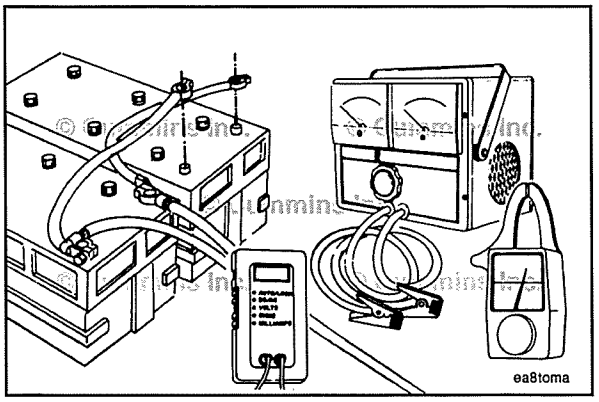
NOTE: The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

Measure the alternator amperage output. Refer to the OEM service manual.

If the alternator output (amps) is **not** within 10 percent of rated output, repair or replace the alternator. Refer to the OEM service manual for repair procedures.

Shut off the engine, and remove the test equipment.

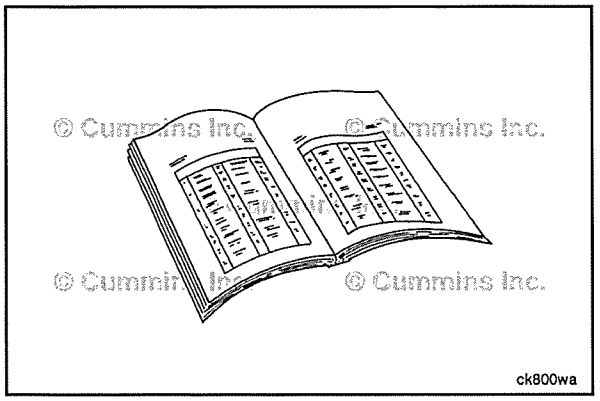
Connect all battery cables, negative (-) cable last.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

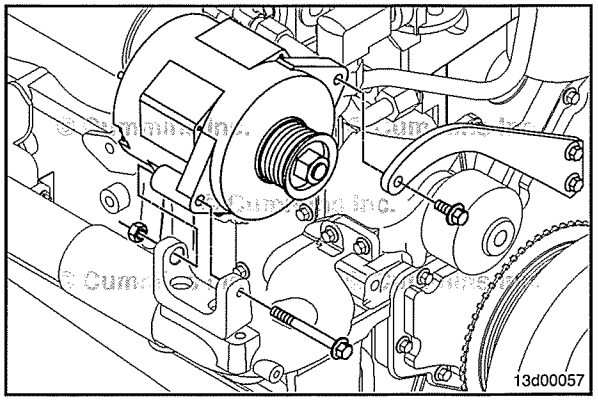
⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.



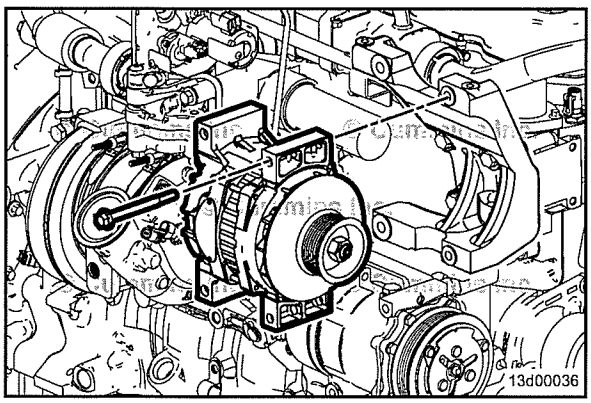
- Disconnect the battery cables. Refer to the OEM service manual.
- Remove the drive belt from the alternator pulley. Refer to Procedure 008-002 in Section 8.
- Tag and label all wires on the alternator.
- Disconnect the wires.

Remove

Spool Mount

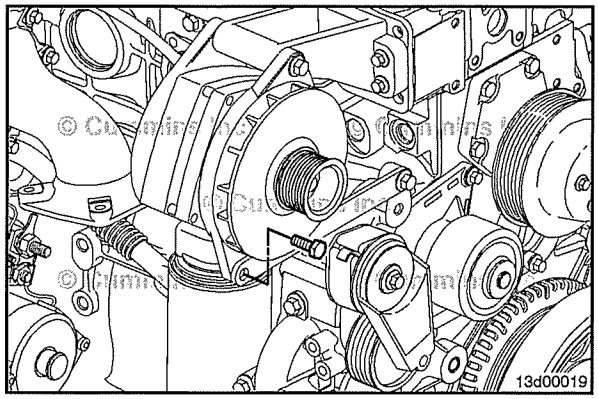


- Remove the upper alternator link capscrew.
- Remove the mounting capscrew and nut at the bottom of the alternator and the alternator mounting bracket.
- Remove the alternator.



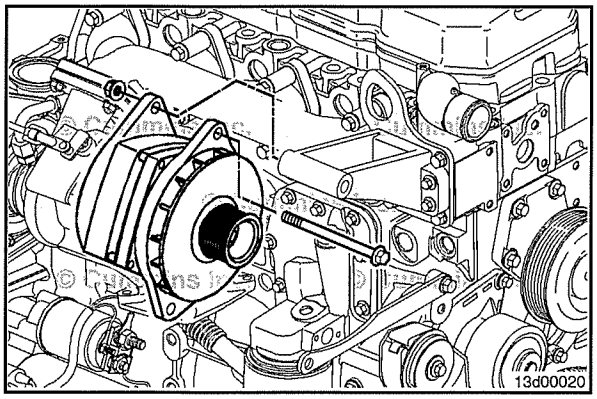
Pad Mount

- Remove the alternator mounting capscrews.
- Remove the alternator.



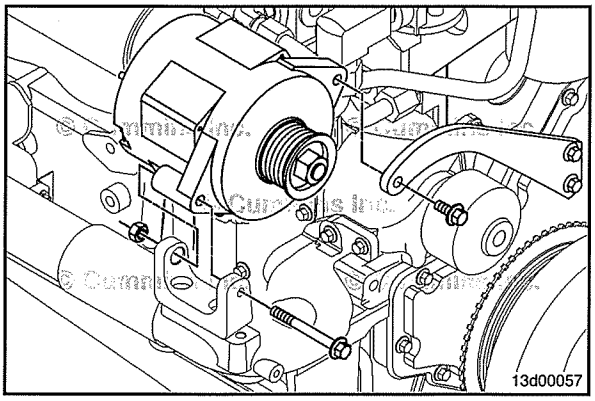
Hinge Mount

- Remove the alternator link capscrew.



Remove the alternator mounting capscrew.

Remove the alternator.



Install

Spool Mount

- Install the alternator and the bottom alternator mounting capscrew and nut.
- Tighten the capscrews.

Torque Value:
Lower Mounting Capscrew 40 N•m [30 ft-lb]

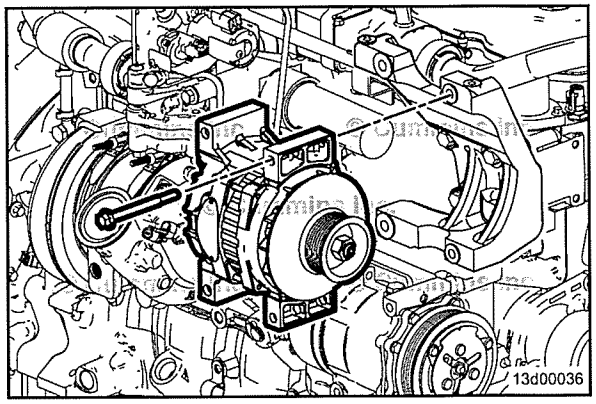
Torque Value:
Upper Link Mounting Capscrew 24 N•m [212 in-lb]

Pad Mount

- Install the alternator.
- Install and tighten the alternator mounting capscrews.

Torque Value:
M10 Capscrew 36 N•m [27 ft-lb]

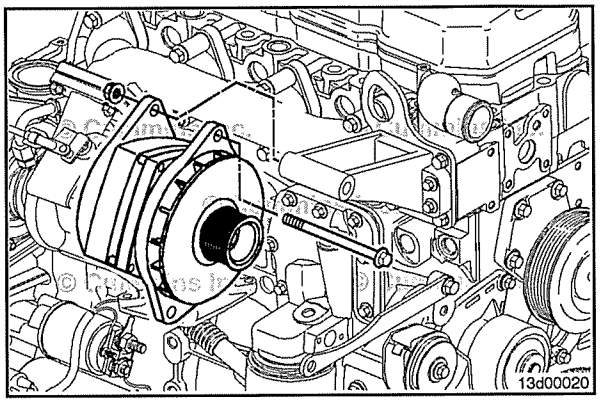
Torque Value:
M12 Capscrew 64 N•m [47 ft-lb]



Hinge Mount

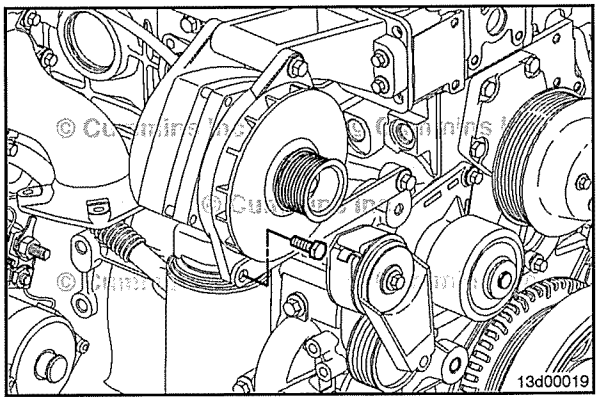
- Install the alternator.
- Install and tighten the alternator mounting capscrew.

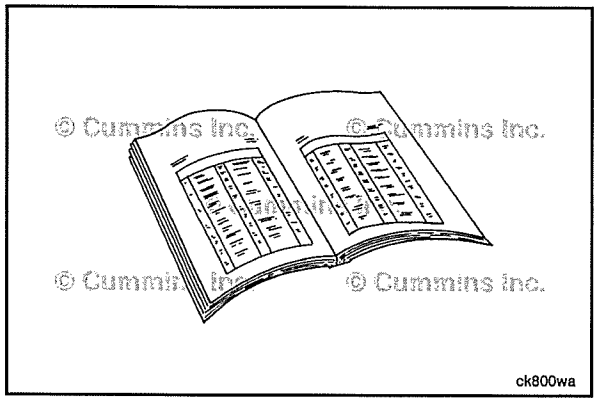
Torque Value: 40 N•m [30 ft-lb]



Install the alternator link capscrew.

Torque Value: 24 N•m [212 in-lb]



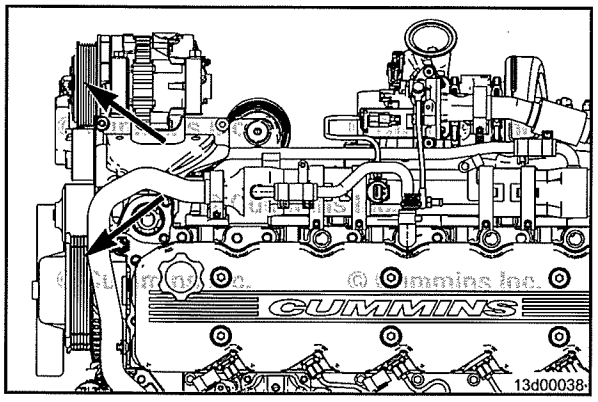


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

- Connect all wires to the alternator.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate engine to check for proper operation.

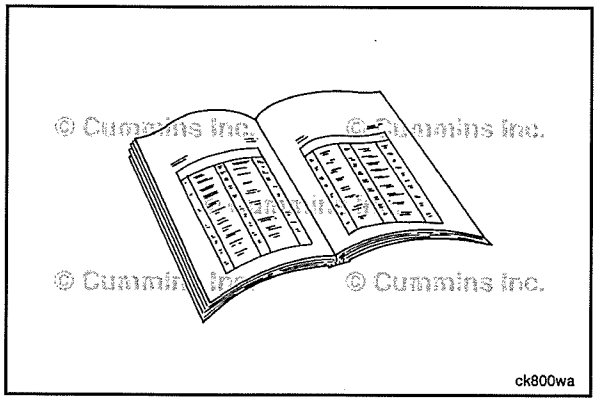


Alternator Bracket (013-003)

Initial Check

Check that the pulley is in line with the other belt-driven pulleys. Use pulley alignment fixture, Part Number 3163524, to check the alignment.

If the pulley is out of alignment, verify the correct alternator brackets have been used and are installed correctly.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

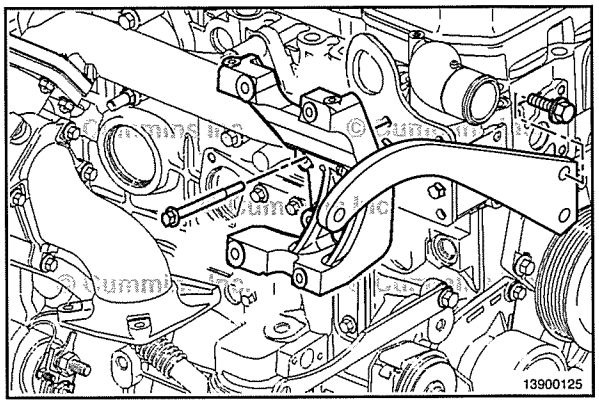
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the alternator. Refer to Procedure 013-001 in Section 13.

Remove

Spool Mount:

Remove the upper alternator bracket mounting capscrews.

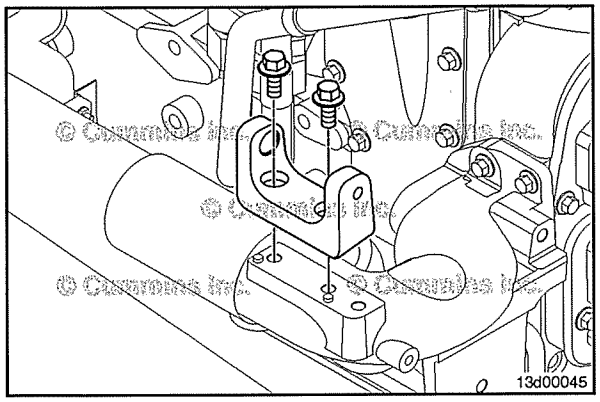
Remove the alternator bracket.



NOTE: On some applications, the lower alternator bracket and water inlet are combined in the same bracket. Refer to Procedure 008-082 in Section 8, where applicable.

Remove the lower alternator bracket mounting capscrews.

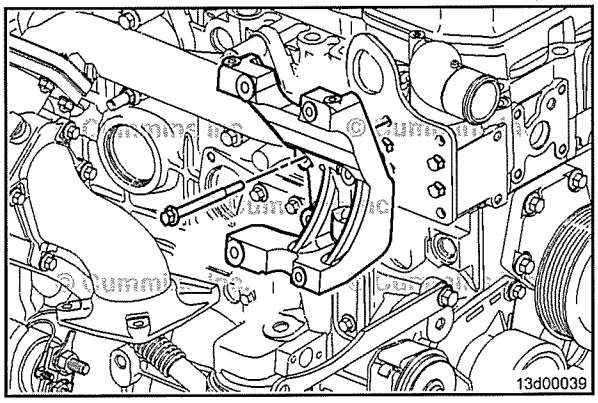
Remove the alternator bracket.



Pad Mount:

Remove the alternator bracket mounting capscrews.

Remove the alternator bracket.

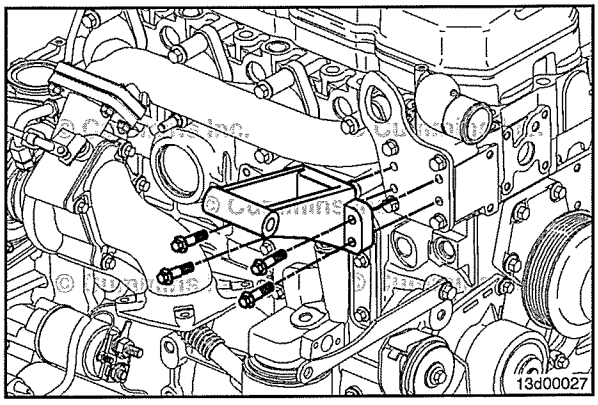


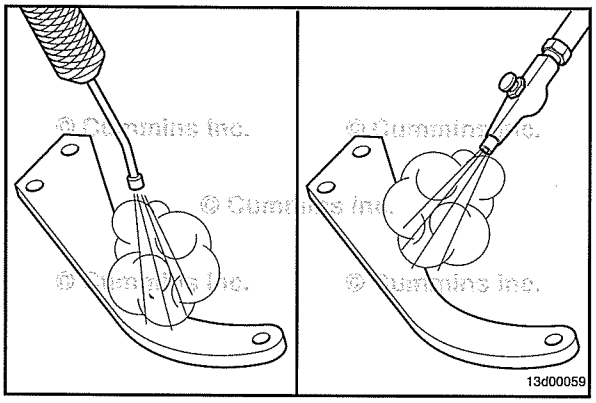
Hinge Mount:

Remove the upper alternator bracket mounting capscrews.

Remove the lower alternator bracket mounting capscrews.

Remove the alternator brackets.





Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

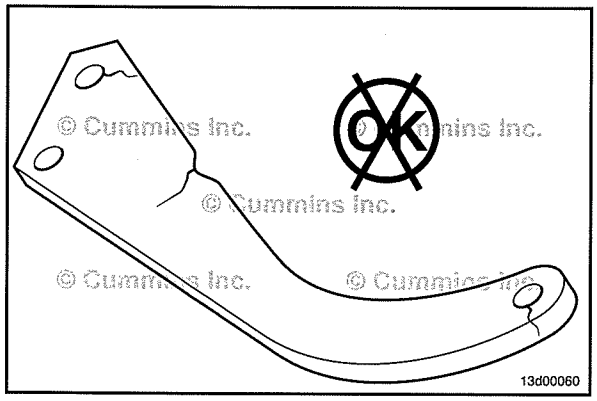
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Use skin and eye protection when handling caustic solutions to reduce the possibility of personal injury.

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

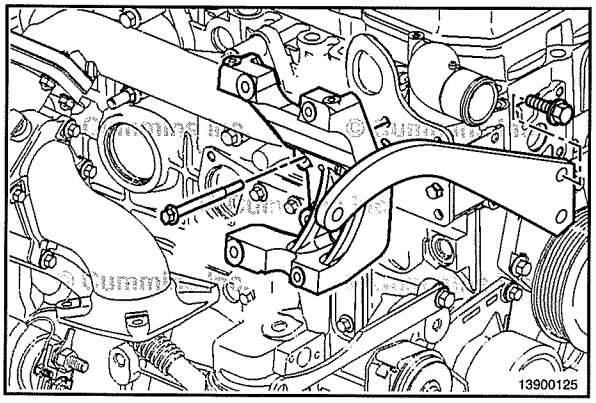
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam or solvent to clean the alternator brackets. Dry with compressed air.



Inspect the alternator brackets for cracks or damage.

If any cracks are found on the alternator brackets, they **must** be replaced.



Install

Spool Mount:

Install the upper alternator bracket and mounting capscrews.

Tighten the upper and lower alternator bracket mounting capscrew.

Torque Value:
M8 24 N•m [212 in-lb]

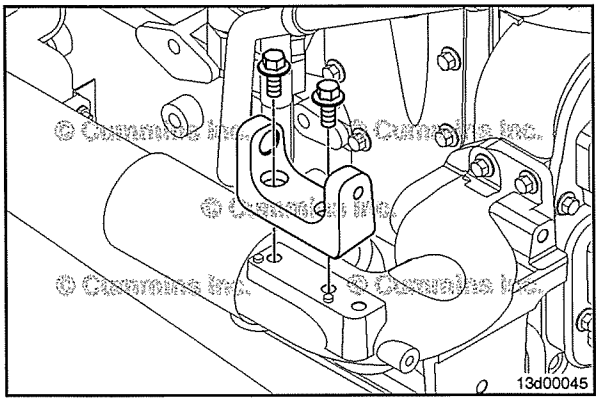
Torque Value:
M10 43 N•m [23 ft-lb]

NOTE: On some applications, the lower alternator bracket and water inlet are combined in the same bracket. Refer to Procedure 008-082, where applicable.

Install the lower alternator mounting bracket over the two dowel pins.

Install the two alternator bracket mounting capscrews and tighten.

Torque Value: 54 N•m [40 ft-lb]



Hinge Mount:

Install the upper alternator bracket and mounting capscrews.

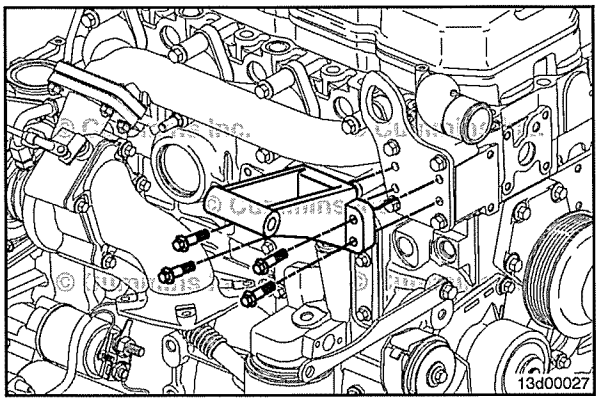
Install the lower alternator bracket and mounting capscrew.

NOTE: Depending on the alternator configuration, it can be necessary to wait until the alternator is installed before tightening the lower alternator bracket. This will allow adjustment of the bracket.

Tighten the upper and lower alternator bracket mounting capscrew.

Torque Value:
M8 24 N•m [212 in-lb]

Torque Value:
M10 43 N•m [32 ft-lb]



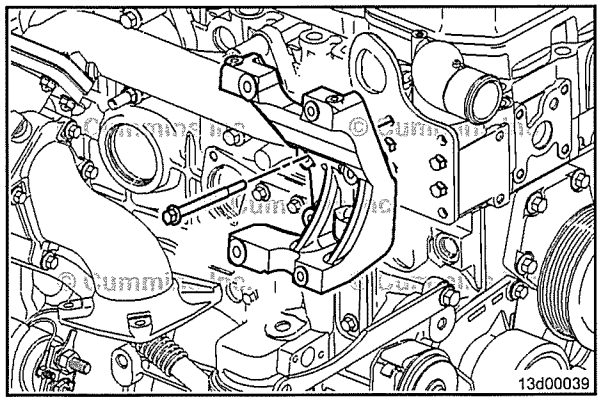
Pad Mount:

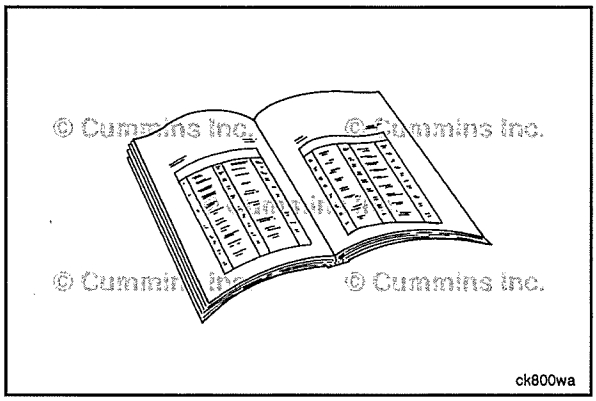
△CAUTION△
If the alternator bracket has alignment roll pins, assure the pins are contacting the surface on the cylinder head when the bracket is installed. Failure to do so will cause misalignment of the alternator pulley.

Install the alternator bracket.

Install and tighten the alternator bracket mounting capscrew.

Torque Value: 45 N•m [33 ft-lb]





Finishing Steps

⚠WARNING⚠

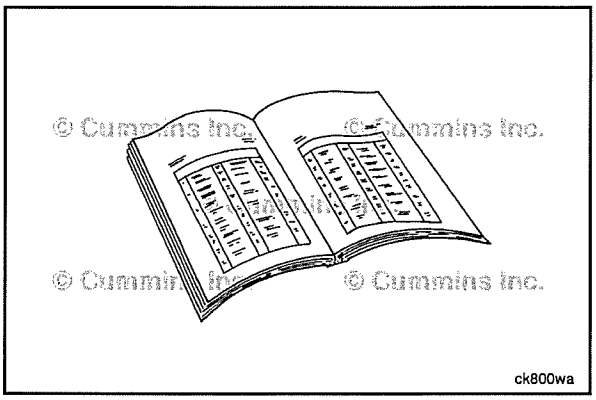
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the alternator. Refer to Procedure 013-001 in Section 13.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.

Alternator Pulley (013-006)

General Information

This procedure **only** covers Cummins® supplied/branded alternators. For non-Cummins® supplied/branded alternators, refer to the original equipment manufacturer (OEM) or alternator manufacturer for instructions.

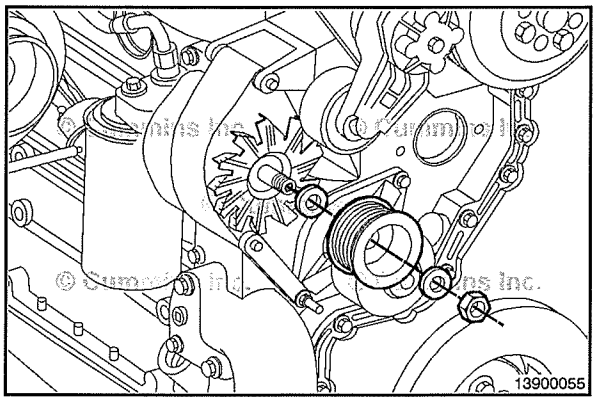


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the OEM service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.



Remove

Hold the shaft or pulley to prevent turning.

Remove the alternator pulley.

Install

Install the alternator pulley, mounting fastener, and any washers and/or spacers.

Hold the shaft or pulley to prevent turning.

Tighten alternator pulley mounting fastener.

Torque Value:
Bosch™ K1 70 N•m [52 ft-lb]

Torque Value:
Bosch™ NCB1 65 N•m [48 ft-lb]

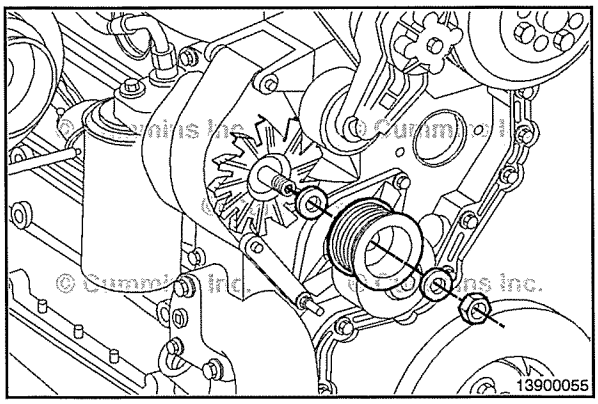
Torque Value:
Bosch™ NCB2 65 N•m [48 ft-lb]

Torque Value:
Delco™ 11 SI 95 N•m [70 ft-lb]

Torque Value:
Delco™ 20 SI 102 N•m [75 ft-lb]

Torque Value:
Delco™ 24 SI 102 N•m [75 ft-lb]

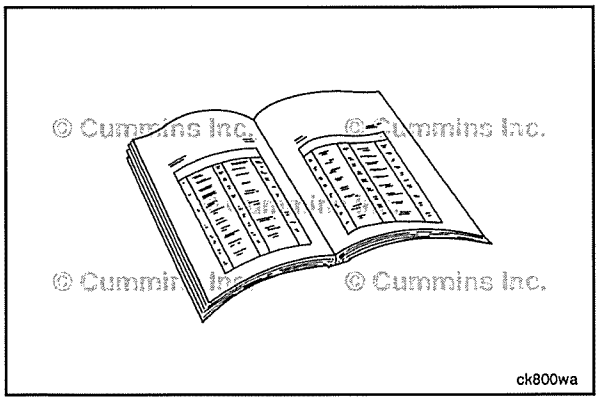
Torque Value:
Delco™ 33 SI 102 N•m [75 ft-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.



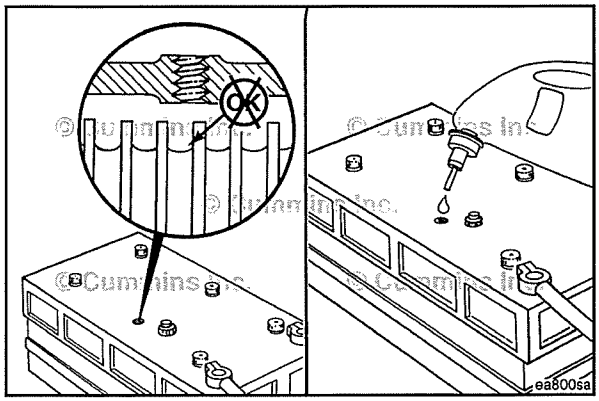
Batteries (013-007)

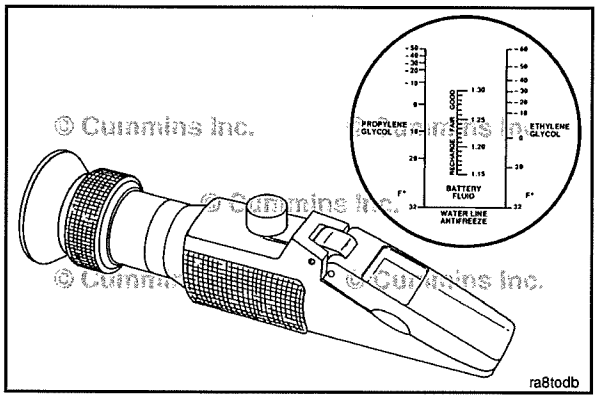
Initial Check

If conventional batteries are used, remove the cell caps or covers, and check the electrolyte level.

NOTE: Maintenance-free batteries are sealed and do **not** require the addition of water.

Fill each battery cell with distilled water. Refer to the battery manufacturer's specifications.

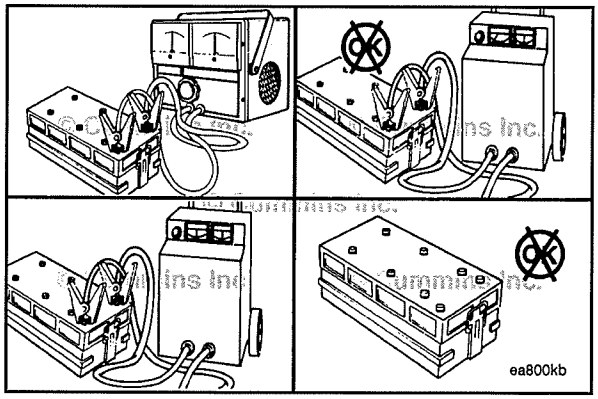




Use the Fleetguard® refractometer, Part Number CC-2800, to check the specific gravity of the battery electrolyte.

Refer to the battery fluid column in the refractometer to determine the state of charge of each battery cell.

If water has been added to a dry cell, recharge the battery to mix the added water with the existing battery electrolyte, to prevent incorrect readings.

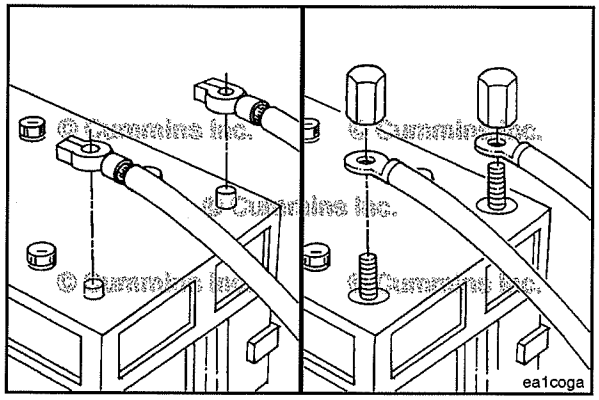


⚠CAUTION⚠
Do not connect battery charging cables to any electronic control system part. This can damage the electronic control system parts.

Use a carbon-pile load (battery/alternator tester) to test the output amperage of maintenance-free or conventional vent cap batteries.

If the output amperage is low, use a battery charger to charge the battery. Refer to the manufacturer's instructions.

Replace the battery if it will **not** charge to the manufacturer's specifications or will **not** maintain a charge.

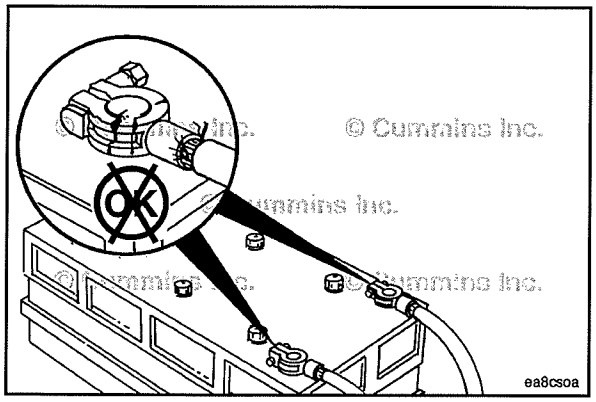


Battery Cables and Connections (013-009)

Initial Check

There are two possible heavy-duty battery connections:

- Battery terminal and clamp (1)
- Threaded battery terminal and nut (2).



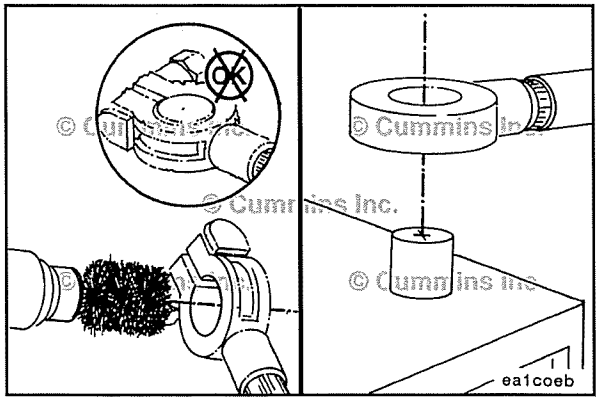
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Remove and inspect the battery cables and connections for cracks or corrosion.

Replace broken terminals, connectors, or cables.

If the connections are corroded, use a battery brush or wire brush to clean the connections until shiny.

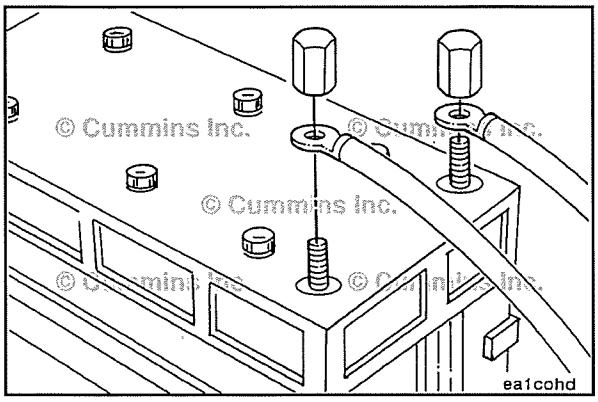
Make sure all debris is removed from the connecting surfaces.



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Install the cables and tighten the battery connections.

Coat the terminals with grease to prevent corrosion.



Starter Magnetic Switch (013-017)

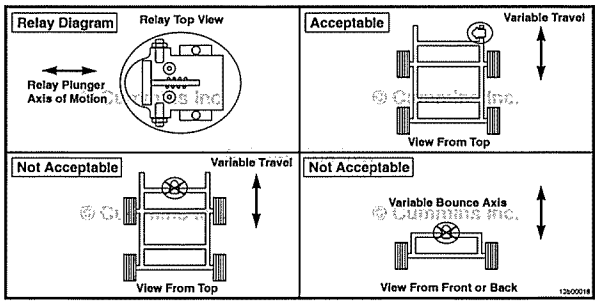
Initial Check

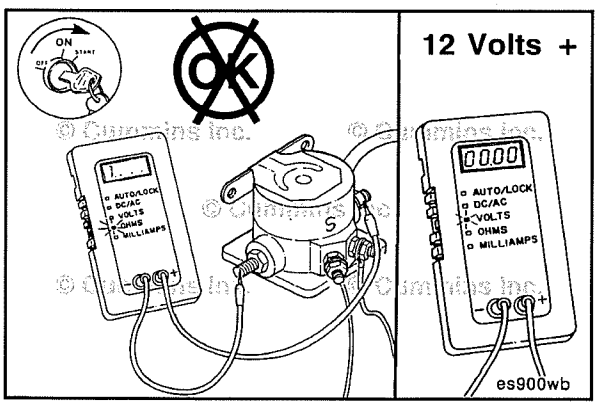
⚠CAUTION⚠
Improper installation of the starter magnetic switch can result in starter over-run damage.

To make sure that the magnetic switch is **not** activated by vehicle movement, the axis of the plunger **must** be horizontal to the ground and perpendicular to vehicle travel.

Do **not** mount an external magnetic switch on the engine or on any metal that can possibly resonate as the result of road or engine vibration.

- Refer to the original equipment manufacturer (OEM) service manual for proper magnetic switch installation.

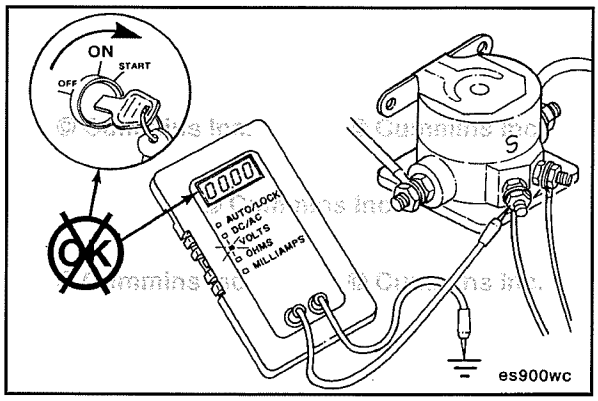




Voltage Check

If the multimeter indicates resistance at greater than 100k ohms with the starting motor switch in the "START" position, turn the starting motor switch to the "OFF" position.

Set the multimeter scale to read DC voltage.



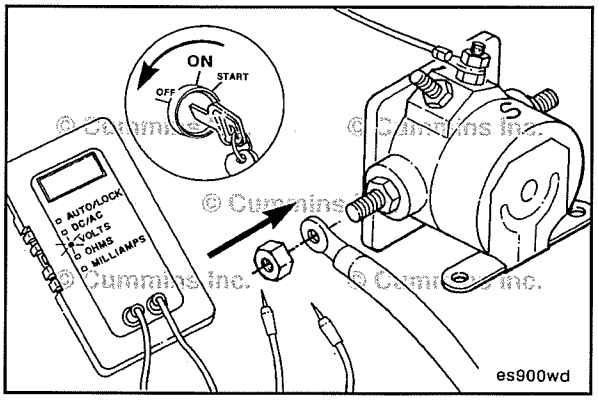
Connect one multimeter lead to the magnetic switch terminal marked "S" and the other lead to the ground.

Turn the starting motor switch to the "START" position.

If the multimeter indicates no voltage, the magnetic switch is **not** the cause of the complaint. Refer to Procedure 013-018 in Section 13.

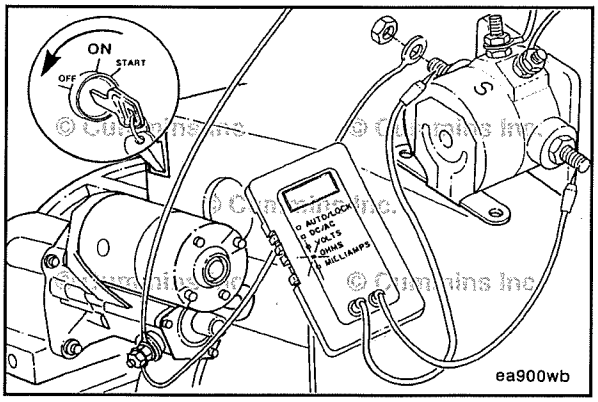
If the starter magnetic switch is **not** within specification, replace the switch according to the manufacturer's instructions.

NOTE: For Cummins® branded Delco-Remy™ starters, a service kit is avaialble to replace **only** the magnetic switch as opposed to the whole starter assembly.



Turn the starting motor switch to the "OFF" position.

Remove the multimeter leads and connect the magnetic switch to the starting motor solenoid wire.



Resistance Check

⚠WARNING⚠
Be sure the starter motor switch is in the OFF position to reduce the possibility of electrical shock and personal injury.

Remove the cable connecting the magnetic switch to the starter motor solenoid from the magnetic switch terminal.

Connect the leads of the digital multimeter, Part Number 3377161 or equivalent, to the two large switch terminals.

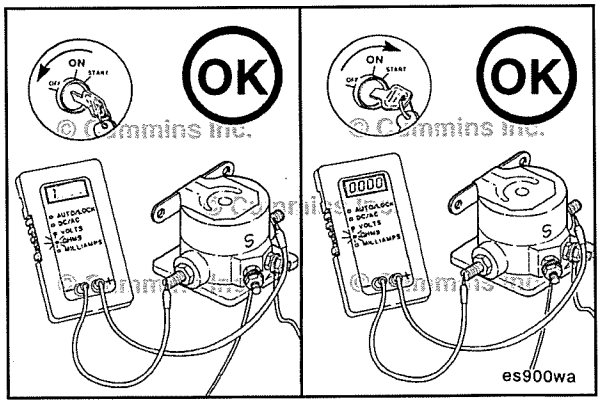
Set the digital multimeter, Part Number 3377161, to measure resistance (ohms).

Connect the leads to the two large switch terminals.

With the keyswitch in the OFF position, the multimeter **must** indicate resistance greater than 100k ohms.

Turn the keyswitch to the START position.

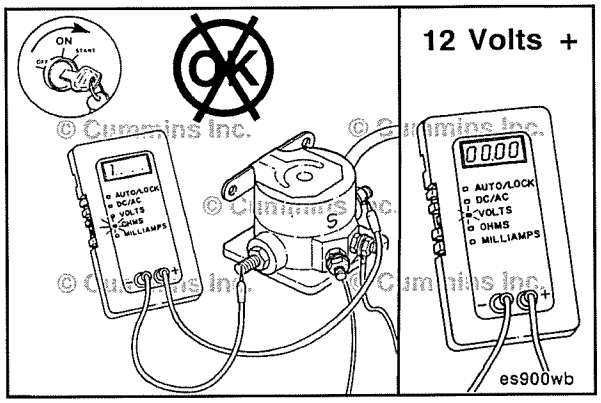
The multimeter **must** indicate less than 10 ohms. If **not** within specifications, replace the starter magnetic switch according to the manufacturer's instructions.



Voltage Check

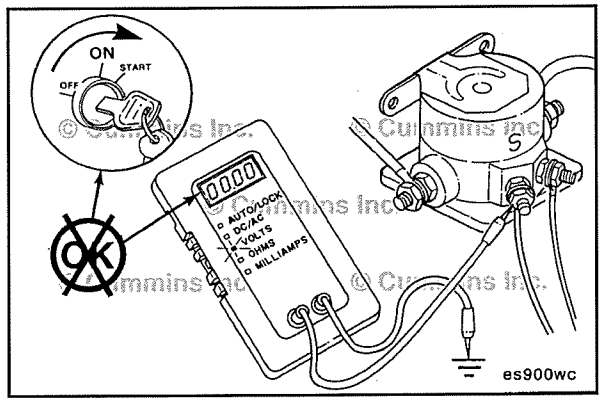
If the multimeter indicates resistance greater than 100k ohms with the keyswitch in the START position:

- Turn the keyswitch to the OFF position.
- Set the multimeter scale to read DC voltage.

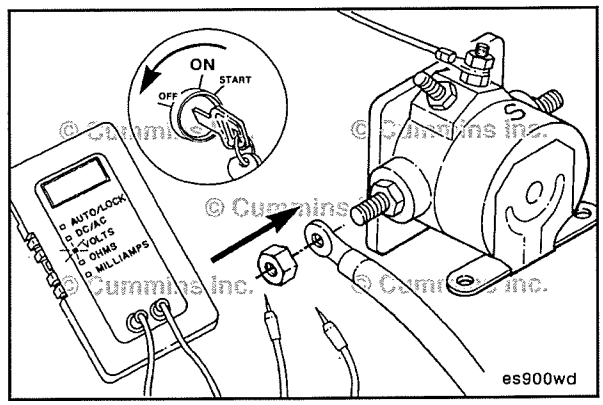


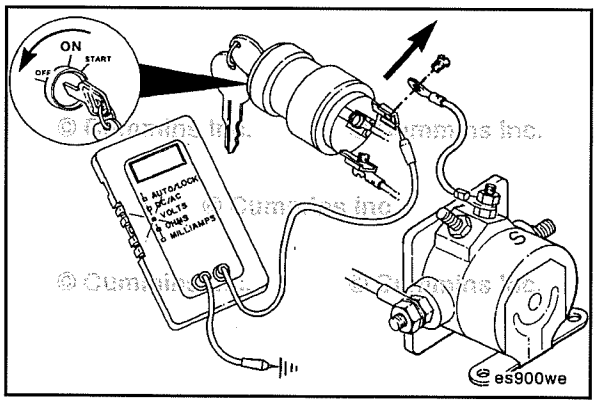
- Connect one multimeter lead to the magnetic switch terminal marked S and the other lead to ground.
- Turn the keyswitch to the START position.
- If the multimeter indicates no voltage, the magnetic switch is **not** the cause of the complaint. If the starter magnetic switch is **not** within specification, replace the switch according to the manufacturer's instructions.

NOTE: For Cummins® branded Delco-Remy™ starters, a service kit is avaialble to replace **only** the magnetic switch as opposed to the whole starter assembly.



- Turn the keyswitch to the OFF position.
- Remove the multimeter leads and connect the magnetic switch to the starter motor solenoid wire.





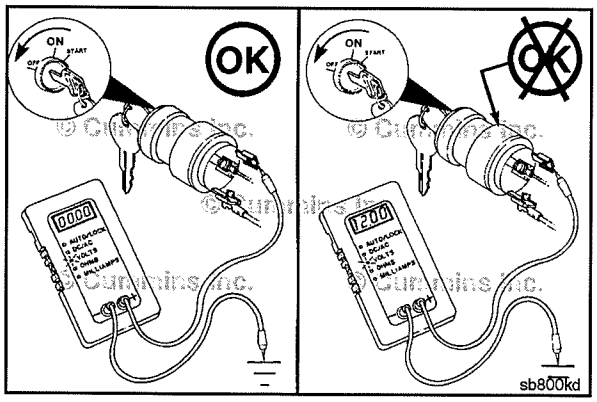
Starter Switch (013-018)

Voltage Check

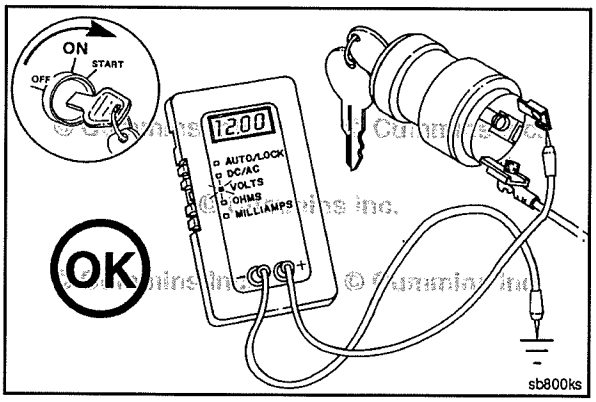
⚠WARNING⚠
Be sure the starting motor switch is in the "OFF" position to prevent electrical shock and personal injury.

Remove the wire connecting the starting motor switch to the magnetic switch (marked "S" or "START") from the starter switch terminal.

Connect the positive (+) lead of the digital multimeter, Part Number 3164488 or equivalent to the starter switch terminal and the negative (-) lead to a chassis or engine ground location.

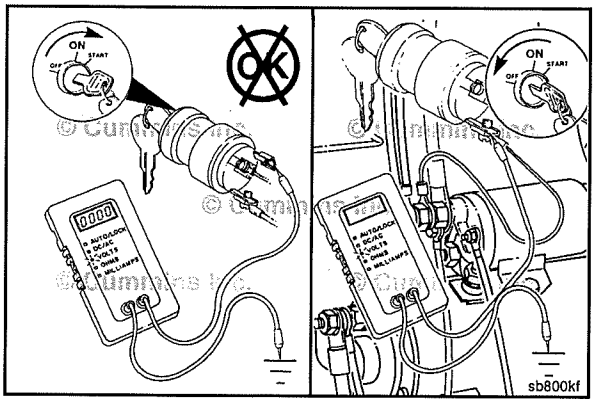


NOTE: Set the multimeter to indicate DC volts with the starting motor switch in the "OFF" position, there must **not** be voltage at the starter switch terminal. If the meter indicates voltage, the starter switch is malfunctioning and **must** be replaced.



Turn the starting motor switch to the "START" position.

The multimeter **must** indicate system voltage.

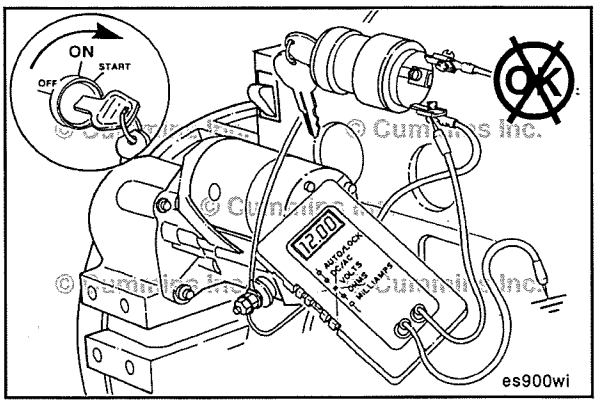


If there is **no** voltage, turn the starting motor switch to the "OFF" position.

Connect the multimeter positive (+) lead to the starter switch terminal having a wire connecting the starter switch to the starting motor solenoid B terminal.

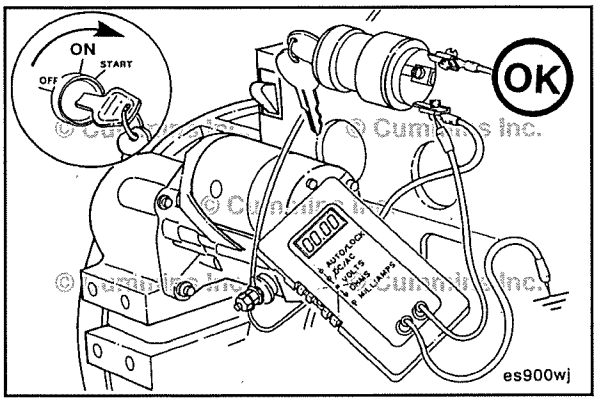
Turn the starting motor switch to the "START" position.

If the meter indicates system voltage at the starter switch input terminal, the starter switch is defective and **must** be replaced. Refer to the OEM service manual for the replacement procedure.



If the meter indicates no voltage, the switch is **not** the cause of the complaint.

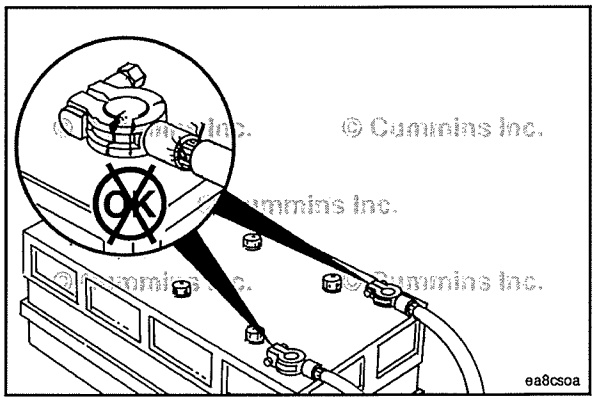
Check the wiring from the starter switch to the starting motor solenoid B terminal and from the starting motor solenoid to the battery for broken or damaged wires.



Starter Solenoid (013-019)

Initial Check

Before troubleshooting the starter motor, make sure the battery terminals are **not** loose or corroded. Refer to Procedure 013-009 in Section 13.



Voltage Check

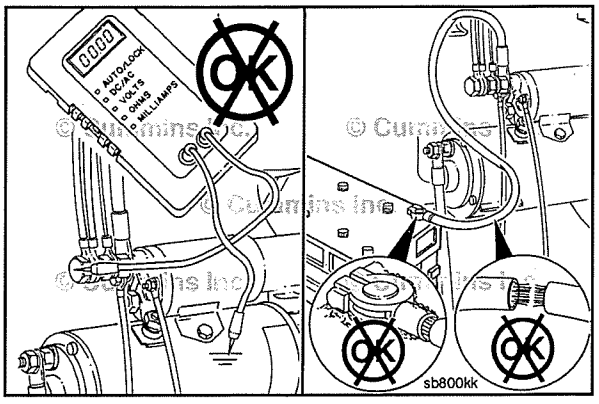
Digital Multimeter, Part Number 3377161

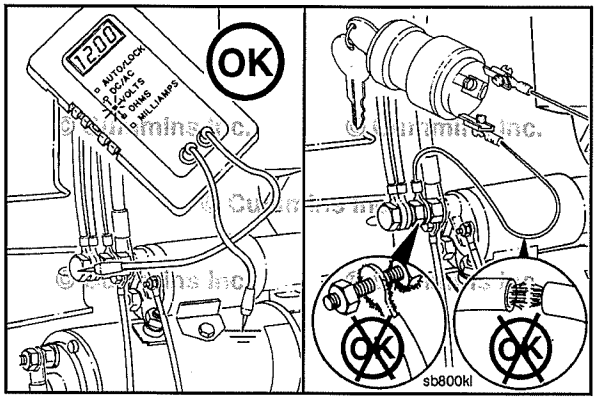
Set the digital multimeter, Part Number 3377161, to measure DC volts.

Connect the multimeter positive (+) lead to the starter solenoid positive cable terminal and the negative (-) lead to a chassis or engine ground location.

The multimeter **must** show voltage with the keyswitch in the OFF position to be normal.

If the multimeter does **not** indicate voltage, check the cable connecting the starter solenoid and battery for breaks. Also, check for loose or corroded connections.

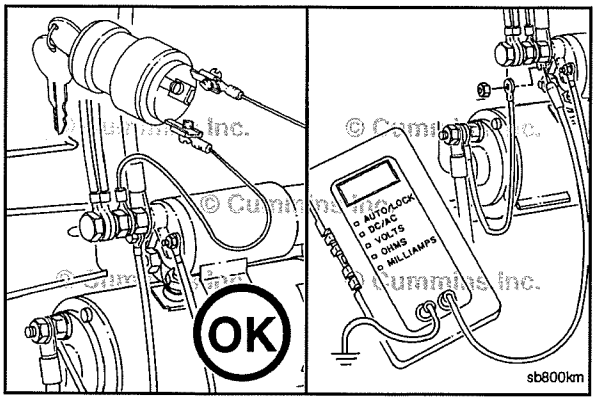




If the multimeter indicates voltage but the starter will **not** operate, check the wire connecting the starter solenoid to the keyswitch for breaks; and also check for loose or corroded connections.

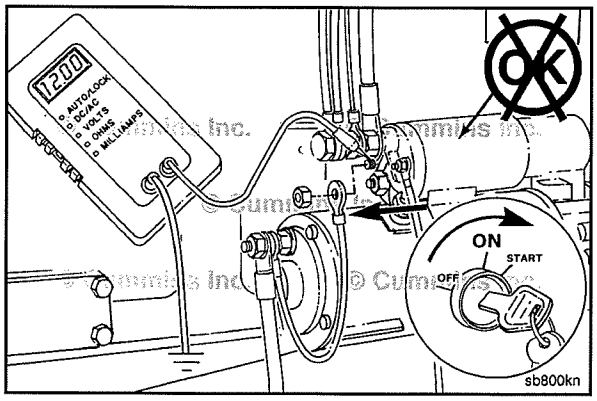
In addition, be sure to check for:

- Fuses
- Application engine shutoff systems.

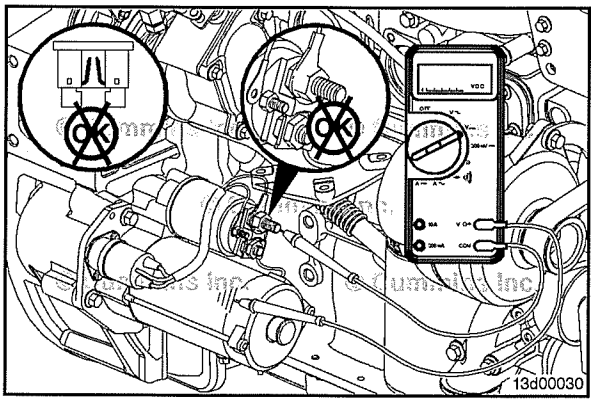


If the wire connecting the starter solenoid and keyswitch is **not** loose or damaged and the starter will **not** operate:

- Remove the cable connecting the starter and starter solenoid from the solenoid terminal.
- Connect the multimeter positive (+) lead to the solenoid "S" or switch terminal and the negative (-) lead to the chassis or an engine ground location.



- Turn the keyswitch to the START position.
- If the multimeter indicates voltage and the starter will **not** operate, the starter solenoid is malfunctioning and **must** be replaced. Refer to Procedure 013-020 in Section 13.

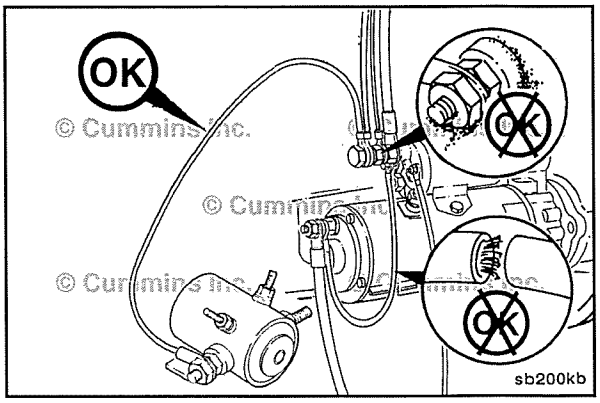


If the multimeter does **not** indicate system voltage:

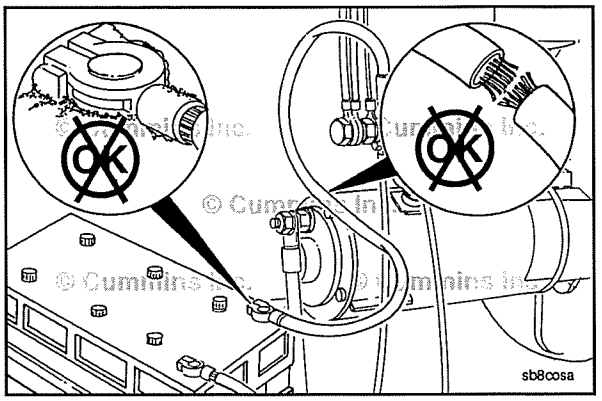
- Check the wire connecting the starter solenoid “S” or switch terminal to the magnetic switch for breaks, and for loose or corroded connections.
- Check that there are no blown fuses.
- Check voltage to the magnetic switch. Refer to Procedure 013-017 in Section 13.
- Check voltage to the keyswitch.Refer to Procedure 013-030 in Section 13.
- Check application of the safety shut-off systems.

If the wire connecting the starter solenoid to the magnetic switch is **not** loose or damaged and the starter will **not** operate:

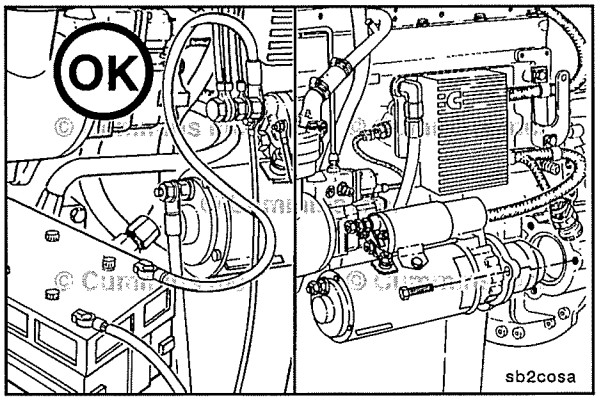
- Check the cable connecting the starter solenoid to the starter motor for breaks, and for loose or corroded connections.

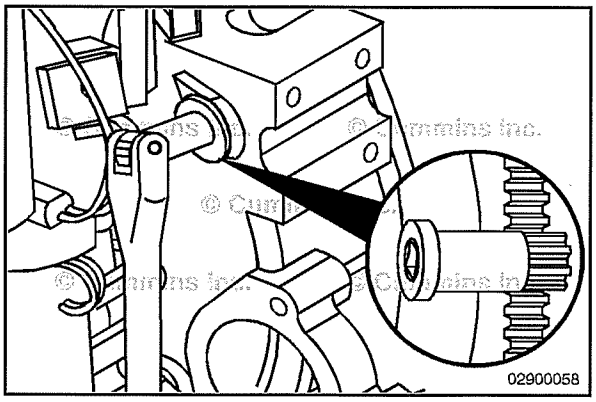


- Check the cable connecting the starter motor to the battery for breaks, and for loose or corroded connections.



- If the cables are **not** loose or damaged, the starter motor is defective and **must** be replaced. Refer to Procedure 013-020 in Section 13.





Starting Motor (013-020)

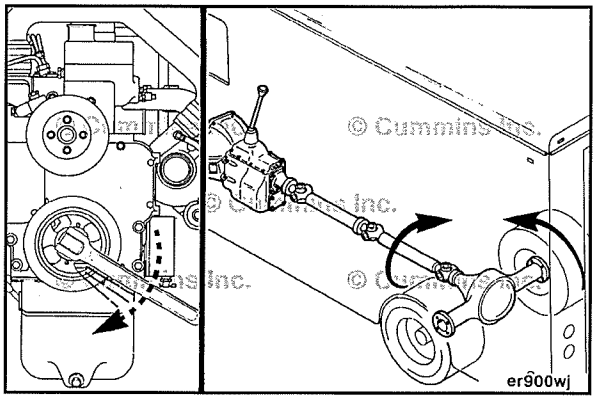
Rotation Check

If the starter solenoid is making a sound but the engine is **not** rotating, turn the keyswitch to the OFF position, and attempt to bar the crankshaft in both directions.

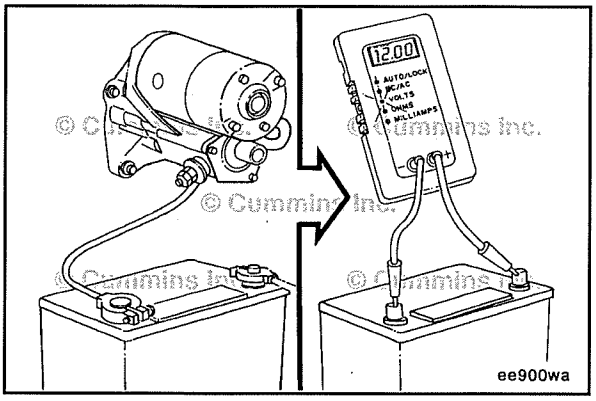
Bar the engine with the barring tool, Part Number 3824591.

If the crankshaft will bar over, attempt to start the engine. If the starter motor cranks the engine, check the starter motor pinion gear and flywheel ring gear for damage.

If damage to the starter motor pinion gear and/or flywheel ring gear is found when replacing the components, make sure to measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear. Follow the measure step of this procedure.



If the crankshaft does **not** rotate or requires more than the normal effort to bar, check for an internal malfunction or a problem with the drive unit and/or accessories.



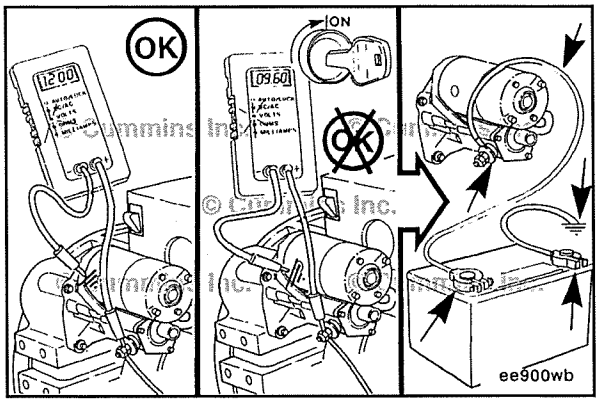
If the engine cranking speed is too slow/will **not** crank at all, and the engine rotates freely:

Make sure the wiring connections are clean, tight, and **not** damaged.

Check the battery voltage. Refer to the original equipment manufacturer (OEM) service manual.

Check the voltage at the starting motor during cranking. If the voltage drops more than 2.4-VDC on a 12 volt system and 4.8-VDC on a 24 volt system, check that all connections are clean and tight.

If the cables are correct and the voltage drop exceeds the limit, replace the starting motor.



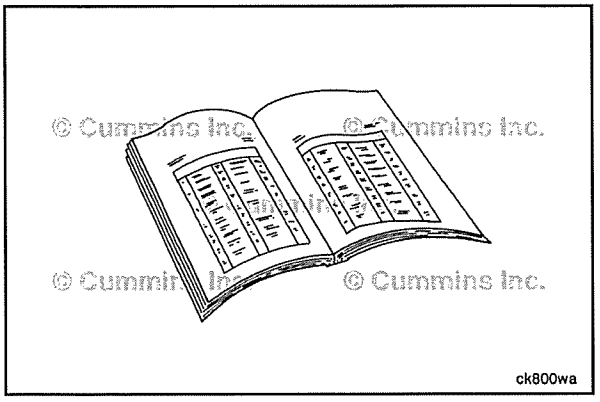
Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Disconnect the battery cables. Refer to the OEM service manual.



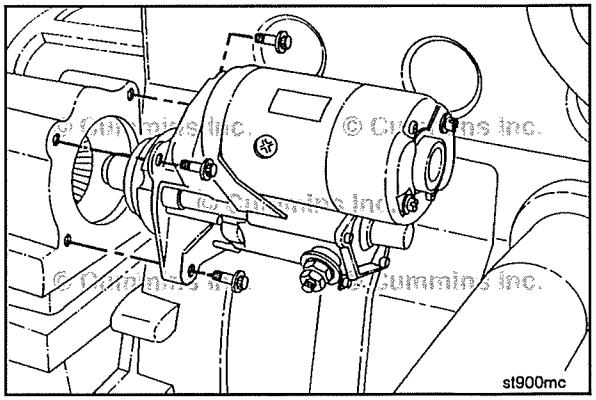
Remove

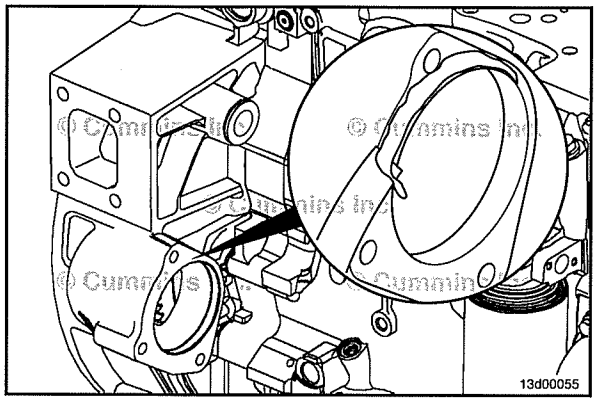
Identify each wire with a tag inicating its location on the starting motor.

Remove the electrical connections from the starting motor.

Remove the three capscrews and the starting motor.

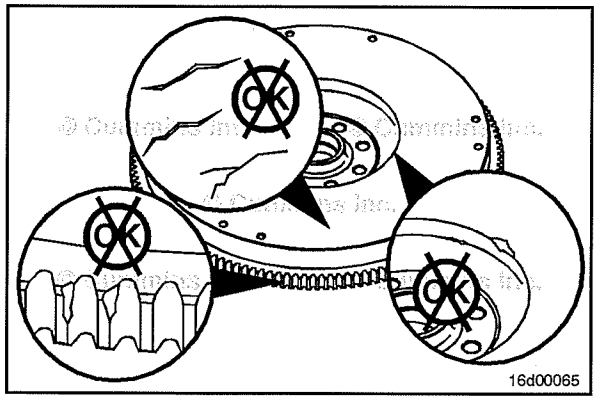
NOTE: If equipped with a starting motor spacer, remove the spacer and clean all surfaces between the starting motor, starting motor spacer, and flywheel housing with a wire brush.





Clean and Inspect for Reuse

For engines that use wet flywheel housings, clean any left over sealant from the starting motor mounting flange on both the flywheel housing and starting motor. Make sure these surfaces are clean of oil and debris.

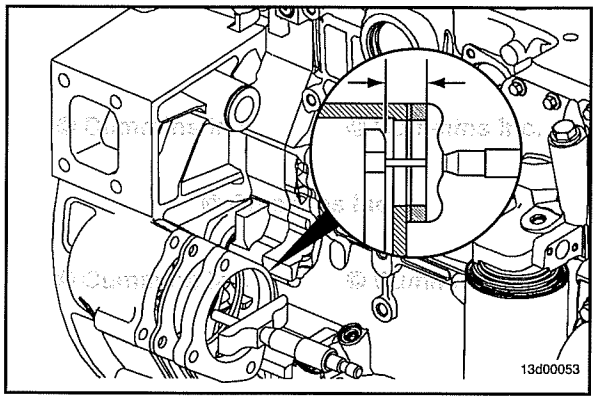


Inspect the starter motor pinion gear and/or flywheel ring gear for chipping or uneven wear.

NOTE: If the starter motor pinion gear and/or flywheel ring gear teeth are damaged, they **must** be replaced.

Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.

Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.



Measure

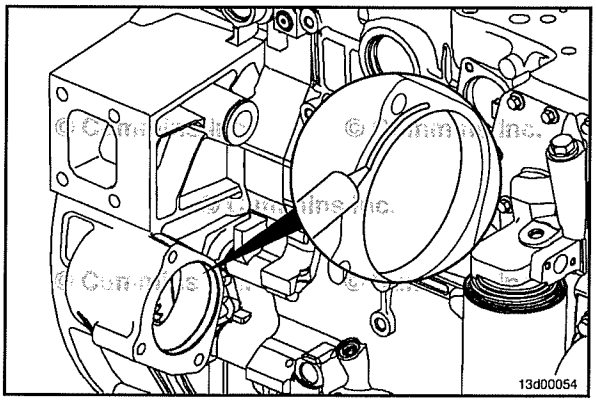
Use a depth micrometer or vernier caliper to measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear.

NOTE: Include any spacers previously removed when completing the measurement.

Starting Motor Spacing

mm		in
49.28	MIN	1.94
52.32	MAX	2.06

Add or remove spacers as necessary to achieve the correct starting motor spacing.



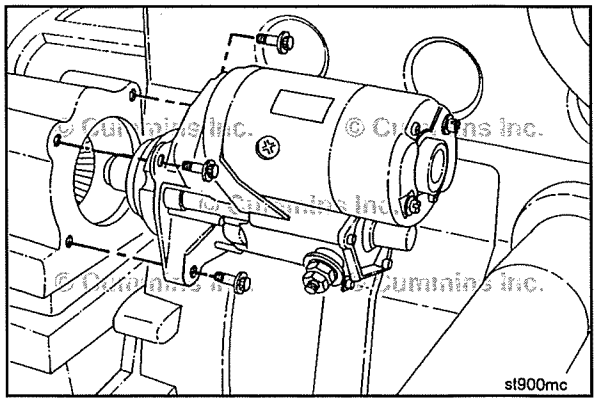
Install

For engines with wet flywheel housings, apply a 1.5 to 2.0 mm [0.06 to 0.09 in] wide bead of sealant, Part Number 3164067, to the flywheel housing starting motor mounting flange.

NOTE: If a starting motor spacer is required, make sure to apply sealant to the side of the spacer that contacts the starting motor.

Install the three capscrews, the starting motor, and starting motor spacer, if required.

Torque Value: 43 N•m [32 ft-lb]



Cummins® Branded Starters

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△CAUTION△
Do not overtighten the electrical connections. Starter damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

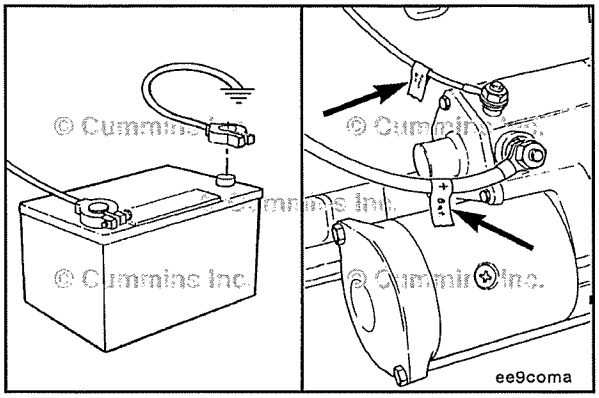
Connect the electrical connections to the starter motor.

Torque Value:
M5 4 N•m [35 in-lb]

Torque Value:
M10 21 N•m [185 in-lb]

Install the jump start protection (JSP) cover and nut on the M terminal post.

NOTE: The JPS cover nut is the third nut on the M terminal, M5 terminal size. Failure to observe the proper torque specification can result in loss of conductivity to the M lead and result in a no crank condition for the starter and engine.



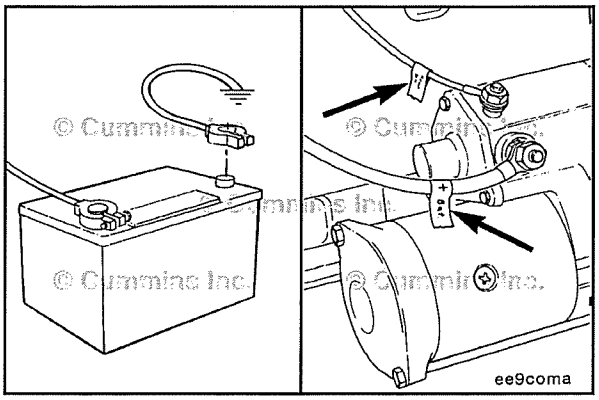
Non-Cummins® Branded Starters

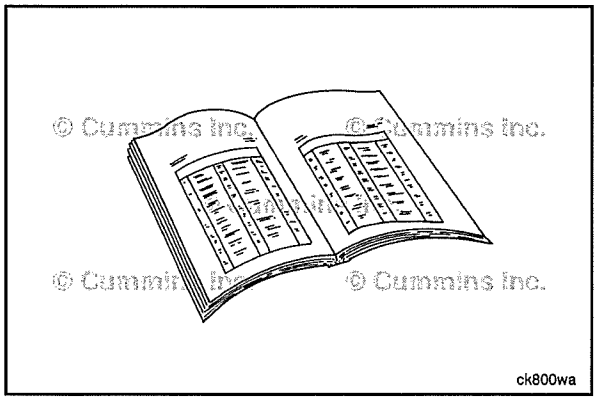
△CAUTION△
Do not overtighten the electrical connections. Starter damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

Connect the electrical connection to the starting motor.

For Non-Cummins® branded starters, refer to the OEM service manual for torque specifications.



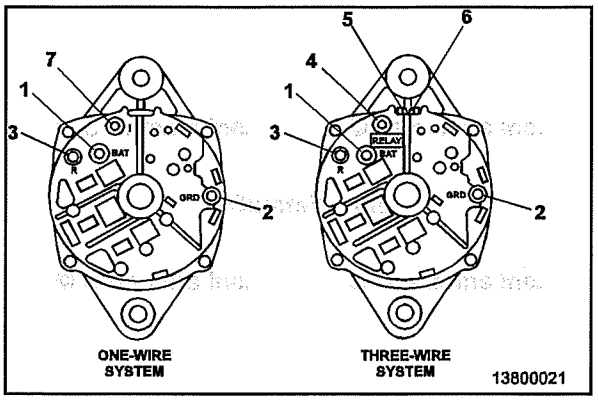


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.
- Operate the starter to check for proper function.

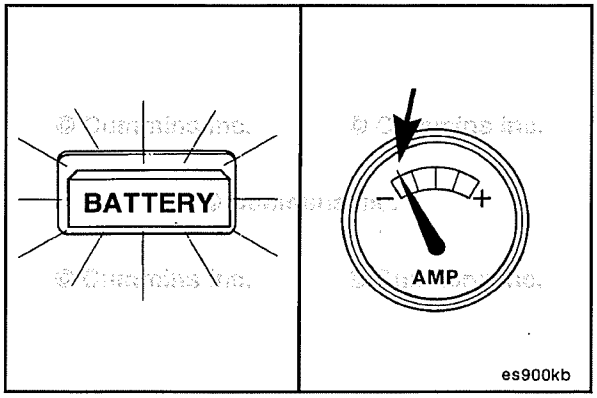


Charging System Indicator (013-023)

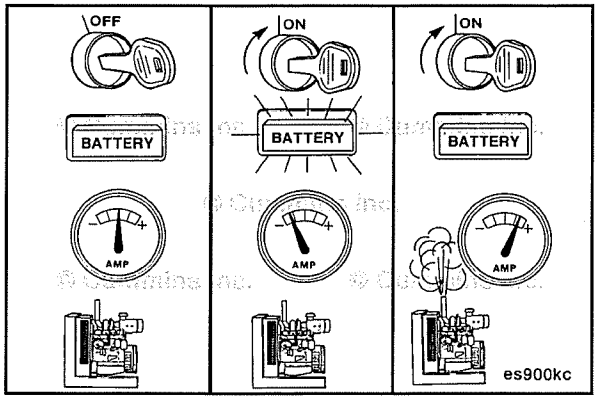
Initial Check

NOTE: Be positive that the correct terminals are used on the alternator.

Refer to the alternator manufacturer's instructions.



Trouble with the charging system can be indicated by the indicator lamp or ammeter.

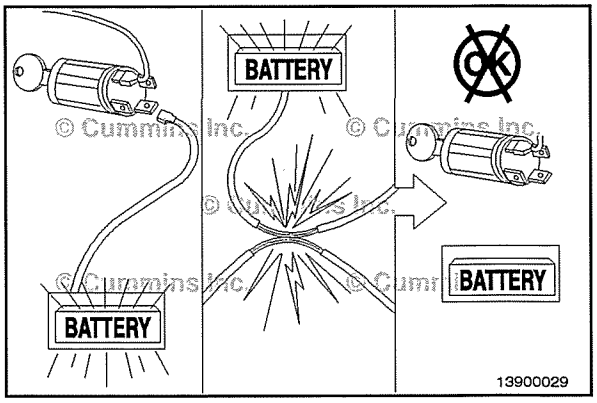


Check the indicator lamp for normal operation as shown below.

Stopped	Off	Off	0
Stopped	On	On	(-)
Running	On	On	(+)

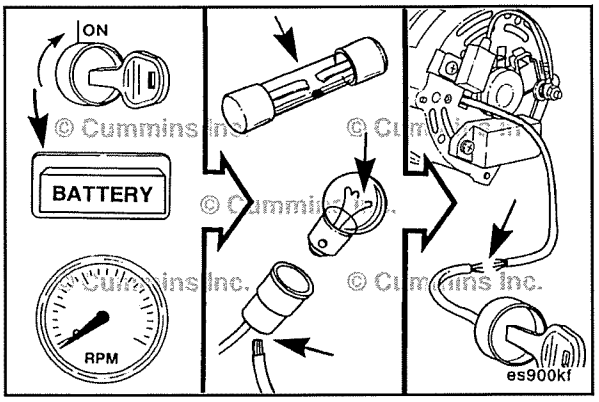
If the lamp is on when the switch is in the OFF position and the engine is **not** running, disconnect the lamp lead at the keyswitch.

- If the lamp stays on, there is a short to a positive (+) wire.
- If the lamp goes out, there is a short in the switch.



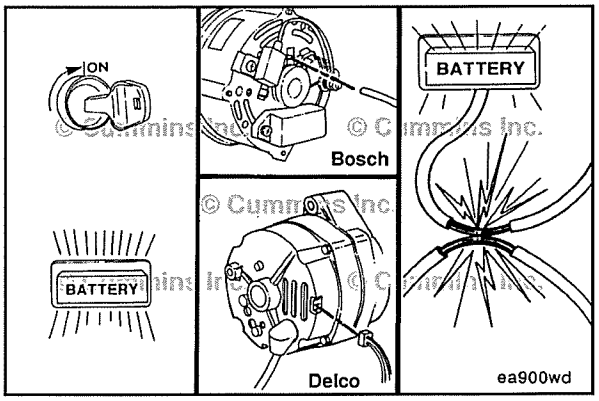
If the lamp is off when the switch is in the ON position and the engine is **not** running, there can be an open circuit.

Check for a blown fuse, a burned out bulb, damaged bulb socket, or an open circuit in number 1 or "D+" lead between alternator and keyswitch.



If the lamp is on when the switch is on and the engine is running, disconnect the lead to the alternator.

- If the lamp stays on, there is a short to ground in the lamp circuit. Refer to Procedure 013-001 in Section 13.
- If the lamp goes out, inspect the alternator. Refer to Procedure 013-001 in Section 13.



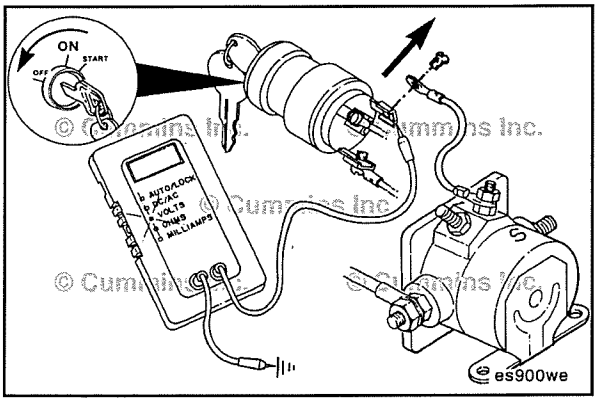
Key Switch (013-030)

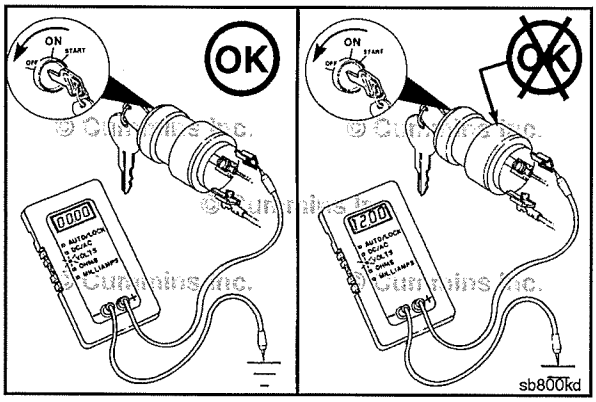
Voltage Check

⚠WARNING⚠
Be sure the keyswitch is in the OFF position to reduce the possibility of electrical shock and personal injury.

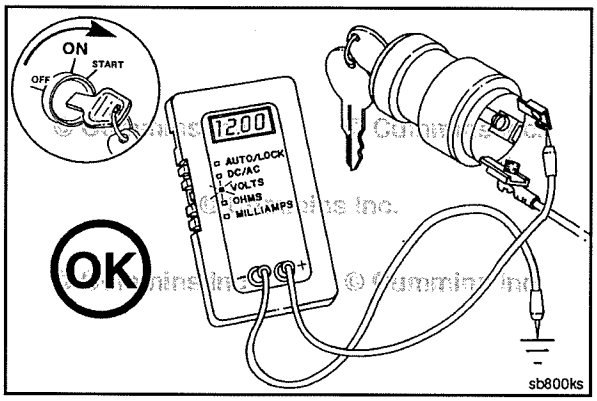
Remove the wire connecting the keyswitch to the magnetic switch (marked S or Start) from the keyswitch terminal.

Connect the positive (+) lead of digital multimeter, Part Number 3377163 or equivalent, to the keyswitch terminal and the negative (-) lead to a chassis or engine ground location.



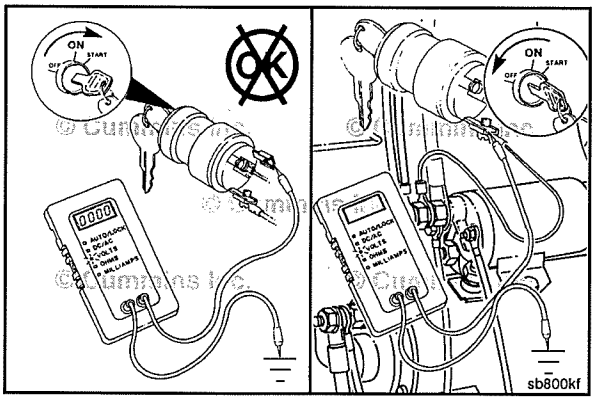


NOTE: Set the multimeter to indicate DC volts with the keyswitch in the OFF position. There **must** be no voltage at the keyswitch terminal. If the meter indicates voltage, the keyswitch is malfunctioning and **must** be replaced.



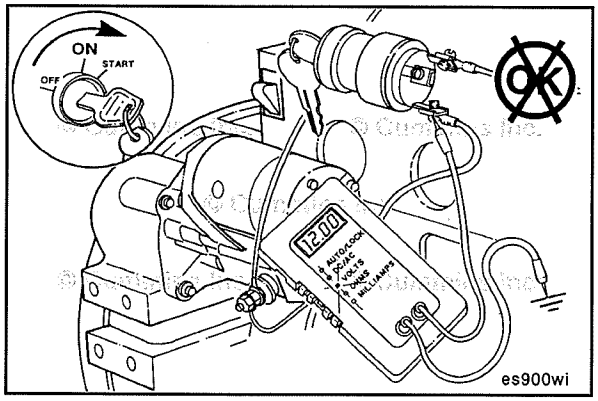
Turn the keyswitch to the START position.

The multimeter **must** indicate system voltage.



If there is no voltage:

- Turn the keyswitch to the OFF position.
- Check for supply voltage to the keyswitch by connecting the multimeter positive (+) lead to the keyswitch terminal having a wire connecting the keyswitch to the starter motor solenoid "B" terminal.

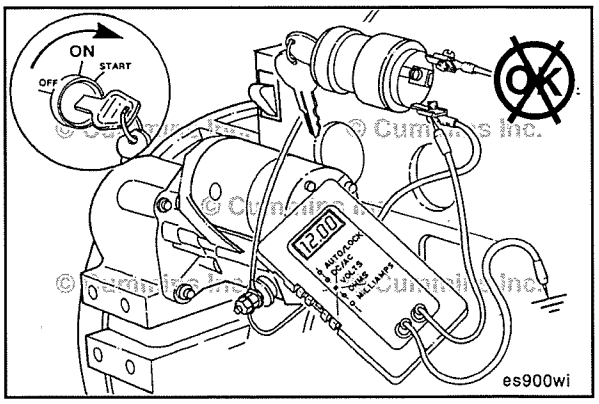


Turn the keyswitch to the START position.

If the meter indicates system voltage at the keyswitch input terminal, the keyswitch is defective and **must** be replaced. Refer to the original equipment manufacturer's manual for replacement.

If the meter indicates no voltage, the keyswitch is **not** the cause of the complaint.

Check the wiring from the keyswitch to the starter motor solenoid "B" terminal, and from the starter motor solenoid to the battery, for broken or damaged wires.



Notes

Section 14 - Engine Testing - Group 14

Section Contents

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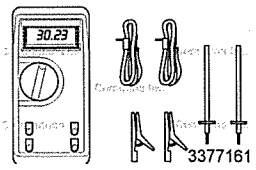
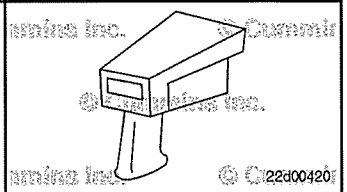
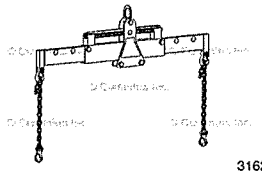
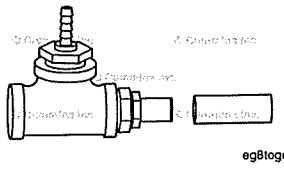
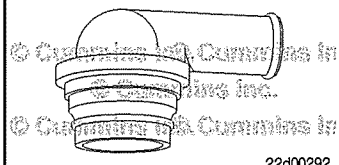
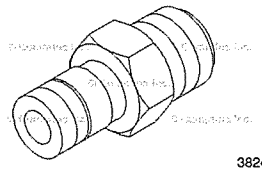
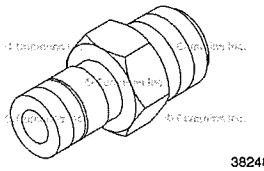
Service Tools

Engine Testing

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164488 or 3164489	**Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amperage). Part Number 3164488 - Standard meter. Part Number 3164489 - Automotive meter with built in temperature adapter and tachometer.	
4919041	**Digital Optical Tachometer** Used to measure engine speed (rpm).	
3162871	**Engine Lifting Fixture** Used to remove and install the engine. Maximum Capacity: 2721 kg [6,000 lb].	
3822566	**Blowby Tool** Used to check engine crankcase blowby.	
3990099	**Oil Fill Adapter** Used to measure blowby from the oil fill port in the rocker lever cover. NOTE: Will **not** work with all rocker lever cover oil fill ports. Thread type and size can be different.	
3377244	**Compuchek™ Fitting** Used to connect diagnostics machine. With 1/8 NPT connection.	

Tool No.	Tool Description	Tool Illustration
3824842	**Compuchek™ Fitting** Used to check fuel filter restriction, with 10 mm o-ring connection.	 3824813

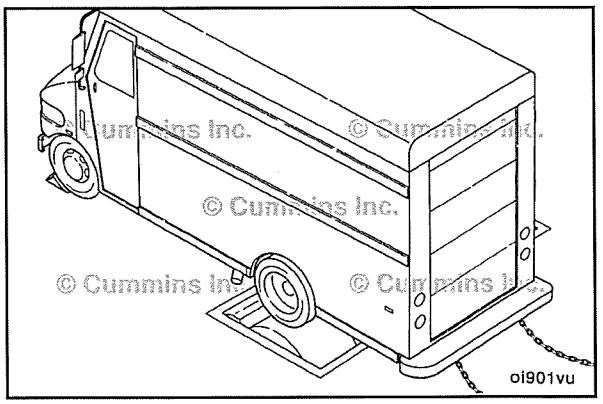
Engine Testing (Chassis Dynamometer) (014-002)

General Information

This procedure describes general guidelines for setting a vehicle up for operation on a chassis dynamometer for:

- Engine Testing
- Engine Run-In

For engine run-in procedure using a chassis dynamometer. Refer to Procedure 014-003 in Section 14.



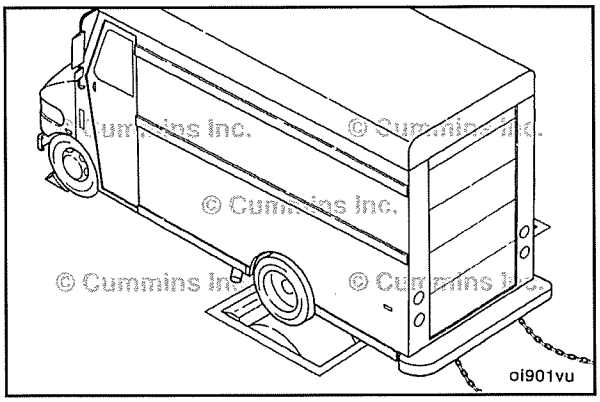
Setup

The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

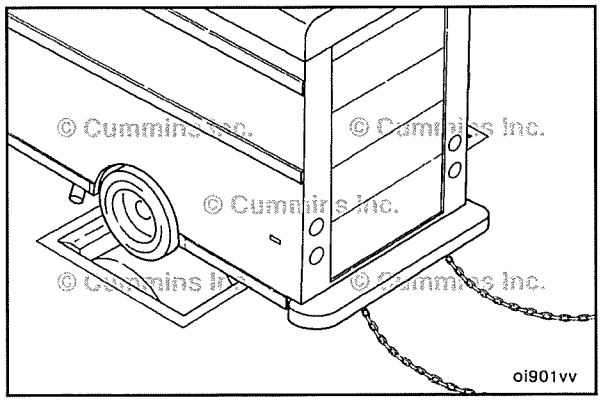
NOTE: Because of drive line efficiency and engine-driven accessories, the engine horsepower when measured at the rear wheels will be reduced by approximately:

- 20 percent for single-axle vehicles
- 25 percent for tandem-axle vehicles
- 35 percent for recreational vehicles.

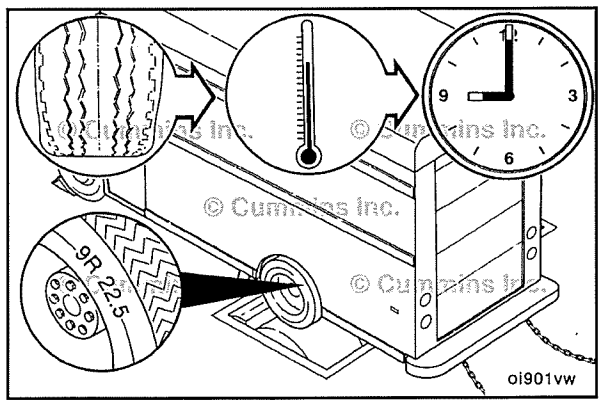
NOTE: These percentages are used for engine run-in **only** and are **not** to be used as absolute figures.

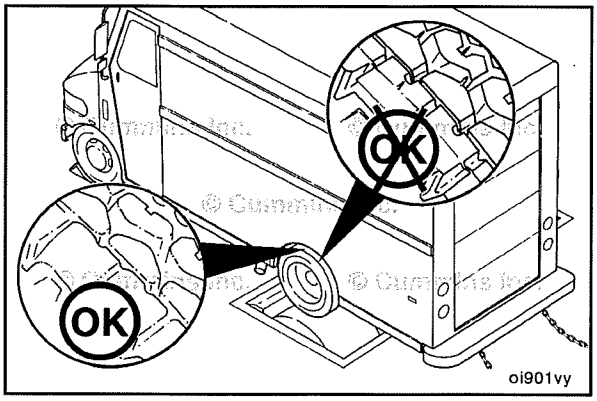


⚠WARNING⚠
Follow all of the original equipment manufacturer (OEM) safety precautions before installing or operating a vehicle on a chassis dynamometer. Failure to do so can cause damage to the vehicle and/or cause personal injury.



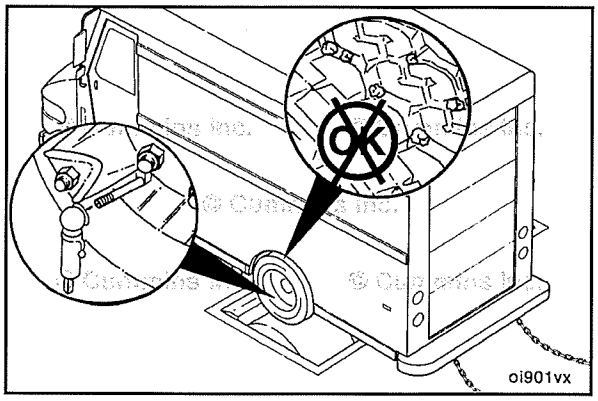
⚠CAUTION⚠
Low-profile tires are more sensitive to heat than bias-ply tires. Excessive operating time at full load can damage the tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.



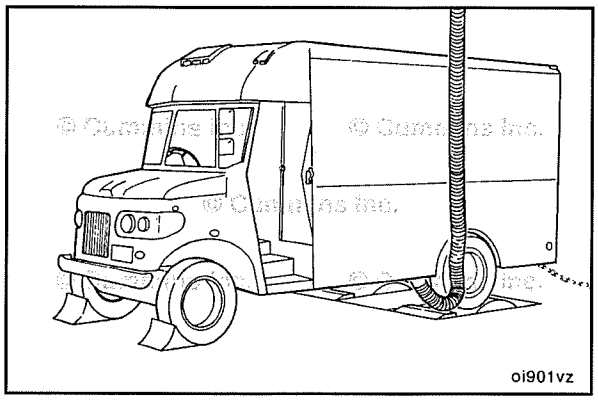


While operating the chassis dynamometer, follow the general safety precautions listed below:

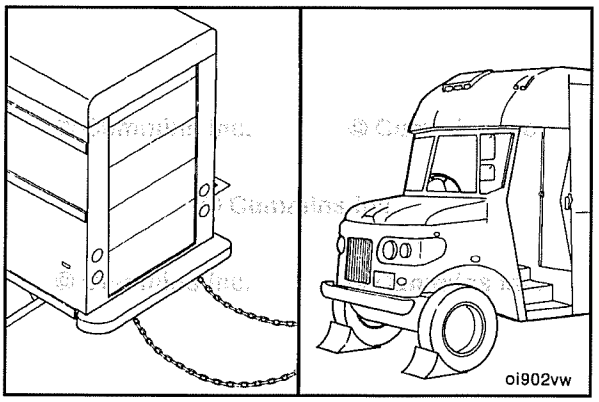
- Use tires that have more than 160 km [99 mi] of use. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.



- Make sure the tires are inflated to the manufacturer's specifications.
- Remove all rocks and other materials from the treads of the tires that will be rotating on the dynamometer rollers.



- Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.



△CAUTION△
To prevent damage to the chassis dynamometer, make sure there is enough slack in the tie-down chains.

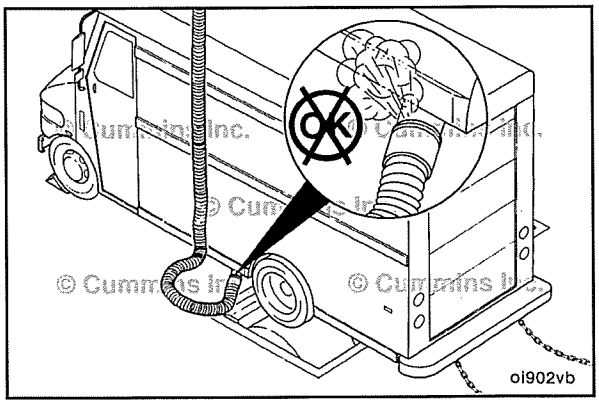
Carefully position the vehicle on the rollers.

Attach the tie-down chains to the rear of the vehicle.

Place wheel chocks in front of the front tires.

Adjust the vehicle and dynamometer room exhaust system to make sure all the exhaust gases are removed from the room.

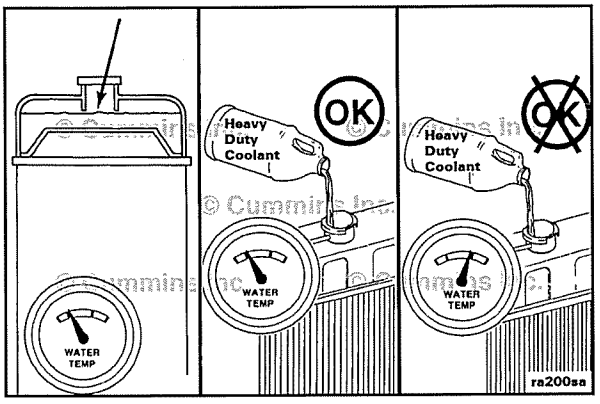
Refer to the chassis dynamometer and vehicle manufacturer's recommendations and specifications for testing procedures.



⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠CAUTION⚠
Do not add cold coolant to a hot engine. This can cause engine casting damage. Allow the engine to cool to below 50°C [120°F] before adding coolant.

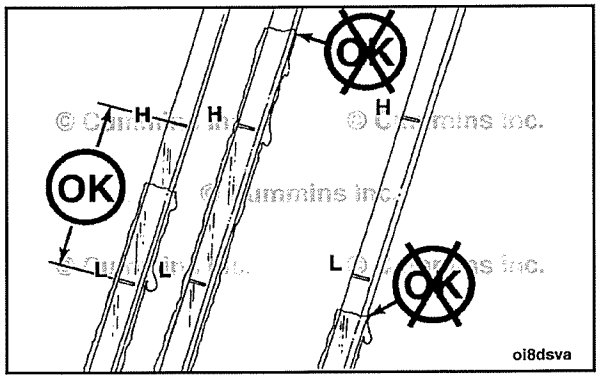
Check the engine coolant level to make sure it is filled to the proper level. Refer to Procedure 008-018 in Section 8.

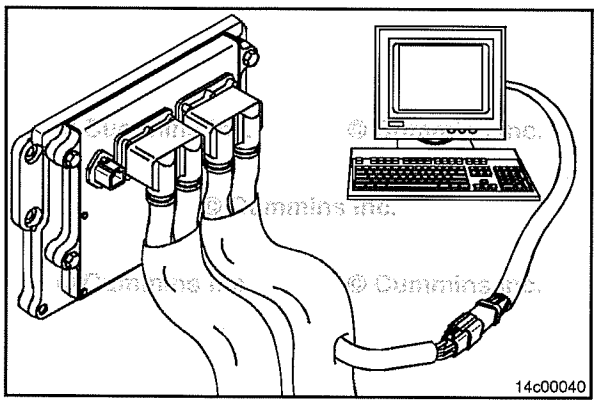


Check the engine lubricating oil level to make sure it is filled to the proper level. Refer to Procedure 007-037 in Section 7.

Verify the fuel supply tanks are filled with a known good quality number 2 diesel fuel.

NOTE: Number 1 diesel fuels, along with most other alternate fuels, are lighter (lower specific gravity, higher American Petroleum Institute (API) gravity) than number 2 diesel fuel. The lighter the fuel, the lower the energy content (British thermal unit (BTU)) per liter [gallon].





Test

To monitor engine performance correctly, record the following parameters. To limit dynamometer operating time, instrument the engine or use INSITE™ electronic service tool to make as many checks as possible.

Record the following common monitor parameters during the test.

Record any additional parameters if troubleshooting a specific problem.

Service Tip: For the INSITE™ electronic service tool monitored parameter, utilize the INSITE™ electronic service tool "Data-Logging" feature for recording the values during the test.

Tasks INSITE™ electronic service tool can monitor (but **not** limited to):

- Engine speed (rpm)
- Vehicle speed
- Intake manifold air temperature
- Intake manifold air pressure
- Engine coolant temperature
- Fuel rail pressure (commanded and actual).

If equipped:

- Ambient air temperature
- Ambient (barometric) pressure
- Crankcase pressure
- Exhaust gas temperature sensor(s)
- Aftertreatment diesel particulate filter differential pressure sensor.

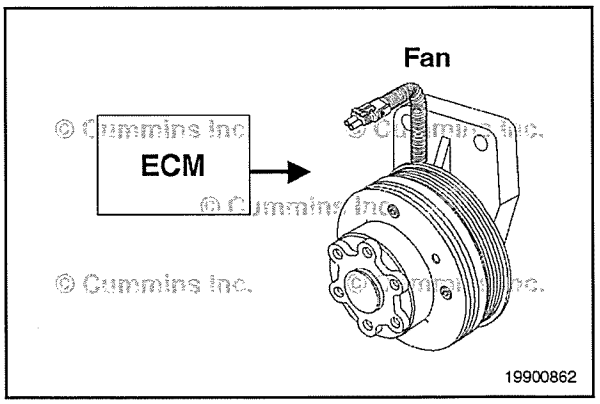
Tasks requiring separate tools and/or gauges.

- Engine fuel temperature (if needed to correct fuel rate).
- Fuel inlet restriction. Refer to Procedure 006-020 in Section 6.
- Fuel drain line restriction. Refer to Procedure 006-012 in Section 6.
- Fuel rate. Refer to the manufacturer's instructions.
- Intake air restriction. Refer to Procedure 010-031 in Section 10.
- Exhaust restriction. Refer to Procedure 011-009 in Section 11.
- Engine oil pressure. Refer to Procedure 007-037 in Section 7.
- Coolant pressure. Refer to Procedure 008-020 in Section 8.

If the vehicle is equipped with a clutched fan, make sure the fan is locked in the ON position when operating an engine on a chassis dynamometer for the best results.

If the engine control module (ECM) controls the ON/OFF function of the fan, use INSITE™ electronic service tool to lock the fan ON if the unit does not have a manual fan switch.

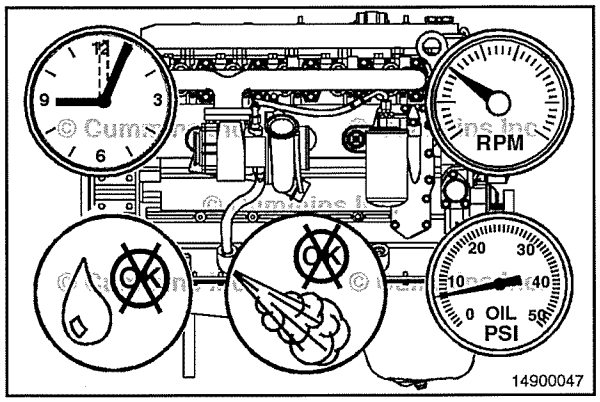
If the ECM does not control the ON/OFF function of the fan, refer to the manufacturers instructions.



⚠CAUTION⚠
Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation can damage the engine.

⚠CAUTION⚠
Do not allow the engine speed to exceed 1000 rpm before run-in. The internal engine components can be damaged.

⚠CAUTION⚠
Do not shut off the engine immediately after the last step of the run-in is completed. Allow the engine to cool by operating at low idle for minimum of 3 minutes to avoid internal engine component damage.



If performing an engine run-in, avoid long idle periods. Operate the engine at low idle **only** long enough (3 to 5 minutes) to check for correct lubricating oil pressure and any fuel, lubricating oil, water, or air leaks.

If a sudden increase in blowby occurs or if blowby exceeds the maximum allowable limit during any run-in step, return to the previous step and continue the run-in. If blowby does **not** reach an acceptable level, discontinue the run-in and determine the cause.

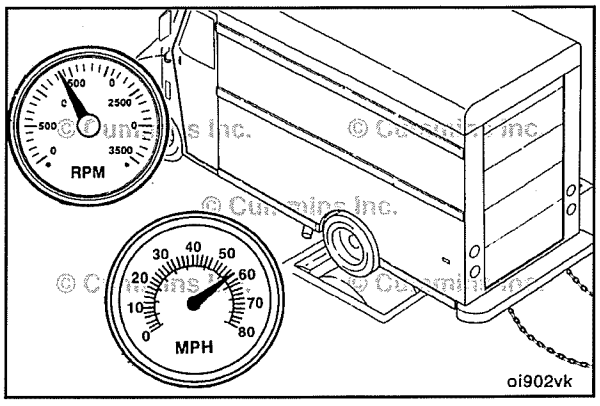
Engine Run-in (Chassis Dynamometer) (014-003)

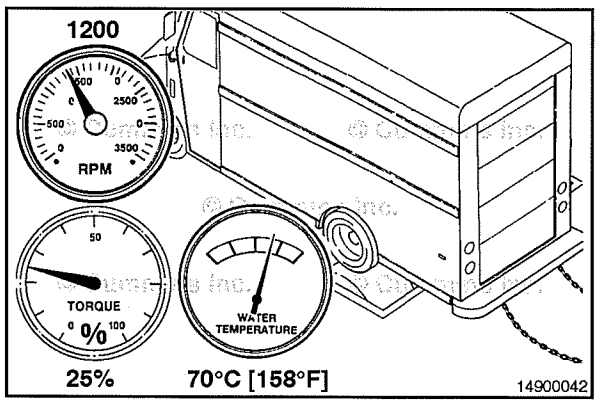
General Information

See the following procedure for general chassis dynamometer, operating/testing procedures, and safety precautions. Refer to Procedure 014-002 in Section 14.

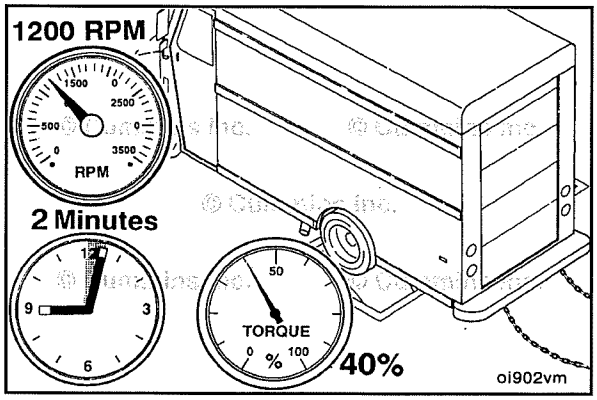
Test

Operate the vehicle in a gear that produces a road speed of 90 to 95 km/h [56 to 59 mph].

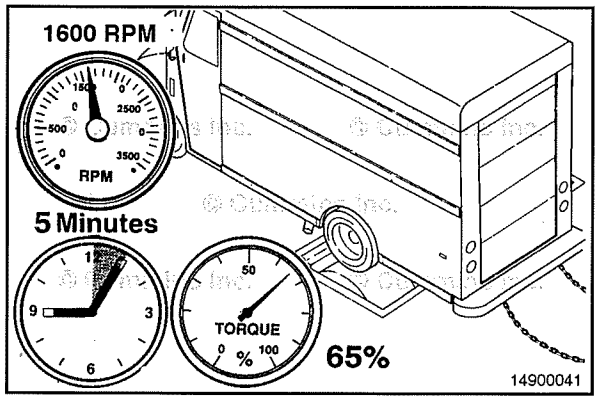




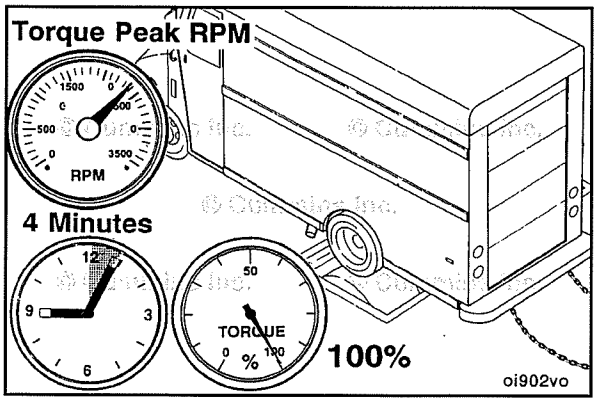
Operate the engine at 1200 rpm and 25 percent of torque peak load until the water temperature reaches 70°C [158°F].



Operate the engine at 1200 rpm and 40 percent of torque peak load for 2 minutes. Check the gauges, and record the readings.



Operate the engine at 1600 rpm and 65 percent of torque peak load for 5 minutes. Check the gauges, and record the readings.

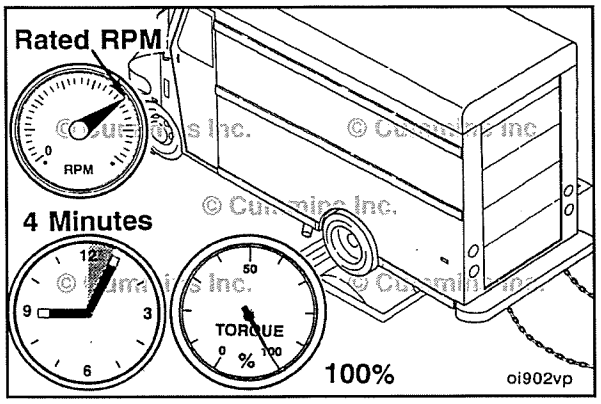


Operate the engine at torque peak rpm and full load for 4 minutes. Check the gauges and record the readings.

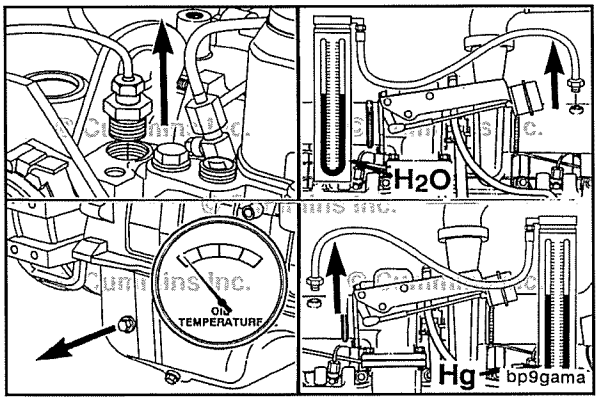
NOTE: Refer to the engine data sheet for the torque peak rpm of the engine model being tested.

⚠CAUTION⚠
Do not shut off the engine immediately after the run-in is completed. Allow the engine to cool by operating it at low idle for a minimum of 3 minutes to avoid engine component damage.

Operate the engine at rated speed (rpm) and full load for 4 minutes. Check the gauges, and record the readings. Compare the readings to those published on the appropriate engine data sheet.



Make sure all instrumentation is removed before removing the vehicle from the dynamometer.



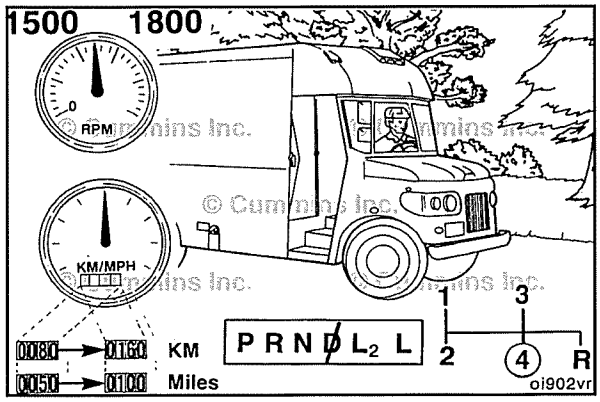
Engine Run-in (Without Dynamometer) (014-004)

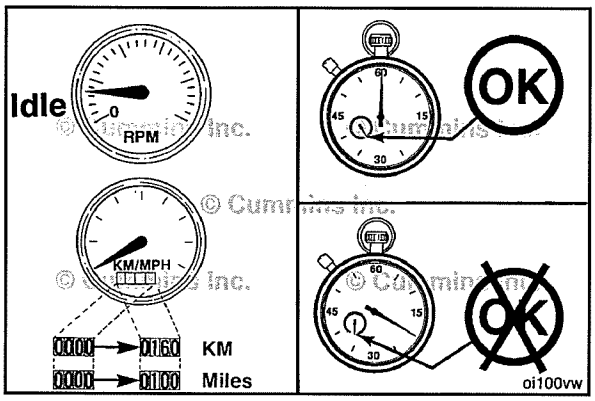
General Information

For general operating/testing procedures and safety precautions. Refer to Procedure 014-002 in Section 14.

Test

Operate the engine at 1500 to 1800 rpm in high gear for the first 80 to 160 km [50 to 99 mi] after rebuild.





NOTE: Do **not** idle the engine for more than 5 minutes at any one time during the first 160 km [99 mi] of operation.

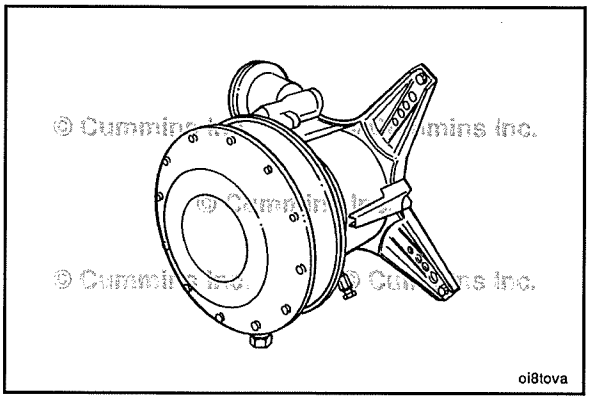
Engine Testing (Engine Dynamometer) (014-005)

General Information

This procedure describes general guidelines for setting an engine up for operation on an engine dynamometer for:

- Engine Testing
- Engine Run-in.

Reference the following for the engine run-in procedure using an engine dynamometer. Refer to Procedure 014-006 in Section 14.



Setup

Use engine lifting fixture, Part Number 3822512, to remove the engine from the chassis. Refer to Procedure 000-001 in Section 0.

Install the engine to the test stand.

Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

Make sure the dynamometer capacity is sufficient to permit testing at 100 percent of the engine's rated horsepower. If the capacity is **not** enough, the testing procedure **must** be modified to the restrictions of the dynamometer.

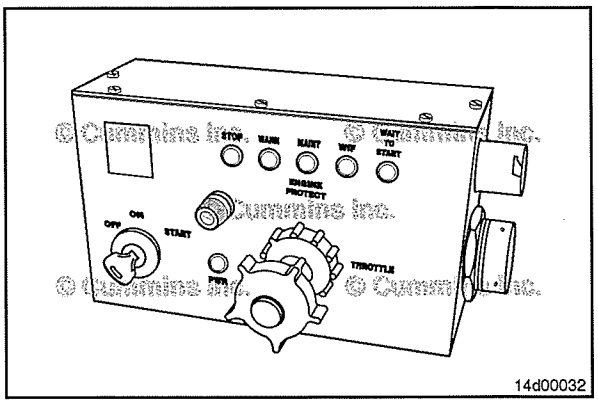
Verify the fuel supply tanks are filled with a known good quality number 2 diesel fuel.

NOTE: Number 1 diesel fuels, along with most other alternate fuels, are lighter (lower specific gravity, higher API gravity) than number 2 diesel fuel. The lighter the fuel, the lower the energy content (BTU) per liter [gallon].

Connect the engine control box, Part Number 3163890 or equivalent, to the engine control module (ECM).

The engine control box simulates the engine being installed in a vehicle by providing accelerator control, keyswitch, and other various switched inputs.

NOTE: A control box is **not** available for engines equipped with aftertreatment.

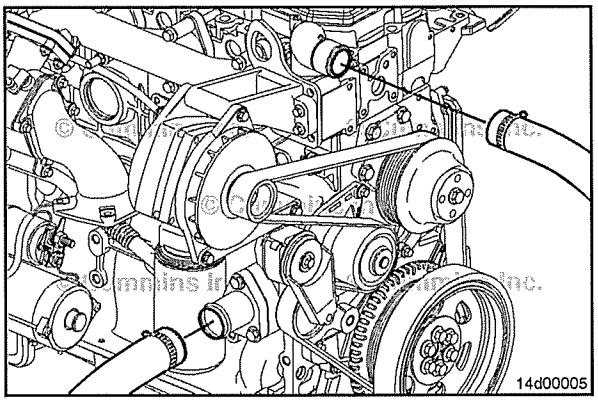


Connect the coolant supply to the coolant inlet connection (1).

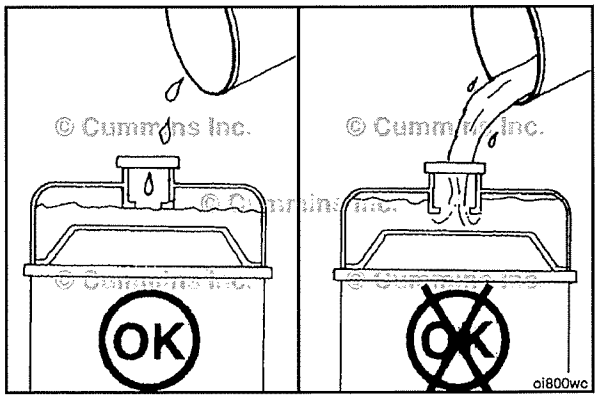
Connect the coolant return to the coolant outlet connection (2).

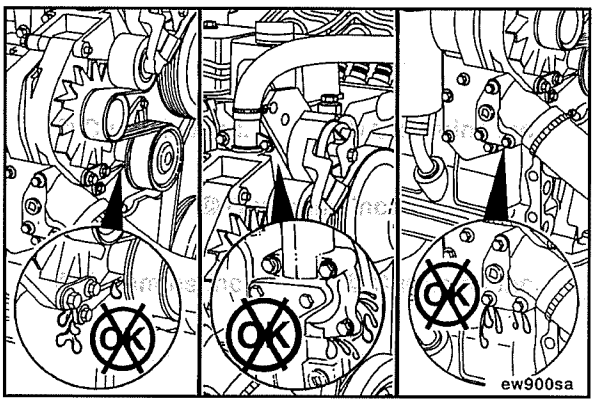
Install the drain plugs and close all the coolant draincocks.

Make sure all the clamps and fittings are tight.



Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill (or expansion) tank. Refer to Procedure 008-018 in Section 8.





Inspect the engine for coolant leaks at connections, fitting, plates, and plugs. Repair as needed. Reference Section 8 in this manual if any leaks are found.

To monitor engine performance correctly, record the following parameters. To limit dynamometer operating time, instrument the engine or use INSITE™ electronic service tool to make as many checks as possible.

Record the following common monitor parameters during the test.

Record any additional parameters if troubleshooting a specific problem.

Service Tip: for the INSITE™ electronic service tool monitored parameter, use the INSITE™ electronic service tool Data-Logging feature for recording the values during the test.

Tasks INSITE™ can monitor (but **not** limited to):

- Engine speed (RPM)
- Vehicle speed
- Intake manifold air temperature
- Intake manifold air pressure
- Engine coolant temperature
- Fuel rail pressure (Commanded and Actual).

If equipped:

- Ambient air temperature
- Ambient (Barometric) pressure
- Crankcase pressure.

Tasks requiring separate tools and/or gauges:

- Engine fuel temperature (if needed to correct fuel rate)
- Fuel inlet restriction. Refer to Procedure 006-020 in Section 6.
- Fuel drain line restriction. Refer to Procedure 006-012 in Section 6.
- Fuel rate. Refer to manufacturer's instructions
- Intake air restriction. Refer to Procedure 010-031
- Exhaust restriction. Refer to Procedure 011-009 in Section 11.
- Engine oil pressure. Refer to Procedure 007-037 in Section 7.
- Coolant pressure. Refer to Procedure 008-020 in Section 8.

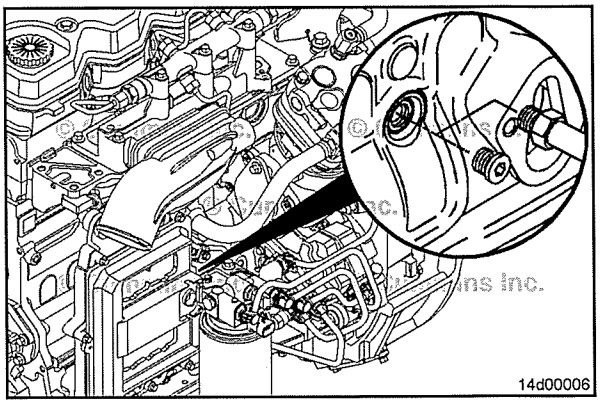
⚠CAUTION⚠

The lubricating oil system must be primed before operating the engine after it has been rebuilt to avoid internal damage.

Priming the Lubricating System:

Remove the plug.

To prime the system using external pressure, connect the supply to a tapped hole in the main oil rifle.

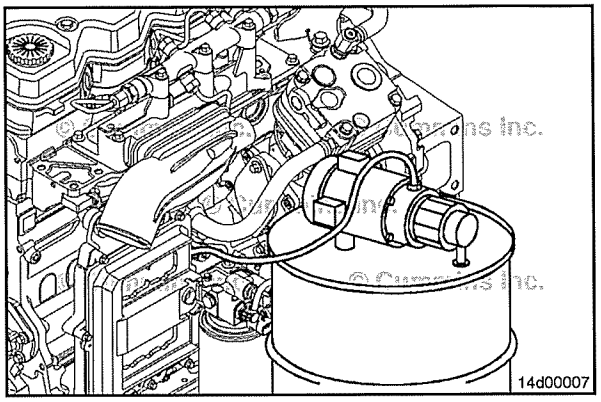


Use a pump capable of supplying 210 kPa [31 psi] of continuous pressure. Connect the pump to the port on the main oil rifle as shown.

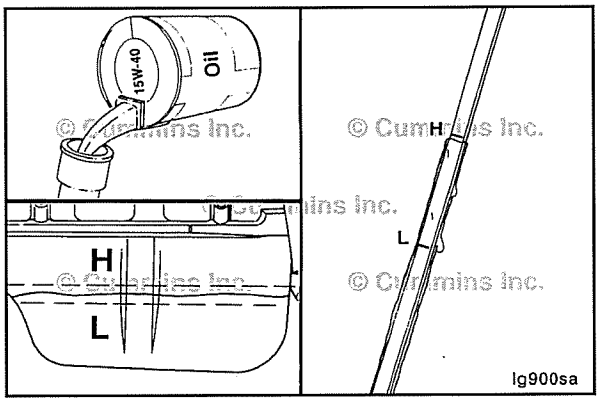
Use clean 15W-40 oil to prime the system until the oil pressure registers on the gauge.

Remove the oil supply tube and install the plug.

Tighten the plug.

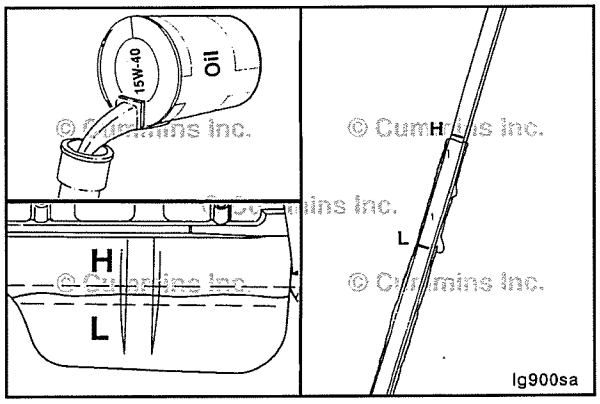


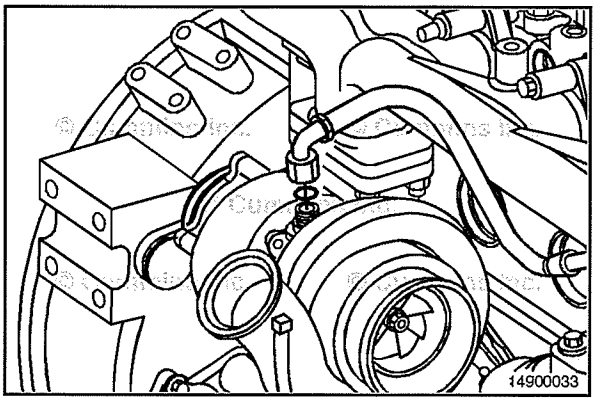
Make sure the lubricating oil has had time to drain to the oil pan and fill the engine to the high mark as measured on the dipstick.



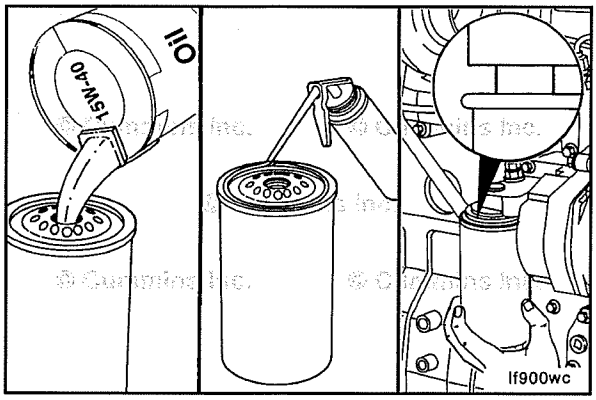
If an external pressure pump is **not** available, prime the lubricating system according to the following procedure:

- Fill the engine with clean 15W-40 oil to the high mark on the dipstick.



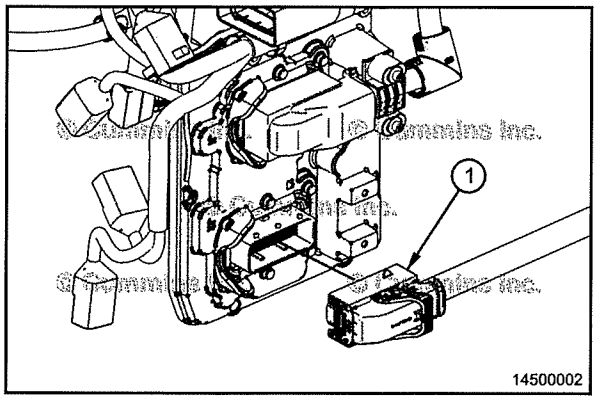


- Disconnect the turbocharger lubricating oil supply tube. Refer to Procedure 010-046 in Section 10.
- Pour 50 to 60 cc [2 to 3 fl oz] of clean 15W-40 oil into the turbocharger oil supply hole.
- Connect the oil supply tube to the turbocharger.

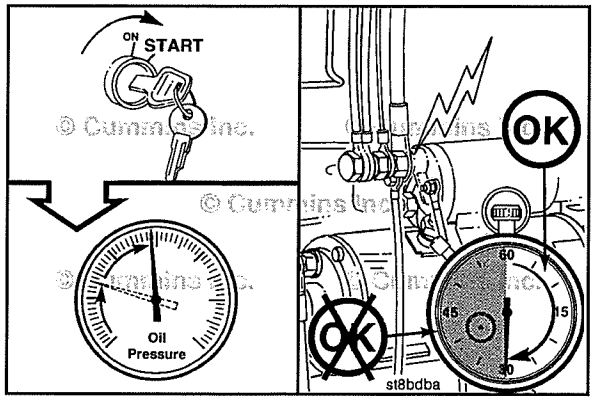


⚠CAUTION⚠
Mechanical overtightening can distort the threads or damage the filter element seal.

- Fill the lubricating oil filters with clean 15W-40 oil.
- Screw the filters onto the filter head until the gasket contacts the filter head surface.
- Tighten the filter as specified by the manufacturer.



Disconnect the 96-pin original equipment manufacturer (OEM) connector (1) from the ECM to prevent the engine from starting.



⚠CAUTION⚠
Do not crank the starter motor for periods longer than 30 seconds. Excessive heat will damage the starter motor.

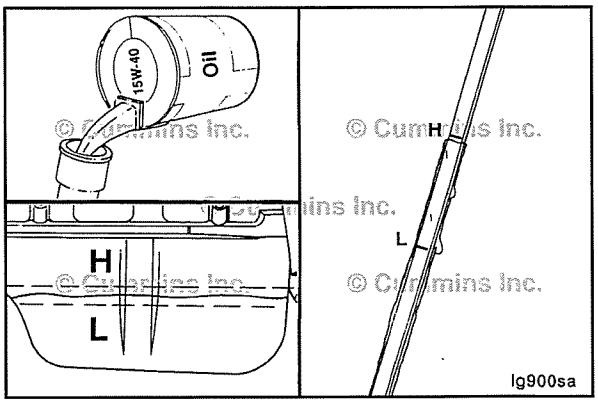
- Crank the engine until the oil pressure gauge indicates system pressure.
- Connect the 4-pin power connector to the ECM.
- Connect the 96-pin OEM connector to the ECM.

NOTE: Allow 2 minutes between the 30-second cranking periods so the starter motor can cool.

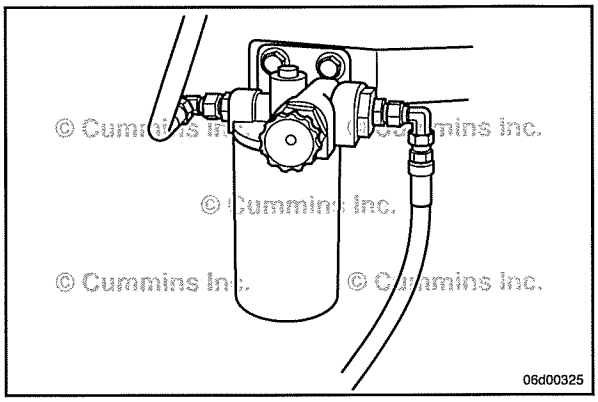
NOTE: If pressure is **not** indicated, find and correct the problem before continuing.

Allow the oil to drain into the oil pan, and measure the oil level with the dipstick.

Add oil, as necessary, to bring the level to the high level mark on the dipstick.



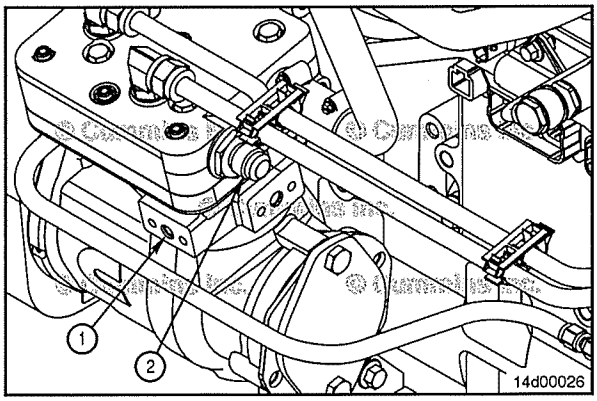
Prime the fuel system. Refer to Procedure 006-015 in Section 6.



To be able to unload the compressor, connect a source of compressed air to the air governor port (1). This air line **must** contain a valve between the source and the unloader.

NOTE: All air compressors manufactured by Cummins Inc. **must** be loaded during engine run-in. All air compressors **must** be unloaded during the engine performance check.

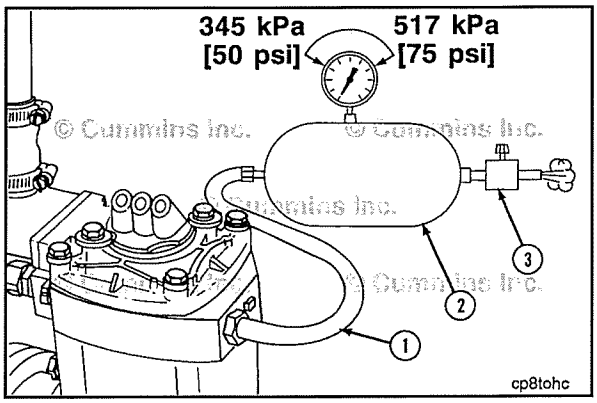
NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).

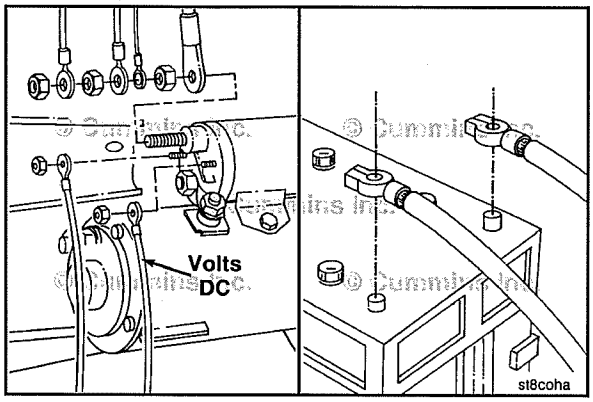


To provide a load on the air compressor, connect an air tank (2) to the compressor outlet, use steel tubing or a high-temperature hose (1).

Install an air regulator (3) that can maintain tank air pressure of 245 to 517 kPa [50 to 75 psi] at both the minimum and the maximum engine rpm.

Hose Temperature (Minimum) 260 °C [500 °F]





Inspect the voltage rating on the starter motor before installing the electrical wiring.

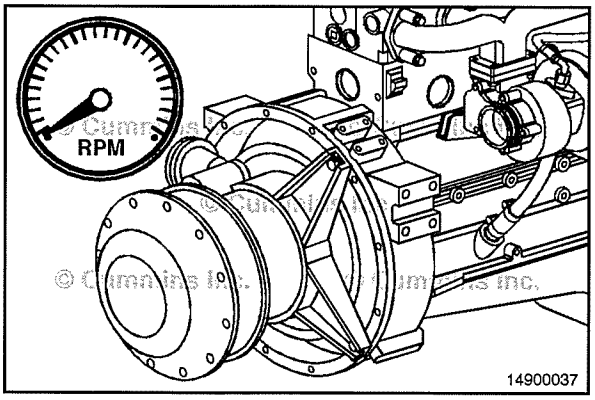
Attach electrical wires to the starter motor and the batteries, if used, negative (-) cable last. Refer to OEM instructions.

NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.

Engine Run-in (Engine Dynamometer) (014-006)

General Information

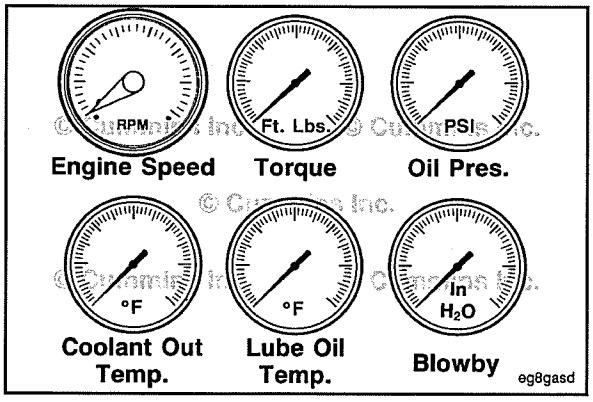
For general engine dynamometer, operating/testing procedures and safety precautions. Refer to Procedure 014-005 in Section 14.



Run-In Instructions

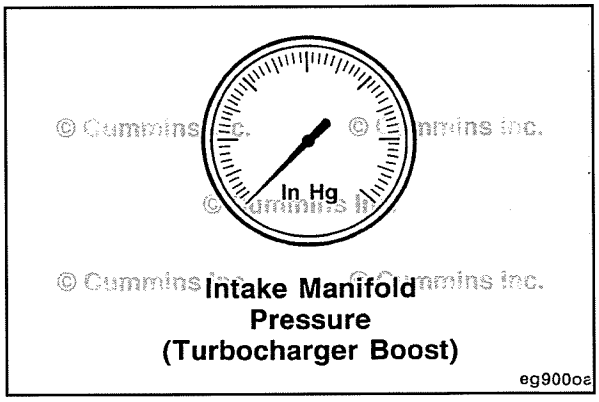
The engine run-in period allows the tester to detect assembly errors and to make final adjustments needed for performance that meets specifications.

NOTE: The amount of time specified for the following engine run-in phases are minimums. Additional time can be used, if desired, at each phase except engine idle periods.

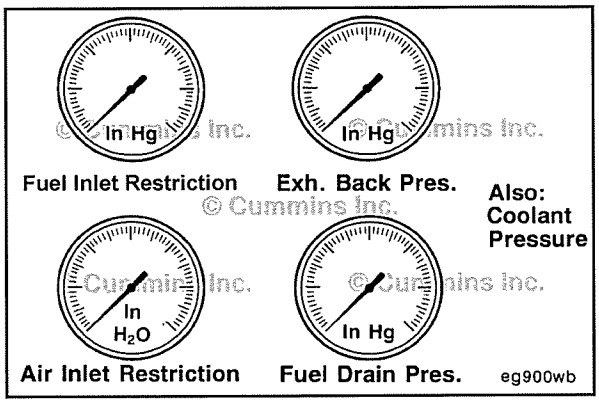


Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period. Refer to Procedure 014-005 in Section 14.

To evaluate engine performance correctly, this additional measurement **must** be observed during engine run-in phases.

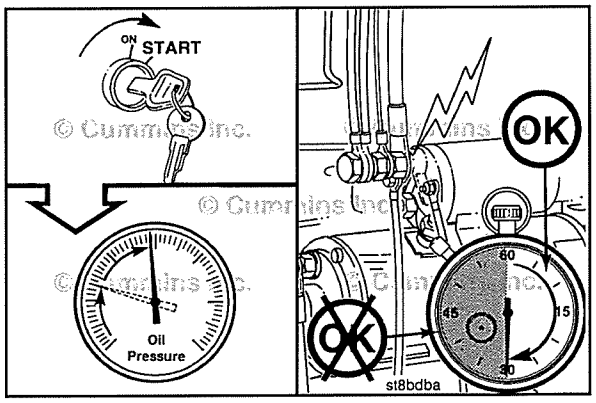


It is good practice to observe these measurements even if engine performance meets specifications. If engine performance does **not** meet specifications, these measurements can indicate possible reasons for under performance.



⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starter motor.

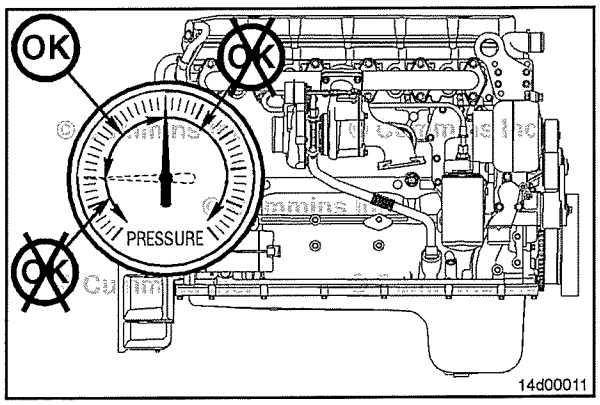
Crank the engine and observe the lubricating oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starter motor to cool for 2 minutes before cranking the engine again.

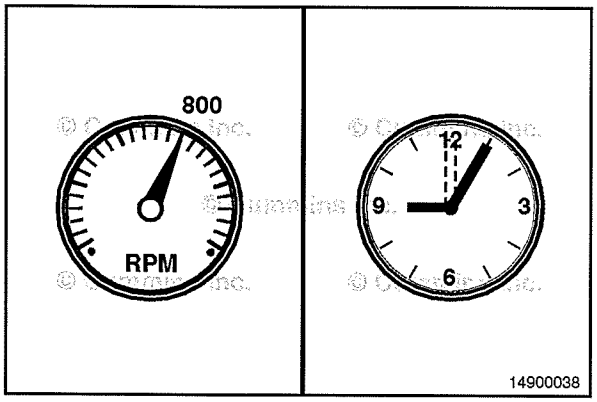


⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage.

Engine lubricating oil pressure **must** be at least 69 kPa [10 psi] at 700 rpm.

Correct the problem if the lubricating oil pressure is **not** within specifications.

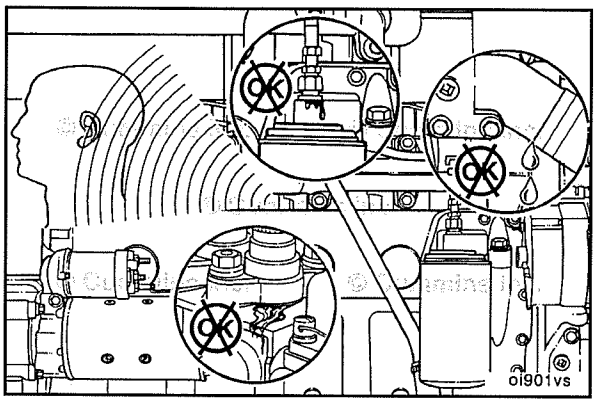




⚠CAUTION⚠

Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will cause damage to the engine.

Operate the engine at approximately 800 rpm for 3 to 5 minutes.

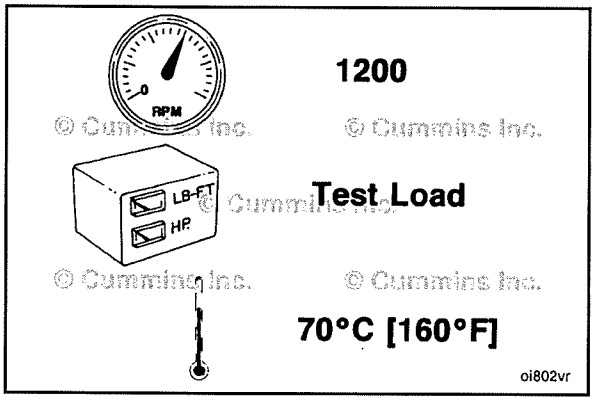


NOTE: Repair all leaks or component problems before continuing the engine run-in.

Listen for unusual noises.

Watch for coolant, fuel, and lubricating oil leaks.

Check for correct engine operation in general.

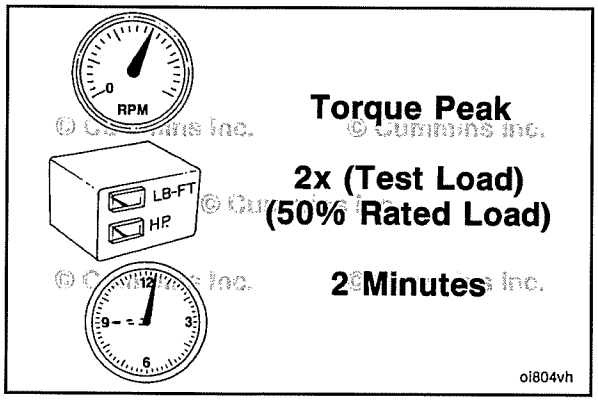


Move the throttle to obtain 1200 rpm engine speed, and set the test load to 25 percent of the rated load.

Operate the engine at this speed and load level until the coolant temperature is 70°C [158°F].

Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until a steady blowby reading is obtained.



Adjust the throttle to obtain peak torque rpm, and adjust the dynamometer load to 50 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes.

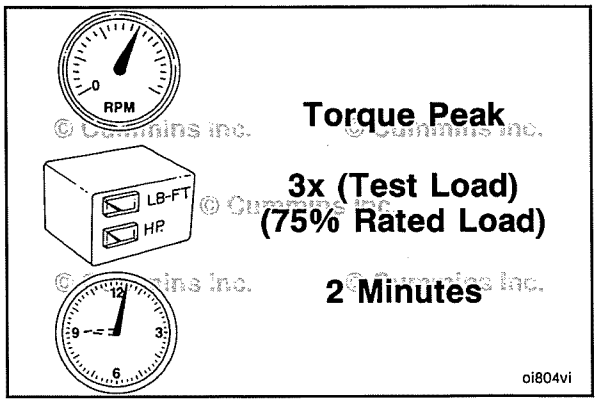
Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable within specifications.

With the engine speed remaining at torque peak rpm, increase the dynamometer load to 75 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes.

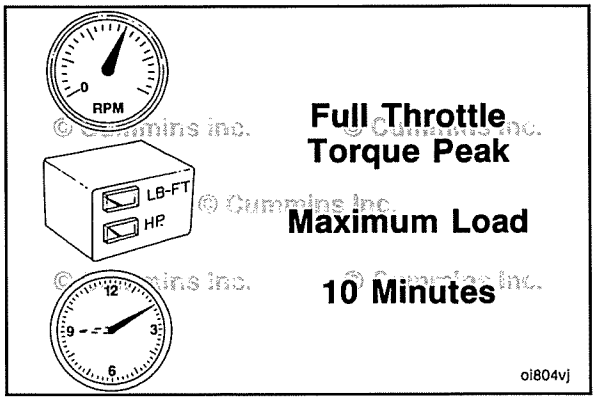
Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable within specifications.



Move the throttle lever to its fully opened position, and increase the dynamometer load until the engine speed is at torque peak rpm. Operate the engine at this speed and load level for 10 minutes or until the blowby becomes stable within specifications.

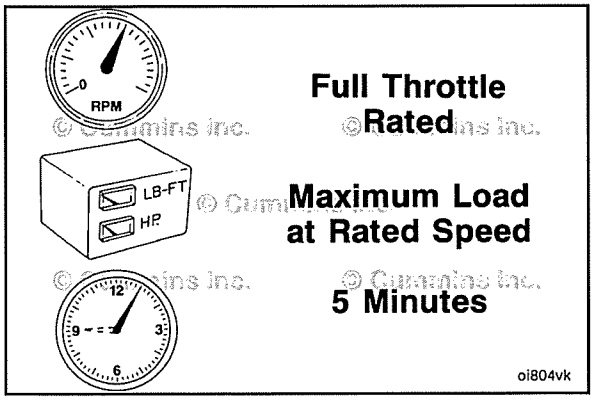
Check all gauges and record the data.



Reduce the dynamometer load until the engine speed increases to the engine's rated rpm.

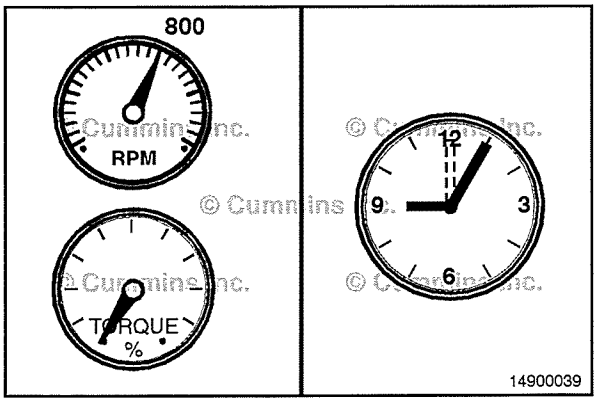
Operate the engine at rated rpm for 5 minutes.

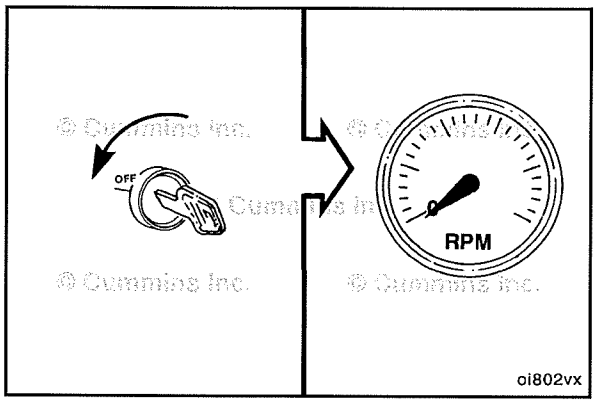
Check all gauges and record the data.



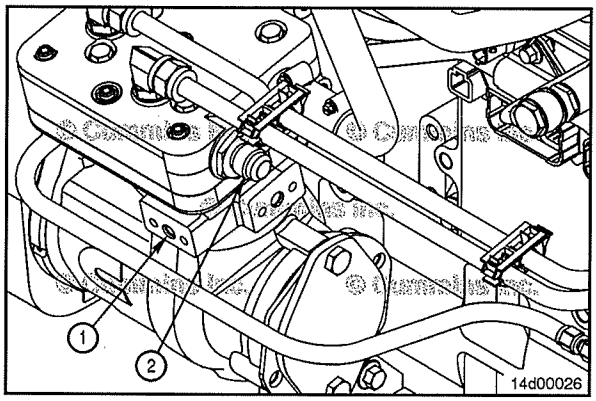
⚠CAUTION⚠
Shutting off the engine immediately after operating at full load will damage the turbocharger and internal components. Always allow the engine to cool before shutting it off.

Remove the dynamometer load completely, and operate the engine at 800 rpm for 3 to 5 minutes. This period will allow the turbocharger and other components to cool.





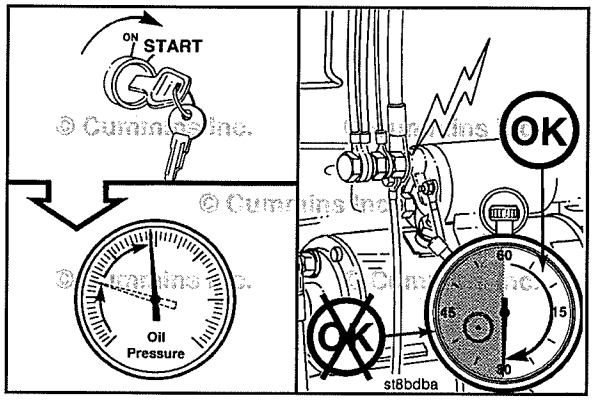
Shut off the engine.



Engine Dynamometer Test - Performance Check

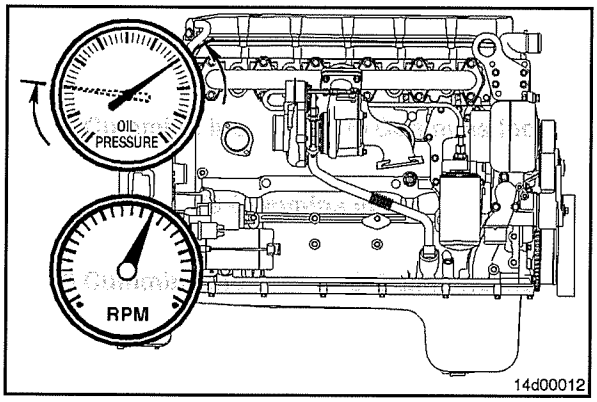
Make sure the air compressor will be unloaded during the performance check.

Apply regulated air pressure of 655 kPa [95 psi] to the air compressor unloader (1).



⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starter motor.

Crank the engine and observe the oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starter motor to cool for 2 minutes before cranking the engine again.



⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage. Correct the problem if lubricating oil pressure is not within specifications.

Engine lubricating oil pressure **must** be at least 69 kPa [10 psi] at approximately 700 rpm.

Make sure the engine is at operating temperature (71.1°C [160°F] minimum coolant temperature).

Move the throttle pedal to 100-percent throttle. Adjust the dynamometer load until the engine maintains the rated rpm.

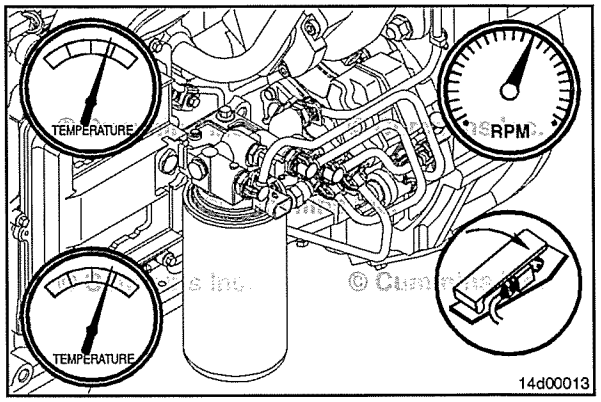
Allow the readings to stabilize. Read the horsepower.

NOTE: The horsepower reading will **not** be accurate if the lubricating oil temperature and fuel temperature are **not** within specifications.

Lubricating Oil Temperature		
°C		**°F**
90	MIN	194

Fuel Temperature		
°C		**°F**
32	MAX	90

Check all gauges and record the data.



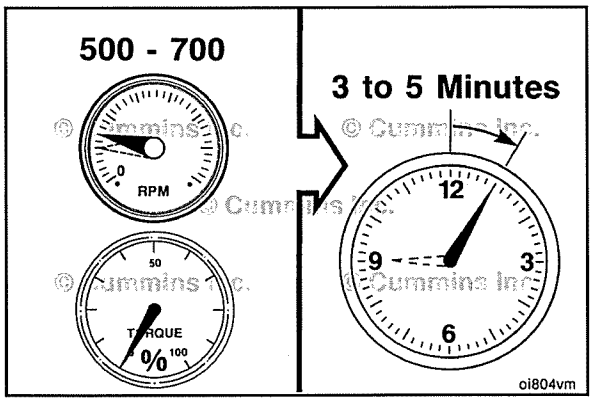
⚠CAUTION⚠
Do not shut off the engine immediately after it has been loaded. It must be allowed to cool sufficiently.

Move the throttle lever to its fully opened position, and increase the dynamometer load until the engine speed is at torque peak rpm. Allow the readings to stabilize. Read the torque. Check all of the gauges and record the readings.

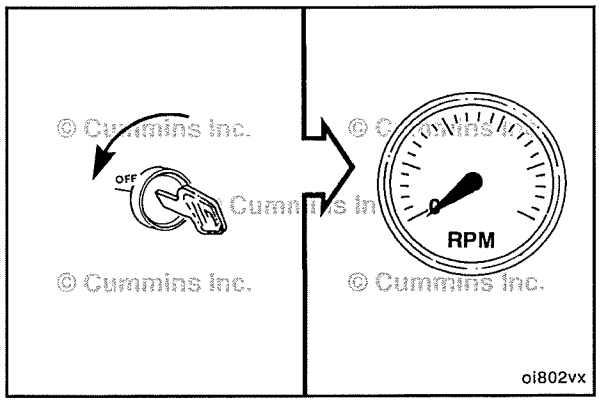
Remove the dynamometer load completely.

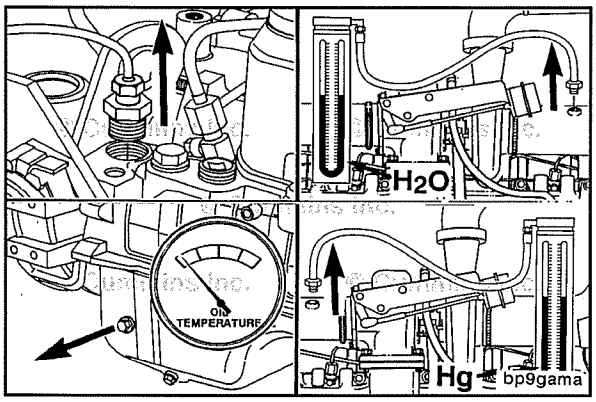
Operate the engine at idle speed for 3 to 5 minutes. This will allow the turbocharger and other components to cool.

NOTE: Idle periods longer than 5 minutes are to be avoided.



Shut off the engine after the cool down period.

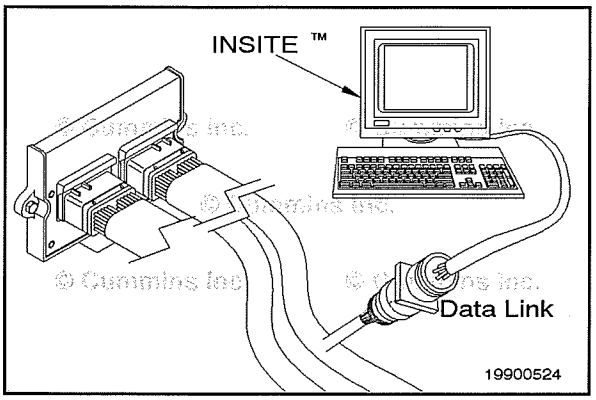




Remove all test instrumentation.

Remove the engine from the dynamometer.

NOTE: If the engine is to be stored temporarily and does **not** have permanent-type antifreeze, it is necessary to drain all coolant.



Engine Testing (In Chassis) (014-008)

Setup

The setup for dynamometer function is used to prepare the attached engine control module (ECM) for advanced diagnostic tests that are run on the dynamometer. For purposes of this test, the maximum engine speed without vehicle speed sensor (VSS), the maximum vehicle speed in top gear, and the maximum vehicle speed in lower gear are set to their maximum values. The idle shutdown feature is disabled. All of these values are automatically reset to their previous values when the engine keyswitch is in the OFF position.

Settings:

Maximum Engine Speed without VSS: For testing purposes, this speed is temporarily set to the maximum value allowed (3000 rpm).

Maximum Vehicle Speed in Top Gear; For testing purposes, this speed is temporarily set to the maximum value allowed (120 mph).

Maximum Vehicle Speed in Lower Gear: For testing purposes, this speed is temporarily set to the maximum value allowed (120 mph).

Idle Shutdown: This feature is temporarily disabled for testing purposes (Disable).

Some J1939 electronic subsystems **must** be disabled. The user has the ability to enable or disable the J1939 data link with the service tool.

Reference INSITE™ electronic service tool user's manual for detailed setup for dynamometer instructions.

Automated Cylinder Performance Test

The automated cylinder performance test is the most thorough test of cylinder performance (versus the single-cylinder cutout test, which tests the performance of individual cylinders **only**). The service tool **must** be attached to an ECM to perform the test. Follow the steps outlined in Preparing to Run the Automated Cylinder Performance test, to make sure the best possible outcome is achieved.

This test is automated in the sense that, once the test is started, the service tool controls what cylinders are disabled or enabled, what ECM values are recorded, and what information displays as a result of the test. Once the test is finished, follow the steps outlined in the After Running the Automated Cylinder Performance Test to make sure the engine returns to its original state.

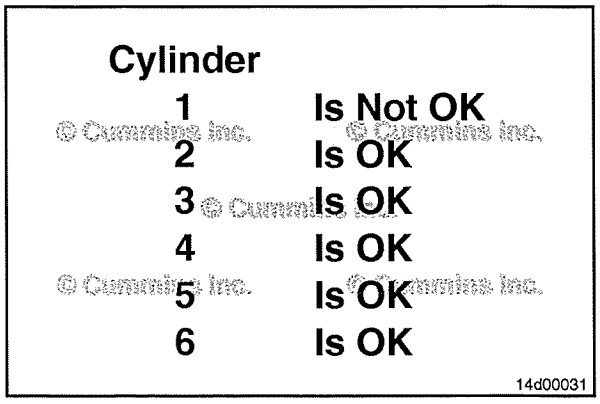
This test will produce a Pass or Fail message for each cylinder. Its percent contribution value is also displayed.

Preparing to Run the Automated Cylinder Performance Test:

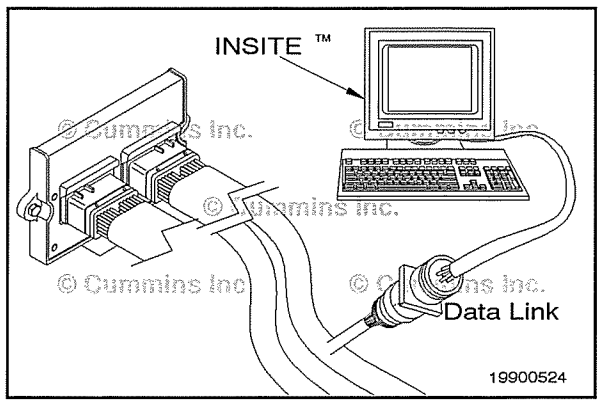
Before performing the test, make sure the following are completed:

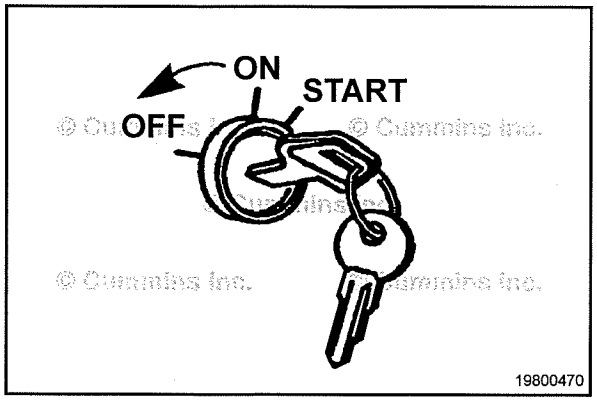
- Clear the areas around the engine and the fan, and make sure the exhaust is vented correctly.
- Operate the engine until the coolant temperature is a minimum of 76.7°C [170°F].
- Shut the engine OFF.
- Lock the fan clutch in the ON position for continuous operation.
- Shut the air conditioning OFF.
- Disengage any devices that can cause the load on the engine to vary.
- With the vehicle stationary, start the engine and let it idle.
- Start the test, use INSITE™ electronic service tool.

NOTE: The Automated Cylinder Performance Test will **not** work on some hybrid applications, as one or more of the test conditions can **not** be met.



Refer to the INSITE™ electronic service tool user's manual for detailed automated cylinder performance test instructions.



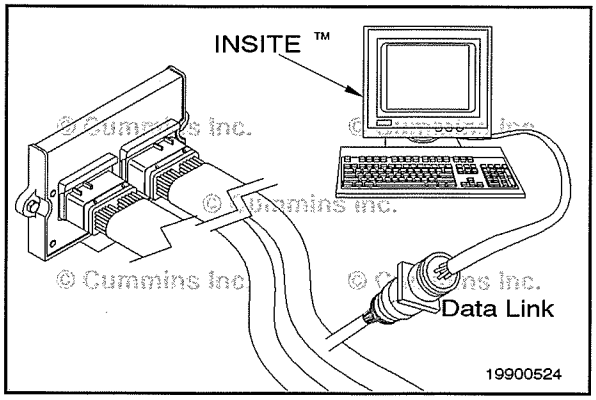


After Running the Automated Cylinder Performance Test:

It is normal for the engine rpm to vary during the test, but if the engine rpm goes to high idle for more than 5 seconds at a time, shut theengine OFF.

Once the test is complete, make sure to complete the following:

- Shut the engine OFF.
- Return the fan to normal operation, if necessary.
- Perform the suggested repairs that resulted from the test.
- Return any disengaged devices to their normal mode of operation.



Cylinder Cutout Test

Use the Single-Cylinder Cutout Test to remove individual cylinders from the engine firing cycle and to monitor a running engine while the selected cylinder is disabled. The system displays the percent load and rpm values while the cylinder is disabled.

The service tool **must** be attached to a running engine in a non-moving vehicle to perform this test.

Reference the INSITE™ electronic service tool user's manual for detailed cylinder cutout test instructions.

Cylinder to be Cut Out:

None: Select this option to run all cylinders.

1 to 6: Select one of these options to shut off cylinder number 1 through number 6, respectively. **Only** one cylinder can be shut off at a time.

Monitor:

Percent Load: The percent of load that the engine is carrying.

rpm: The engine's revolutions per minute.

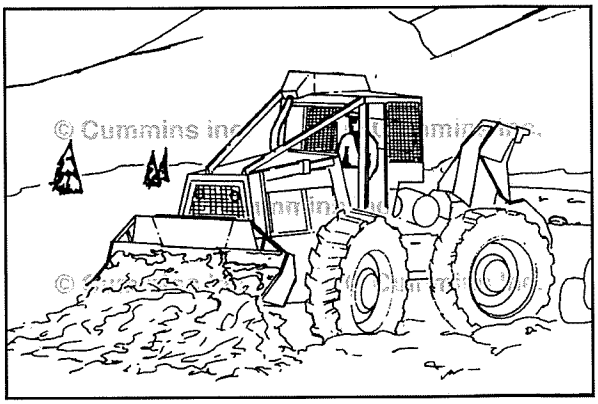
Turbocharger Actuator Test:

Use the turbocharger actuator test to verify the correct functioning of the variable geometry turbocharger actuator.

The INSITE™ electronic service tool **must** be attached to an ECM to perform this test.

Reference the INSITE™ electronic service tool user's manual for detailed turbocharger actuator test instructions.

Stall Speed Check

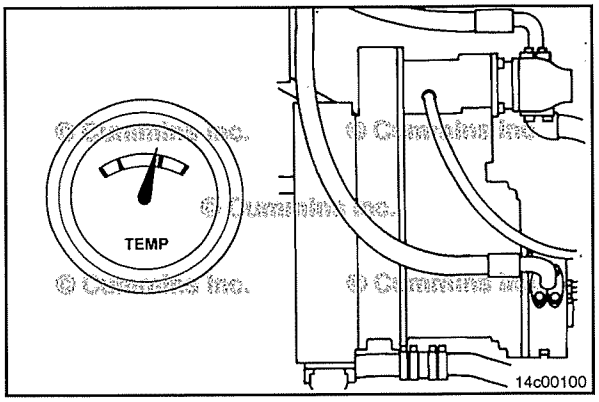


Converter Transmission's Stall Speed:

The stall speed is the engine speed (rpm) obtained at full throttle when the converter output shaft is locked.

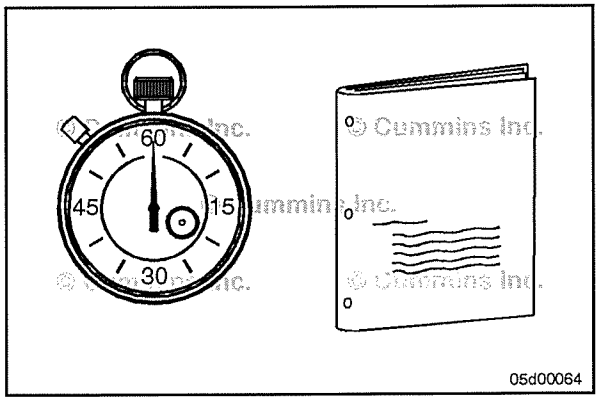
NOTE: It is possible that the vehicle brakes will **not** hold an electronically controlled transmission.

⚠CAUTION⚠
Do not exceed 120°C [248°F] converter oil temperature. Overheating can result and converter damage can occur. If the oil temperature exceeds 120°C [248°F], put the transmission in neutral, and operate the engine until the oil temperature is below 120°C [248°F]. Check the converter oil level.

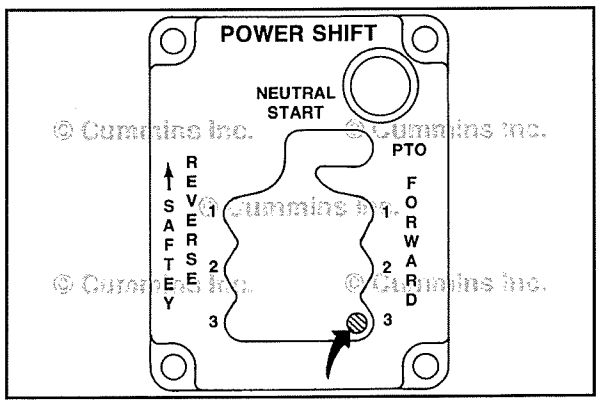


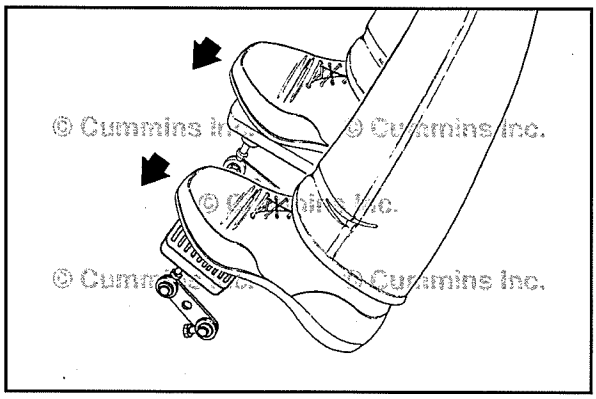
The following equipment is needed for this check:

- Stopwatch
- Equipment manufacturer's stall speed and time-to-stall specifications.



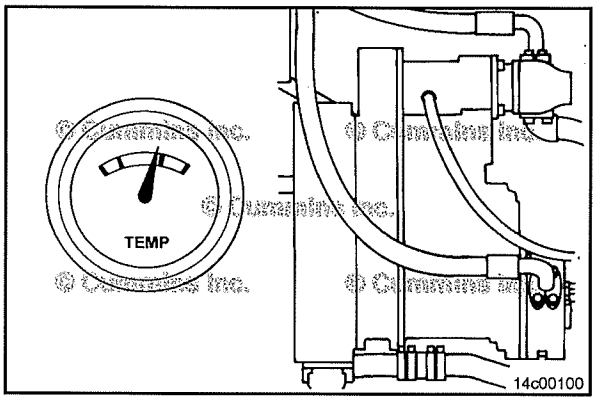
Place the gear selector in the highest gear or full forward.



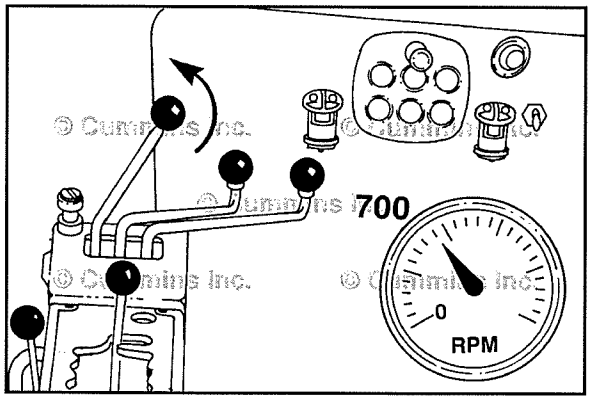


Make sure the vehicle has good brakes and air pressure in the brake system.

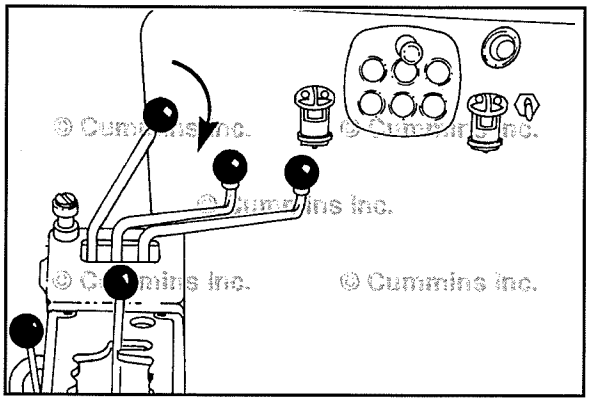
NOTE: The brakes **must** prevent the vehicle from moving when the engine is at full throttle. Engage the vehicle brakes to keep the vehicle from moving.



Operate the engine until the converter oil temperature is 80°C [176°F] or above.



Bring the engine speed back to low idle.

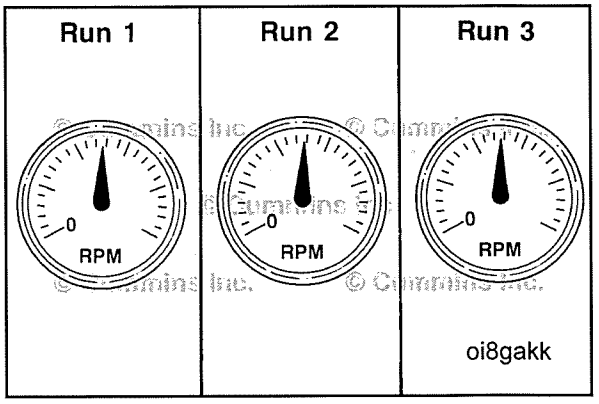


⚠CAUTION⚠
Do not exceed 120°C [248°F] converter oil temperature. Overheating and damage to the converter can occur.

Quickly move the throttle to the full-open position with the vehicle brakes applied.

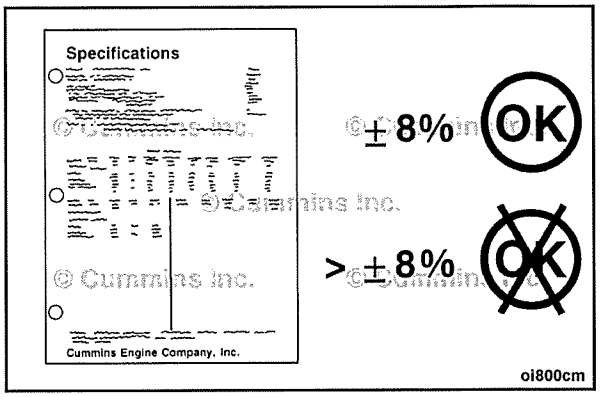
Check the engine speed (rpm) at the point of stall:

- **Always** hold the speed until it is stable.
- Take several readings.
- Make sure the readings are accurate.



Check the speed (rpm) against the specifications for the equipment, converter, or automatic transmission.

NOTE: The stall speed for the engine and converter/ transmission can vary ± 8 percent from the manufacturer's specifications.



If the stall speed is **not** within the specifications, reference the Stall Speed Checklist in this procedure.

Check the equipment manufacturer's troubleshooting procedures for other reasons for stall speed problems.

STALL SPEED CHECK LIST

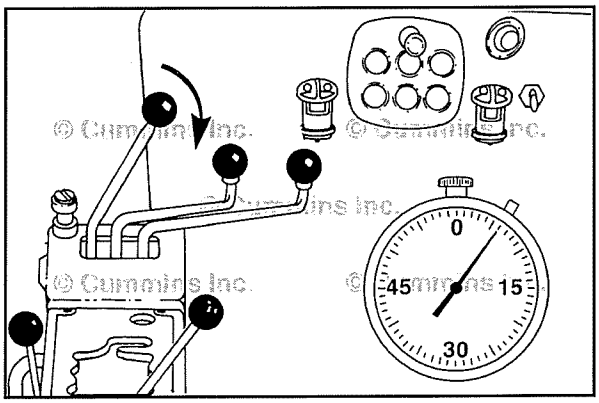
IF THE STALL SPEED IS TOO LOW, CHECK THE FOLLOWING:

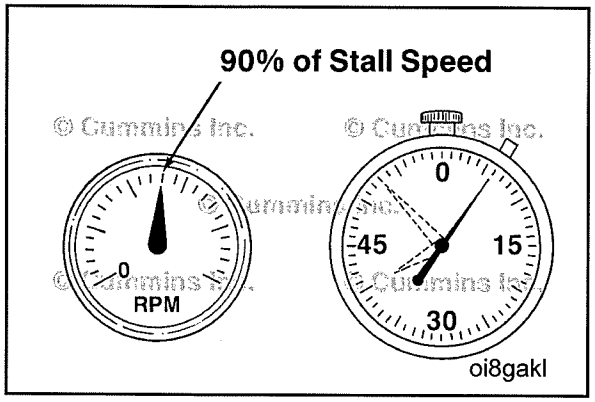
	Yes	No	
1.	. . .	. . .	The tachometer is in error.
2.	. . .	. . .	The engine is up to or above 70°C [160°F].
3.	. . .	. . .	The converter oil is up to temperature 80°C [180°F] minimum.
4.	. . .	. . .	The stall has been held long enough for the engine to accelerate to full power.
5.	. . .	. . .	The match curve stall speed was recorded correctly.
6.	. . .	. . .	The converter oil is to the converter manufacturer's recommendation. (SAE 30 instead of SAE 10 for instance.)
7.	. . .	. . .	The engine driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize compressors, etc. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.	. . .	. . .	The AFC (Air Fuel Control) is propery adjusted.
9.	. . .	. . .	The unit is operating at an altitude high enough to affect the engine power.
10.	. . .	. . .	The converter charging pressure is correct.
11.	. . .	. . .	The tailshaft governor is interfering with and preventing a full throttle opening. (Disconnect the tailshaft governor.)
12.	. . .	. . .	The converter blading is interfering or in a stage of failure. Check the sump or filter for metal particles.
13.	. . .	. . .	The converter stators are free-wheeling instead of locking up.
14.	. . .	. . .	The engine is set for power other than that specified on the power curve.

Time Speed Check

Perform the previous Stall Speed Check procedure through the "Bring the engine speed back to low idle" step, then complete the following:

- Quickly move the throttle to the full-open position, and start the stopwatch at the same time.

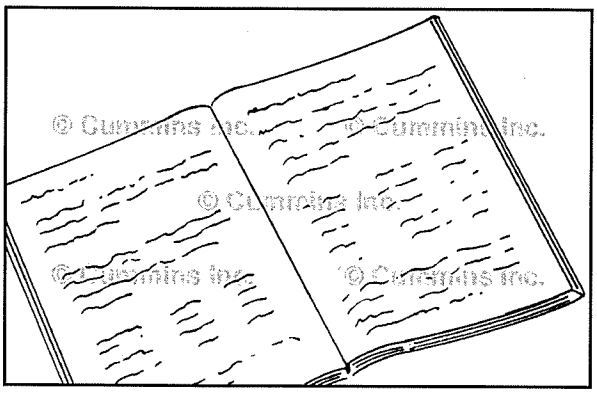




- When the engine speed is 90 percent of the stall speed rpm, stop the stopwatch.

Example: Stall speed 2089 [2089 x 0.90 = 1880 rpm].

NOTE: The type of unit and the stall speed rpm can make the stall speed time a maximum of 10 seconds.



Check the equipment manufacturer's specifications for the time to stall or the acceleration time.

If the time is excessive, refer to the Stall Speed Checklist in this procedure.

Stall Speed Checklist

Stall Speed Too Low

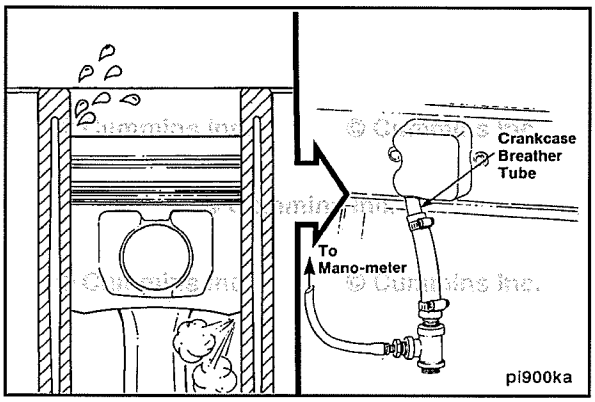
	Yes	No	
1.			The tachometer is in error.
2.			Engine temperature is up to or above 70°C [158°F].
3.			The converter oil is up to temperature 80°C [176°F].
4.			The stall has been held long enough for the engine to accelerate to full-power.
5.			The match curve stall speed was recorded correctly.
6.			The converter oil is to the converter manufacturer's recommendation (SAE 30 instead of SAE 10, for instance).
7.			The engine-driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversized compressors, and so on. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.			The unit is operating at an altitude high enough to affect the engine's power.
9.			The converter charging pressure is correct.
10.			The tailshaft governor is interfering with and preventing a full-throttle opening. Disconnect the tailshaft governor. Do **not** exceed the manufacturer's maximum output speed.
11.			The converter blading is interfering or in a stage of failure. Check the sump or filter for particles.
12.			The converter stators are free-wheeling instead of locking up.
13.			The engine is set for power other than that specified on the power curve.
14.			The converter is wrong due to improper build or rebuild of unit.
15.			The converter is performing to the published absorption curve.
16.			The engine and converter match is correct. Check the engine and converter models for the proper match.

	Yes	No	
17.			The engine is matched to too large of a converter. If this condition is believed to exist, please report the engine-converter-accessory information to the factory.
18.			The engine power is down. The engine torque rise could be less than shown on the standard engine curve. See the fuel setting adjustments and the turbocharger air manifold pressure check.

Stall Speed Too High

	Yes	No	
1.			The engine is high in power.
2.			The tachometer is in error.
3.			The accessory power requirements are less than 10 percent of the gross engine power.
4.			The converter oil is aerating or foaming. Check for low oil level, air leaks in suction line, lack of foam inhibitor in the oil, or suction screen or filter. It would be accompanied by a noticeable loss of machine performance.
5.			The converter is being held at full-stall. Check for slipping front disconnect clutch or a rotating output shaft. On the converter-transmission package, this can be impossible to check.
6.			The converter turbine element is beginning to fail and lose blades, or the converter was originally built with the wrong size element.
7.			The engine and converter match is correct due to a revision in the engine rating or the converter performance.
8.			If the oil level is too high on the transmission-converter units with the oil sump in the transmission, it can cause severe aeration due to parts dipping into the oil.
9.			The converter is performing to the published absorption curve.
10.			The converter charging pressure is correct.

The reasons for abnormal stall speeds listed above are some that have been encountered by Cummins Inc. representatives and probably do **not** include all possible causes. The correction of the problem is either covered in the vehicle service manual, the converter service manual, or is self-explanatory.



Crankcase Blowby, Measure (014-010)

General Information

Excessive crankcase blowby can indicate an engine or engine-related component malfunction that allows combustion gases or air to enter the crankcase. This results in the buildup of higher than normal crankcase pressure, which results in increased levels of blowby.

This procedure describes how to measure crankcase blowby and how to determine what component is malfunctioning.

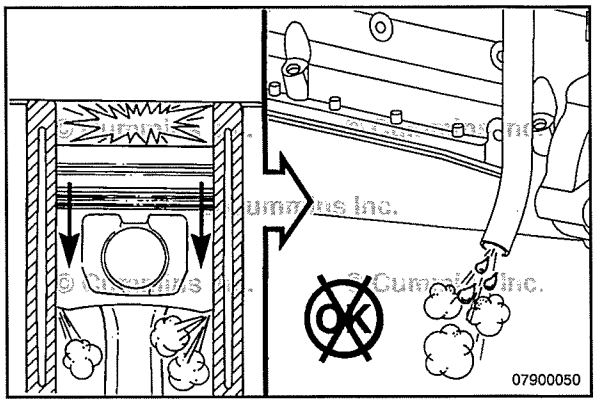
Blowby is typically measured for the following situations:

- Verifying engine break-in after an engine rebuild
- Troubleshooting for excessive lubricating oil out of the crankcase breather tube, commonly referred to as oil carryover (for open crankcase ventilation systems)
- Troubleshooting oil in the air intake system (for closed crankcase ventilation systems)
- Troubleshooting high crankcase pressure (for engines equipped with a crankcase pressure sensor)
- Troubleshooting possible internal engine damage (worn piston rings, valve stem seals, or guides, turbocharger, air compressor, etc.).

NOTE: For specific crankcase gases (blowby) symptom information and direction, reference the Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS of the appropriate engine service manual.

The following measure step will give general guidelines for measuring blowby relative to the above situations.

NOTE: Some illustrations in this procedure do **not** show actual engine configurations. However, the procedure is the same.



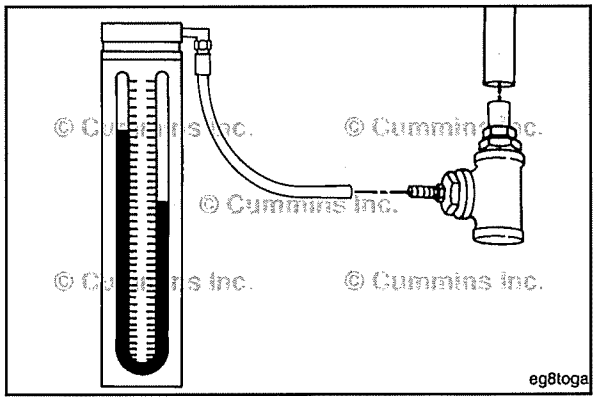
It is important to note that the terms blowby and carryover (oil out of the breather tube) are commonly used interchangeably.

When measuring blowby, and there is an excessive amount of oil coming out of the breather tube, the quantity of oil can affect the blowby measurement.

The blowby measurement is affected by the oil collecting on the orifice of the blowby measurement service tool. This reduces the size of the orifice, which results in higher than actual blowby measurements.

If this occurs, it will be necessary to:

- Find a different location on the engine to measure blowby (oil fill, oil fill cap, unused turbocharger drain location, etc.)
- Clean any oil residue from the breather and dry thoroughly before measuring blowby
- Determine if there is an issue causing the breather to be flooded with oil, for example:
- Incorrect oil level
- Vehicle operation (excessive angularity, excessive engine side-to-side movement)
- Internal engine components deflecting oil toward the breather cavity (piston cooling nozzles, accessory oil drains, etc.)
- Determine if another breather option is available for the engine being serviced.



The tools used to measure blowby are similar in design. The difference between the tools is in the size of the orifice. Different size orifices are available to more accurately measure blowby by accommodating the wide variety of engine configurations and ratings. This is due to the fact that engine blowby is dependent on the volume of intake airflow.

For example:

If measuring blowby on two identically configured and sized engines, but the horsepower ratings and rated speed are different, the maximum blowby values measured will be different.

The engine with the higher horsepower rating and rated speed will have a higher volume of intake airflow, which will result in higher blowby. This means that if the smaller orifice blowby tool was used on the engine with a higher horsepower rating and rated speed, the measurement can exceed the limits of the pressure measuring tool.

Blowby Tool Part Number	Orifice Size mm [in]
3822476	5.61 mm [0.221 in]
3822566	7.67 mm [0.302 in]

To measure the crankcase blowby pressure, connect a water manometer, Part Number ST1111-3, or equivalent, pressure gauge, or transducer to the blowby tool.

NOTE: Water manometer, Part Number ST1111-3, can measure a maximum of 944 mm [36 in] of water.

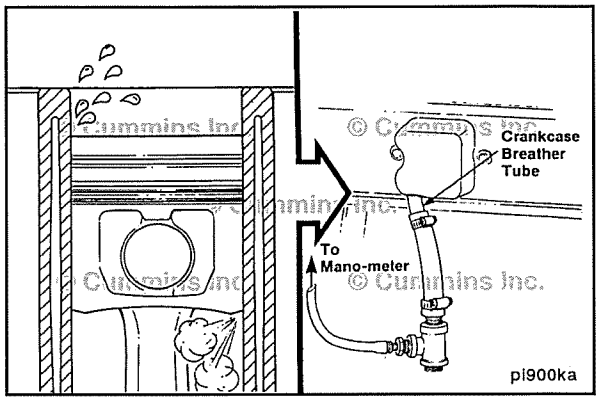
The following charts show the relationship of measured pressure to flow rate, depending on the blowby tool used.

Blowby Conversion Table (5.61-mm [0.221-in] orifice, Blowby Tool, Part Number 3822476)	
mm [in] of H_2O	Liter [cfm] per Minute
25.4 [1]	27 [0.953]
50.8 [2]	40 [1.413]
76.2 [3]	48 [1.695]
101.6 [4]	58 [2.048]
127 [5]	64 [2.260]
152.4 [6]	71 [2.507]
177.8 [7]	76 [2.684]
203.2 [8]	81 [2.860]
228.6 [9]	86 [3.037]
254 [10]	90 [3.178]
279.4 [11]	94 [3.320]
304.8 [12]	98 [3.461]
330.2 [13]	102 [3.602]
355.6 [14]	105 [3.708]
381 [15]	109 [3.849]
406.4 [16]	112 [3.955]
431.8 [17]	115 [4.061]
457.2 [18]	118 [4.167]
482.6 [19]	121 [4.723]
508 [20]	124 [4.379]
533.4 [21]	128 [4.520]
558.2 [22]	131 [4.626]
584.2 [23]	135 [4.767]
609.6 [24]	137 [4.838]
635 [25]	140 [4.944]
660.4 [26]	144 [5.085]
685.8 [27]	147 [5.191]
711.2 [28]	150 [5.297]
736.6 [29]	154 [5.438]
762 [30]	157 [5.544]
787.4 [31]	160 [5.650]
812.8 [32]	163 [5.756]
838.2 [33]	166 [5.862]
863.6 [34]	169 [5.968]
889 [35]	172 [6.074]

Blowby Conversion Table (7.67-mm [0.302-in] orifice, Blowby Tool, Part Number 3822566)	
mm [in] of H_2O	Liter [cfm] per Minute
25.4 [1]	50 [1.766]
50.8 [2]	84 [2.966]
76.2 [3]	103 [3.637]
101.6 [4]	119 [4.202]
127 [5]	133 [4.697]
152.4 [6]	145 [5.121]
177.8 [7]	155 [5.474]
203.2 [8]	164 [5.792]

Blowby Conversion Table (7.67-mm [0.302-in] orifice, Blowby Tool, Part Number 3822566)	
mm [in] of H_2O	Liter [cfm] per Minute
228.6 [9]	172 [6.074]
254 [10]	180 [6.357]
279.4 [11]	187 [6.604]
304.8 [12]	193 [6.816]
330.2 [13]	200 [7.063]
355.6 [14]	206 [7.275]
381 [15]	211 [7.451]
406.4 [16]	217 [7.663]
431.8 [17]	222 [7.840]
457.2 [18]	226 [7.981]
482.6 [19]	229 [8.087]
508 [20]	235 [8.299]
533.4 [21]	239 [8.440]
558.8 [22]	242 [8.546]
584.2 [23]	246 [8.687]
609.6 [24]	248 [8.758]

The following chart contains general blowby specifications for MidRange engines. Due to the wide variety of engine types, configurations, and ratings, these specifications are intended to **only** be used as a guide to help identify if a problem exists. These specifications are **not** intended to be used as engine condemnation limits.

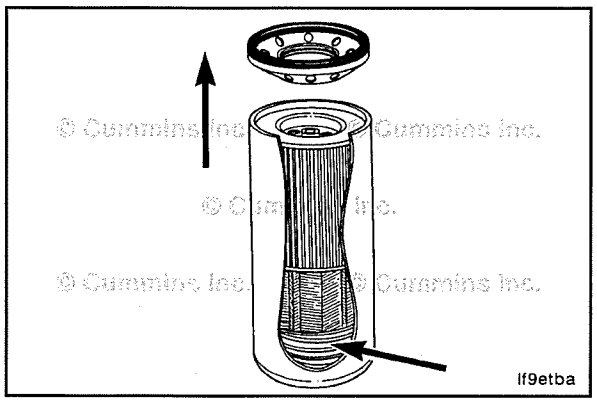


NOTE: If internal engine damage is suspected to be the cause of the excessive blowby condition, other steps can be taken to confirm this.

Measuring blowby **must only** be considered when confirming engine break-in after a rebuild or if another symptom is present. These symptoms can include:

- Excessive carryover (oil out of the crankcase breather tube)
- High crankcase pressure (for engines equipped with a crankcase pressure sensor)
- Low power
- Oil consumption
- Exhaust smoke.

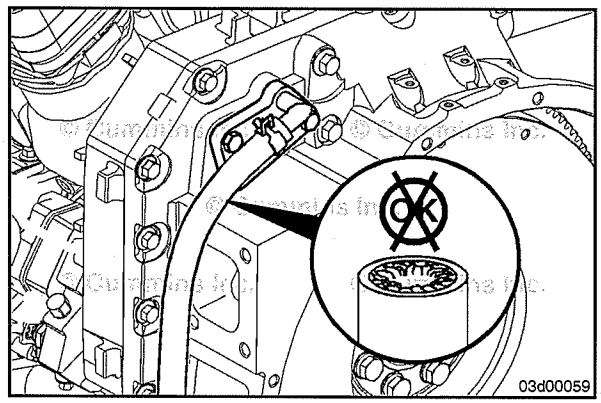
If no other symptom is present, blowby measurements need **not** be taken.



If internal engine damage is suspected to be the cause of the excessive blowby condition, other steps can be taken to confirm this. The steps include:

- Confirm engine maintenance practices
- Cut the oil filter open and check for debris
- Take an oil sample and inspect for contamination.

MidRange Blowby Specifications Chart				
	Blowby Specification For New or Rebuild - mm [in] H_2O		Blowby Specification For Troubleshooting - mm [in] H_2O	
Engine Model	Blowby Tool 3822476-5.61 mm [0.221 in] Orifice	Blowby Tool 3822566-7.67 mm [0.302 in] Orifice	Blowby Tool 3822476-5.61 mm [0.221 in] Orifice	Blowby Tool 3822566-7.67 mm [0.302 in] Orifice
A1400 and A1700 (Naturally Aspirated)	25.4 [1]		25.4 [1]	
A2000 and A2300 (Naturally Aspirated)	25.4 [1]		38.1 [1.5]	
A2000 and A2300 (Turbocharged)	38.1 [1.5]		50.8 [2]	
ISF2.8	147.3 [5.8]		711.2 [28]	
ISF3.8		71.1 [2.8]		254 [10]
B3.3 Tier 1, 2		50.8 [2]		101.6 [4]
B3.3, QSB3.3 Tier 3		101.6 [4]		152.04 [6]
B3.3, QSB3.3 Tier 4 Interim (Less than 74 HP)		50.8 [2]		101.6 [4]
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Naturally Aspirated) (Less than 250 hp)	25.4 [1]		76.2 [3]	
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Turbocharged) (Less than 250 hp)	101.6 [4]		431.8 [17]	
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Turbocharged) (Greater than 250 hp)		25.4 [1]		127 [5]
B5.9 (Naturally Aspirated)	50.8 [2]			
B5.9, and QSB5.9-30, (Less than 250 hp)	228 .6 [9]		863.6 [34]	
B5.9, and QSB5.9-30, (Greater than 250 hp)		50.8 [2]		228.6 [9]
ISB, ISB^{e}, QSB^{e}, ISD^{e}, QSB5.9-44, ISB6.7, and QSB6.7		101.6 [4]		254 [10]
C8.3		101.6 [4]		254 [10]
ISC, ISC^{e}, QSC8.3, ISL, ISL^{e}, and QSL9		203.2 [8]		304.8 [12]
B Gas International, B Gas Plus, B LPG Plus, B5.9G, B5.9 LPG	228.6 [9]		889 [35]	
C8.3G, C Gas Plus, ISL G, L Gas Plus		203 [8]		457 [18]
ISB4.5 CM2350 B104	152.4		330.2	



Initial Check

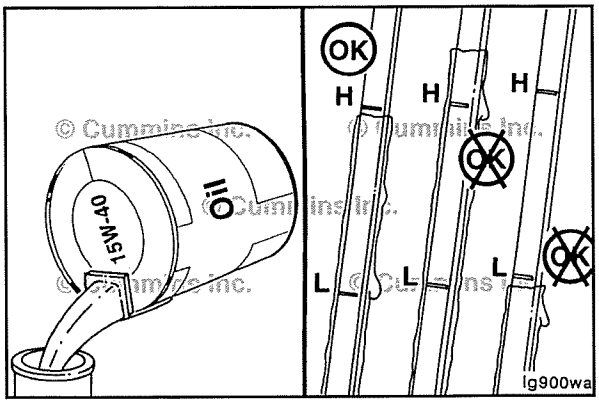
NOTE: The location and type of crankcase breathers vary by engine configuration (Front Gear Train or Rear Gear Train) and/or engine application (Marine, Industrial, and Automotive).

Prior to measuring blowby pressure, check the crankcase breather tube for obstructions.

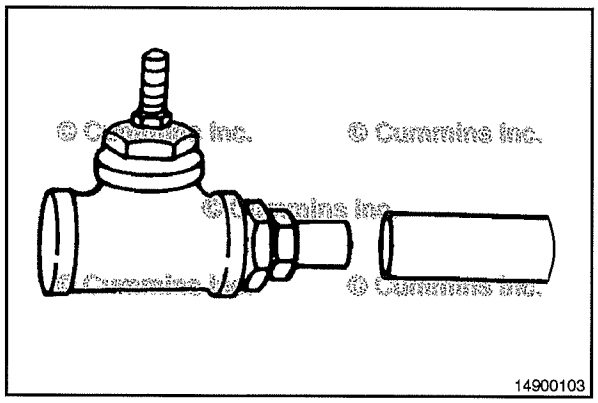
- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 003-018 in Section 3.
- Reference the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Use the following procedure for Open Crankcase Ventilation systems. Refer to Procedure 003-018 in Section 3. Use the following procedure for Closed Crankcase Ventilation systems. Refer to Procedure 003-024 in Section 3.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 003-024 in Section 3. Refer to Procedure 003-026 in Section 3.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 003-024 in Section 3.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 003-024 in Section 3.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 003-018 in Section 3.

If troubleshooting a complaint of excessive oil out of the breather tube, it can be necessary to remove the breather components to clean and remove any lubricating oil buildup before performing any blowby measurements.

Check the engine oil level and, if necessary, proper calibration of the dipstick. If the level is too high, it can cause a higher than normal blowby pressure and/or excessive carryover.



- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISFF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN, and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 007-043 in Section 7.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 007-043 in Section 7.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 007-011 in Section 7.

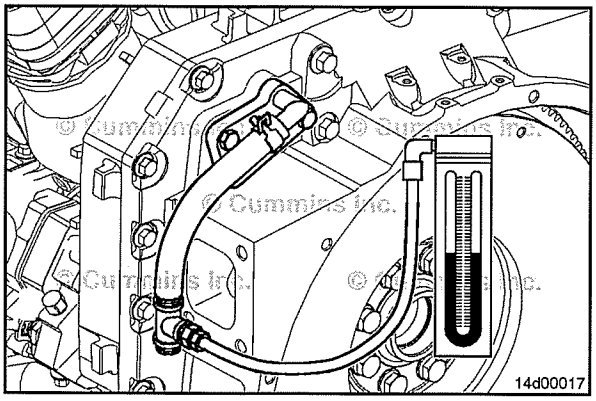


Measure

Choose the appropriate blowby measurement service tool to use for the engine being serviced. Reference the MidRange Blowby Specifications Chart in this procedure and determine the appropriate blowby measurement service tool to use, based on engine type and/or horsepower.

Blowby Tool Part Number	Orifice Size mm [in]
3822476	5.61 mm [0.221 in]
3822566	7.67 mm [0.302 in]

NOTE: Either service tool can be used to measure blowby, as long as the blowby measurement is correctly matched to the correct flow rate. Reference the flow rate conversion tables in this procedure for the correct orifice.



To measure the crankcase blowby pressure, connect a water manometer, Part Number ST1111-3, pressure gauge, or transducer to the blowby measurement service tool.

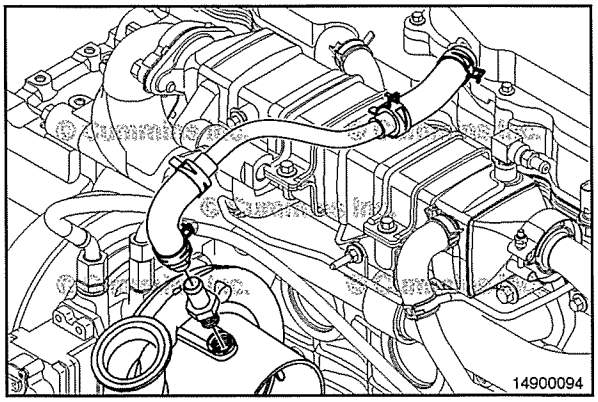
NOTE: The location of the crankcase breather tube can vary by engine configuration (front gear train or rear gear train) and/or application (Marine, Industrial, and Automotive). See Section E (Engine Identification) for crankcase breather tube locations.

Install the appropriate blowby service tool(s):

- For typical open crankcase breather/ventilation systems, connect the appropriate blowby service tool to the end of the crankcase breather tube. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.
- For engines with closed crankcase ventilation systems (without a crankcase ventilation filter), disconnect the breather tube and plug the intake manifold or turbocharger compressor housing port. Connect the appropriate blowby service tool to the end of the crankcase breather tube. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.
- For crankcase breather/ventilation systems with crankcase ventilation filters, follow the proceeding steps on connecting the blowby measurement equipment.

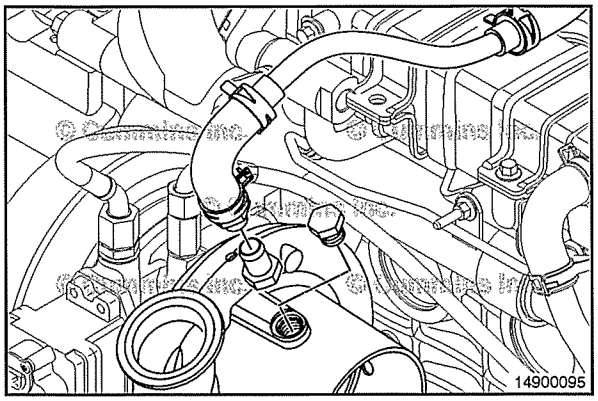
For ISB CM2150 engines that have the crankcase ventilation filter located on top of the rocker lever cover, use the following steps to connect the blowby measurement tools.

- Disconnect the crankcase ventilation line from the turbocharger/original equipment manufacturer (OEM) intake plumbing. If the crankcase ventilation line is connected to the turbocharger housing, remove the inlet fitting.

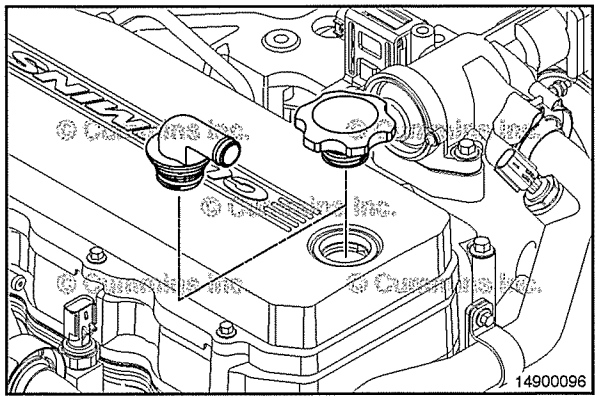


- If the crankcase ventilation line is connected to the turbocharger housing, install a straight thread plug, Part Number 3089567. Plug the crankcase ventilation line with a suitable fitting.

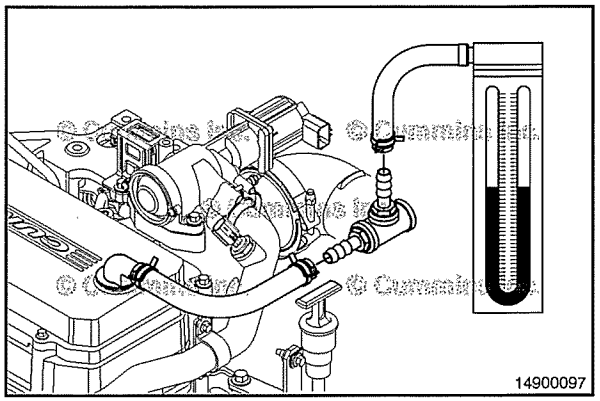
NOTE: If the crankcase ventilation line is connected to the OEM intake plumbing (**not** shown), use a suitable fitting to plug the port in the intake plumbing. Also plug the crankcase ventilation line coming from the engine with a suitable fitting.

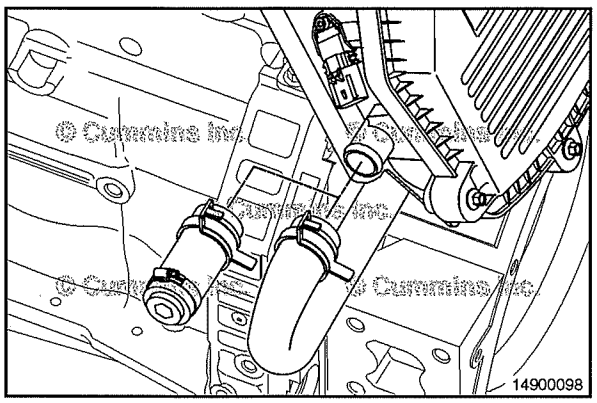


- Remove the oil fill cap from the rocker lever cover. Install an oil fill adapter, Part Number 3990099.



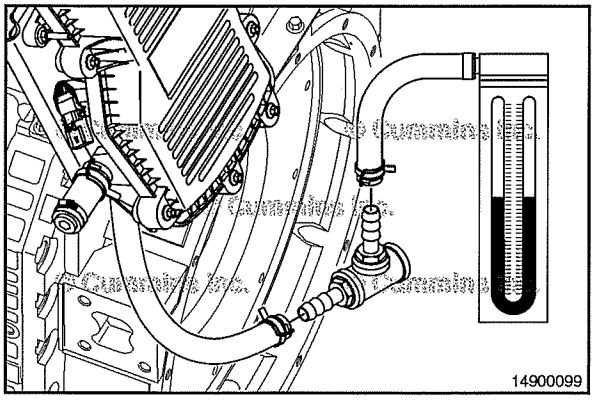
- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.



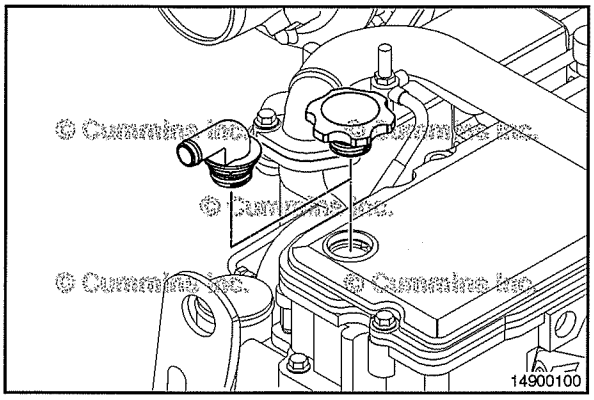


For ISB CM2150 engines that have the crankcase ventilation filter located at the rear of the engine, use the following steps to connect the blowby measurement tools.

- Disconnect the crankcase ventilation line from the crankcase ventilation filter housing. Plug or cap the crankcase ventilation filter housing.

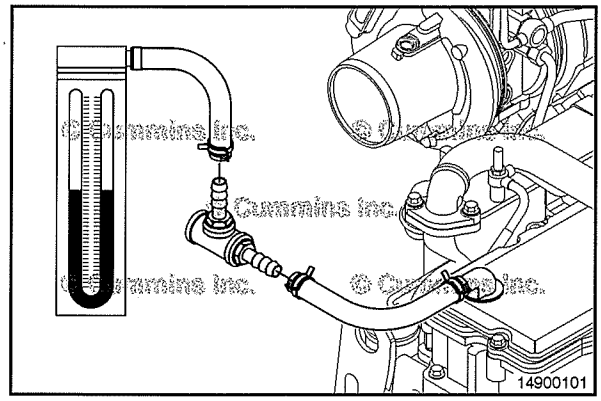


- Connect the appropriate blowby service tool to the crankcase ventilation line exiting the flywheel housing. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.



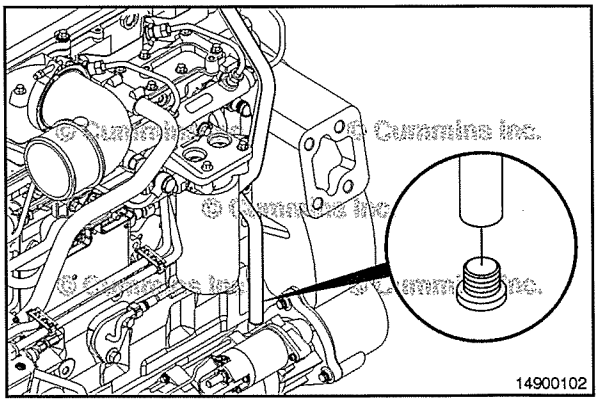
For ISC and ISL CM2150 engines, use the following steps to connect the blowby measurement tools.

- Remove the oil fill cap from the rocker lever cover. Install an oil fill adapter, Part Number 3990099.



- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.

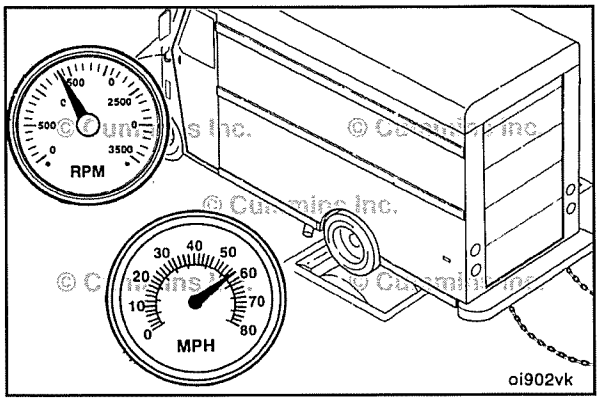
- Use a suitable fitting to plug the crankcase breather tube.



Engine Blowby Contribution:

Operate the engine at rated speed and under load by:

- For engine run-in, a chassis dynamometer or engine dynamometer.
- For engine testing, a chassis dynamometer or engine dynamometer.
- A stall speed test (for engines equipped with automatic transmissions **only**).



⚠CAUTION⚠

When measuring blowby and there is an excessive amount of oil coming out of the breather tube, the quantity of oil can affect the blowby measurement.

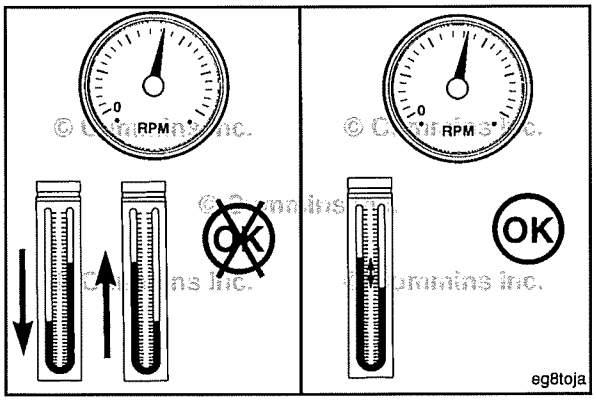
Operate the engine at rated rpm and full load until a steady reading is obtained.

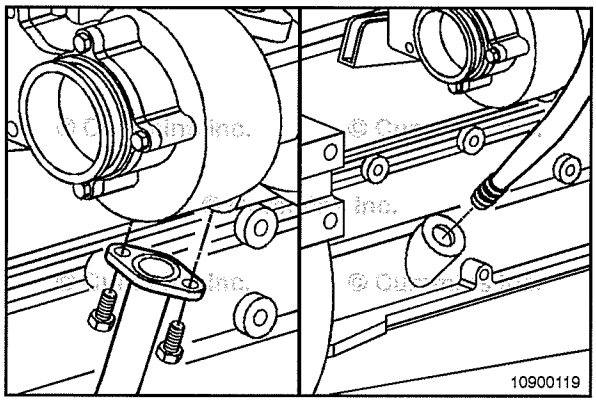
NOTE: When measuring blowby, the value can "spike" initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.

NOTE: For engine run-in, if a sudden increase in blowby occurs, or if blowby exceeds the maximum allowable limit during any run-in step, return to the previous step and continue the run-in. If blowby does **not** reach an acceptable level, discontinue the run-in and determine the cause.

Record the steady blowby measurement.

Remove the engine blowby service tool and the water manometer, pressure gauge, or transducer, if the blowby is within specification.





Turbocharger Blowby Contribution:

NOTE: For engines equipped with dual turbochargers, the Turbocharger Oil Drain Line Isolation Test may need to be conducted twice to determine which turbocharger is contributing high blowby. The first test should be conducted with both turbocharger drain lines isolated. If the blowby contribution is above specifications, conduct a second test with **only** the low pressure turbocharger oil drain line isolated. If the blowby contribution is within specification, inspect the compressor and turbine areas of the low pressure turbocharger for signs of an oil leak. Replace the low pressure turbocharger, if necessary. If the blowby contribution is out of specification, replace the high pressure turbocharger.

With the engine blowby service tool and water manometer or pressure gauge still installed:

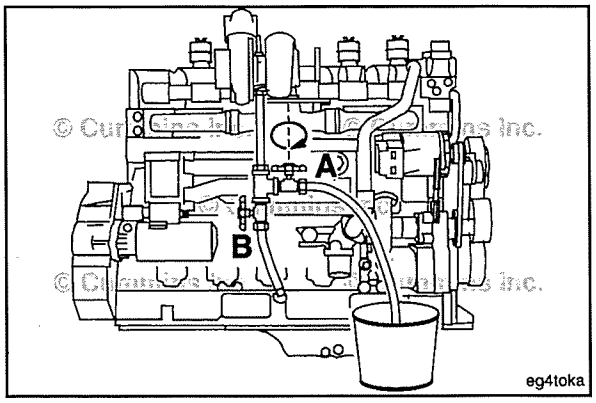
- Isolate the turbocharger, if equipped, to determine if the high blowby pressure is due to turbocharger seal leakage.
- To measure the turbocharger blowby contribution, disconnect the turbocharger oil drain line.
- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-045 in Section 10.

Preferred Turbocharger Isolation Method:

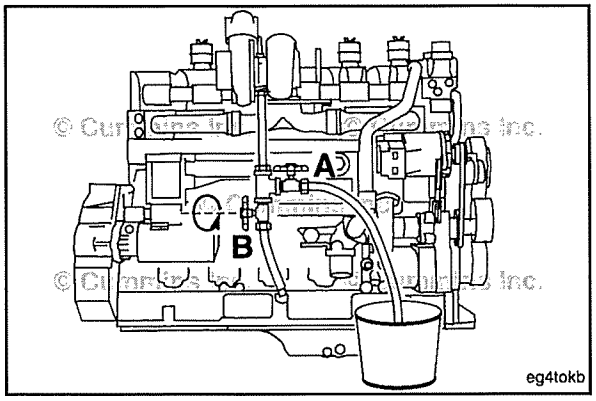
Install a hose assembly with two shutoff valves (A and B), as shown in the illustration, between the turbocharger and turbocharger drain line location in the cylinder block. The valves **must** have a minimum inside diameter of 19 mm [0.75 in]. Place the other hose in a 8 to 9 liter [2 to 3 gal] container.

NOTE: Some turbocharger oil drain tubes are a single one piece tube. It can be necessary to create a turbocharger isolation tool. Use a new or used turbocharger drain line and cut a middle section out of the turbocharger drain line to fit the check valves and hoses.

Close the valve (A) that allows oil to drain into the bucket.



Open the valve (B) that allows oil to drain into the engine.

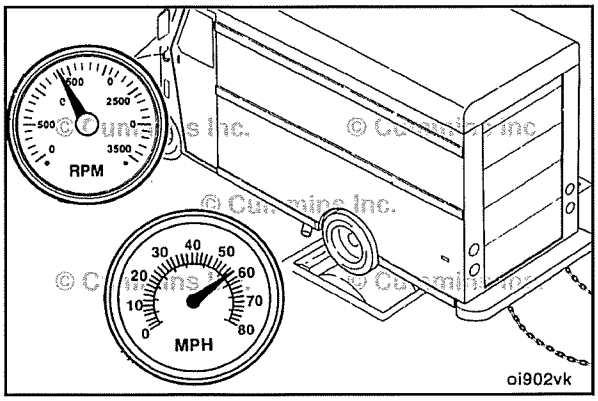


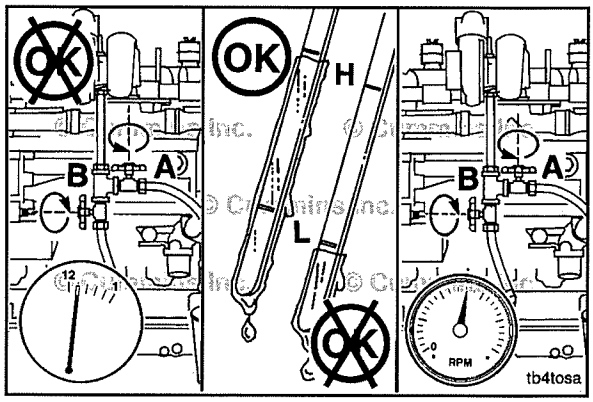
Operate the engine at rated speed and under load by either:

- For engine testing, a chassis dynamometer or engine dynamometer
- A stall speed test (for engines equipped with automatic transmissions **only**).

Operate the engine at rated rpm and full load until a steady reading is obtained.

NOTE: When measuring blowby, the value can "spike" initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.





⚠WARNING⚠
To reduce the possibility of personal injury, keep hands, long hair, jewelry, and loose fitting or torn clothing away from fans and other moving parts.

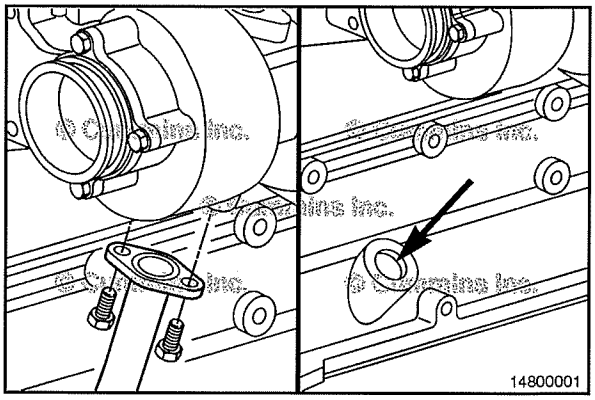
⚠WARNING⚠
Troubleshooting presents the risk of equipment damage, personal injury, or death. Troubleshooting must be performed by trained, experienced technicians.

△CAUTION△
Do not operate the engine with valve (A) open and valve (B) closed for more than 1 minute. Monitor the amount of oil accumulating in the bucket. The engine can run out of lubricating engine oil and severe engine damage will occur.

Continue operating at rated speed and load.

Open valve (A) and close valve (B).

Record the blowby pressure reading.



△CAUTION△
Do not operate the engine for more than 1 minute. Monitor the amount of oil accumulating in the container. The engine can be run out of lubricating engine oil and severe engine damage will result.

Alternate Turbocharger Isolation Method:

With the turbocharger oil drain line disconnected from the cylinder block, run the turbocharger drain line into a large container.

Plug the turbocharger oil drain port in the cylinder block.

Operate the engine at rated speed and under load by either:

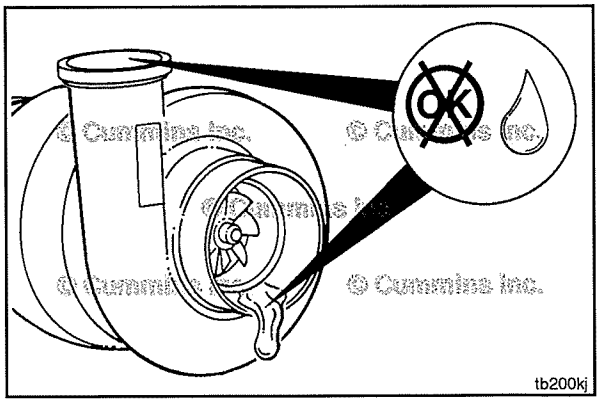
- For engine testing, a chassis dynamometer or engine dynamometer
- A stall speed test (for engines equipped with automatic transmissions **only**).

Record the peak blowby pressure measurement.

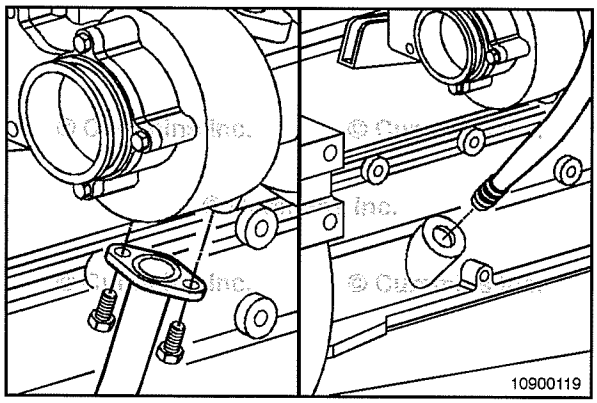
Determine the turbocharger blowby pressure contribution by determining the difference in the blowby pressure measurement with the turbocharger drain isolated, valve (A) open, and turbocharger drain **not** isolated, valve (A) closed.

Blowby Pressure Differential	
Turbocharger Blowby Contribution	Maximum: 30 percent

If the turbocharger blowby contribution is out of specification, inspect the compressor and turbine areas of the turbocharger for signs of an oil leak. Replace the turbocharger, if necessary.



- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 010-033 in Section 10 (single turbocharger). Refer to Procedure 010-034 in Section 10 (dual turbocharger). Refer to Procedure 010-035 in Section 10 (dual turbocharger).
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and (dual turbocharger applications) ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178 for single turbocharger applications. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-033 in Section 10.



If installed, remove the turbocharger oil drain line assembly and shutoff valves.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220 E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-045 in Section 10.

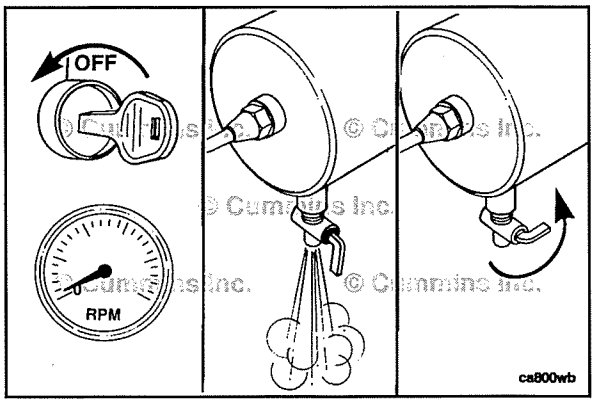
Check the engine oil level and add oil if necessary.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Air Compressor Blowby Contribution:

With the engine blowby service tool and the water manometer, pressure gauge, or transducer still installed, isolate the air compressor, if equipped, to determine if there is internal damage to the air compressor contributing to high engine crankcase pressure. The air compressor can be isolated by unloading the air compressor.

With the engine shut off, bleed the vehicle's air system down by opening the drain cock on the wet tank to release compressed air from the system.

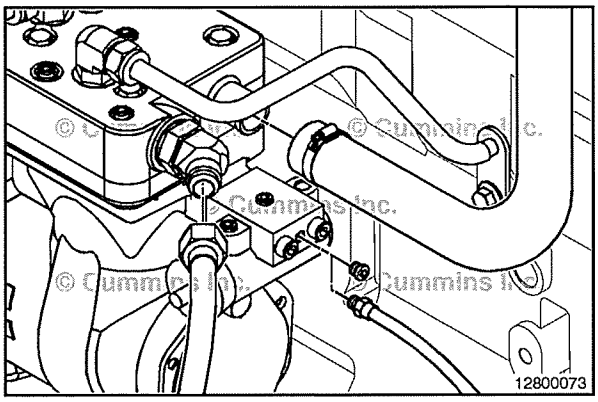


NOTE: The air compressor governor/unloader location can vary on each engine application. The air governor/ unloader can be air compressor mounted or chassis mounted.

Disconnect the air signal line from the air compressor governor/unloader air signal port.

Disconnect the air compressor discharge line and air intake hose from the air compressor.

NOTE: On turbocharged air compressors, make sure to plug the air intake hose connected to the engine intake manifold or the engine will **not** reach full power during test.



To unload the air compressor, determine the pressure needed at the governor/unloader air signal port to start and stop the air compressor from pumping.

NOTE: Typical 621 kPa [90 psi] of air pressure is the set point between starting and stopping of the air compressor pumping. Refer to the OEM service manual.

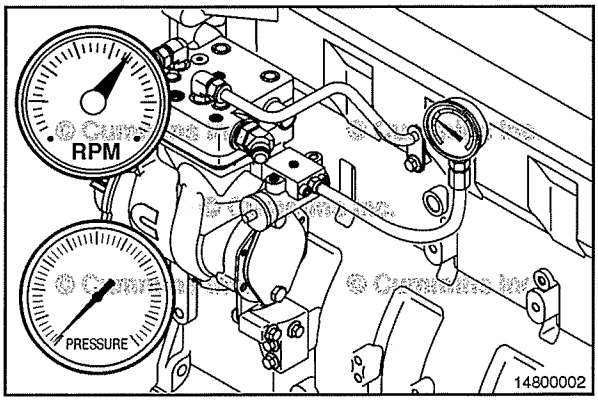
Connect a regulated shop air pressure line, with pressure gauge, to the air compressor governor/unloader air signal port.

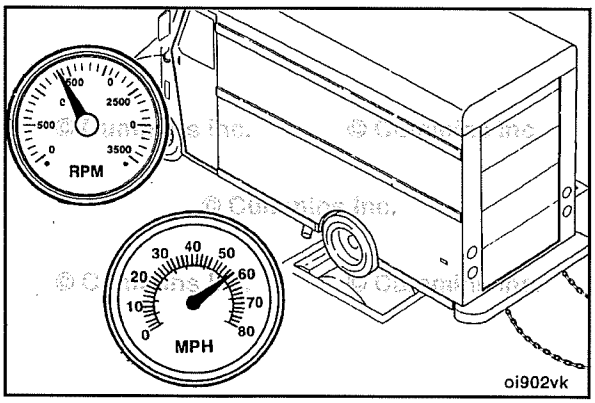
NOTE: When performing the test, make sure that the air system pressure does **not** exceed the manufacturer's maximum allowable pressure.

Run the engine and increase the signal pressure to the air governor/unloader to determine when the air compressor will stop pumping (system pressure stops rising at this point). Record the signal line pressure.

Reduce the signal pressure to determine when system pressure starts the air compressor pumping again (system pressure will begin to rise again at this point). Record the signal line pressure.

NOTE: Allow the air compressor to pump long enough to build enough pressure in the system to release and operate the air brakes.





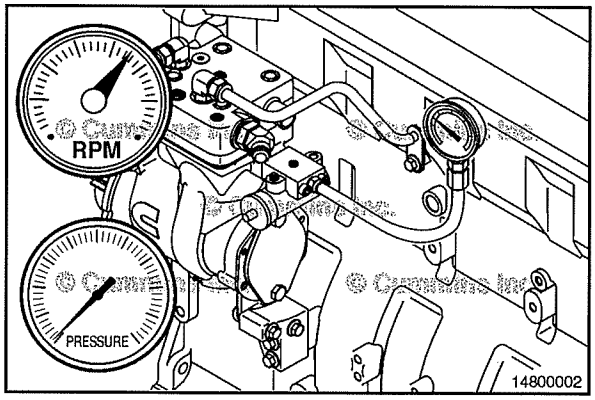
With the regulated shop air pressure line still connected to the air compressor governor/unloader air signal port, regulate the signal pressure so that the air compressor starts pumping (system pressure will begin to rise again at this point). Use the pressure value recorded previously as a set point.

Operate the engine at rated speed and under load by either:

- For engine testing, a chassis dynamometer or engine dynamometer.
- A stall speed test (for engines equipped with automatic transmissions **only**).

Operate the engine at rated rpm and full load until a steady reading is obtained.

NOTE: When measuring blowby, the value can "spike" initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.



Continue operating the engine at rated speed and load.

Increase the signal pressure (system pressure stops rising at this point). Use the pressure value recorded previously as a set point.

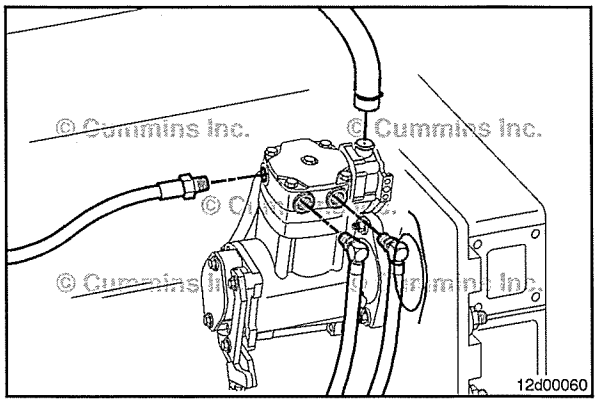
Operate the engine at rated rpm and full load until a steady reading is obtained.

NOTE: When measuring blowby, the value can "spike" initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.

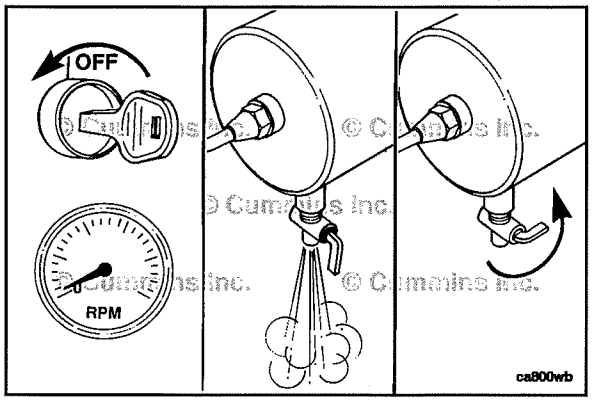
Determine the air compressor blowby pressure contribution by determining the difference in the blowby pressure measurement with the air compressor pumping and the air compressor **not** pumping.

Blowby Pressure Differential	
Air Compressor Contribution	Maximum: 30 percent

If the air compressor blowby contribution is out of specification, replace the air compressor.

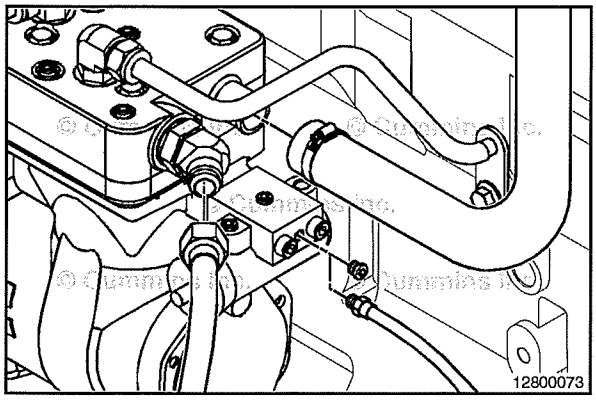


- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 012-014 in Section 12.



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

With the engine shut off, bleed the vehicle's air system down by opening the drain cock on the wet tank to release compressed air from the system.



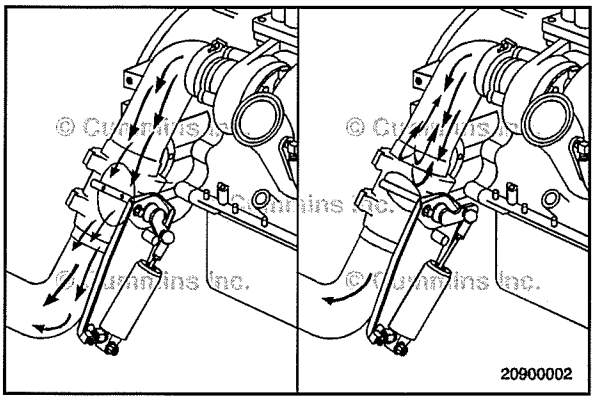
Disconnect the regulated shop air pressure line, with pressure gauge, from the air compressor governor/ unloader air signal port.

Connect the air signal line. Refer to the OEM service manual.

Remove the engine blowby service tool and water manometer or pressure gauge if the blowby is within specification.

NOTE: On turbocharged air compressors, make sure to remove the plug previously installed in the air intake hose connected to the engine intake manifold.

Connect the air compressor discharge line and air intake hose from the air compressor.



Exhaust Brake Blowby Contribution:

NOTE: Not all vehicles are equipped with an exhaust brake.

With the engine blowby service tool and the water manometer, pressure gauge, or transducer still installed, measure blowby pressure during exhaust brake operation, if equipped.

Operate the vehicle going down a long inclined road such as a highway or interstate off ramp. Begin exhaust brake operation at rated engine speed while measuring blowby pressure during exhaust brake operation.

Also, measure exhaust back pressure during exhaust brake operation.

Operate the engine until a steady reading is obtained.

NOTE: When measuring blowby, the value can "spike" initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.

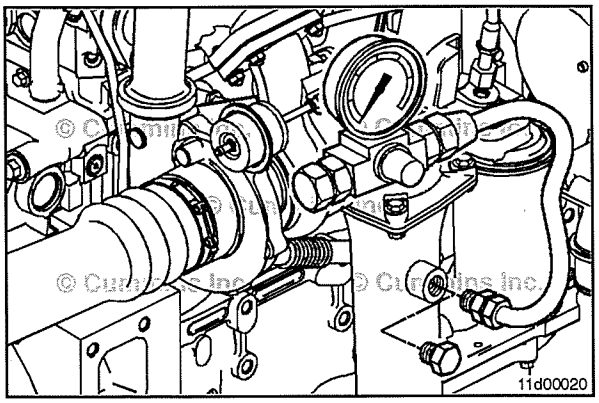
If blowby pressure is above specification during exhaust brake operation and exhaust back pressure is above specification, repair or replace the exhaust brake. See the manufacturer's instructions.

If the blowby pressure is above specification during exhaust brake operation and the exhaust back pressure is within specification, check the turbocharger blowby contribution. Reference the turbocharger oil drain isolation step previously in this procedure.

Remove the engine blowby service tool and the water manometer, pressure gauge, or transducer.

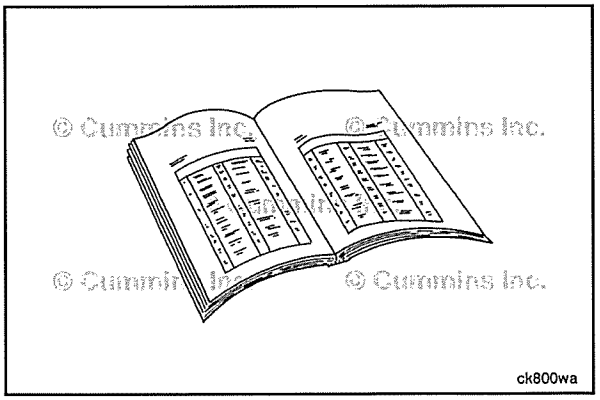
Remove the pressure gauge used to measure exhaust back pressure during exhaust brake operation.

Install a plug in the test port.



Base Engine Component Blowby Contribution:

Base engine components can also be contributing factors of increased crankcase blowby and higher than normal crankcase pressure. Reference the Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS of the appropriate engine service manual to evaluate the remaining possible causes for increased blowby and higher than normal crankcase pressure. The following are listed as possible base engine component causes:



Valve stem clearance is excessive or the valve stem seals are damaged.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220 E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 002-004 in Section 2.

Cylinder head valve guides are excessively worn.

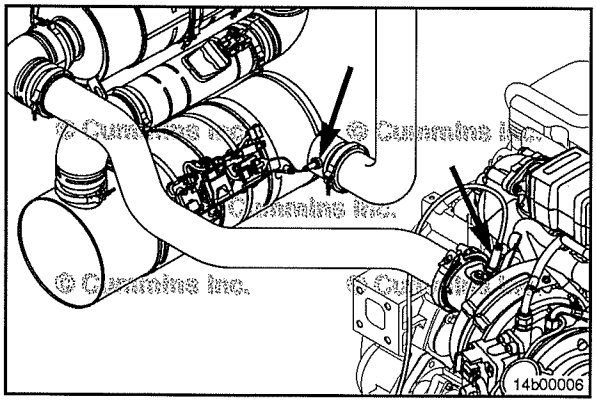
- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 002-004 in Section 2.

Air compressor is malfunctioning.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 012-014 in Section 2.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISF3.8 CM2220 Service Manual, Bulletin 4021704. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 012-014 in Section 12.

Piston or piston rings are worn or damaged.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220 E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 001-043 in Section 1.Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 001-043 in Section 1.



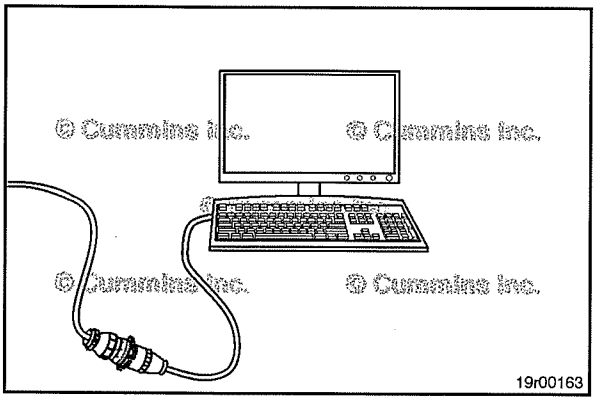
Aftertreatment Selective Catalytic Reduction (SCR) Performance Test (014-015)

General Information

Use the following procedure for additional information on the aftertreatment system. Refer to Procedure 011-999 in Section F.

The following procedure contains information on how to perform an SCR Performance Test using INSITE™ electronic service tool.

The INSITE™ electronic service tool SCR Performance Test uses the Aftertreatment Intake NOx sensor and Aftertreatment Outlet NOx sensor readings to test the efficiency of the SCR catalyst.



Initial Check

Use INSITE™ electronic service tool to check for fault codes. If **any** fault codes are present, follow the corresponding troubleshooting tree before performing **any** part of this procedure.

The fault code troubleshooting tree, in some cases, will refer back to this procedure to complete the diagnostics.

Test

⚠WARNING⚠

During testing, exhaust gas temperature could reach 800°C [1500°F] and exhaust system surface temperature can exceed 700°C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle stops moving. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

Before performing an SCR Performance Test, follow the steps listed below:

1 Select an appropriate location to park the vehicle.

a On a surface that will **not** burn or melt under high temperatures (such as clean concrete or gravel, **not** grass or asphalt)

b Away from anything that can burn, melt, or explode

- Nothing within 0.6 m [2 ft] of the exhaust outlet
- Nothing that can burn, melt, or explode within 1.5 m [5 ft] (such as gasoline, wood, paper, plastics, fabric, compressed gas containers, and hydraulic lines)
- No gas or vapors nearby that could burn, explode, or contribute to a fire (such as liquid petroleum gas, gasoline vapors, oxygen, and nitrous oxide).

2 Park the truck securely.

a Set the parking brake.

b Place the transmission in Park, if provided. Otherwise, place the transmission in Neutral.

c Set the wheel chocks at the front and rear of at least one tire.

3 Set up a safe exhaust area.

a If bystanders can possibly enter the area, use barriers to keep people at least 1.5 m [5 ft] from the exhaust outlet during the SCR Performance Test.

b When indoors, attach an exhaust discharge pipe rated for at least 800°C [1500°F].

c Keep a fire extinguisher nearby.

4 Check exhaust system surfaces.

a Confirm that nothing is on or near the exhaust system surfaces (such as tools, rags, grease, or debris).

5 Prepare for engine speed changes during the SCR Performance Test.

a Do **not** operate **any** PTO-powered devices. Disconnect these devices before starting the SCR Performance Test.

b Stay clear of the engine compartment.

6 Begin the SCR Performance Test.

a The INSITE™ electronic service tool **must** be used to perform the SCR Performance Test.

b The engine will create enough heat to run the test. Engine speed will increase and the turbocharger can whistle loudly during the testing process. Once the test is complete, the engine will automatically return to normal idle speed.

7 Monitor the area.

a Make sure that the vehicle and surrounding area is monitored during the SCR Performance Test. If **any** unsafe condition occurs, shut the engine OFF immediately.

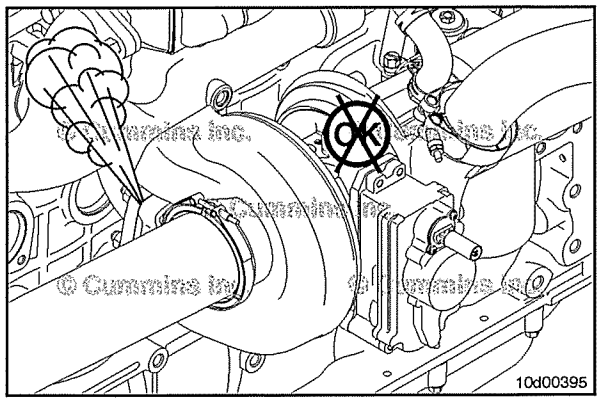
To stop the test, engage the clutch, brake, or throttle pedal; or turn the engine OFF.

Once the test is complete, exhaust gas and exhaust surface temperatures will remain elevated for 3 to 5 minutes.

Before starting the SCR Performance Test, inspect the exhaust piping for leaks, cracks, and loose connections. Refer to Procedure 010-024 in Section 10.

Tighten the exhaust clamps, if necessary. Refer to the OEM service manual for the correct torque value.

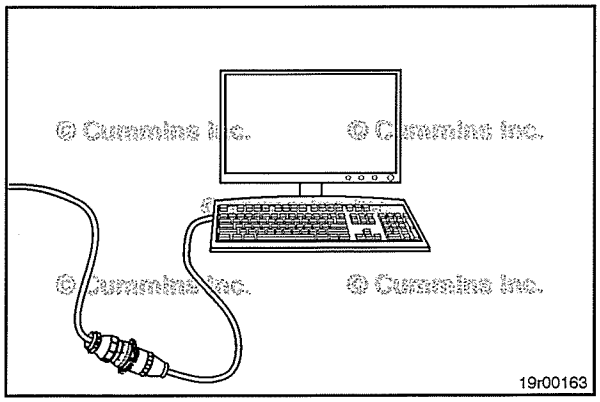
Any leaks in the exhaust system will cause the SCR Performance Test to be less efficient. This will result in the test running longer and possibly **not** completing.

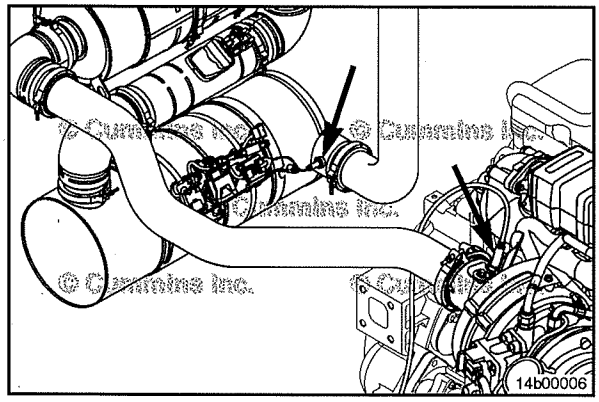


The test can be found under the ECM Diagnostics Test menu in INSITE™ electronic service tool. Follow the on-screen instructions to perform the test.

To stop the SCR Performance Test at **any** time during the test:

- Select the stop button on the INSITE™ electronic service tool monitor screen.
- Depress the clutch, if equipped.
- Depress the brake.
- Depress the accelerator pedal.
- Turn the engine off.





The SCR Performance Test will perform the following actions:

Clean the aftertreatment system of **any** DEF deposits.

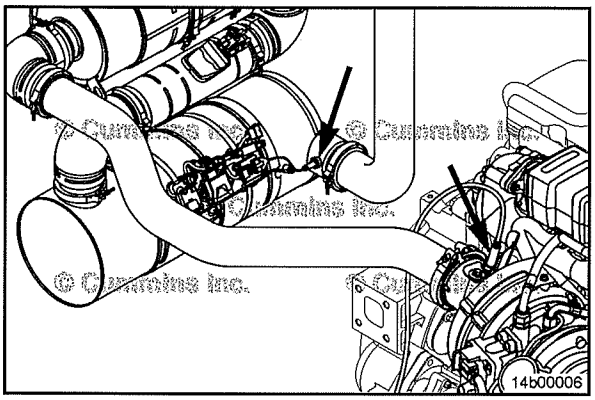
- Cleaning the aftertreatment system of DEF deposits can take up to 2 hours to complete. If deposits are detected after 2 hours of run time, the test will time out.

Perform a NOx sensor rationality test.

- The Aftertreatment Intake NOx sensor and Aftertreatment Outlet NOx sensor readings will be compared to determine if they are working properly.
- If one, or both, of the NOx sensors fail the rationality test, the test will stop and a pop-up message will be displayed, stating that the NOx sensor has failed and troubleshooting is required.

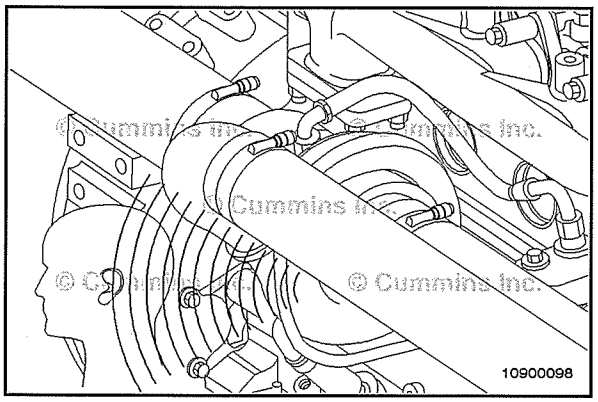
Check the SCR catalyst efficiency.

- DEF will be injected into the aftertreatment system and the Aftertreatment Outlet NOx sensor reading will be compared to the Aftertreatment Intake NOx sensor reading to determine the efficiency of the SCR catalyst.
- If the SCR catalyst fails the efficiency test, a pop-up message will be displayed, stating that the SCR Catalyst **must** replaced.



During the SCR Efficiently Test, the following will be monitored:

- SCR catalyst inlet temperature
- SCR catalyst outlet temperature
- Aftertreatment intake NOx sensor reading
- Aftertreatment outlet NOx sensor reading.

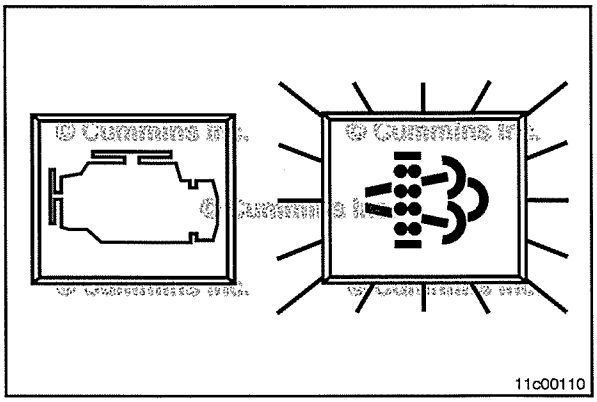


Once the SCR Performance Test is started, follow the INSITE™ electronic service tool on-screen instructions. When the test is started, the engine idle speed will be raised automatically to the required level.

Through engine controls, the engine will operate in a manner to build exhaust heat. The turbocharger will emit a slight whining noise during this test. This is normal.

Once the SCR Performance Test is complete, the engine will automatically return to normal idle speed.

Once the test is complete, check for active fault codes and/or engine indicator lamps. If **any** active fault codes are present, follow the appropriate fault code troubleshooting tree.

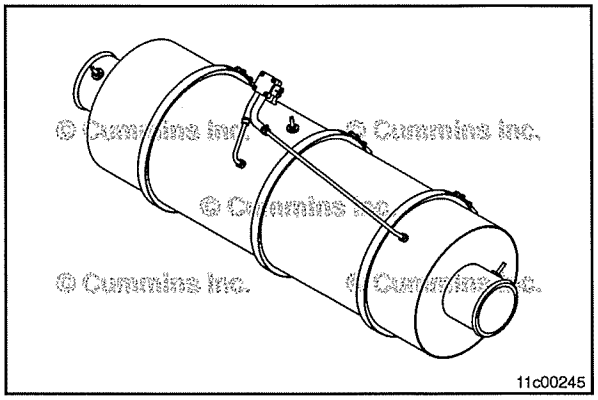


Snap Acceleration Test (014-017)

General Information

Use the following procedure for additional information on the aftertreatment system. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-999 in Section F. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-999 in Section F.

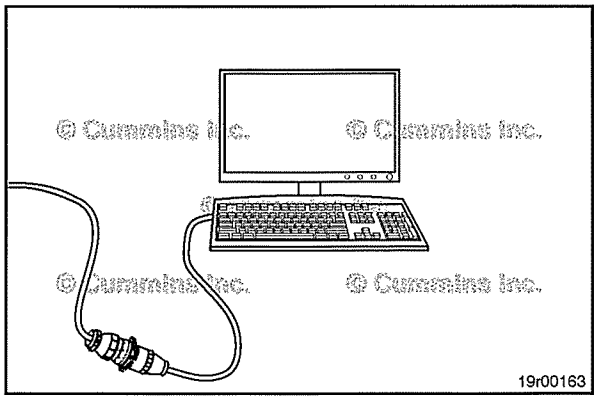
The following procedure contains information about how to perform a Snap Acceleration Test with the aftertreatment system connected and disconnected.

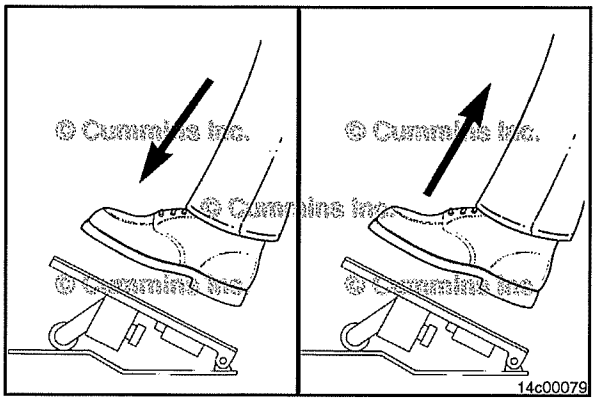


Initial Check

Use INSITE™ electronic service tool to check for fault codes. If **any** fault codes are present, follow the corresponding troubleshooting tree before performing **any** part of this procedure.

The fault code troubleshooting tree, in some cases, will refer back to this procedure to complete the diagnostics.





Test

Snap Acceleration - Aftertreatment Connected

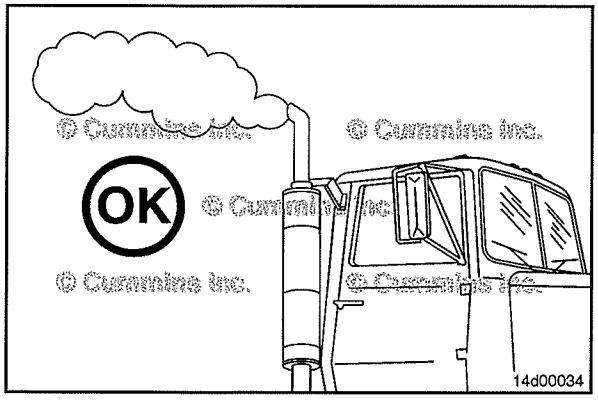
Monitoring the condition of the exhaust leaving the exhaust system outlet during a snap acceleration can reveal the condition of the aftertreatment system.

The engine **must** be at minimum operating temperature or above when completing this test. The vehicle transmission **must** be in neutral and the vehicle parking brake **must** be applied.

Start and idle the engine. Rapidly depress the accelerator pedal from 0 to 100 percent. This can be performed multiple times, if necessary.

During this test, check for black smoke exiting the exhaust stack, as the engine is accelerated from low idle to high idle.

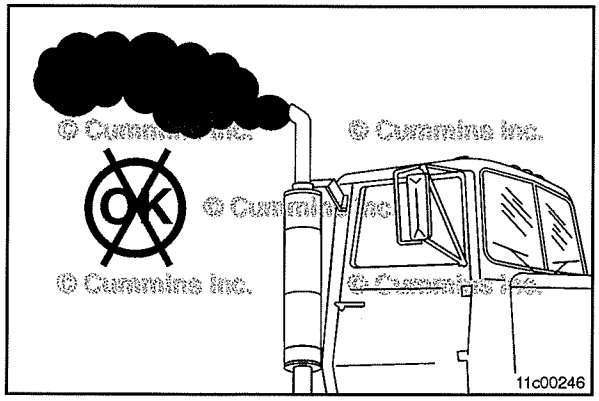
NOTE: In some applications, a Snap Acceleration Test may **not** provide the conditions necessary to reveal a malfunctioning aftertreatment system. If there is a heavy buildup of exhaust residue/soot on the exhaust system outlet and a snap acceleration does not reveal a condition outlined in the following steps, it may be necessary to perform a brief acceleration run under partial to full load and/or a stall test. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 014-008 in Section 14. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 014-008 in Section 14.



NOTE: If an opacity meter is used to measure the condition of the exhaust gas leaving the exhaust system outlet, the engine and aftertreatment system **must** be at operating temperature.

White smoke can indicate condensation in the exhaust and/or some unburned fuel. White smoke is **not** an indication of a malfunction of the aftertreatment system.

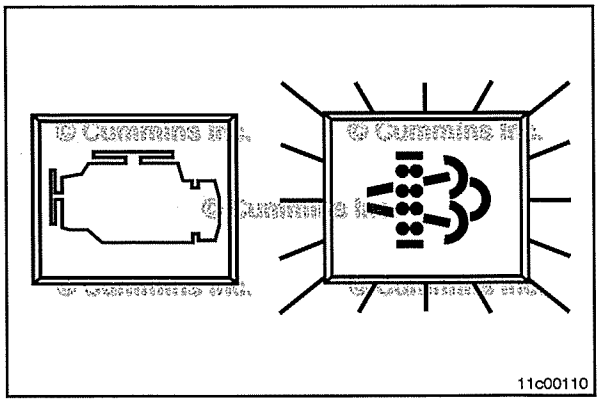
If excessive white smoke is present, see the Engine Performance troubleshooting symptom tree in Section TS.



A small puff of black smoke upon acceleration that clears at steady state high idle is normal. Visible black smoke out of the exhaust system outlet that does not clear at steady state indicates a malfunction of the aftertreatment or engine systems. Reference the appropriate troubleshooting symptom tree in Section TS.

NOTE: If the vehicle has experienced the aftertreatment lamp illuminating frequently, high exhaust temperature lamp, if equipped, illuminating frequently, and/or requires frequent stationary regenerations, use the appropriate troubleshooting symptom tree in Section TS.

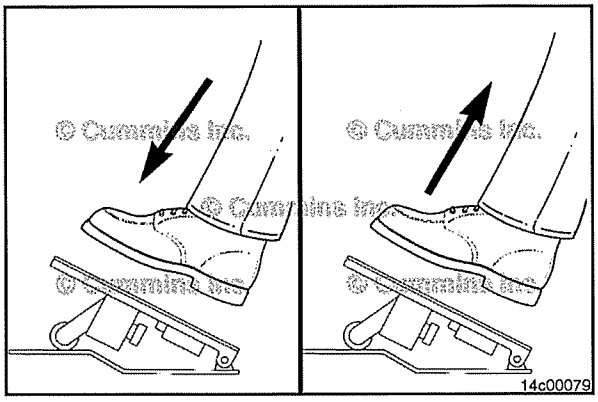
Snap Acceleration - Aftertreatment Disconnected



⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components.

The Snap Acceleration Test (aftertreatment disconnected) is used to check for abnormally high amounts of black smoke in the exhaust gas.

Disconnect the exhaust pipe from the turbocharger turbine outlet.



The vehicle transmission **must** be in neutral.

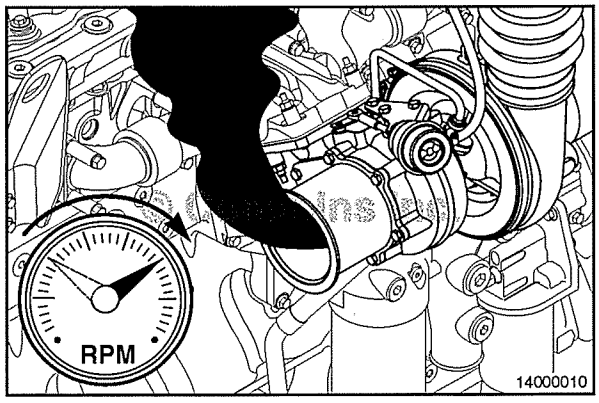
The vehicle parking brake **must** be applied.

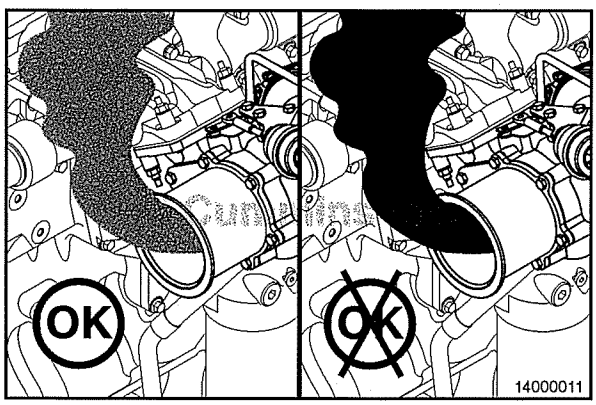
It may be necessary to temporarily adjust the maximum engine speed with no vehicle speed sensor (VSS) parameter in INSITE™ electronic service tool to the high idle speed of the engine.

Start the engine and let it idle.

Quickly depress the accelerator pedal from 0 percent to 100 percent and hold for 5 seconds then release. This can be performed multiple times, if necessary.

During this test, check for black smoke exiting the turbocharger turbine outlet as the engine is accelerated from low idle to high idle and at high idle.

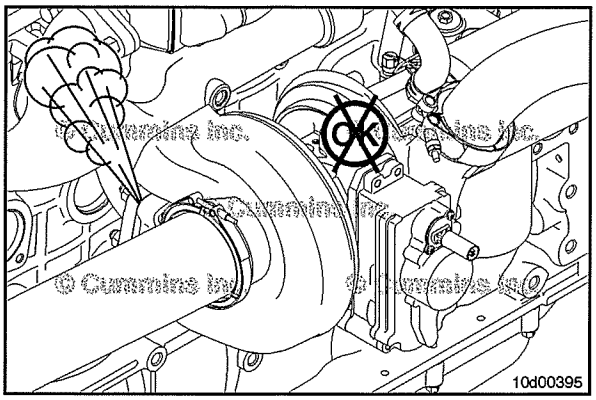




A small puff of black smoke upon acceleration that clears at a steady high idle speed is normal.

White smoke during the Snap Acceleration Test does **not** indicate a malfunction. No repair is necessary.

Heavy black smoke indicates other upstream engine issues that need to be diagnosed. Reference the Black Smoke - Excessive troubleshooting symptom tree in Section TS.

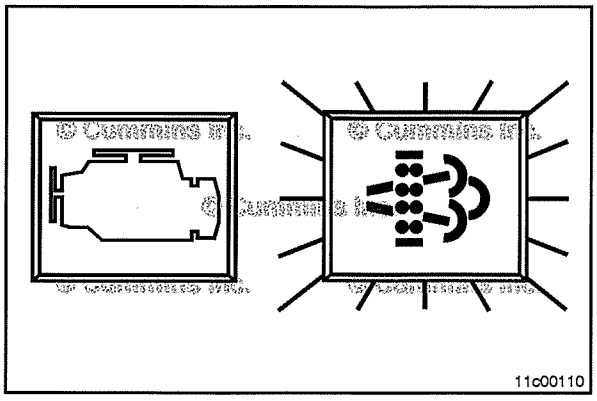


Reconnect the exhaust system.

Inspect the exhaust piping for leaks, cracks, and loose connections.

Tighten the exhaust clamps, if necessary.

Refer to the original equipment manufacturer (OEM) service manual for the correct torque value.



Once the test is complete, check for active fault codes and/or illuminated engine indicator lamps. If **any** active fault codes are present, follow the appropriate fault code troubleshooting tree.

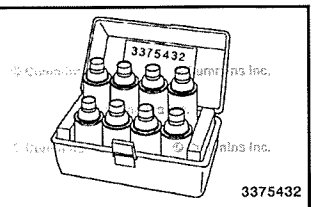
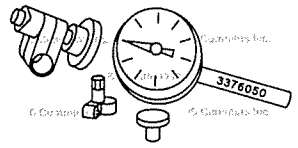
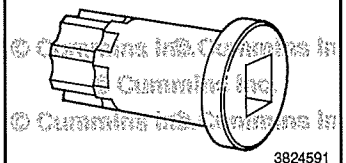
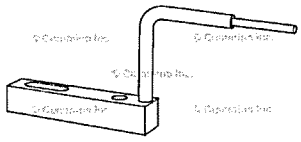
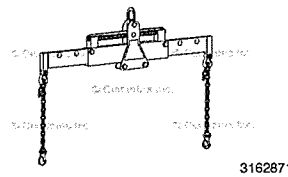
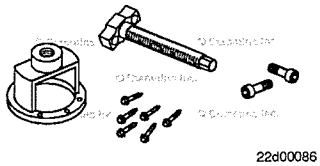
Section 16 - Mounting Adaptations - Group 16

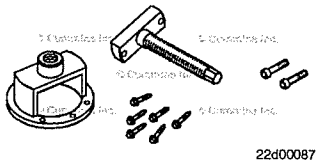
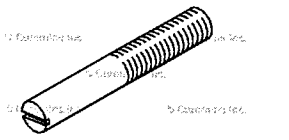
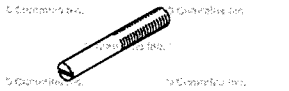
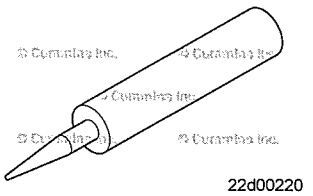
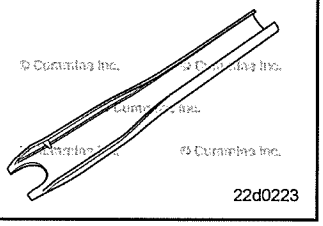
Section Contents

Service Tools

Mounting Adaptations

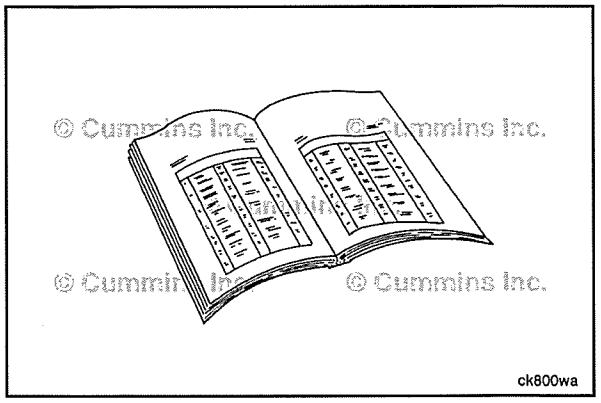
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3375432	**Crack Detection Kit** Used to detect cracks in engine components.	 3375432
3376050	**Dial Indicator Gauge** Used with attachment Part Number ST-1325 for checking flywheel housing runout.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591
ST-1325	**Dial Gauge Attachment** Used with dial indicator Part Number 3376050 for checking flywheel housing runout.	 st-1325
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	 3162871
3164659	**Oil Seal Replacer (Front)** Used to remove/install the front crankshaft seal.	 22d00086

Tool No.	Tool Description	Tool Illustration
3164660	**Oil Seal replacer (Rear)** Used remove/install rear crankshaft seal on engines equipped with unitized seal.	 22d00087
3376638	**Vibration Damper Guide Pin** Used to help align the vibration damper. M12 x 1.75	 22d00114
3376488	**Accessory Drive Support Guide Pin** Used to help align the accessory drive support. M10 x 1.5	 22d00115
3164070	**RTV Sealant** Used to seal flywheel housing to gear housing joint.	 22d00220
3165175	**Barring Plug Remover.** Removes flywheel housing plug. Removal of this plug is required prior to using Barring Tool, Part Number 3824591.	 22d0223

Engine Lifting Brackets (016-001)

Preparatory Steps



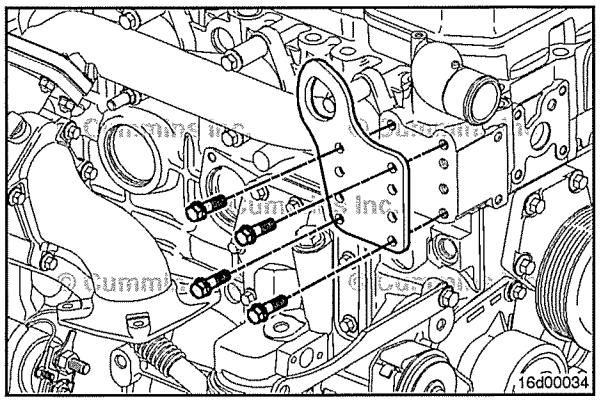
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- For the front lifting bracket it may be necessary to remove the alternator. Refer to Procedure 013-001 in Section 13.
- For the front lifting bracket it may be necessary to remove the alternator bracket. Refer to Procedure 013-003 in Section 13.

Remove

Front

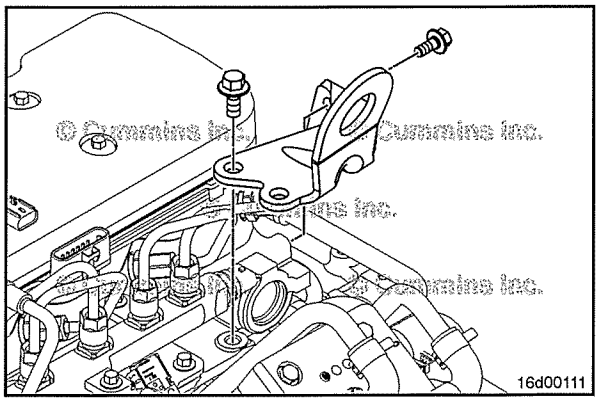
Remove the capscrews and the front lifting bracket.

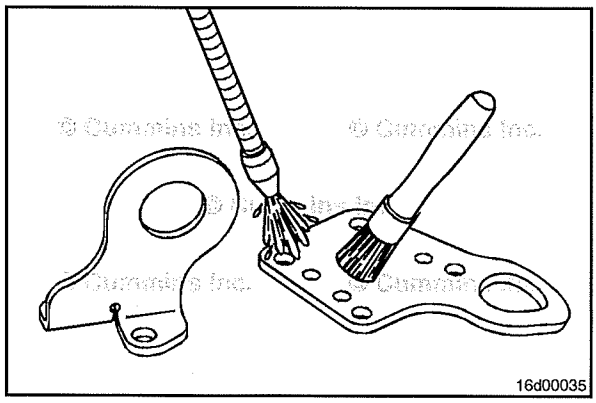


Rear

NOTE: Some engines use a two bolt rear lifting bracket and some engines use a four bolt rear lifting bracket.

Remove the capscrews and the rear lifting bracket.





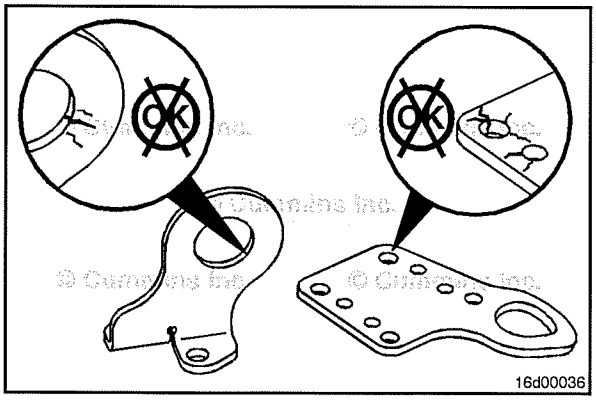
Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

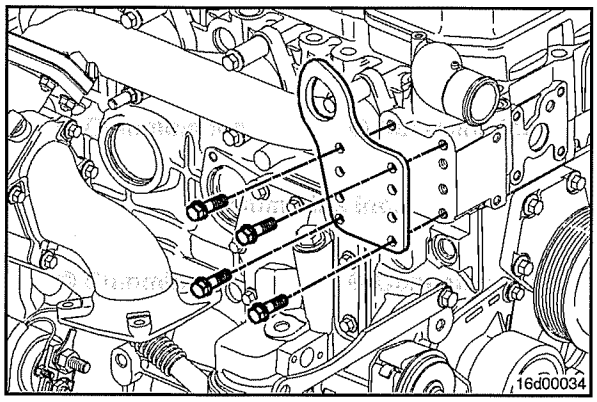
Use steam or solvent to clean the lifting brackets. Dry with compressed air.



⚠WARNING⚠
Do not use a cracked or damaged bracket. Do not weld a cracked bracket. Personal injury can result.

Inspect the brackets for cracks or other damage.

Replace the bracket if it is cracked or damaged.



Install

Front

For engines **not** equipped with pad mount alternators, install the capscrews and front bracket.

Tighten the capscrews.

Torque Value:
M8 24 N•m [212 in-lb]

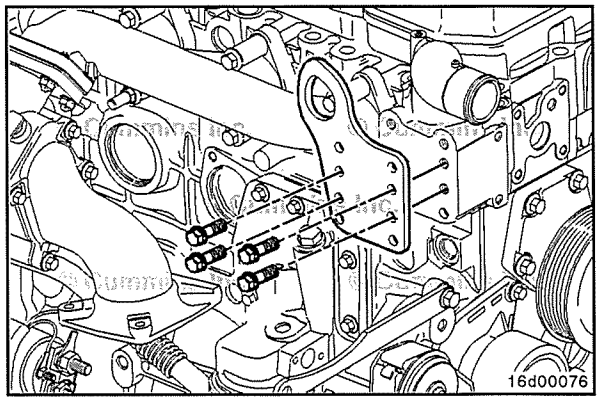
Torque Value:
M10 43 N•m [32 ft-lb]

⚠WARNING⚠
Four 20 mm, grade 10.9 hex head capscrews must be used to install the front lifting bracket. If shorter capscrews or capscrews of a different grade are used, the engine can fall when lifting the engine. Personal injury and property damage can result.

For engines equipped with pad mount alternators, install the capscrews and front bracket.

Tighten the capscrews.

Torque Value: 32 N•m [24 ft-lb]



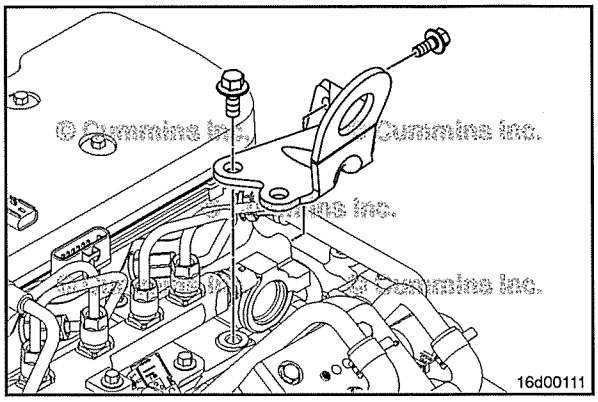
Rear

NOTE: Some engines use a two bolt rear lifting bracket and some engines use a four bolt rear lifting bracket.

Install and tighten the rear bracket and capscrews.

Torque Value:
M10 43 N•m [32 ft-lb]

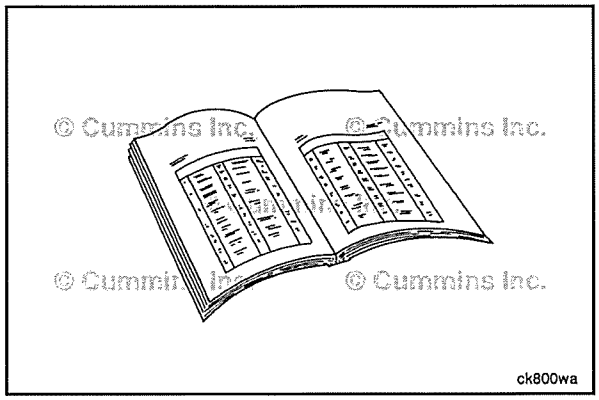
Torque Value:
M12 77 N•m [57 ft-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

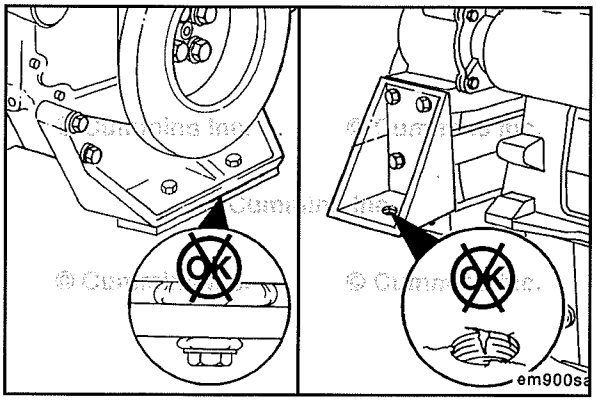
- If previously removed, install the alternator. Refer to Procedure 013-001 in Section 13.
- If previously removed, install the alternator bracket.Refer to Procedure 013-003 in Section 13.
- Connect the battery cables. Refer to the OEM service manual.



Engine Support Bracket, Front (016-002)

General Information

Due to the number of different engine mounting configurations, the following procedure is written to be generic. Some of the illustrations will **not** represent the actual part being removed and installed.



Initial Check

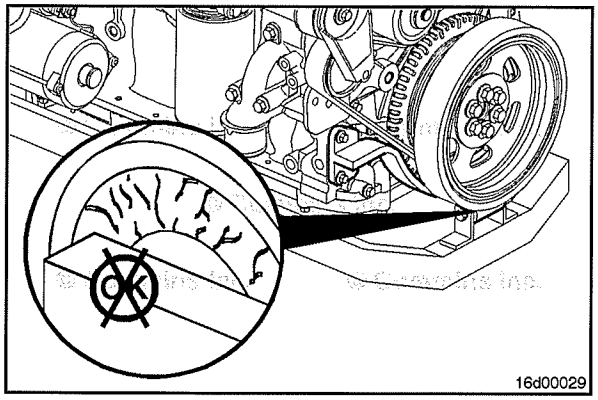
⚠CAUTION⚠

Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage can result in excessive vibration complaints.

For All Engine Mounts, inspect all rubber-cushioned mounts for cracks or other damage.

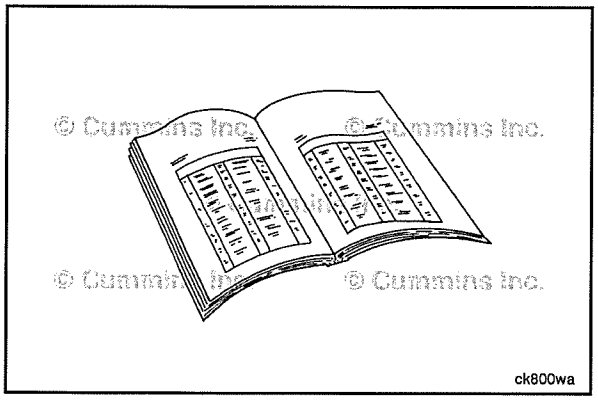
Inspect all mounting brackets for cracks or damaged bolt holes.

Replace any damaged parts as necessary.



For Barrel Mounts, inspect for signs of contact between the side brackets and the front engine support bracket.

Contact between the engine mount and side brackets can cause vibration complaints. If contact is found, replace the front engine support bracket.

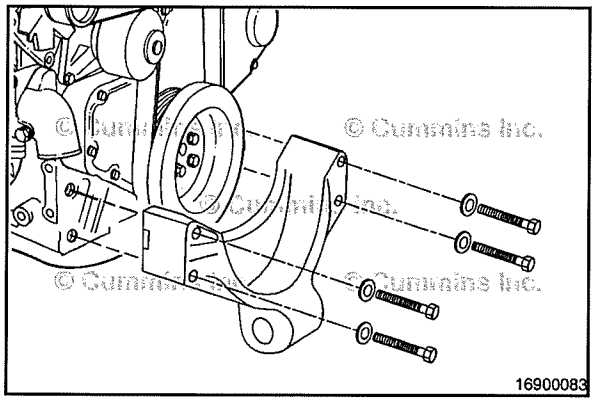


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

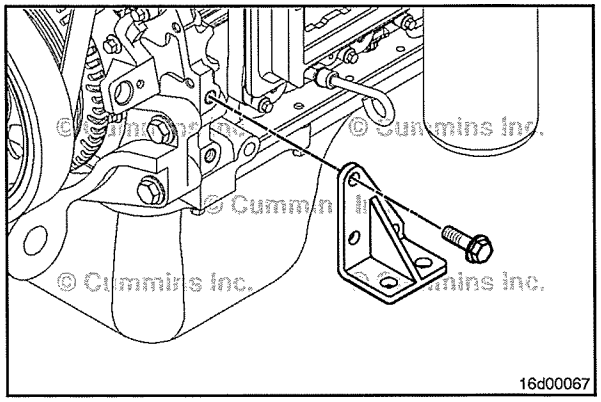
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.



Remove

For Front Mount, remove the front mount capscrews and bracket.

For Side Mount, remove the side engine mount capscrews and the brackets.



Clean and Inspect for Reuse

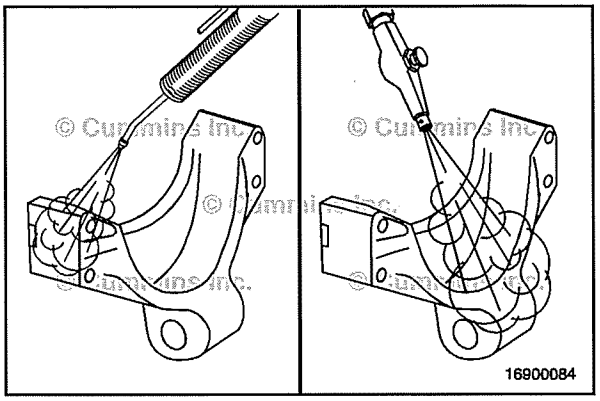
⚠WARNING⚠
When using a steam cleaner, wear protective clothing as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles as well as protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Compressed air used for cleaning must not exceed 207 kPa[30 psi]. Use only with protective clothing, as well as goggles/shield, and gloves to reduce the possibility of personal injury.

Use steam or solvent to clean the front engine support bracket(s).

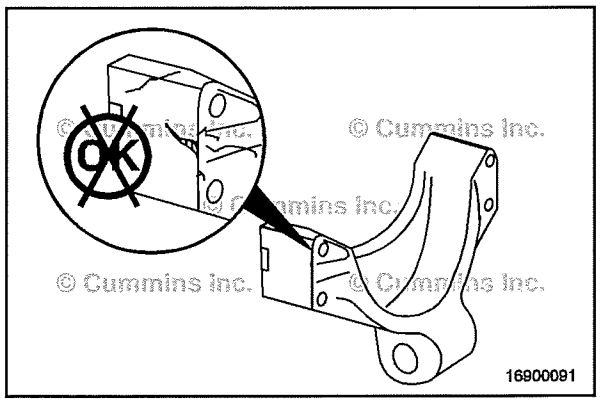
Dry with compressed air.

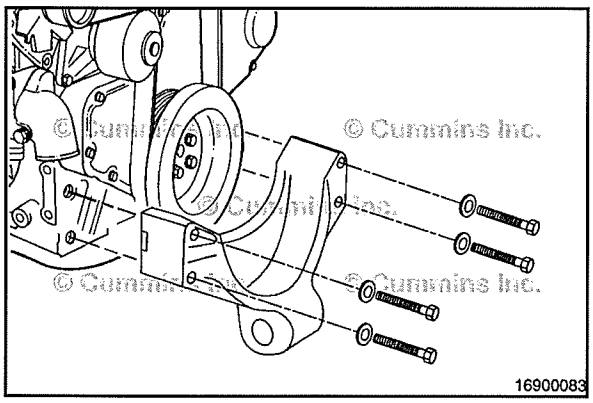


Inspect the engine support bracket for cracks or other damage.

If the engine support bracket is cracked, it **must** be replaced.

NOTE: Some front engine support brackets have rubber inserts. Make sure to inspect the inserts for separation, cracking and deterioration. If any damage is found, the front engine support bracket **must** be replaced.





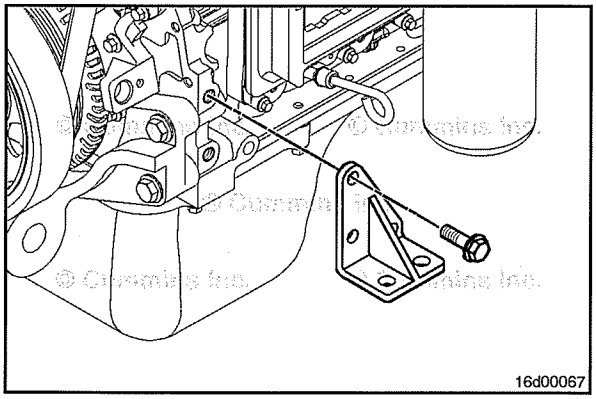
Install

For Front Mount, install the front mount bracket and capscrews.

Torque Value:
Grade 8.8 80 N•m [60 ft-lb]

Torque Value:
Grade 10.9 115 N•m [85 ft-lb]

Torque Value:
Grade 12.9 125 N•m [95 ft-lb]

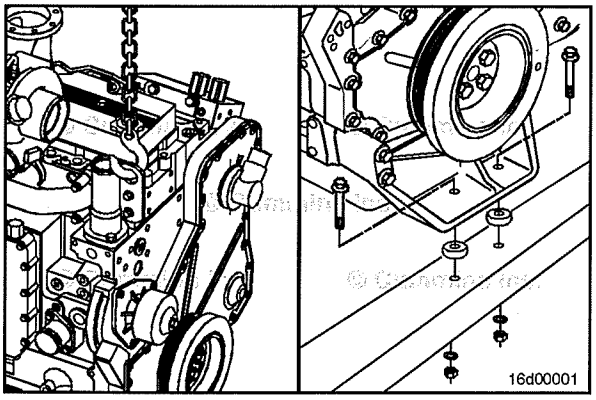


For Side Mount, install the side mount brackets and capscrews.

Torque Value:
Grade 8.8 80 N•m [60 ft-lb]

Torque Value:
Grade 10.9 115 N•m [85 ft-lb]

Torque Value:
Grade 12.9 125 N•m [95 ft-lb]



Non Cummins® Engine Mounting Bolts

NOTE: Make sure to install any shims or spacers in the same location as removed.

Install the front engine mount fasteners and tighten. Refer to OEM specifications.

If previously loosened, tighten the rear engine mounting fasteners. Refer to OEM specifications.

Remove the lifting fixture or hoist from the front of the engine.

Cummins® Engine Mounting Bolts

NOTE: Make sure to install any shims or spacers in the same location as removed.

Install the front engine mounting bolt.

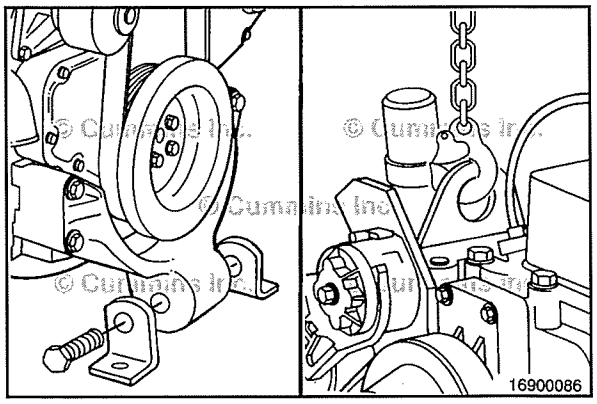
Install the hexagonal jam nut and tighten.

Torque Value: 350 N•m [258 ft-lb]

After tightening the engine mounting bolt, inspect for signs of contact between the side brackets and the front engine support bracket. Contact between the engine mount and side brackets can cause vibration complaints. If contact is found, verify that all spacers and shims previously removed have been installed.

If previously loosened, tighten the rear engine mount fasteners. Refer to OEM specifications.

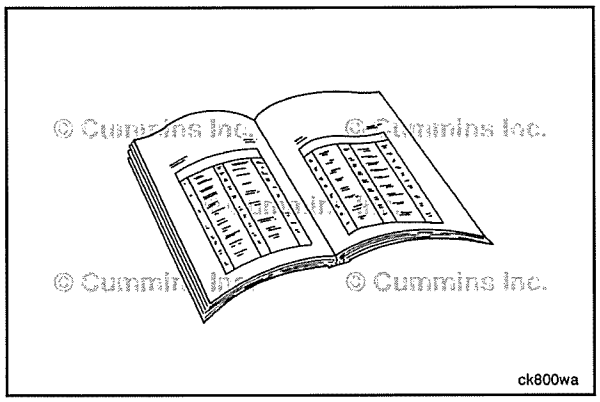
Remove the lifting fixture or hoist from the front of the engine.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Start the engine and check for proper operation.



Engine Support Bracket, Rear (016-003)

General Information

Due to the number of different engine mounting configurations, the following procedure is written to be generic. Some of the illustrations will **not** represent the actual part being removed and installed.

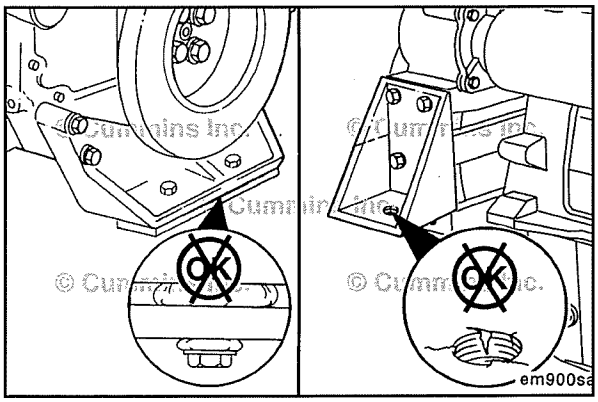
Initial Check

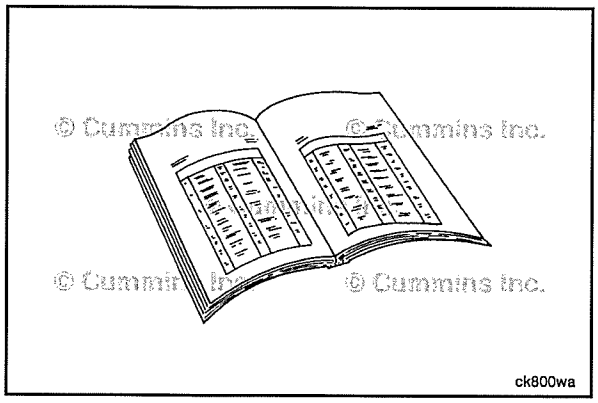
⚠CAUTION⚠
Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage can result in excessive vibration complaints.

Inspect all rubber-cushioned mounts for cracks or other damage.

Inspect all mounting brackets for cracks or damaged bolt holes.

Replace any damaged parts as necessary.

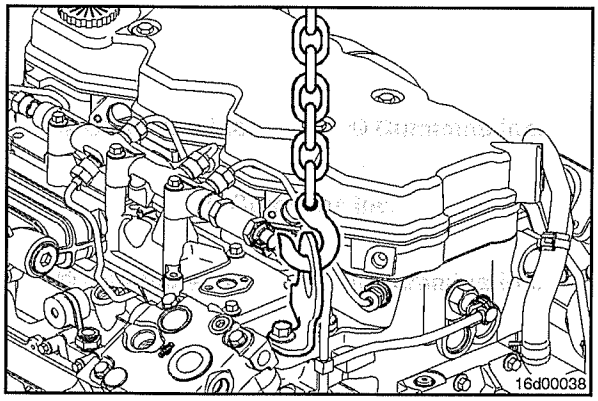




Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.

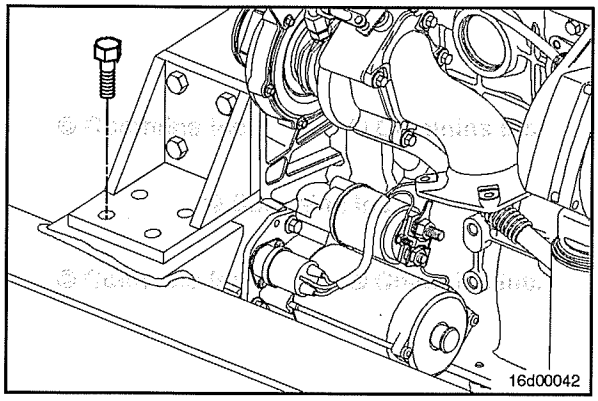


Remove

⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

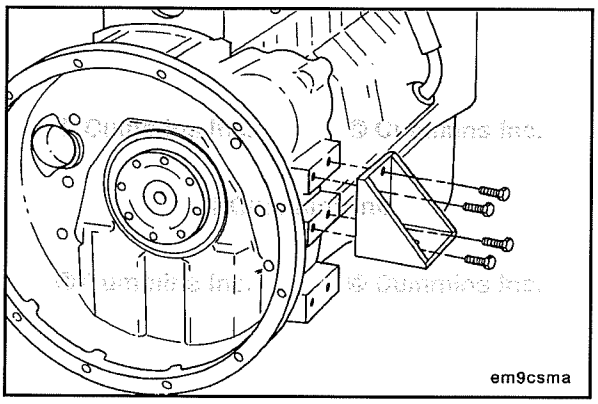
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Use a hoist or lifting fixture to support the rear of the engine.



NOTE: When removing the rear engine mount fasteners, note the location of any shims or spacers used.

Remove the engine mount fasteners.



Remove the rear support capscrews and bracket.

Clean and Inspect for Reuse

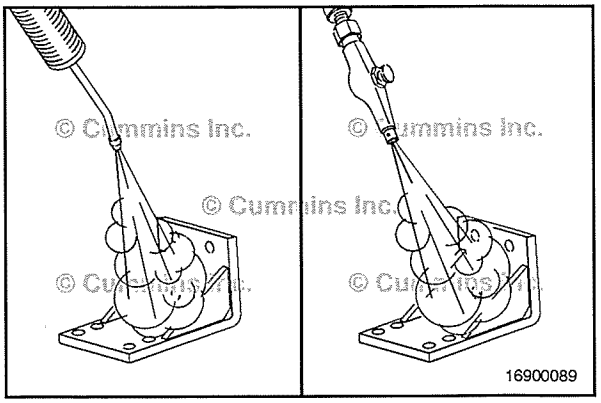
⚠WARNING⚠
When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturers recommendations for use. Wear goggles, and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam or solvent to clean the rear engine support.

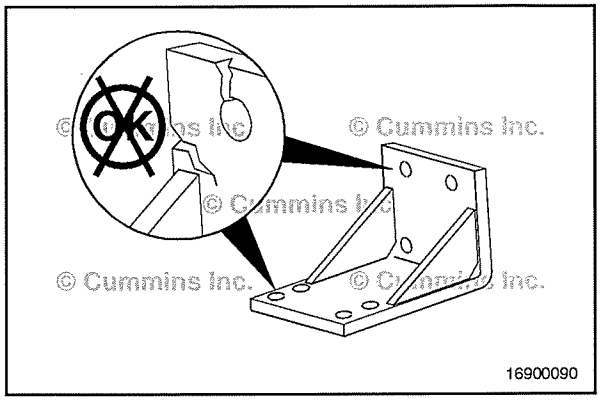
Dry with compressed air.



Inspect the support bracket for cracks or other damage.

If the support bracket is damaged, it **must** be replaced.

NOTE: Some rear engine support brackets have rubber inserts. Make sure to inspect the inserts for separation, cracking and deterioration. If any damage is found, the rear engine support bracket **must** be replaced.



Install

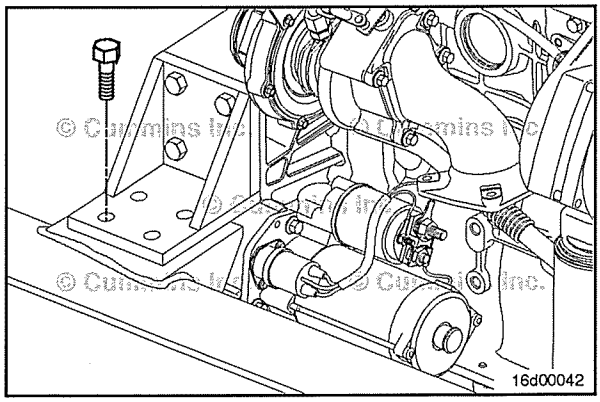
NOTE: Make sure to install any shims or spacers in the same location as removed.

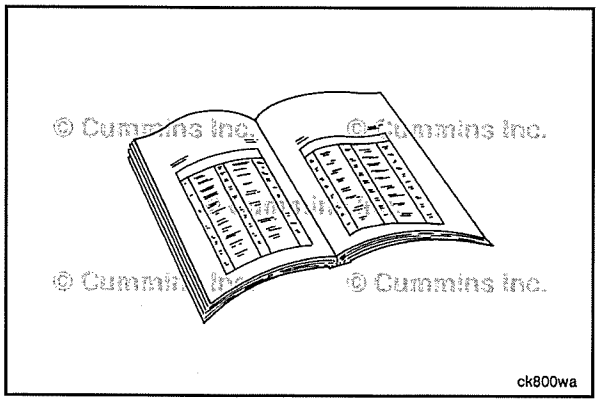
Lower the rear of the engine.

Install the rear engine mount fasteners.

Tighten to the original equipment manufacturer's specifications.

Remove the lifting fixture or hoist from the rear of the engine.

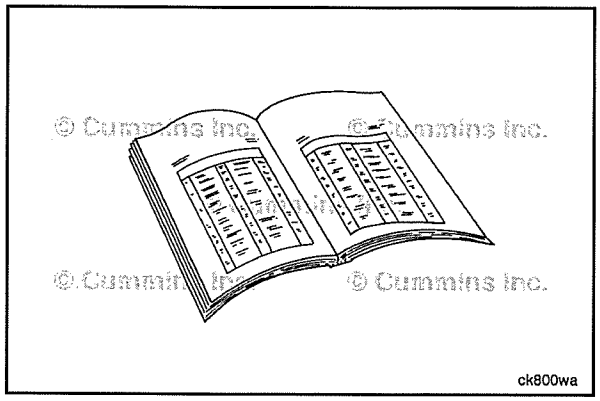




Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Start the engine and check for proper operation.



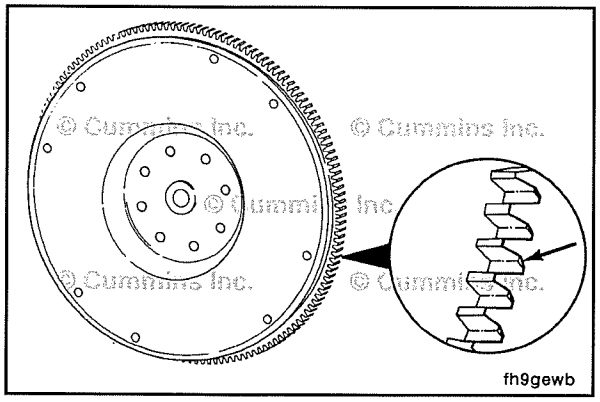
Flexplate (016-004)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

- Disconnect the batery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the transmission and related components. Refer to the OEM service manual.



Initial Check

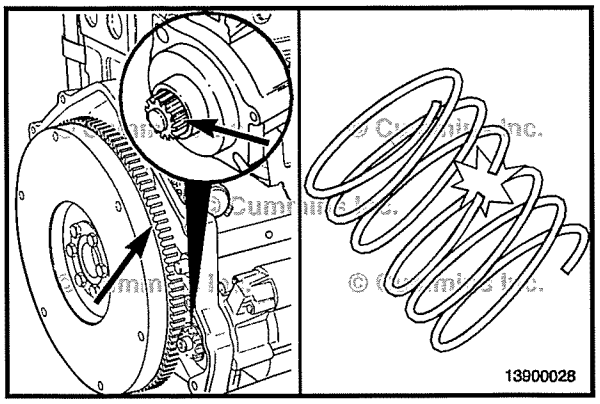
For automotive and industrial applications, inspect the flexplate ring gear teeth for damage.

If the flexplate ring gear is damaged make sure to inspect the following possible causes prior to replacing the flexplate.

Mechanical

A mechanical issue can typically be identified by seeing damage to the ring gear of the flexplate in 3 distinct locations for 6 cylinder engines (commonly called 120 degree milling), and 2 locations for 4 cylinder engines (commonly called 180 degree milling). The following could be causes for mechanical issues:

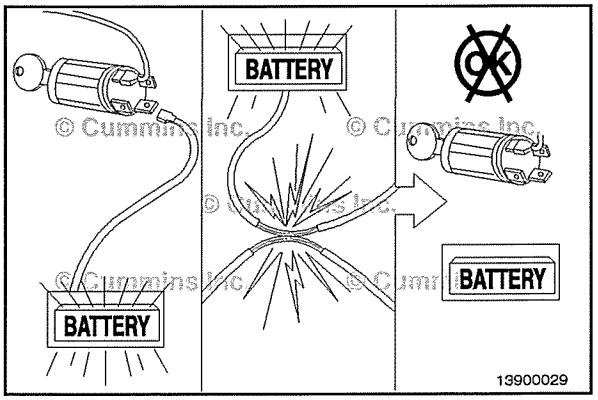
- Upon installation of the flexplate, make sure to check for proper starting motor spacing. Refer to Procedure 013-020 in Section 13.
- Interference between the ring gear land area and the starting motor pinion. The wrong starting motor can be installed. Refer to the original equipment manufacturer's specifications
- There can be a defect with the starting motor pinion. Inspect the pinion for nicks and burrs. Replace the starting motor, if necessary. Refer to Procedure 013-020 in Section 13.
- Torque Converter/transmission is damaged/incorrectly mounted. Refer to the original equipment manufacturer's specifications
- Incorrect starting motor pinion to flexplate ring gear pitch/teeth match. Refer to the original equipment manufacturer's specifications.

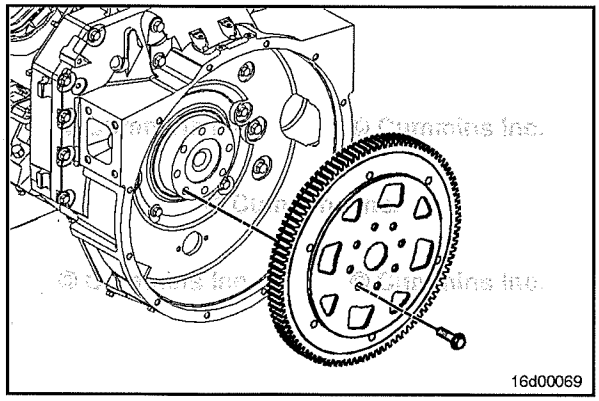


Electrical

An electrical issue can typically be identified by seeing damage to the ring gear of the flywheel 360 degrees around the circumference of the ring gear (commonly called 360 degree milling). The following could be causes for electrical issues:

- Operator is attempting to start engine while engine is already running. Check if a starter lockout feature is available through the OEM (activated with the INSITE™ electronic service tool) or the starting motor manufacturer
- Key switch causing intermittent starting motor engagement when the engine is running. Inspect the key switch. Refer to Procedure 013-030 in Section 13.
- Orientation of the starter relay so that the direction of the pull contact is in the direction of the vehicle's travel. This results in intermittent starting motor engagement when the engine is running. Relocate the starter relay. Refer to the original equipment manufacturer's specifications
- Intermittent starting motor wiring issues. Refer to the original equipment manufacturer's specifications.

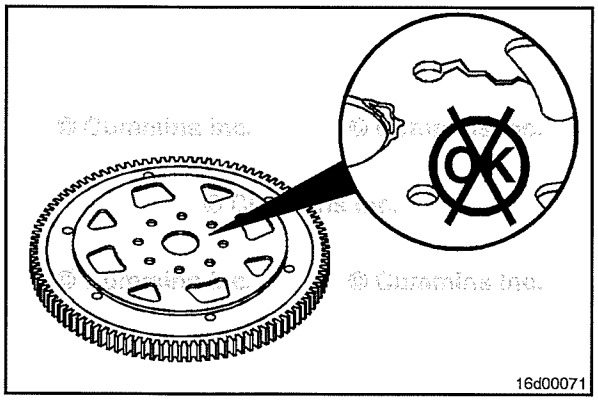




Remove

Remove the flexplate capscrews and flexplate.

NOTE: Some flexplates require mounting plates and/or adapters. It will be necessary to remove any mounting plates and/or adapters prior to or with the flexplate. Make sure to note the location of any mounting plates and/or adapters for later installation.

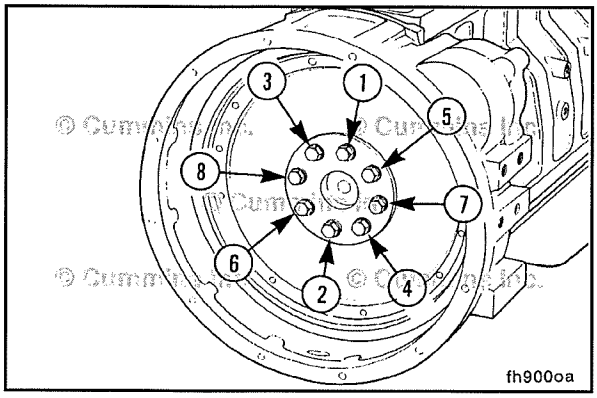


Inspect for Reuse

Inspect the teeth of the ring gear for chips or uneven wear.

Check the flexplate for cracks or other damage.

Replace the flexplate if any damage is found.



Install

NOTE: Some flexplates require mounting plates and/or clamp rings. It will be necessary to install any mounting plates and/or clamp rings prior to or with the flexplate as noted during removal.

Install the flexplate capscrews, flexplate, and tighten.

Torque Value:

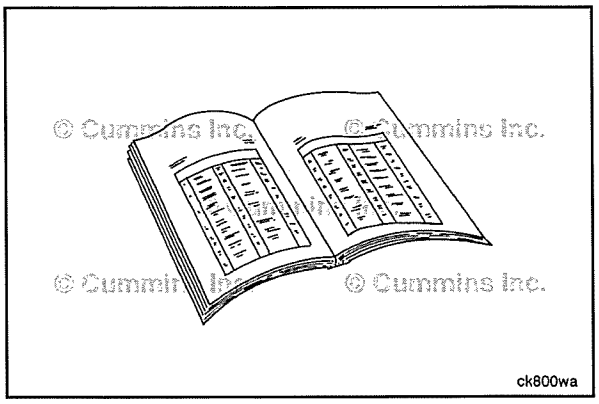
Flexplate Capscrews		
Step 1	30 N•m	[22 ft-lb]
Step 2	Plus 60-degree turn.	

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

- Install the transmission and related components. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.



Flywheel (016-005)

Preparatory Steps

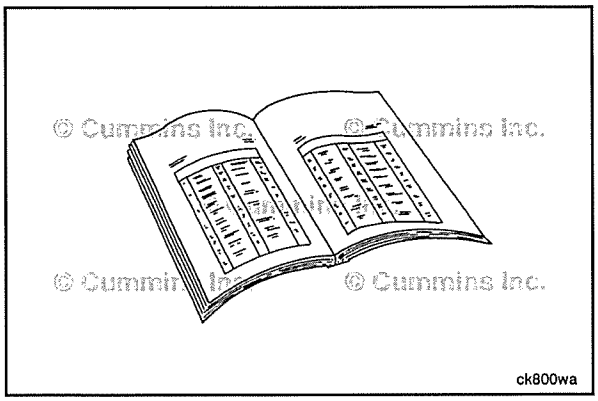
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

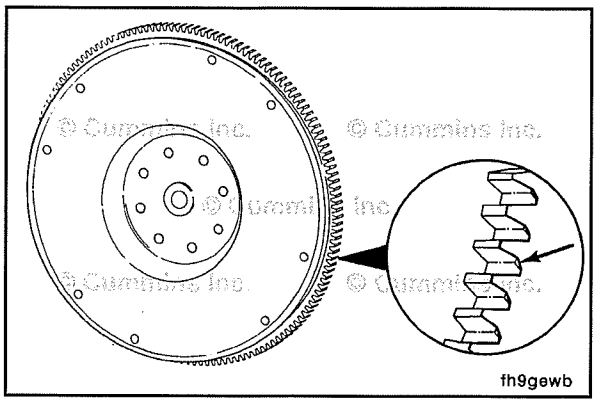
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- If equipped with a wet flywheel housing, drain the oil from the flywheel housing by removing the plug in the bottom of the flywheel housing.

NOTE: Use a container that can hold at least 26 liters [27 qt] of lubricating oil.

- Remove the transmission and all related components, if equipped. Refer to the OEM service manual.



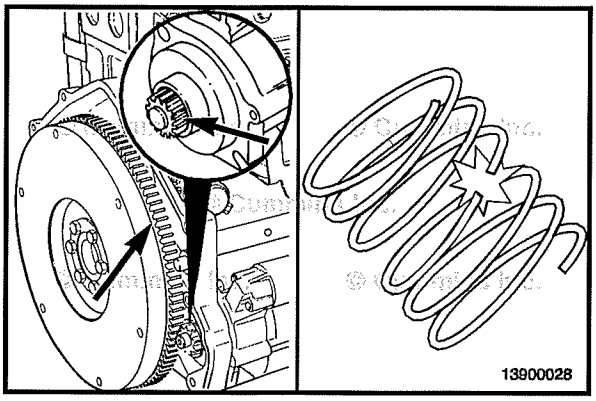


Initial Check

Inspect the flywheel ring gear teeth for damage.

If the flywheel ring gear is damaged make sure to inspect the following possible causes prior to replacing the flexplate.

- Mechanical
- Electrical.



Mechanical

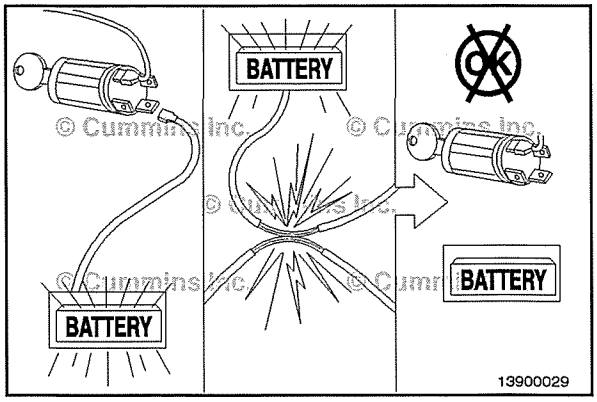
A mechanical issue can typically be identified by seeing damage to the ring gear of the flywheel in 3 distinct locations for 6 cylinder engines (commonly called 120 degree milling), and 2 locations for 4 cylinder engines (commonly called 180 degree milling). The following can be causes for mechanical issues:

- Upon installation of the flywheel, make sure to check for proper starting motor spacing. Refer to Procedure 013-020 in Section 13.
- Interference between the ring gear land area and the starting motor pinion. The wrong starting motor can be installed. Refer to the original equipment manufacturer's specifications.
- There can be a defect with the starting motor pinion. Inspect the pinion for nicks and burrs. Replace the starting motor, is necessary. Refer to Procedure 013-020 in Section 13.
- The ring gear can be improperly installed or damaged. Refer to Procedure 016-008 in Section 16.
- The flywheel face runout may be out of specification. See the Measure section of this procedure.
- Incorrect starting motor pinion to flywheel ring gear pitch/teeth match. Refer to the original equipment manufacturer's specifications.

Electrical

An electrical issue can typically be identified by seeing damage to the ring gear of the flywheel 360 degrees around the circumference of the ring gear (commonly called 360 degree milling). The following could be causes for electrical issues:

- Operator is attempting to start engine while engine is already running. Check if a starter lockout feature is available through the OEM (activated with INSITE™ electronic service tool) or the starting motor manufacturer.
- Keyswitch is causing intermittent starting motor engagement when the engine is running. Inspect the keyswitch. Refer to Procedure 013-030 in Section 13.
- Orientation of the starter relay is positione so the direction of the pull contact is in the direction of the vehicle's travel. This results in intermittent starting motor engagement when the engine is running. Relocate the starter relay. Refer to the original equipment manufacturer's specifications.
- Intermittent starting motor wiring issues. Refer to the original equipment manufacturer's specifications.



Remove

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

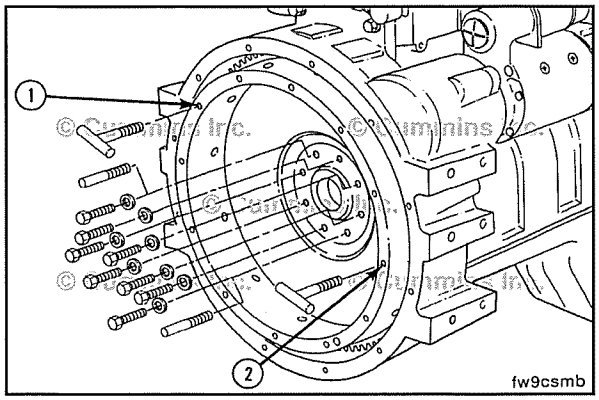
Remove two capscrews 180 degrees apart.

Install two M12 x 1.25 x 90-mm guide pins.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

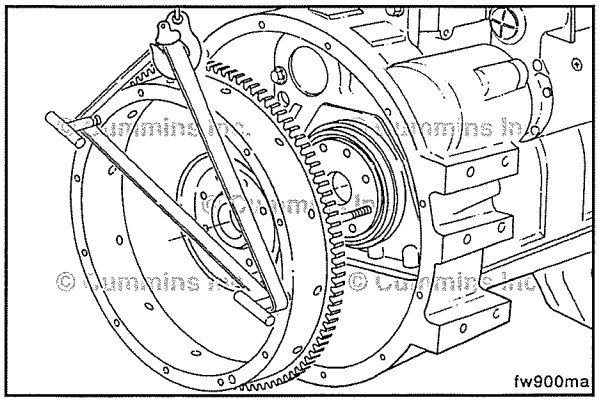
Determine the capscrew thread design and size, and install two T-handles in the flywheel at points (1 and 2).

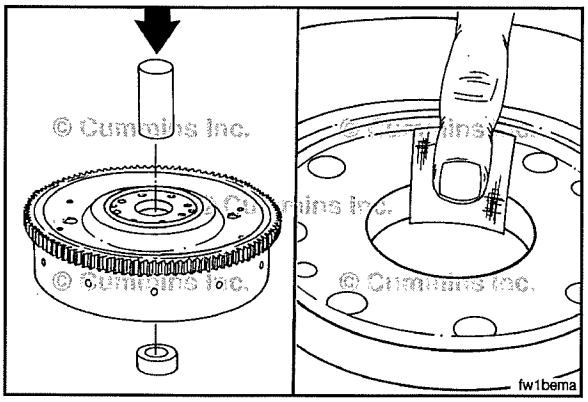
Remove the remaining six flywheel mounting capscrews.



⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Remove the flywheel from the guide pins.





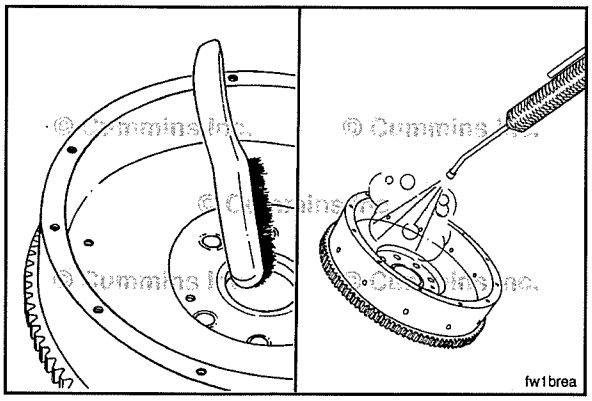
Disassemble

NOTE: Removal of the pilot bearing is only necessary if damaged or when installing a new or rebuilt clutch.

If equipped, remove the pilot bearing.

Use a mandrel and hammer to remove the pilot bearing.

Use an abrasive pad, Part Number 3823258 or equivalent, to clean the pilot bore.



Clean and Inspect for Reuse

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

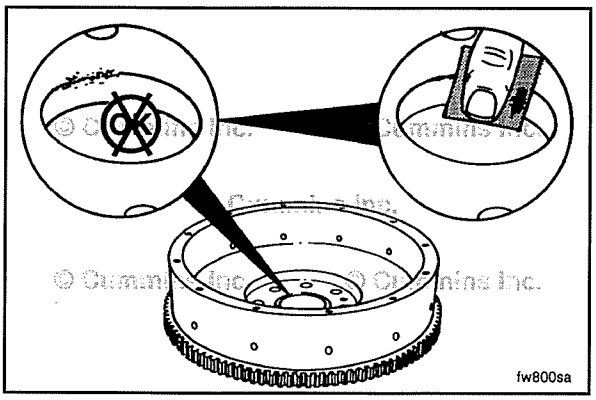
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Compressed air used for cleaning must not exceed 207 kPa[30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

If the pilot bearing was removed, use a wire brush to clean the crankshaft pilot bore.

Use steam or solvent to clean the flywheel.

Dry with compressed air.

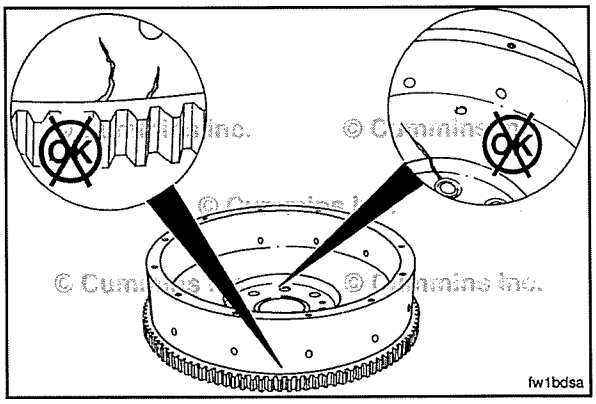


Inspect for nicks or burrs.

Use Scotch-Brite™ 7448 abrasive pad, or equivalent, to remove small nicks and burrs.

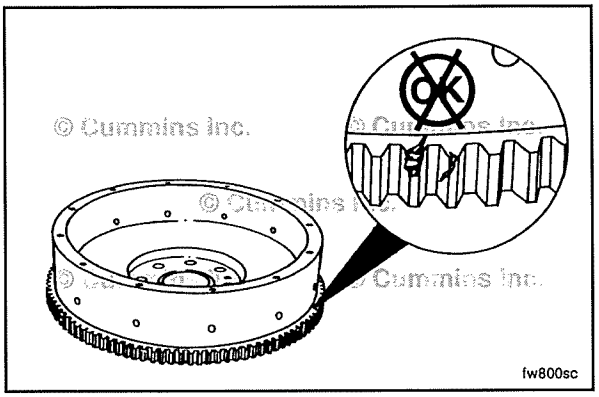
⚠WARNING⚠
Do not use a cracked or resurfaced flywheel. These can break, causing serious personal injury or property damage.

Use the crack detection kit, Part Number 3375432, to check for cracks in the flywheel. Follow the instructions provided with the kit.



Inspect the flywheel ring gear teeth for cracks and chips.

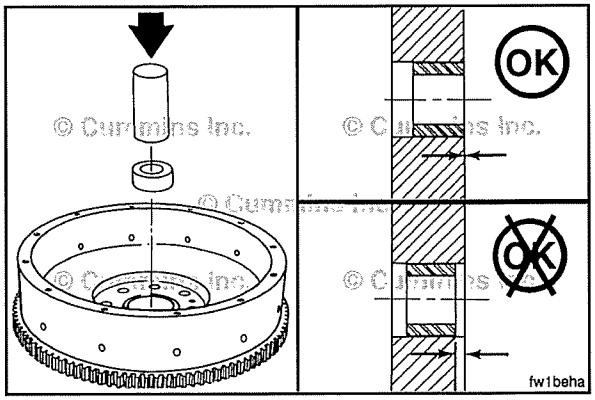
If the ring gear teeth are cracked or broken, the ring gear **must** be replaced. Refer to Procedure 016-008 in Section 16.



Assemble

If removed, install a new pilot bearing.

Use a mandrel and hammer to install the pilot bearing. The pilot bearing **must** be installed evenly with the pilot bore surface.

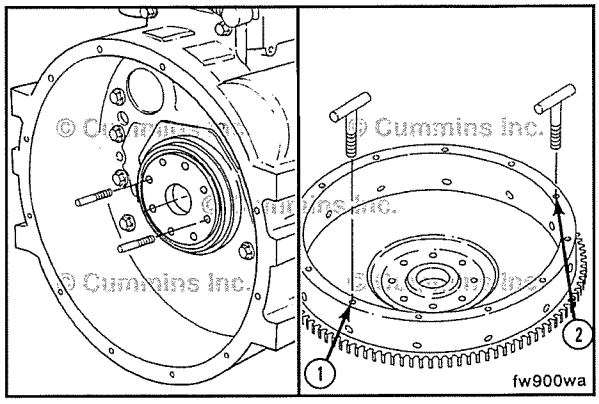


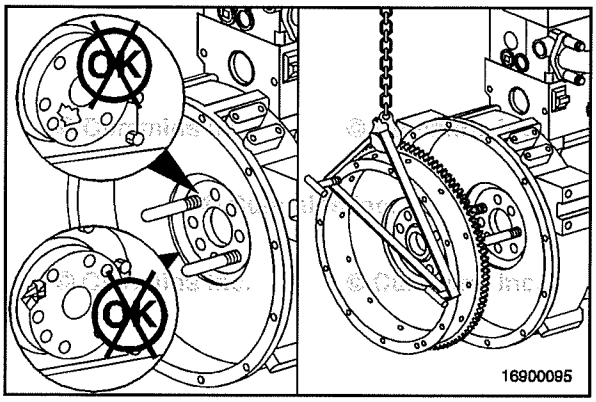
Install

Install two M12 x 1.25 x 90-mm guide pins into the crankshaft flange 180 degrees apart.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

Determine the capscrew thread design and size, and install two T-handles into the flywheel (at points 1 and 2).

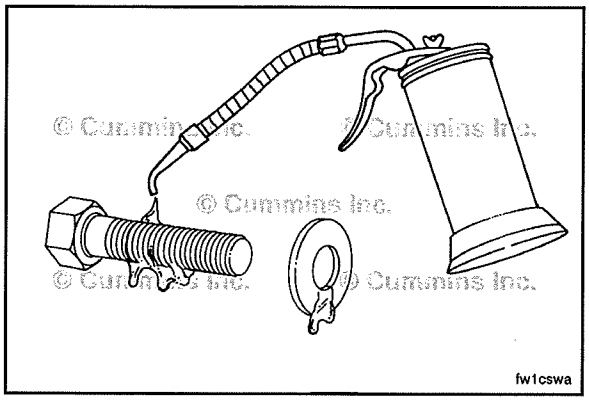




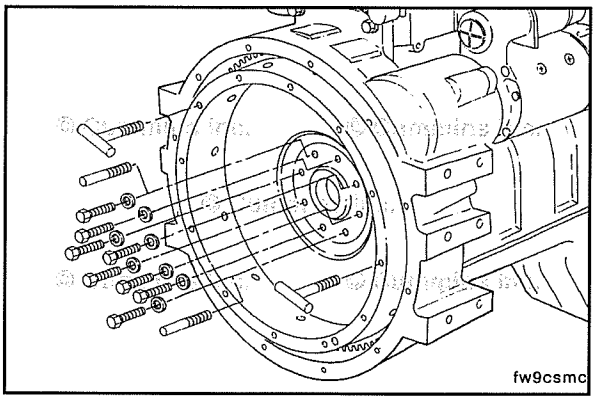
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and raised nicks or burrs.

Install the flywheel on the guide pins.



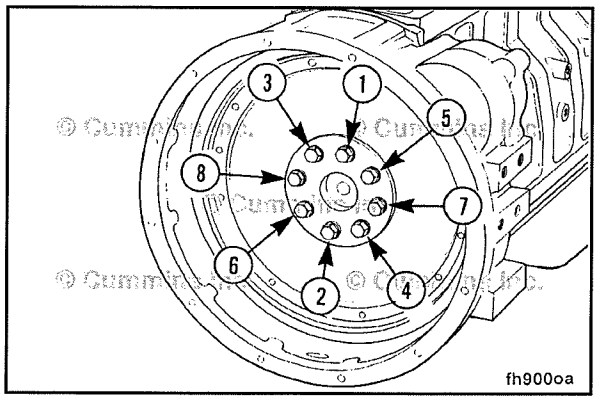
Lubricate the threads of the capscrews and the surface of the washers with clean lubricating engine oil.



Install the six capscrews.

Remove the T-handles and guide pins.

Install the remaining capscrews into the holes from which the guide pins were removed.



NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

Tighten the capscrews in a star pattern.

Torque Value:

Step 1	30 N•m	[22 ft-lb]
Step 2	Plus 60-degree turn	

Measure

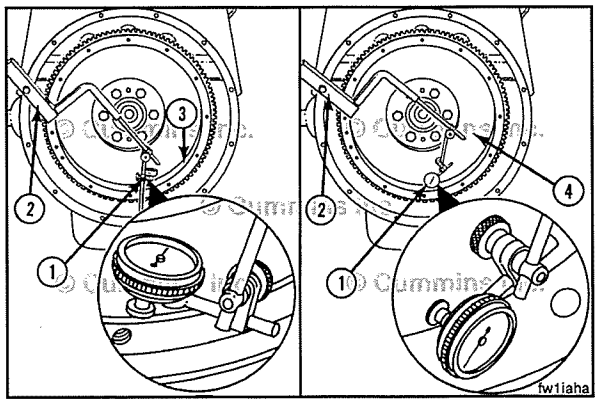
Bore Runout

Use the dial indicator gauge (1), Part Number 3376050, or its equivalent, and dial gauge attachment (2), Part Number ST-1325, to inspect the flywheel bore (3) and the surface (4) runout.

Install the attachment to the flywheel housing.

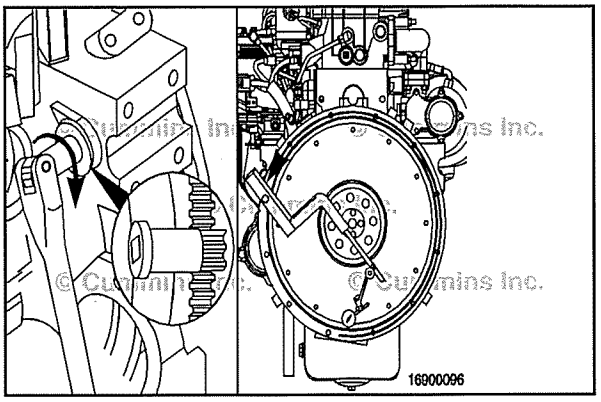
Install the gauge on the attachment.

Install the contact tip of the indicator against the inside diameter of the flywheel bore, and set the dial indicator at zero.



Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution.

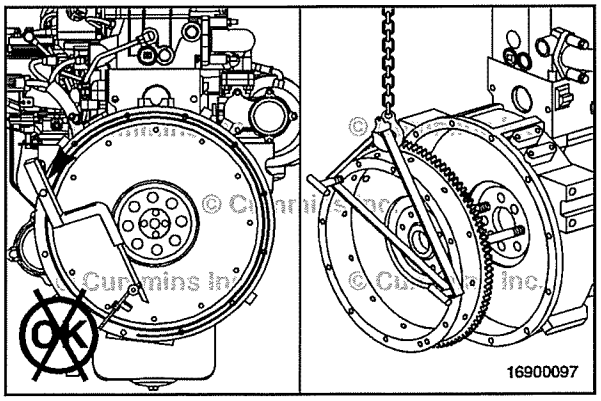
Flywheel Total Indicator Reading		
mm		in
0.127	MAX	0.0050



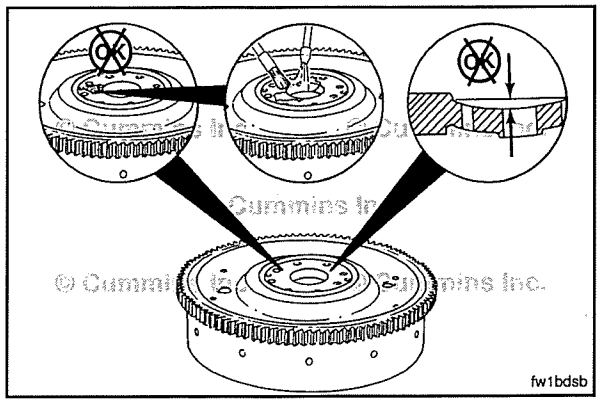
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

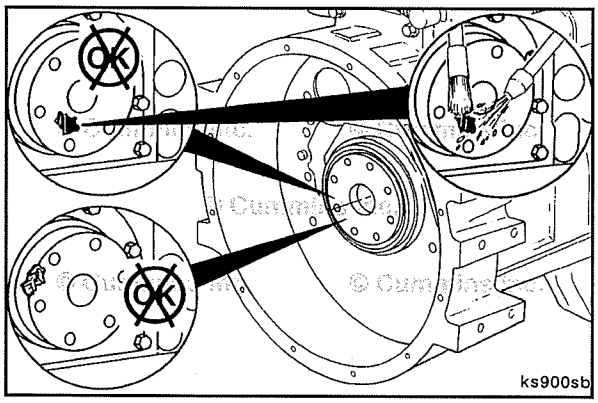
If the total indicator reading is greater than the specification, do the following:

- Remove the flywheel.

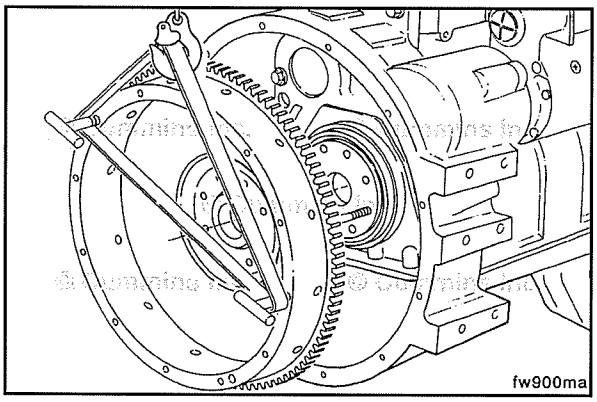


- Inspect the flywheel mounting surface for dirt or damage.



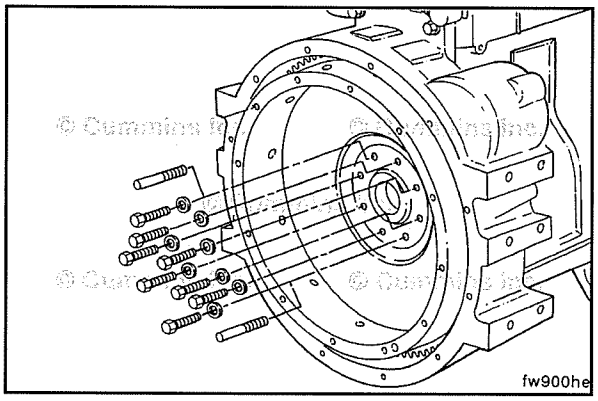


- Inspect the crankshaft for dirt or damage.



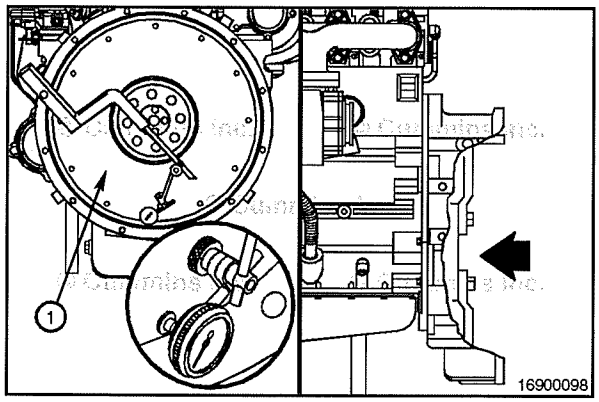
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

- Install the flywheel.
- Inspect the bore runout again.



- Replace the flywheel if the runout does **not** meet specifications.

Flywheel Bore Runout		
mm		in
0.127	MAX	0.005



Face Runout

Flywheel Face Runout

Install the contact tip of the indicator against the flywheel face.

When locating the contact tip, see the Flywheel Face Runout Total Indicator Reading Table later in this procedure. Locate the contact tip so that it corresponds with a radius listed in the table, but is still as close to the outside diameter of the flywheel as possible, to inspect the flywheel face (1) runout.

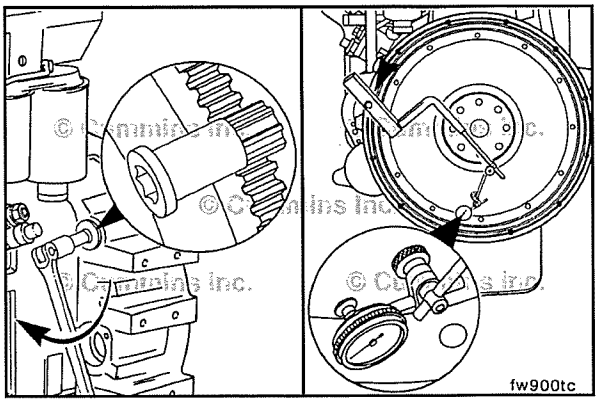
Push the flywheel forward to remove the crankshaft end clearance. Adjust the dial on the indicator until the needle points to zero.

Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution. Measure and record the flywheel runout at four equal points on the flywheel.

The flywheel **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

Determine the total indicator reading (TIR).

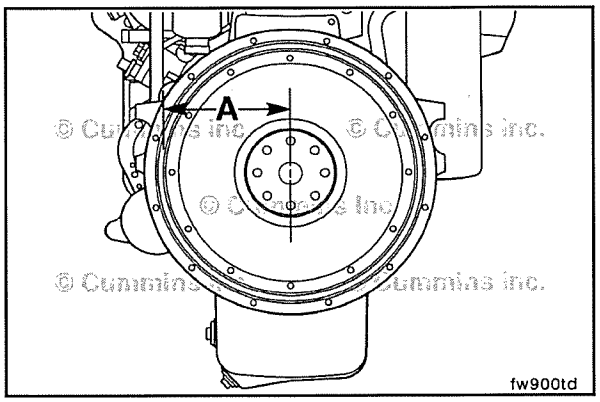
Total indicator reading is determined by calculating the difference between the highest and lowest measurement from the four locations measured.



Measure the distance from the center of the flywheel to the contact tip of the indicator (A). Use this measurement to determine which specification to use from the table below.

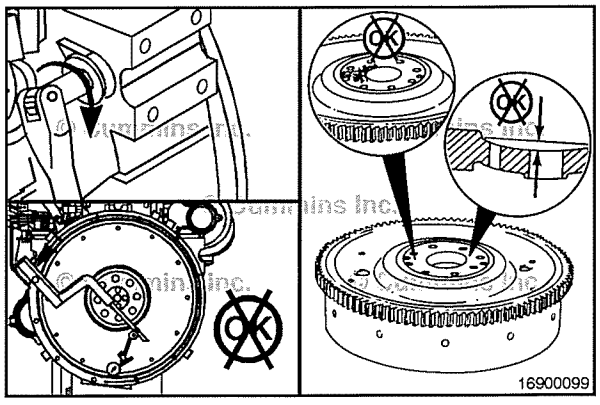
The total indicator reading **must not** exceed the following specifications:

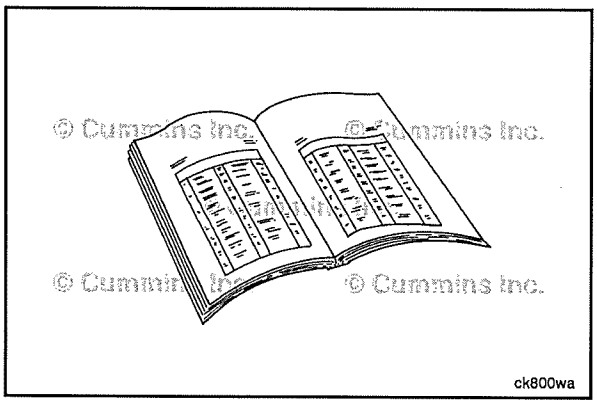
Flywheel Radius (A)		Maximum Total Indicator Reading of Flywheel Face	
mm	in	mm	in
101.6	4	0.140	0.004
127	5	0.13	0.005
152.4	6	0.156	0.006
177.8	7	0.182	0.007
203.2	8	0.208	0.008
228.6	9	0.234	0.009
254	10	0.26	0.01



If the flywheel face runout is **not** within specifications, remove the flywheel. First check for nicks, burrs, or foreign material between the flywheel mounting surface and the crankshaft flange.

Replace the flywheel if the runout is **not** within specification.





Finishing Steps

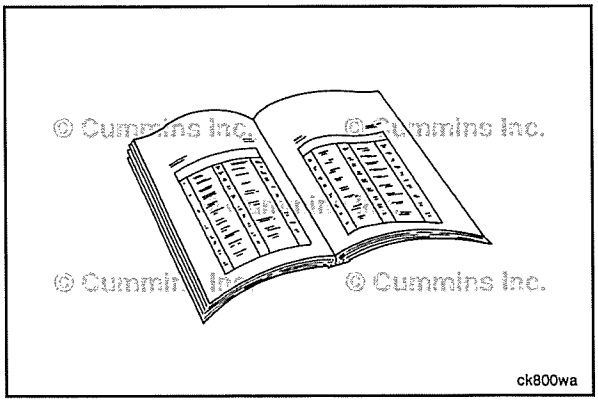
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the transmission and all related components, if equipped. Refer to the OEM service manual.
- If equipped with a wet flywheel housing, fill the flywheel housing with oil. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for noise or vibration.

Flywheel Housing (016-006)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

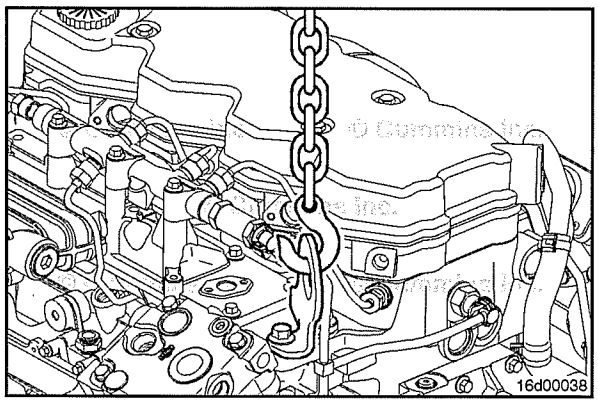
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use lifting equipment to lift this component or assembly.

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the cylinder head. Failure to support the engine can cause personal injury.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.

NOTE: Use a container that can hold at least 16 liters [27 qt] of lubricating oil.

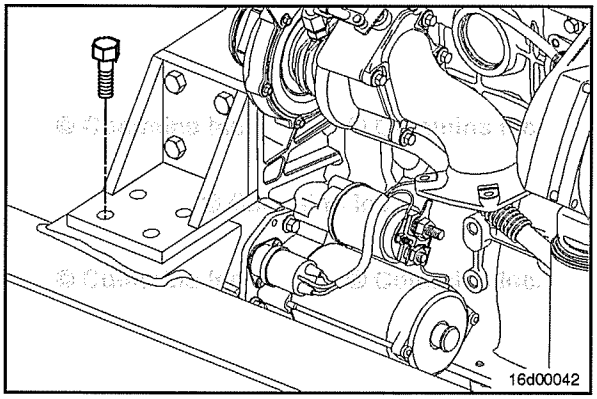
- If equipped with a wet flywheel housing, drain the oil from the flywheel housing by removing the plug in the bottom of the flywheel housing.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the transmission, clutch, and all related components, if equipped. Refer to the OEM service manual.
- Remove the flexplate assembly, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel assembly, if installed. Refer to Procedure 016-005 in Section 16.
- Remove the rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Remove any OEM-attached components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM service manuals.
- For engines equipped with external mounted breather system, remove the necessary components to remove the flywheel housing. Refer to Procedure 003-001 in Section 3.



Remove

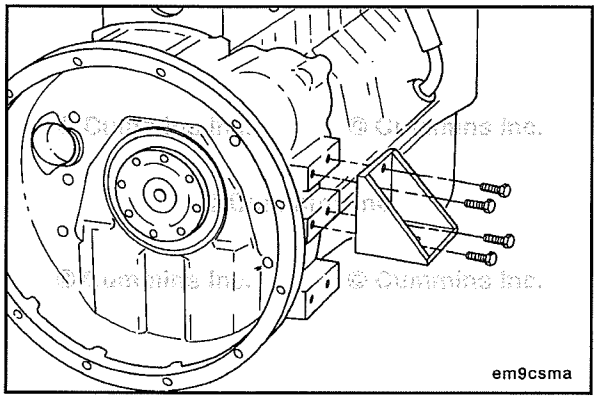
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Use a hoist or lifting fixture to support the rear of the engine.



NOTE: When removing the rear engine mount fasteners, keep track of the location of any shims or spacers used.

Remove the engine mount fasteners.



Remove the rear support capscrews and bracket.

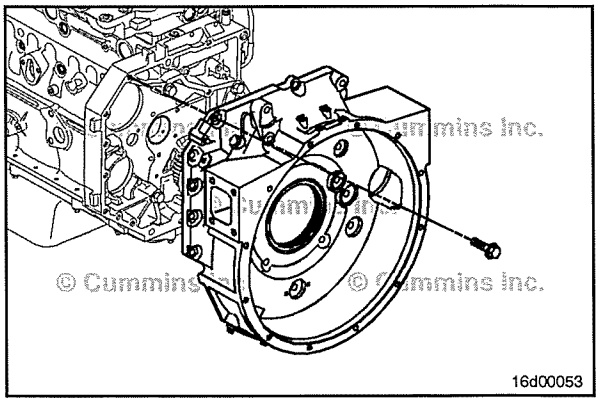
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use lifting equipment to lift this component or assembly.

Loosen the flywheel housing capscrews, but do **not** remove.

Use a rubber hammer to loosen the flywheel housing so that the seal is broken between the flywheel housing and rear gear housing.

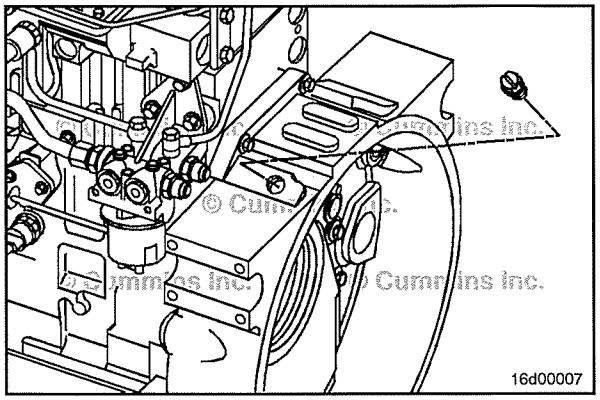
While supporting the flywheel housing, remove the mounting capscrews and the flywheel housing.

Note the location of the flywheel housing capscrews as removed. Some of the capscrews are different length/size fasteners and **must** be installed in the same location as removed.

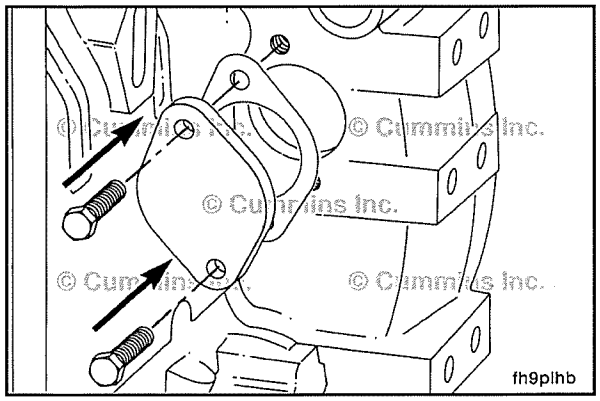


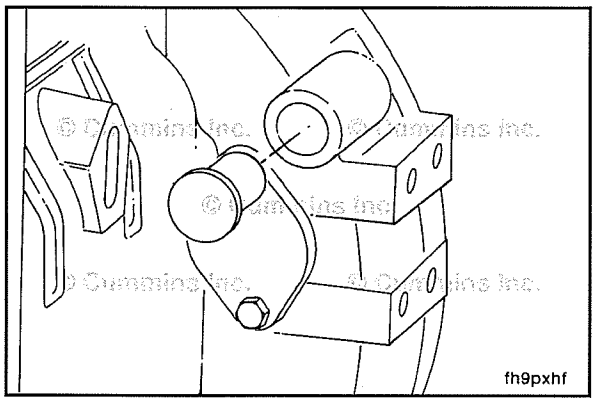
Disassemble

Remove and note the location of any threaded plugs in the flywheel housing.

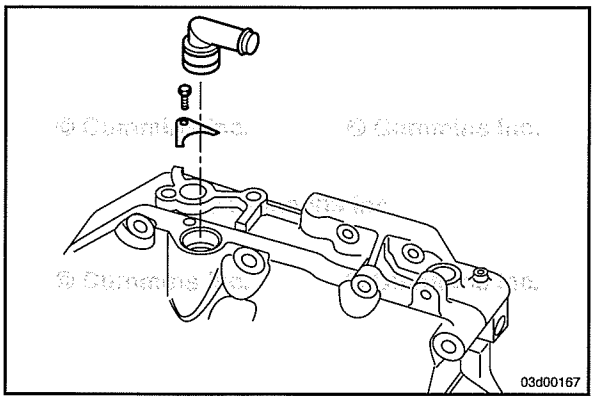


Remove the access plate and, if equipped, the gasket.





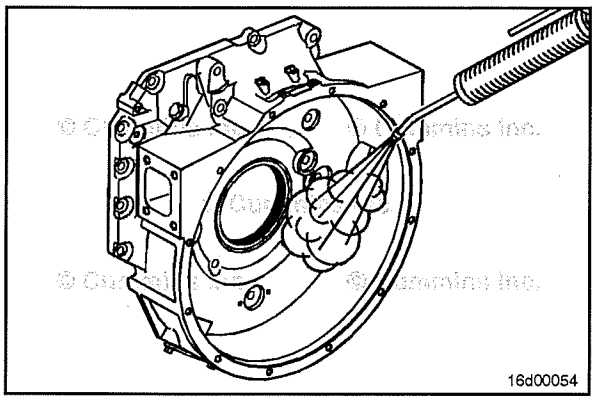
Remove the plug from the barring gear hole.



For engines with an externally mounted breather system, remove the capscrews securing the crankcase ventilation tube adapter clamp plate to the flywheel housing.

Remove the clamp plate.

Remove the crankcase ventilation tube adapter.



Clean and Inspect for Reuse

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

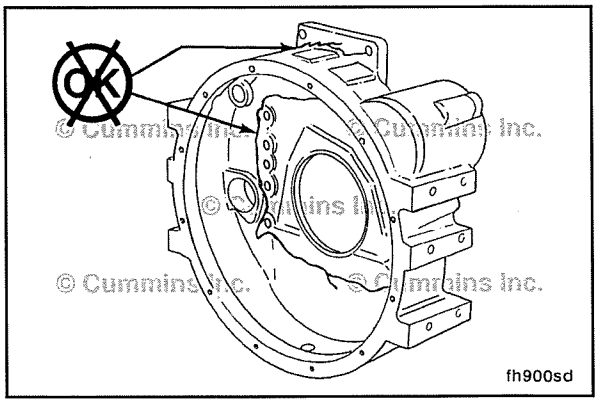
⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Use only with protective clothing, as well as goggles/shield, and gloves to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam or solvent to clean the flywheel housing.

Dry with compressed air.

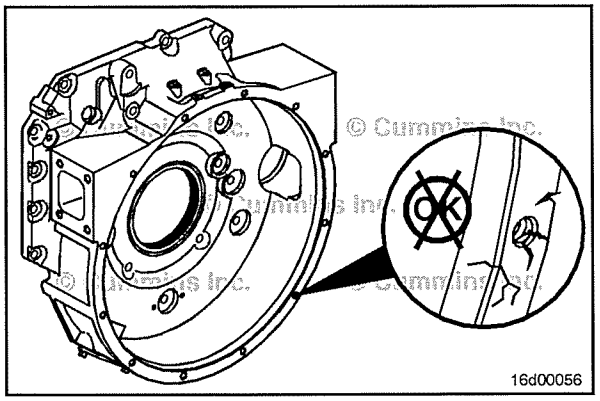
Inspect the flywheel housing for cracks, especially in the area of the flywheel housing that mounts to the rear gear housing.



Inspect the flywheel housing transmission/drive unit mounting surface for cracks.

Also inspect for damaged threads commonly caused by cross-threaded capscrews or installing an incorrect capscrew.

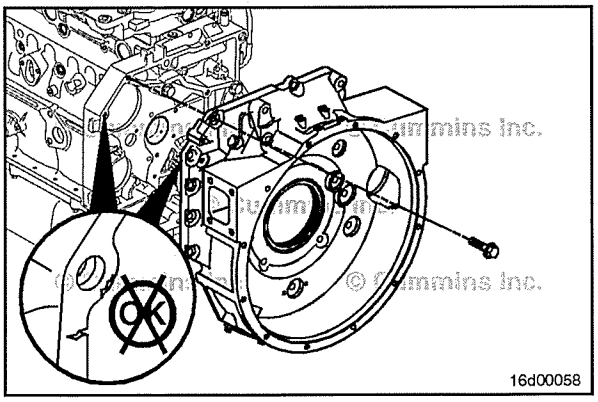
NOTE: Helicoils are available to repair damaged threads.

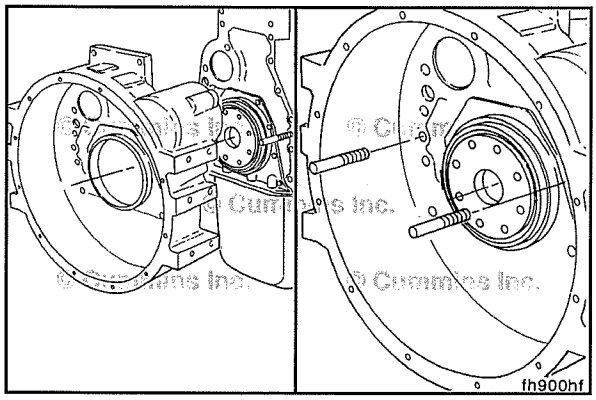


Inspect the rear face of the gear housing and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

Use fine crocus cloth to remove small nicks and burrs.

Thoroughly clean the flywheel housing and gear housing mating surfaces. These surfaces **must** be clean of oil and debris.





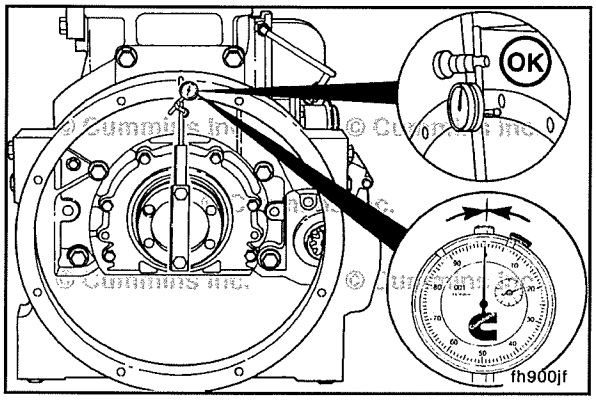
Measure

⚠CAUTION⚠
When barring the engine using service tool, Part Number 3824591, be careful to not apply excessive side loading to the flywheel housing. This may cause the flywheel housing to move and cause inaccurate measurement readings.

NOTE: Follow this step **only** if the rear gear housing is being replaced or if troubleshooting a vibration/alignment issue. It is **not** necessary to measure bore alignment or face alignment when installing the original rear gear housing unless the dowel rings were removed during a previous repair.

Install the flywheel housing following the Install Step of this procedure, but do **not** torque the capscrews. **Only** tighten the capscrews enough to hold the flywheel housing in place.

Service Tip: When installing a new flywheel housing to check flywheel housing bore alignment and face alignment, do **not** apply sealant to the flywheel housing prior to installing for measurement.



Face Alignment

⚠CAUTION⚠
The dial indicator tip must not enter the capscrew holes, or the gauge will be damaged.

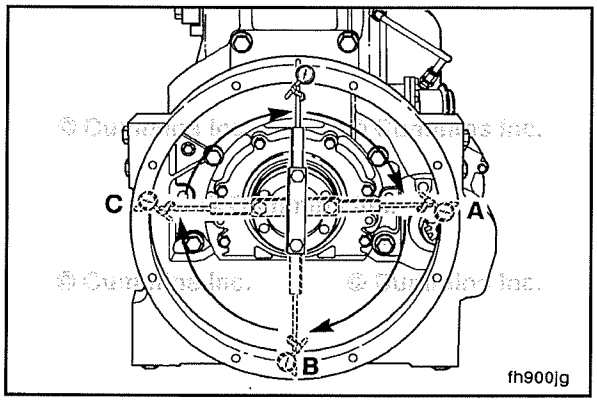
Face alignment is determined by calculating the total indicator reading (TIR).

Attach the dial indicator gauge, Part Number 3376050, to the crankshaft. Use mounting tool, Part Number ST1325, to attach the dial indicator to the crankshaft as illustrated.

NOTE: The dial indicator can be mounted by any method that holds the extension bar of the indicator rigid, so it does **not** sag. If the bar sags or the indicator slips, the readings obtained will **not** be accurate.

Position the indicator at the 12-o'clock position, and zero the gauge.

NOTE: The crankshaft **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.



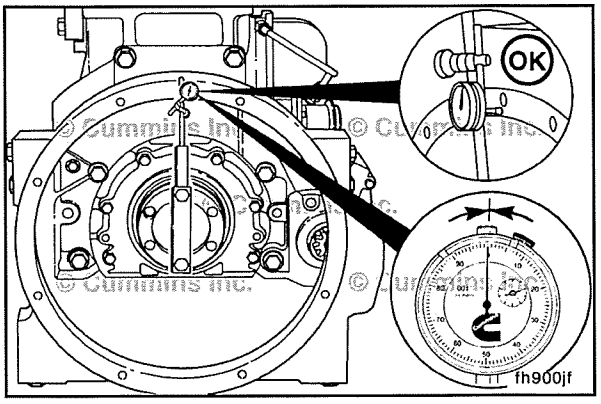
Use the barring tool, Part Number 3824591, to slowly rotate the crankshaft.

Record the readings at the 3-o'clock (A), 6-o'clock (B) , and 9-o'clock positions (C).

The values for A, B, and C can be positive or negative.

Continue to rotate the crankshaft until the indicator is at the 12-o'clock position.

Check the indicator to make sure the needle points to zero. If it does **not**, the readings will be incorrect and the procedure will have to be repeated.



Determine the total indicator reading (TIR).

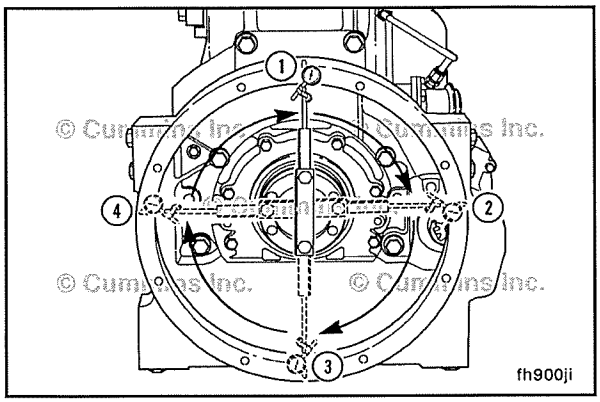
TIR is determined by calculating the difference between the highest and lowest measurement from the four locations measured.

As the example below illustrates, the TIR is:

+ 0.08 mm - (-0.05 mm) = 0.13 mm

[+.003 in - (-0.002 in) = 0.005 in]

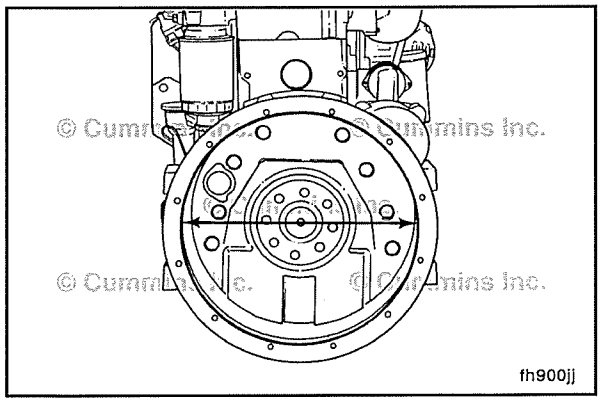
Example:		
12 o'clock	0.00 mm	[0.000 in]
3 o'clock	+0.08 mm	[+0.003 in]
6 o'clock	- 0.05 mm	[- 0.002 in]
9 o'clock	+0.08 mm	[+0.003 in]
Equals TIR	0.13 mm	[0.005 in]

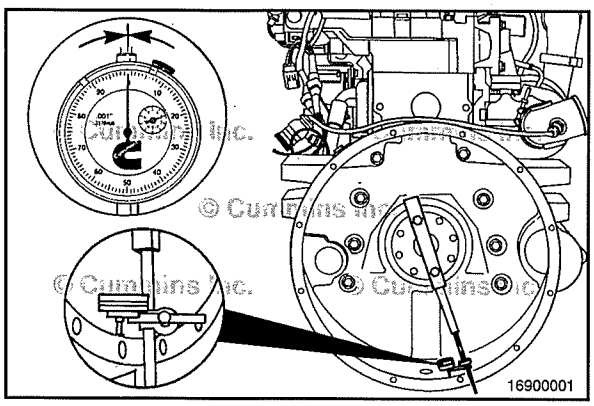


The maximum allowable total indicator reading (TIR) is determined by the diameter of the housing bore. If out of specifications, replace the housing.

NOTE: The rear gear housing can also be the cause of the TIR being out of specification.

Flywheel Housing Bore and Face Runout				
SAE	**Bore Diameter**			**Total Indicator Reading Maximum**
Number	mm	in	mm	in
00	784.15 to 784.65	30.990 to 31.010	0.48	0.19
0	657.45 to 647.95	25.490 to 25.510	0.41	0.016
1/2	584.00 to 584.40	22.992 to 23.008	0.36	0.014
1	510.98 to 511.38	20.117 to 20.133	0.40	0.016
2	447.55 to 447.81	17.620 to 17.630	0.40	0.016
3	409.45 to 409.71	16.120 to 16.130	0.40	0.016



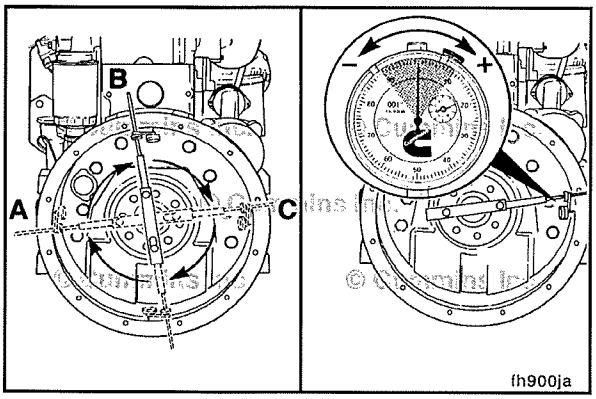


Bore Alignment

Attach the dial indicator gauge, Part Number 3376050, to the crankshaft. Use mounting tool, Part Number ST1325, to attach the dial indicator to the crankshaft as illustrated.

NOTE: The dial indicator can be mounted by any method that holds the extension bar of the indicator rigid, so it does **not** sag. If the bar sags or the indicator slips, the readings obtained will **not** be accurate.

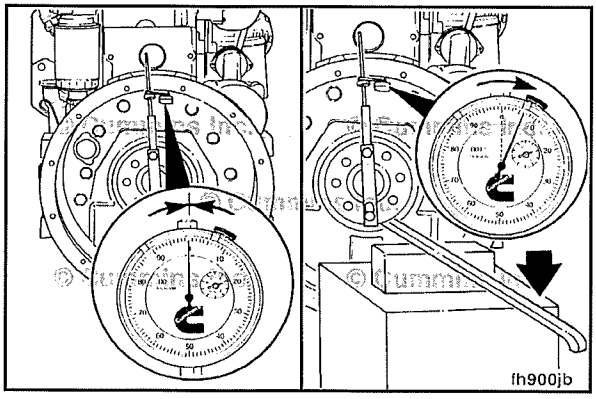
Position the indicator in the 6-o'clock position, and zero the gauge.



Slowly rotate the crankshaft. Record the readings obtained at the 9-o'clock, 12-o'clock, and 3-o'clock positions as A, B, and C in the concentricity work sheet.

Check zero at the 6-o'clock position. If it does **not**, the readings will be incorrect and the procedure will have to be redone.

The values for A, B, and C can be positive or negative. See the accompanying figure to determine the correct sign when recording these values.



△CAUTION△

Do not force the crankshaft beyond the point where the bearing clearance has been removed. Do not pry against the flywheel housing. These actions could cause false bearing clearance readings and result in engine damage.

Rotate the crankshaft until the dial indicator is at the 12-o'clock position and zero the gauge.

Use a pry bar to raise the rear of the crankshaft to its upper limit. Record the value as D on the concentricity work sheet. This is the vertical bearing clearance adjustment, which will **always** be positive.

Create a concentricity work sheet as illustrated to determine the values for the "total vertical" and "total horizontal" values.

NOTE: The values listed in the concentricity work sheet illustrated are for example only and are listed in inches. The actual numbers measured may differ.

Input the values recorded for A, B, C and D into the concentricity work sheet.

The total horizontal is the 9-o'clock reading, A, minus the 3-o'clock reading, C.

The total vertical is the 12-o'clock reading, B, plus the bearing clearance, D.

Example:

- Six o'clock = reference = 0
- Nine o'clock = (a) = 0.004
- Twelve o'clock = (b) = 0.003
- Three o'clock = (c) = (-0.002)

Using the work sheet and the numbers from the example, the total horizontal value equals 0.006 and the total vertical value equals 0.005.

Concentricity Worksheet

9 o'clock	a = 0.004
3 o'clock	c = -0.002
Total Horizontal	a – c = .006
12 o'clock	b = .003
Bearing Clearance	d = .002
Total Vertical	b + d = .005

oi900vf

NOTE: Use the corresponding chart for the SAE 1, 2 or 3 flywheel housings being measured.

Using the illustration, mark the total horizontal value on the horizontal side of the chart and the total vertical on the vertical side of the chart.

Use a straightedge to find the intersection point of the total horizontal and total vertical values. The intersection point **must** fall within the shaded area for the flywheel housing concentricity to be within specification.

Using the total horizontal and total vertical values from the previous example, the intersection point falls within the shaded area. Therefore, the flywheel housing concentricity is within specification.

NOTE: Make sure to use the correct total indicator reading (TIR) specifications for the flywheel housing being measured when comparing measurements.

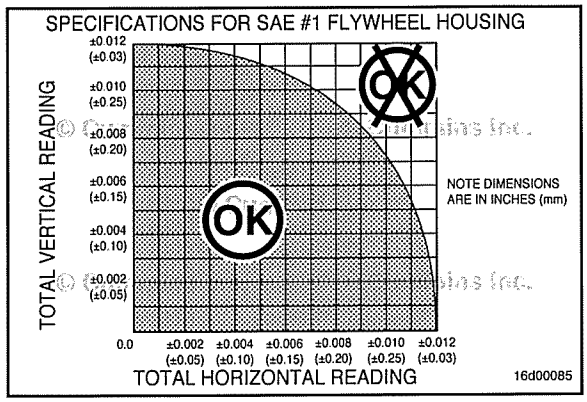
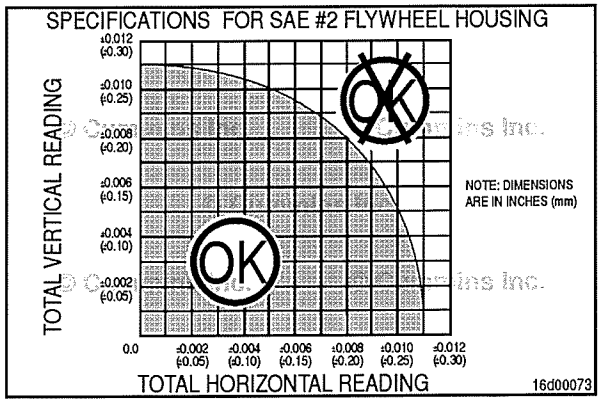


Chart for an SAE 2 flywheel housing.



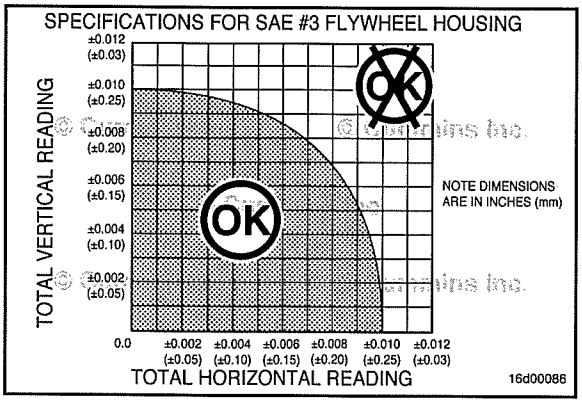
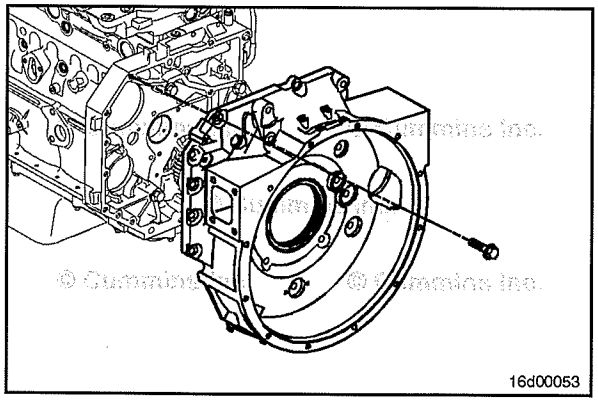


Chart for an SAE 3 flywheel housing.

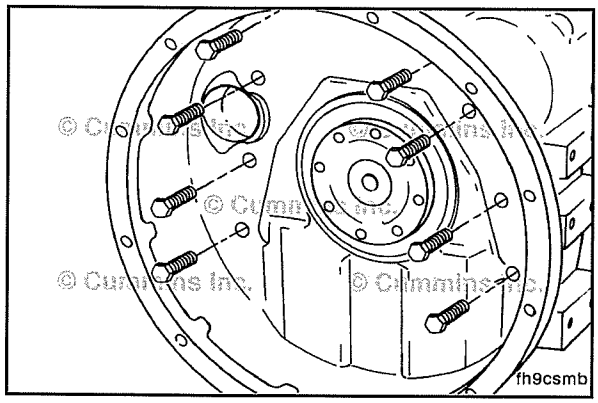


⚠CAUTION⚠
Do not remove the dowel rings located in the rear gear housing in an attempt to relocate the flywheel housing. The dowel rings are required to locate the rear gear housing to the cylinder block for proper gear alignment. Improper gear alignment will result in engine damage.

If the bore alignment is out of specification:

1 Determine if the flywheel housing, rear gear housing, or cylinder block has recently been replaced. If any of these components have been replaced, remove and inspect/replace the component.

2 If the flywheel housing, rear gear housing or cylinder block have **not** been recently replaced. Remove the flywheel housing. Inspect the rear gear housing and flywheel housing mounting surfaces. If no damage is found, remove the rear gear housing and inspect the cylinder block and rear gear housing mounting surfaces.



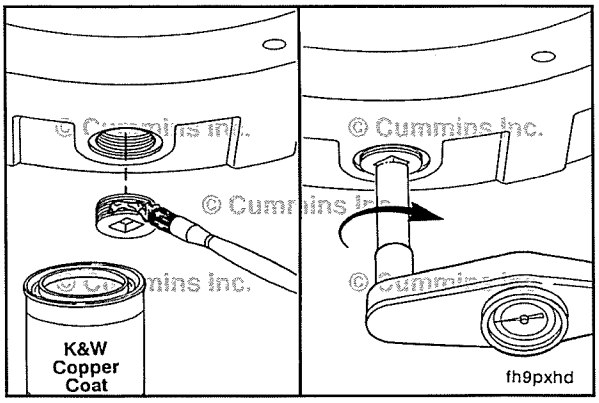
After the ring dowels are discarded, install the flywheel housing on the engine following the Install Step of this procedure, but do **not** torque the capscrews. Tighten the capscrews enough to hold the flywheel housing in place, but loose enough to allow small movement when struck lightly with a rubber mallet.

Check the bore alignment. When bore alignment is within specification, tighten the capscrews to the specified torque value outlined in the Install Step of this procedure.

Assemble

For wet flywheel housings, apply pipe sealant, Part Number 3375066, to any threaded plugs previously removed.

Install and tighten the plugs. Refer to Procedure 017-007 in Section 17.

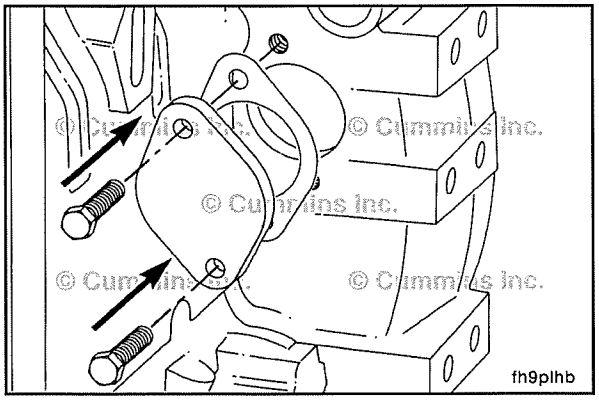


Install the access plate and new gasket.

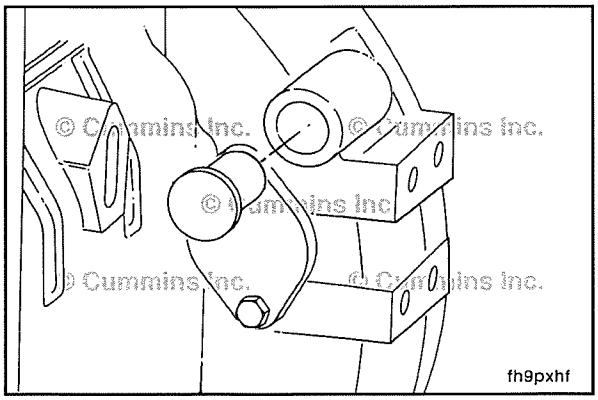
Install the capscrews and tighten.

Torque Value: 24 N•m [212 in-lb]

NOTE: If a gasket was **not** previously installed, apply sealant, Part Number 3164067, to the perimeter of the access plate.



Install the barring gear hole plug with a new o-ring.

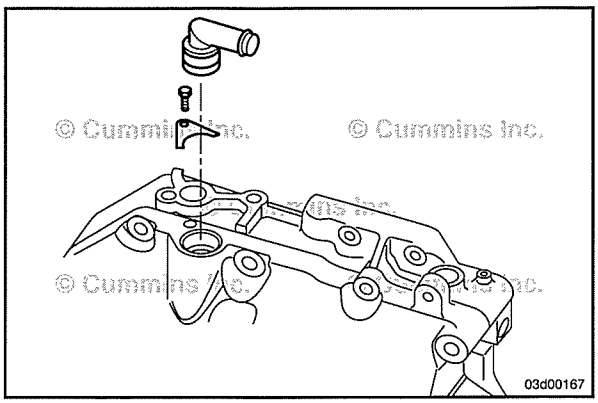


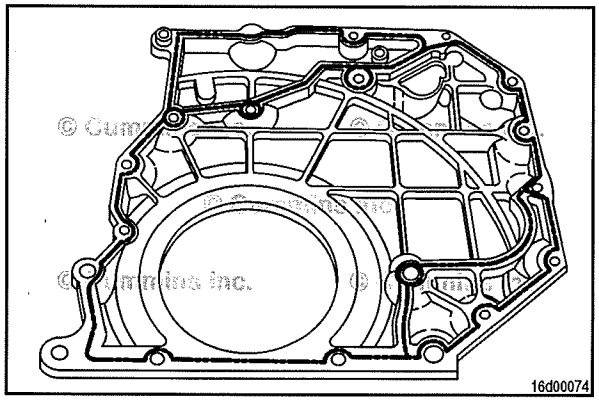
For engines with an externally mounted breather system, lubricate the o-ring on the crankcase ventilation tube adapter with clean engine oil.

Install the breather tube adapter in the flywheel housing.

Install the capscrew and clamp plate to secure the breather tube adapter to the flywheel housing.

Torque Value: 24 N•m [212 in-lb]





Install

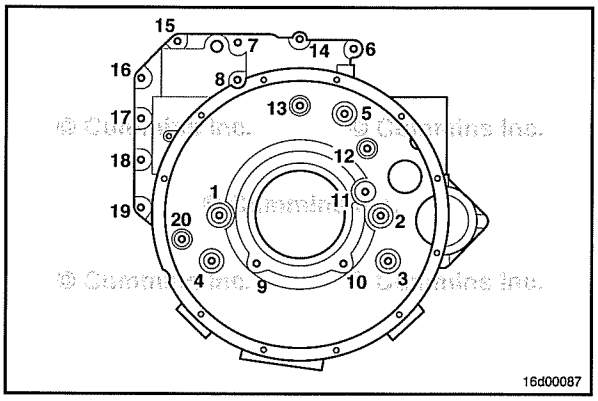
NOTE: Before installing the flywheel housing, make sure any locating dowel rings are in the same position as when the flywheel housing was removed.

NOTE: The sealant called for in the following step can appear different than what was originally used to build the engine.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Part Number 3164070, to the back side of the flywheel housing in the path illustrated.

NOTE: Install the flywheel housing within 10 minutes of applying the sealant or it will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before running the engine.

Install the flywheel housing and capscrews.

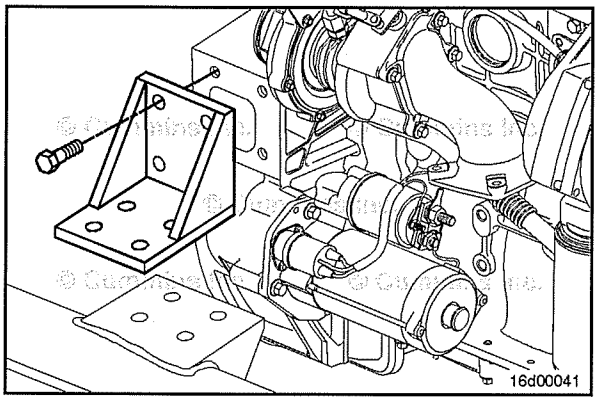


Tighten the flywheel housing capscrews in the sequence shown.

NOTE: Due to different SAE size flywheel housings, the location of the mounting capscrews can appear different than the illustration shown. The sequence shown will work for all sizes of flywheel housings.

Torque Value:
M10 49 N•m [36 ft-lb]

Torque Value:
M12 85 N•m [63 ft-lb]



Install the rear engine support bracket and mounting capscrews.

Torque Value: 77 N•m [57 ft-lb]

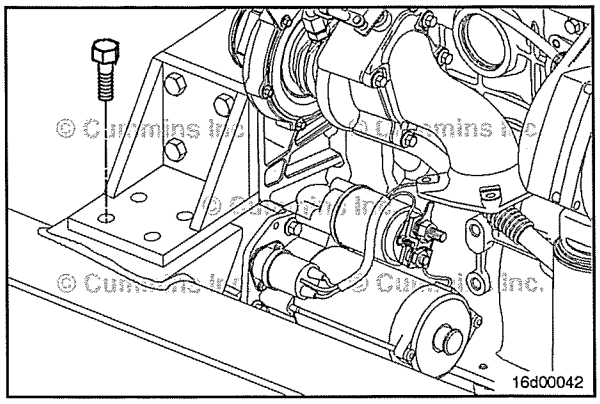
NOTE: Make sure to install any shims or spacers in the same location as removed.

Lower the rear of the engine.

Install the rear engine mount fasteners.

Tighten to the OEM specification.

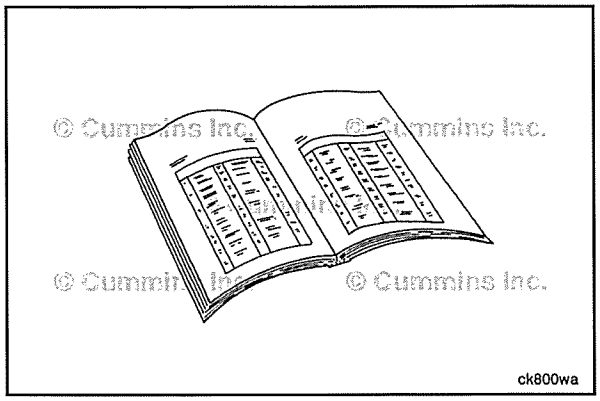
Remove the lifting fixture or hoist from the rear of the engine.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Install the flywheel assembly, if removed. Refer to Procedure 016-005 in Section 16.
- Install the flexplate assembly, if removed. Refer to Procedure 016-004 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the transmission and related components, if equipped. Refer to the OEM service manual.
- If equipped with a wet flywheel housing, fill the flywheel housing with oil. Refer to the OEM service manual.
- If previously removed, attach any OEM components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM service manual.
- For engines equipped with external mounted breather system, install any removed components. Refer to Procedure 003-001 in Section 3.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Flywheel Ring Gear (016-008)

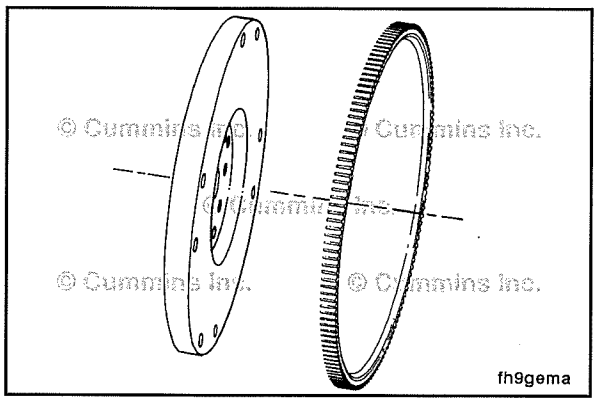
General Information

Prior to removing the damaged flywheel ring gear, first check if:

- The ring gear is removable/replaceable
- A replacement ring gear is available.

If may be necessary to replace the entire flywheel assembly.

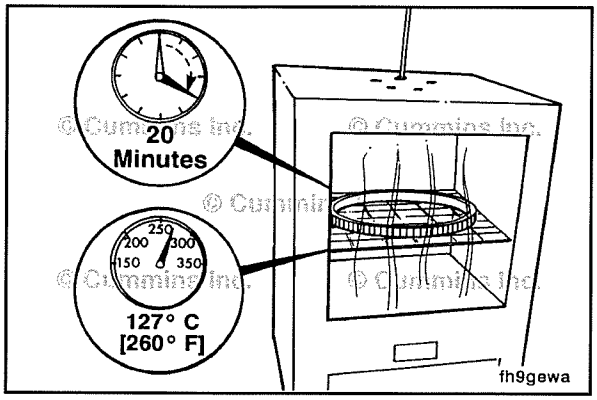
NOTE: The ring gear on a flexplate is **not** replaceable. If the ring gear is damaged on a flexplate, the flexplate **must** be replaced as an assembly.



Disassemble

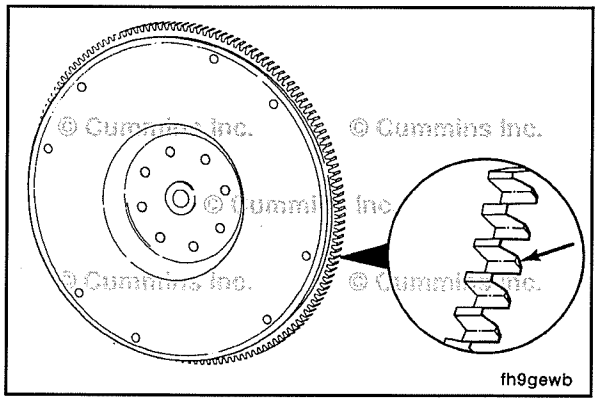
⚠WARNING⚠
To reduce the possibility of severe eye damage, wear eye protection when you drive the gear from the flywheel. Do not use a steel drift pin or damage to the component can occur.

Use the brass drift pin to drive the ring gear from the flywheel.



Assemble

Heat the new ring gear for 20 minutes in an oven preheated to 127°C [261°F].



⚠WARNING⚠
To reduce the possibility of burns, wear protective gloves when installing the heated gear.

The ring gear **must** be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.

Install the ring gear.

Engine Mounts (016-010)

General Information

Some vibration exists in all piston type engines, due to the pulsating power inputs and reciprocating components. Some of these vibrations are internal to the engine and are compensated, or balanced, by opposing forces within the engine structure. These are generally **not** of interest to vibration isolation designs. The vibrations that are offset or balanced internally will cause shaking moments and forces that **must** be reacted to by the engine mounts. If these moments and forces are **not** adequately reduced by the engine mounting and isolation systems, they can cause customer dissatisfaction and/or damage, due to component fatigue.

The effectiveness of an engine mounting system in isolating the vehicle structure from engine vibration depends on the relationship between the frequency of the vibration coming from the engine and the natural frequency of the engine mounting system. The mounting system effectiveness is commonly measured with the term “transmissibility”. Transmissibility is the amount of engine vibration which is transmitted through the mounting system to the vehicle structure.

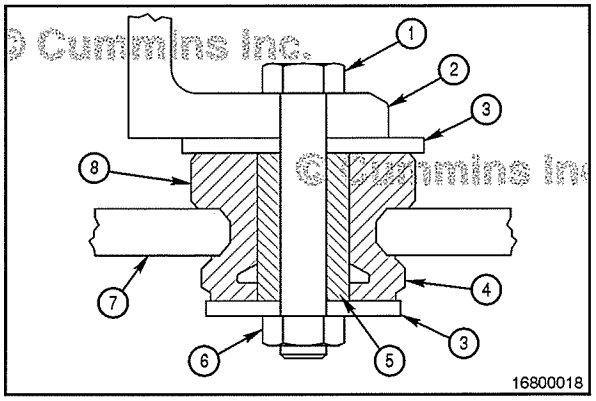
Transmissibility values greater than one indicate the engine mounting system is actually transmitting more vibration into the vehicle structure than is coming from the engine. This is possible if the natural frequency of the mounting system is close to the frequency of the engine vibration. This can result in the mounting system operating at or near resonance, with a resulting magnification of the input vibration. This is obviously an undesirable situation.

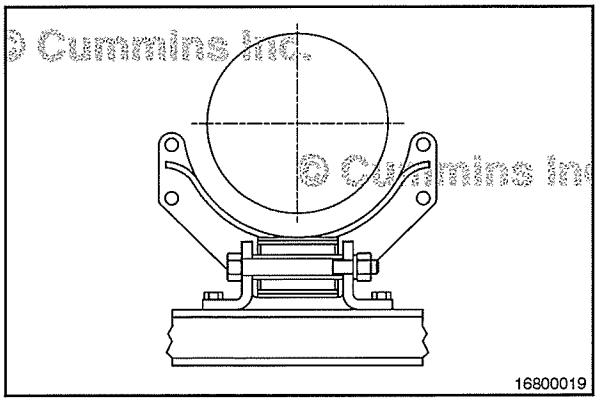
Transmissibility values of less than one indicate the mounting system is transmitting **only** a fraction of the vibration input from the engine, thus isolating the vehicle from engine vibration. Good engine mounts will reduce the amount of engine vibration transmitted to the chassis frame by at least 50 percent at idle.

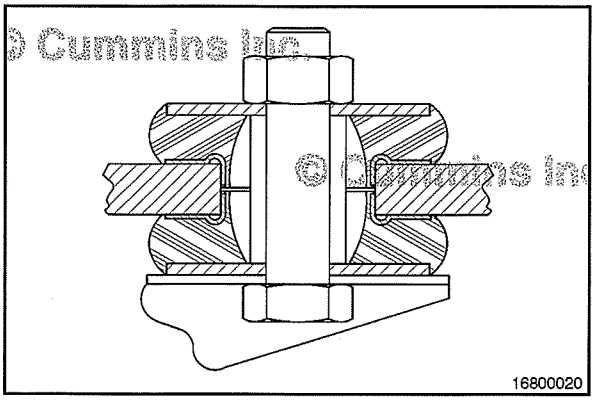
Stiffness (durometer) and size of the isolator, along with the weight of the engine or component applied, are the determining factors when designing a mounting system. An isolator that is correct for one engine may **not** be right for another. Likewise, because of weight differential, a particular isolator designed for the rear of an engine probably will **not** be ideal for the front. Hard engine mounts will give little or no isolation, and can actually magnify the vibration transmitted to the chassis.

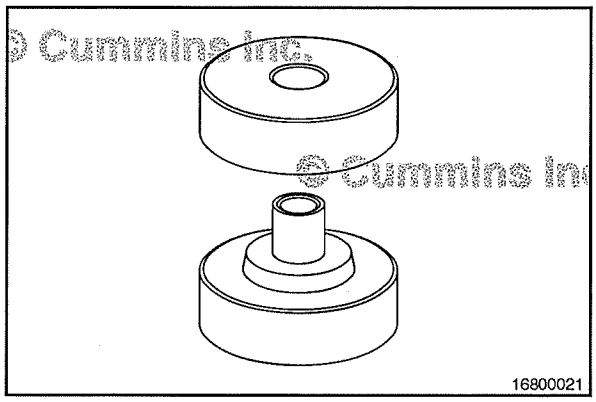
The following are illustrations of typical FRONT engine mounts.

1 Bolt
2 Supported member
3 Snubbing washer (or flat bracket surface of equal diameter
4 Rebound tail
5 Bonded metal center
6 Locknut
7 Supporting member
8 Rubber mount.

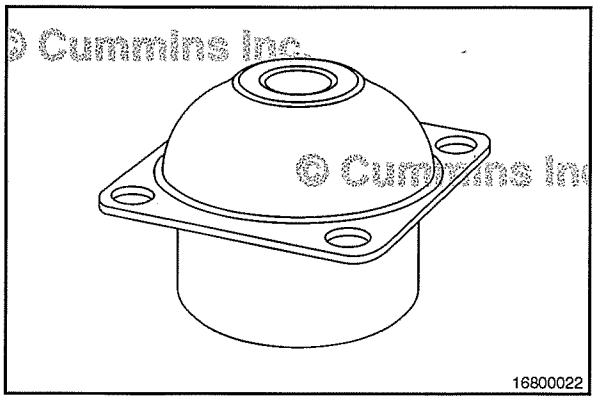


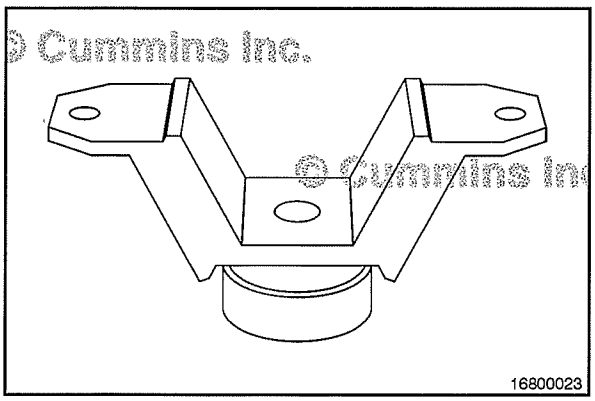


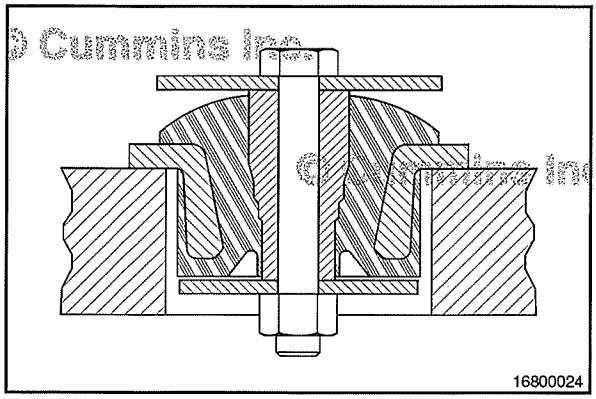


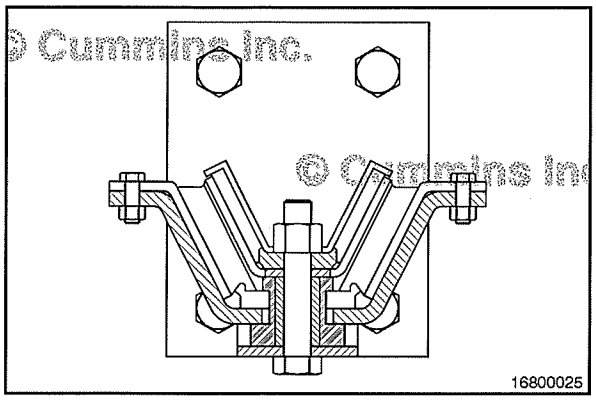


The following are illustrations of typical REAR engine mounts.









Remove

⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

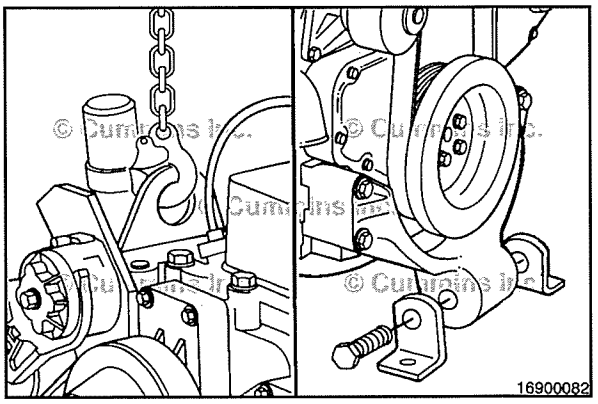
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Use a hoist or lifting fixture to support the engine.

NOTE: When removing the engine mount fasteners, note the location of any shims or spacers used.

Remove the capscrews from the engine mounts.

NOTE: Certain applications will require loosening of the rear engine mount fasteners to allow removal of the front engine support bracket.



Inspect for Reuse

△CAUTION△
Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage can result in excessive vibration complaints.

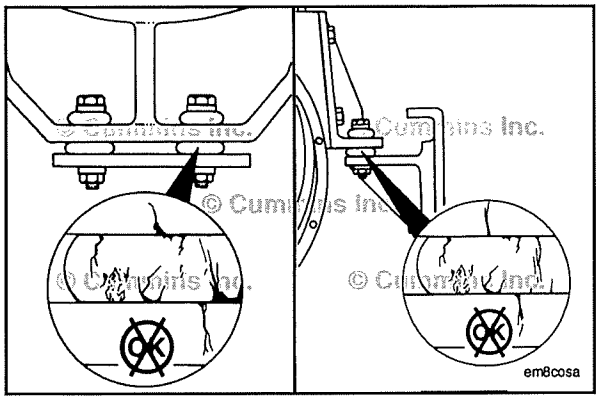
Inspect all rubber-cushioned mounts for cracks and other damage. Look for interference or contact between metal components.

Inspect all mounting brackets for cracks and damaged bolt holes.

Inspect the mounting capscrew to make sure it is **not** too long, which will **not** provide enough preload on the mount.

Replace any damaged parts as necessary.

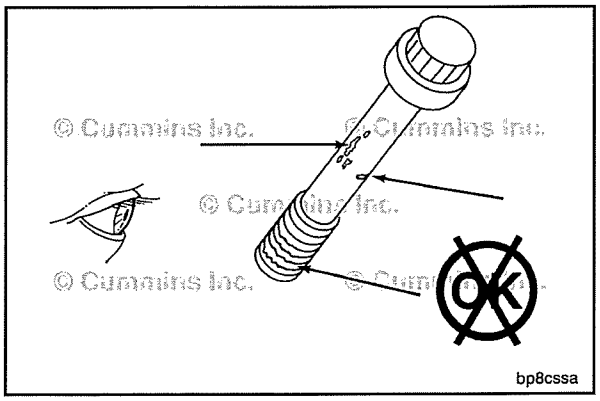
NOTE: Damaged engine mounts, brackets, and mounting hardware can cause the engine to move out of alignment and damage the driveline components in the equipment. This can result in vibration complaints.

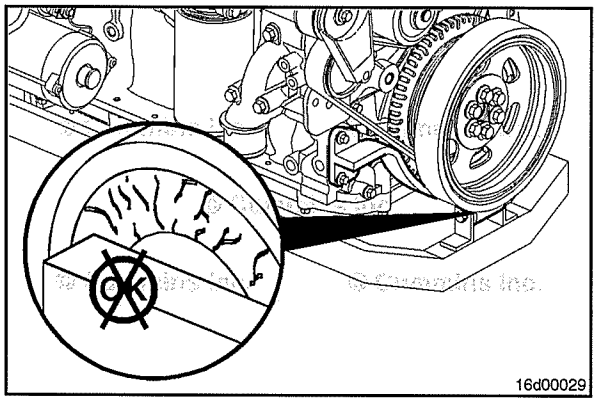


Inspect the capscrew for the following:

- Damaged threads
- Rust or corrosion-caused pitting
- Nicked, bent, stretched, or galled.

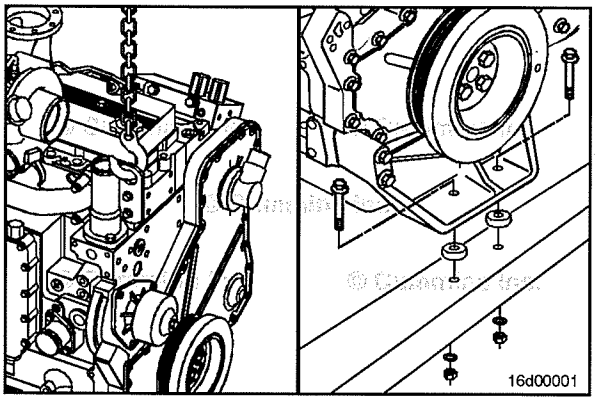
The capscrew **must** be replaced if it has any of the listed damages.





For barrel mounts, inspect for signs of contact between the side brackets and the front engine support bracket.

Contact between the engine mount and side brackets can cause vibration complaints. If contact is found, replace the front engine support bracket.



Install

NOTE: Make sure to install any shims or spacers in the same location as removed.

Align the engine in the chassis.

Install the engine mount fasteners and tighten. Refer to the OEM service manual for torque specifications.

Remove the lifting fixture or hoist from the engine lifting brackets.

Connect all engine and chassis mounted accessories that were removed.

Section 17 - Miscellaneous - Group 17

Section Contents

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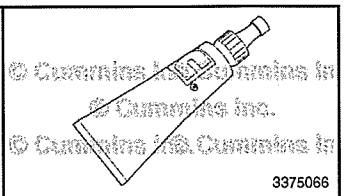
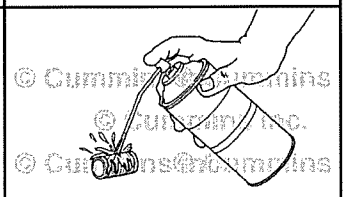
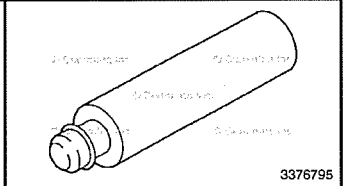
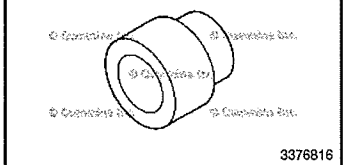
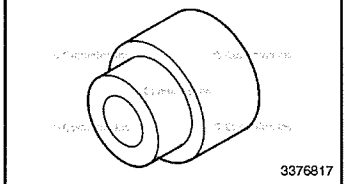
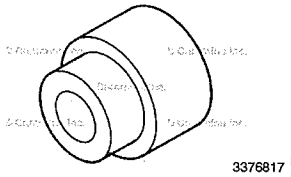
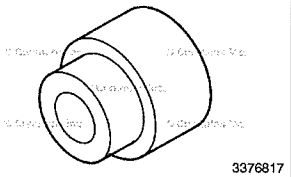
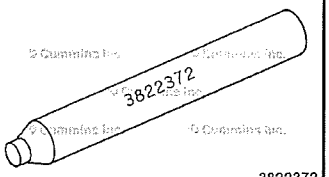
Service Tools

Miscellaneous

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3375066	**Pipe Plug Sealant** Used when installing pipe plugs to reduce the possibility of leaks.	
3375068	**Cup Plug Sealant** Used when installing cup plugs to reduce the possibility of leaks.	
3824510	**Quick Dry Spray Cleaner** Used to clean cup plug opening.	
3164085	**Cup Plug Driving Tools (universal handle)** Required use with driver heads to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3376816	**Cup Plug Driving Tools (driver head, 1-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3376817	**Cup Plug Driving Tools (driver head, 1-1/4-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	

Tool No.	Tool Description	Tool Illustration
3823520	**Cup Plug Driving Tools (driver head, 11/16-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	 3376817
3823524	**Cup Plug Driving Tools (driver head, 2-1/4-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	 3376817
3822372	**Cup Plug Driving Tools** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	 3822372

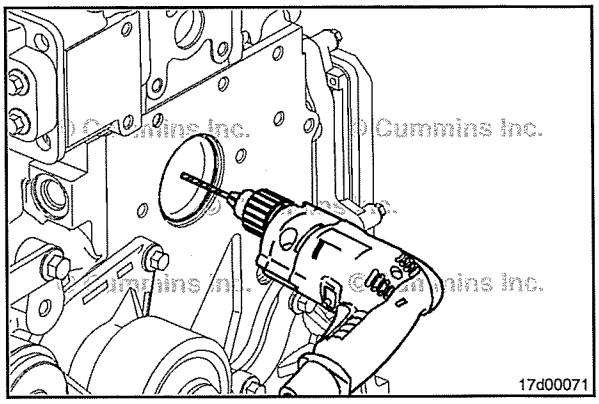
Cup Plug (017-002)

Remove

⚠CAUTION⚠
Do not allow metal shavings to fall inside the engine when drilling a hole in the cup plug. Damage to engine components can occur.

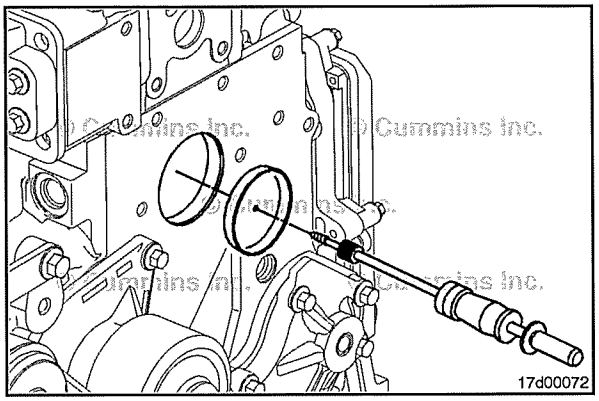
Use a center punch to mark the cup plugs for drilling.

Drill a 1/8-inch hole in the cup plug.



Use a dent puller to remove the plug.

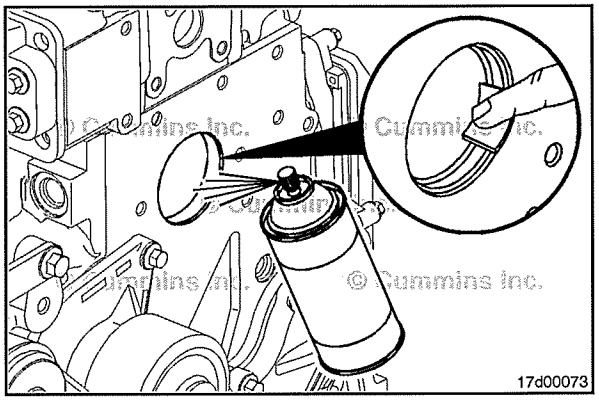
Discard all used cup plugs. Do **not** use them again.



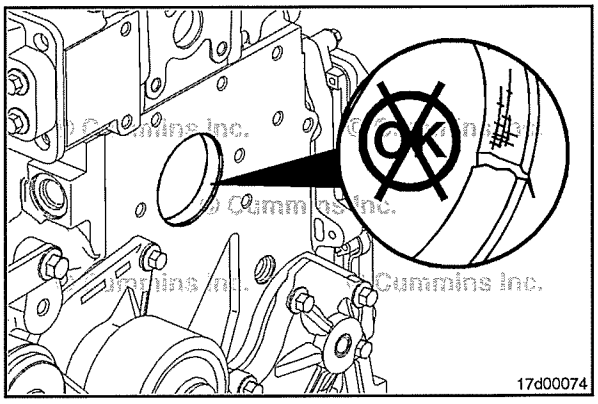
Clean and Inspect for Reuse

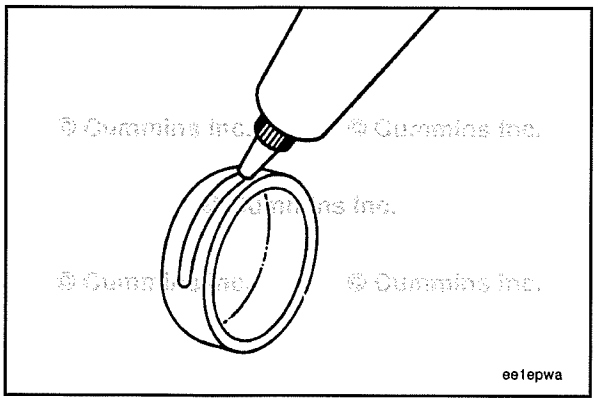
Thoroughly clean the cup plug hole using Scotch-Brite™ pad, or equivalent.

Use spray cleaner, Part Number 3375433 or equivalent, to clean the bore for the final time.



Inspect the cup plug bores for damage.



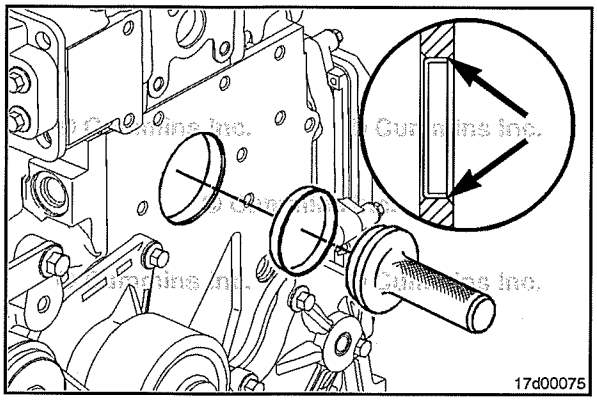


Install

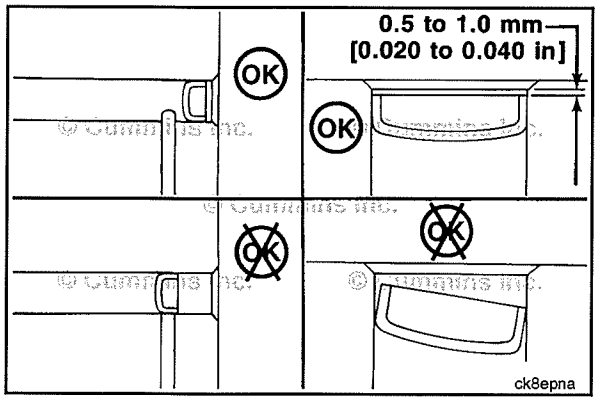
⚠CAUTION⚠
Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of 2 hours before operating the engine. The plug can come out of the bore if the sealant is not dry.

Apply a 2-mm [1/16-in] bead of cup plug sealant, Part Number 3375068, or equivalent, to the outside circumference of the cup plug and the inside circumference of the cup plug bore.

NOTE: Do **not** install a used cup plug. Discard all plugs after removal.

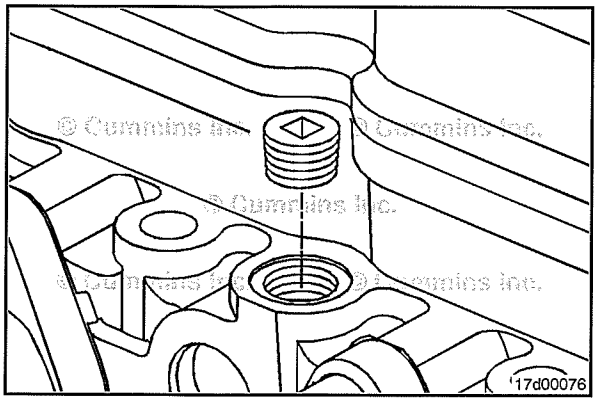


Install the cup plug with the appropriate cup plug driver.



⚠CAUTION⚠
Do not install the cup plug too deeply. If the cup plug is not installed straight and flat, it must be replaced with a new cup plug or engine damage can result.

The cup plug **must** be installed with the edge of the cup plug 0.5 to 1.0 mm [0.020 to 0.040 in] deeper than the leading chamfer of the bore.



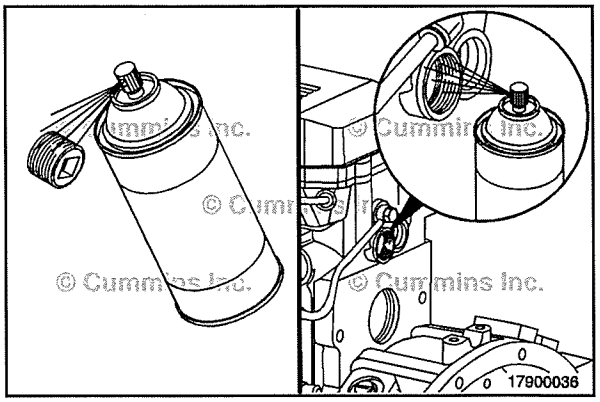
Pipe Plug (017-007)

Remove

Remove the pipe plug.

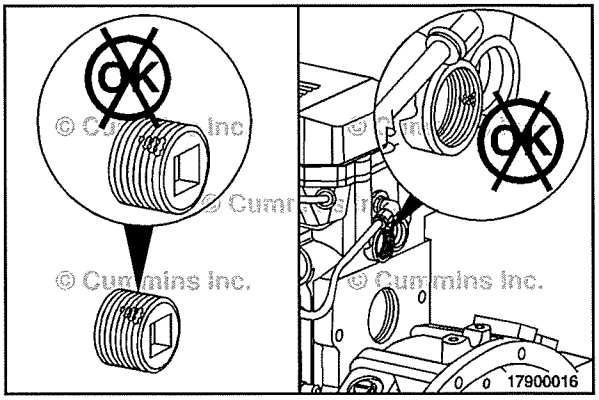
Clean and Inspect for Reuse

Use spray cleaner, Part Number 3375433 or equivalent, to clean the threads of the pipe plugs and threaded bores.



Inspect the threads of the pipe plugs for mutilation or damage.

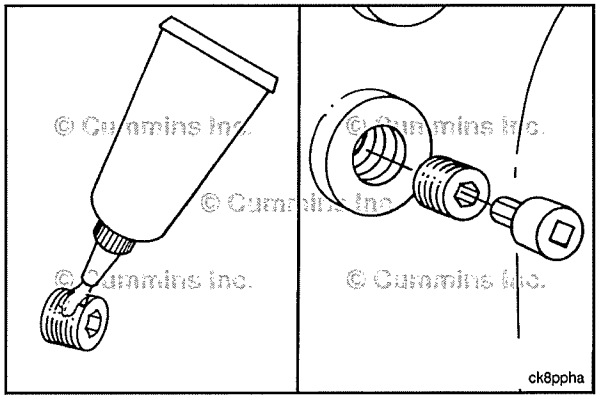
Inspect the threaded bores for damage.



Install

Apply a film of pipe plug sealant, Part Number 3375066 or equivalent, to the threads.

Install the pipe plugs.

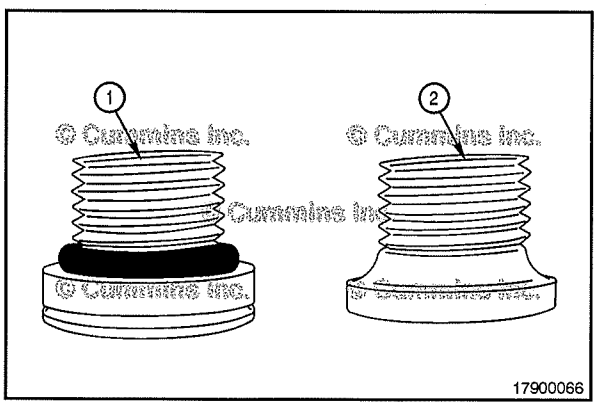


Tighten the pipe plugs. Refer to the illustration for the appropriate torque values.

Pipe Plug Torque Values

Size			Torque		Torque	
Thread	Actual Thread O.D.		In Aluminum Components		In Cast Iron or Steel Components	
in.	mm	[in]	N•m	[ft-lbs]	N•m	[ft-lbs]
1/16	8.1	[0.32]	5	[45 in-lb]	15	[10]
1/8	10.4	[0.41]	15	[10]	20	[15]
1/4	13.7	[0.54]	20	[15]	25	[20]
3/8	17.3	[0.68]	25	[20]	35	[25]
1/2	21.6	[0.85]	35	[25]	55	[40]
3/4	26.7	[1.05]	45	[35]	75	[55]
1	33.5	[1.32]	60	[45]	95	[70]
1¼	42.2	[1.66]	75	[55]	115	[85]
1½	48.3	[1.90]	85	[65]	135	[100]

ck8ppoa



Straight Thread Plug (017-011)

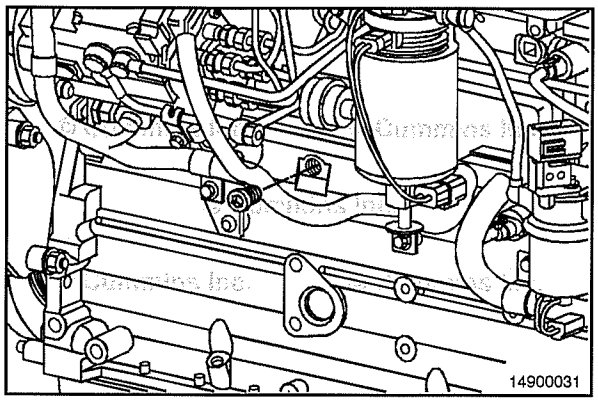
General Information

Two types of straight thread plugs are used:

1 Straight thread plug with o-ring

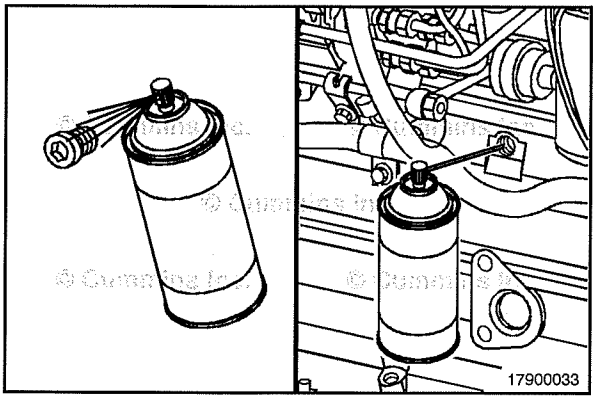
2 Straight thread plug with formed in-place sealant.

The two plugs are interchangeable and reusable. The **only** difference between the two plugs is the installation torque value. See the install step of this procedure.



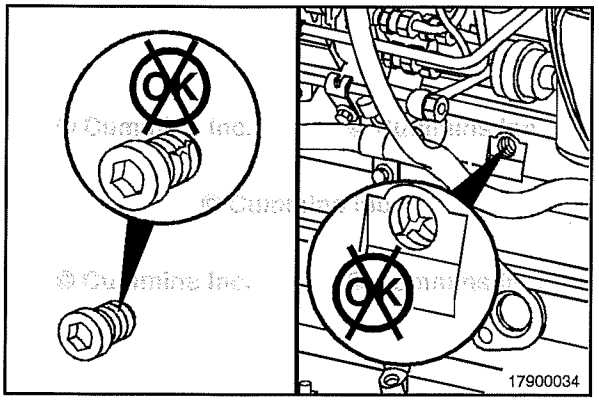
Remove

Select the appropriate size Allen wrench or socket, and remove the plug.



Clean and Inspect for Reuse

Use spray cleaner, Part Number 3375433, or equivalent, to clean the threads of the straight-thread plugs and threaded bores.



Inspect the threads of the pipe plugs for mutilation or damage.

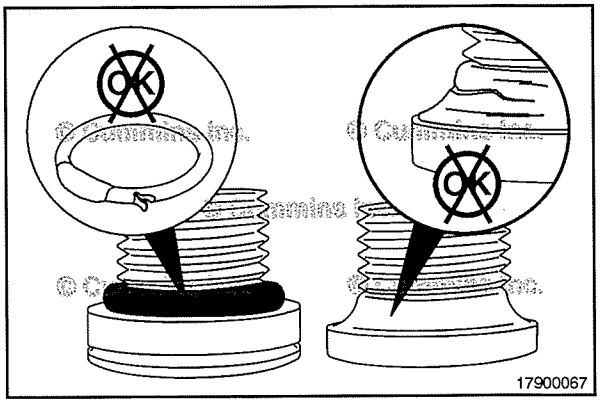
Replace the plugs, if damaged.

Inspect the threaded bores for damage.

Repair the bores, if necessary.

For straight thread plugs with an o-ring, inspect the o-ring for cuts, tears, or deformation. Replace the o-ring if necessary.

For straight thread plugs with formed in-place sealant, inspect the sealant for damage. If damaged, replace the entire plug.



Install

If equipped with a straight thread plug with o-ring, install a new o-ring on the straight-thread plug, if required.

Lubricate the o-ring with clean 15W-40 oil.

Install and tighten the plug.

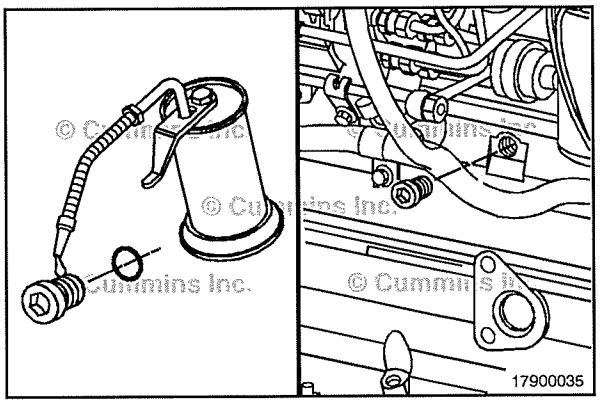
Torque Value:
M10 10 N•m [89 in-lb]

Torque Value:
M12 20 N•m [177 in-lb]

Torque Value:
M14 25 N•m [221 in-lb]

Torque Value:
M16 35 N•m [25 ft-lb]

Torque Value:
M18 45 N•m [33 ft-lb]



If equipped with a straight thread plug with formed in-place sealant, install and tighten the plug.

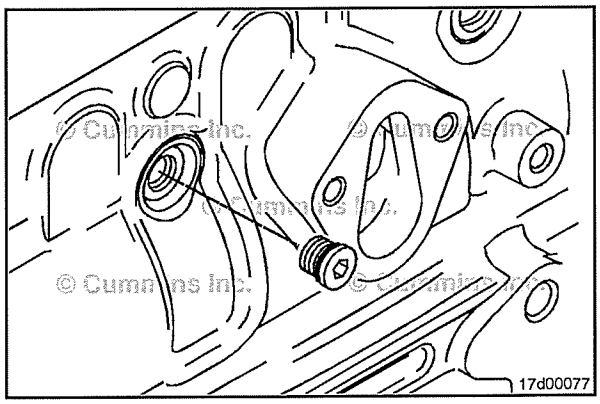
Torque Value:
M10 18 N•m [160 in-lb]

Torque Value:
M12 25 N•m [221 in-lb]

Torque Value:
M14 30 N•m [22 ft-lb]

Torque Value:
M16 40 N•m [30 ft-lb]

Torque Value:
M18 50 N•m [37 ft-lb]



Notes

Section 19 - Electronic Controls - Group 19

Section Contents

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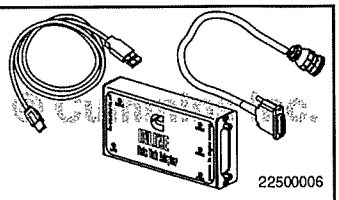
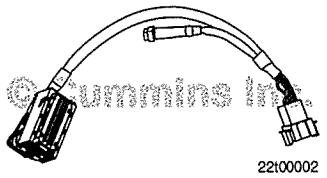
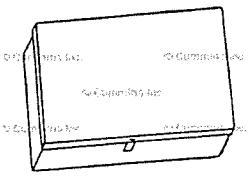
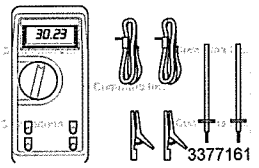
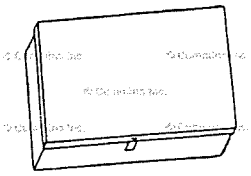
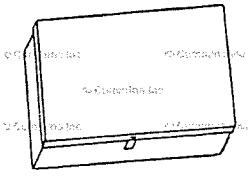
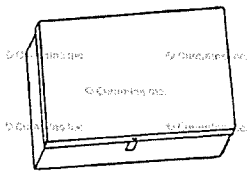
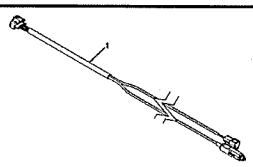
Service Tools

Electronic Engine Controls

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

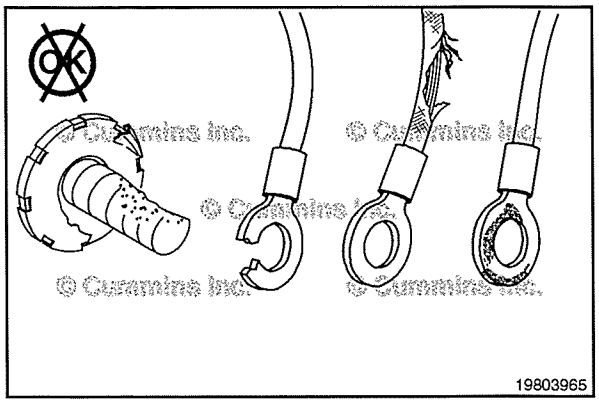
Tool No.	Tool Description	Tool Illustration
2892092	**Data Link Adapter Kit** INLINE™ 6 adapter and associated cables are used to connect a computer to an engine data link.	
2892289	**ECM Bench Top Calibration Harness Adapter** Used to calibrate CM2350 electronic control modules off of the engine. Use with base harness, Part Number 3163151. Reference Service Tool Instruction, Bulletin 3377791, for additional information.	
2892512	**CM2350 ECM Connector Repair Kit** Contains the following service tools: Pinout Connector Tool, Part Number 2892510; Test Leads (2), Part Number 3164113; Delphi Retainer Removal Tool, Part Number 4918921. Reference Service Tool Instruction 3400414, for additional information.	
3164489	**Digital Multimeter (Standard Multimeter)** Automotive multimeter with built-in temperature adapter and tachometer.	
3400280	**Cummins® Wiring Repair Service Tools Bulletin** Contains information on a variety of service tools available for connector and wiring harness repair.	
4919115	**Electrical Test Lead Kit** Contains various test leads for testing electrical circuits. Reference Service Tool Instruction, Bulletin 3400282, for kit contents.	

Tool No.	Tool Description	Tool Illustration
5298734	**CM2350 Wiring Harness Repair Kit** Contains the following service tools: Backshell Locking Assembly, Part Number 4918925; Retainer, Red Locking Comb, Part Number 4918926; Terminal 20 AWG Grey Wire, Part Number 2892507; Terminal 16 AWG Grey/Red Stripe Wire, Part Number 4918916; Wire Ties, Part Number 3822924; ECM Cable Hold-Down Clamp, Part Number 5298539; and ECM Connector Dust Boot, Part Number 3688983. Reference Service Tool Instruction, Bulletin 3400445, for additional information.	
5298821	**NOx Sensor Service Tool: 2013 Engines** The harness allows the inlet and/or outlet NOx sensor to be isolated from the engine wiring harness and/or the OEM wiring harness for testing on 2013 engines.	

Battery Ground Circuit (019-008)

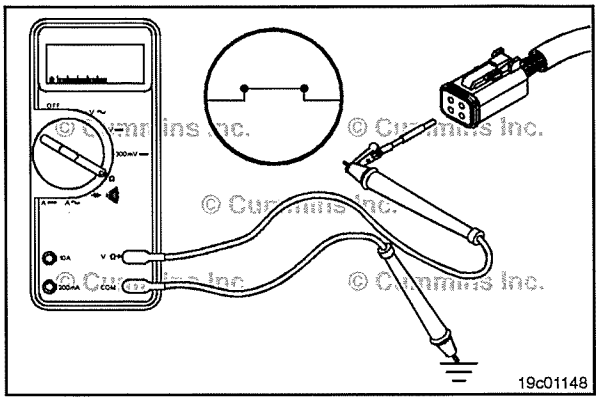
Resistance Check

Check the Original Equipment Manufacturer harness ground connection for loose, corroded, or broken connections.



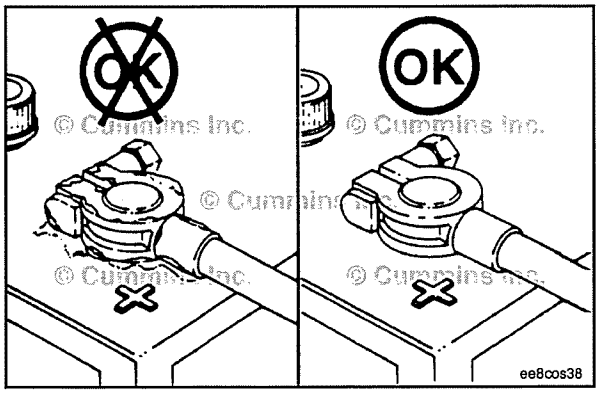
⚠CAUTION⚠
The leads must fit tightly in the connector without expanding the pins in the connector otherwise the connector will be damaged.

Measure the resistance between the battery supply negative (-) pin of the Original Equipment Manufacturer harness control module connector(s) and engine block ground or chassis ground for each control module. Reference the wiring diagram for connector pin identification. The resistance **must** be 10 ohms or less.



If the resistance value is **not** correct, check the batteries, cables, and cable connections.

Repair or replace the parts as required.

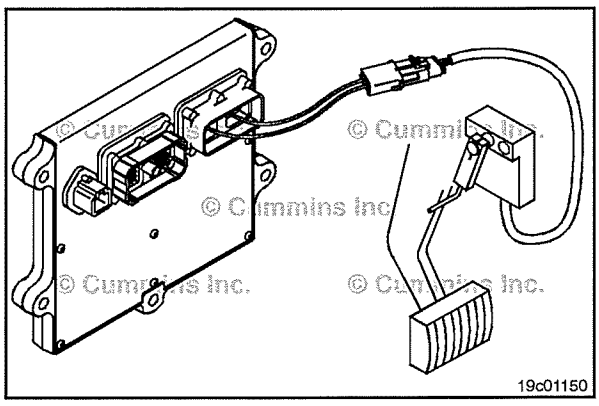


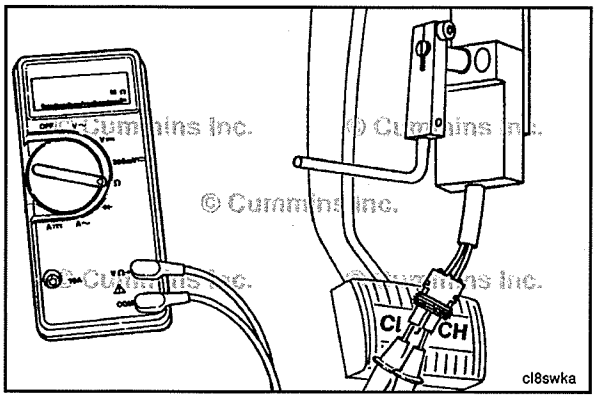
Clutch Pedal Position Switch (019-009)

General Information

The clutch pedal position switch circuit is used to disable the PTO and cruise control features.

The circuit consists of an open control switch, a clutch pedal position switch signal wire, and a switch return. When the clutch pedal position switch is installed and adjusted, the contact points are held closed. When the clutch pedal is depressed, the clutch pedal position switch is in its normally open position. This will disable the PTO or cruise control operation.





Resistance Check

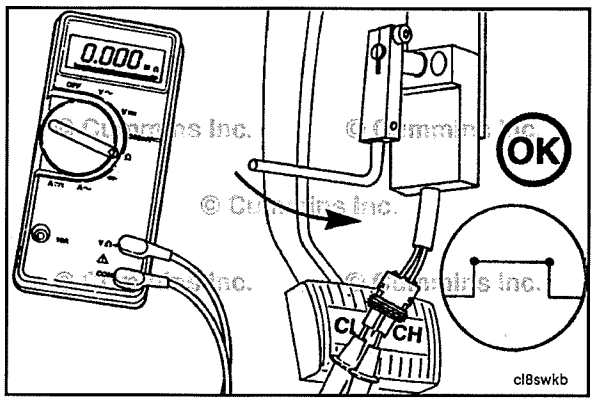
If INSITE™ is available, monitor the clutch switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Find the clutch pedal position switch. The location will depend on the OEM installation procedures.

Disconnect the wiring harness attached to the switch terminals.

Adjust the multimeter to measure resistance.

Touch the probes of a multimeter to the two terminals in the connector of the clutch pedal position switch.

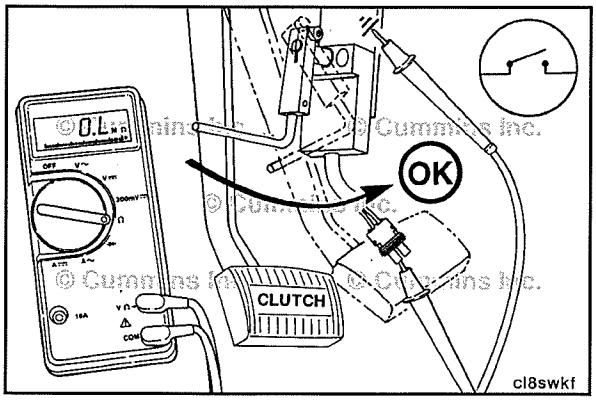


Release the clutch pedal. The multimeter **must** show a closed circuit (10 ohms or less).

If the switch is **not** closed when the clutch is fully engaged, adjust the clutch switch trip lever. If the switch is **not** closed after adjusting the trip lever, the switch has failed. Refer to the OEM troubleshooting and repair manual for the replacement procedures.

Depress the clutch pedal. The clutch pedal position switch **must** open. The multimeter **must** show an open circuit (100k ohms or more).

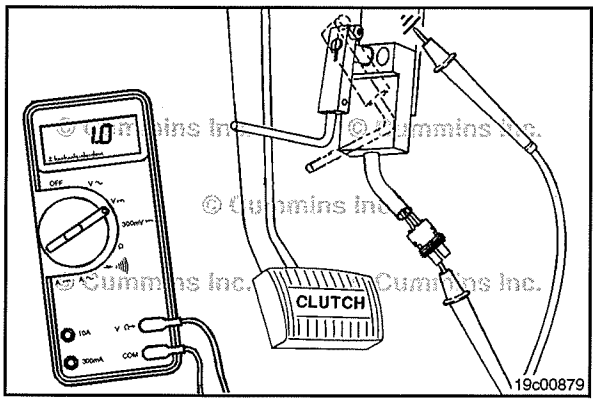
If the switch is **not** open when the clutch is fully engaged, adjust the clutch switch trip lever. If the switch is **not** open after adjusting the trip lever, the switch has failed. Refer to the OEM troubleshooting and repair manual for the replacement procedures.



Check for Short Circuit to Ground

Remove one multimeter probe from the clutch pedal position switch connector and touch the probe to the chassis ground. The multimeter **must** show an open circuit (100k ohms or more) when the clutch pedal is released. If the circuit is closed, replace the clutch pedal position switch.

Refer to the OEM troubleshooting and repair manual.



Check for Short Circuit to External Voltage Source

Turn the keyswitch to the ON position.

Adjust the multimeter to measure VDC.

Insert one of the multimeter probes into the clutch pedal position switch connector.

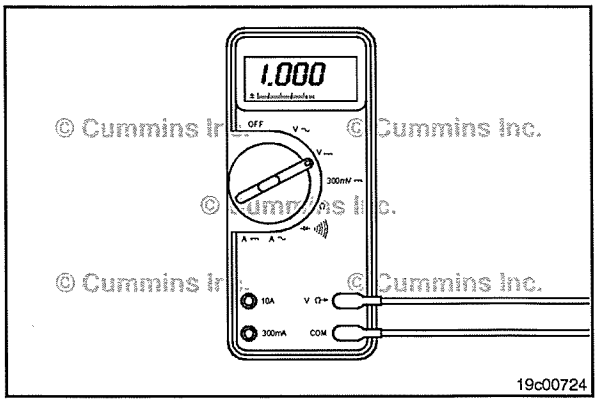
Touch the other multimeter probe to the engine block ground and measure the voltage. The voltage **must** be 1.5 VDC or less with the clutch pedal released and depressed.

If the voltage value is more than 1.5 VDC, there is a short circuit to an external voltage source.

NOTE: An external voltage source is any wire in the OEM harness wiring that carries the voltage.

Remove the external voltage source.

If the clutch pedal position switch passed all previous checks, connect the switch to the wiring harness. The clutch pedal position switch circuit **must** be checked.



Clutch Pedal Position Switch Circuit (019-010)

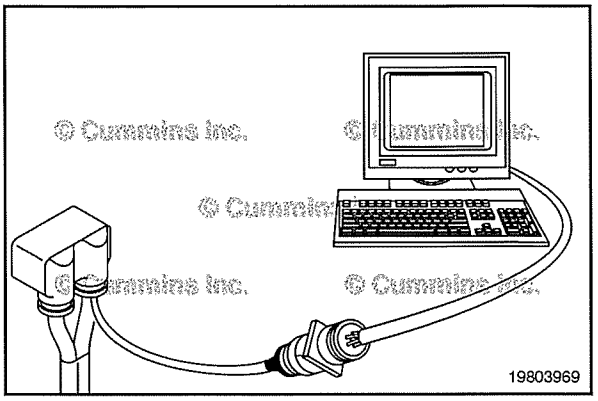
Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the clutch pedal position switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.

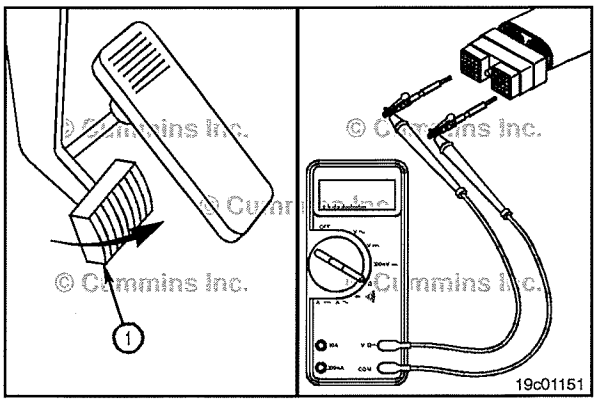
Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM).

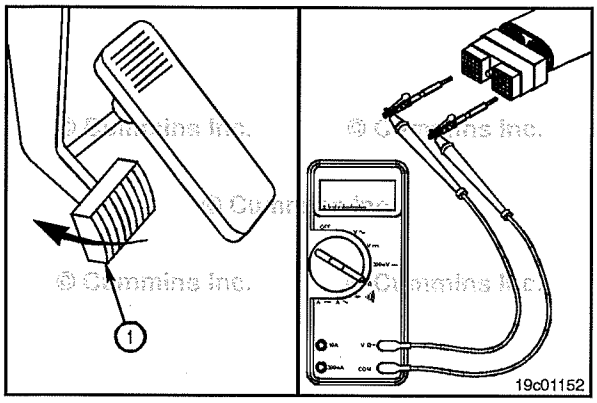
Insert a test lead into the clutch pedal position switch return pin depending on the OEM application of the OEM connector. Insert the other test lead into the clutch pedal position switch signal pin of the OEM connector.



Connect the alligator clips to the two probes of the multimeter. Adjust the multimeter to measure resistance.

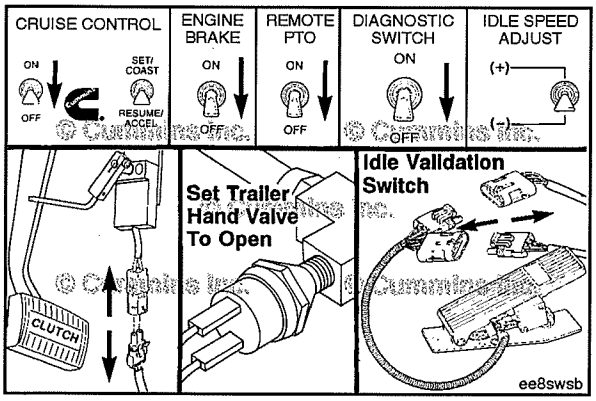
The multimeter **must** show a closed circuit (10 ohms or less) when the clutch pedal (1) is released.





Depress the clutch pedal (1). The multimeter **must** show an open circuit (100k ohms or more). If the resistance values are **not** correct, the clutch pedal position switch signal wire and the return wire **must** be checked for an open circuit, provided the clutch pedal position switch was previously checked.

If the values are correct, the circuit **must** still be checked for a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.

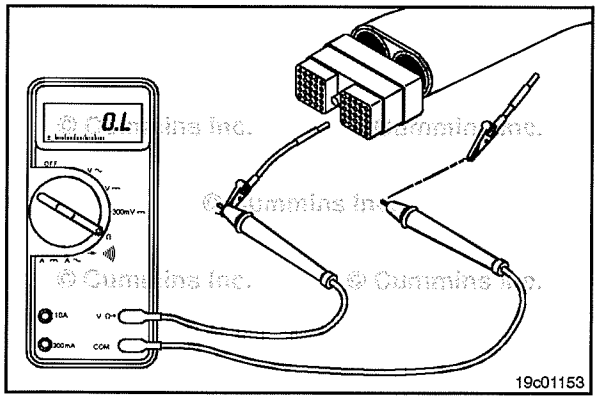


Check for Short Circuit to Ground

To isolate the clutch pedal position switch circuit when checking for a short circuit to ground, turn all cab panel switches to the OFF or neutral position.

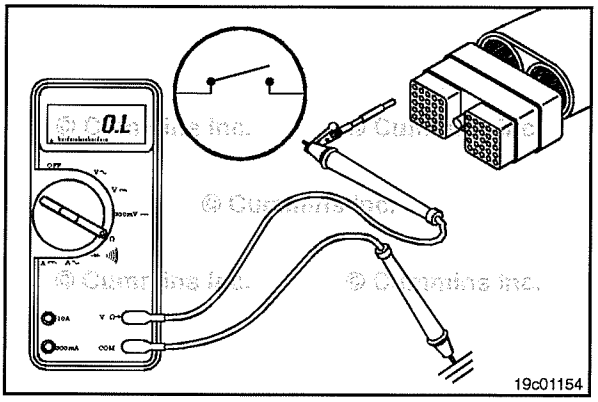
Set the service brake using the trailer brake hand valve.

Disconnect the clutch pedal position switch, the idle validation switch, and the throttle pedal.



Remove the test lead from the switch return pin.

Disconnect the multimeter probe from the alligator clip.

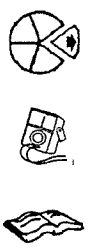


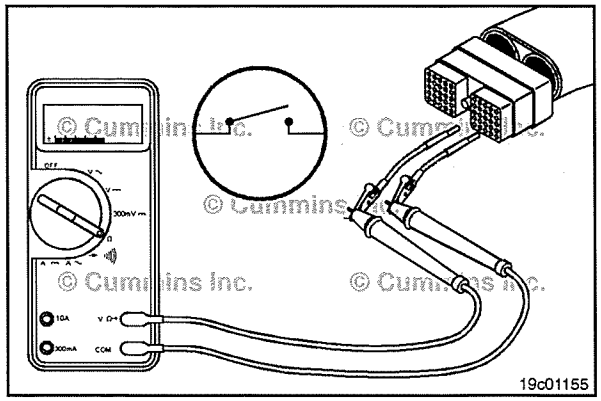
Touch the other multimeter probe to the engine block ground. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the clutch pedal position switch circuit.

Repair or replace the wire connected to the clutch pedal position switch signal pin in the OEM harness according to the vehicle manufacturer's procedures.

Connect all components when the repair is complete.

Check for Short Circuit from Pin to Pin





Isolate the clutch pedal position switch circuit as described in previous step. Set all cab panel switches to the OFF or neutral position, and disconnect the clutch pedal position switch and the throttle pedal.

Adjust the multimeter to measure resistance. Then insert one test lead into the clutch pedal position switch signal pin of the OEM harness connector. Insert the other test lead into the clutch pedal position switch return pin. Connect the alligator clips to the multimeter probes.

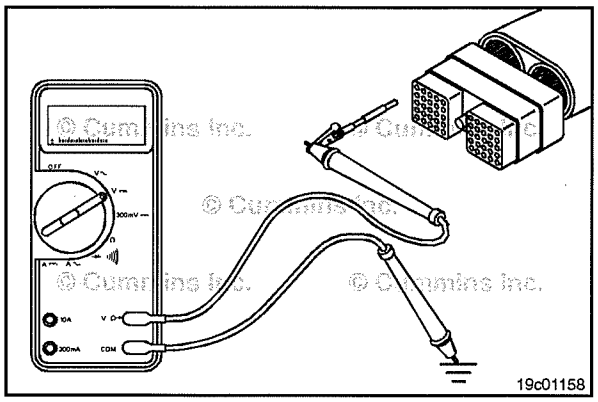
Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

With the first test lead still touching the clutch pedal position switch signal pin, remove the test lead from the clutch pedal position switch return pin and touch it to all other pins, one at a time. The multimeter **must** show an open circuit (100k ohms or more) at all pins.

If the circuit is **not** open, there is a short circuit between the wire connected to the clutch pedal position switch signal pin and any pin that shows a closed circuit. Repair or replace the wires in the OEM harness according to the vehicle manufacturer's procedures.

Remove the test lead from the clutch pedal position switch signal pin and touch it to the clutch pedal position switch return pin. Touch the other test lead to all other pins, one at a time. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more), except for the clutch pedal position switch return pin.

If the circuit is **not** open, there is a short circuit between the wire connected to the clutch pedal position switch return wire and any pin that measured a closed circuit. Repair or replace the wires in the OEM harness according to the vehicle manufacturer's procedures.



Check for Short Circuit to External Voltage Source

Isolate the clutch pedal position switch circuit as described in the previous steps. Set the cab panel switches to the OFF or neutral position, and disconnect the clutch pedal position switch and the throttle pedal. Turn the keyswitch to the ON position. Adjust the multimeter to measure VDC.

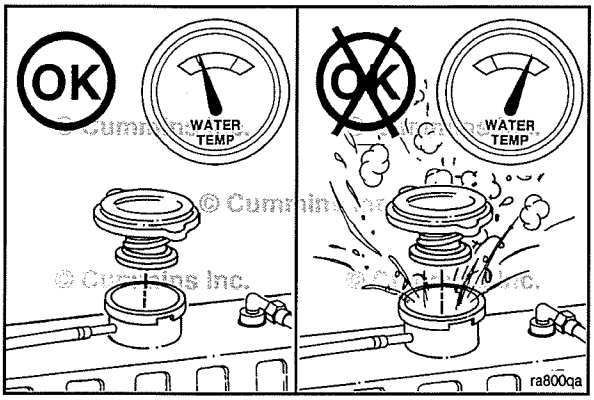
Insert test lead connected to the positive multimeter probe into the clutch pedal position switch signal pin. Disconnect the negative multimeter probe from the test lead and touch it to the engine block ground. Measure the voltage. The voltage **must** be 1.5 VDC or less.

NOTE: An external voltage source is any wire in the OEM wiring that carries voltage.

If the voltage value is more than 1.5 VDC, there is a short circuit between the wire connected to the clutch pedal position switch signal pin and a wire carrying power in the OEM harness. Repair the OEM harness according to the vehicle manufacturer's procedures.

Remove the test lead from clutch pedal position switch signal pin and insert it into the clutch pedal position switch return pin. With the multimeter probe still touching the engine block ground, measure the voltage. The voltage **must** be 1.5 VDC or less. If the voltage value is **not** correct, there is a short circuit between the wire connected to the clutch pedal position switch return and a wire carrying power in the OEM harness. Repair the OEM harness according to the vehicle manufacturer's procedures.

Connect all components after completing the repairs.



Engine Coolant Level Sensor (019-017)

Preparatory Steps

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

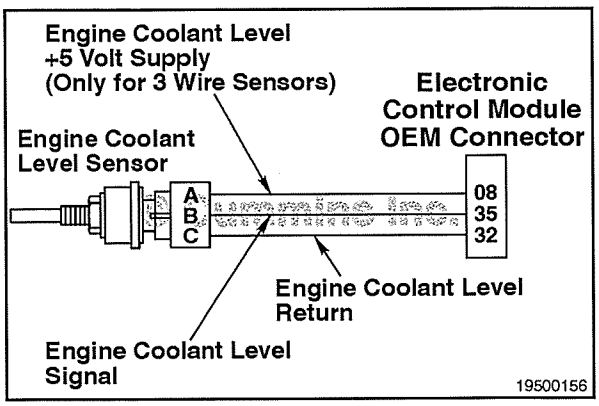
- Remove the radiator cap.
- Drain enough coolant from the cooling system to empty the radiator top tank. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-018 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-018 in Section 8.

Initial Check

Three Wire Sensor OEM Harness and Engine Control Module Check

⚠CAUTION⚠

The engine coolant level sensor can be damaged when removed. It should not be removed unless it is being replaced. Leave the engine coolant level sensor installed during the functional test.



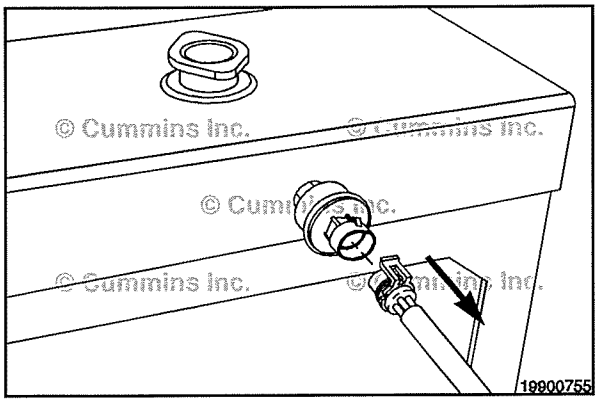
Verify there are no fault codes present. If Fault Codes 195, 196, 1695, 1696 or any other fault codes are present, troubleshoot the fault codes in section TF.

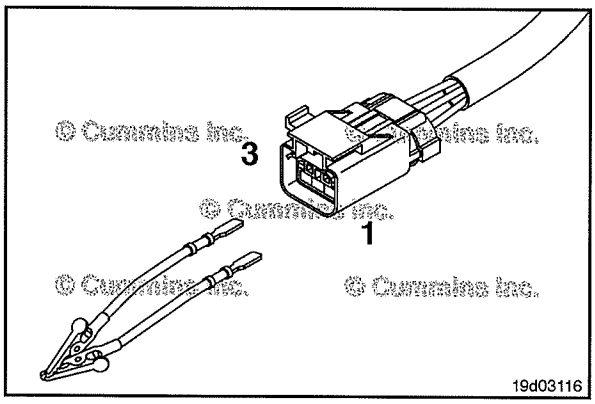
Inspect the original equipment manufacturer (OEM) harness and engine coolant level sensor connector pins for the following:

- Loose connector
- Corroded pins
- Bent or broken pins
- Pushed back or expanded pins
- Moisture in or on the connector
- Missing or damaged connector seals
- Dirt or debris in or on the connector pins
- Connector shell broken
- Wire insulation damage
- Damaged connector locking tab.

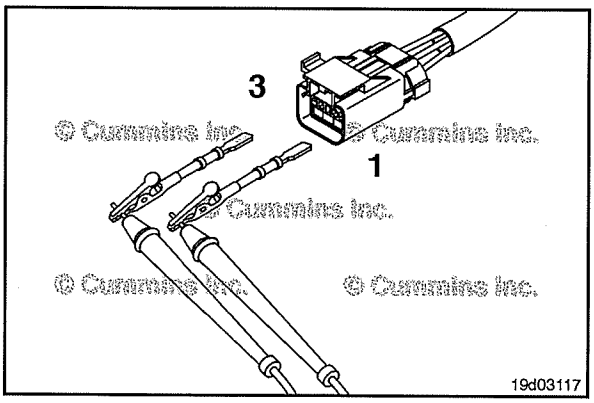
Use the following procedure for general inspection techniques. Refer to Procedure 019-361 in Section 19.

Key OFF, then lift up on the locking tab and pull the electrical connectors for the coolant level sensor apart from the OEM harness. With the engine coolant level sensor disconnected from the OEM harness, key ON, wait 30 seconds and check for active Fault Code 195. If Fault Code 195 is **not** active, there is a problem with either the OEM harness or the engine control module (ECM). Troubleshoot the OEM harness and the ECM as detailed below.

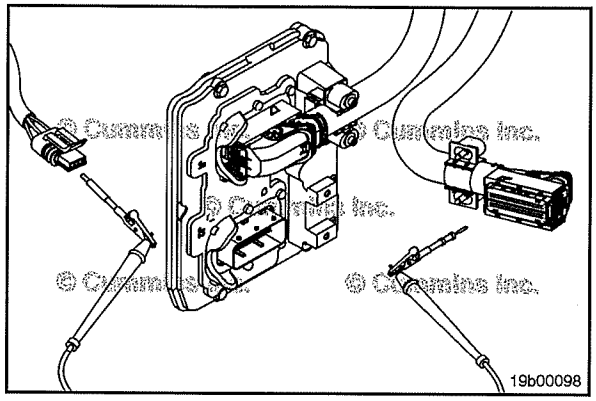




With the OEM wiring harness disconnected from the coolant level sensor, place a jumper wire between the engine coolant level sensor SIGNAL pin and the engine coolant level sensor RETURN pin at the engine coolant level sensor connector of the OEM harness. Check for active Fault Code 196. If Fault Code 196 is **not** active, there is a problem with either the OEM harness or the ECM. Troubleshoot the OEM harness and the ECM as detailed below. If unplugging the sensor causes an active Fault Code 195 and placing a jumper wire between the SIGNAL pin and the RETURN pin on the OEM harness causes an active Fault Code 196, the ECM and OEM harness are both functioning properly and further troubleshooting for the harness and the ECM can be skipped.



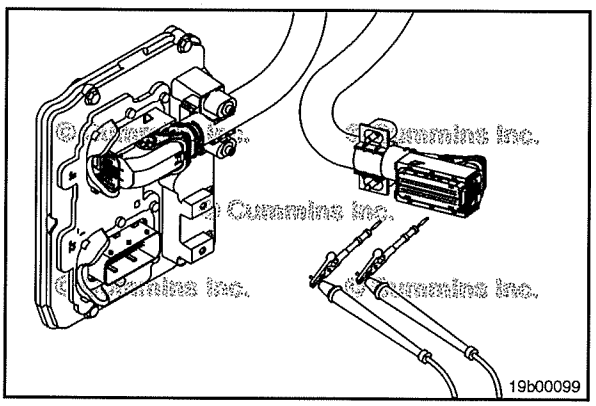
With the engine coolant level sensor disconnected from the OEM harness, key ON and measure the voltage between the engine coolant level SUPPLY pin and the engine coolant level RETURN pin at the engine coolant level sensor connector of the OEM harness. If this measurement is **not** between 4.75 to 5.25-VDC, there is a problem with either the OEM harness or the ECM. Troubleshoot the OEM harness and the ECM in the next step.



Check for continuity in the OEM wiring harness for the engine coolant level sensor SUPPLY, SIGNAL, and RETURN wires. Use the following procedure for general resistance measurement techniques. Refer to Procedure 019-360 in section 19.

Repair or replace the OEM harness as needed. Refer to Procedure 019-071 in Section 19.

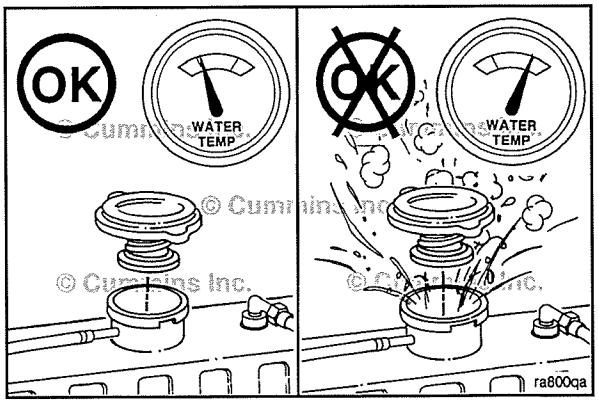
If the resistance for the engine coolant level sensor SUPPLY, SIGNAL, and/or RETURN wires is greater than 10 ohms, repair or replace the OEM wiring harness. Refer to Procedure 019-071 in Section 19.



Check for a short between the engine coolant level sensor SUPPLY, SIGNAL, and RETURN wires and all other wires in the OEM wiring harness. If the resistance measured is less than 100K ohms, repair or replace the OEM wiring harness. Refer to Procedure 019-071 in Section 19.

If a problem exists with the ECM, replace the ECM. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 019-031 in Section 19. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 019-031 in Section 19.

Test



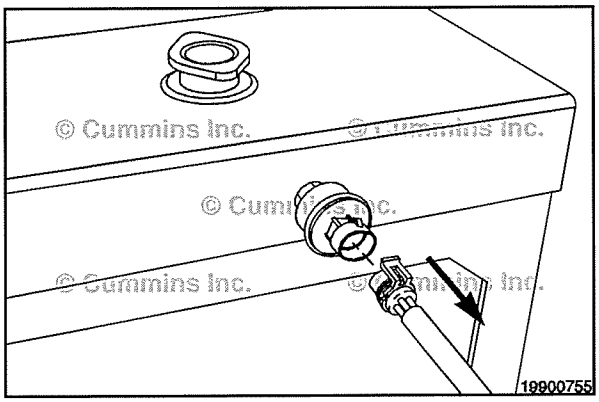
⚠CAUTION⚠
The engine coolant level sensor can be damaged when removed. It should not be removed unless it is being replaced. Leave the engine coolant level sensor installed during the functional test.

First check the function of the ECM and the OEM wiring harness. Reference the Three Wire Sensor OEM Harness and ECM Initial Check section.

With coolant full, above coolant level sensor, key ON, wait 30 seconds, and check for active Fault Codes 197 and/or 2448. If these fault codes become active, a damaged engine coolant level sensor has been detected and needs to be replaced. Reference the Remove and Install sections in this procedure.

Drain the coolant level below the engine coolant level sensor. Reference the Preparatory Steps section in this procedure. Key ON, wait for 60 seconds, and check to see if Fault Codes 197 and/or 2448 become active. If Fault Codes 197 and/or 2448 do **not** become active, a damaged engine coolant level sensor has been detected and needs to be replaced. Reference the Remove and Install sections in this procedure.

Remove

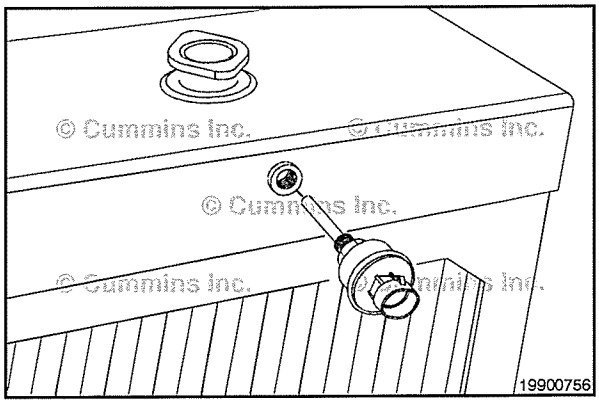


⚠CAUTION⚠
The engine coolant level sensor can be damaged when removed. It should not be removed unless it is being replaced. Leave the engine coolant level sensor installed during the functional test.

Lift up on the locking tab and pull the electrical connectors apart.

Remove the sensor.

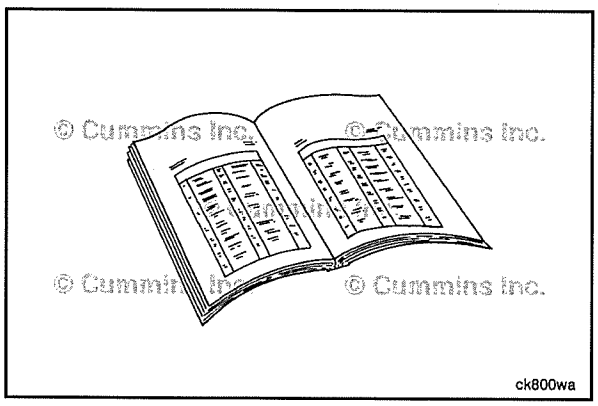
Install



⚠CAUTION⚠
The engine coolant level sensor can be damaged when removed. It should not be removed unless it is being replaced. Leave the engine coolant level sensor installed during the functional test.

Install and tighten the new sensor according to the vehicle manufacturer's instructions.

Push the electrical connectors together until they lock.



Finishing Steps

- Fill the cooling system. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 008-018 in Section 8. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 008-018 in Section 8.
- Operate the engine and check for leaks.

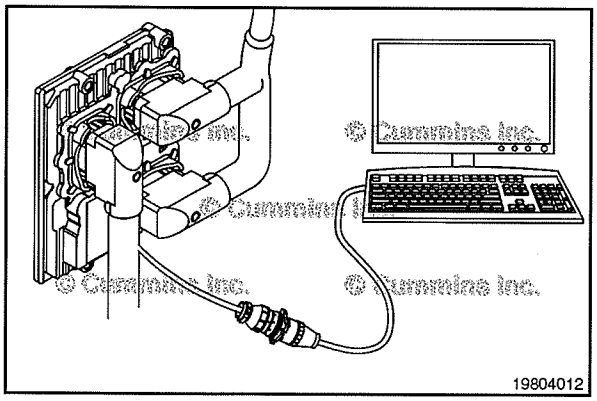
Engine Coolant Temperature Sensor (019-019)

General Information

The coolant temperature sensor is used to measure the temperature of the engine coolant.

The coolant temperature sensor is located on the exhaust side of the engine, near the thermostat.

Use the following procedure for a detailed component location view. Refer to Procedure 100-002 in Section E.



Initial Check

Use an electronic service tool to monitor the value of the coolant temperature sensor with the key in the ON position and the engine off.

The engine **must** be off long enough for the coolant temperature to be equal to the local ambient air temperature. The coolant temperature sensor should read within 5.5°C or 10°F of the local ambient air temperature on a cold engine.

Replace the coolant temperature sensor if the ambient temperature value is out of specification.

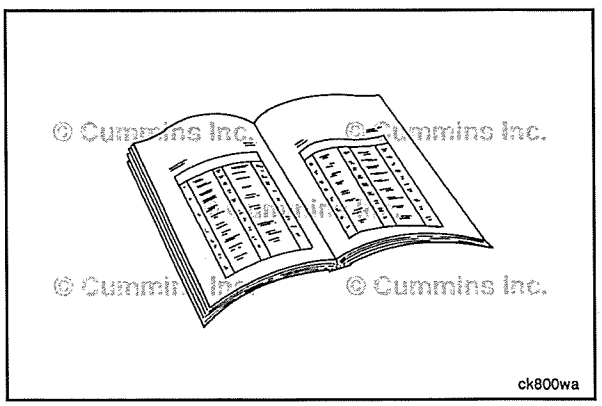
Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

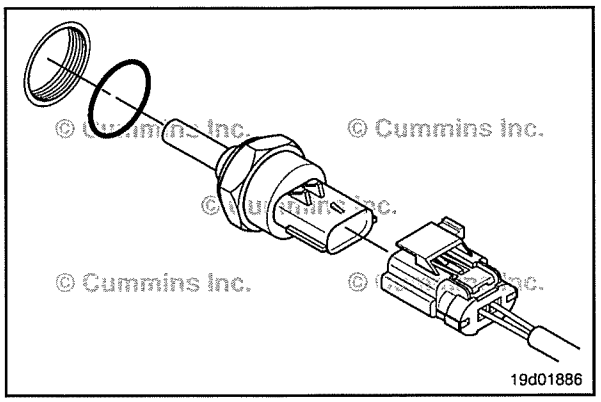
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Clean the area around the coolant temperature sensor.



Remove

Disconnect the coolant temperature sensor from the engine harness.

Remove the sensor from the engine.

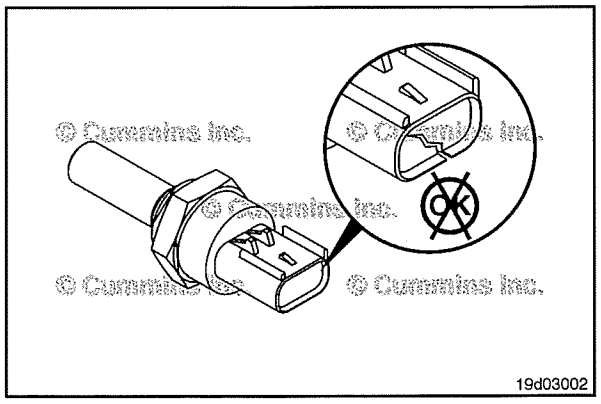


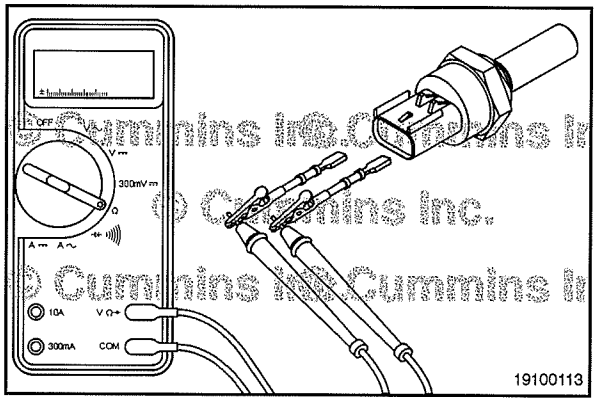
Clean and Inspect for Reuse

Inspect the engine harness connector and coolant temperature sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.

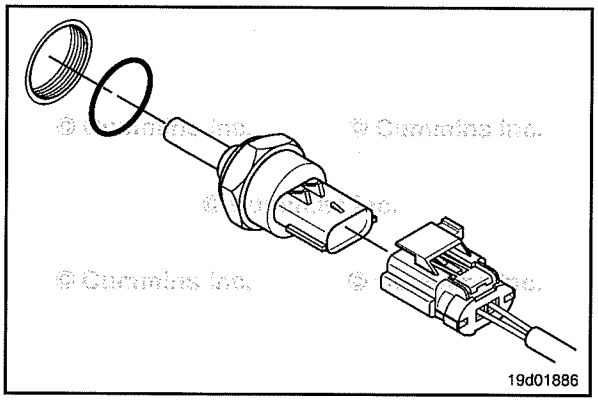
Repair or replace parts as necessary.





Measure the resistance across the sensor signal and return terminals to be sure they agree with the table shown below. If the sensor ambient conditions change, the resistance values should be measured **only** after 2.5 minutes of the ambient change.

Temperature (°C)	Temperature (°F)	Resistance (ohms)
0	32	30k to 37k
25	77	9.3k to 10.7k
50	122	3.2k to 3.8k
80	176	1.1k to 1.3k
100	212	605 to 669



Install

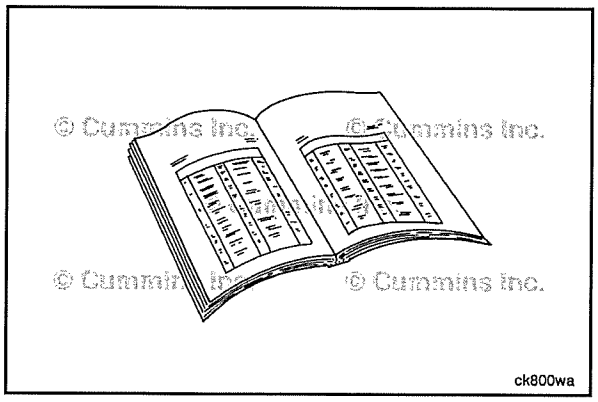
Check to be sure the sensor has an o-ring installed.

Install the sensor into the engine.

Tighten the sensor.

Torque Value: 18 N•m [159 in-lb]

Connect the engine harness connector to the sensor.

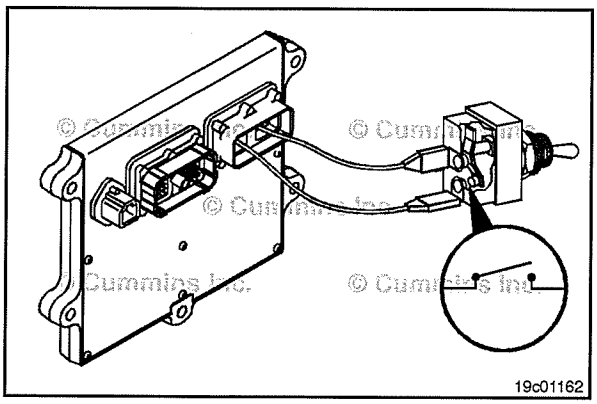


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Operate the engine and check for leaks.



Cruise Control or PTO ON/OFF Switch (019-021)

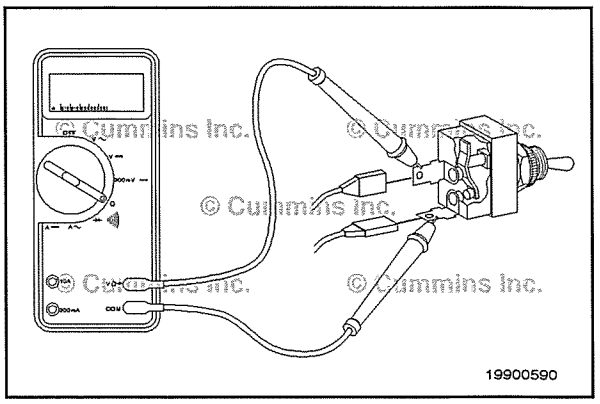
General Information

The ON/OFF toggle switch is used to activate or disable the cruise control operation and PTO operation. The cruise control/PTO ON/OFF switch circuit consists of the cruise control ON/OFF switch signal, the switch return, and the OEM cab-mounted toggle switch.

Resistance Check

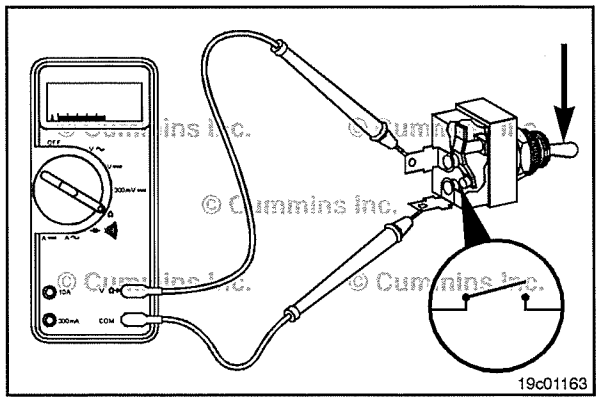
If INSITE™ is available, monitor the switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Locate the desired ON/OFF toggle switch. Remove and tag the two connectors from the terminals on the switch. Touch the multimeter probes to the terminals on the switch.



Move the switch to the OFF position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

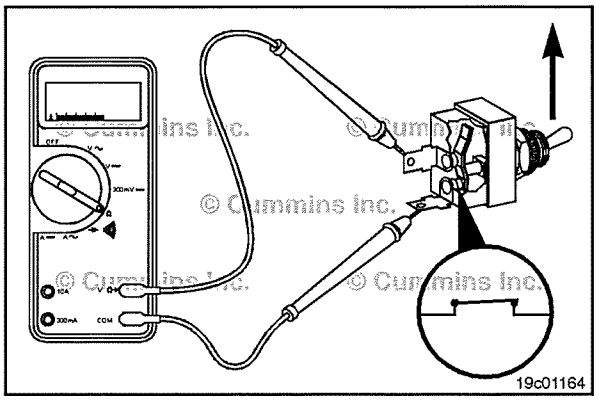
If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for the replacement procedures.



Move the switch to the ON position and measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less).

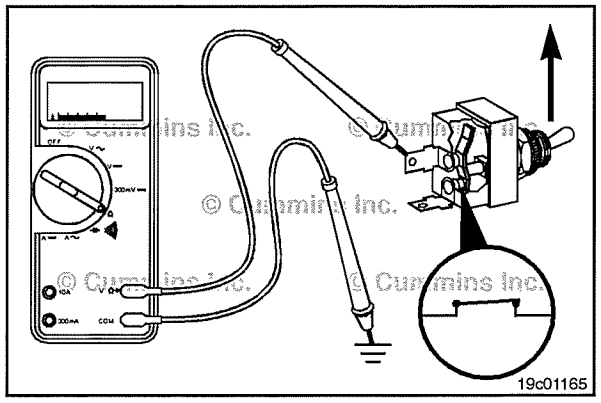
If the circuit is **not** closed, the switch has failed. Refer to the OEM troubleshooting and repair manual for the replacement procedures.

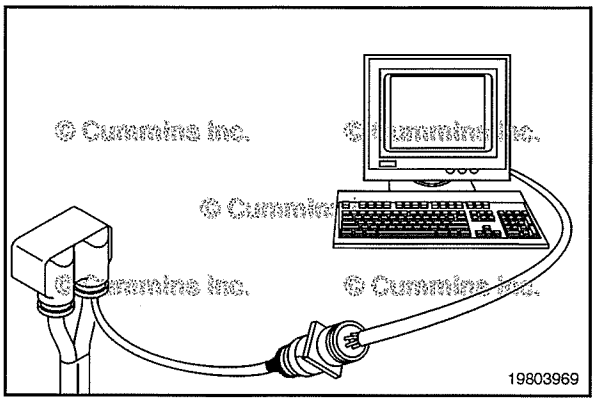
If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the ON position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.



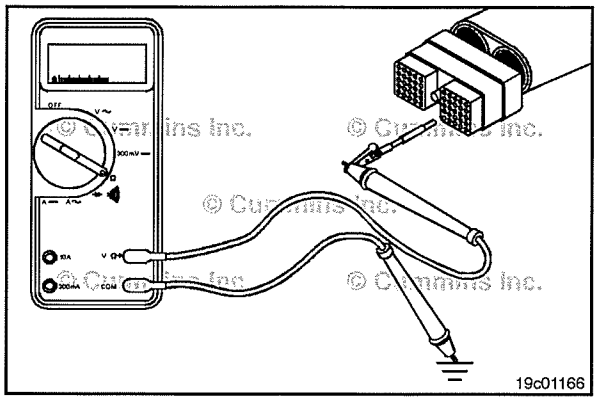


Cruise Control or PTO ON/OFF Switch Circuit (019-022)

Resistance Check

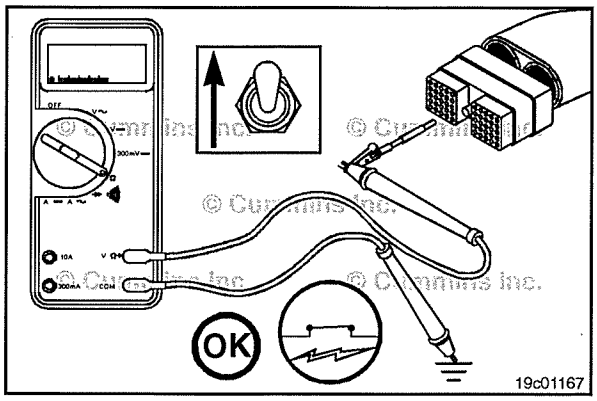
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.



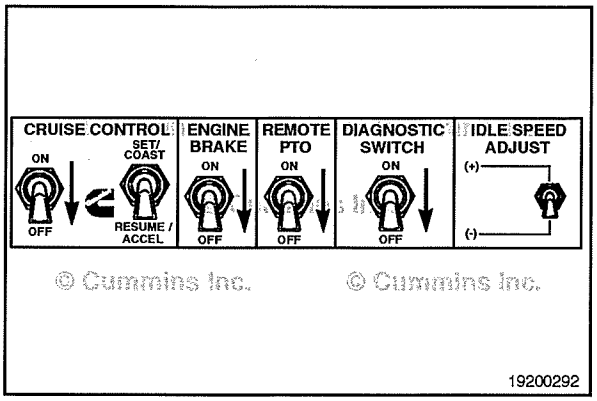
Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM).

Insert the test lead into the cruise control ON/OFF switch signal pin of the original equipment manufacturer (OEM) harness connector and attach it to the multimeter probe. Touch the other probe to the engine block ground.



Move the ON/OFF switch to the ON position. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the cruise control ON/OFF switch input for an open circuit. Refer to the OEM troubleshooting and repair manual.

If the resistance is within specification, the cruise control ON/OFF switch input **must** be checked for a short circuit to ground, a short circuit from terminal to terminal, and a short circuit to an external voltage source.



Check for Short Circuit to Ground

To isolate the cruise control circuit when checking for a short circuit, disconnect the OEM harness connector from the ECM and the OEM harness from the cruise control switch.

Disconnect the clutch pedal position switch, idle validation on/off switch, and the accelerator pedal position switch. Set all cab panel switches to the OFF or neutral position.

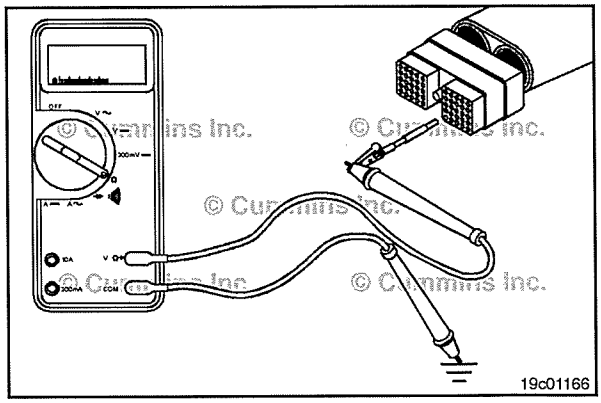
Set the service brake using the trailer brake hand valve.

Adjust the multimeter to measure resistance. Insert a test lead into the cruise control ON/OFF switch input of the OEM harness connector and attach it to a multimeter probe. Remove the other multimeter probe from the alligator clip and touch it to the engine block ground.

Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the cruise control circuit, provided that the switch has been previously checked.

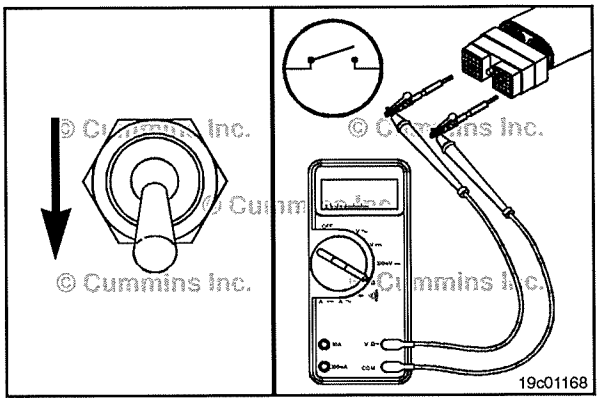
Repair or replace the wire connected to the cruise control ON/OFF switch input in the OEM harness according to the vehicle manufacturer's procedures.



Check for Short Circuit from Pin to Pin

Check for a short circuit from pin-to-pin. Isolate the cruise control circuit by setting the switches as in the previous section. Set the cruise control/PTO ON/OFF switch to the OFF position. Insert the lead into the cruise control ON/OFF switch input. Connect the alligator clip to the multimeter. With the other lead inserted into the switch return wire(s), measure the resistance.

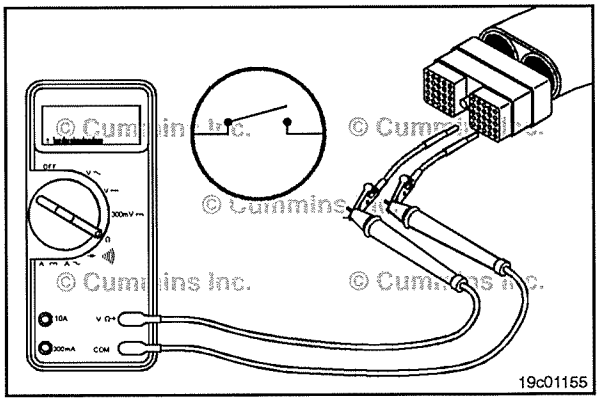
The multimeter **must** show an open circuit (100k ohms or more).

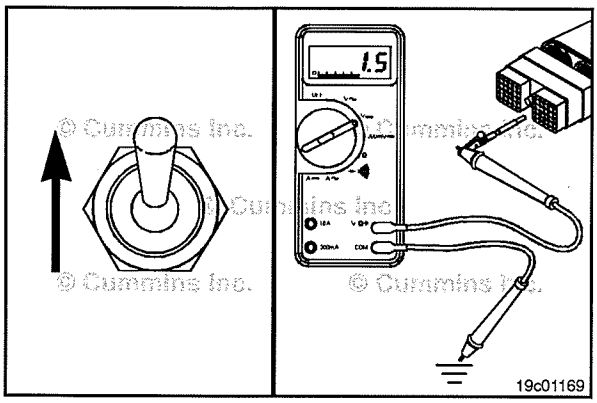


Remove the lead from the cruise control ON/OFF switch input and check all other pins. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit between the cruise control ON/OFF switch input circuit and any pin that shows a closed circuit, provided the switch has previously been checked.

Repair or replace the wires in the OEM harness according to the vehicle manufacturer's procedures.



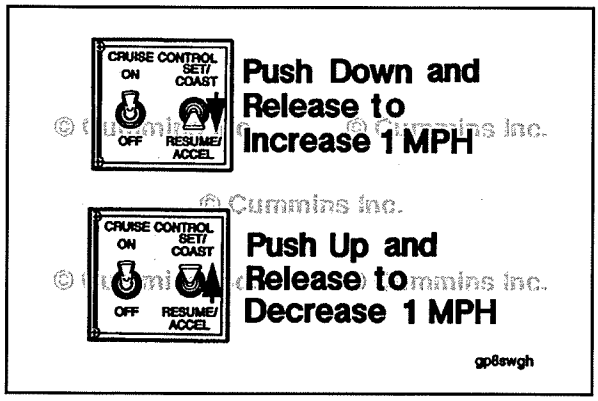


Check for Short Circuit to External Voltage Source

Turn the vehicle keyswitch to the ON position. Set the cruise control/PTO ON/OFF switch to ON. Adjust the multimeter to measure VDC. Insert a test lead into the cruise control ON/OFF switch input and attach it to a multimeter probe. Disconnect the other multimeter probe from the other lead and touch it to the engine block ground. Measure the voltage. The voltage **must** be 1.5 VDC or less.

If the voltage is **not** correct, there is an external voltage source connected to the circuit, or there is a short circuit between the cruise control/PTO ON/OFF switch circuit and a wire carrying power in the OEM harness. Remove the voltage source or repair the wiring in the OEM harness according to the vehicle manufacturer's procedures. Connect all components after completing the repair.

NOTE: If the cruise control/PTO ON/OFF switch circuit was approved in all of the previous tests, it is functioning correctly.



Cruise Control or PTO Set/Resume Select Switch (019-023)

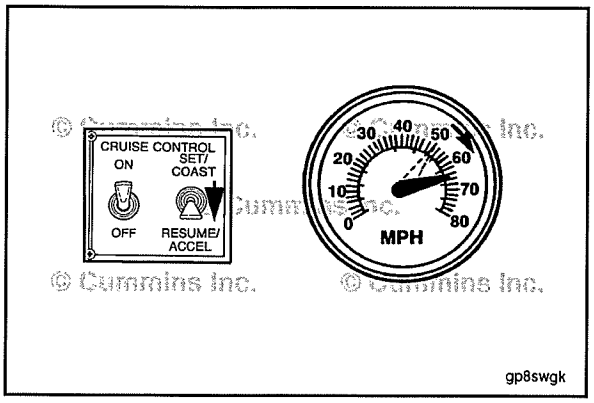
General Information

The cruise control/PTO set/resume select switch has two positions: SET/COAST and RESUME/ACCEL.

The switch can be used for: Cruise Control SET/COAST and RESUME/ACCEL, PTO INCREASE/DECREASE, IDLE INCREASE/DECREASE, ROAD SPEED GOVERNOR INCREASE/DECREASE, DIAGNOSTIC FAULT CODE INCREASE/DECREASE. For additional information, see Section F.

The operator can set the vehicle cruising speed when the switch is in the SET/COAST position. The SET/COAST position can also be used to reduce the vehicle cruising speed. Hold the switch in the SET/COAST position and the vehicle will coast down to a lower speed. When the select switch is released, the cruising speed will be reset.

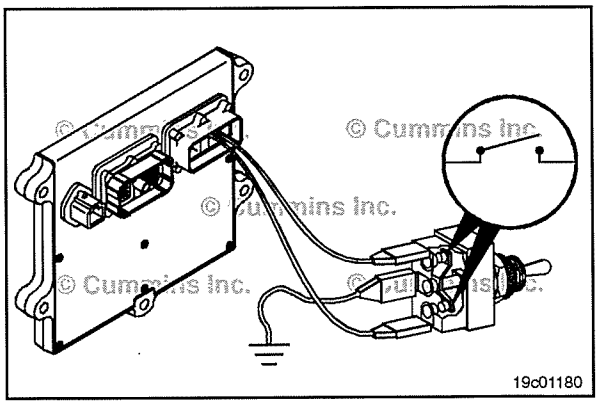
NOTE: Some OEM's have switches labeled SET/ACCEL and RESUME/COAST.



The operator can resume cruise control, after clutching or braking, by moving the switch to RESUME/ACCEL. The vehicle speed will return to the last set mph.

The RESUME/ACCEL position can also be used to increase the vehicle cruising speed. Hold the select switch in the RESUME/ACCEL position and the vehicle will increase in speed. When the switch is released, the cruising speed will be reset.

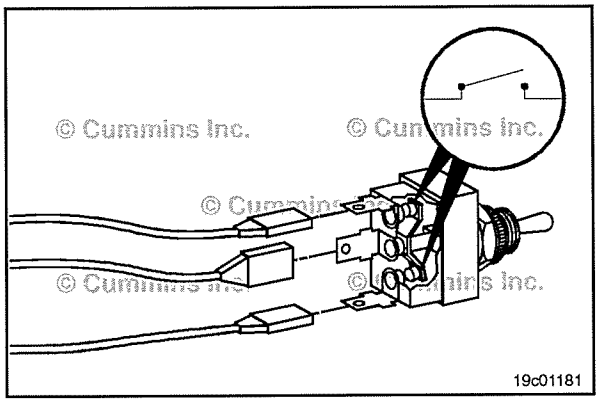
The cruise control/PTO set/resume switch circuit consists of the switch return, the cruise control/PTO resume/accel switch signal, cruise control/PTO set/coast switch signal and the vehicle mounted switch.



Resistance Check

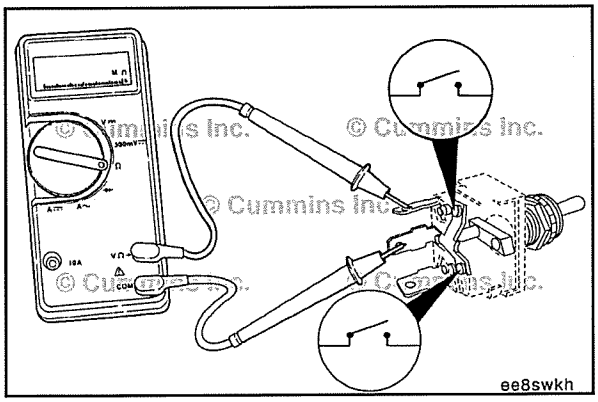
If INSITE™ is available, monitor the cruise control/PTO set/resume select switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Label the wires with the location on the switch or the wire number. Remove the three electrical connectors from the switch.



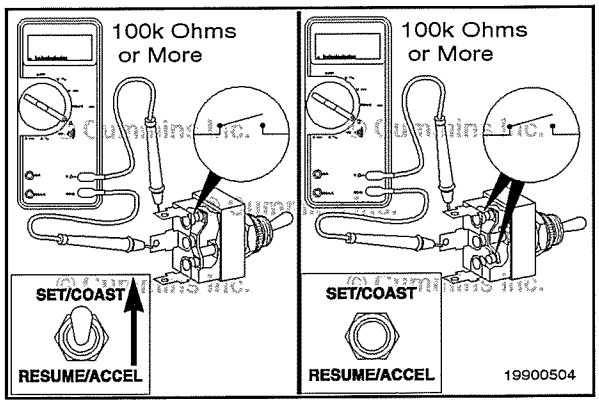
Adjust the multimeter to measure resistance.

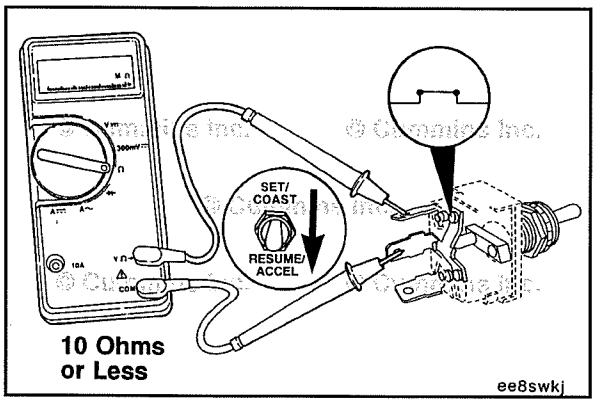
Touch one multimeter probe to the center terminal of the switch. Touch the other multimeter probe to the RESUME/ ACCEL terminal of the switch.



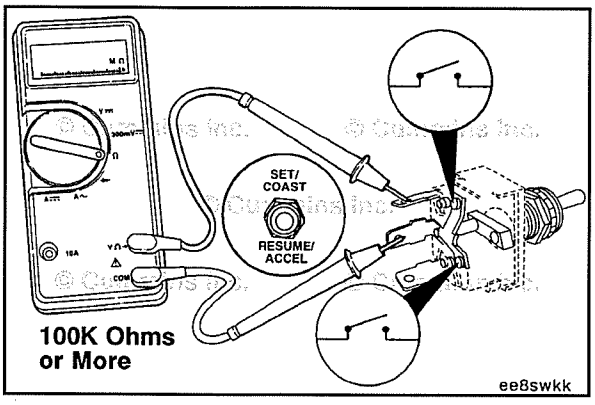
Hold the switch in the SET/COAST position. The multimeter **must** show an open circuit (100k ohms or more) when the switch is held in the SET/COAST position and after it is released. If the circuit is **not** open, the switch has failed.

Refer to the OEM troubleshooting and repair manual for replacement procedures.





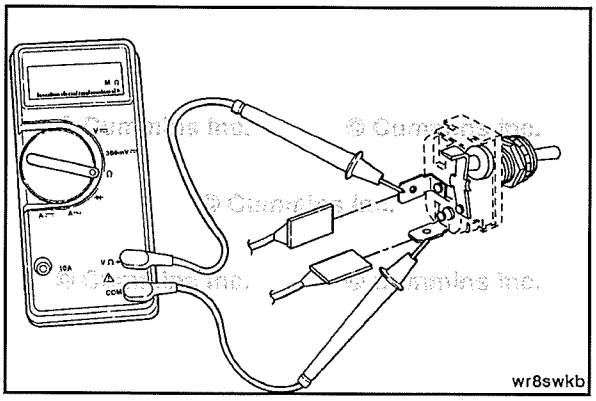
Hold the switch in the RESUME/ACCEL position. The multimeter **must** show a closed circuit (10 ohms or less) when the switch is held in the RESUME/ACCEL position.



When the switch is released, the multimeter **must** show an open circuit (100k ohms or more). If the multimeter does **not** show the correct values in either test, the switch has failed.

Refer to the OEM troubleshooting and repair manual for replacement procedures.

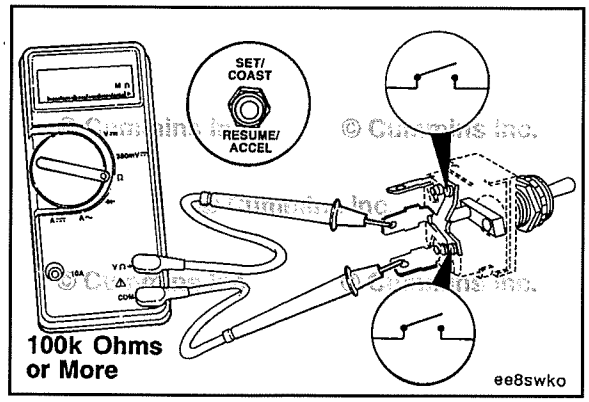
If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Touch one multimeter probe to the center terminal of the switch. Touch the other multimeter probe to the SET/ COAST terminal of the switch.

Hold the switch in the SET/COAST position.

The multimeter **must** show a closed circuit (10 ohms or less) while the switch is held to the SET/COAST position.



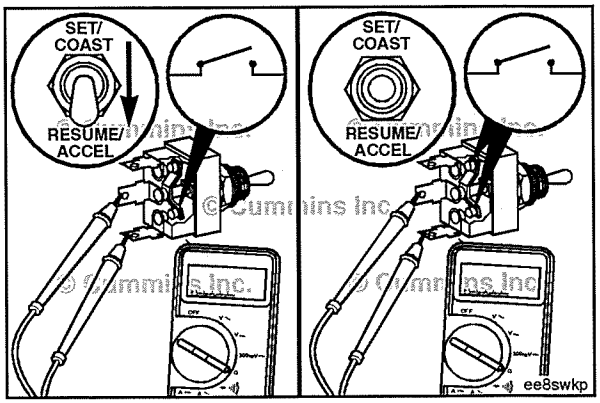
When the switch is released, the multimeter **must** show an open circuit (100k ohms or more). If the multimeter does **not** show the correct values in either test, the switch has failed.

Refer to the OEM troubleshooting and repair manual for replacement procedures.

Move the switch to the RESUME/ACCEL position.

The multimeter **must** show an open circuit (100k ohms or more) when the switch is held in the RESUME/ACCEL position and when it is released. If the circuit is **not** open, the switch has failed.

Refer to the OEM troubleshooting and repair manual for replacement procedures.

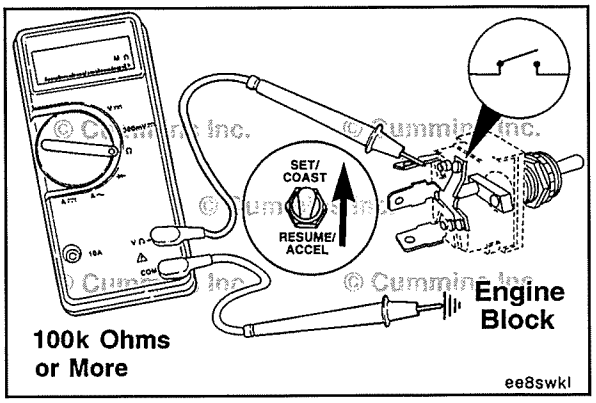


Check for Short Circuit to Ground

Adjust the multimeter to measure resistance.

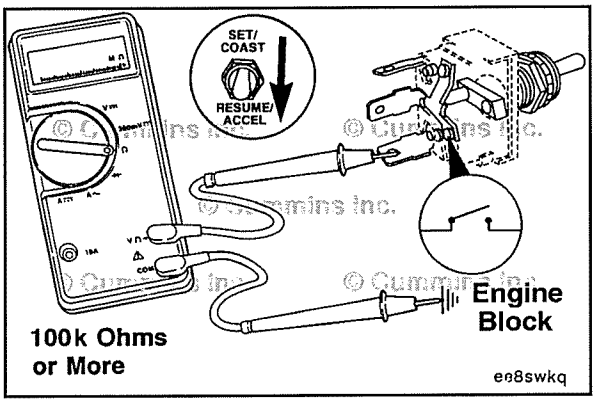
Touch one multimeter probe to the RESUME/ACCEL terminal of the switch. Touch the other multimeter probe to the chassis ground. Move the switch to the SET/COAST position then to the RESUME/ACCEL position. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more) when the switch is in all positions. If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures.



Touch one multimeter probe to the SET/COAST terminal of the switch. Touch the other multimeter probe to chassis ground. Move the switch to the RESUME/ACCEL position, then to the SET/COAST position. Measure the resistance.

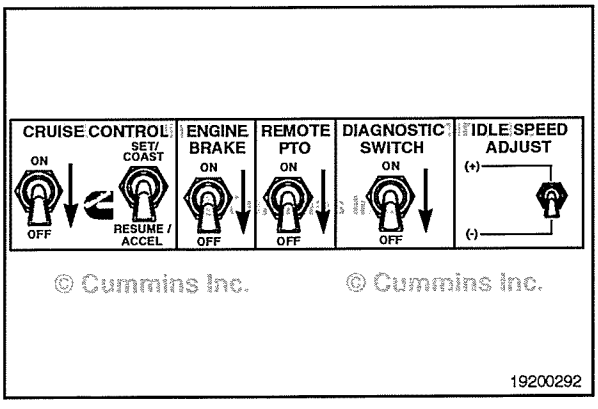
The multimeter **must** show an open circuit (100k ohms or more) when the switch is in all positions. If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures.

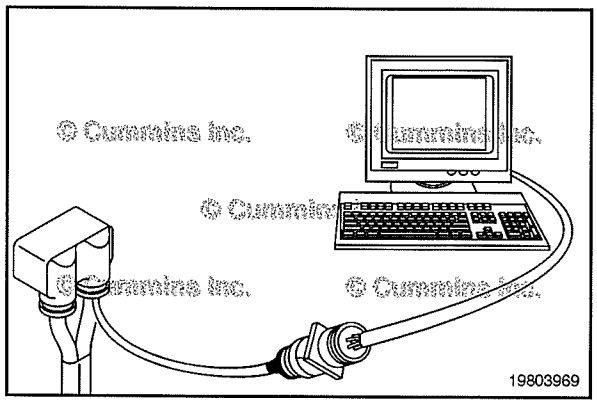


Cruise Control or PTO Set/Resume Select Switch Circuit (019-024)

General Information

In addition to cruise control functions, the cruise control select switch also provides for increasing/decreasing idle speed, PTO speed, fault code flashout, and road speed governor limit.

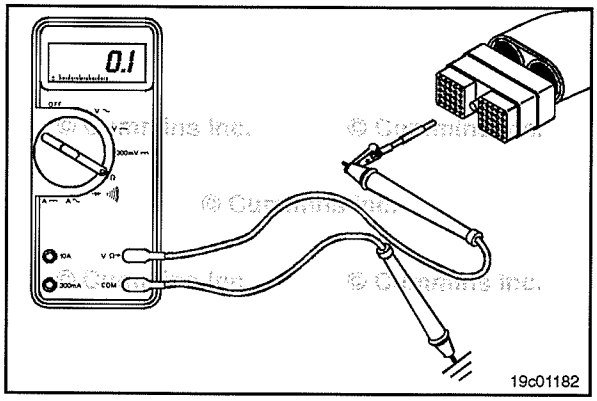




Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

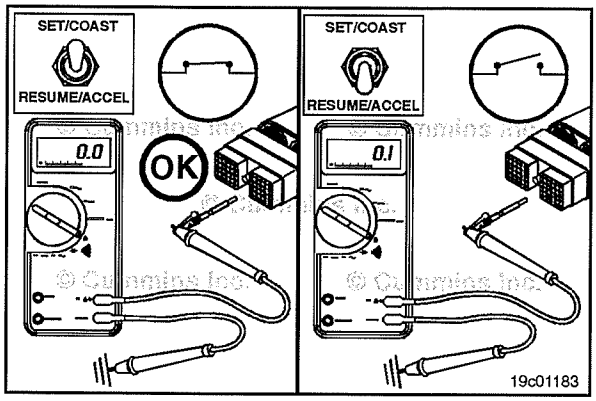
If INSITE™ electronic service tool is available, monitor the cruise control/PTO set/resume select switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.



Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM).

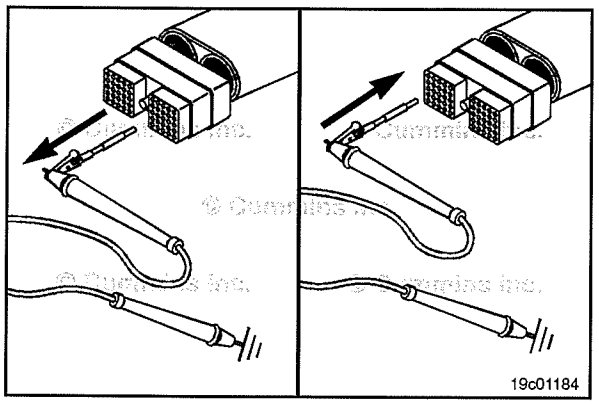
Insert a test lead into the cruise control/PTO set/coast switch signal of the OEM harness connector and connect the alligator clip to the multimeter probe.

Touch the other probe to engine block ground.



Hold the cruise control select switch in the SET/COAST position. The multimeter **must** show a closed circuit (10 ohms or less) while holding the switch in the SET/COAST position and return to an open circuit (100k ohms or more) when the switch is released. The circuit **must** remain an open circuit (100k ohms or more) when the switch is in the RESUME/ACCEL position.

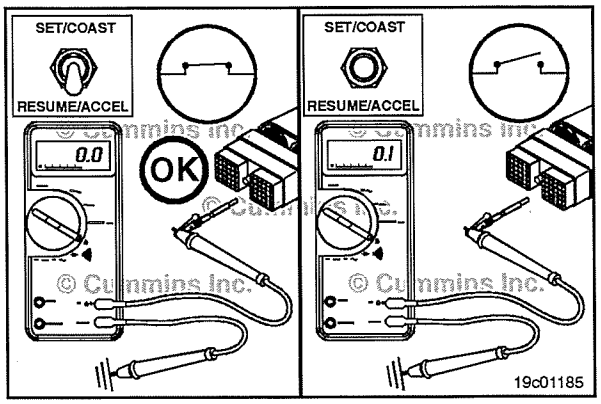
If the resistance values are **not** correct, make sure the cruise control/PTO set/coast input and the cruise control/PTO resume/accel input wires are properly installed on the cruise control select switch. If both control wires are correctly installed, inspect the cruise control/PTO set/coast input and the cruise control/PTO resume/accel wires for an open circuit, provided the cruise control select switch has been previously checked.



Remove the lead from the cruise control/PTO set/coast switch signal and insert it into the cruise control/PTO resume/accel switch signal.

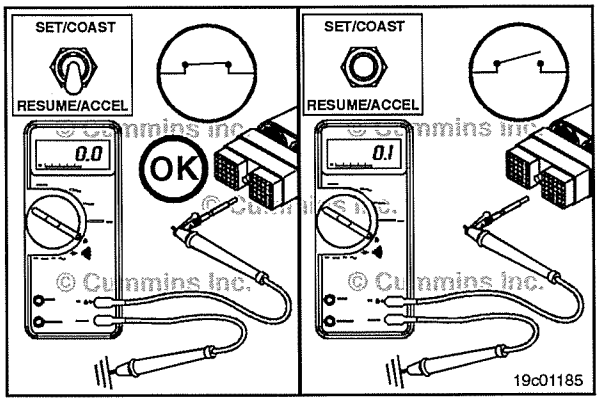
Hold the cruise control select switch in the RESUME/ ACCEL position. The multimeter **must** show a closed circuit (10 ohms or less) when the switch is in the RESUME/ACCEL position and an open circuit (100k ohms or more) when the switch is released.

The circuit **must** remain an open circuit (100k ohms or more) when the switch is held in the SET/COAST position.



If the resistance values are **not** correct, make sure the cruise control/PTO resume/accel wire is properly installed on the cruise control select switch. If the cruise control/ PTO resume/accel wire is properly installed on the cruise control select switch, inspect the cruise control/PTO resume/accel signal for an open circuit, provided the cruise control select switch has been previously checked.

If the resistance values are correct in the previous checks, the cruise control/PTO set/coast signal and cruise control/ PTO resume/accel signal **must** still be checked for a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.



Check for Short Circuit from Pin to Pin

Isolate the cruise control/PTO set/resume select switch circuit as described in the previous section. Insert a test lead into the cruise control/PTO set/coast switch signal pin of the OEM harness connector. Insert the other lead into the first pin in the connector. Connect the alligator clips to the multimeter probes. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

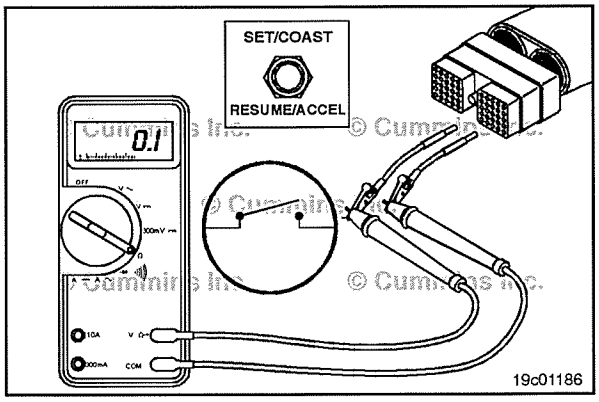
Remove the lead from the first pin in the connector and check all other pins. The multimeter **must** show an open circuit (100k ohms or more).

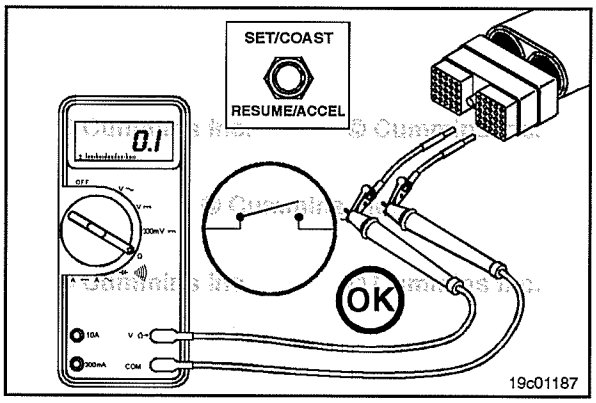
If the circuit is **not** open, there is a short circuit from the wire connected to the cruise control/PTO set/coast switch signal pin and any pin that measured less than 100k ohms.

Repair or replace the wires in the OEM harness. Refer to Procedure 019-071.

Remove the lead from the cruise control/PTO set/coast signal pin and insert it into the cruise control/PTO resume/ accel switch signal pin. Insert the other lead into the first pin in the connector.

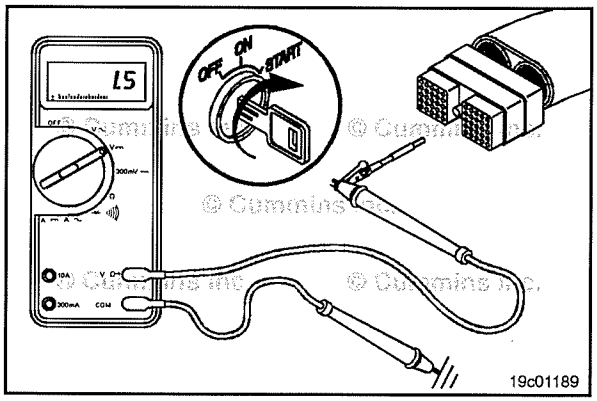
Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).





Remove the lead from the first pin in the connector and measure the resistance to all other pins. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit between the wire connected to the cruise control/PTO resume/accel switch signal pin and any pin that measured less than 100k ohms.

Repair or replace the wires in the OEM harness. Refer to Procedure 019-071.



Check for Short Circuit to External Voltage Source

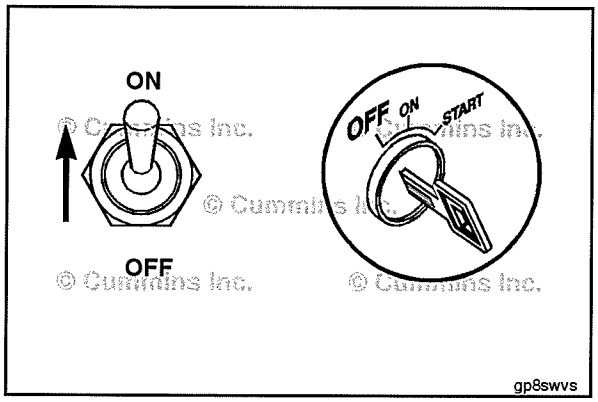
Isolate the cruise control/PTO resume/accel switch circuit as described in the previous section. Turn the vehicle keyswitch to the ON position. Adjust the multimeter to measure VDC. Insert a test lead into the cruise control/PTO resume/accel switch signal of the OEM harness connector. Connect the test lead alligator clip to the positive (+) multimeter probe. Touch the negative (-) multimeter probe to the engine block ground and measure the voltage. The multimeter **must** show less than 1.5 VDC.

If the voltage value is **not** correct, there is an external voltage source short circuit to the cruise control/PTO set/coast switch signal in the OEM harness. Remove the voltage source. Repair or replace the wire in the OEM harness. Refer to Procedure 019-071.

Remove the lead from the cruise control/PTO set/coast switch input pin and insert it into the cruise control/PTO resume/accel switch input pin. Touch the negative multimeter probe to the engine block ground and measure the voltage. The multimeter **must** show less than 1.5 VDC.

If the voltage value is **not** correct, there is an external voltage source short circuit to the cruise control/PTO resume/accel switch input pin in the OEM harness. Remove the voltage source. Repair or replace the wire in the OEM harness. Refer to Procedure 019-071.

Connect all components after completing the repair.



Diagnostic Test Mode Switch (019-027)

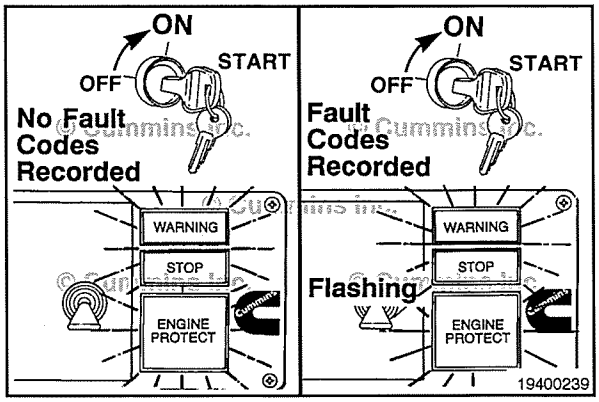
General Information

The diagnostic ON/OFF switch circuit signals the system that the operator is requesting to read any active fault code recorded in the ECM.

NOTE: Some OEM's use a shorting plug rather than a switch.

When the ECM receives the signal from the diagnostic ON/OFF switch, the yellow and red warning lights will come on and start flashing if any active fault code is recorded in the ECM. If both warning lights remain on and do **not** flash, there are no active fault codes present.

NOTE: The equipment **must** be stationary. If road speed is detected, the flashing sequence will **not** occur.

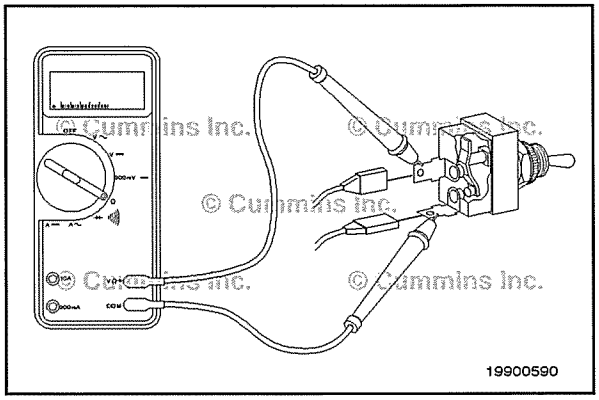


Resistance Check

If INSITE™ is available, monitor the switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Locate the desired ON/OFF toggle switch. Remove and tag the two connectors from the terminals on the switch.

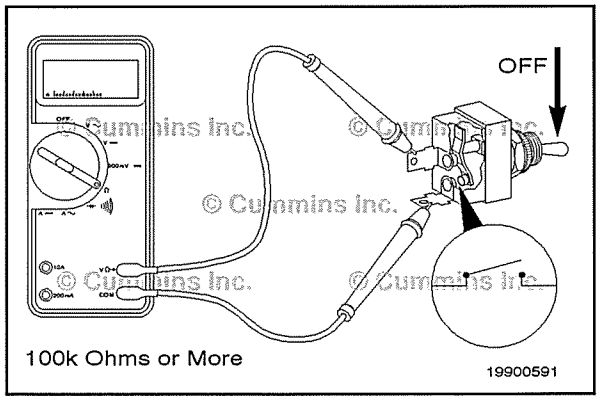
Touch the multimeter probes to the terminals on the switch.



Move the switch to the OFF position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, the switch has failed.

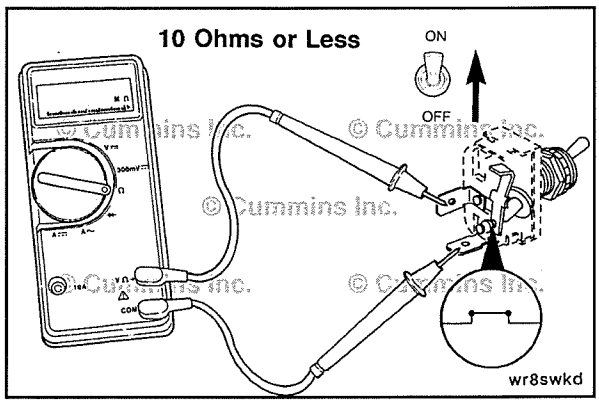
Refer to the OEM troubleshooting and repair manual for the replacement procedures.

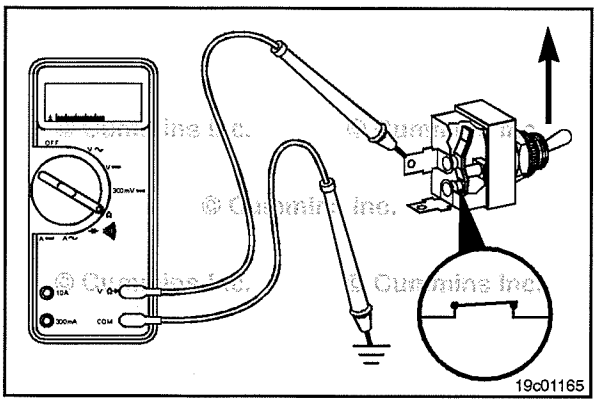


Move the switch to the ON position and measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, the switch has failed.

Refer to the OEM troubleshooting and repair manual for the replacement procedures.

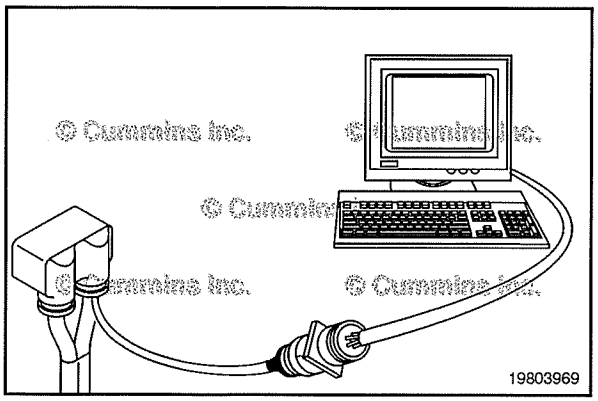
If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.





Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the ON position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.

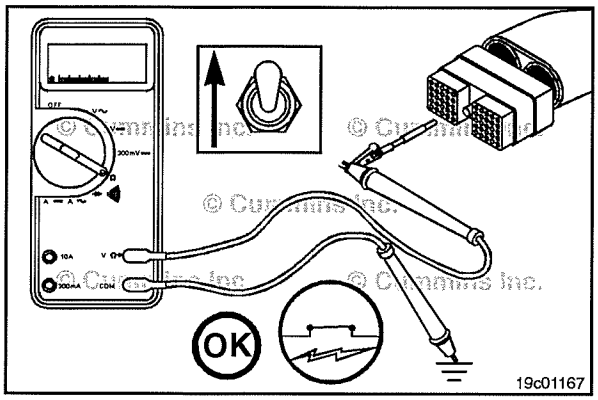


Diagnostic Test Mode Switch Circuit (019-028)

Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.



Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control unit. Insert the test lead into the diagnostic test mode switch signal pin in the OEM harness connector and connect it to the multimeter probe.

Touch the other probe to the engine block or chassis ground.

Move the ON/OFF switch to the ON position.

If the OEM wired the switch return to chassis ground, the multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the diagnostic test mode switch signal wire for an open circuit.

If the OEM wired the switch return to the OEM wire harness, the multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, inspect the diagnostic test mode switch signal wire for a closed circuit.

Refer to the OEM troubleshooting and repair manual.

If the resistance is within specification, the diagnostic test mode switch signal wire **must** be checked for a short circuit to ground, a short circuit from terminal to terminal, and a short circuit to an external voltage source.

Check for Short Circuit to Ground

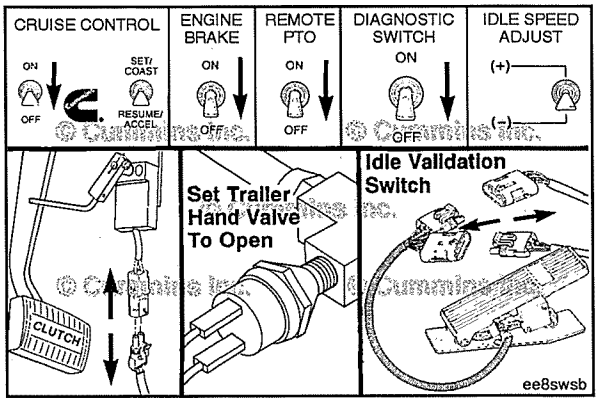
To isolate the diagnostic test mode switch signal circuit when checking for an electrical short, turn all cab panel switches to the OFF or neutral position.

Set the service brake using the trailer brake hand valve.

Disconnect the clutch pedal position switch.

Disconnect the idle validation switch.

NOTE: Some equipment may vary, depending on OEM application.

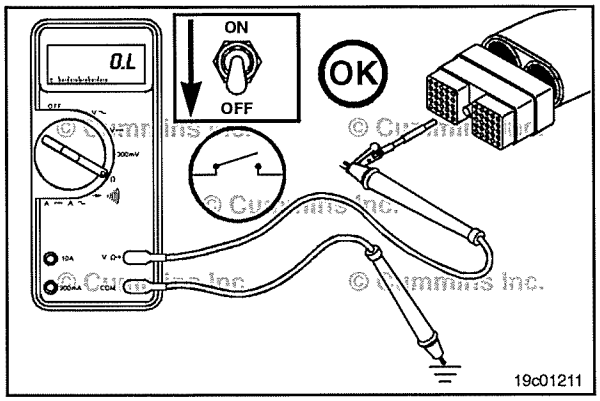


Disconnect the OEM harness connector from the electronic control unit. Set the diagnostic test mode switch to the OFF position.

Insert one of the test leads into the diagnostic test mode switch signal pin of the OEM harness connector and connect it to a multimeter probe.

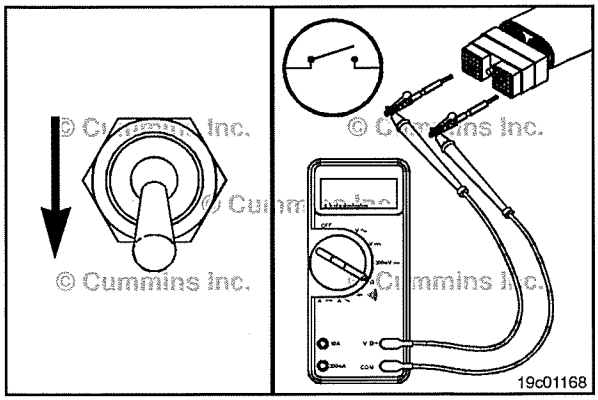
Touch the other probe to engine block or chassis ground.

The multimeter **must** show an open circuit (100k ohms or more).



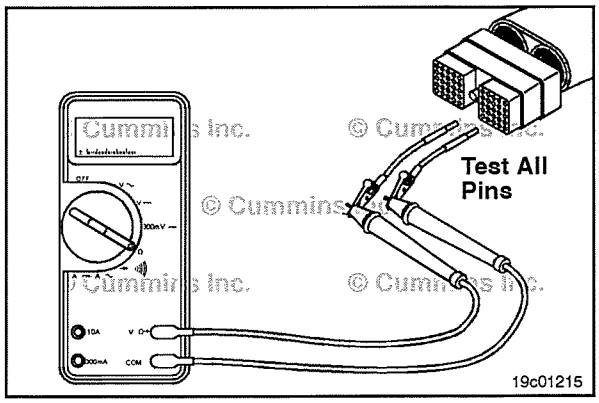
Check for Short Circuit from Pin to Pin

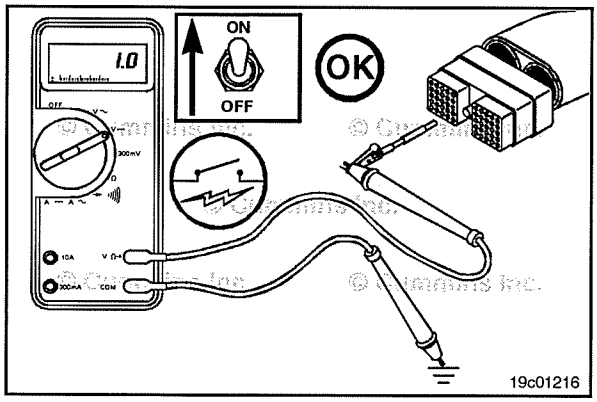
Check for a short circuit from pin-to-pin. Isolate the switch circuit by setting the cab panel switches as described in the previous section. Set the diagnostic test mode switch to the OFF position. Insert a test lead into the switch return pin of the OEM harness connector and connect it to the multimeter probe. With the other lead inserted into the diagnostic test mode switch signal pin of the connector, measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).



Remove the lead from the switch return and test all pins in the connector. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit between the switch circuit and any pin that shows a closed circuit, provided the switch has previously been checked. Repair or replace the wires in the OEM harness. Refer to Procedure 019-071.



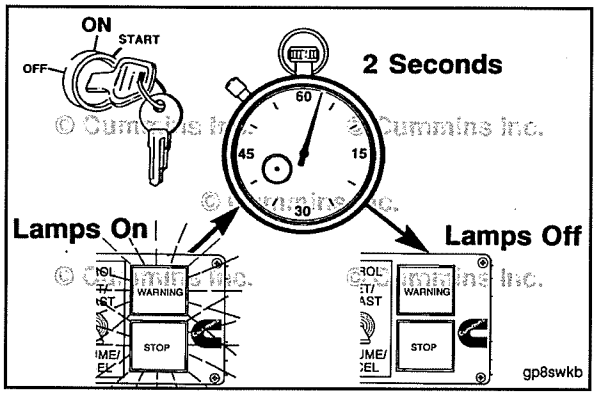


Check for Short Circuit to External Voltage Source

Turn the vehicle keyswitch to the ON position. Set the diagnostic test mode switch to ON. Adjust the multimeter to measure VDC. Insert a test lead into the diagnostic test mode switch signal pin of the OEM harness connector. Touch the other lead to the engine block or chassis ground. Measure the voltage. The voltage **must** be 1.5 VDC or less.

If the voltage is **not** correct, there is an external voltage source connected to the circuit or there is a short circuit between the switch circuit and a wire carrying power in the OEM harness. Remove the voltage source or repair the wiring in the OEM harness. Refer to Procedure 019-071.

Connect all components after completing the repair.

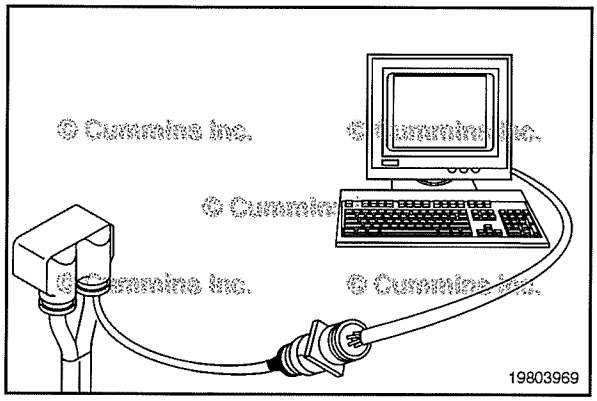


Engine Control Module (019-031)

Initial Check

Turn the keyswitch to the ON position while monitoring the fault lamps. The fault lamps **must** illuminate for 2 to 3 seconds.

If the lamps do **not** illuminate, check for burned out bulbs.



Turn the keyswitch to the OFF position.

Connect an electronic service tool to the vehicle data link.

Turn the keyswitch to the ON position.

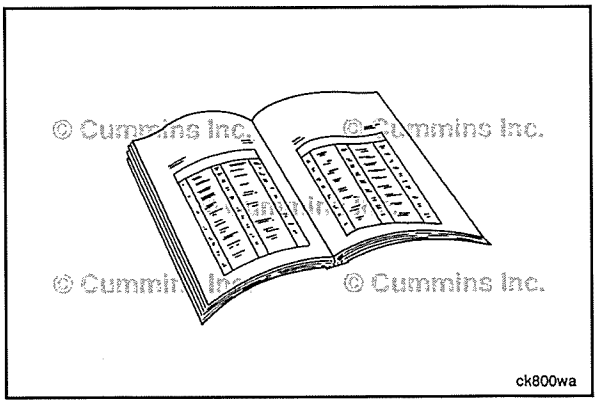
Select the monitor mode on the electronic service tool. The electronic service tool **must** be able to communicate with the engine control module (ECM). If the ECM will **not** communicate with the service tool, see the Communication Error - Electronic Service Tool or Control Device symptom tree.

Record the values of ECM Distance Offset, ECM Time Offset, Engine Distance Offset, and Engine Time Offset prior to replacement or calibration of the ECM. These parameters can be found in the Trip Information section of Features and Parameters.

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.

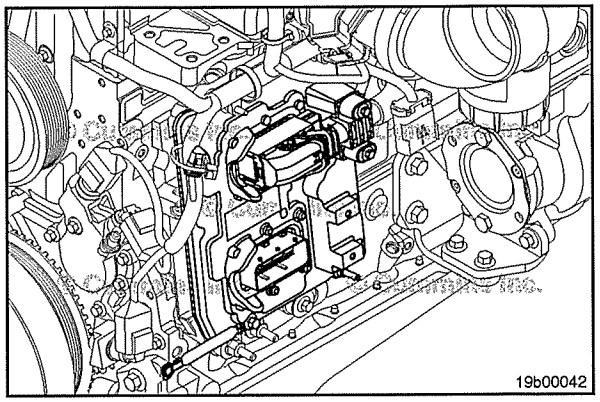


Remove

The ECM is located at the middle of the engine block, on the cold side of the engine.

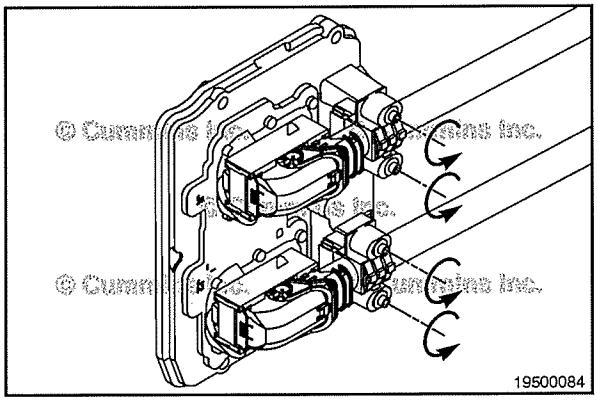
NOTE: Some engines are equipped with remote mount ECMs for better accessibility. Refer to the OEM service manual.

NOTE: Record all programmable parameters, features, and calibration information from the old ECM before disconnecting the harness connectors. This information will be needed to program the new ECM.



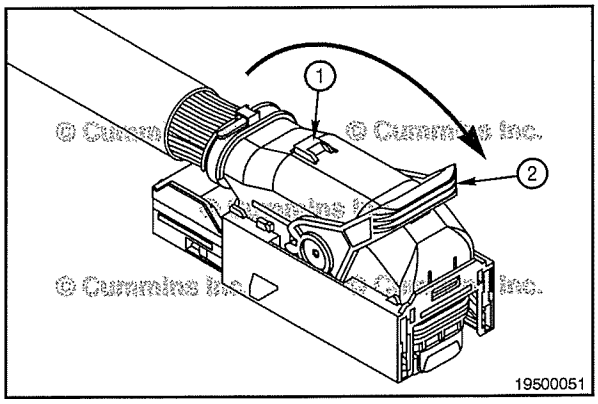
Remove the wiring harness hold-down clamps from the ECM.

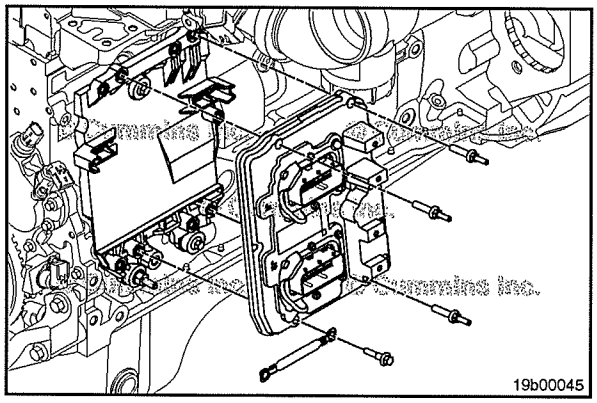
NOTE: Do **not** remove the wire ties attaching the hold-down clamps to the wiring harness.



Remove the OEM connector and the engine harness connector from the ECM by pressing down on the locking tab (1) and pulling up on the lever (2).

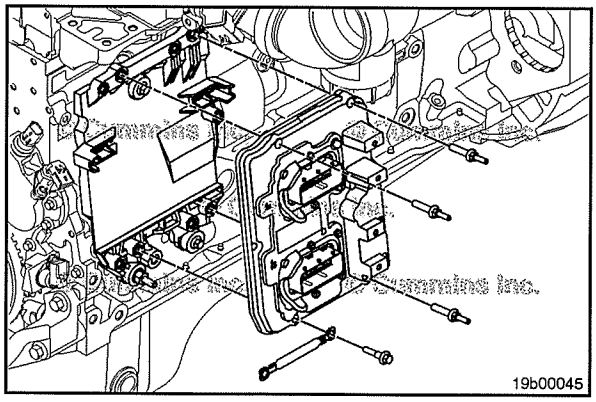
NOTE: Do **not** close the lever after the connector has been removed from the ECM. Attempting to do so will cause damage to the connector.





Remove the capscrews that secure the ECM to the ECM mounting plate.

Remove the ECM.



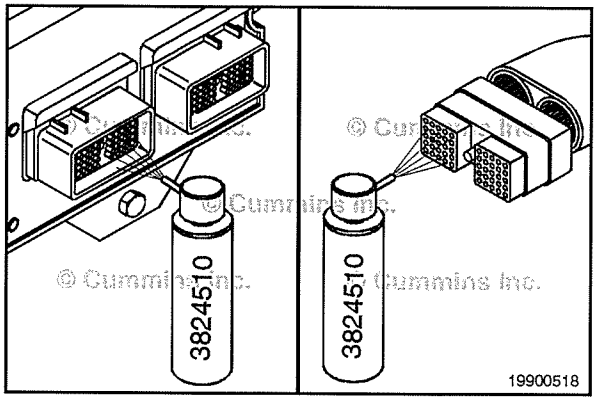
Install

⚠CAUTION⚠
Do not paint the back side of the ECM. Make sure no grease or dirt is between the ECM and the mounting plate.

Install the new ECM to the mounting plate. Tighten the capscrews.

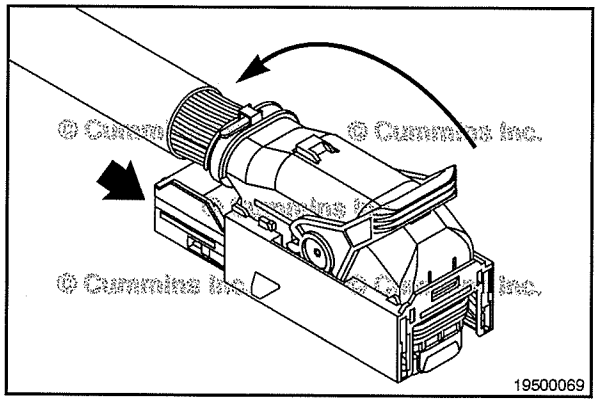
Torque Value: 18 N•m [159 in-lb]

NOTE: Make sure the ECM ground strap is attached to the lower-left ECM mounting capscrew. Failure to install this ground strap can cause damage to the ECM.



⚠CAUTION⚠
Do not blow compressed air into the ECM ports or connectors. Compressed air can contain moisture due to condensation.

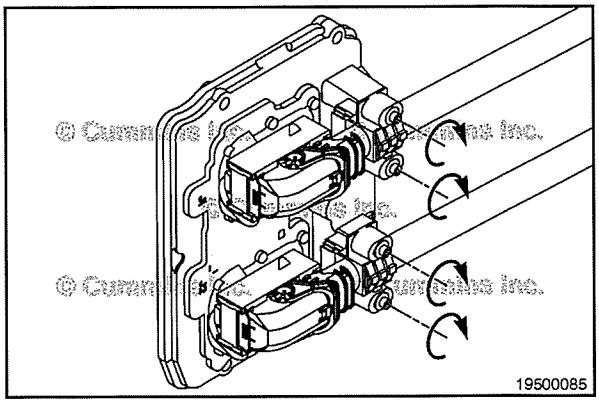
Use electrical contact cleaner, Part Number 3824510, to remove all dirt and moisture from the ECM connector ports and the harness connectors.



Connect the harness to the ECM by placing the harness connector into the ECM header and pull back on the locking lever until the connector is fully seated and the lever locking tab is engaged.

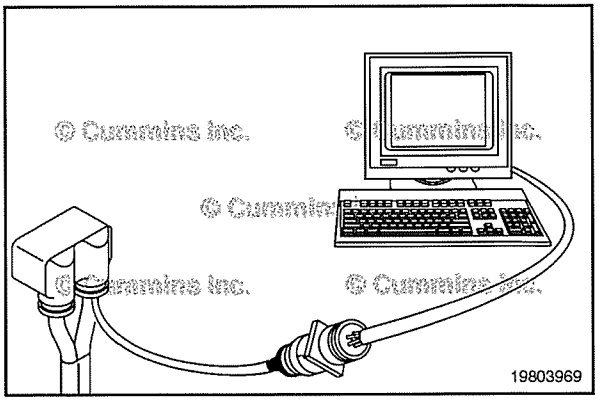
Install the wire harness hold-down clamps. Refer to Procedure 019-043 in Section 19.

NOTE: Do **not** overtighten the harness hold-down clamp mounting screws or damage to the ECM will occur.



NOTE: When an ECM is replaced, the new ECM **must** be calibrated. Refer to Procedure 019-032 in Section 19.

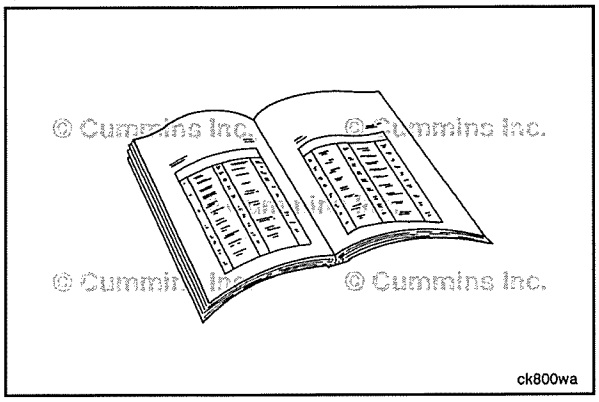
Adjust the values of ECM Distance Offset, ECM Time Offset, Engine Distance Offset, and Engine Time Offset after calibrating the ECM. These parameters can be found in the Trip Information section of Features and Parameters.

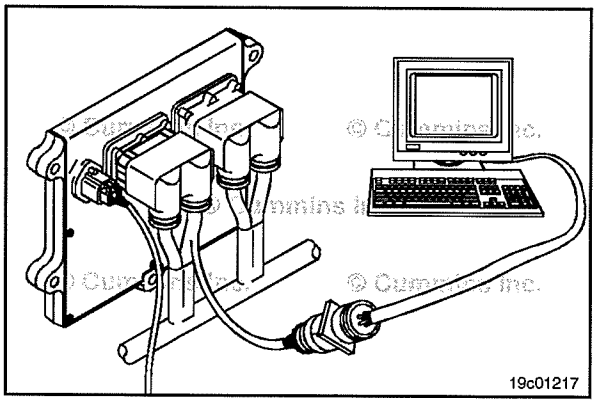


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for loose components.





Engine Control Module Calibration Code (019-032)

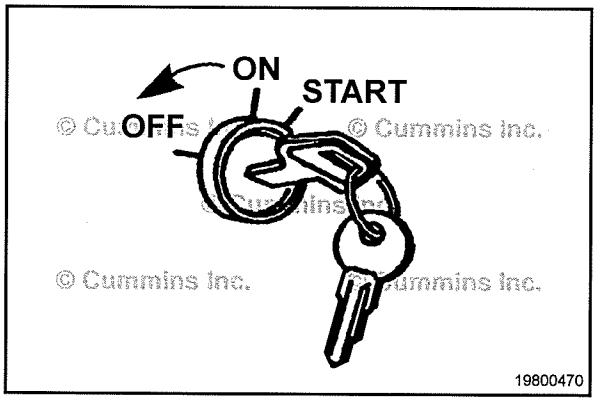
General Information

NOTE: Due to the number of various engine control module (ECM) configurations, this procedure has been written to be common. **Not** all illustrations within this procedure will represent the application that is being worked on.

ECM calibrations can be performed by INSITE™ electronic service tool.

After an ECM is replaced or calibrated, the actual engine hours / distance **must** be entered correctly into the ECM.

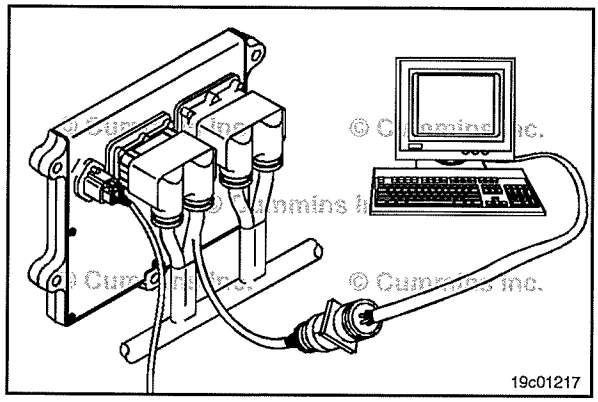
Record the values of ECM Distance Offset, ECM Time Offset, Engine Distance Offset, and Engine Time Offset prior to replacement or calibration of the ECM. These parameters can be found in the Trip Information section of Features and Parameters.



Initial Check

NOTE: If the tool will **not** communicate with the keyswitch in the ON position, cycle the keyswitch and try again.

The ECM calibration process occurs with the keyswitch turned ON. **Always** follow the instructions on the service tool screens.



Preparatory Steps

Connect INSITE™ electronic service tool to the service tool data link, which is located on the engine or in the cab.

See the help section within INSITE™ electronic service tool for detailed ECM calibration procedures.

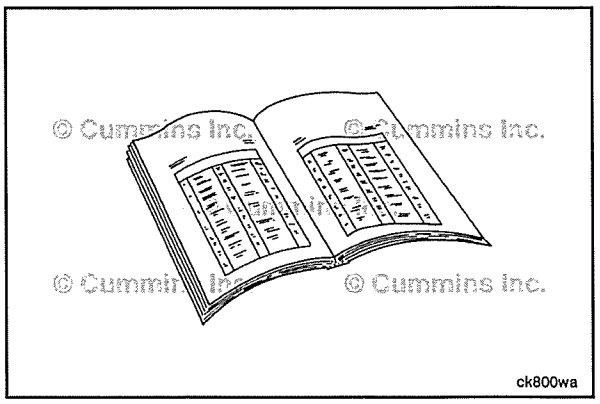
After an ECM is replaced or calibrated, the actual engine hours / distance **must** be entered correctly into the ECM.

Input the values of ECM Distance Offset, ECM Time Offset, Engine Distance Offset, and Engine Time Offset prior to replacement or calibration of the ECM. These parameters can be found in the Trip Information section of Features and Parameters.

Following calibration download, if new fault codes or fault conditions exist, perform the following steps in order to understand if the calibration is working correctly and is the appropriate calibration for the application.

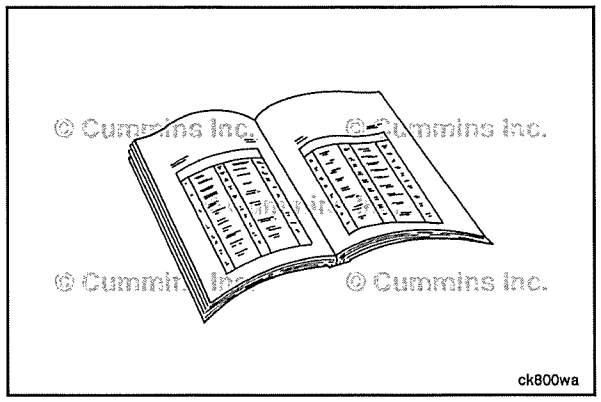
If it is suspected that the calibration is **not** working correctly, make sure that the appropriate calibration was loaded for the engine, equipment, and application.

If no issues are found, no further action is required.



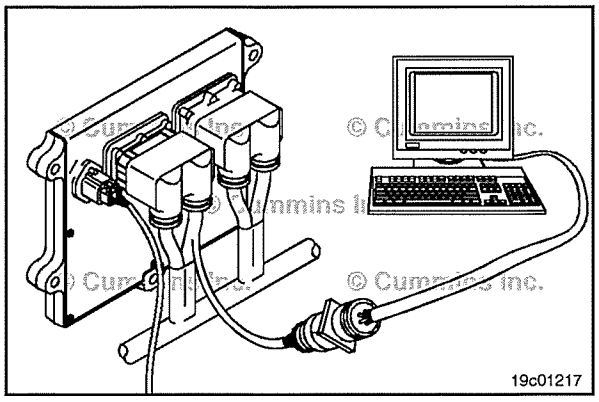
Inspect

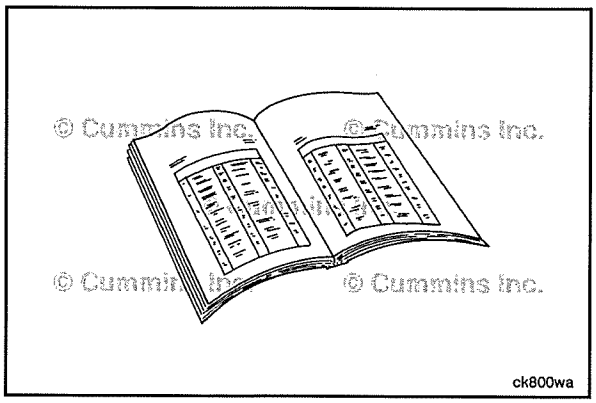
Establish if the suspected feature creating the problem is operating correctly. Reference the relevant "Electronic Controlled Fuel System" (Procedure 101-007) in Section 1 of the appropriate Operation and Maintenance Manual or in INSITE™ electronic service tool "Fault Information System" for further information.



NOTE: To access INSITE™ electronic service tool "Adjustable Engine Features" section, either select Help -> Contents from the menu bar, or press F1 with an individual feature within the Features and Parameters section in INSITE™ electronic service tool highlighted.

Review the INSITE™ electronic service tool help files "Adjustable Engine Features" section to determine if the suspected error is due to an incorrectly set adjustable engine feature.

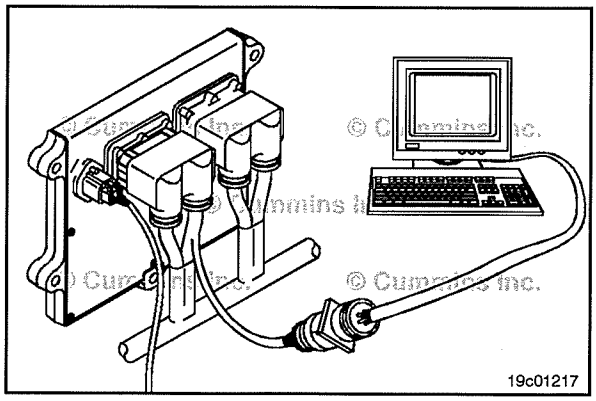




Use QuickServe™ Online to inspect the calibraton revision history.

1 Log into QuickServe™ Online
2 Select "My Applications"
3 Select "ECM Calibraton Revisions"
4 Enter the calibration code and select "Search"
5 Review the calibration revision information.

NOTE: The calibration revision history provides information relating to changes made to a calibration each time a new revision is released. This information can be used to establish if there is a commonality between changes made to the calibration and the symptoms being observed. The calibration revision history can also be downloaded in Excel format by selecting “Spreadsheet” in the record filter box.



NOTE: The greater the number of parameters, the slower the rate at which they can be logged. Therefore, **only** log the minimum number of parameters if sample rate is important.

If no issue can be identified using the steps listed above, the following information should be collected to allow the issue to enter the technical escalation chain:

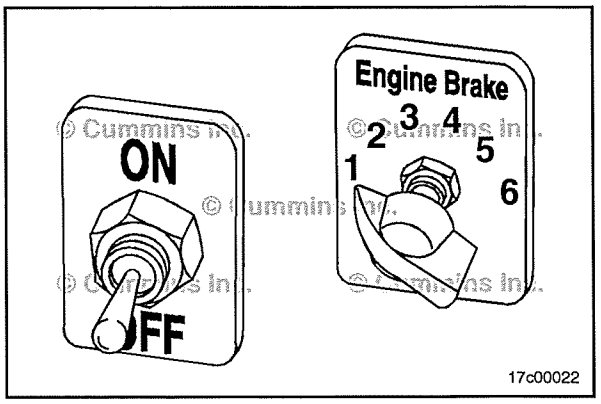
1 Engine specifics engine serial number (ESN), application, rating, engine hours, maintenance history, etc.)
2 ECM codes (the codes before and after, including revision numbers)
3 ECM images (before and after calibration downloads)
4 Data logs (utilize existing, pre-defined parameter groups, found in INSITE™ electronic service tool, or use the relevant wiring diagram to identify if multiple circuits utilize a common supply or ground, or monitor parameters which logically would be linked - i.e. User Fuelling State, Engine Speed, Commanded Fuel Rail Pressure, Measured Fuel Rail Pressure, etc.).

Engine Brake ON/OFF Switch (019-034)

General Information

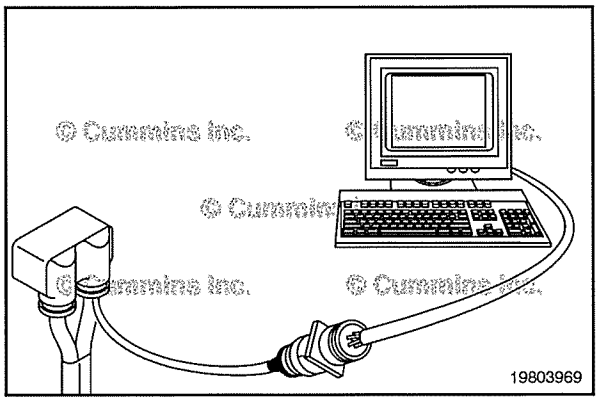
The engine brake ON/OFF switch circuit signals the system that the operator is requesting the engine brake system to be activated. The engine brake level switch determines what percentage of engine braking power will be used for engine braking. Three inputs to the electronic control module (ECM) from the engine brake level switch are used to communicate the setting to the ECM. Engine brake selector number 1 signal, engine brake selector number 2 signal, and engine brake selector number 3 signal in the original equipment manufacturer (OEM) connector are used. Various combinations of the three wires are used to represent the six switch positions.

After the ECM receives the signal from the engine brake ON/OFF switch and all other engine braking preconditions are met (engine RPM and road speed limits), the ECM will supply 12 VDC to the appropriate engine brake solenoids depending on how the 3 or 6 position engine brake level switch is set.



Resistance Check

If INSITE™ electronic service tool is available, monitor the engine brake ON/OFF switches for proper operation. If **not**, follow the troubleshooting procedures in this section.

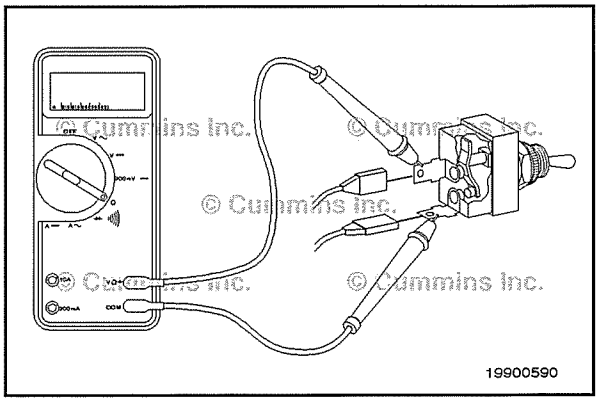


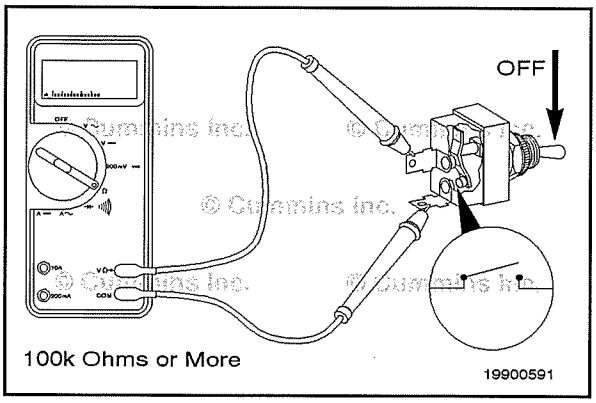
Locate the engine brake ON/OFF switch. Remove the electrical connectors from the switch.

Label the wires with the location on the switch or the wire number. Remove the electrical connectors from the switch.

Adjust the multimeter to measure resistance.

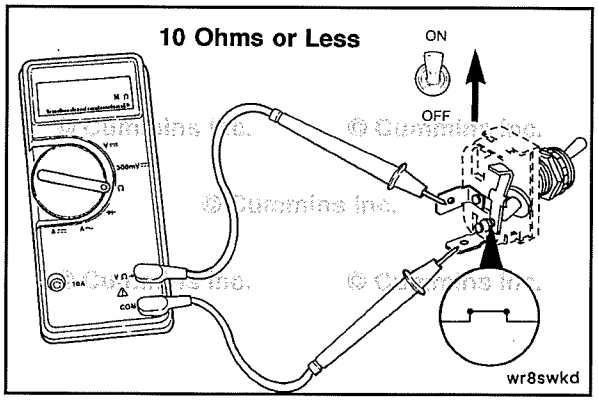
Touch one multimeter probe to one of the terminals of the switch. Touch the other multimeter probe to the other terminal of the switch.





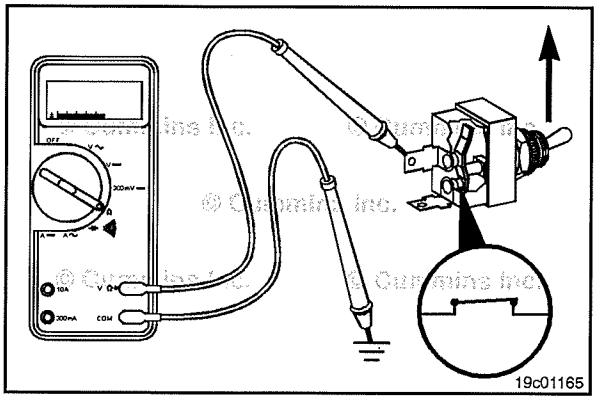
Move the switch to the OFF position. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed.

Refer to the OEM troubleshooting and repair manual for replacement procedures.



Place the switch in the ON position. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, the switch has failed.

Refer to the OEM troubleshooting and repair manual for replacement procedures.



Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the ON position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.

Engine Brake ON/OFF Switch Circuit (019-035)

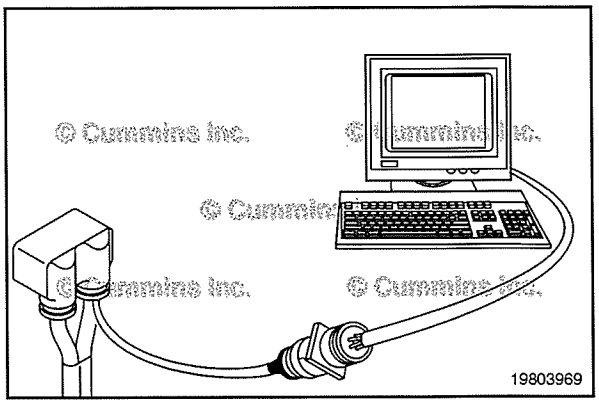
Resistance Check

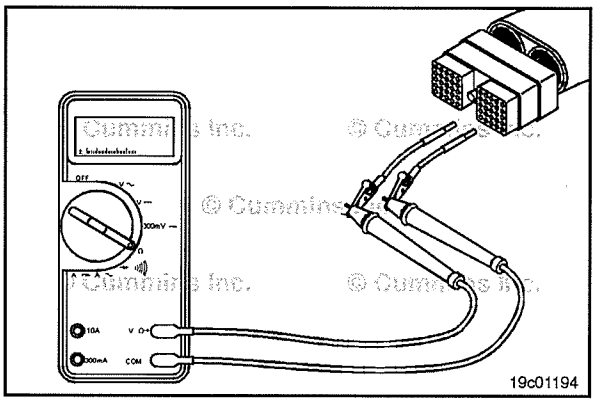
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the engine brake switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.

Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM).

Insert one of the test leads into the switch return of the OEM harness connector and connect the alligator clip to the multimeter probe. Insert the other lead into engine brake selector signal number 1 of the OEM harness connector and connect the alligator clip to the other multimeter probe.





Move the engine brake ON/OFF switch to the ON position. Move the engine brake level switch to position number 1 for a six-position switch or to position number 2 for a three-position switch. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the switch return and engine brake selector signal number 1 for an open circuit, provided that the switch has been previously checked. Refer to the OEM troubleshooting and repair manual for repair procedures. If the resistance is within the specification, the switch return and engine brake selector signal number 1 **must** be checked for a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.

Remove the lead from engine brake selector signal number 1 and insert it into engine brake selector signal number 2 of the OEM harness connector.

Move the engine brake ON/OFF switch to the ON position. Move the engine brake level switch to position number 2 for a six-position switch or to position number 1 for a three-position switch.

The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect engine brake selector signal number 2 wire for an open circuit, provided that the switch has been previously checked. Refer to the OEM troubleshooting and repair manual for repair procedures.

If the resistance is within the specification, engine brake selector signal number 2 wire **must** be checked for a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.

Remove the lead from engine brake selector signal number 2 and insert it into engine brake selector signal number 3 of the OEM harness.

Move the engine brake ON/OFF switch to the ON position. Move engine brake level switch to position number 3.

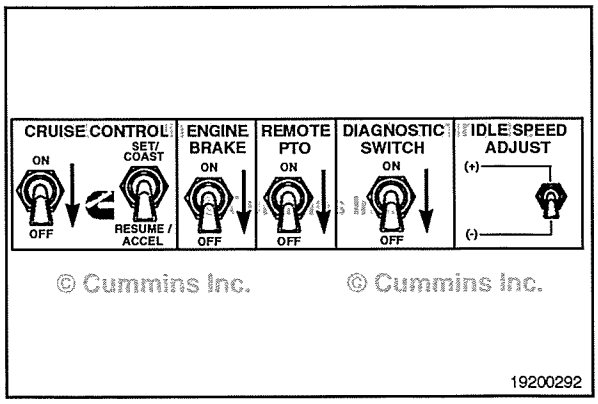
The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the engine brake selector signal number 3 wire for an open circuit, provided that the switch has been previously checked. Refer to the OEM troubleshooting and repair manual for repair procedures.

If the resistance is within the specification, the engine brake selector signal number 3 wire **must** be checked for a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.

Connect all components after completing the repair.

Check for Short Circuit to Ground

To isolate the engine brake circuit when checking for an electrical short, turn all cab panel switches to the OFF or neutral position.



Move the engine brake level switch to position number 1 for a six-position switch or position number 2 for a three-position switch.

Insert a test lead into engine brake selector signal number 1 pin of the OEM harness connector and connect it to a multimeter probe.

Touch the other multimeter probe to the engine block ground.

Switch the engine brake ON/OFF switch to the OFF position.

Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the engine brake circuit, provided the engine brake ON/OFF switch and engine brake selector switch have been previously checked.

Repair or replace the wire connected to the switch return or engine brake selector signal number pin 1 in the OEM harness connector according to the vehicle manufacturer's procedures.

Remove the lead from engine brake selector signal number 1 pin and insert it into engine brake selector signal number 2 pin of the OEM harness connector.

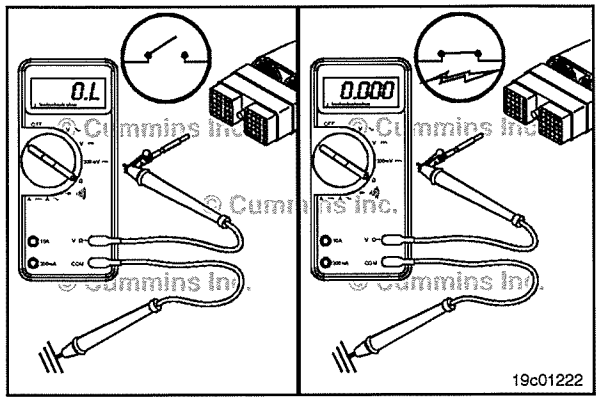
Move engine brake level switch to position number 2 for a six-position switch or to position number 1 for a three-position switch.

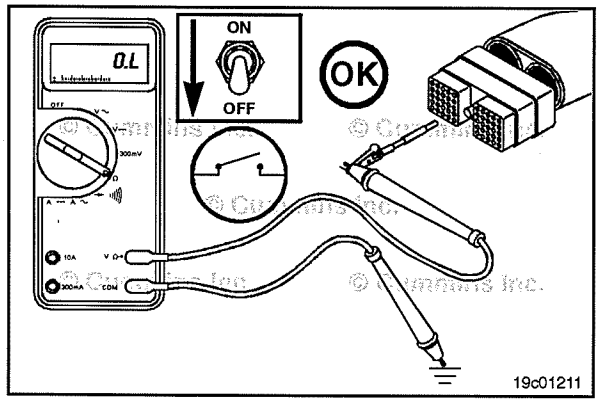
Switch the engine brake ON/OFF switch to OFF.

Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the engine brake circuit, provided the engine brake ON/OFF switch has been previously checked.

Repair or replace the wire connected to engine brake selector signal number 2 pin in the OEM harness according to the vehicle manufacturer's procedures.





Remove the lead from engine brake selector signal number 2 pin and insert it into engine brake selector signal number 3 pin of the OEM harness connector.

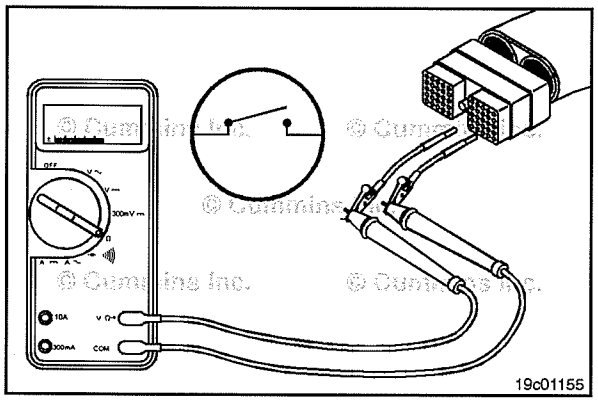
Move engine brake level switch to position number 3.

Switch the engine brake ON/OFF switch to the OFF position.

Measure the resistance with the multimeter.

The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the engine brake circuit, provided the engine brake ON/OFF switch has been previously checked.

Repair or replace the wire connected to engine brake selector signal number 3 pin in the OEM harness according to the vehicle manufacturer's procedures.



Check for Short Circuit from Pin to Pin

Isolate the circuit by setting the cab panel switches as described in the previous section. Set the engine brake ON/OFF switch to the ON position. Place engine brake level to position number 6 for a six-position switch or position number 3 for a three-position switch.

Insert a test lead into the switch return of the OEM harness connector and check all pins except the switch return, engine brake selector signal number 1 pin, and engine brake selector signal number 3 pin.

Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

Remove the lead from the switch return and insert it into engine brake selector signal number 2 pin. Check all pins except the switch return engine, brake selector signal number 1 pin and engine brake selector signal number 3 pin. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

Remove the lead from engine brake selector signal number 2 pin and insert it into engine brake selector signal number 3 pin. Check all pins except the switch return. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

Remove the lead from the engine brake selector signal number 3 pin and inert it in the engine brake selector signal number 1 pin. Check all pins except the switch return. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

Check for Short Circuit to External Voltage Source

Turn the vehicle keyswitch to the ON position. Set the engine brake ON/OFF switch to the ON position.

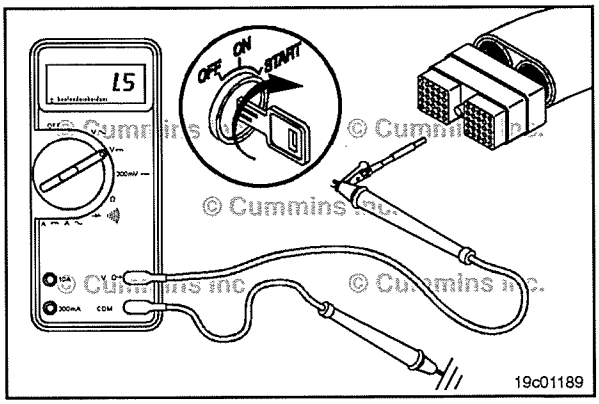
Adjust the multimeter to measure the VDC.

Insert a test lead into the switch signal pin of the OEM harness connector.

Disconnect the multimeter probe from the test lead and touch it to the engine block ground. Measure the voltage. The voltage **must** be 1.5 VDC or less.

If the voltage is **not** correct, there is an external voltage source connected to the circuit, or there is a short circuit between the engine brake on/off circuit and a wire carrying power in the OEM harness. Remove the voltage source or repair the wiring in the OEM harness according to the vehicle manufacturer's procedures.

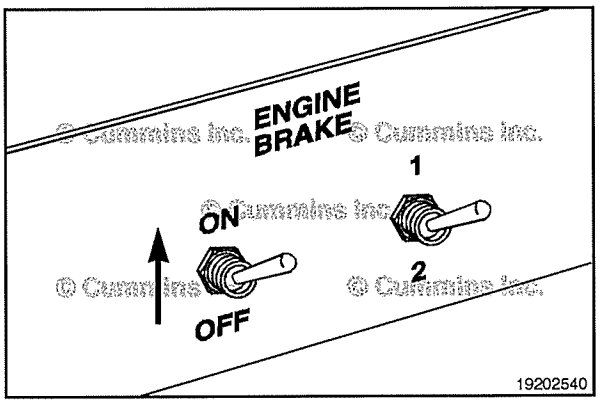
Connect all components after completing the repair.

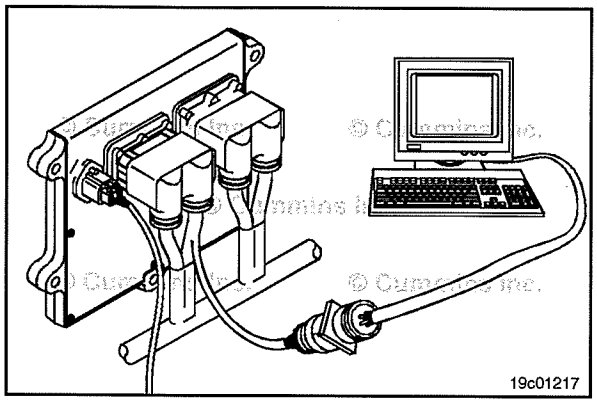


Engine Brake Level Switch (019-036)

General Information

The engine brake level switch determines the percentage of engine braking power that will be applied when the engine brakes are activated. The engine brake ON/OFF switch needs to be turned ON to activate the engine brake system. Vehicles can be wired with a 2 or 3 position switch.





Resistance Check

If INSITE™ electronic service tool is available, monitor the engine brake selector switch for proper operation. If INSITE™ electronic service tool is **not** available then follow the troubleshooting procedures for this section.

Label the wires with the location on the switch or the wire number. Disconnect the three electrical connectors from the switch.

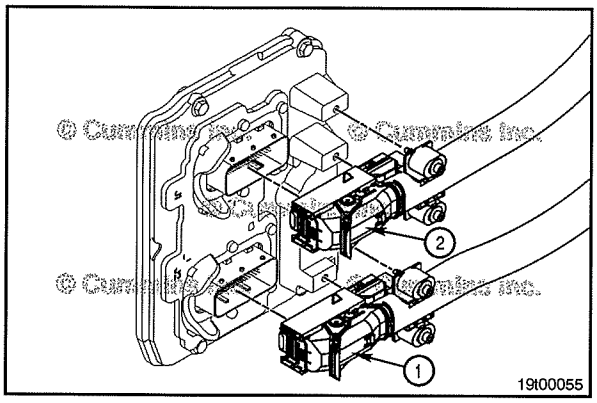
Adjust the multimeter to measure resistance

Three Position Switch		
Switch Position	Terminal A - Engine Brake Selector Signal Number 1	Terminal B - Engine Brake Selector Signal Number 2
1	Closed	Open
1	Open	Closed
2	Open	Closed
2	Closed	Open
3	Closed	Closed

Two Position Switch		
Switch Position	Terminal A - Engine Brake Selector Signal Number 1	Terminal A - Engine Brake Selector Signal Number 2
1	Closed	Open
1	Open	Closed
2	Closed	Closed

Check the resistance for each position of the 2 or 3 position switch. An open circuit **must** have a resistance greater than 100k ohms. A closed circuit **must** have a resistance of 10 ohms or less.

If the multimeter does **not** show the correct values in both tests, the switch has failed. Refer to the original equipment manufacturer (OEM) troubleshooting and repair manual for replacement procedures.



Engine Wiring Harness (019-043)

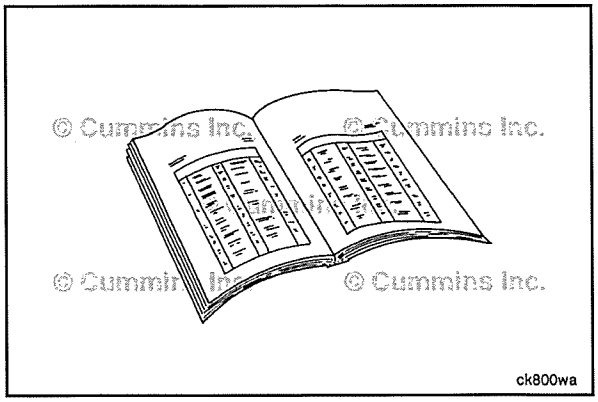
General Information

The engine uses two separate wiring harnesses to control the engine and some of the vehicle operations. Shown are the engine control module (ECM) ports for the following connectors:

1 96-pin original equipment manufacturer (OEM) harness connector

2 96-pin engine harness connector.

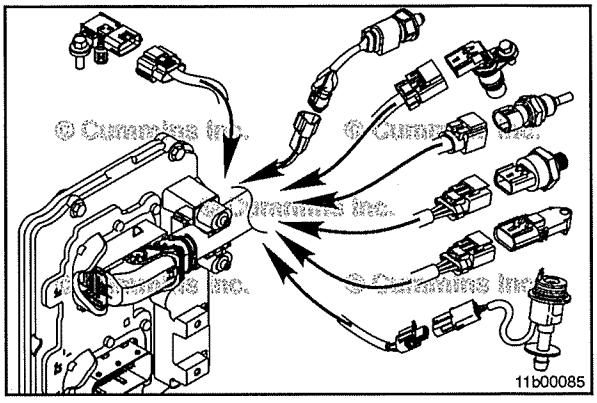
Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

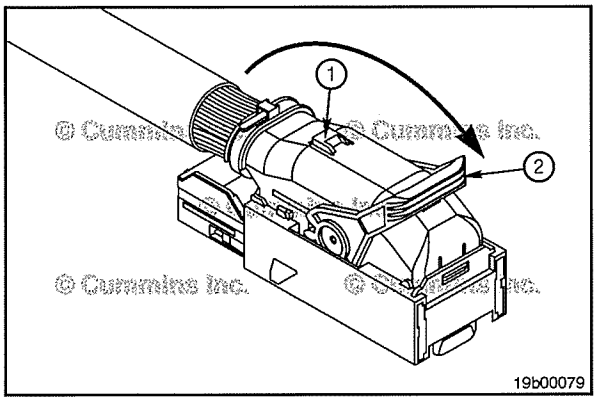
- Disconnect the batteries. Refer to the OEM service manual.
- Disconnect the 24-pin connector OEM crossover connector.

Remove



Disconnect the engine harness from the sensors and switches.

△CAUTION△
Do not close the lever after the connector has been removed from the ECM. Attempting to do so will cause damage to the connector.



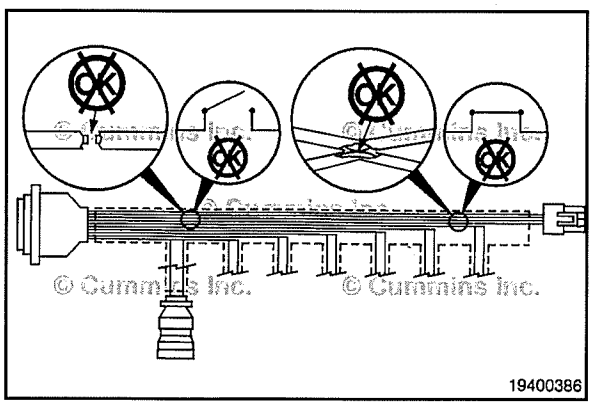
Pull back the protective boot to access the connector.

Remove the wire harness hold down clamps from the ECM.

NOTE: Do **not** remove the wire ties attaching the hold down clamps to the wire harness.

Remove the OEM connector and the engine harness connector from the ECM by pressing down on the locking tab (1) and pulling up on the lever (2).

Note the engine harness routing and location of the wire ties and mounting clips holding the engine harness before removal. It may be helpful to take pictures and/or add tags to help rout the harness properly during assembly

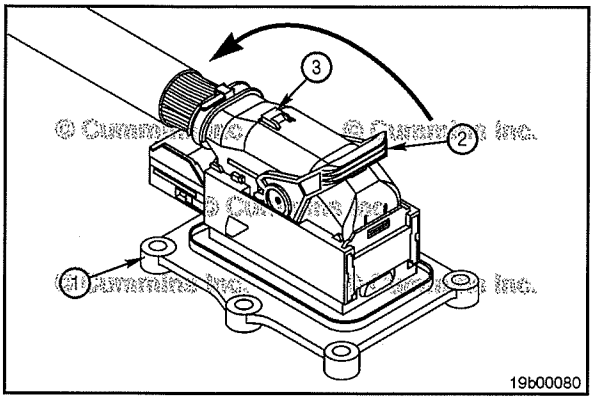


Inspect for Reuse

Inspect the engine wiring harness. If there is an open circuit or short circuit, determine the location of the damaged wiring.

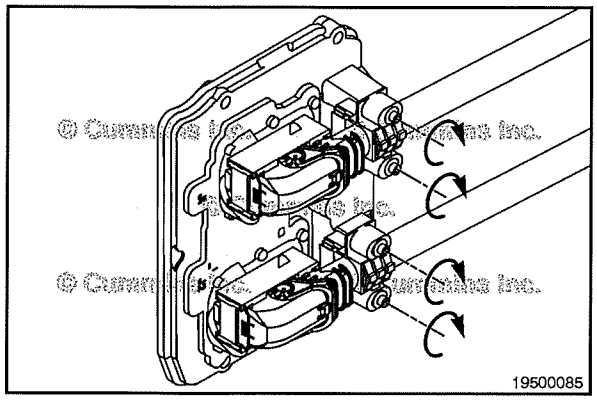
Wiring inside the protective covering can be repaired.

Inspect the protective boot on the 96-way connector for damage. Refer to Procedure 019-505 in Section 19.



Install

Connect the harness to the ECM by placing the harness connector into the ECM header (1) and pulling back on the locking lever (2) until the connector is fully seated and the lever locking tab (3) is engaged.



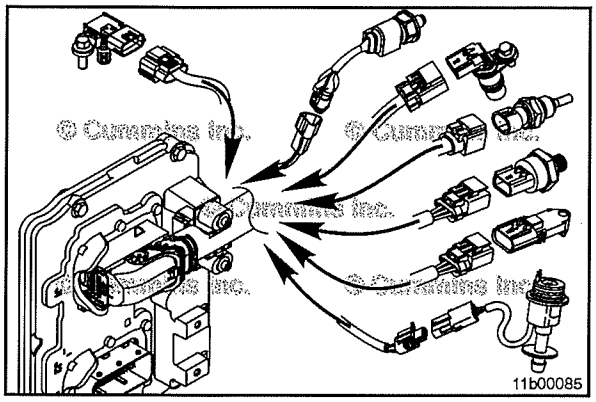
△CAUTION△
Do not overtighten the harness hold down clamp mounting screws or damage to the ECM will occur.

Install the harness hold-down clamps.

Torque Value: 8 N•m [89 in-lb]

The harness should be routed as far away from hot components as possible.

Make sure all mounting clips and wire ties are reused or replaced to prevent the harness from rubbing on other components.

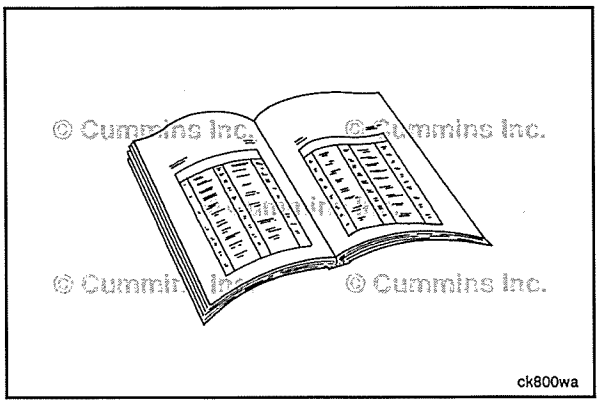


Connect the sensors and switches to the engine harness.

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the 24-pin OEM crossover connector.
- Connect the batteries. Refer to the OEM service manual.
- Operate engine and check for loose wires and proper operation.

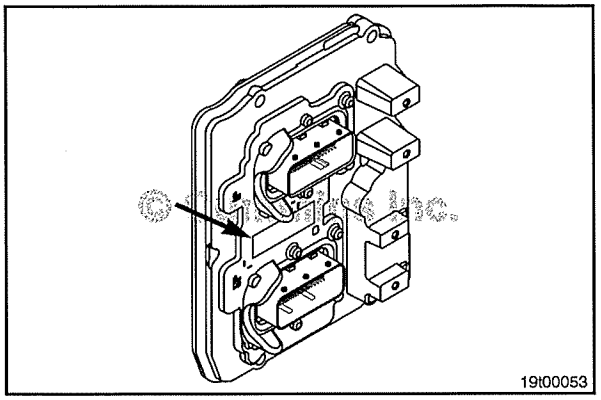


Fan Control Circuit (019-045)

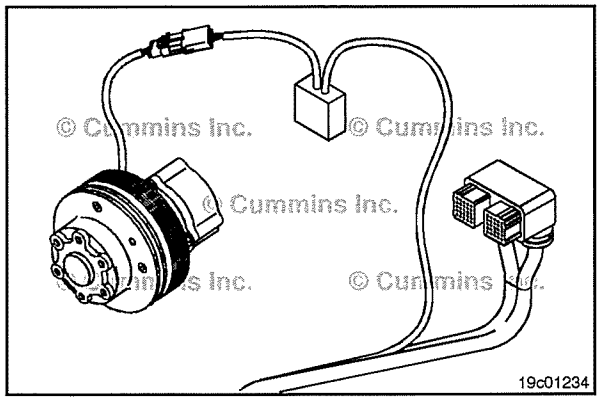
General Information

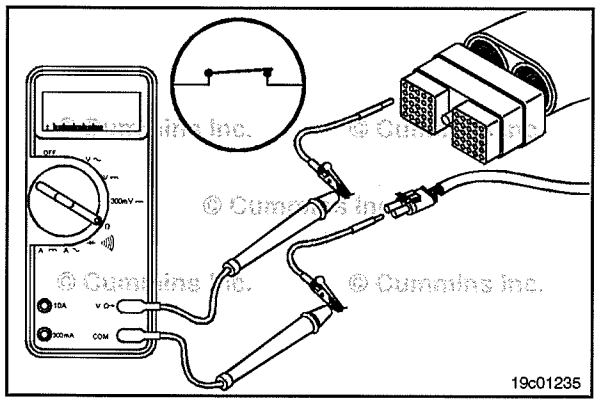
The CM2350 control system can control the fan clutch activation. The engine control module (ECM) energizes the air valve solenoid or an electric fan clutch.

Refer to the original equipment manufacturer (OEM) service manual for more information on the fan clutch wiring.



The fan control circuit resides in the OEM harness. The fan control signal wire is in the OEM connector on the ECM. The fan control signal wire leads to the fan clutch air solenoid through the OEM wiring harness. The fan control signal is grounded through the clutch body/engine block ground.





Resistance Check

⚠CAUTION⚠
Do not use probes or leads other than, Part Number 3822758. The connector will be damaged. The leads must fit tightly in the connector without expanding the pins of the connector.

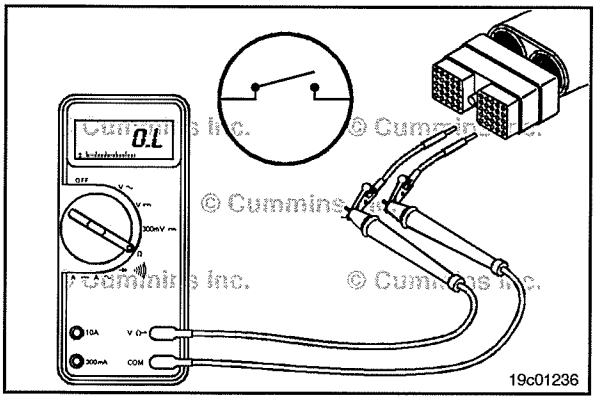
Disconnect the OEM harness connector from the ECM connector. Disconnect the OEM wiring at the fan control solenoid.

Insert a test lead into the fan control signal pin of the OEM harness connector and connect it to the multimeter probe.

Touch the other multimeter probe to the connector terminal of the fan clutch solenoid. Make sure the fan clutch solenoid is disconnected.

Measure the resistance.

The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is closed, it **must** still be checked for a short circuit to ground and a short circuit from pin-to-pin. If the circuit is **not** closed, there is a connection problem or an open circuit in the wiring harness.



Check for Short Circuit from Pin to Pin

Check for a short circuit between the fan control signal pin and all of the other pins in the OEM harness. Make sure the fan control solenoid is disconnected. Make sure the battery voltage supply is disconnected.

Insert a test lead into the fan control signal pin of the OEM harness connector. Insert the other test lead into all of the other pins of the OEM harness connector, one at a time.

Measure the resistance.

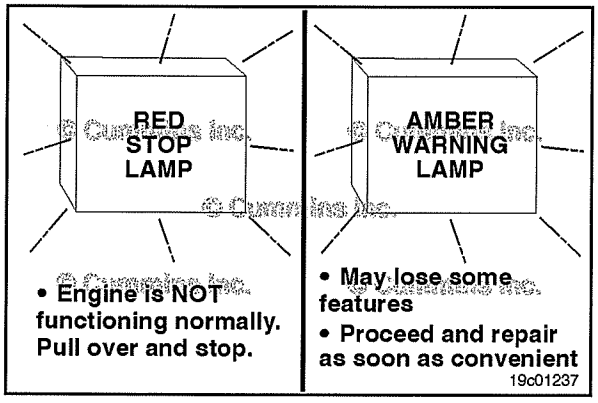
The multimeter **must** show an open circuit (more than 100k ohms).

If the circuit is **not** open, there is a short circuit between the fan control signal pin and any pins that measured a closed circuit.

Repair or replace the OEM wiring harness.

Refer to Procedure 019-043 in Section 19.

Refer to Procedure 019-071 in Section 19.



Fault Lamp (019-046)

General Information

The fault code warning lamps let the operator know when a part or a system fault is detected. The amber lamp can have the word WARNING printed on it. The red lamp can have the word STOP printed on it

The fault code lamp circuits consist of the light bulb, lamp signal output, and VDC supply from the keyswitch circuit.

Voltage Check

Measure the voltage between each fault lamp and ground.

Turn the keyswitch to the ON position.

Touch the positive (+) multimeter probe to the amber warning lamp signal terminal.

Touch the negative (-) multimeter probe to the chassis ground. Measure the voltage.

Repeat this check for the other terminal of the amber fault lamp. The multimeter **must** show the battery voltage.

Touch the positive (+) multimeter probe to the red stop lamp signal terminal.

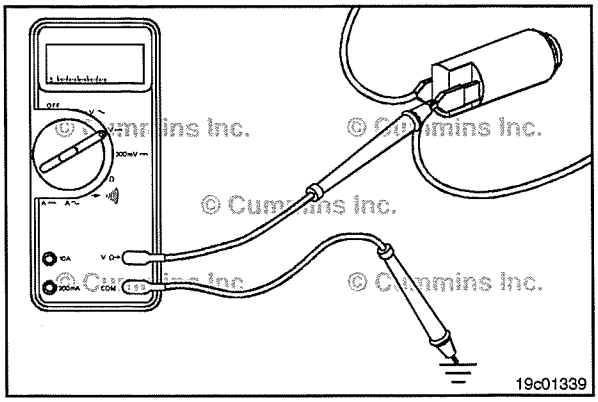
Touch the negative (-) multimeter probe to chassis ground.

Measure the voltage.

Repeat this check for the other terminal of the red fault lamp. The multimeter **must** show battery voltage.

If battery voltage is **not** present, there is a problem with the keyswitch line or the lamp has failed. Refer to the OEM troubleshooting and repair manual for repair procedures.

Connect all components after the repair is complete.



Fault Lamp Circuit (019-047)

Voltage Check

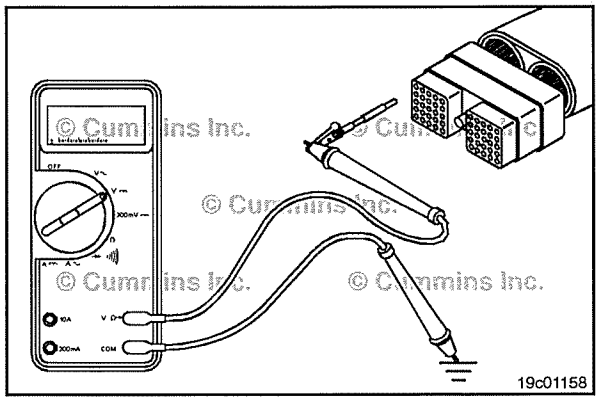
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

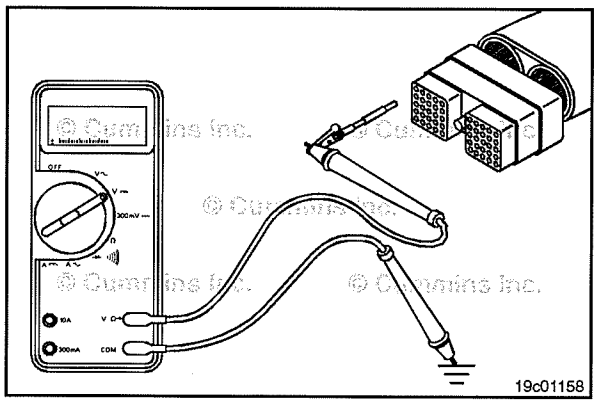
Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM).

Turn the keyswitch to the ON position. Adjust the multimeter to measure VDC. Insert the multimeter lead into the amber warning lamp signal pin and attach it to the multimeter probe. Touch the other multimeter probe to the engine block. Read the display on the multimeter.

The multimeter **must** show battery voltage. If battery voltage is **not** present, there is a problem with an OEM harness wire, provided the amber warning lamp has previously been checked.

Refer to the OEM troubleshooting and repair manual for repair procedures.

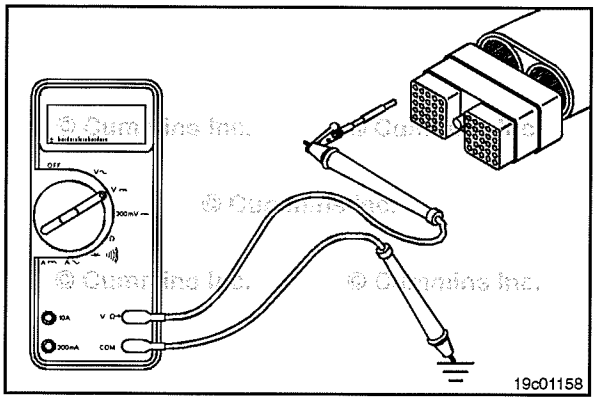




Remove the lead from the amber warning lamp signal pin and insert it into the malfunction indicator lamp (MIL) signal pin. Touch the other multimeter probe to the engine block.

The multimeter **must** show battery voltage. If battery voltage is **not** present, there is a problem with the malfunction indicator lamp (MIL) OEM harness wire, provided the malfunction indicator lamp (MIL) has been previously checked.

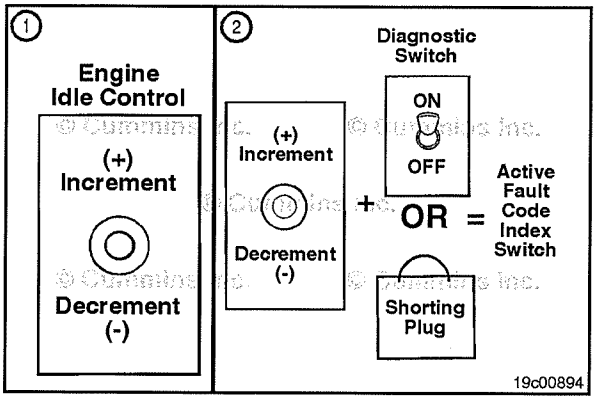
Refer to the OEM troubleshooting and repair manual for repair procedures.



Remove the lead from the malfunction indicator lamp (MIL) signal pin and insert it into the red stop lamp signal pin. Touch the other multimeter probe to the engine block.

The multimeter **must** show battery voltage. If battery voltage is **not** present, there is a problem with the red stop lamp OEM harness wire, provided the red stop lamp has been previously checked. Refer to the OEM troubleshooting and repair manual for repair procedures.

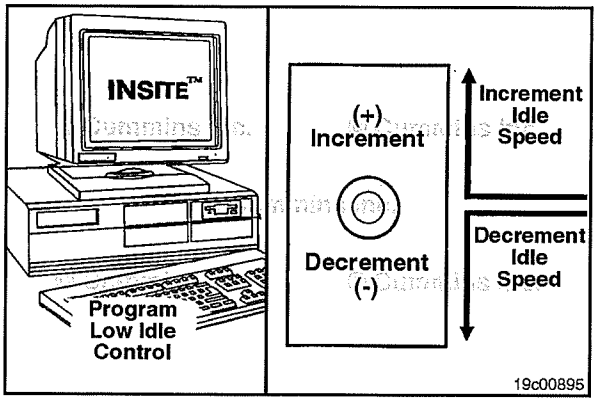
Connect all components after completing the repair.



Idle Adjust Switch (019-052)

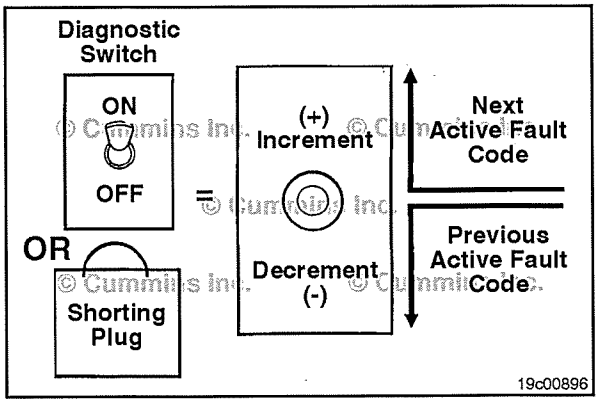
General Information

The idle adjustment feature is a part of the cruise control set/resume multi-functionality switch. Moving the switch to the set position increases the low idle speed and moving the switch to the resume position decreases the low idle speed.

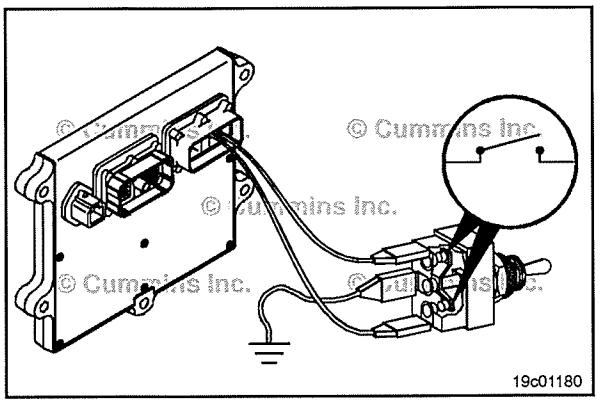


Depending on how the switch is configured, moving the switch in one direction will increase the low idle speed.

Push the diagnostic switch to the ON position or install the shorting plug. After the first active fault code has flashed out, push the idle adjust switch positive (+) up to advance to the next active fault code. Push the switch again until all of the active fault codes have been recorded.



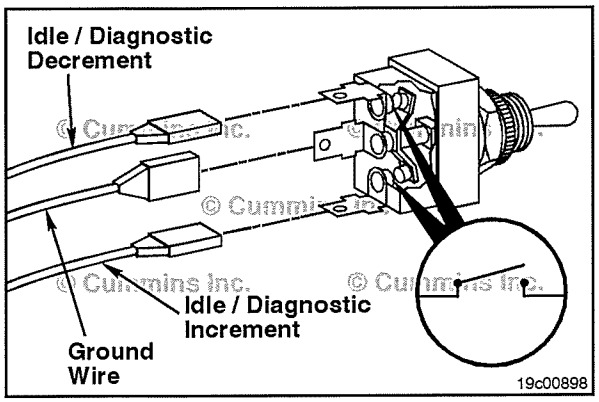
The idle adjust switch circuit consists of the idle/diagnostics increment signal, the idle/diagnostics decrement signal, the return wire, and the two-position switch located in the vehicle.



Resistance Check

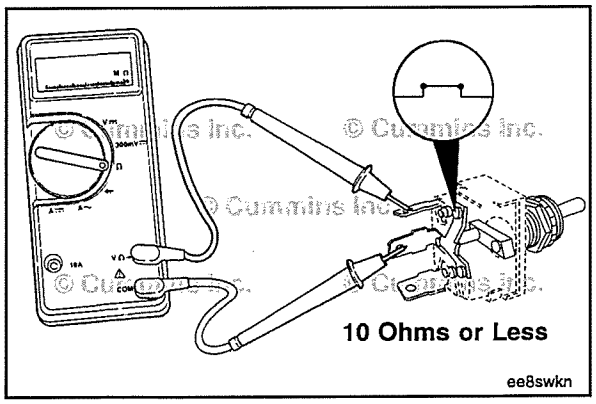
If INSITE™ is available, monitor the idle adjust switch for proper operation. If **not,** follow the troubleshooting procedures in this section.

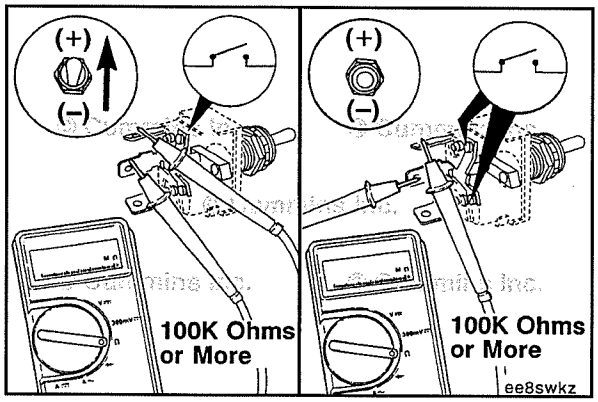
Remove the three electrical connectors from the switch. Label the wires with the switch location and the circuit name.



Touch one probe of the multimeter to the center terminal of the switch.

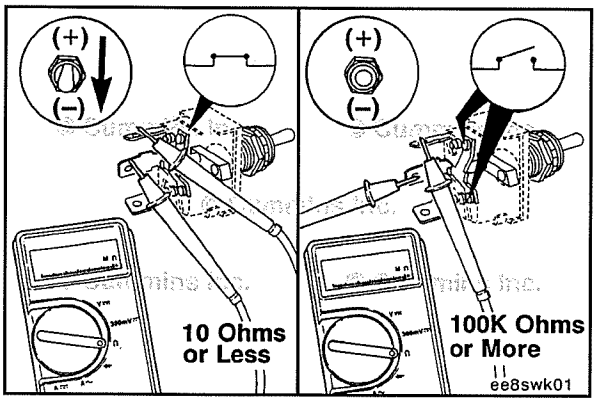
Touch the other probe to the cruise control/PTO resume/ accelerate switch signal terminal of the switch.





Hold the idle adjust switch in the positive (+) increment position. The multimeter **must** show an open circuit (100k ohms or more) when the switch is held in the positive (+) increment position and after it is released. If the circuit is **not** open, the switch has failed.

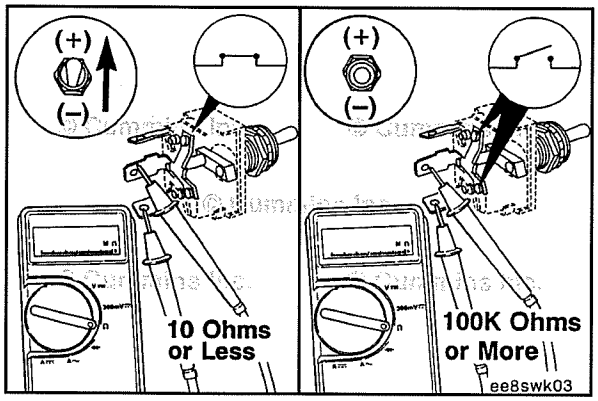
Refer to the OEM troubleshooting and repair manual for the replacement procedures.



Hold the switch in the negative (-) decrement position. The multimeter **must** show a closed circuit (10 ohms or less) when the switch is held in the negative (-) decrement position.

When the switch is released, it **must** show an open circuit (100k ohms or more). If the multimeter does **not** show the correct values, the switch has failed.

Refer to the OEM troubleshooting and repair manual for the replacement procedures.

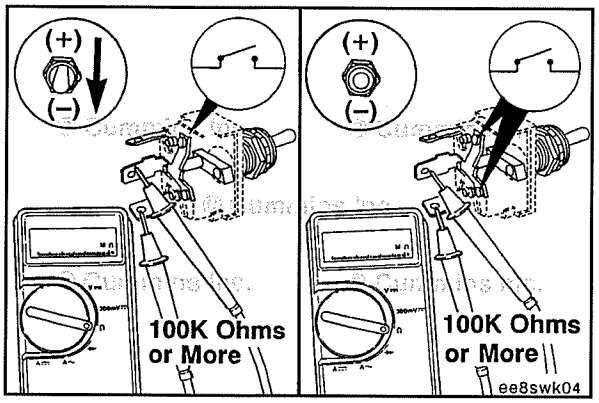


Move the electrical lead from the cruise control/PTO resume/accelerate switch signal terminal to the cruise control/PTO set/coast switch signal terminal.

Hold the idle adjust switch in the positive (+) increment position. The multimeter **must** show a closed circuit (10 ohms or less) while the switch is held in the positive (+) increment position.

When the switch is released, the multimeter **must** show an open circuit (100k ohms or more). If the multimeter does **not** show the correct values, the switch has failed.

Refer to the OEM troubleshooting and repair manual for the replacement procedures.



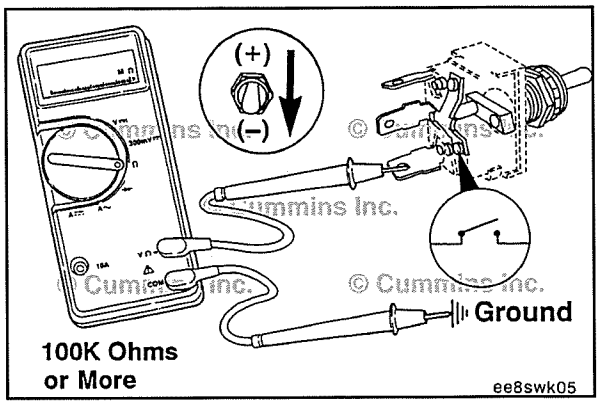
Move the idle adjust switch to the negative (-) decrement position. The multimeter **must** show an open circuit (100k ohms or more) when the switch is held in the negative (-) decrement position and when it is released. If the circuit is **not** open, the switch has failed.

Refer to the OEM troubleshooting and repair manual for the replacement procedures.

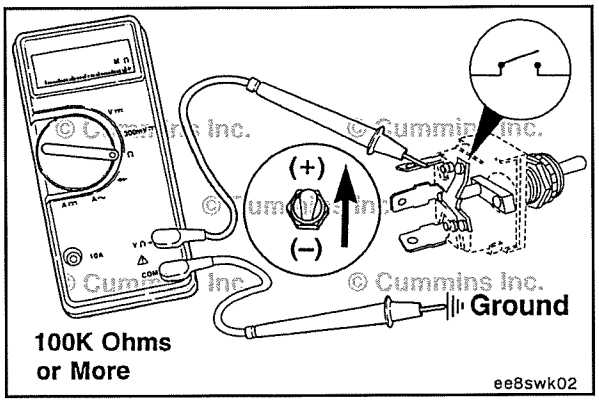
If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.

Check for Short Circuit to Ground

Touch one multimeter probe to the cruise control PTO set/coast switch signal terminal of the switch and touch the other multimeter probe to chassis ground. Move the idle adjust switch to the negative (-) decrement position then to the positive (+) increment position. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more) when the switch is in all positions. If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for the replacement procedures.



Check for a short circuit to ground. Remove the multimeter probe from the cruise control/PTO set/coast switch signal terminal and touch it to the cruise control/PTO resume/accelerate switch signal terminal of the switch. Keep the other multimeter touching chassis ground. Move the switch to the positive (+) increment position then to the negative (-) decrement position. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more) when the switch is in all positions. If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for the replacement procedures. If the switch passes all of the previous checks, the switch circuit **must** be checked.



Idle Adjust Switch Circuit (019-053)

Resistance Check

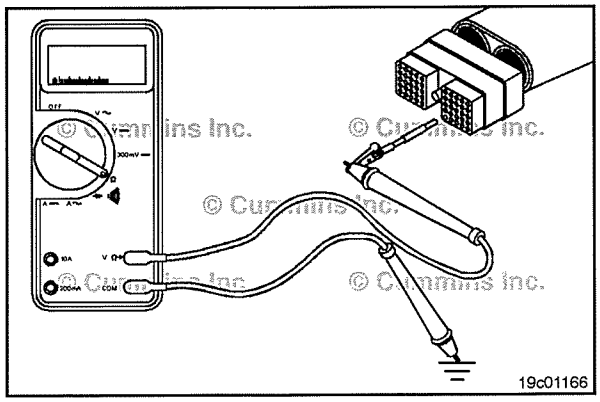
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

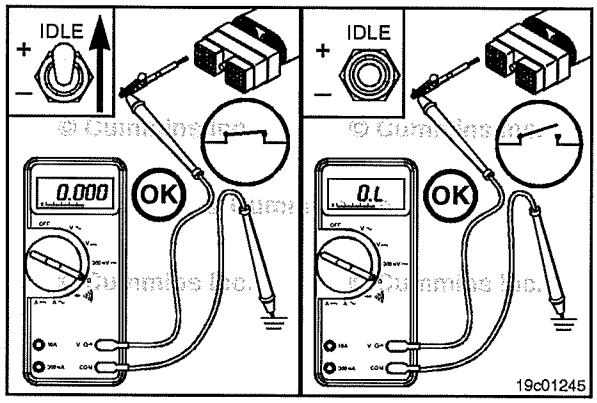
NOTE: The idle/diagnostic increment/decrement switch is the cruise control/PTO/set/resume select switch.

If INSITE™ electronic service tool is available, monitor the idle adjust switch circuit for proper operation. If **not,** follow the troubleshooting procedures in this section.

Remove the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM).

Insert the pin of the test lead into the cruise control/PTO set/coast switch signal in the OEM harness connector. Measure the resistance from the cruise control/PTO set/coast switch signal to the engine block.



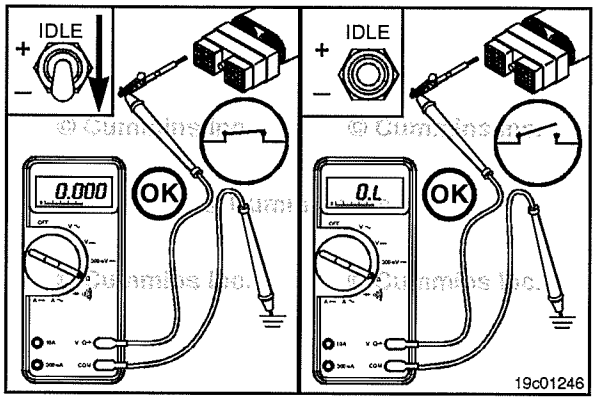


Hold the idle adjust switch in the positive (+) increment position.

If the OEM connected the return wire to chassis ground the multimeter **must** show a closed circuit (10 ohms or less) while holding the switch on and return to an open circuit (100K ohms or more) when the switch is released. The circuit **must** remain an open circuit when the switch is in the decrement negative (-) position.

If the OEM connected the return wire to the ECM OEM connector the multimeter **must** show an open circuit (100k ohms or more) while holding the switch on and return to a closed circuit (10 ohms or less) when the switch is released. The circuit **must** remain a closed circuit when the switch is in the decrement negative (-) position.

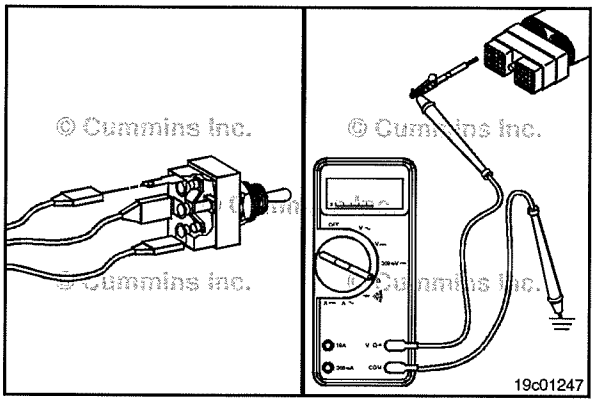
If the resistance values are **not** correct, make sure the return wire and the cruise control/PTO set/coast switch signal wire are properly installed on the idle adjust switch. If both wires are correctly installed, inspect the return wire and the cruise control/PTO set/coast switch signal wire for open circuits, provided the idle adjust switch has been previously checked for short circuits to ground.



Remove the lead from the cruise control/PTO set/coast switch signal and insert it into the cruise control/PTO resume/accelerator switch signal.

Hold the idle adjust switch in the negative (-) decrement position. The multimeter **must** show a closed circuit (10 ohms or less) when the switch is held in the decrement position and an open circuit (100K ohms or more) when the switch is released. The circuit **must** remain an open circuit when the switch is in the positive (+) increment position.

If the resistance values are **not** correct, make sure the cruise control/PTO resume/accelerator switch signal wire is properly installed on the idle adjust switch. If the cruise control/PTO resume/accelerator switch signal wire is properly installed on the idle adjust switch, inspect the cruise control/PTO resume/accelerator switch signal wire for an open circuit, provided the idle adjust switch has been previously checked for short circuits to ground.



Check for Short Circuit to Ground

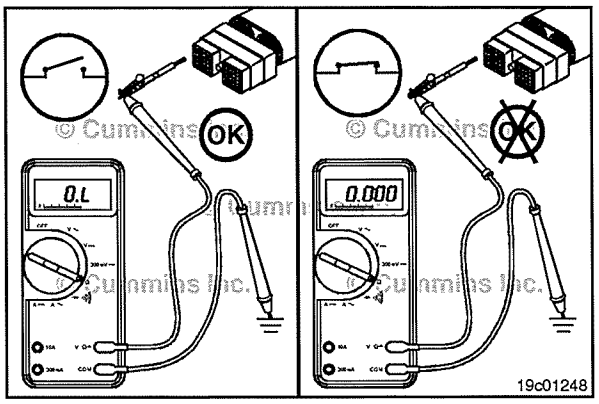
Disconnect the idle/diagnostic decrement wire (attached to the cruise control/PTO resume/ accelerator switch signal) from the switch.

Measure the resistance from the cruise control/PTO resume/accelerator switch signal of the OEM harness connector to the engine block.

The multimeter **must** show an open circuit (100K ohms or more). If the circuit is **not** open, there is a short circuit to ground in the cruise control/PTO resume/accelerator switch signal circuit, provided the idle adjust switch has been previously checked.

Repair or replace the wire connected to the cruise control/ PTO resume/accelerator switch signal in the OEM harness according to the vehicle manufacturer's instructions.

To check the idle/diagnostic increment wire (attached the to cruise control/PTO set/coast switch signal) for short circuits to ground, follow the same procedure as described above for the idle/diagnostic decrement wire.



Check for Short Circuit from Pin to Pin

Measure the resistance from the cruise control/PTO resume/accelerator switch signal of the OEM harness connector to all other pins in the connector. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit between the wire connected to the cruise control/PTO resume/ accelerator switch signal and any pin that measured less than 100k ohms.

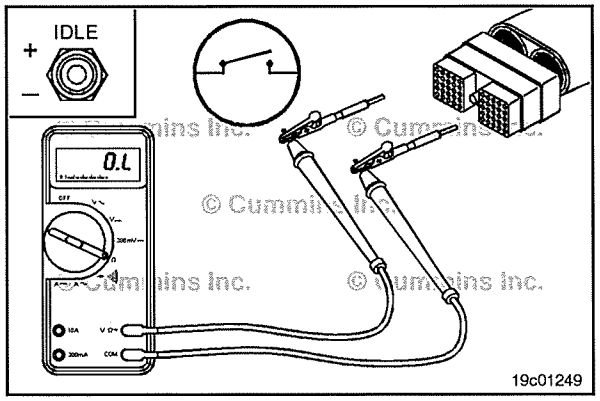
Repair or replace the wires in the OEM harness according to the vehicle manufacturer's instructions.

Remove the lead from the cruise control/PTO resume/ accelerator switch signal of the OEM harness connector and insert it into the cruise control/PTO set/coast switch signal of the connector. Measure the resistance from the cruise control/PTO set/coast switch signal to all other pins in the connector. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit between the wire connected to the cruise control/PTO set/coast switch signal and any pin that measured less than 100k ohms, provided the idle adjust switch has been previously checked.

Repair or replace the wires in the OEM harness according to the vehicle manufacturer's instructions.

Connect all components after completing the repair.

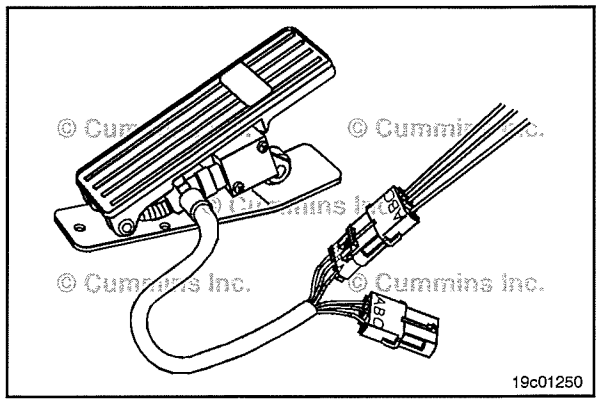


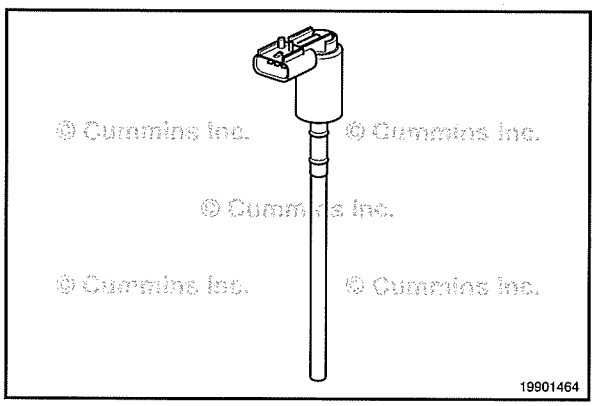
Idle Validation Switch (019-054)

General Information

The idle validation switch will vary with OEM. Refer to vehicle manufacturer's manual for the specific troubleshooting and repair procedures.

The idle validation switch, on the accelerator pedal assembly, is used to detect when the accelerator pedal is at idle. The idle validation circuit consists of the idle validation switch, switch return wire, on-idle switch input, and off-idle switch input.

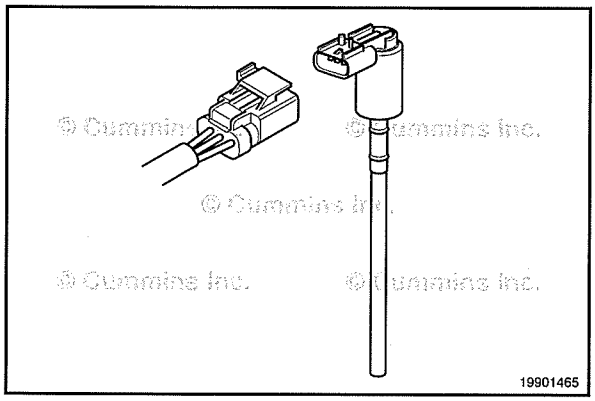




Lubricating Oil Level Sensor (019-056)

General Information

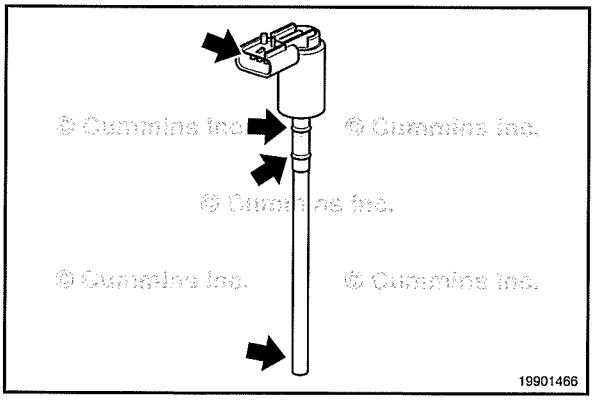
The lubricating oil level sensor is used to monitor the engine lubricating oil level. The sensor is integrated into the dipstick tube on the engine.



Remove

Lift up on the locking tab and pull the electrical connectors apart.

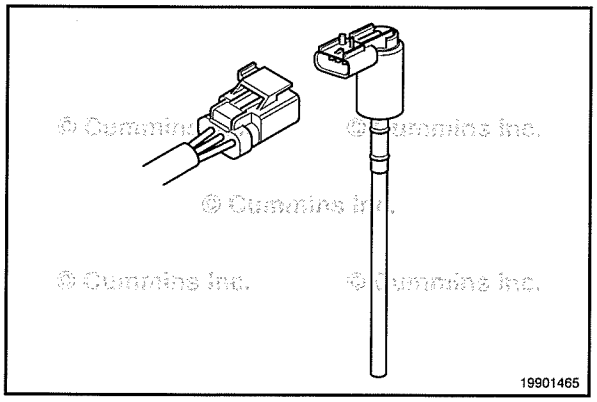
Remove the lubricating oil level sensor from the dipstick tube.



Clean and Inspect for Reuse

Inspect the lubricating oil level sensor for damage to wiring or body.

Inspect the o-rings for damage.



Install

Install the sensor into the dipstick tube.

Push the sensor and sensor harness connectors together until they lock.

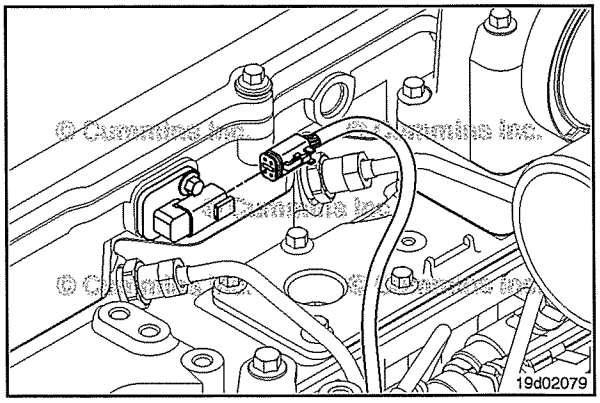
Internal Actuator Wiring Harness (019-063)

Remove

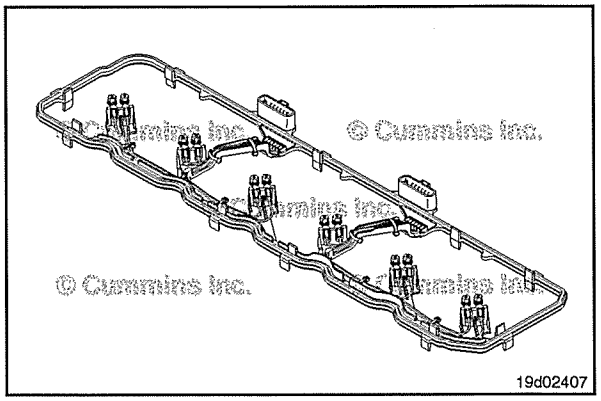
Disconnect the three Deutsch™ 4-pin connectors on the engine harness from the pass-through connector.

Remove the crankcase breather tube. Refer to Procedure 003-018 in Section 3.

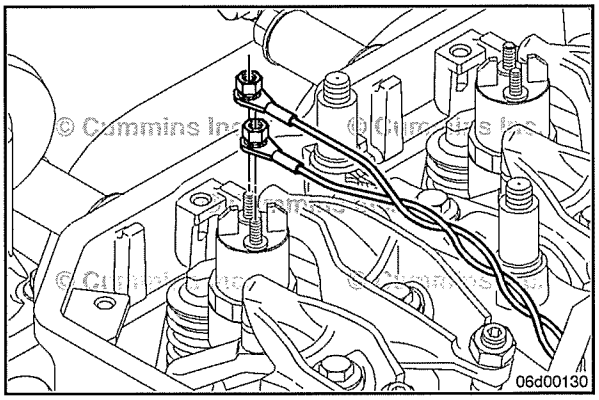
Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.



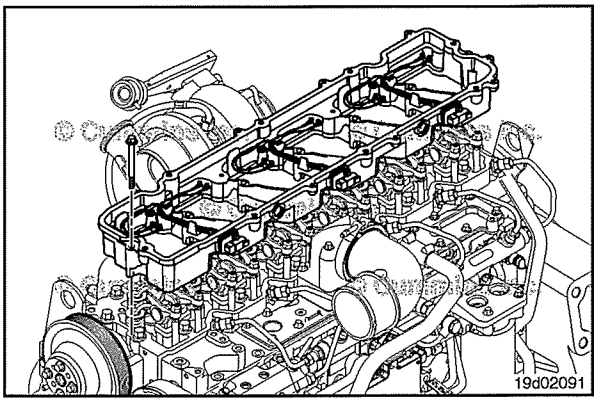
Some QSB engines use an optional injector pass-through wiring harness built into the rocker lever cover gasket.

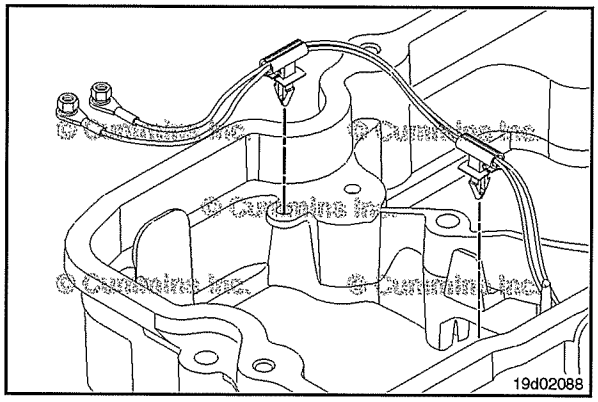


Remove the pigtail capscrews from all injector solenoids.

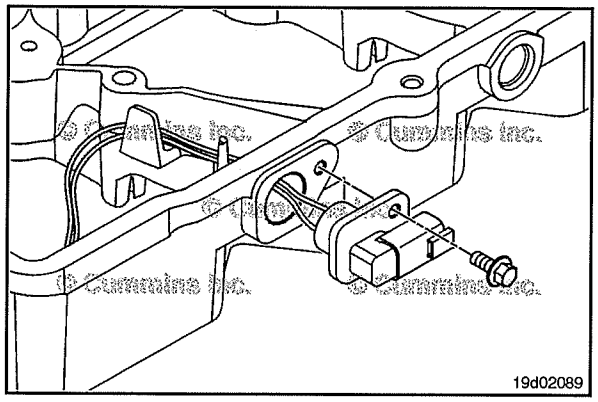


Remove the rocker housing. Refer to Procedure 003-013 in Section 3.

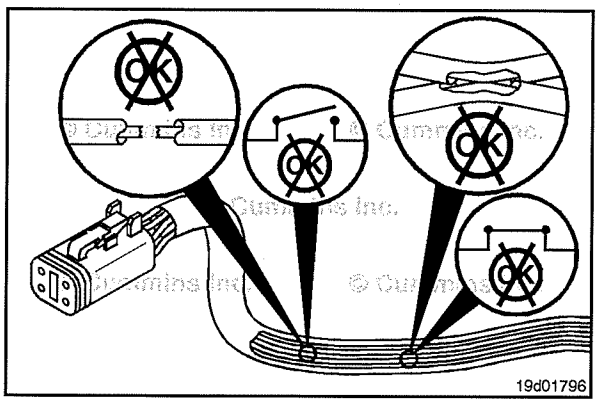




Remove the internal injector harness and the plastic clips from the rocker lever housing.



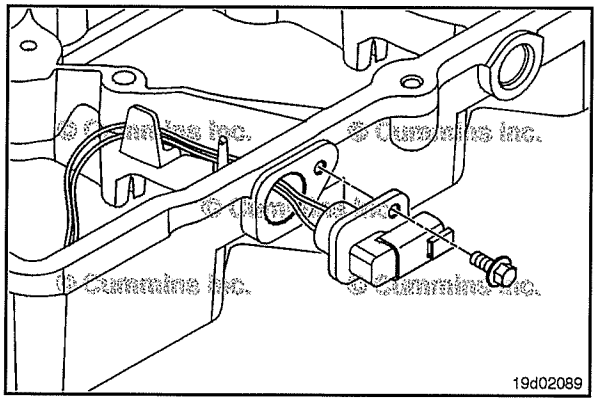
Remove the pass-through connector from the rocker housing.



Inspect for Reuse

Inspect for damaged or exposed wires, bent or broken pins, or damaged connectors.

Replace, if necessary.



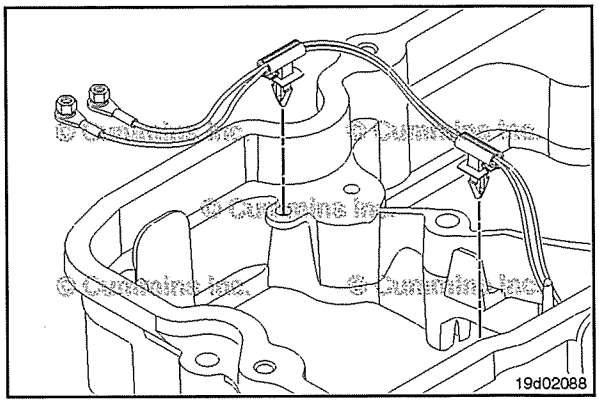
Install

Install the pass-through connector into the rocker housing.

Torque Value: 10 N•m [89 in-lb]

Route the injector wiring around the metal tabs to the injectors.

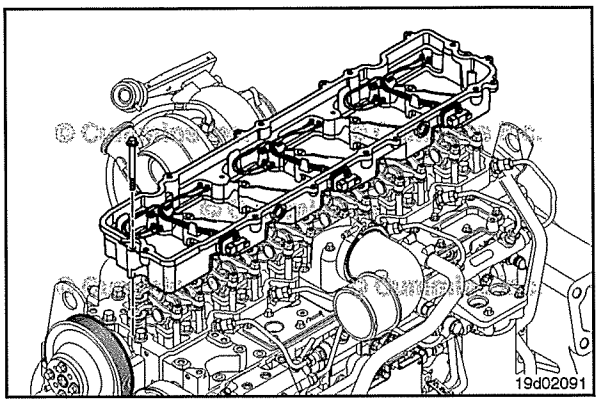
Install new plastic clips into the rocker housing.



Install the rocker housing. Refer to Procedure 003-013 in Section 3.

NOTE: Verify that the internal injector harness does **not** rest on any sharp corners.

NOTE: Verify that the pigtail wires are **not** "crossed over" to the wrong injectors.

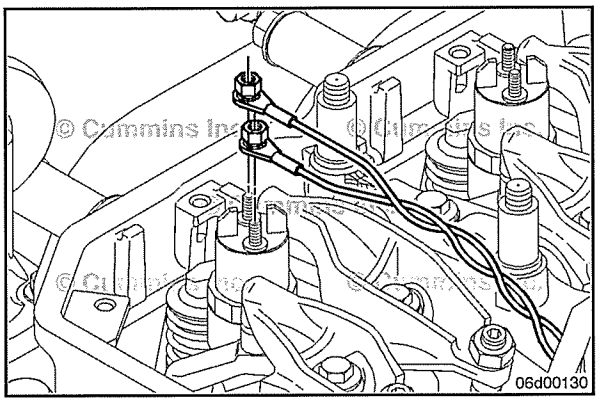


Install pigtail nuts on injectors.

Torque Value: 1.25 N•m [11 in-lb]

NOTE: Injector wire to injector orientation is **not** significant.

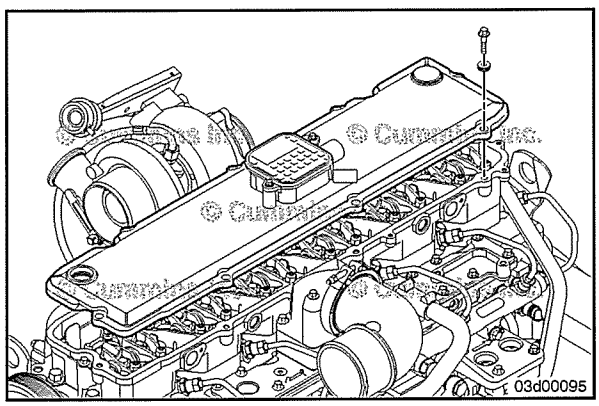
NOTE: Orient the injector wires so they will **not** interfere with a rocker lever or the engine brake housing. If a rocker lever contacts the injector harness, it will rub through the wire insulation causing injector circuit fault codes.

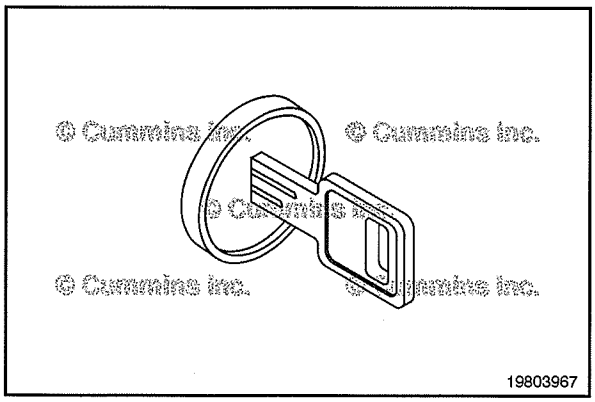


Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.

Connect the engine harness to the pass-through connector.

Install the crankcase breather tube. Refer to Procedure 003-018 in Section 3.

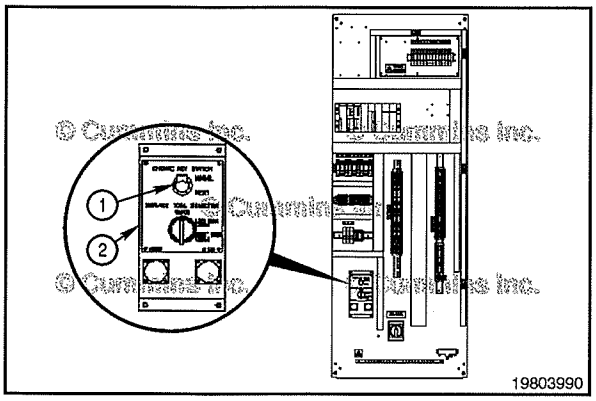




Key Switch Battery Supply Circuit (019-064)

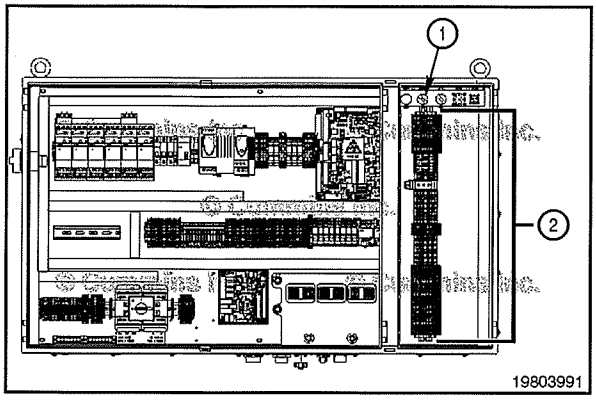
Voltage Check

The vehicle keyswitch supplies an input signal to the electronic control module (ECM) which turns the ECM on or off.

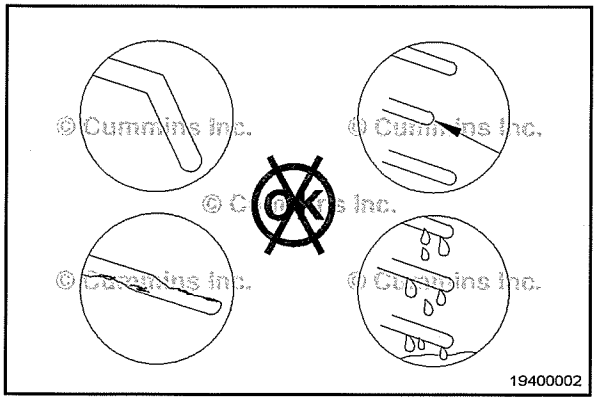


The Generator Set ECM Keyswitch supplies an input signal to all generator set electronic control modules (ECMs) which turns to ECM on or off.

For generator sets using the PowerCommand Supervisor 3100 mounted in the Generator Control Panel (GCP), the ECM keyswitch (1) is mounted on the Service Tool Connector Panel (2), located inside the main panel.



For generator sets using the PowerCommand Supervisor 3300 mounted in the Generator Interface Box, the ECM keyswitch (1) is mounted within the customer terminal box above the customer connection terminal connection strip (2).



Turn the keyswitch to the OFF position.

Disconnect the Actuator harness connector from the ECM.

Inspect the connector pins.

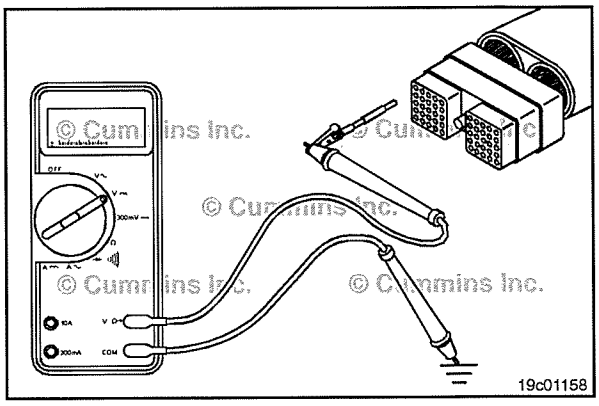
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Adjust the multimeter to measure VDC.

Insert a test lead into the keyswitch input signal pin of the Actuator connector. Connect the lead to the multimeter probe. Touch the other probe to a clean, unpainted surface on the engine block ground.

Turn the keyswitch to the ON position.

The measured voltage **must** show battery voltage. If the measured voltage is more than 0.5 VDC below battery voltage, continue with the next step.



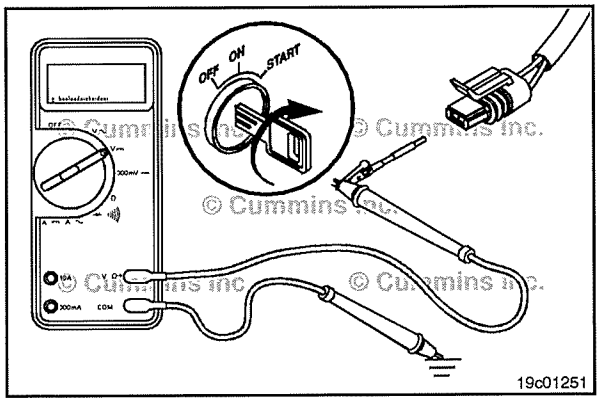
Disconnect the bulkhead connector.

Inspect the connector pins. Refer to the OEM troubleshooting and repair manual for the proper procedure.

Measure the voltage. Refer to the OEM troubleshooting and repair manual for the proper procedure.

The measured voltage **must** show battery voltage. If the voltage is **not** correct, there is a problem with the keyswitch input signal wire, keyswitch, or battery connection.

Repair or replace the wiring harness, keyswitch, or check the battery connections. Refer to the OEM troubleshooting and repair manual for the proper procedures.

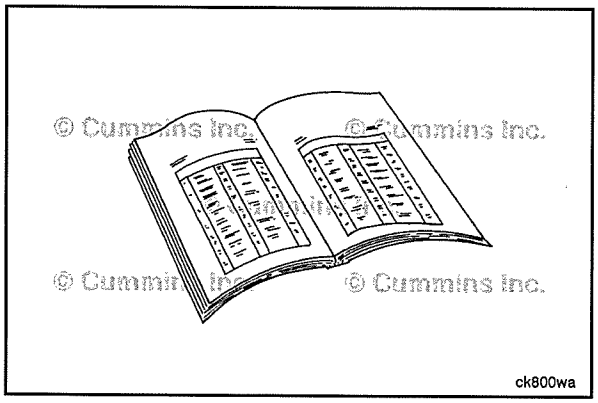


Engine Oil Pressure Sensor/Switch (019-066)

General Information

The oil pressure switch is located on the front of the engine, near the camshaft. Refer to Procedure 100-002 in Section E.

Some engines can be equipped with an optional engine oil pressure sensor. The oil pressure sensor is mounted in the same location as the engine oil pressure switch.

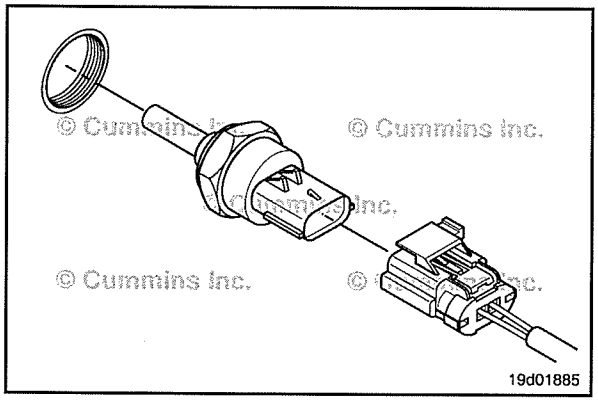


Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

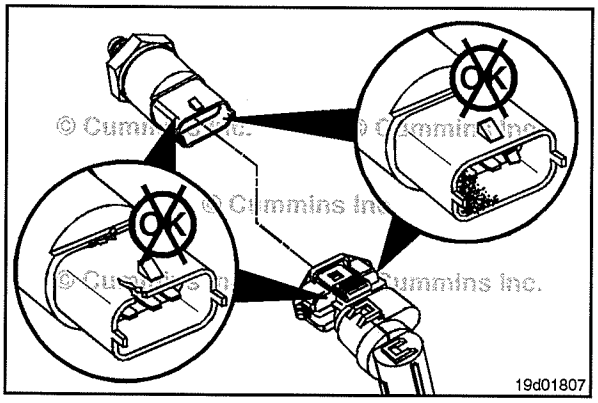
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area around the oil pressure switch/sensor.



Remove

Disconnect the oil pressure switch/sensor from the engine harness.

Remove the oil pressure switch/sensor.



Clean and Inspect for Reuse

Inspect the engine harness connector and the oil pressure switch/sensor for the following:

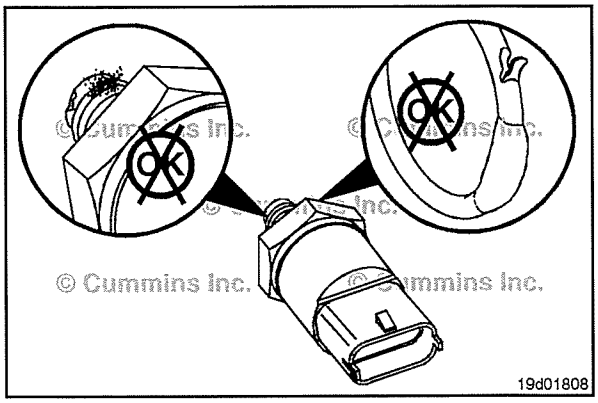
- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins.

Repair or replace the engine harness connector as needed.

Inspect the oil pressure switch/sensor for the following:

- Damaged seal surface in the rail
- Damaged seal surface on the switch/sensor
- Damaged switch/sensor hex surfaces
- Corrosion on the switch/sensor mounting threads.

Replace the oil pressure switch/sensor if damage is found.



Install

Check to make sure the switch/sensor has an o-ring installed.

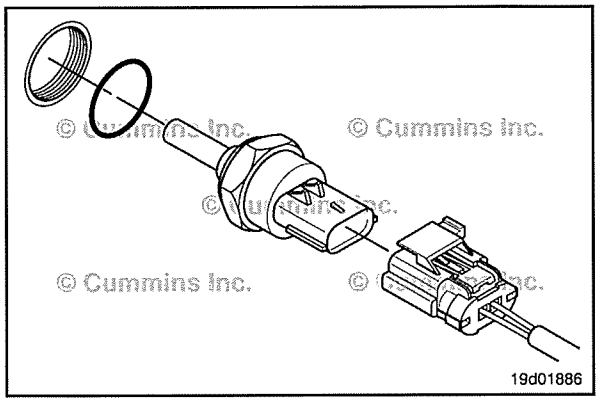
Install and tighten the engine oil pressure switch.

Torque Value:
Oil Pressure Switch 14 N•m [124 in-lb]

If equipped with and oil pressure sensor, install and tighten the oil pressure sensor.

Torque Value:
Oil Pressure Sensor 24 N•m [212 in-lb]

Connect the oil pressure switch/sensor to the engine harness.

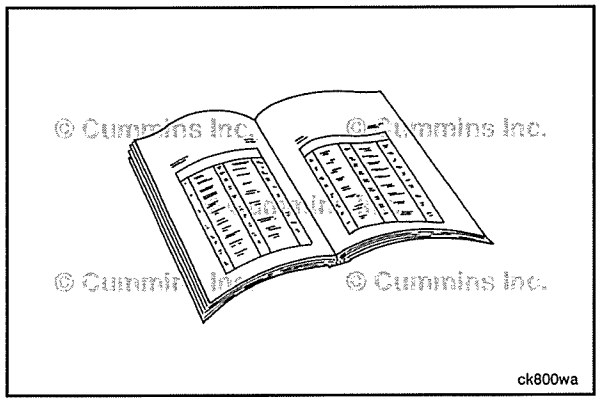


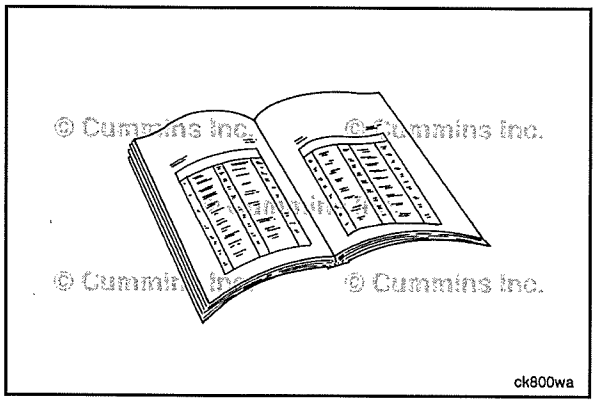
Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

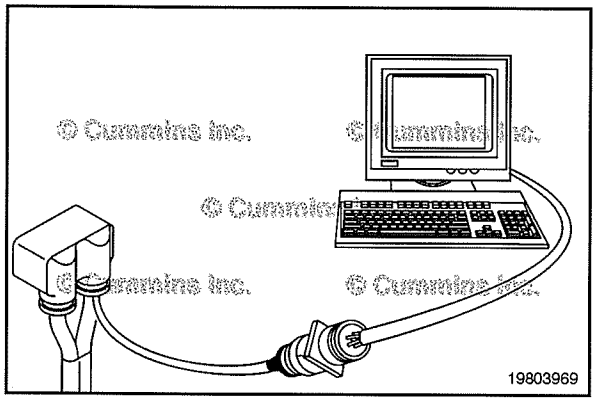




OEM Wiring Harness (019-071)

General Information

The original equipment manufacturer (OEM) harness is supplied and installed by the vehicle manufacturer. Follow the vehicle manufacturer's procedures, if replacement is necessary. Refer to the vehicle manufacturer's troubleshooting and repair manual.



Programmable Features and Parameters Not Correct (019-078)

General Information

This procedure was developed due to the increasing number of parameters and features offered which can affect vehicle performance. Use the following table to troubleshoot performance complaints by locating the appropriate symptom in the left column. Then follow the probable cause and corrective action in the adjacent columns.

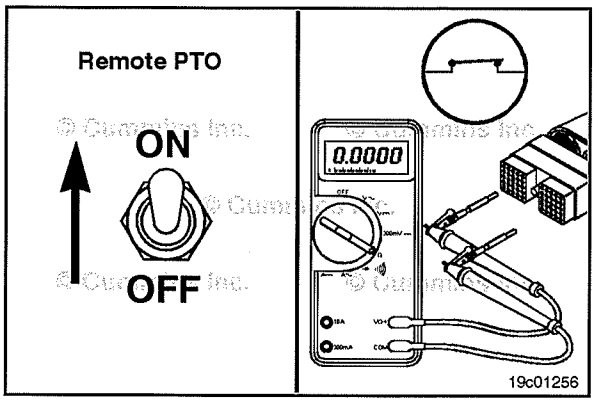
Consult the appropriate electronic service tool manual to adjust the parameters or features.

Adjust

Programmable Feature/Parameters Not Correct		
Symptom	**Probable Cause**	**Correction**
Exceeding road speed governor set speed down hills	Cruise control or road speed governor lower droop is set too high.	Change the cruise control or road speed governor lower droop to a lower value. If the problem continues, change the cruise control engine brake activation to lower value.
Poor acceleration up hills	Cruise control and/or road speed governor upper droop is set too high.	Change the cruise control or road speed governor upper droop to a lower value.
Cruise control turns on automatically	Cruise control auto-resume feature is enabled.	Turn off the cruise control auto-resume feature.
Exhaust brakes turn on automatically	Cruise control auto engine brake feature is enabled or exhaust brake switch has failed close.	Turn off the cruise control auto engine brake feature or repair the switch.
Unable to obtain maximum vehicle speed	Gear-down protection feature is enabled.	Turn off or adjust the gear-down protection parameters.
Poor clutch engagement	The low idle speed is set too low for the application.	Increase the low-idle speed using the idle adjust switch. Refer to Procedure 019-052. Increase the low-idle speed parameter.
Speedometer on the dashboard is **not** correct or vehicle exceeding road speed governor set speed	Vehicle speed parameters **not** correct.	Make sure the following are correct: tire size, rear axle ratio, vehicle speed sensor type, and gear teeth per revolution.
Trip information mileage readings are **not** correct	The tire size parameter was changed without resetting the trip information system.	Set the trip information system again whenever the tire size parameter is changed.

Programmable Feature/Parameters Not Correct		
Symptom	**Probable Cause**	**Correction**
Can **not** obtain maximum vehicle speed with semiautomatic transmission	The gear-down protection parameters are **not** correct.	Change the top gear ratio parameter to be equal to the first gear-down ratio, **not** the top gear ratio. For example, on a transmission with a 0.75, 0.87, and 1.0 ratio set, the top gear ratio parameter **must** be set to 0.87.
Engine won't start	Antitheft password active.	Enter antitheft personal identification number (PIN) using RoadRelay™ or delete password with Zap-It.
Low power in lower gears or top gear	Power train protection parameters set too low.	Change power train protection torque limits to match torque capability of the vehicle's transmission.
Semiautomatic transmission will **not** shift into top gear	Top gear ratio setting does **not** match top gear of transmission.	Using INSITE™ electronic service tool, set the proper top gear ratio.
	Centinel™ feature has been turned on but vehicle has a Spicer Top 2™ transmission.	Turn off the Centinel™ feature and turn on the Top 2 feature using INSITE™ electronic service tool.
Engine recently started overheating because the fan will **not** turn on	Fan control feature is **not** set properly.	Verify all fan control feature parameters are properly set for the vehicle.
Fan will **not** turn off	Fan control feature is **not** set properly.	Verify all fan control feature parameters are properly set for the vehicle.
Fan control switch will **not** turn on the fan	Fan control 1 accessory switch control is turned off.	Turn on fan control 1 accessory switch control using INSITE™ electronic service tool.
Unable to obtain maximum vehicle speed	Cruise control maximum vehicle speed or accelerator maximum vehicle speed **not** set high enough.	Verify or change settings using INSITE™ electronic service tool.
	Driver reward system is penalizing the driver with reduced top vehicle speed or cruise control maximum speed for poor fuel economy or extended idle time.	Explain feature to the driver or change parameter settings to more appropriate values.
Accelerator pedal has no effect on engine speed	Vehicle is in PTO mode and PTO accelerator override is turned on in the ECM.	Turn off PTO accelerator override using INSITE™ electronic service tool.
	Vehicle has a multiplexed throttle pedal and the multiplexing feature has been turned off.	Verify that the throttle pedal is multiplexed. Turn on the multiplexing feature for the throttle pedal using INSITE™ electronic service tool.
Remote accelerator control has no effect on engine speed	Remote accelerator feature has been turned off.	Turn on the remote accelerator feature using INSITE™ electronic service tool.
	Vehicle has a multiplexed remote accelerator control and the multiplexing feature has been turned off.	Verify that the remote accelerator control is multiplexed. Turn on the multiplexing feature for the remote throttle control using INSITE™ electronic service tool.
Lamps do **not** operate	5 A or 15 A Power fuse in engine harness blown.	Check fuses and verify the ECM is getting power on the keyswitch wire.
	Vehicle has multiplexed lamps and the multiplexing feature has been turned off.	Verify that the lamps are multiplexed. Turn on the multiplexing feature for the lamps using INSITE™ electronic service tool.
Engine brakes do **not** operate	Vehicle has multiplexed engine brake switches and the multiplexing feature has been turned off.	Verify that the engine brake switches are multiplexed. Turn on the multiplexing feature for the engine brake switches using INSITE™ electronic service tool.

Programmable Feature/Parameters Not Correct		
Symptom	**Probable Cause**	**Correction**
Engine will **not** respond to one or all of the operator's switch(es)	Vehicle has multiplexed switches and the multiplexing feature has been turned off.	Verify that the switches are multiplexed. Turn on the multiplexing feature for the switches using INSITE™ electronic service tool.



Remote PTO Switch Circuit (019-079)

Resistance Check

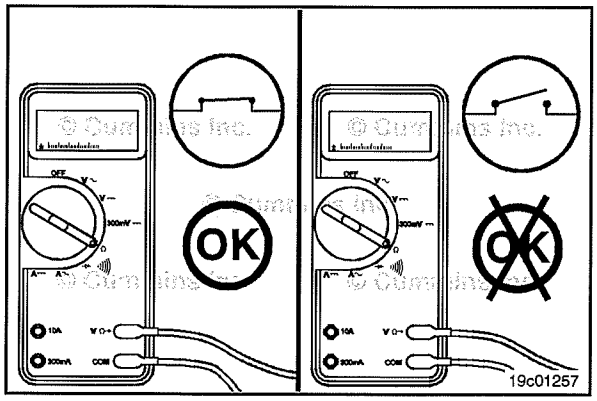
⚠CAUTION⚠

Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM).

Insert a test lead into the remote power take-off (PTO) switch return pin of the OEM harness connector and connect it to the multimeter probe. Insert the other test lead into the remote PTO switch signal pin of the connector and connect it to the other probe.

Make sure the switch is connected to the circuit. Move the remote PTO switch to the ON position. Measure the resistance with the multimeter. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the switch return wire and the remote PTO switch signal wire for an open circuit. Repair or replace the OEM harness, provided the switch has been previously checked. Refer to the OEM troubleshooting and repair manual for the procedures.



If the resistance is correct, the remote PTO switch return wire and the remote PTO switch signal wire **must** be checked for a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.

Connect all components after the repair is complete.

Check for Short Circuit to Ground

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

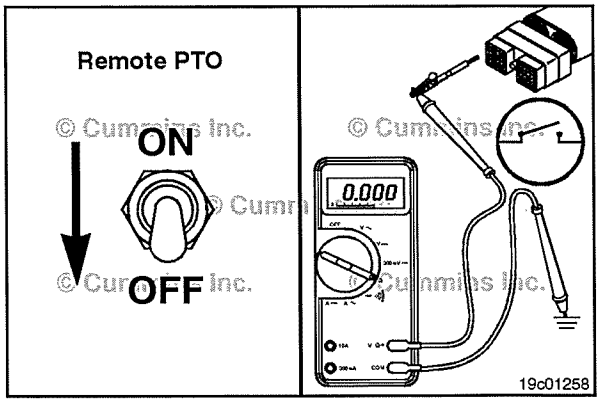
Disconnect the OEM harness from the ECM.

Insert the test lead into the remote PTO switch signal pin in the OEM harness connector and connect it to the multimeter probe. Touch the other probe to engine block ground.

With the remote PTO switch in the OFF position, read the resistance.

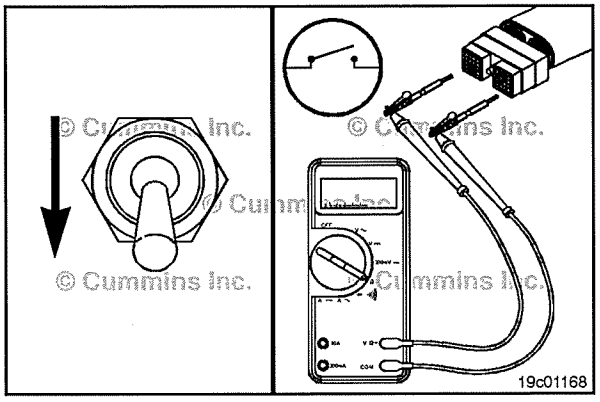
The multimeter **must** show an open circuit (100k ohms or more).

If the resistance values are **not** correct, make sure the remote PTO switch signal wire and the ground wire are properly installed on the switch. If both wires are correctly installed, inspect the wires for a short to ground circuit, provided the remote PTO switch has been previously checked.



Check for Short Circuit from Pin to Pin

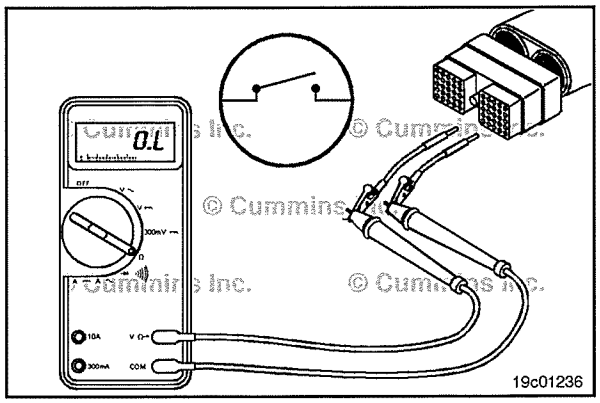
Check for a short circuit from pin to pin. Set the remote PTO switch to the OFF position. Insert the test lead into the remote PTO switch return pin of the OEM harness connector and connect it to the multimeter probe. With a test lead connected to the other multimeter probe, check all the other pins in the connector. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

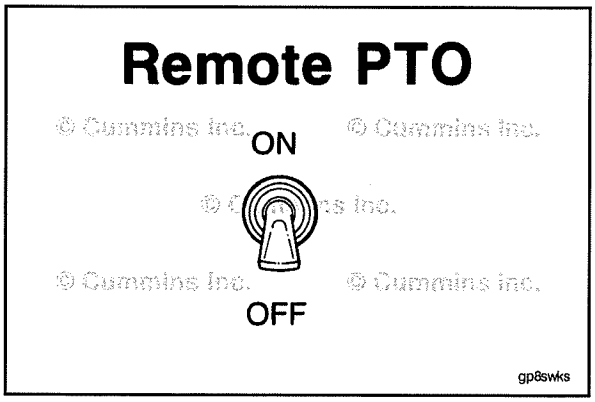


Remove the lead from the remote PTO switch return pin and insert it into the remote PTO switch signal pin of the harness connector. With the other test lead, check all other pins in the connector. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit between the switch circuit and any pin that did **not** measure an open circuit, provided the switch has previously been checked. Repair or replace the wires in the OEM harness according to the vehicle manufacturer's procedures.

Connect all components after completing the repair.



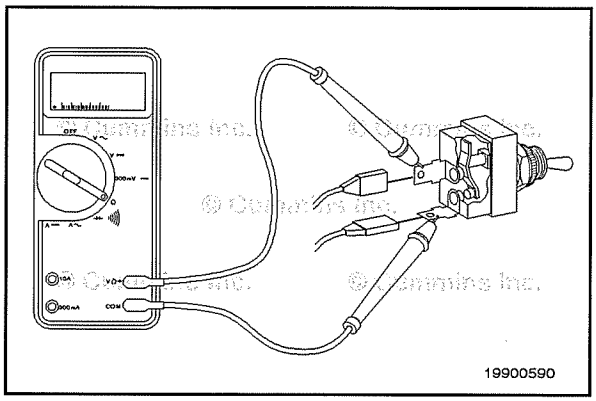


Remote PTO Switch (019-080)

General Information

A remote PTO switch is available for applications where PTO operation control is desired away from the operator controls.

The remote PTO switch circuit consists of the remote PTO switch signal wire and a switch common return.

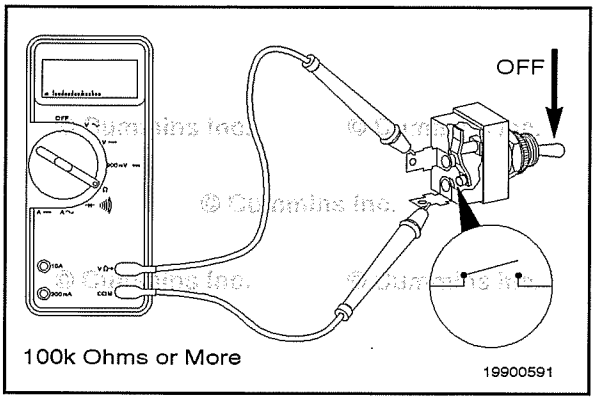


Resistance Check

Locate the desired ON/OFF toggle switch.

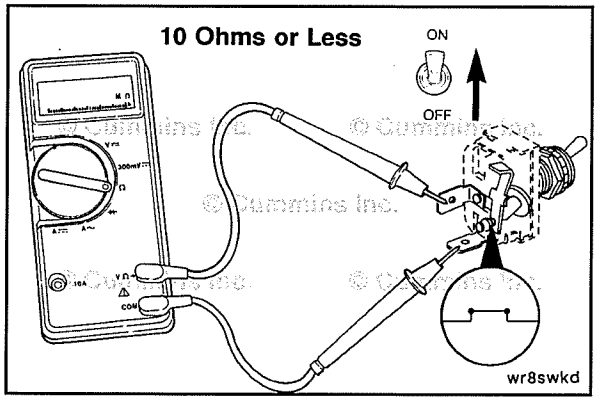
Remove and tag the two connectors from the terminals on the switch.

Touch the multimeter probes to the terminals on the switch.



Move the switch to the OFF position and measure the resistance. The multimeter **must** show 100k ohms or more (open circuit). If the circuit is **not** open, the switch has failed.

Replace the switch. Refer to the OEM troubleshooting and repair manual for the replacement procedures.



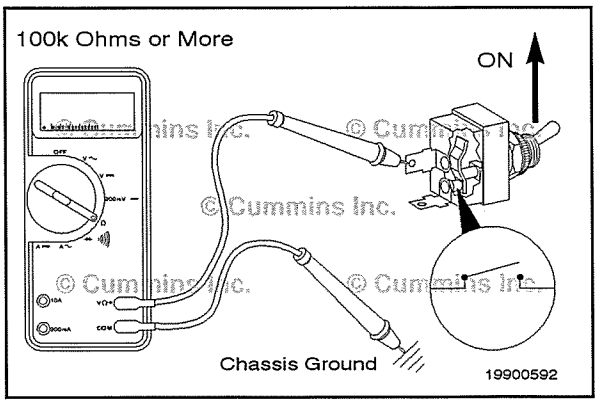
Move the switch to the ON position and measure the resistance. The multimeter **must** show 10 ohms or less (closed circuit). If the circuit is **not** closed, the switch has failed.

Replace the switch. Refer to the OEM troubleshooting and repair manual for the replacement procedures.

If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.

Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the ON position and measure the resistance. The multimeter **must** show 100k ohms or more (open circuit). If the circuit is **not** open, the switch has failed. Replace the switch. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.

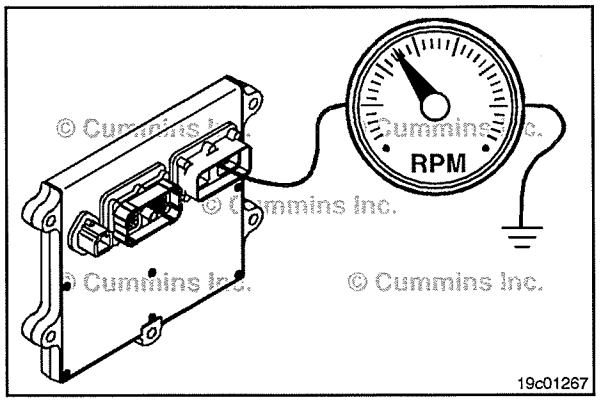


Tachometer Circuit (019-083)

General Information

The engine control module (ECM) can supply an output signal to operate the vehicle tachometer.

The circuit is the tachometer signal wire and a return line in the original equipment manufacturer (OEM) harness.



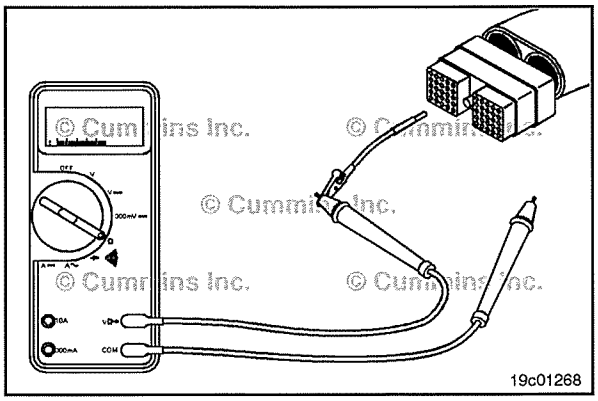
Resistance Check

⚠CAUTION⚠
Do not use probes or leads other than Part Number 3822758. The connector will be damaged. The leads must fit tightly in the connector without expanding pins in the connector.

Disconnect the OEM harness from the ECM connector.

Disconnect the tachometer from the OEM harness.

Insert the test lead into the tachometer signal pin of the OEM harness connector and connect it to the multimeter probe.



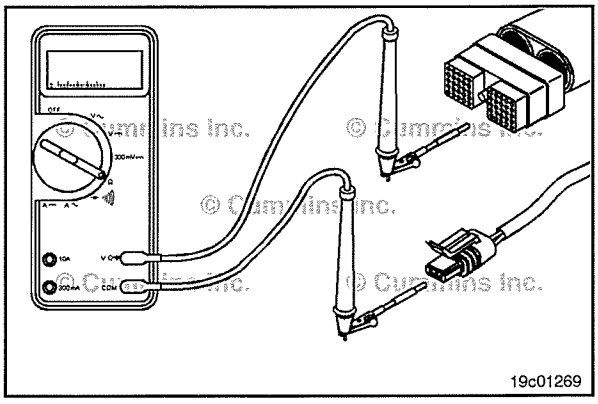
Locate the tachometer connector of the OEM harness.

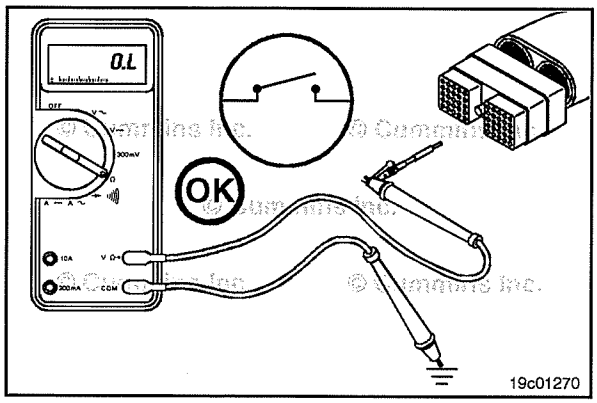
Connect the other lead to the multimeter probe and connect it to the tachometer signal pin of the tachometer connector that is coming from the engine ECM. Consult the OEM troubleshooting and repair manual for wiring schematics.

Adjust the multimeter to the resistance setting.

Measure the resistance.

The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, there is an open circuit or the wires in the tachometer connector are reversed. Repair or replace the wire connected to the tachometer signal pin in the OEM harness according to the vehicle manufacturer's procedures.





Check for Short Circuit to Ground

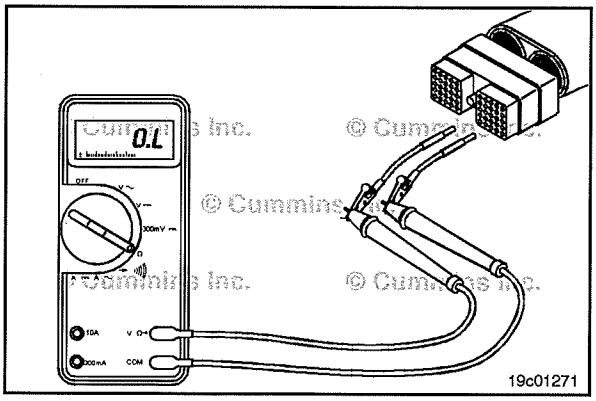
Disconnect the tachometer from the OEM harness.

Insert the test lead into the tachometer signal pin of the OEM harness connector and connect it to the multimeter probe. Touch the other multimeter probe to the engine block ground.

Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open in either of the prior checks, repair the wires which have incorrect readings. Refer to the OEM troubleshooting and repair manual for the repair procedures.



Check for Short Circuit from Pin to Pin

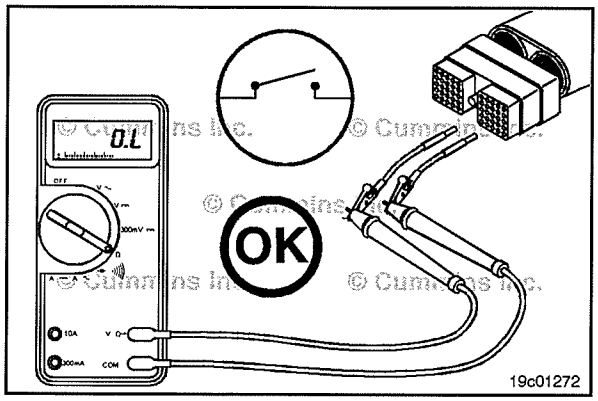
Disconnect the tachometer from the OEM harness.

Insert the test lead into the tachometer signal pin of the OEM harness connector and connect it to the multimeter probe. Insert the other lead into any pin, except the tachometer switch return, of the OEM harness connector, and connect it to the other multimeter probe.

Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

Measure the resistance from the tachometer signal pin to all other pins in the OEM connector. The multimeter **must** show an open circuit.



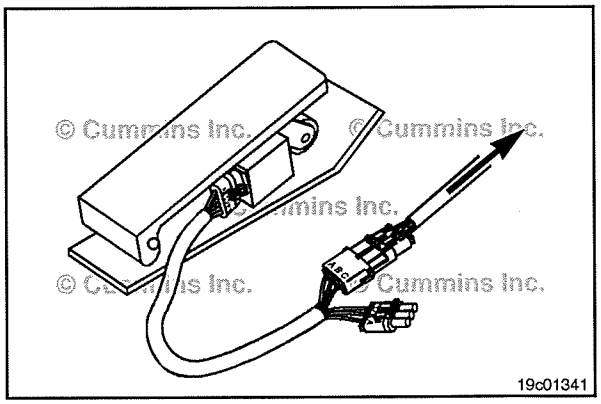
Remove the test lead from the last tested pin, insert it into the tachometer switch return pin. Measure the resistance from the tachometer switch return pin to the tachometer signal pin in the OEM harness connector.

The multimeter **must** show an open circuit (100k ohms or more) at all pins.

If any pin-to-pin check measures as **not** open, there is a short circuit between the tachometer signal pin and any other pin that measured a **not** open circuit. Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.

Accelerator Pedal or Lever Position Sensor (019-085)

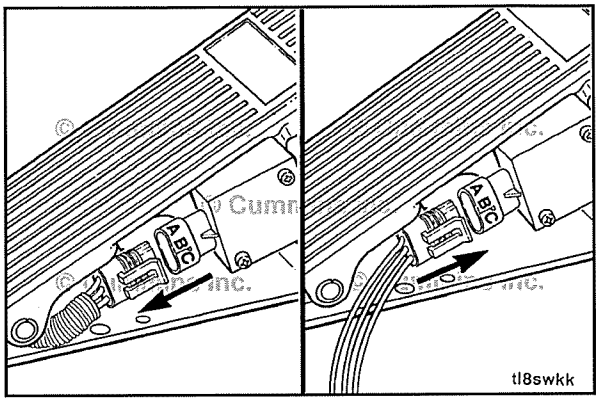
General Information



The accelerator pedal or lever position sensor will vary with OEM. Refer to the vehicle manufacturer's manual for the specific troubleshooting and repair procedures. This section contains troubleshooting and repair procedures for one typical accelerator pedal or lever position sensor.

The accelerator pedal or lever position sensor sends a signal to the ECM when the operator pushes on the accelerator pedal or lever. The accelerator position circuit consists of the accelerator pedal or lever position sensor, the ECM, accelerator pedal/lever position +5 volt, accelerator pedal/lever position signal, and accelerator pedal/lever position return wires.

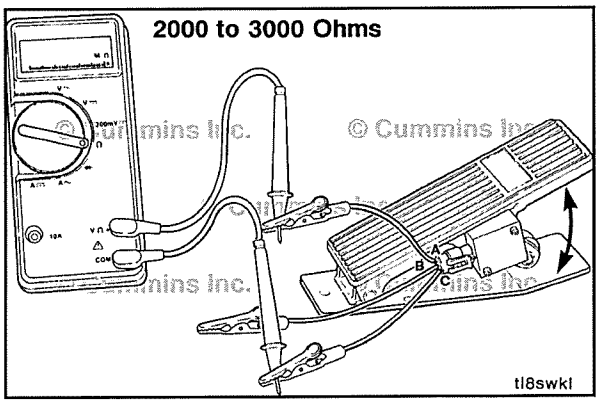
Resistance Check



If INSITE™ is available, monitor the accelerator position sensor for proper operation. If **not**, follow the troubleshooting procedures in this section.

Disconnect the 3-pin connector from the accelerator position sensor.

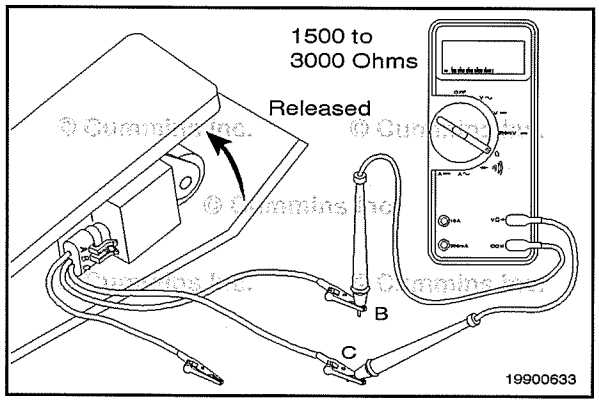
Connect the test connector.



Connect the multimeter positive (+) test lead to the accelerator pedal/lever position +5 volt supply test connector wire. Connect the negative (-) multimeter test probe to the accelerator pedal/lever position return test connector wire.

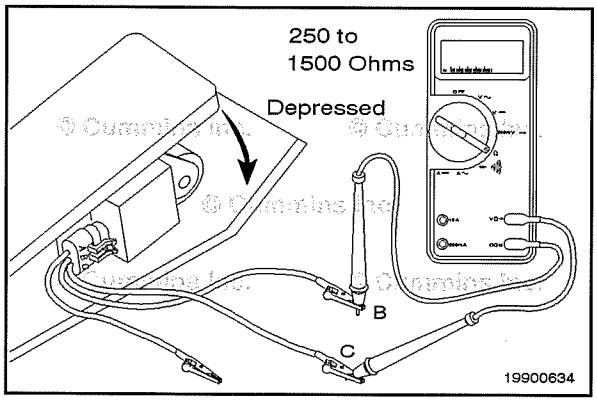
Measure the resistance. The multimeter **must** show between 2000 and 3000 ohms when the accelerator pedal is released (idle position) or depressed (full-fuel position).

If the resistance is **not** within the specification, the accelerator position sensor has failed. Replace the accelerator position sensor. Refer to the OEM troubleshooting and repair manual for the procedures.

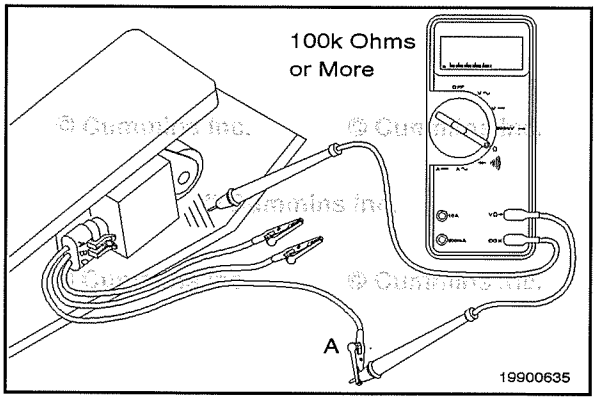


Remove the multimeter probe from the accelerator pedal/lever position +5 volt supply test connector wire and connect it to the accelerator pedal/lever position signal test connector wire.

When the accelerator pedal is in the released (idle) position, measure the resistance. The multimeter **must** show between 1500 and 3000 ohms.



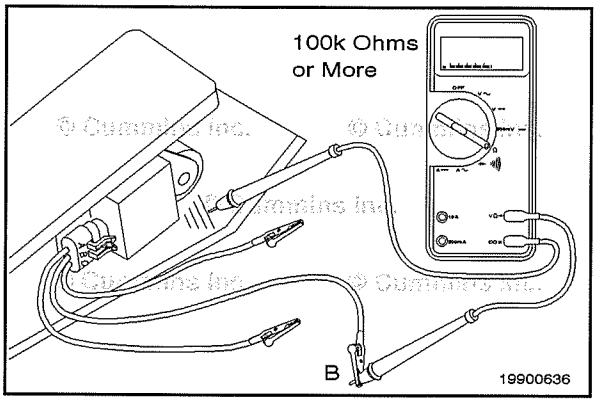
Depress the accelerator pedal assembly (full-fuel position) and measure the resistance. The multimeter **must** show between 250 and 1500 ohms. This resistance value **must** be at least 1000 ohms lower than the resistance value of 1500 to 3000 ohms measured in the above check. If the resistance values in the two previous steps are **not** within the specification, the accelerator position sensor has failed. Replace the accelerator position sensor according to the vehicle manufacturer's procedures. If the resistance values are within the specifications, the accelerator position sensor **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

Connect the multimeter positive (+) probe to the accelerator pedal/lever position return test connector wire. Touch the negative (-) multimeter probe to the chassis ground and measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).



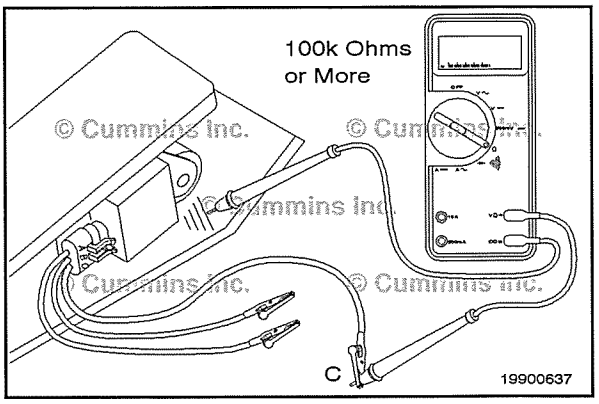
Remove the multimeter positive (+) probe from accelerator pedal/lever position return test connector wire and connect it to the accelerator pedal/lever position signal test connector wire. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

Remove the multimeter positive (+) probe from the accelerator pedal/lever position signal test connector wire and connect it to the accelerator pedal/lever position +5 volt supply test connector wire. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the resistance values are **not** within the specifications in the previous check, the accelerator position sensor has failed. Replace the accelerator position sensor according to the vehicle manufacturer's procedures.

If the accelerator position sensor has passed all the previous checks, connect the sensor to the wiring harness. The accelerator position sensor circuit **must** still be checked.



Unswitched Battery Supply Circuit (019-087)

General Information

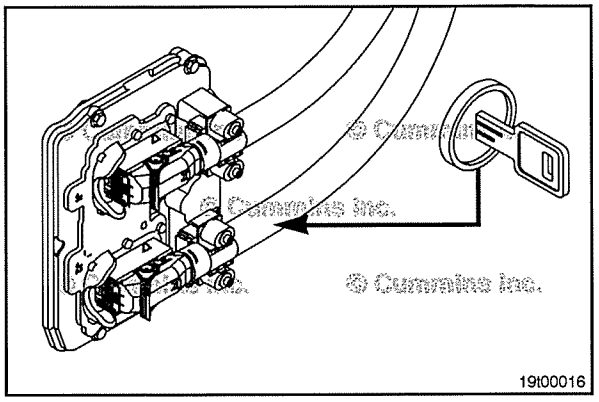
The engine control module (ECM) receives constant voltage from the batteries through the ECM battery supply positive (+) wire that is connected directly to the positive (+) battery post. There is one in-line 30 ampere fuse in the ECM supply wire to protect the ECM. The ECM receives switched battery input through the keyswitch input signal when the vehicle keyswitch is turned on. The ECM battery supply negative (-) wire is connected directly to the negative (-) battery post.

The ECM battery supply positive (+) and the ECM battery supply negative (-) wires are in the OEM wiring harness.

Always check the ECM battery supply fuse when troubleshooting the ECM and power supply circuit.

NOTE: All of the aftertreatment components receive battery power by an OEM supplied and ECM controlled relay. Reference the OEM wiring diagram.

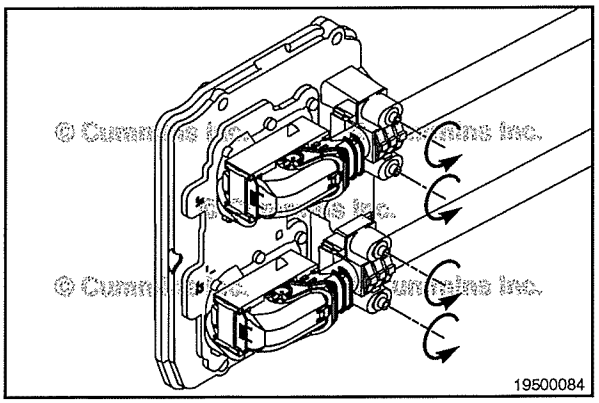
Check the battery voltage. Refer to Procedure 019-008 in Section 19.

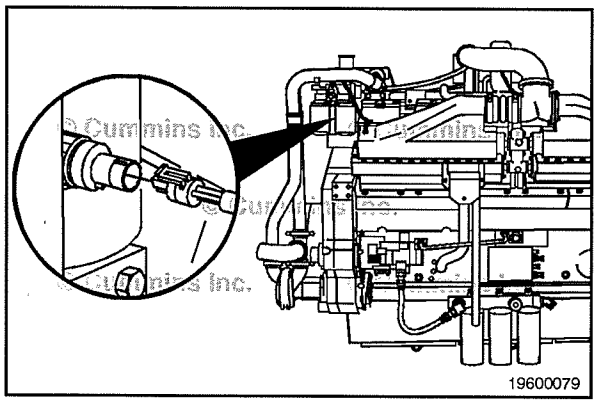


Remove

Remove the wire harness hold-down clamps from the ECM.

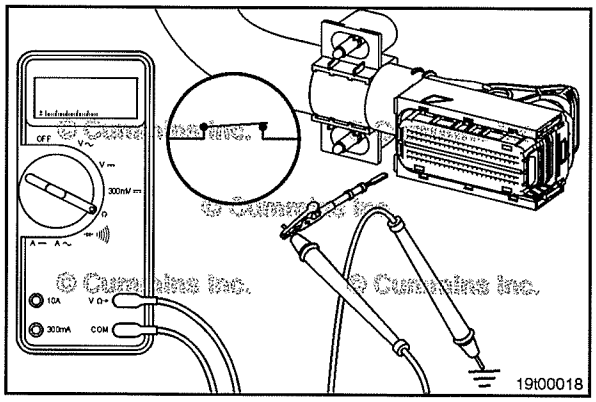
NOTE: Do **not** remove the wire ties attaching the hold-down clamps to the wire harness.





Remove the OEM connector from the ECM by pressing down on the locking tab (1) and pulling up on the lever (2). This connector includes the battery supply wires.

NOTE: Do **not** close the lever after the connector has been removed from the ECM. Attempting to do so will cause damage to the connector.



Resistance Check

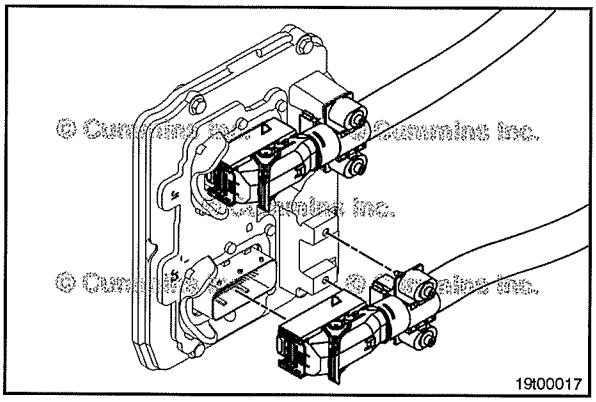
⚠CAUTION⚠
Do not insert test leads into the ECM connector terminals. Doing so may cause terminals to spread and cause intermittent electrical connections. To perform pin-out diagnostic checks, use ECM connector break-out header, Part Number 2892510, and test lead, Part Number 3164113.

Adjust the multimeter to measure resistance.

Using an ECM connector break-out header, connect a test lead into the ECM battery supply negative (-) pin of the OEM wiring harness connector. Reference the appropriate wiring diagram for pin locations. Attach it to the multimeter probe. Touch the other multimeter probe to the engine block ground and measure the resistance.

The multimeter **must** show 10 ohms or less.

Repeat the measurement for all other ECM battery supply negative (-) pins that are populated in the OEM wiring harness connector.



If the resistance value is **not** correct, check the OEM wiring harness.

Repair or replace the OEM wiring harness.

When the checks have been completed, connect the OEM wiring harness connector.

NOTE: Some OEM applications have all available power supply and return pins populated in the OEM wiring harness.

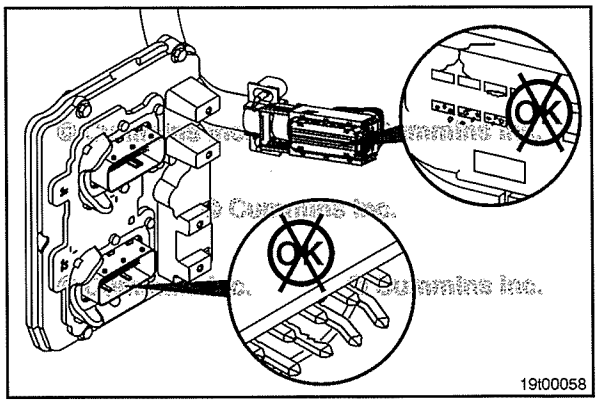
Check the battery return wire(s) in the OEM wiring harness for proper grounding.

Disconnect the harness from the ECM connector.

Check for damaged pins in the ECM and the harness.

Repair or replace any damaged pins.

Refer to Procedure 019-505 in Section 19.



Voltage Check

⚠CAUTION⚠
Do not insert test leads into the ECM connector terminals. Doing so may cause terminals to spread and cause intermittent electrical connections. To perform pin-out diagnostic checks, use ECM connector break-out header, Part Number 2892510, and test lead, Part Number 3164113.

Check the battery voltage supply at the ECM battery supply positive (+) pins of the OEM wiring harness connector.

Turn the keyswitch to the OFF position.

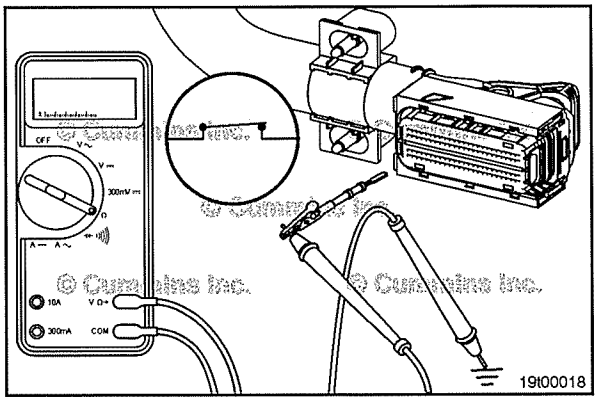
Set the multimeter to measure VDC.

Using an ECM connector break-out header, connect a test lead into the ECM battery supply positive (+) pin of the OEM wiring harness connector. Reference the appropriate wiring diagram for pin locations. Attach it to the multimeter probe. Touch the other multimeter probe to the engine block ground stud, located below the ECM, and measure the voltage.

The voltage **must** read within 1-VDC of battery voltage at this pin.

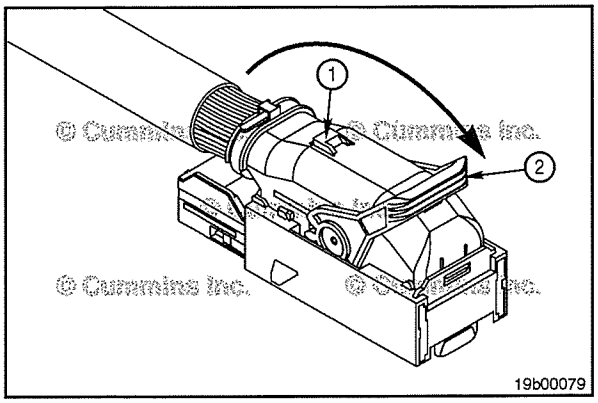
Repeat the measurement for all other ECM battery supply positive (+) pins that are populated in the OEM wiring harness connector.

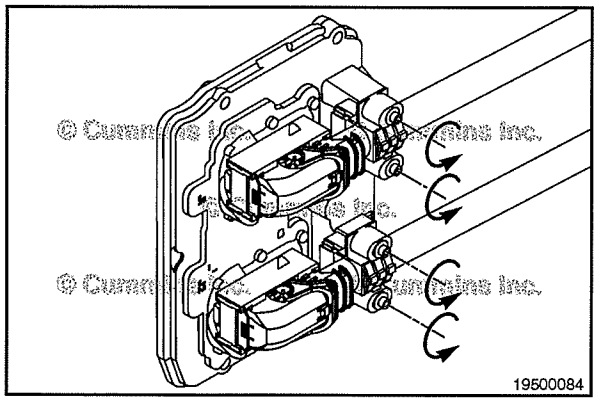
If the voltage is **not** correct, repair or replace the ECM power harness.



Install

Connect the harness to the ECM by placing the harness connector into the ECM header and pull back on the locking lever until the connector is fully seated and the lever locking tab is engaged.

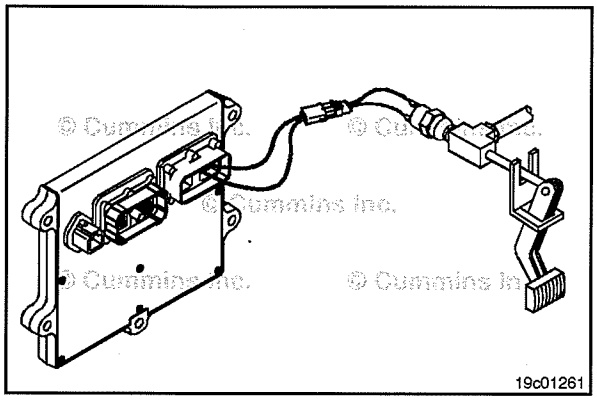




Install the wire harness hold-down clamps.

See the following procedure for torque value. Refer to Procedure 019-043 in Section 19.

NOTE: Do **not** overtighten the harness hold down clamp mounting screws or damage to the ECM will occur.

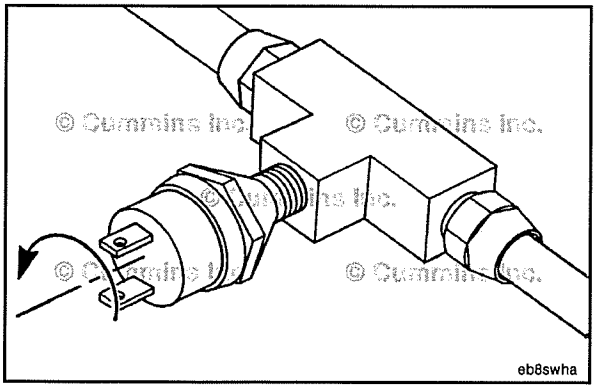


Brake Pedal Position Switch (019-088)

General Information

⚠CAUTION⚠
When troubleshooting the brake line switch circuit, make sure the brake pressure switch is identified. The vehicle brake light pressure switch, which is not a part of the Signature system, is commonly mistaken for the brake line switch used in the Signature system.

The brake pedal position switch detects the position of the service brake pedal. Certain features such as cruise control and PTO respond to the state of the brake pedal position switch and disengage when the brakes are applied. The circuit has a normally-closed switch, switch return wire, and brake pedal position switch signal wire of the OEM harness. The brake pedal position switch is mounted in the low pressure side of the vehicle pneumatic brake system. When the vehicle brakes are applied, the normally-closed switch opens and disables the cruise control operation.



Remove

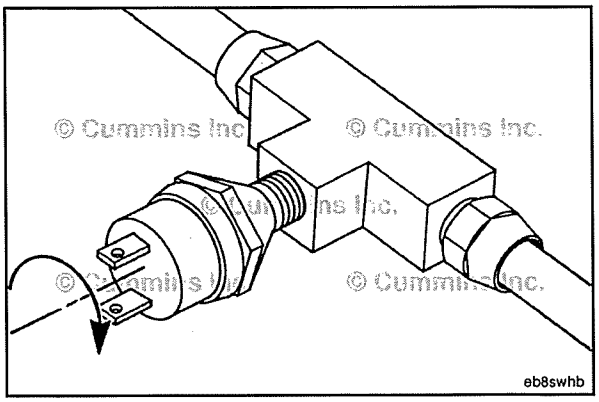
⚠WARNING⚠
To avoid personal injury or death, do not apply the vehicle brakes when the switch is removed from the brake line fitting.

Disconnect the OEM harness from the brake pedal position switch.

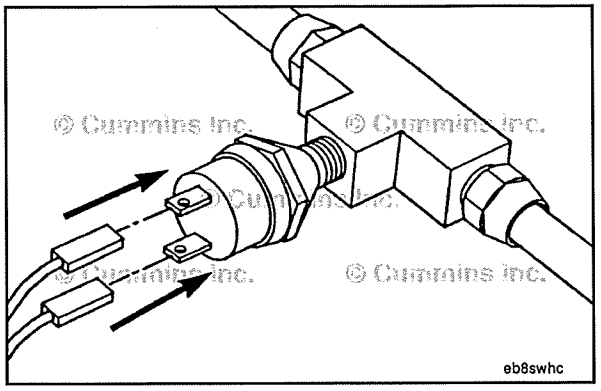
Remove the brake pedal position switch from the fitting.

Install

Install the new brake pedal position switch into the fitting according to the vehicle manufacturer's procedures.



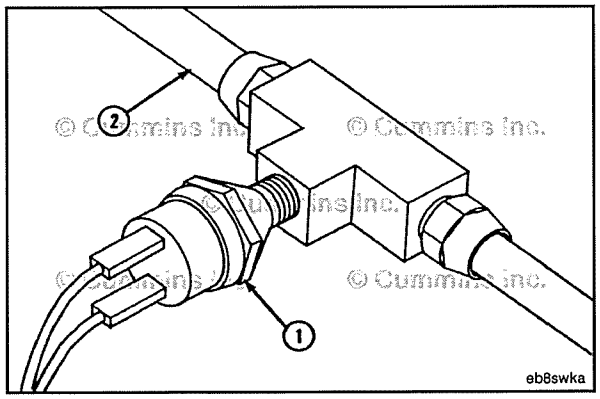
Connect the two wire connectors to the brake pedal position switch.



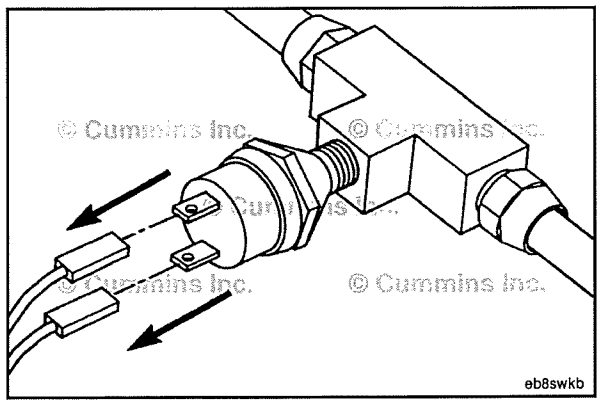
Resistance Check

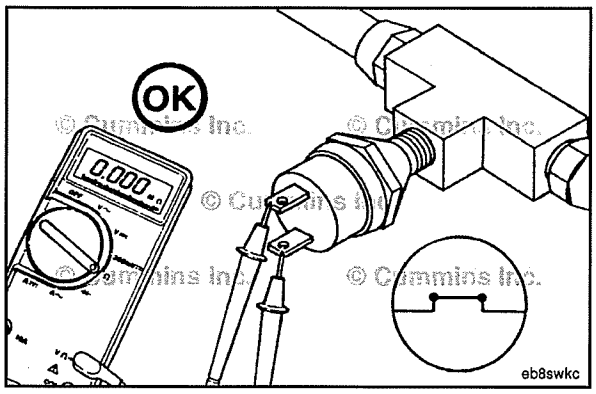
If INSITE™ is available, monitor the brake pedal position switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

The brake pedal position switch (1) will be located in the vehicle brake line (2). The location will depend on the OEM installation procedures.



Disconnect the two wire connectors from the brake pedal position switch.

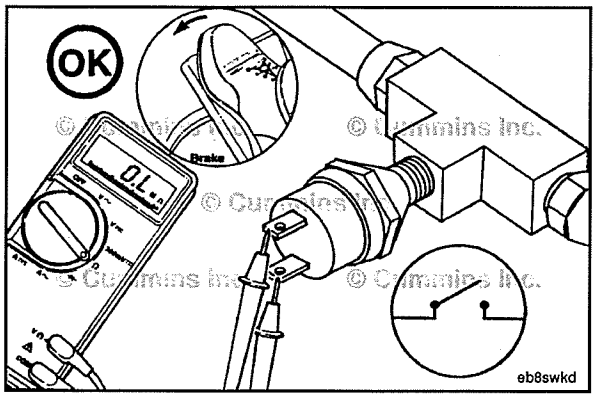




Connect the probes of the multimeter to the brake pedal position switch terminals.

Measure the resistance.

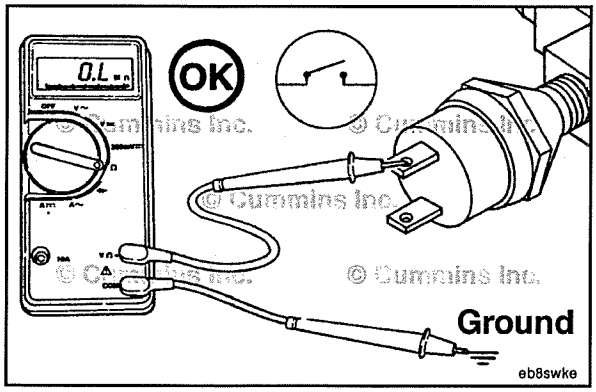
The multimeter **must** show a closed circuit (10 ohms or less) when the brakes are **not** applied. If the circuit is **not** closed, replace the brake pedal position switch.



⚠CAUTION⚠
The vehicle must have enough air pressure to activate the brakes.

Depress the vehicle brake pedal. The multimeter **must** show an open circuit (100k ohms or more) when the brakes are applied. If the circuit is **not** open, replace the brake pedal position switch.

If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

Touch one multimeter probe to one of the brake pedal position switch terminals. Touch the other multimeter probe to chassis ground. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more) when the brake pedal is released. If the circuit is **not** open, replace the brake pedal position switch.

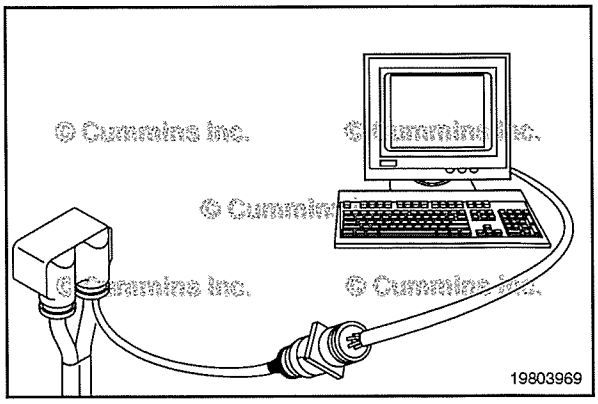
If the brake pedal position switch passed all the previous checks, connect the switch to the wiring harness. The brake pedal position switch circuit **must** still be checked.

Brake Pedal Position Switch Circuit (019-089)

Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

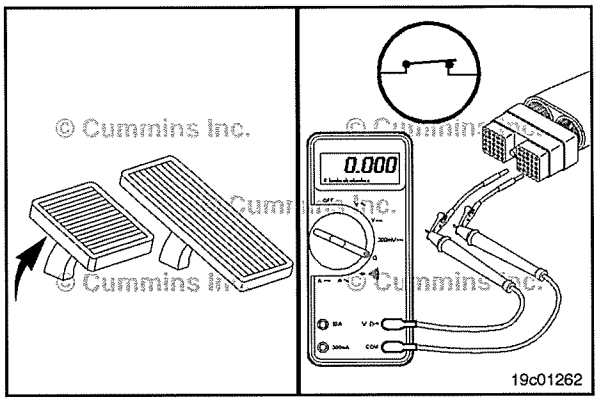
If INSITE™ electronic service tool is available, monitor the brake pedal position switch for proper operation. If **not**, follow the troubleshooting procedures in this section.



Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM).

Make sure the brake pedal position switch is connected to the circuit.

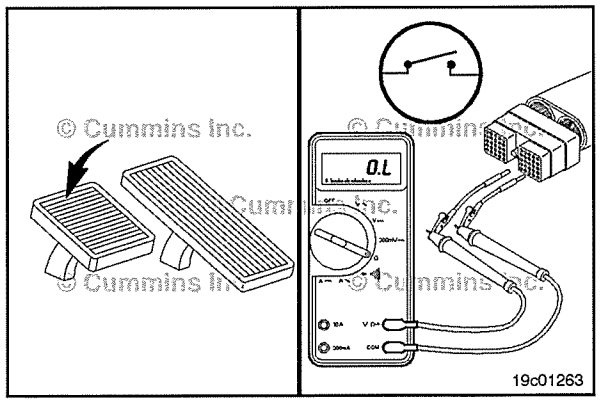
Insert a test lead into the brake pedal position switch signal pin of the OEM harness connector. Attach the lead to a multimeter probe. Insert the other test lead into the switch return pin of the connector and attach it to the other probe.



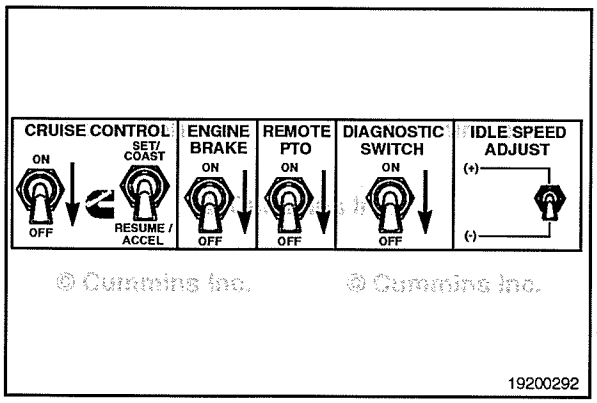
Adjust the multimeter to the resistance setting and measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less) when the brakes are **not** engaged (brake pedal released). If the circuit is **not** closed, there is a problem with the OEM harness, provided the brake pedal position switch has been previously checked.

⚠CAUTION⚠
The vehicle must have enough air pressure to activate the brakes.

Depress the vehicle brake pedal and repeat the resistance check. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a problem with the OEM harness, provided the brake pedal position switch has been previously checked.



If the values are correct, the circuit **must** still be checked for a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.



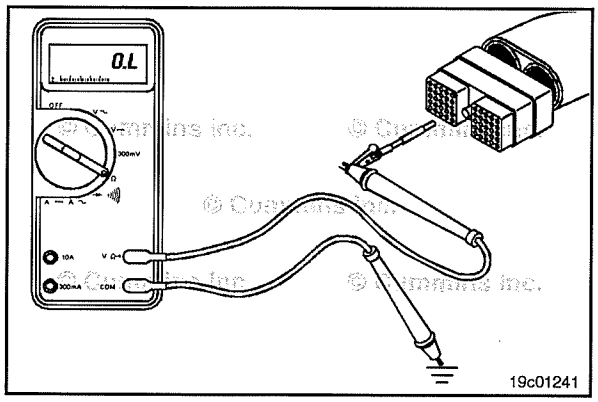
Check for Short Circuit to Ground

To isolate the brake pedal position switch circuit when checking for a short circuit, turn all cab panel switches to the OFF or neutral position.

Disconnect the OEM harness connector from the ECM and the OEM harness from the brake pedal position switch.

Set the service brake using the trailer brake hand valve.

Disconnect the clutch pedal position switch, accelerator position switch and the idle validation on/off switch.

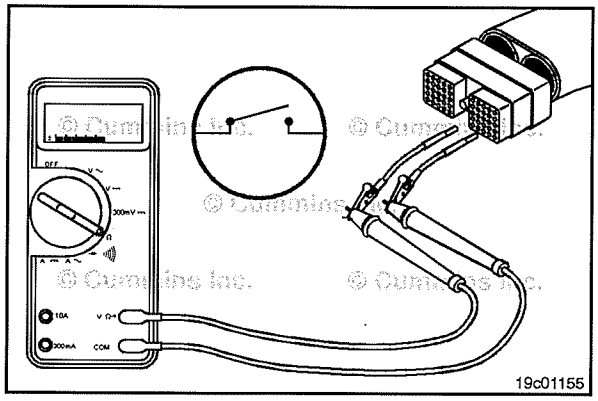


Insert a test lead into the brake pedal position switch signal pin of the OEM harness connector. Connect the lead to the multimeter probe. Remove the alligator clip from the other multimeter probe and touch the probe to the engine block.

The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the brake pedal position switch signal wire, provided that the switch has been previously checked.

Repair or replace the wire connected to the brake pedal position switch signal pin in the OEM harness according to the vehicle manufacturer's procedures.

Measure the resistance.



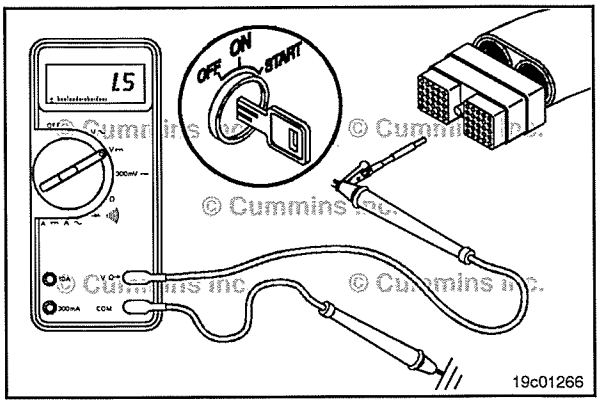
Check for Short Circuit from Pin to Pin

Isolate the brake pedal position switch circuit by disconnecting the brake pedal position switch connector and the OEM harness connector at the ECM. Insert a test lead into the brake pedal position switch signal pin of the OEM harness connector. Insert the other test lead into the switch return pin of the OEM harness connector. Connect the alligator clips to the multimeter probes. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

Remove the lead from the switch return pin and test all other pins in the connector. The multimeter **must** show an open circuit (100k ohms or more) at all pins. If the circuit is **not** open, there is a short circuit between the wire connected to the service brake switch signal pin and any pin that did **not** show an open circuit.

Repair or replace the wires in the OEM harness according to the vehicle manufacturer's procedures.

Check for Short Circuit to External Voltage Source



Disconnect the brake pedal position switch from the OEM harness and disconnect the OEM harness from the ECM. Turn the vehicle keyswitch to the ON position. Adjust the multimeter to measure VDC. Insert a test lead into the brake pedal position switch signal pin and connect it to the positive multimeter probe. Remove the lead from the negative multimeter probe and touch the probe to the engine block ground. Measure the voltage. The voltage **must** be 1.5 VDC or less.

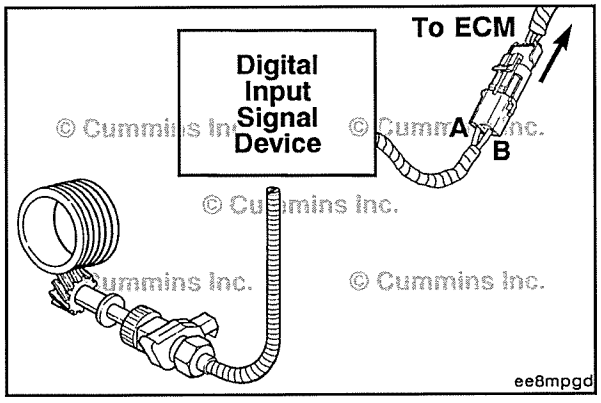
NOTE: An external voltage source is any wire in the OEM wiring that carries voltage.

If the voltage is more than 1.5 VDC, there is a short circuit between the wire connected to the brake pedal position switch signal pin and a wire carrying power in the OEM harness. Repair the OEM harness according to the vehicle manufacturer's procedures.

Connect all components after completing the repair.

Vehicle Speed Sensor, Digital Input (019-090)

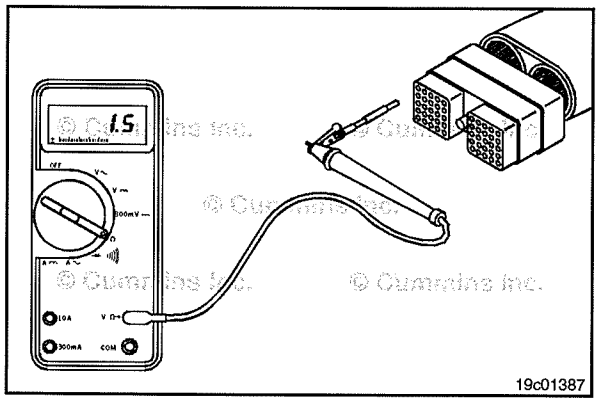
General Information



The digital input signal device is an OEM optional part. It changes the signal pulses from AC to DC. This part is near the transmission or in the vehicle cab. The DC voltage pulses are then sent to the ECM and computed into miles per hour.

The digital vehicle speed sensor circuit consists of the speed sensor, the digital vehicle speed sensor +5 volt supply wire, the digital vehicle speed sensor signal wire, and the digital vehicle speed sensor return wire.

⚠CAUTION⚠
When the OEM-supplied signal conditioner is internally grounded, do not connect the vehicle speed sensor signal negative (-) wire to the ECM. This will create a ground loop in the system that will inject unwanted electrical noise into the system. Only the digital vehicle speed sensor +5 volt supply wire is required in this case.



Resistance Check

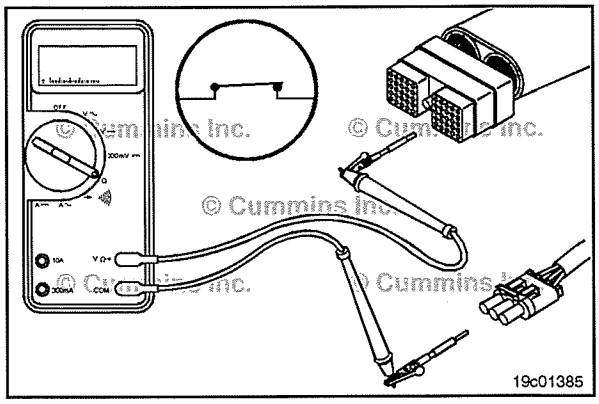
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECM connector.

Disconnect the digital vehicle speed sensor from the OEM harness.

Insert a test lead into the digital vehicle speed sensor +5 volt supply pin in the OEM harness connector, and connect it to the multimeter probe.

Insert the other test lead to the digital vehicle speed sensor +5 volt supply in the vehicle speed sensor connector and connect the alligator clip to the other multimeter probe. Adjust the multimeter to the resistance setting and measure the resistance.



The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, there is an open circuit. Repair or replace the wire connected to the digital vehicle speed sensor +5 volt supply pin in the OEM harness according to the vehicle manufacturer's procedures.

Remove the lead from the digital vehicle speed sensor +5 volt supply pin and insert it into the digital vehicle speed sensor signal pin of the OEM harness connector. Remove the multimeter lead from the digital vehicle speed sensor +5 volt supply at the speed sensor connector and connect it to the digital vehicle speed sensor signal pin in the vehicle speed sensor connector. Measure the resistance.

The multimeter **must** show a closed circuit (10 ohms or less).

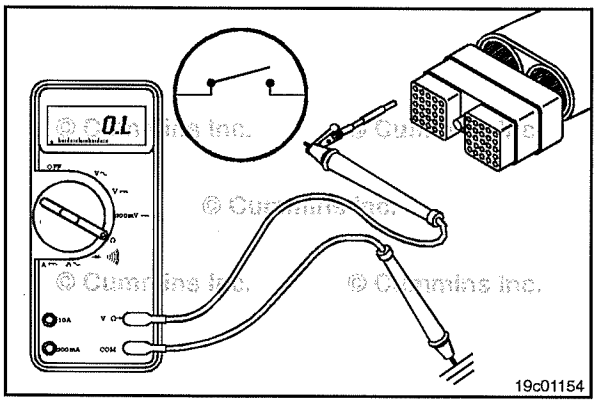
If the circuit is **not** closed, there is an open circuit. Repair or replace the wire connected to the vehicle speed sensor signal pin in the OEM harness according to the vehicle manufacturer's procedures.

Remove the lead from the digital vehicle speed sensor signal pin and insert it into the digital vehicle speed sensor return pin of the OEM harness connector. Remove the multimeter lead from the digital vehicle speed sensor signal pin at the speed sensor connector and connect it to the digital vehicle speed sensor return pin in the vehicle speed sensor connector. Measure the resistance.

The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, there is an open circuit. Repair or replace the wire connected to the vehicle speed sensor return pin in the OEM harness according to the vehicle manufacturer's procedures.

If the values are correct, the circuit **must** still be checked for a short circuit to ground and a short circuit from pin-to-pin.



Check for Short Circuit to Ground

Disconnect the vehicle speed sensor from the OEM harness. Disconnect the OEM harness connector from the ECM.

Insert a test lead into the digital vehicle speed sensor signal return pin of the OEM harness connector, and connect it to the multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

Remove the test lead from the digital vehicle speed sensor signal return pin and insert it into the digital vehicle speed sensor +5 volt supply pin of the OEM harness connector. Touch the other multimeter probe to the engine block ground. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

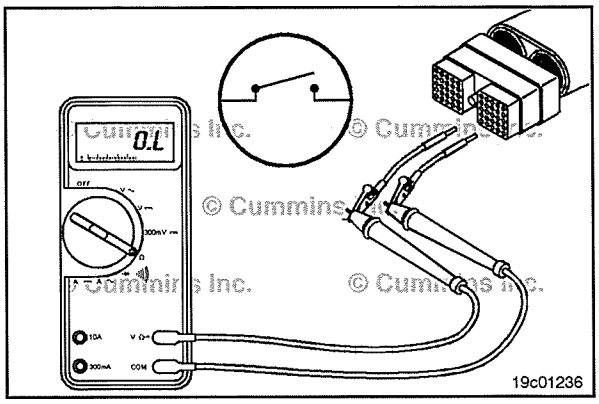
Remove the test lead from the digital vehicle speed sensor signal +5 volt supply pin and insert it into the digital vehicle speed sensor signal pin of the OEM harness connector. Touch the other multimeter probe to the engine block ground. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open in either of these checks, there is a short circuit to ground in the digital vehicle speed sensor circuit in the OEM harness.

Repair the wires which have a short circuit according to the vehicle manufacturer's procedures.

Check for Short Circuit from Pin to Pin



Disconnect the vehicle speed sensor from the OEM harness.

Disconnect the OEM harness connector from the ECM connecter.

Insert one test lead into the digital vehicle speed sensor +5 volt supply pin of the OEM harness connector, and connect it to the multimeter probe. Connect the other test lead to the other multimeter probe and check all pins in the OEM harness connector.Measure the resistance.

The multimeter **must** show an open circuit at all pins (100k ohms or more).

Remove the test lead from the digital vehicle speed sensor +5 volt supply pin, and insert it into the digital vehicle speed sensor signal return pin.

Use the other test lead to check all pins in the connector. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

Remove the test lead from the digital vehicle speed sensor return pin, and insert it into the digital vehicle speed sensor signal signal pin.

Use the other test lead to check all pins in the connector. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

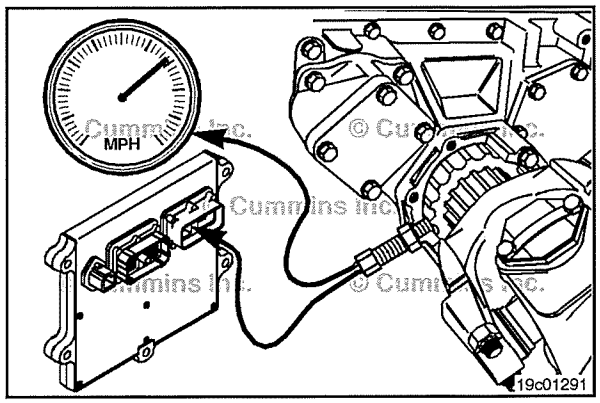
If the circuit is **not** open in any of the checks, repair the wires that have the short circuit according to the vehicle manufacturer's procedures.

NOTE: If the values are correct for all of the circuit checks in Procedure 019-090, the vehicle speed sensor circuit is good.

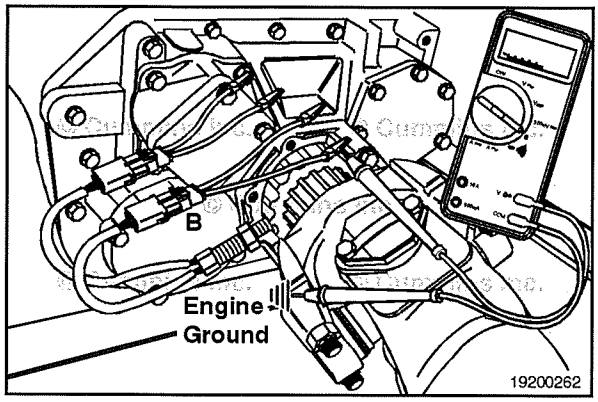
The problem is in the vehicle speed sensor. Repair or replace the vehicle speed sensor according to the vehicle manufacturer's procedures.

Vehicle Speed Sensor, Magnetic Pick Up (019-091)

General Information



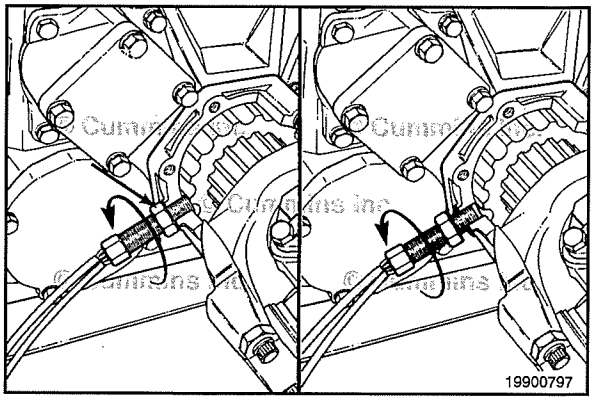
The vehicle speed sensor (VSS) senses the speed of the output shaft of the transmission. The vehicle's road speed is computed from this data by the electronic control module (ECM). The ECM uses programmed gearing and tire size data to compute the road speed.



The vehicle speed sensor is located in the rear of the transmission housing.

The vehicle speed sensor has two coils. One coil is connected to the ECM and the other coil is connected to the vehicle speedometer, or some other vehicle device.

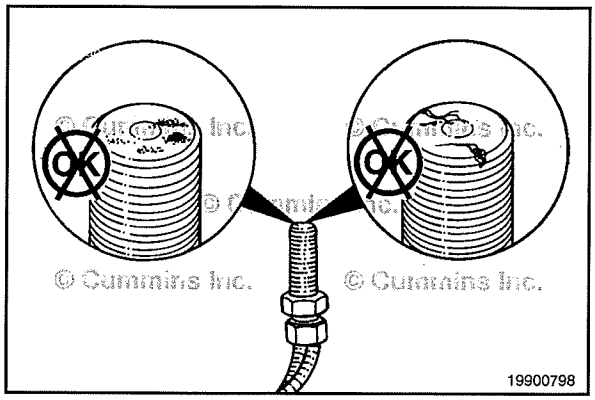
NOTE: Vehicle speed sensor design varies with the application. Refer to the original equipment manufacturer (OEM) troubleshooting and repair manual to understand which type of vehicle speed sensor is being used in a given location.



Remove

Disconnect the engine harness from the vehicle speed sensor.

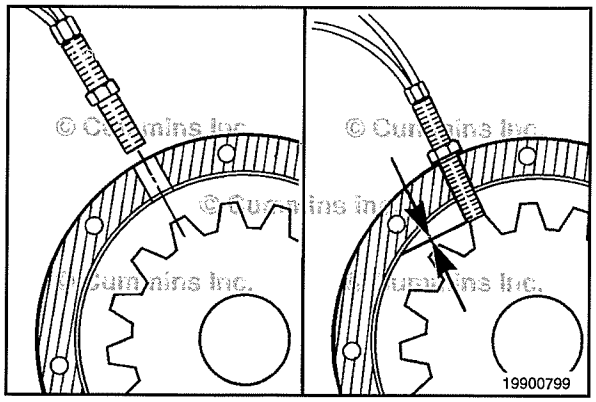
Loosen the locknut. Turn the vehicle speed sensor out of the transmission housing.



Inspect for Reuse

Inspect the tip of the vehicle speed sensor for dirt, debris, or physical damage (cracked potting, and so forth).

Clean the tip if dirty, or replace the vehicle speed sensor if damaged.



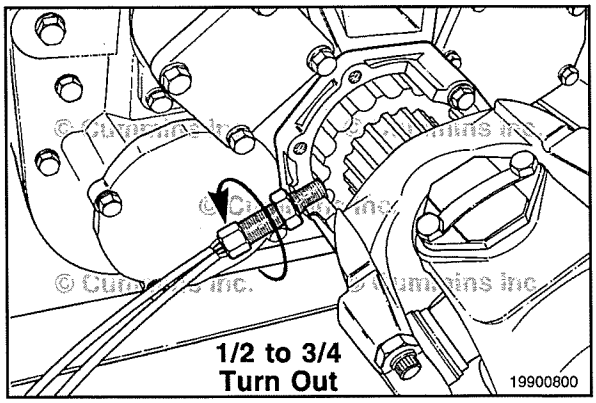
Install

△CAUTION△

Make sure a gear tooth is aligned with the hole in the housing. Install the vehicle speed sensor into the hole until it touches the gear tooth.

NOTE: If the vehicle speed sensor does **not** turn in with finger pressure, check the transmission hole threads and the sensor threads for dirt or damage.

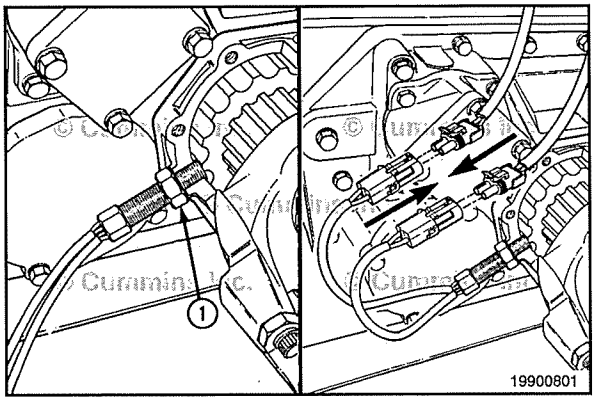
Turn the vehicle speed sensor out 1/2 to 3/4 of a turn.



Tighten the locknut against the transmission housing.

Torque the sensor according to the OEM or transmission specifications. Refer to the OEM troubleshooting and repair manual for detailed procedures.

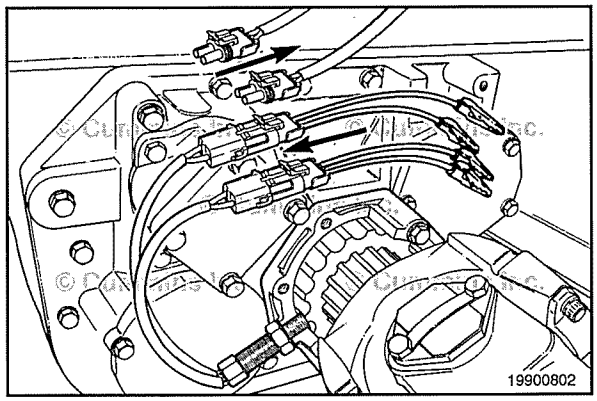
Install both of the connectors together until connectors "snap" into position. The connectors can be interchanged with each other without changing the performance of the system.



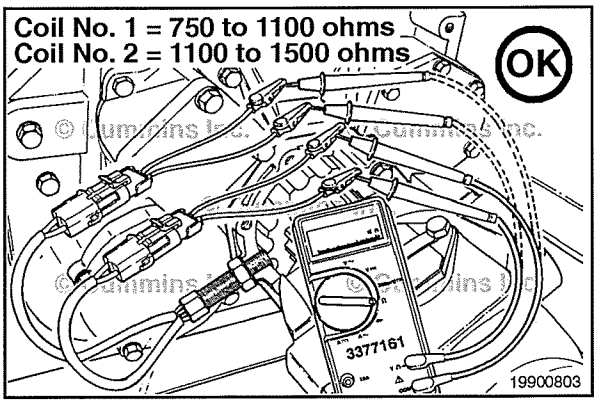
Resistance Check

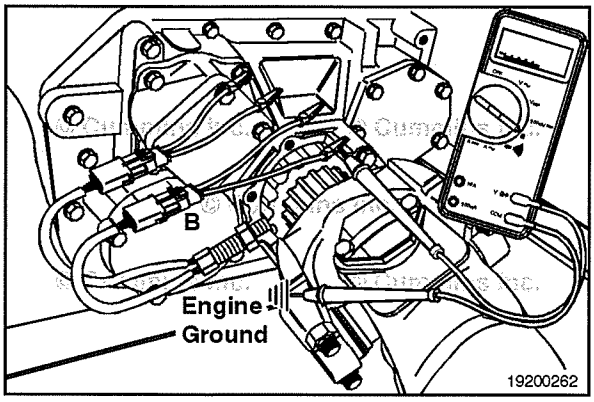
Lift the tab on the connectors and pull them apart.

NOTE: When measuring the resistance value of the vehicle speed sensor coils, use two female test leads. This will allow the electrical leads of the sensor to be softly flexed to check for damaged or partially broken wire strands under the insulation.



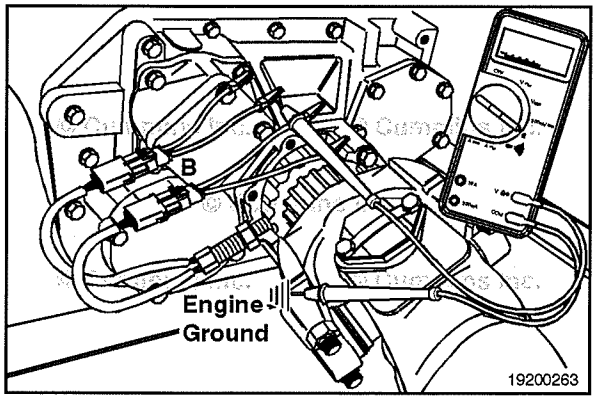
Use a multimeter to measure the resistance between the two pins of each connector on the vehicle speed sensor. Refer to the OEM troubleshooting and repair manual for detailed procedures. If the resistance is **not** correct, replace the vehicle speed sensor. If the resistance value is correct, the vehicle speed sensor **must** still be checked for a short circuit to ground and a short circuit between coils.



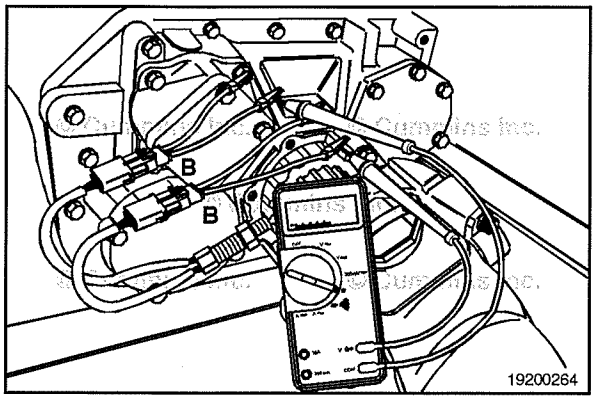


Check for Short Circuit to Ground

Measure the resistance between the magnetic vehicle speed sensor signal negative (-) pin of one of the connectors and the engine block. Refer to the OEM troubleshooting and repair manual for detailed procedures.



Measure the resistance between the magnetic vehicle speed sensor signal negative (-) pin of the other connector and the engine block. Refer to the OEM troubleshooting and repair manual for detailed procedures.



Check for a short circuit between coils

Use a multimeter to measure the resistance between the magnetic vehicle speed sensor signal negative (-) pin of one of the connectors and the magnetic vehicle speed sensor signal (-) pin of the other connector. Refer to the OEM troubleshooting and repair manual for detailed procedures.

Vehicle Speed Sensor Circuit (019-093)

Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

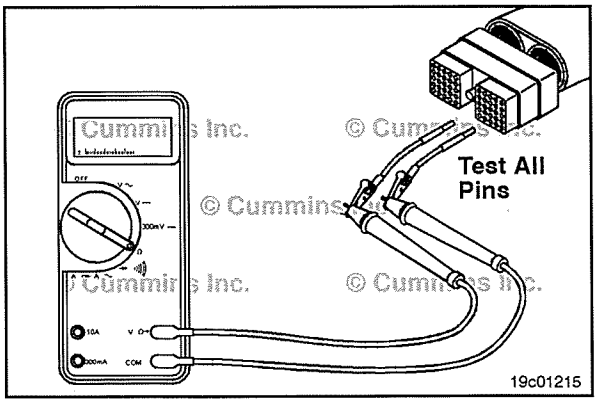
Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM). Make sure the vehicle speed sensor is connected to the OEM harness.

Insert a test lead into the magnetic vehicle speed sensor signal positive (+) pin in the OEM harness connector. Insert the other lead into the magnetic vehicle speed sensor signal negative (-) pin of the connector.

Connect the two alligator clips to the two probes of the multimeter. Adjust the multimeter to the resistance setting and measure resistance. When measuring the resistance with the sensor connected, refer to the OEM troubleshooting and repair manual for the correct resistance value. If the value is **not** correct, there is a problem with the OEM harness, provided that the vehicle speed sensor component has been previously checked.

NOTE: Repair or replace the OEM harness. Refer to Procedure 019-071, or to the OEM troubleshooting and repair manual for OEM harness replacement.

If the value is correct, the circuit **must** still be checked for a short circuit to ground and a short circuit from pin-to-pin.

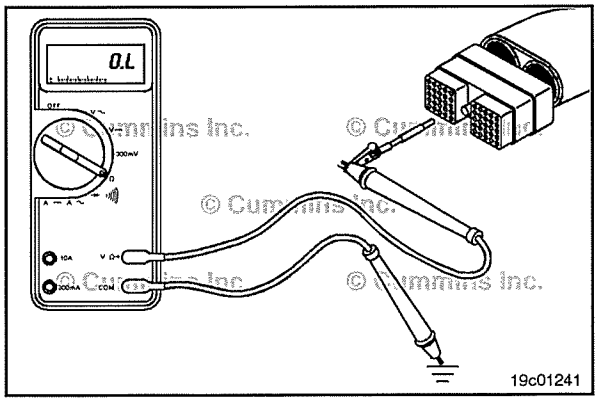


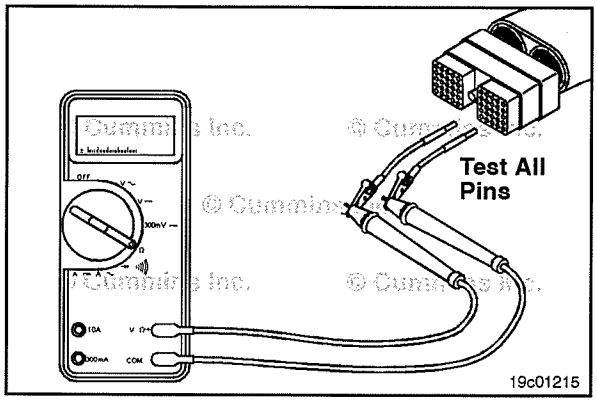
Check for Short Circuit to Ground

Check for a short circuit to ground. Insert the multimeter probe with attached test lead into the magnetic vehicle speed sensor signal positive (+) pin of the OEM harness connector. Touch the other multimeter probe to the engine block. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit to ground in the vehicle speed sensor circuit in the engine harness or OEM harness.

Repair the wires which are shorted in the circuit according to the vehicle manufacturer's procedures.

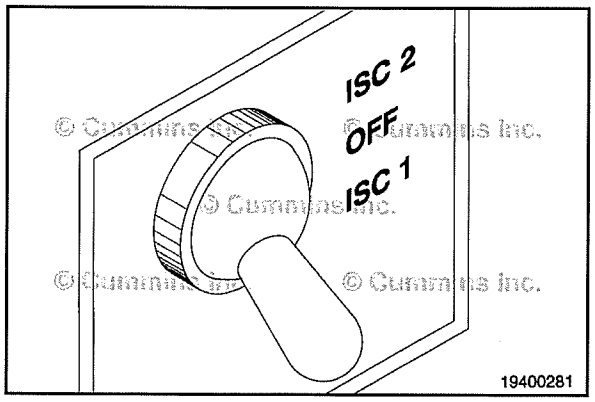




Check for Short Circuit from Pin to Pin

Check for a short circuit from pin-to-pin. Insert the multimeter probe with attached test lead into the magnetic vehicle speed sensor signal positive (+) pin of the OEM harness connector. Insert the other test lead into all the other pins, one at a time, to check for a short to another pin.

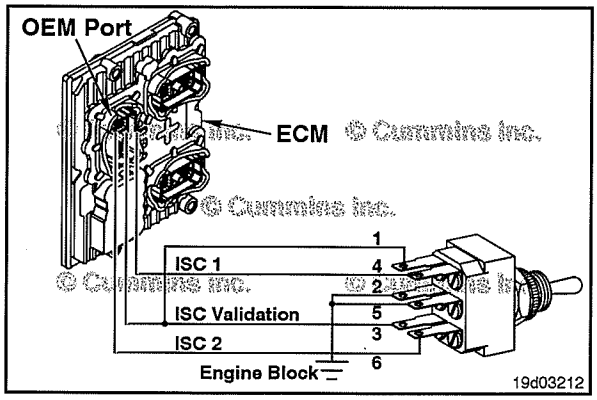
Measure the resistance. The multimeter **must** show an open circuit (more than 100k ohms).



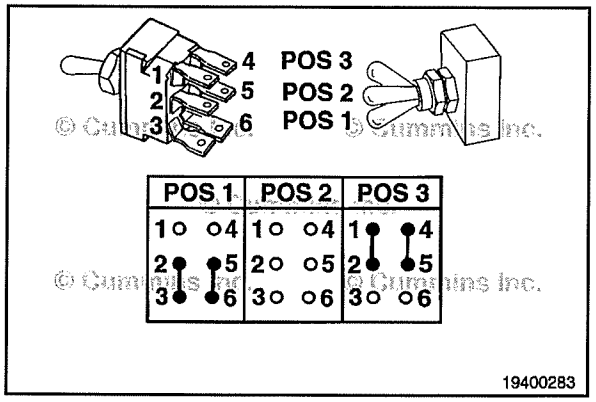
Intermediate Speed Control Switch (019-107)

General Information

The intermediate speed control (ISC) switch circuit signals the engine control module (ECM) that the operator is requesting the engine to run at a preset engine speed between low idle and high idle. Depending on the configuration, up to 8 speeds are available. This procedure can **not** cover every possible configuration, but the functionality checks provided in this procedure will be similar for all of them.



The ISC circuit is shown for ISC 1 and ISC 2 features. The calibration can have **only** one ISC active feature. The ISC circuit is wired with a double pole, double throw (DPDT), three-position switch.



The DPDT three position switch functions to selectively ground the three ISC input wires to the ECM. Refer to the wiring diagram for terminal locations. The logic of the switch is shown.

The lines that connect the switch terminals at the three lever positions are lines of continuity between the terminals.

In position 1, switch terminals No. 2, 3 and 5, 6 are connected, which shorts ISC 2 and ISC validation (pins 25 and 33) to ground.

In position 2, no pins are grounded.

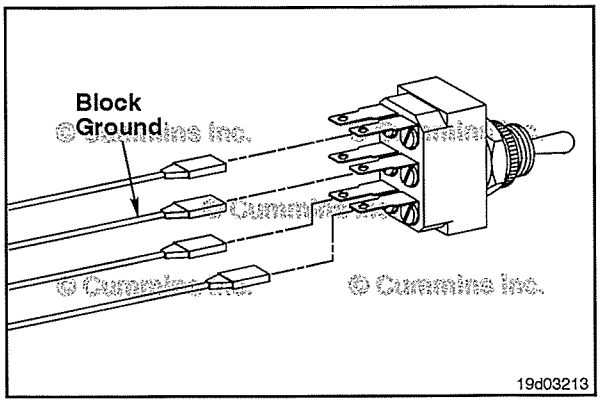
In position 3, switch terminals No. 1, 2 and 4, 5 are connected, which shorts ISC 1 and ISC validation (pins 23 and 33) to ground.

Resistance Check

Use the following steps for the intermedate speed control switch:

If INSITE™ electronic service tool is available, monitor the ISC switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Remove the four connectors from the switch. Label the wires with the switch location and the wire numbers before removing them from the switch.

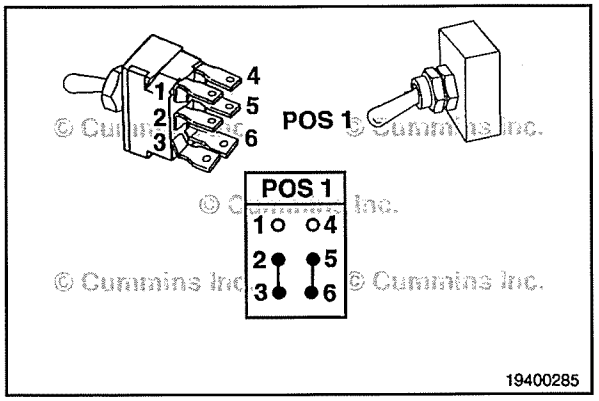


With the switch in position 1, measure the resistance from switch terminal 2 to switch terminal 3. The resistance **must** be 10 ohms or less.

Measure the resistance from switch terminal 5 to switch terminal 6. The resistance **must** be 10 ohms or less.

Measure the resistance from switch terminal 1 to all switch terminals. The resistance **must** be 100K ohms or more.

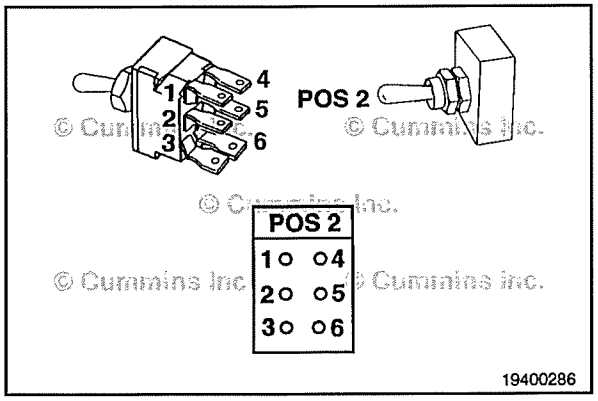
Measure the resistance from switch terminal 4 to all other terminals. The resistance **must** be 100K ohms or more.



Move the switch lever to position 2.

Measure the resistance from switch terminal 1 to all other terminals. The resistance **must** be 100K ohms or more.

Measure the resistance from switch terminal 2 to all other terminals. The resistance **must** be 100K ohms or more.



Move the switch lever to position 3.

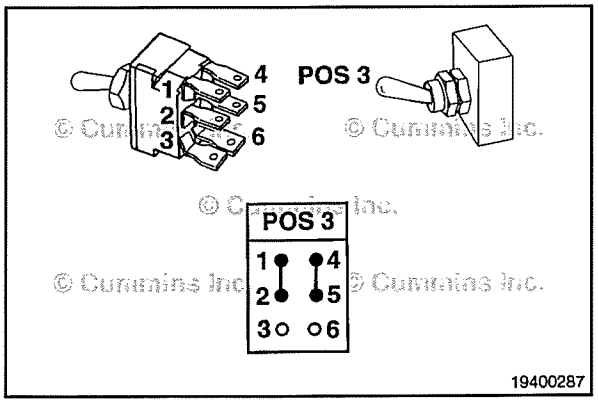
Measure the resistance from switch terminal 1 to terminal 2. The resistance **must** be 10 ohms or less.

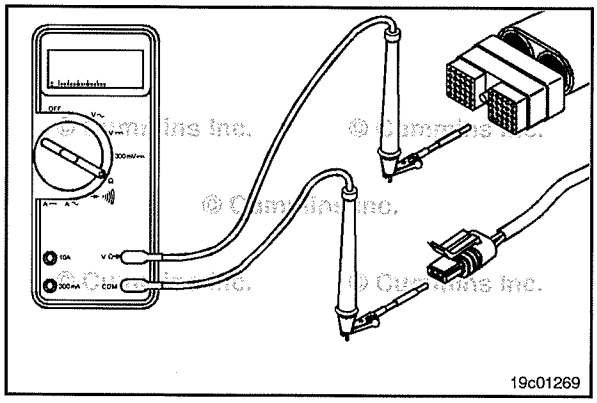
Measure the resistance from switch terminal 4 to terminal 5. The resistance **must** be 10 ohms or less.

Measure the resistance from switch terminal 3 to all other terminals. The resistance **must** be 100K ohms or more.

Measure the resistance from switch terminal 6 to all other terminals. The resistance **must** be 100K ohms or more.

If the multimeter does **not** show the correct values, the switch has malfunctioned. Verify the switch type and terminal location numbers. Refer to the OEM service manual for replacement and to verify the switch type and terminal location.



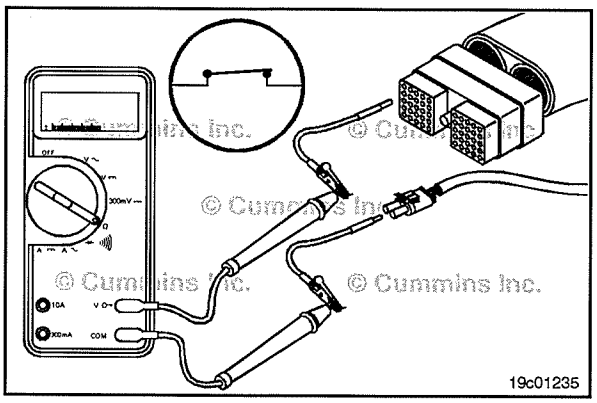


⚠CAUTION⚠
The leads must fit tightly in the connector without expanding the pins in the connector otherwise the connector will be damaged.

Use the following steps for the variable intermediate speed control switch.

Disconnect the OEM harness connector from the ECM. Disconnect the variable intermediate speed control switch from the OEM harness. Set the multimeter to measure resistance.

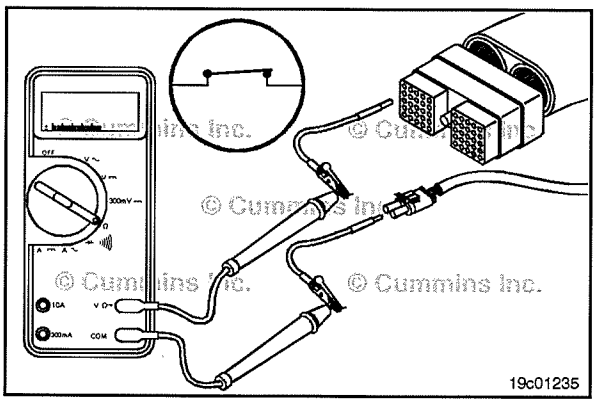
Insert a test lead into the variable intermediate speed control switch signal pin of the OEM harness connector. Connect the alligator clip to a multimeter probe. Insert the second test lead to the signal pin of the intermediate speed control switch and connect the clip to the other multimeter probe. Measure the resistance.



The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the signal wire.

Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.



Repeat the resistance check for the return wire. Measure the resistance from the variable intermediate speed control switch return pin of the OEM harness connector to the variable intermediate speed control switch return pin of the switch.

The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the return wire.

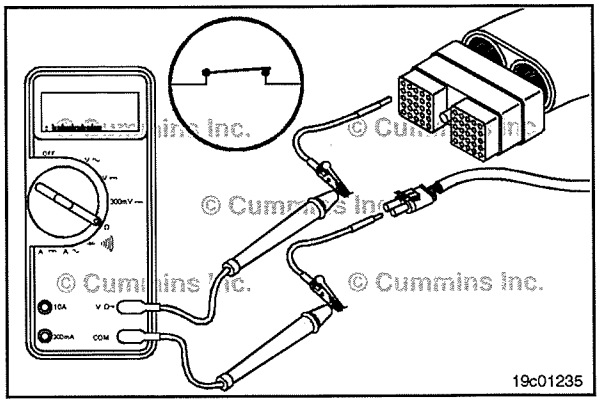
Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.

Repeat the resistance check for the 5 volt supply wire. Measure the resistance from the variable intermediate speed control switch 5 volt supply pin of the OEM harness connector to the variable intermediate speed control switch 5 volt supply pin of the switch.

The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the 5 volt supply wire.

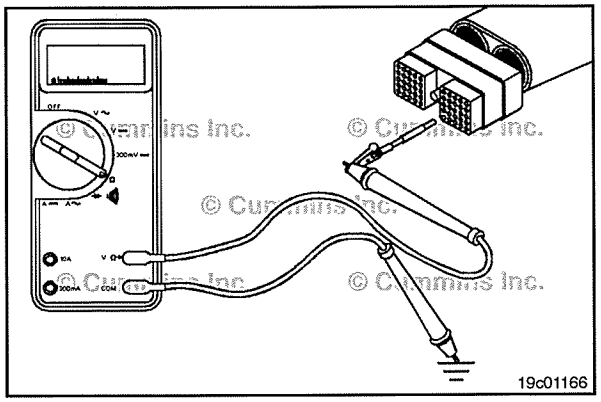
Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.



Check for Short Circuit to Ground

Disconnect the OEM harness connector from the ECM. Disconnect the variable intermediate speed control switch from the OEM harness. Set the multimeter to measure resistance.

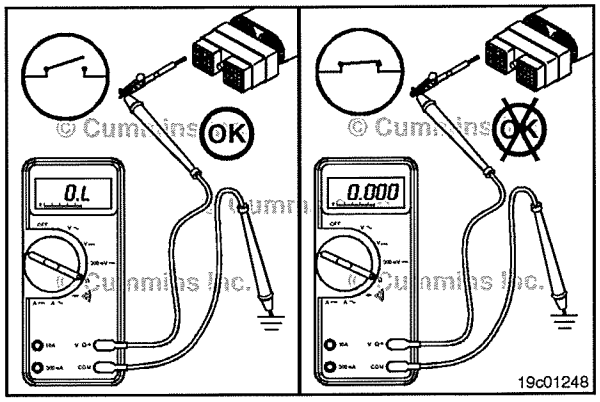
Insert the test lead into the variable intermediate speed control switch signal pin of the OEM harness connector. Touch the other multimeter probe to engine block ground. Measure the resistance.



The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the signal wire.

Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.

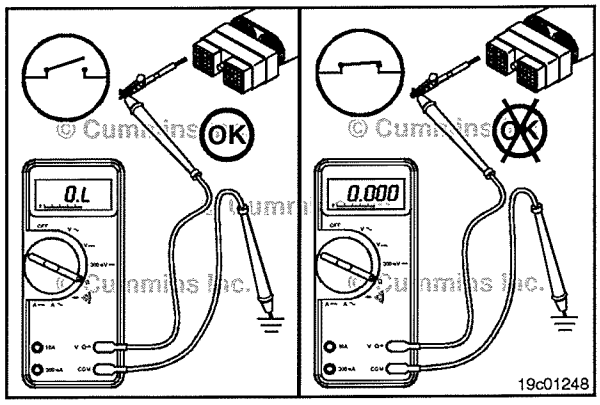


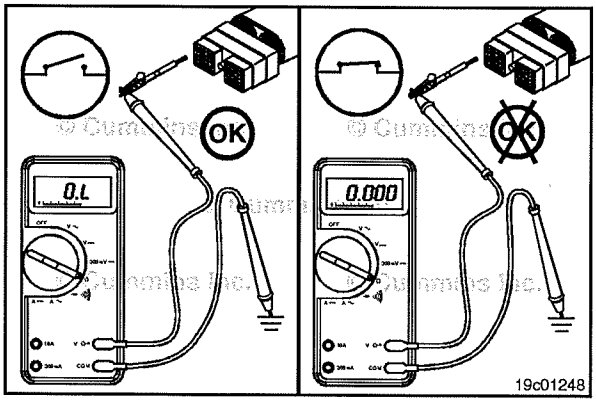
Repeat the short-to-ground check for the return wire. Measure the resistance from the variable intermediate speed control switch return pin of the OEM harness connector to engine block ground.

The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the return wire.

Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.



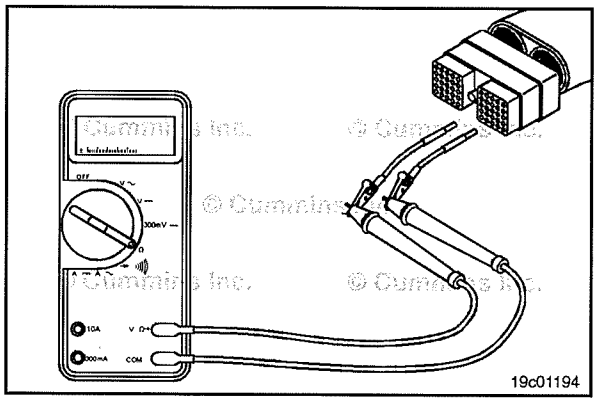


Repeat the short-to-ground check for the 5 volt supply wire. Measure the resistance from the variable intermediate speed control switch 5 volt supply pin of the OEM harness connector to engine block ground.

The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the 5 volt supply wire.

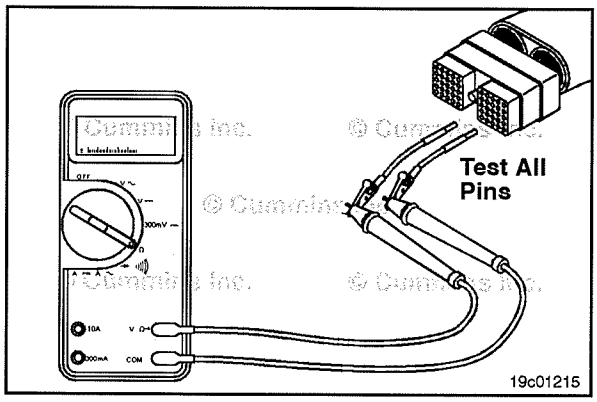
Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.



Check for Short Circuit from Pin to Pin

Disconnect the OEM harness connector from the ECM. Disconnect the variable intermediate speed control switch from the OEM harness. Set the multimeter to measure resistance.

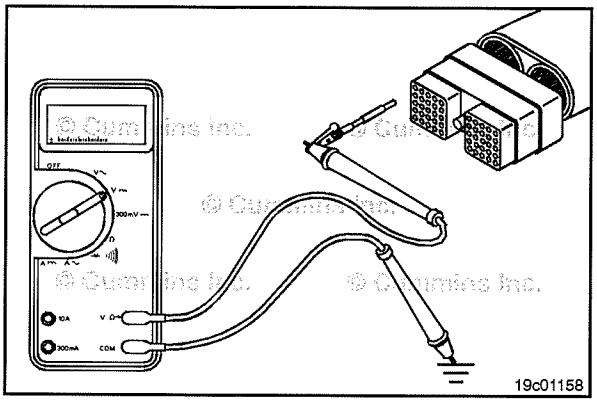
Measure the resistance from the variable intermediate speed control switch signal pin in the OEM harness connector to all other pins in the connector.



The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit between the signal wire and any other pin that measured a closed circuit.

Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.



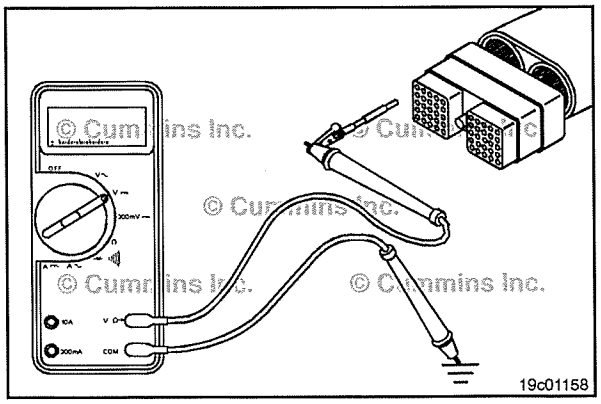
Check for Short Circuit to External Voltage Source

Disconnect the OEM harness connector from the ECM. Disconnect the variable intermediate speed control switch from the OEM harness. Set the multimeter to measure VDC. Turn the vehicle keyswitch to the ON position.

Insert the test lead connected to the positive (+) multimeter probe into the variable intermediate speed control switch signal pin of the OEM harness connector. Touch the negative (-) multimeter probe to engine block ground and measure the voltage.

If there is voltage present, there is a short circuit from the signal wire to an external voltage source.

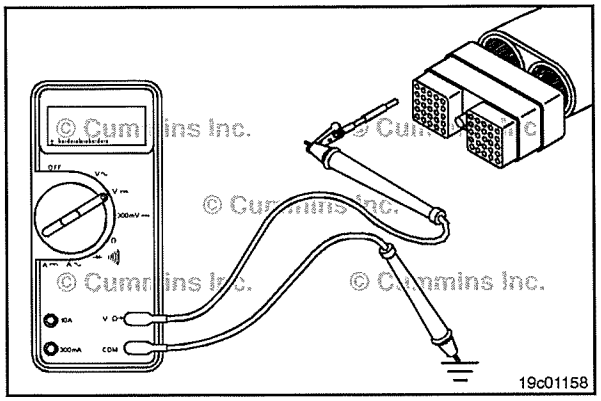
Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.



Repeat the short to external voltage source check for the return wire. Measure the voltage from the variable intermediate speed control switch return pin of the OEM harness connector to engine block ground.

If there is voltage present, there is a short circuit from the return wire to an external voltage source.

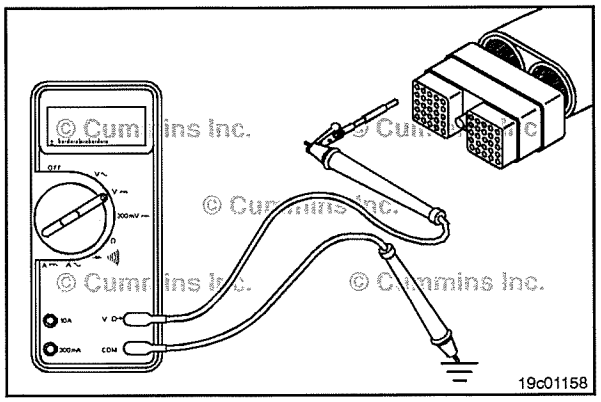
Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.



Repeat the short to external voltage source check for the 5 volt supply wire. Measure the voltage from the variable intermediate speed control switch 5 volt supply pin of the OEM harness connector to engine block ground.

The multimeter **must** show a voltage of less than 5.5 VDC. If the voltage is greater than 5.5 VDC, there is a short circuit from the 5 volt supply wire to an external voltage source.

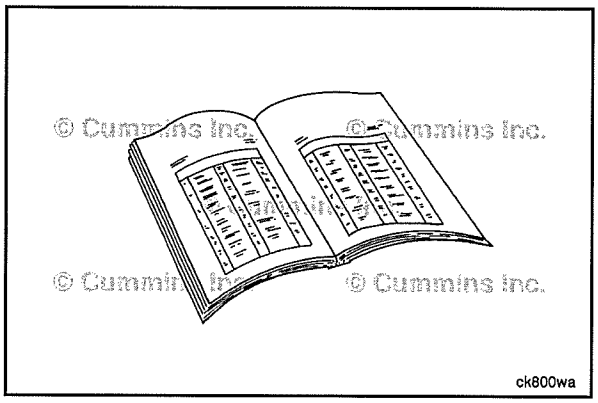
Repair or replace the OEM harness. Refer to Procedure 019-071 in Section 19.



Rail Fuel Pressure Sensor (019-115)

General Information

The rail fuel pressure sensor is located on the fuel rail. Use the following procedure for a detailed component location view. Refer to Procedure 100-002 in Section E.



Preparatory Steps

⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain fuel under pressure sufficient to penetrate the skin and cause serious personal injury. Do not loosen any fittings while the engine is operating. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump to rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

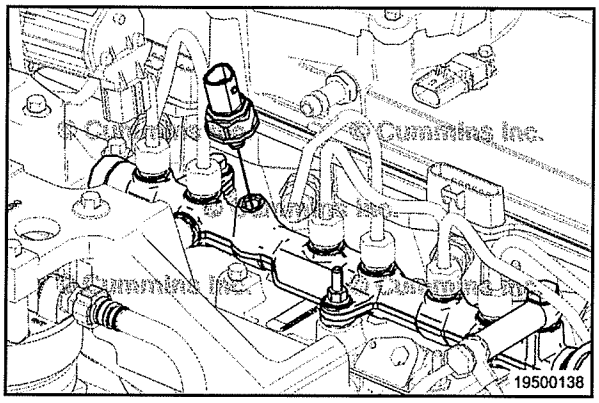
Pressure relief:

NOTE: Machined slots in these fittings direct the fuel spray toward the engine block.

- Before servicing the fuel system, loosen the pump-to-rail lines at the rail to vent the pressure. Keep hands clear of the lines when loosening.
- Tighten the fuel rail nut.

Torque Value: 40 N•m [30 in-lb]

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area around the rail fuel pressure sensor.



Remove

Disconnect the rail fuel pressure sensor connector from the engine harness.

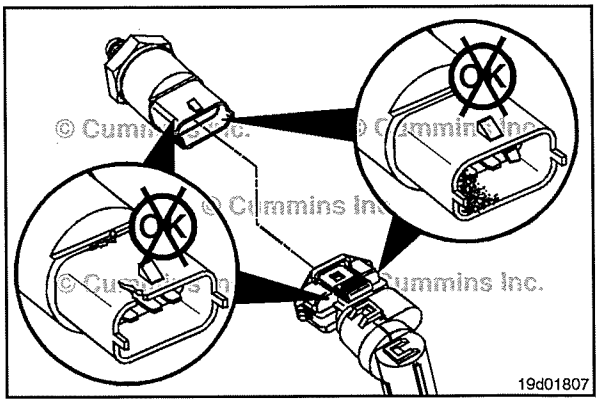
Remove the rail fuel pressure sensor.

Clean and Inspect for Reuse

Inspect the engine harness connector and the rail fuel pressure sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins.

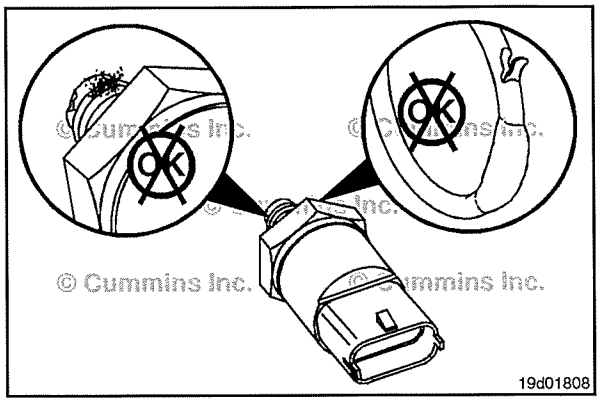
Repair or replace the engine harness connector as needed.



Inspect the rail fuel pressure sensor for the following:

- Damaged seal surface in the rail
- Damaged seal surface on the sensor
- Thread damage.

Replace the rail fuel pressure sensor if damage is found.

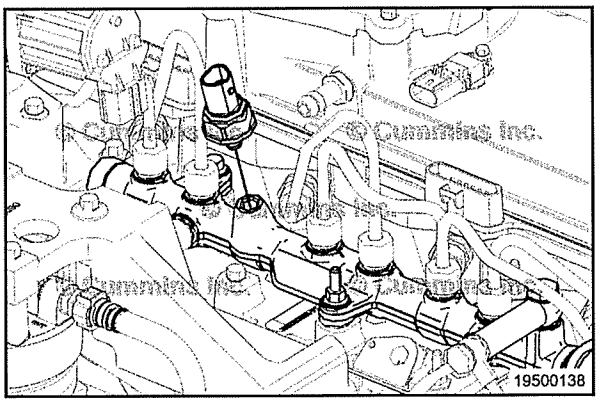


Install

Install the rail fuel pressure sensor.

Torque Value: 70 N•m [52 ft-lb]

Connect the rail fuel pressure sensor to the engine harness.

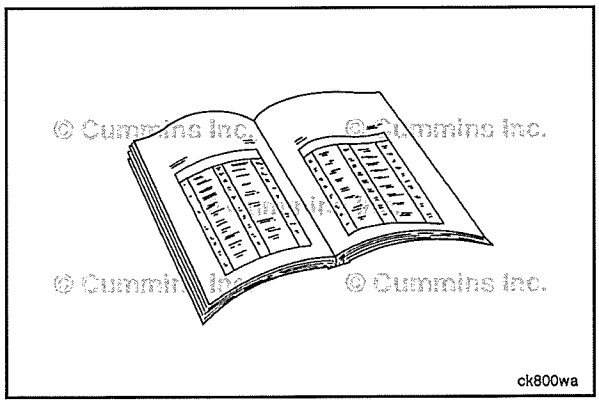


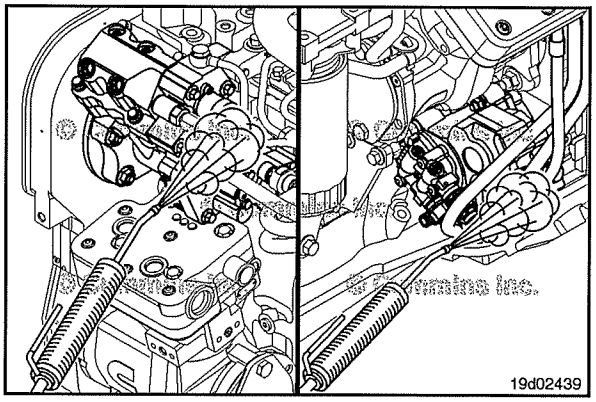
Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM serivce manual.
- Operate the engine and check for leaks.





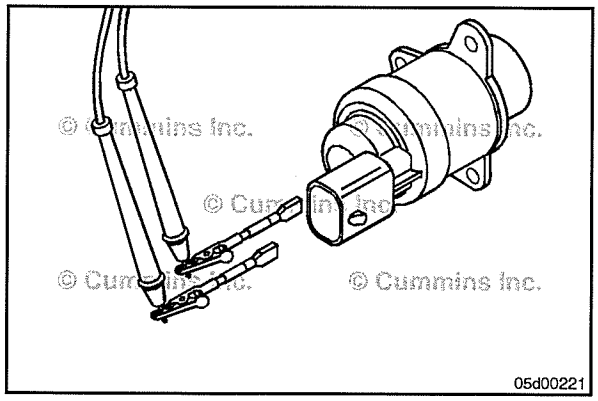
Fuel Pump Actuator (019-117)

Preparatory Steps

⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

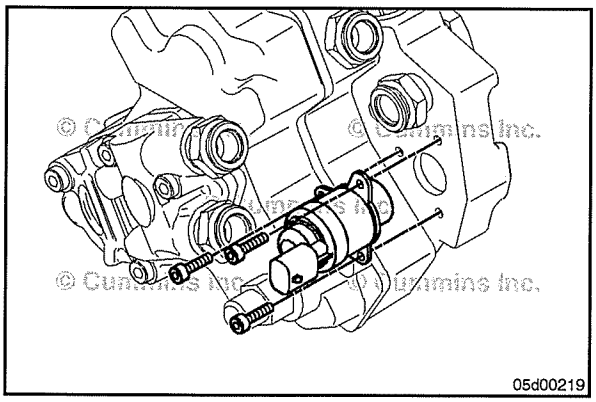
- Steam clean the fuel pump and the area around the fuel pump.
- Dry with compressed air.
- Disconnect the fuel pump actuator harness connector.



Initial Check

Measure the fuel pump actuator resistance.

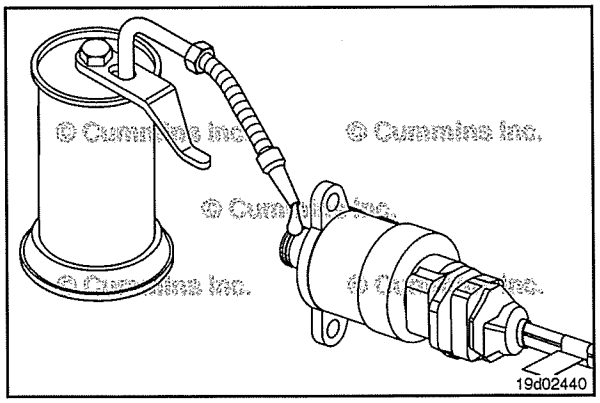
- Minimum Resistance: 1 ohm
- Maximum Resistance: 5 ohms



Remove

Remove the capscrews and fuel pump actuator.

Install



⚠CAUTION⚠
Do not pause more than 2 minutes between torque steps 1 and 2. This can cause the capscrews not to maintain their torque value. Leakage or engine damage can result.

Lubricate the o-ring with clean oil before installation.

Fully press the fuel pump actuator into the fuel pump housing, use a slight twisting motion. Do this before starting the capscrews.

NOTE: Fully installing the fuel pump actuator prior to starting the capscrews reduces the risk of side loading the plunger and reduced component life.

NOTE: Be sure the fuel pump actuator flange is flush with the mounting surface on the fuel pump before tightening the capscrews.

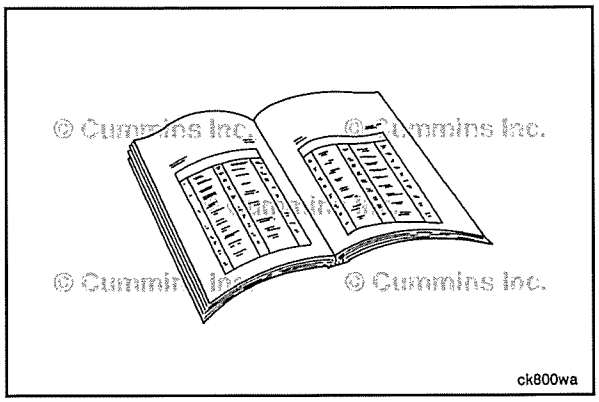
Install and tighten the capscrews.

Torque Value:

Step 1	3 N•m	[27 in-lb]
Step 2	6.5 N•m	[58 in-lb]

Finishing Steps

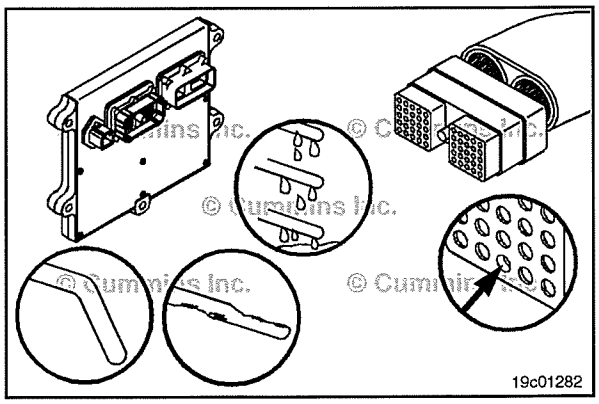
- Connect the fuel pump actuator harness connector.
- Operate the engine and check for leaks.

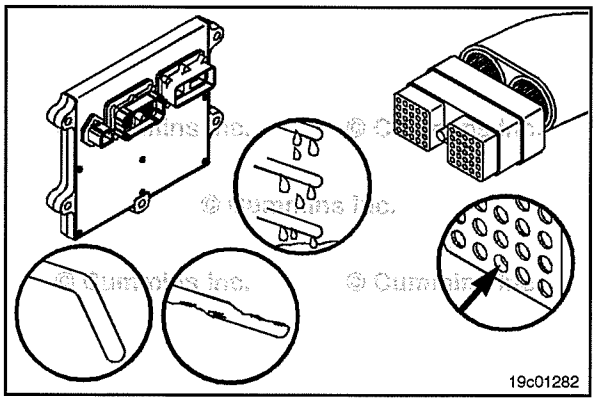


Water in Fuel Sensor (019-127)

General Information

The water-in-fuel sensor separator is located at the base of the fuel filter. The water-in-fuel sensor sends a signal to the engine control module (ECM) when a set volume of water has accumulated in the fuel filter. The water-in-fuel circuit contains two wires, the water-in-fuel return wire and the water-in-fuel signal wire.





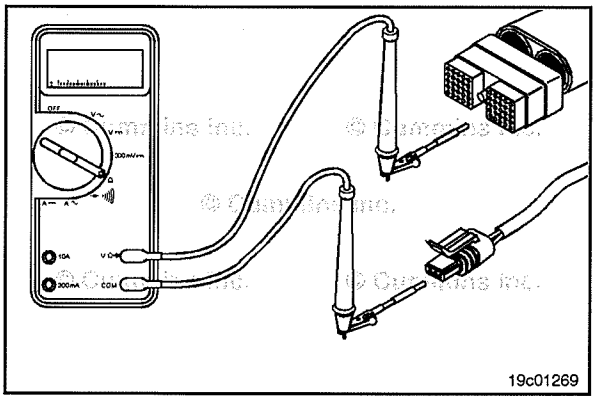
Resistance Check

NOTE: The water-in-fuel sensor is the water-in-fuel signal wire and the water-in-fuel return wire in the engine harness connector.

Disconnect the engine harness from the ECM.

Check for damaged pins.

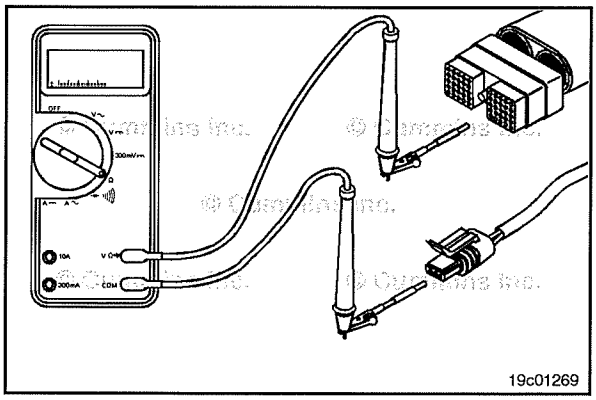
Disconnect the water-in-fuel sensor from the engine harness.



⚠CAUTION⚠
To reduce the possibility of pin and connector damage, use test lead, Part Number 3822758, when taking a measurement.

Return Wire Resistance - Checking

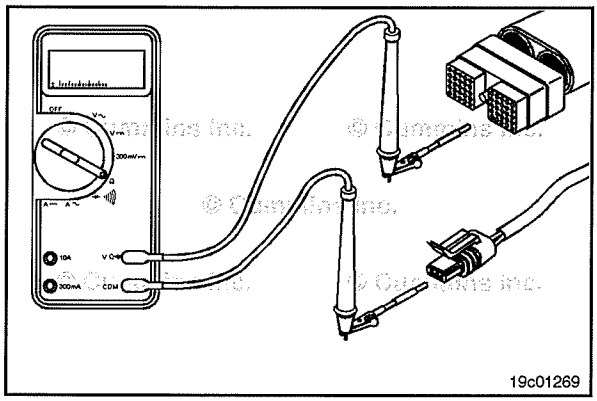
Insert the test lead into sensor return pin (common return) of the engine harness connector. Connect the alligator clip to the multimeter probe. Touch the other multimeter probe to water-in-fuel return pin of the water-in-fuel sensor, harness side.



Measure the resistance.

The multimeter **must** show a closed circuit (10 ohms or less).

If more than 10 ohms are measured, there is an open circuit in the return wire. Repair the wire, or replace the engine harness.



Signal Wire Resistance - Checking

Insert the test lead into the water-in-fuel signal pin of the engine harness connector. Connect the alligator clip to the multimeter probe. Touch the other multimeter probe to the signal wire pin of the water-in-fuel sensor, harness side.

Measure the resistance.

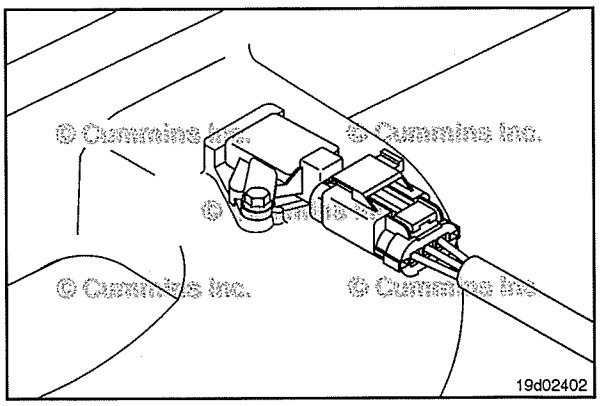
The multimeter **must** show a closed circuit (10 ohms or less).

If more than 10 ohms are measured, there is an open circuit in the signal supply wire. Repair the wire, or replace the engine harness.

Ambient Air Temperature Sensor (019-134)

General Information

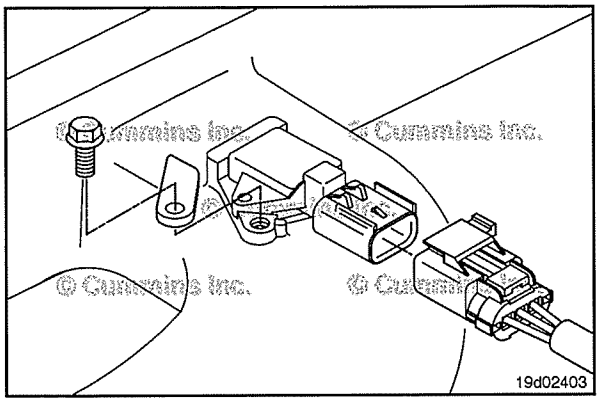
The ambient air temperature sensor and the barometric pressure sensors are combined into a single sensor. The sensor is located in the air intake connection between the air cleaner and the turbocharger compressor inlet.



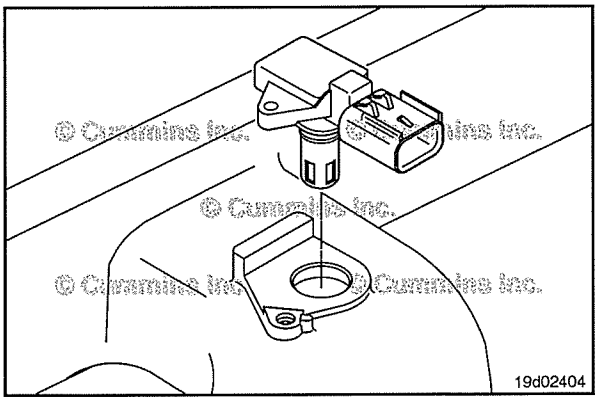
Remove

Lift up on the locking tab and pull the electrical connectors apart.

Remove the capscrew.



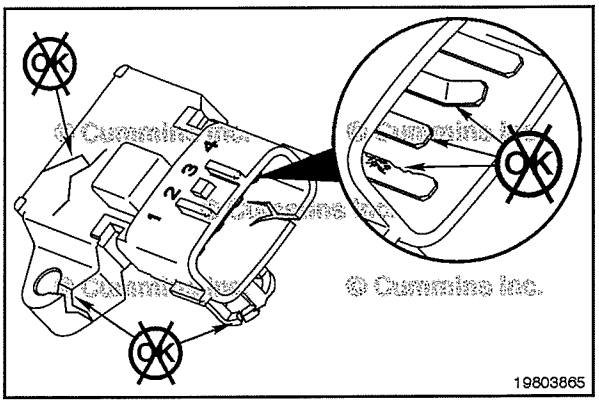
Remove the sensor from the engine by pulling straight up on the sensor. Be careful **not** to damage the o-ring seal when removing the sensor.

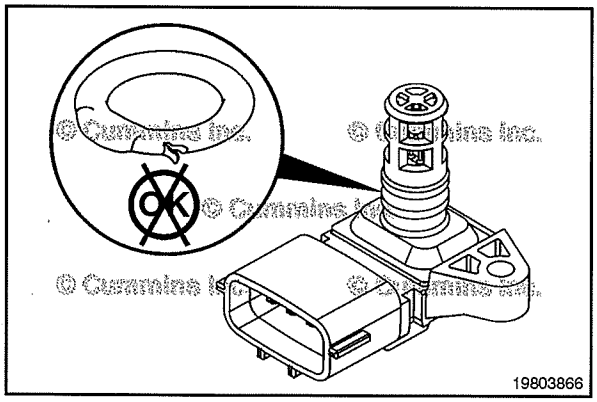


Inspect for Reuse

Inspect the engine harness connector and the ambient air temperature/barometric pressure sensor for the following:

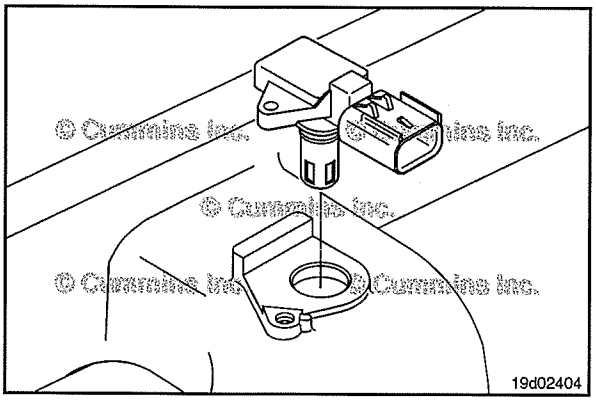
- cracked or broken shell
- missing or damaged connector seals
- dirt, debris, or moisture in or on the connector pins
- corroded, bent, broken, pushed back, or expanded pins.





Inspect the ambient air temperature/barometric pressure sensor for the following:

- swollen o-ring
- nicks or cuts in or on the o-ring.



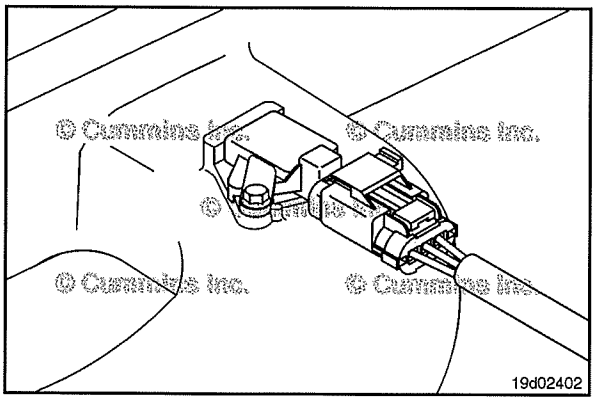
Install

Make sure the new sensor has an o-ring.

Install the new sensor into the engine.

Tighten the capscrew.

Torque Value: 6 N•m [53 in-lb]



Push the connectors together until they lock.

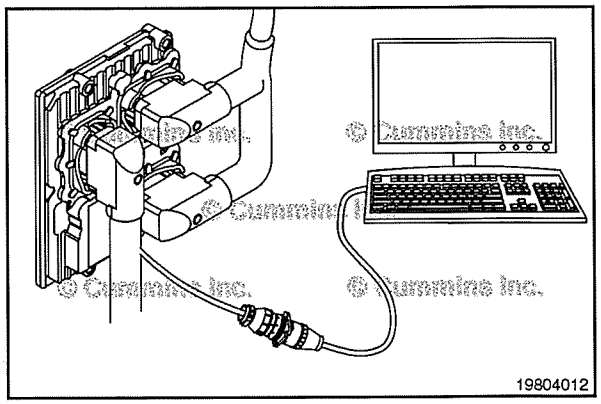
An audible click will be heard as the connector locks in place.

Intake Manifold Pressure/Temperature Sensor (019-159)

General Information

The intake manifold temperature sensor and intake manifold pressure sensors are combined into a single sensor. The sensor is located in the intake manifold. Use the following procedures for a detailed component location view. Refer to Procedure 100-002 in Section E.

Initial Check



Use an electronic service tool to monitor the value of the intake manifold pressure/temperature sensor with the key on and the engine not running.

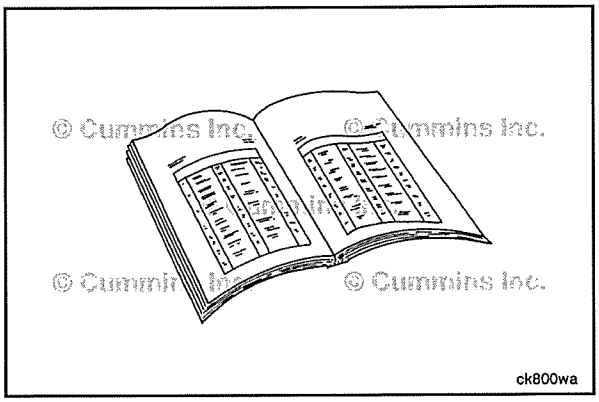
The value of the intake manifold temperature sensor should be checked when the engine is cold, and should read within 5.5°C [10°F] of the local ambient air temperature.

The value of the intake manifold pressure should read 0 kPa +/- 15 kPa [5 in Hg].

If either value is out of specification, first verify the correct intake manifold pressure/temperature sensor is installed on the engine. Compare the part number of the intake manifold pressure/temperature sensor to the part number listed in the parts catalog in QuickServe™ Online for the ESN.

If the correct part is installed, and either value is still out of specification, replace the intake manifold pressure/ temperature sensor.

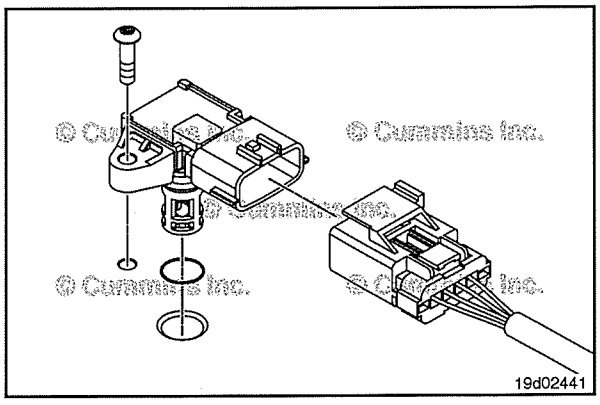
Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area around the intake manifold pressure/ temperature sensor.

Remove

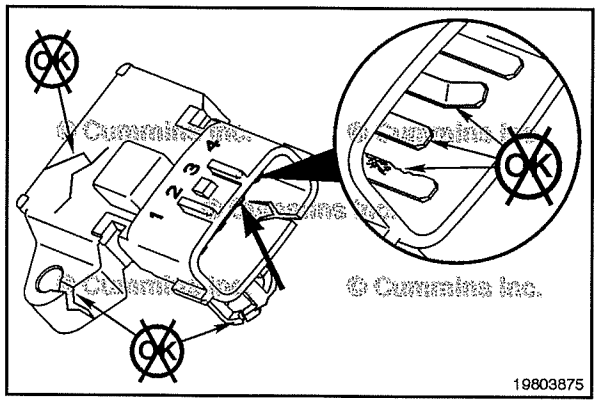


Disconnect the sensor connector from the engine harness.

Remove the mounting capscrew.

Remove the sensor from the engine by pulling straight up on the sensor.

Be careful **not** to damage the o-ring seal when removing the sensor. Do **not** pry the sensor, as damage to the plastic cage can occur.

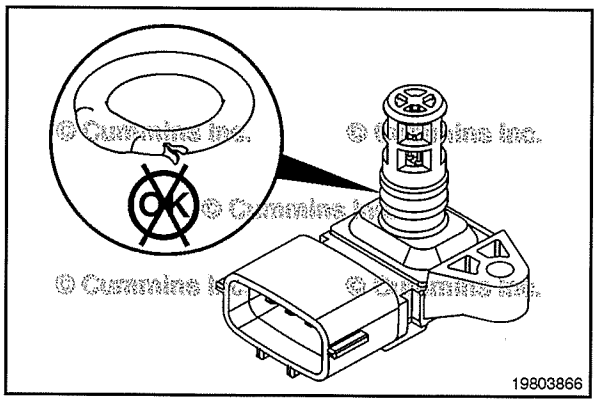


Clean and Inspect for Reuse

Inspect the engine harness connector and the intake manifold pressure/temperature sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.

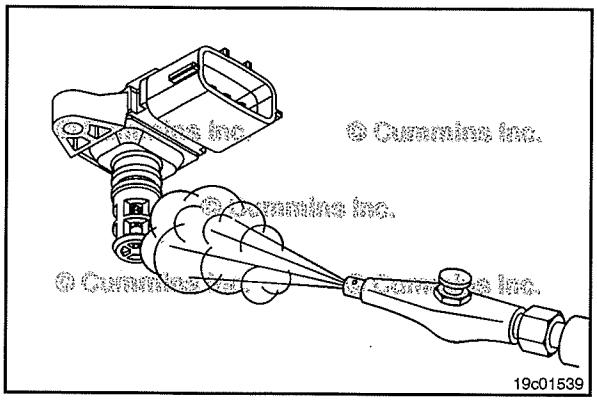
Repair or replace parts as necessary.



Inspect the intake manifold pressure/temperature sensor o-ring for the following:

- Swollen o-ring
- Nicks or cuts in or on the o-ring.

Replace the o-ring if any damage is found.

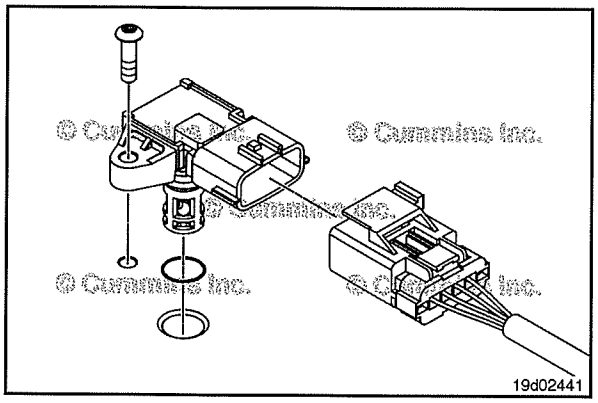


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Inspect the tip of the sensor for soot and carbon buildup.

Use compressed air to remove the soot from the sensor, if necessary.

Do **not** replace the sensor for soot in the sensor.



Install

Lubricate the o-ring with clean engine oil before installation.

Install the intake manifold pressure/temperature sensor by pressing firmly on the top of the sensor until the o-ring is fully seated.

Install and tighten the mounting capscrew.

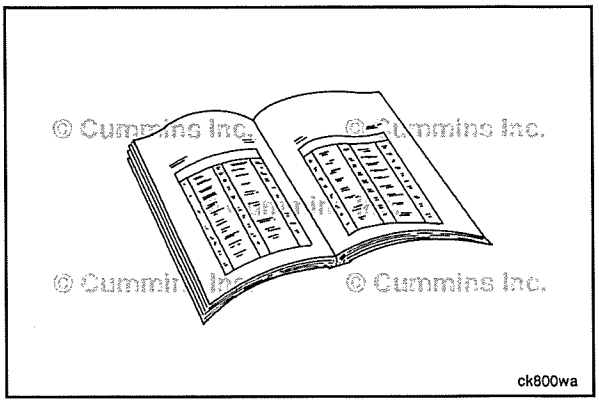
Torque Value: 7 N•m [62 in-lb]

Connect the engine harness to the intake manifold pressure/temperature sensor.

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Data Link Circuit, SAE J1939 (019-165)

General Information

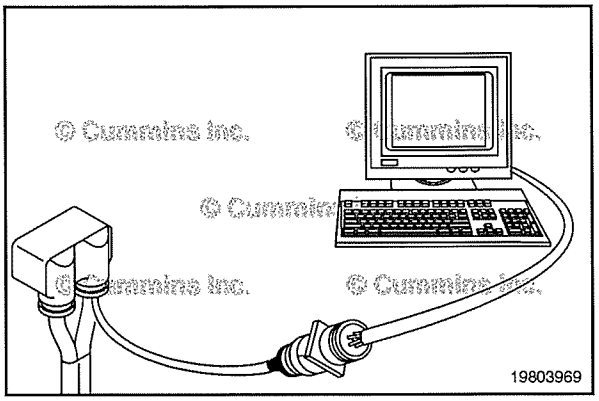
The OEM J1939 datalink circuit is located in the OEM wiring harness.

The purpose of this datalink is to allow communication with vehicle control-operated systems such as transmission controllers, traction control system, etc.

The traditional OEM J1939 datalink circuit is described as a shielded twisted pair and includes the wires connected to the J1939 datalink positive (+) pin, the J1939 datalink negative (-) pin, and the J1939 (shield) pin in the OEM harness.

On newer vehicles and equipment, OEM's can utilize an OEM J1939 datalink circuit that is described as an unshielded twisted pair (UTP). The unshielded twisted pair (UTP) J1939 datalink does **not** include the J1939 (shield) pin and **only** includes the J1939 datalink positive (+) pin and the J1939 datalink negative (-) pin in the OEM harness.

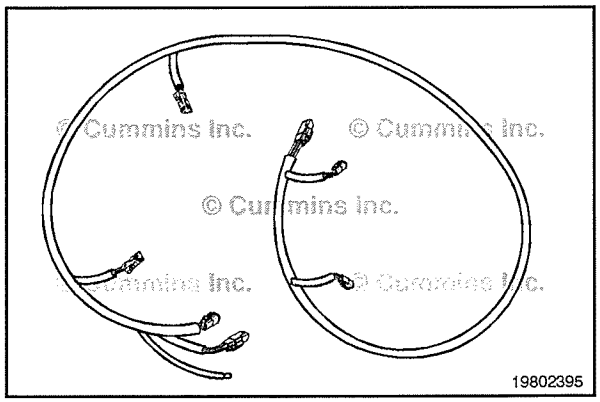
With the keyswitch in the ON position, public datalink messages will be broadcast on the OEM J1939 datalink. The broadcast will stop when the keyswitch is turned to the OFF position.

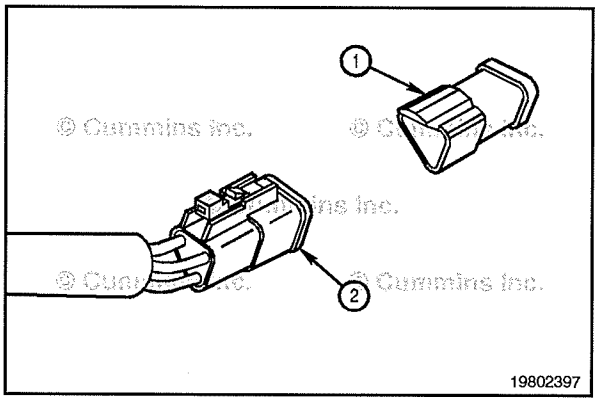


The Society of Automotive Engineers (SAE) J1939 has strict guidelines that **must** be followed for successful communication. Understanding some fundamentals about SAE J1939 will help make sure these guidelines are followed.

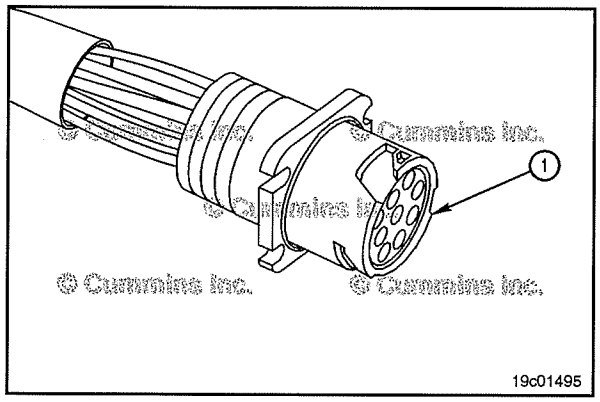
The main component of an SAE J1939 system is a backbone harness. The harness can be up to 40 meters [131 feet] in length. The backbone harness is terminated at each end with a 120 ohm resistor.

A maximum of thirty different devices can be attached to the SAE J1939 backbone at once. Each device, such as the datalink adapter, is connected to the backbone through a stub, which can be up to 1 meter [3.3 ft] in length. The stub connector is a 3-pin plug.





The terminating resistor caps (1) **must** be in place on the OEM backbone harness plugs (2) to maintain proper communication. Each resistor is 120 ohms and can be located in a removable cap.



Some OEMs will choose to provide a complete SAE J1939 backbone harness. If this is supplied, connection to the INSITE™ electronic service tool is accomplished by a 9-pin datalink connector (1), Part Number 3162848.

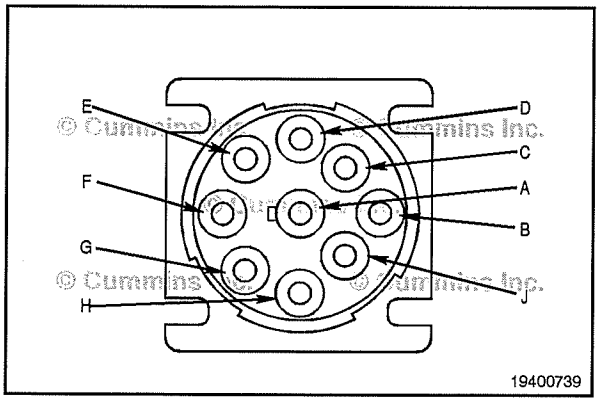
NOTE: Some OEM's place a 9-pin connector in the cab, but do **not** connect all of the pins to support J1939 protocol.

To check for the OEM J1939 backbone, turn the keyswitch to the OFF position. Measure the resistance from the SAE J1939 datalink positive (+) pin to the SAE J1939 datalink negative (-) pin of the 9-pin Deutsch™ connector.

The multimeter **must** read between 50 and 65 ohms for the INSITE™ electronic service tool to be able to establish communication.

If the OEM does **not** supply the J1939 backbone harness to the 9-pin connector, the **only** way to establish J1939 communication is through either the bench communication setup or for the Engine Control Module through the engine communication setup. Refer to Procedure 022-999.

NOTE: The typical SAE J1939 connector will be a 9-pin connector.



Pin	Signal
A	Ground
B	Unswitched Battery
C	J1939 datalink (+)
D	J1939 datalink (-)
E	J1939 datalink (shield) (if available)
F	J1708 datalink (+)
G	J1708 datalink (-)
H	Open
J	Open

Resistance Check

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Turn the keyswitch to the OFF position.

Disconnect the batteries.

Disconnect the OEM harness connector from the ECU.

Insert a test lead into the SAE J1939 datalink positive (+) pin of the OEM harness connector, and connect it to the multimeter probe. Insert the other test lead into the SAE J1939 datalink positive (+) pin of the 9-pin Deutsch™ connector, and connect it to the multimeter.

Measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual for the procedures.

Insert the multimeter lead into the SAE J1939 datalink negative (-) of the OEM harness connector. Touch the other lead to the SAE J1939 datalink negative (-) pin of the 9-pin Deutsch™ connector. Measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less)

If the circuit is **not** closed, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual for the procedures.

If the values are correct, the circuit **must** still be checked for a short circuit to ground and a short circuit from pin to pin.

Remove the lead from the SAE J1939 datalink negative (-) pin of the OEM harness connector and insert it into the SAE J1939 datalink (shield) pin, if the shield pin is available.

If the J1939 datalink circuit is an unshielded twisted pair (UTP), the shield pin will **not** be provided.

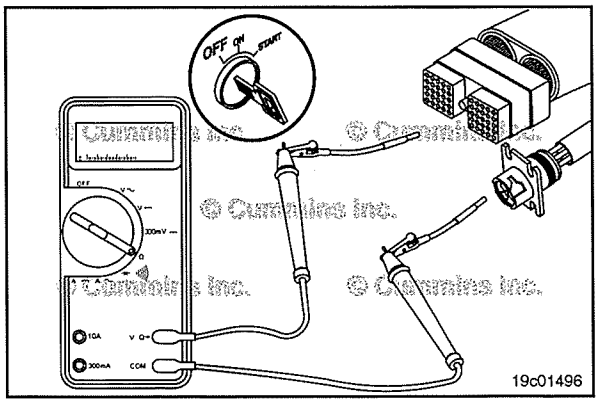
If the shield pin is provided, measure the resistance from the SAE J1939 datalink (shield) pin of the OEM harness connector to the SAE J1939 datalink (shield) pin of the 9-pin Deutsch™ connector.

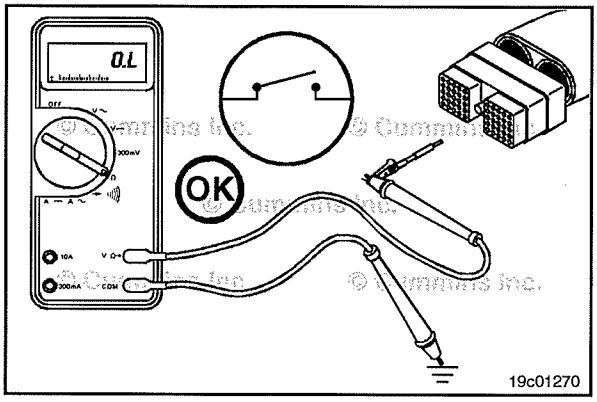
The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual for the procedures.

If the (shield) pin is provided, measure the resistance from the SAE J1939 datalink (shield) pin of the 9-pin Deutsch™ connector to the engine block or chassis ground. The SAE J1939 datalink shield **must** be grounded to the vehicle battery ground. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, refer to the OEM troubleshooting and repair manual for repair instruction.

If more than 10 ohms are measured in any of these steps, there can be an open circuit in the SAE J1939 datalink positive (+) pin, the SAE J1939 datalink negative (-) pin, or the SAE J1939 (shield) pin, or the polarity is **not** correct. There can also be an open circuit from the datalink (shield) pin to vehicle battery ground.

If the values are correct, the SAE J1939 datalink positive (+) pin and the datalink negative (-) pin **must** still be checked for a short circuit to ground. The SAE J1939 datalink positive (+) pin, the datalink negative (-) pin, and the datalink (shield) pin **must** still be checked for a short circuit from pin to pin.





Check for Short Circuit to Ground

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

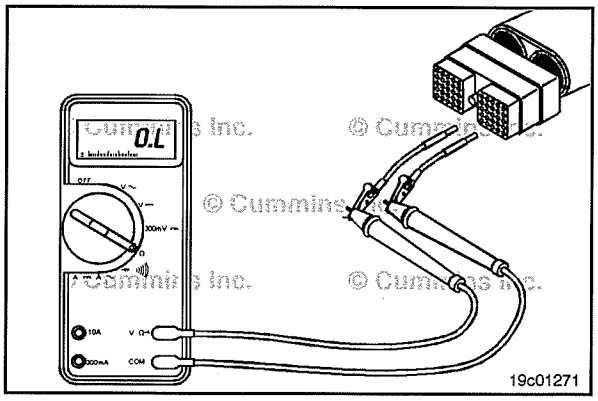
Disconnect the OEM harness connector from the ECU. Insert a test lead into the SAE J1939 datalink positive (+) pin of the OEM harness connector and connect it to a multimeter probe. Touch the other multimeter probe to the engine block or chassis ground.

Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

Remove the test lead from the SAE J1939 datalink positive (+) pin and insert it into the SAE J1939 datalink negative (-) pin. Measure the resistance from the SAE J1939 datalink negative (-) pin of the OEM harness connector to the engine block or chassis ground. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.



Check for Short Circuit from Pin to Pin

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECU.

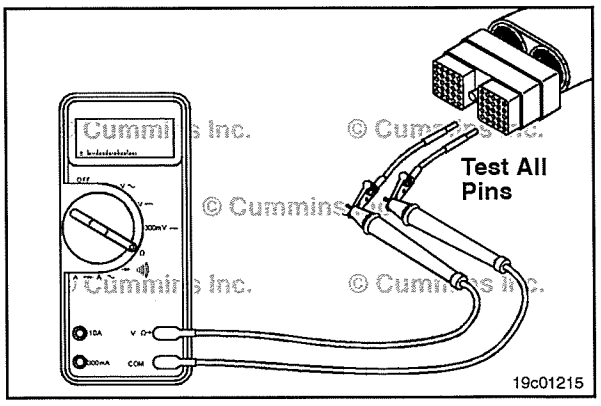
Insert a test lead into the SAE J1939 datalink positive (+) pin of the OEM harness connector and connect it to the multimeter probe. Insert the other test lead into another pin in the connector of the OEM harness and connect it to the other multimeter probe.

Measure the resistance from the SAE J1939 datalink positive (+) pin to the first pin in the connector. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

Measure the resistance from the SAE J1939 datalink positive (+) pin of the OEM harness connector to all other pins in the connector, one at a time. The multimeter **must** show an open circuit (100k ohms or more) at all pins, except the J1939 datalink negative (-).

If the circuit is **not** open, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.



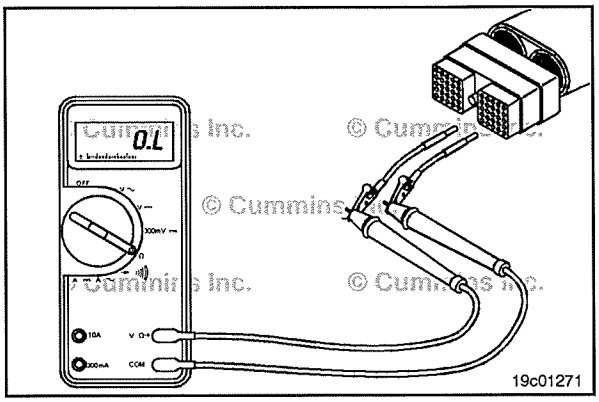
Remove the test lead from the J1939 datalink positive (+) pin and insert it into the J1939 datalink (shield) pin of the OEM harness connector, if the shield pin is available

NOTE: If the J1939 datalink circuit is an unshielded twisted pair (UTP), the (shield) pin will **not** be provided. If the shield pin is **not** provided, the datalink negative (-) pin **must** still be checked for a short circuit to the other pins.

Insert the other test lead into another pin in the connector. Measure the resistance.

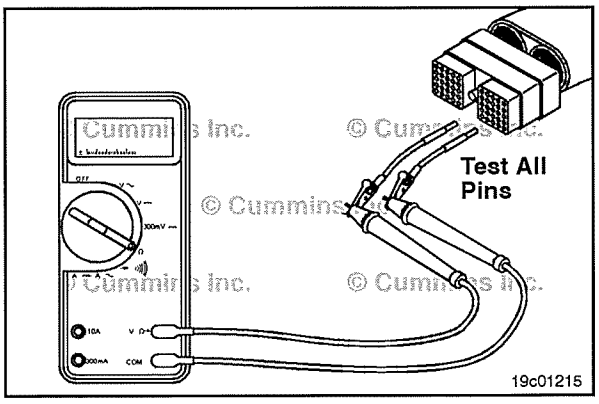
The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.



Measure the resistance from the SAE J1939 datalink (shield) pin, if available, to all other pins in the connector, one at a time. The multimeter **must** show an open circuit (100k ohms or more).

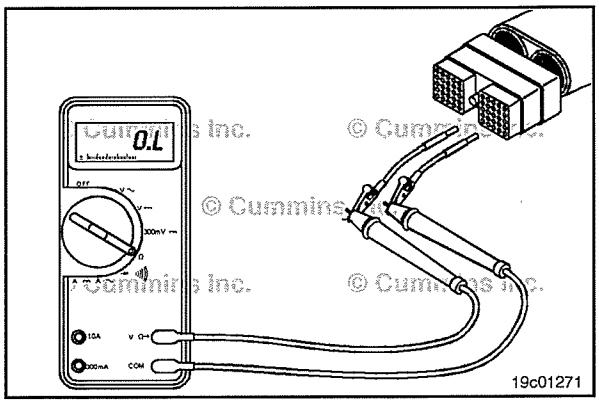
If the circuit is **not** open, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

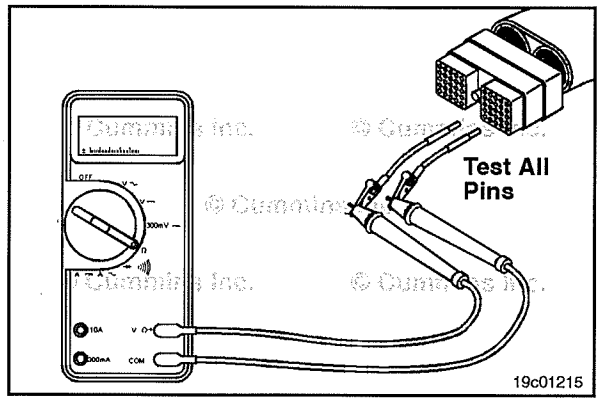


Remove the test lead from the SAE J1939 datalink (shield) pin and insert it into the SAE J1939 datalink negative (-) pin of the OEM harness connector. Insert the other test lead into another pin in the connector. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

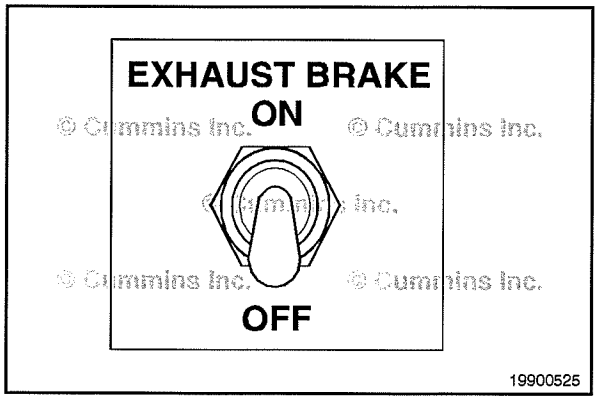




Measure the resistance from the SAE J1939 datalink negative (-) pin of the OEM harness connector to all other pins in the connector. The multimeter **must** show an open circuit (100k ohms or more) at all pins, except the J1939 datalink positive (+) pin.

If the circuit is **not** open, repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

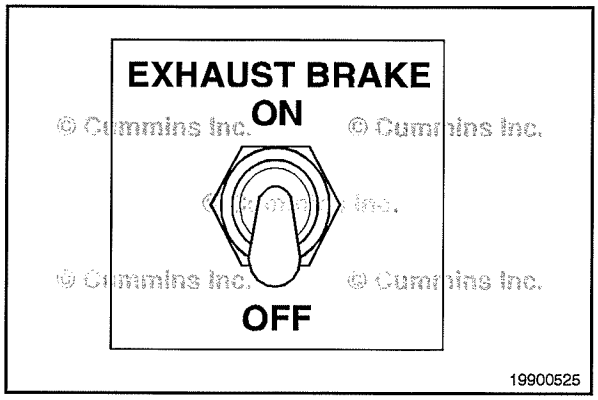
Connect all the components after the repair is complete.



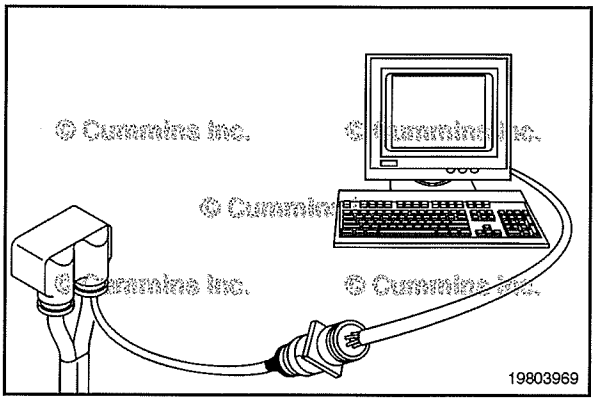
Exhaust Brake ON/OFF Switch (019-193)

General Information

The exhaust brake on/off switch circuit signals the system that the operator is requesting the exhaust brake system to be activated.



After the ECM receives the signal from the exhaust brake on/off switch, the ECM will supply 12 VDC to the exhaust brake signal pin in the engine harness, provided the engine speed is **not** below 1000 rpm and the driver is **not** in cruise control or depressing the accelerator or clutch pedals.



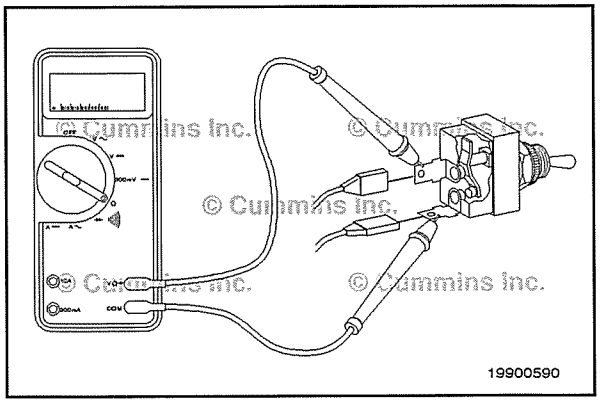
Resistance Check

If INSITE™ electronic service tool is available, monitor the exhaust brake select switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Label the wires with the location on the switch or the wire number. Remove the electrical connectors from the switch.

Set the multimeter to measure resistance.

Touch one multimeter probe to the center terminal of the switch. Touch the other multimeter probe to the bottom terminal of the switch.

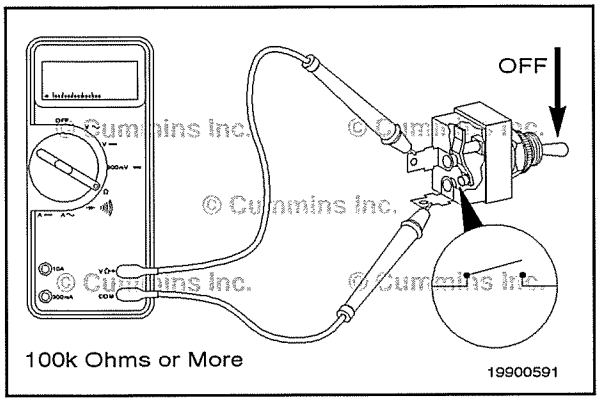


Set the switch to the OFF position.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, the switch has failed. Replace the switch.

Refer to the OEM repair manual for replacement instructions.

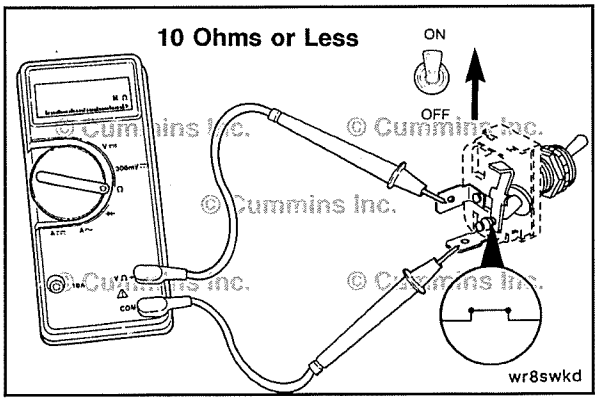


Set the switch to the ON position.

The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, the switch has failed. Replace the switch.

Refer to the OEM troubleshooting and repair manual for replacement instructions.



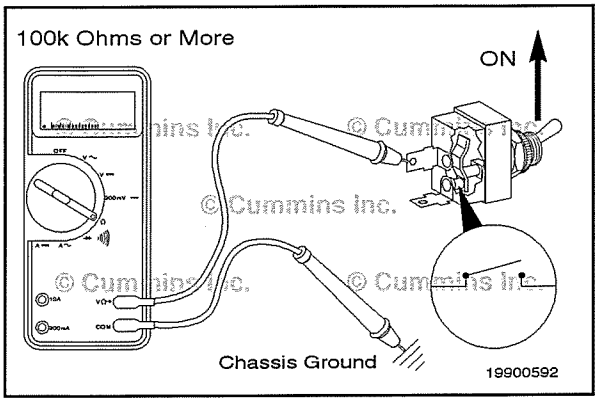
Check for Short Circuit to Ground

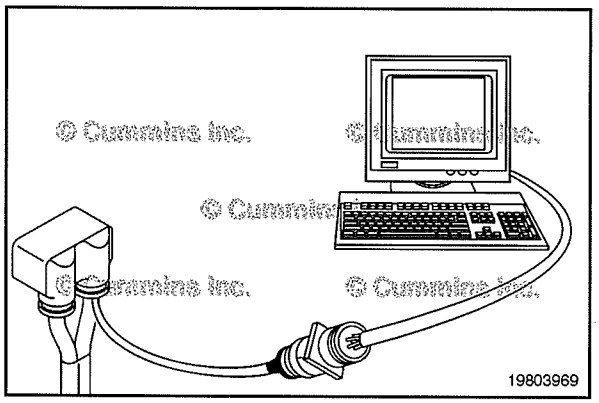
Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the ON position, and measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, the switch has failed. Replace the switch. Refer to the OEM troubleshooting and repair manual for replacement instructions.

If the switch passes all of the previous checks, the circuit **must** be checked for open circuits, short circuits to ground, short circuits from pin to pin, and short circuits to an external voltage source.





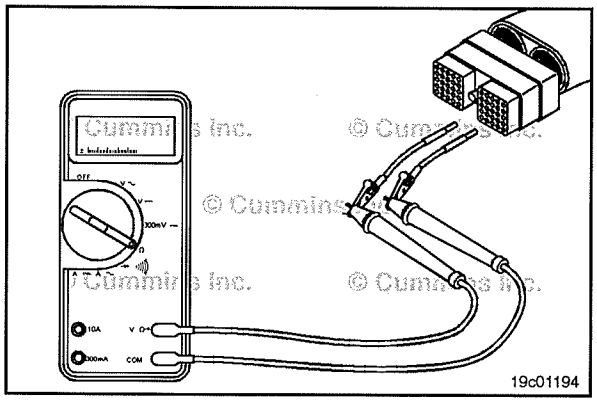
Exhaust Brake ON/OFF Switch Circuit (019-194)

Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the exhaust brake switch circuit for proper operation.

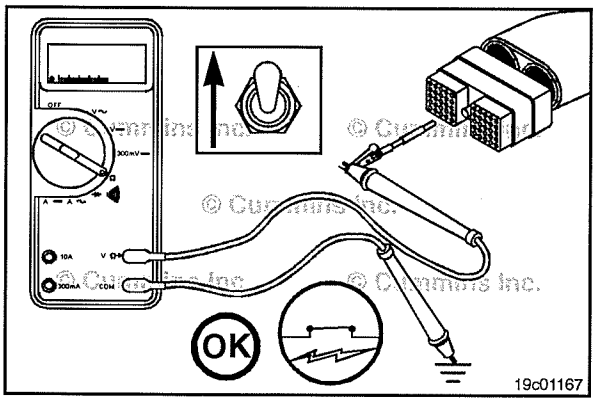
If **not**, follow the troubleshooting procedures in this section.



Disconnect the OEM harness from the ECM connector.

Insert the appropriate test lead into exhaust brake ON/OFF switch input pin of the OEM harness connector.

Insert the other appropriate test lead into switch return pin of the connector.

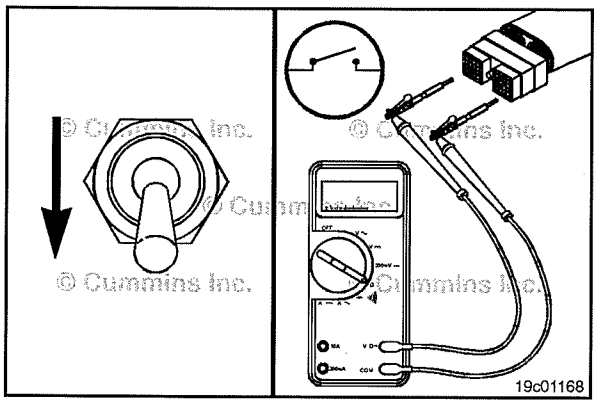


Set the exhaust brake switch to the ON position.

The multimeter **must** show a closed circuit (10 ohms or less).

Set the exhaust brake switch to the OFF position.

The multimeter **must** show an open circuit (100k ohms or more).



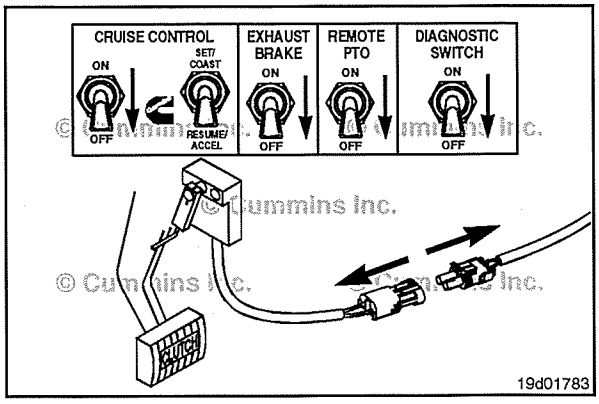
If the resistance values are **not** correct, make sure exhaust brake ON/OFF switch input pin and the battery positive (+) bus to switch return pin are properly installed on the switch.

If both wires are correctly installed, inspect exhaust brake ON/OFF switch input pin and the battery positive (+) bus to switch return pin for open circuits to ground and short circuits to other pins, provided the switch has been previously checked.

If the resistance values are correct in the previous checks, exhaust brake ON/OFF switch input pin and switch return pin **must** still be checked for short circuits to ground and short circuits from pin-to-pin.

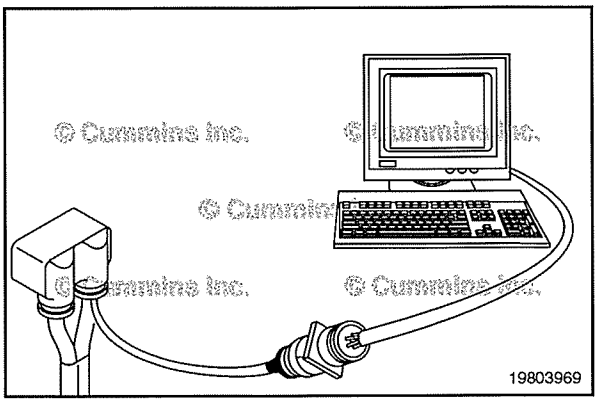
Check for Short Circuit to Ground

To isolate the exhaust brake circuit when checking for an electrical short, turn all cab switches to the OFF or NEUTRAL position.



If INSITE™ electronic service tool is available, monitor the engine brake ON/OFF switch circuit for proper operation.

If **not**, follow the troubleshooting procedures in this section.



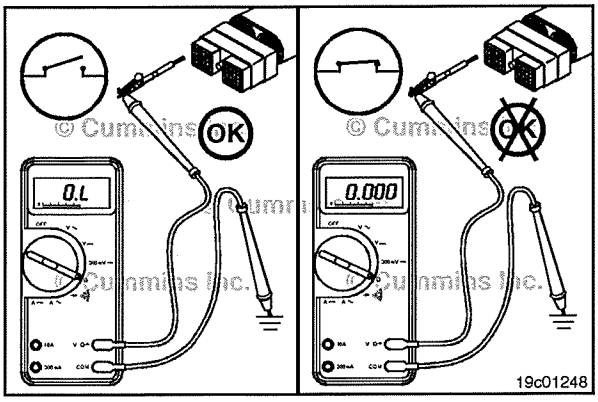
Disconnect the OEM harness from the ECM connector.

Insert the appropriate test lead into exhaust brake ON/ OFF switch input pin of the OEM harness connector. Touch the other multimeter probe to engine block ground. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the resistance value is **not** correct, there is a short circuit to ground in the harness.

Repair or replace the OEM harness. Refer to Procedure 019-071.

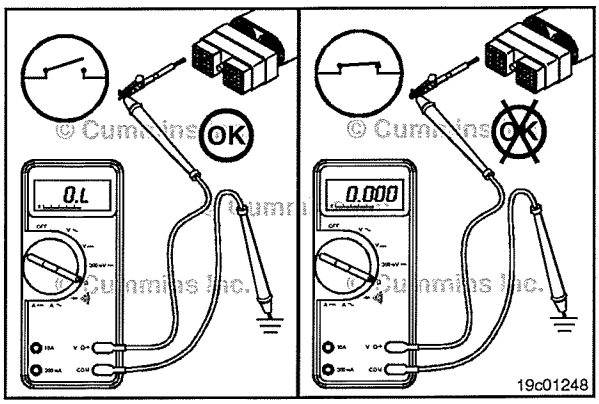


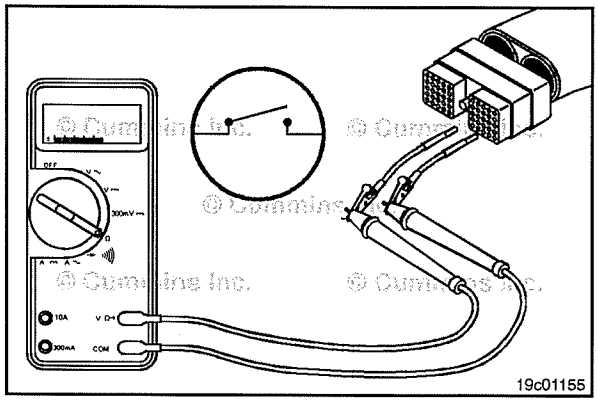
Touch one multimeter probe to the engine block. Insert the other multimeter probe with attached appropriate test lead into switch return pin of the OEM harness connector. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the resistance value is **not** correct, there is a short circuit to ground in the harness. Repair or replace the OEM harness. Refer to Procedure 019-071.

If the resistance value is correct in the previous checks, the exhaust brake ON/OFF switch input pin **must** still be checked for short circuits from pin-to-pin.





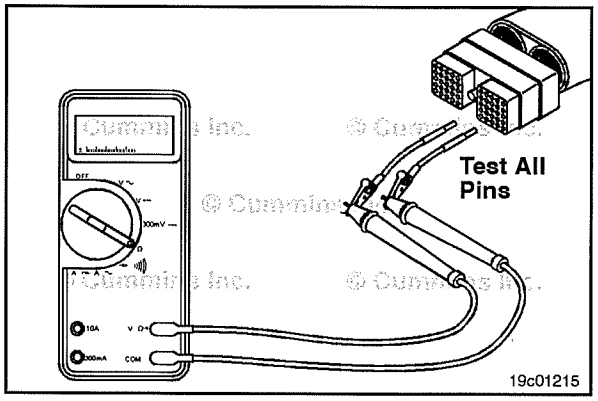
Check for Short Circuit from Pin to Pin

Isolate the switch circuit as in the previous section.

Insert the appropriate test lead into exhaust brake ON/OFF switch input pin of the OEM harness connector.

Insert the other appropriate test lead into pin 1 of the connector. Connect the alligator clips to the multimeter probes. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

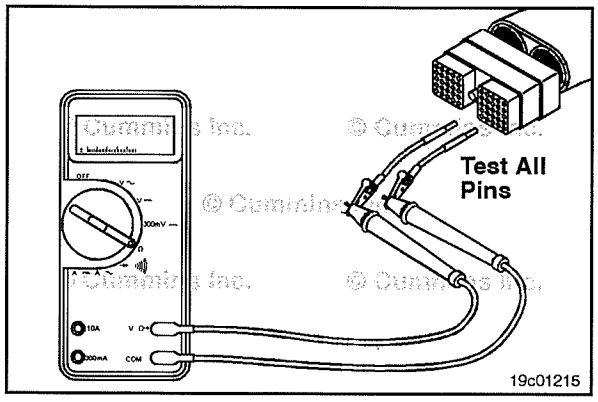


Remove the lead and check all other pins.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit between the wire connected to exhaust brake ON/OFF switch input pin and any pin that measured less than 100k ohms.

Repair or replace the OEM harness. Refer to (Procedure Refer to Procedure 019-071).



Insert the test lead into switch return pin of the OEM harness connector. Check all pins of the harness connector. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more) at all pins.

If the circuit is **not** open, there is a short circuit to ground in the positive switch supply bus, provided the switch has been previously checked.

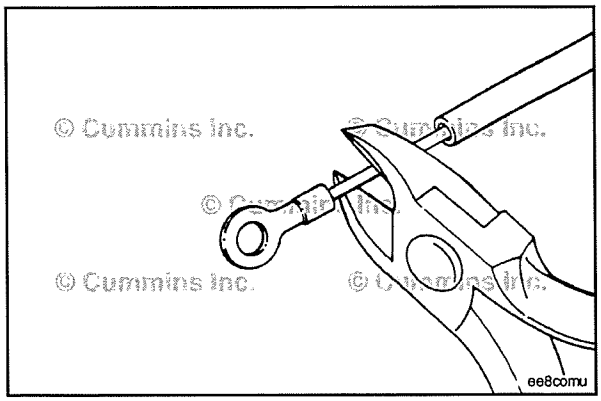
Repair or replace the wiring connected to switch return pin in the OEM harness. Refer to Procedure 019-071.

Ring Terminal (019-197)

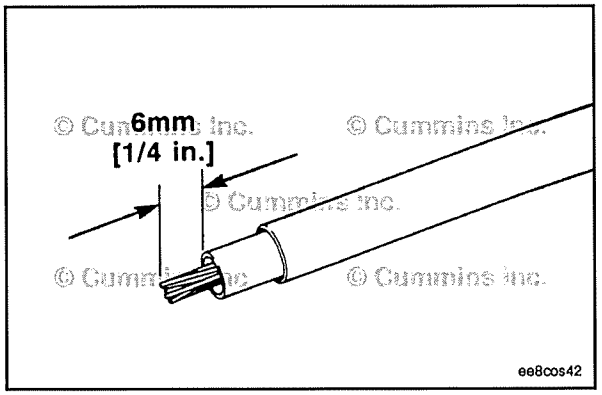
Connector Replacement

Terminals are used for various connections including grounds and fuel shutoff valve supply.

Use wire crimp tool, Part Number 3822930, to cut and remove the ring terminal connector as shown.

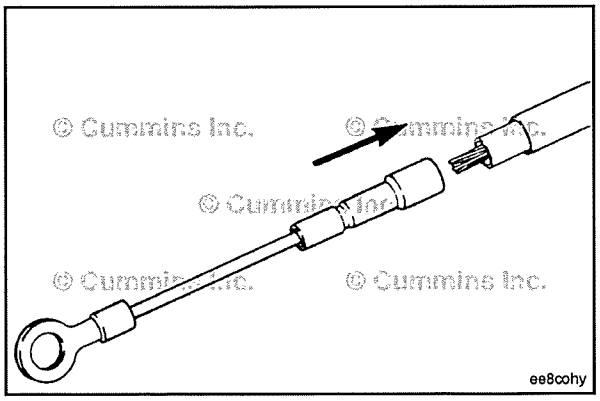


Use wire crimp tool, Part Number 3822930, to remove 6 mm [1/4 in] of insulation from the harness wire.



Install the proper-size ring terminal on the bare wire. The ring terminals that are included in the wiring repair kit, Part Number 3164572, are as follows:

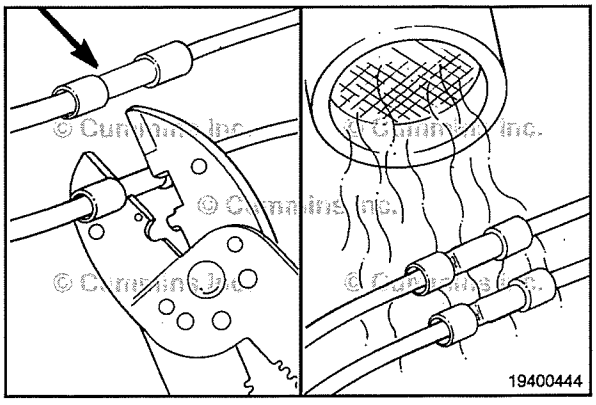
Ring Terminal Size	Part No.
No. 10	3823760
1/2 inch	3823761

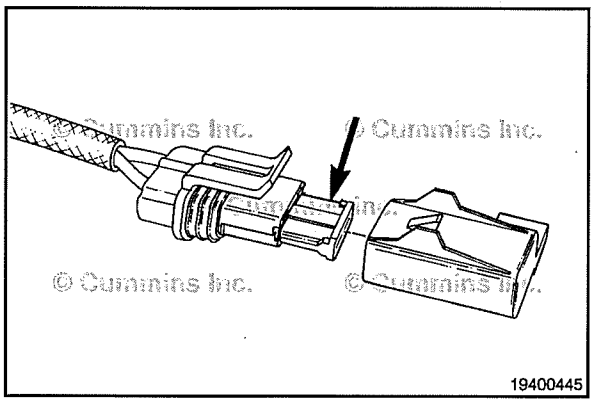


⚠CAUTION⚠
Only use wire crimping pliers, Part Number 3822930, when repairing electrical terminals.

Crimp the repair wire on the bare wire.

Use a heat gun, Part Number 3822860, or open flame to heat the shrink tubing. The tubing will shrink and make the connection waterproof.

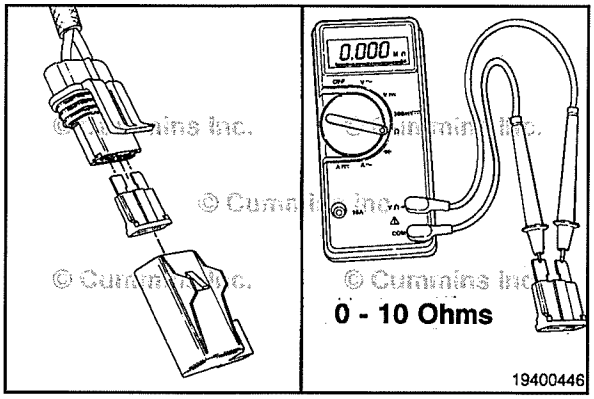




Fuse, Harness In-Line (019-198)

Inspect

Remove the fuse protective covers from the fuse(s) that are being checked. Check to make sure the fuse is installed in the fuse holder correctly.

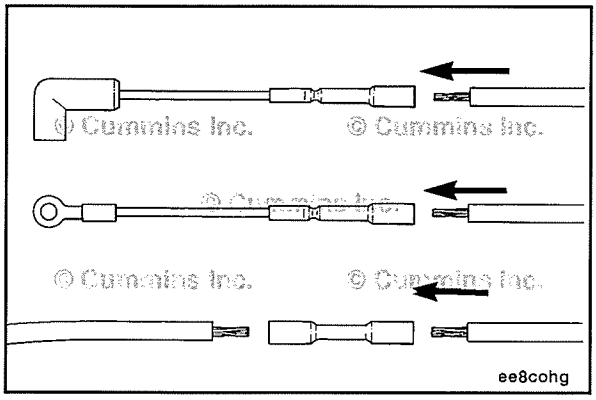


If the fuse is installed correctly, check for a blown fuse.

Remove the fuse(s) to be checked.

Touch each one of the multimeter leads to each fuse terminal. Measure the resistance.

The multimeter **must** show less than 10 ohms, which is a closed circuit. If the circuit is closed then put the fuse back into the holder and connect the fuse cover.

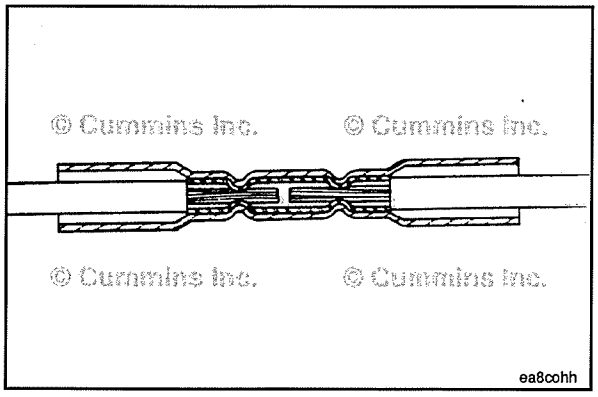


Connector, Butt Splice (019-199)

General Information

Butt splice connectors are used when repairing harnesses or damaged wires.

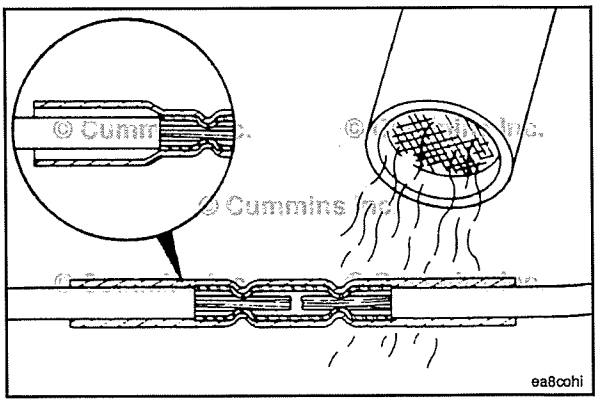
Only use the butt splices that are supplied with the wiring repair kit, Part Number 3164572, when repairs are necessary.



Butt splices are designed to provide the best possible cold joint connection when properly crimped.

Use wire crimp tool, Part Number 3822930, supplied with the electrical wiring repair kit.

Butt splices also provide protection against corrosion. After crimping the connection, heat the shrink tube with the heat gun, Part Number 3822860, or an open flame, until the shrink tube has sealed the joint.



Weather Pak Connector Series (019-201)

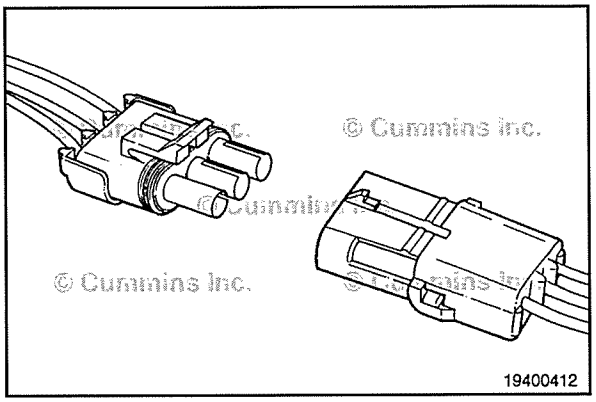
Pin Replacement

This connector is used to connect many different components to the engine, or other devices. The connector can have many different pin configurations. All types of connectors are repaired in the same manner. The two-way connector is displayed in this procedure.

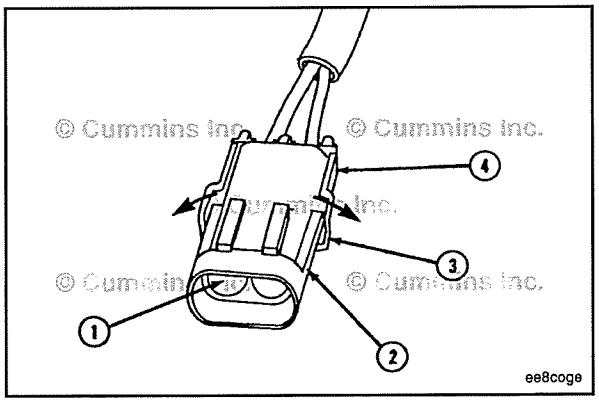
Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

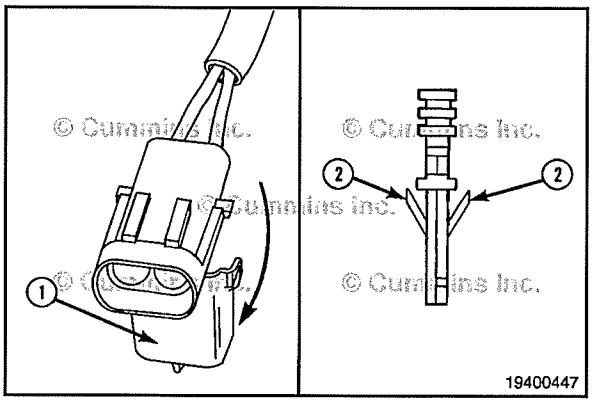
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire. Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.



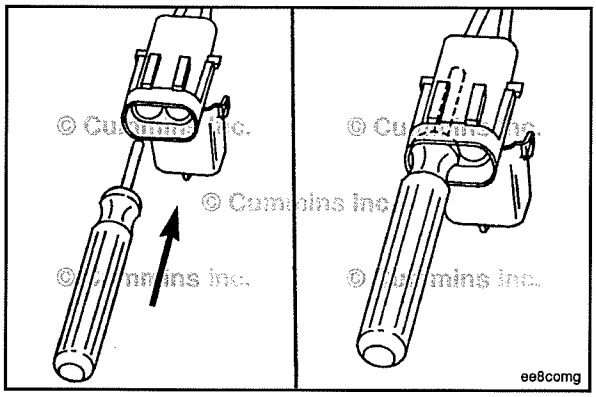
To replace the Weather-Pack terminal (1), pull the locking tabs (3) apart on the wire lock (4).





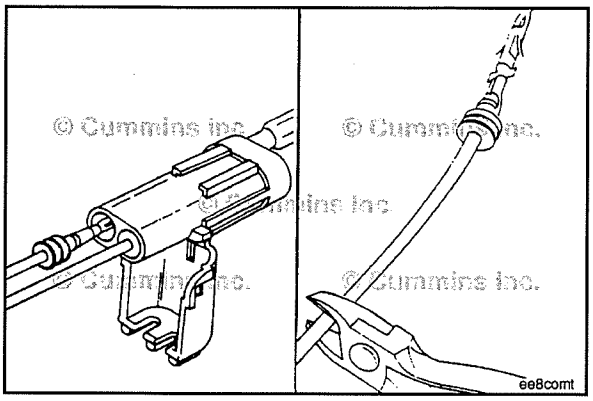
NOTE: The wire is held in the connector body by the wire lock (1) and two locking lances (2) on the terminal.

Open the wire lock.



⚠CAUTION⚠
This tool can be easily broken. Care must be taken when using this tool. Do not force the tool into place.

Insert the Weather-Pack extraction tool, Part Number 3822608, over the terminal. Use a twisting motion to push the tool to the bottom of the cavity.

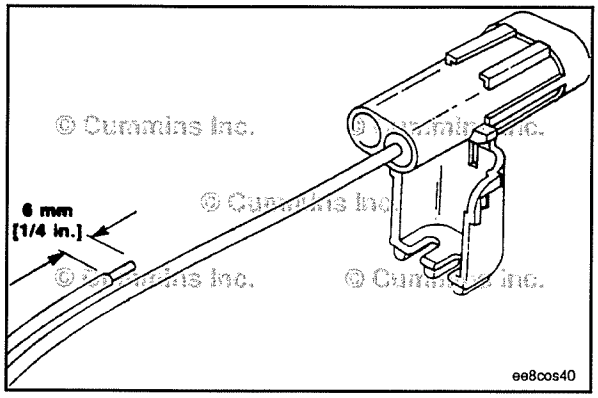


⚠CAUTION⚠
If more than one wire is being repaired, tag each wire and install it in the original location. Electrical problems can occur if wires are switched.

Pull the wire and the terminal out of the connector body.

NOTE: The repair wire and the terminal is 127 mm [5 in] long.

Use crimping tool, Part Number 3822930, to cut 127 mm [5 in] of the terminal wire.



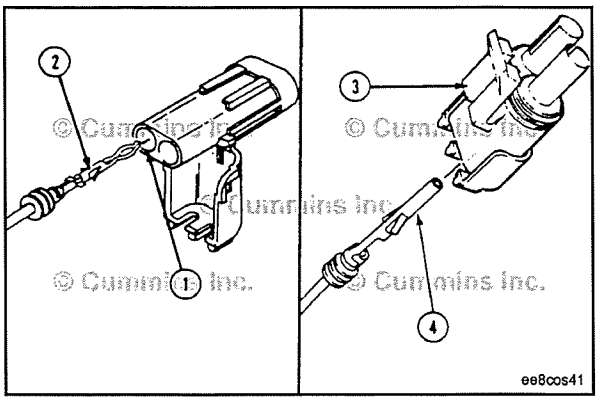
Use wire crimping tool, Part Number 3822930, to remove approximately 6 mm [¼ in] of insulation from the wire.

NOTE: The shroud connector bodies (1) use pin terminals (2). The tower connector bodies (3) use socket terminals (4).

Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

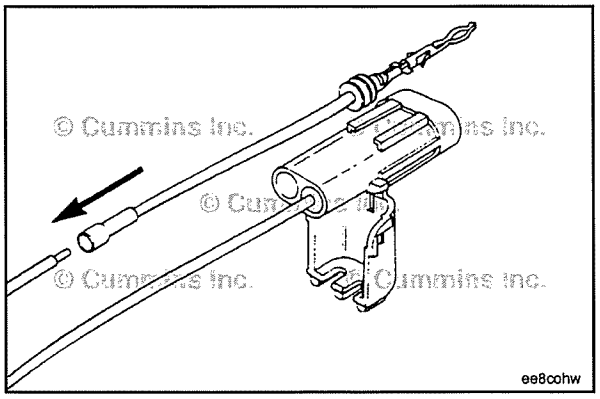
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire. Replace one contact wire at a time. If more than one wire needs to be replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

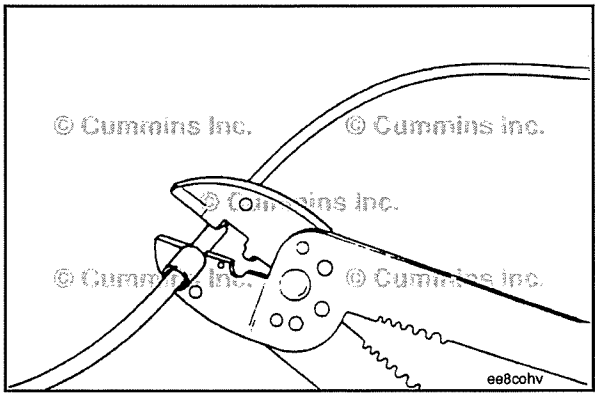


Install the correct repair wire on the bare wire.

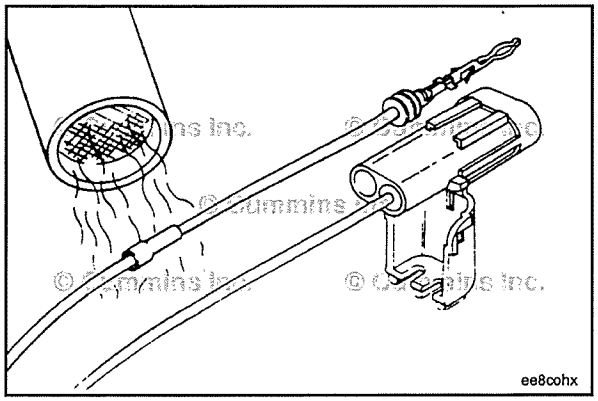
Make sure that the bare wire extends into the insulated butt splice connector.

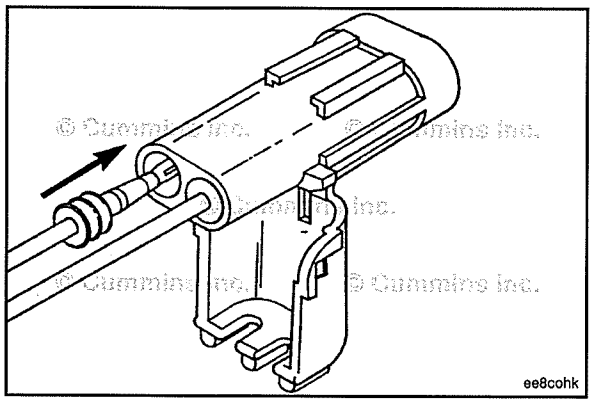


Use wire crimping tool, Part Number 3822930, to crimp the repair wire on the bare wire.



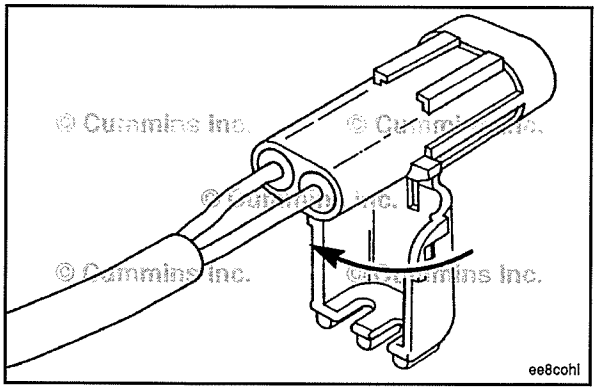
Use heat gun, Part Number 3822860, to heat the shrink tubing. The tubing will shrink and make the connection waterproof.



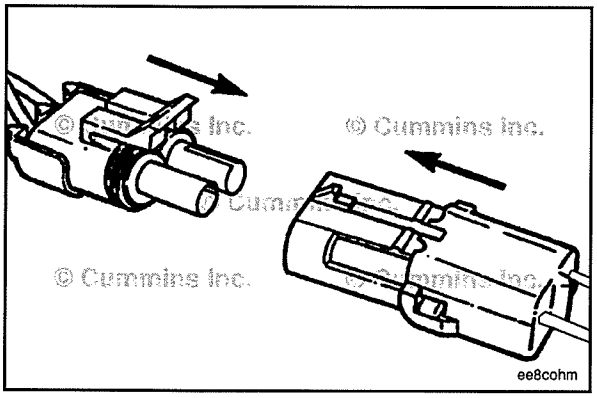


⚠CAUTION⚠
If more than one wire is repaired or if the connector body is replaced, make sure to insert the wires into the same locations as they were in. Electrical problems can occur if wires are switched.

Insert the terminal into the connector body. The terminal locking lances **must** click and hold the terminal in the body.



Close and latch the wire on the connector body.



Insert the two connector halves together.

Connector Replacement

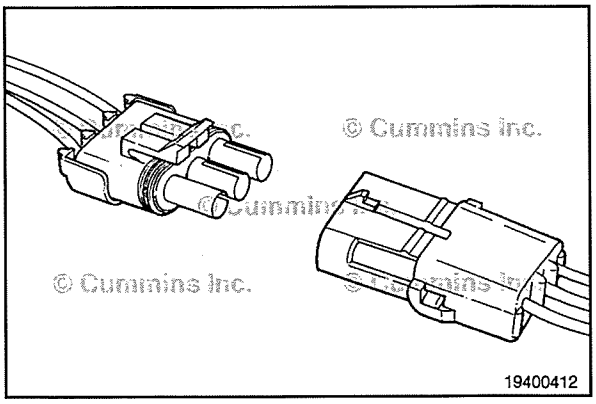
The connector is used to connect many different components to the engine, or other devices. The connector can have many different pin configurations. All types of connectors are repaired in the same manner. The two-way connector is displayed in this procedure.

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

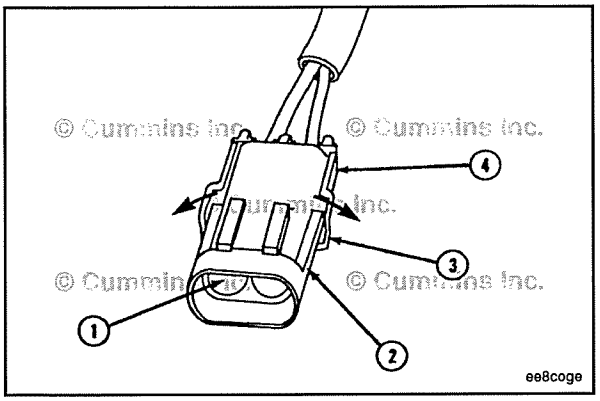
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.

Replace one contact wire at a time. If more than one wire needs to be replaced, attach a lettered tag to each wire removed.

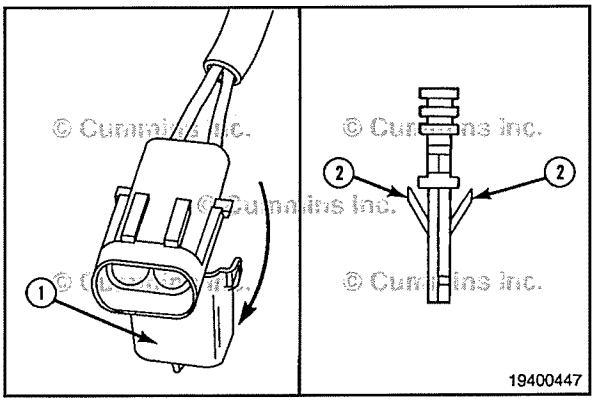


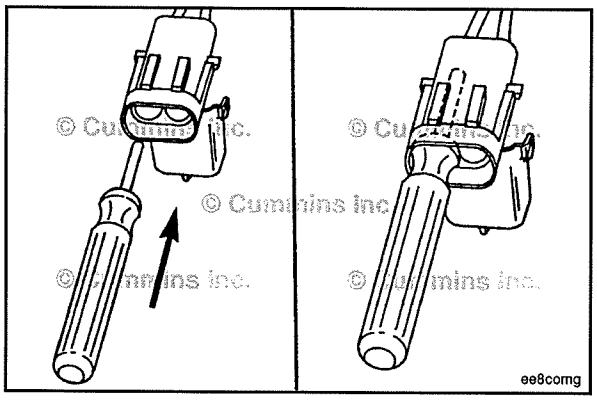
To replace the Weather-Pack connector body (2), pull the locking tabs (3) apart on the wire lock (4).



The wire is head in the connector body by the wire lock (1) and two locking lances (2) on the terminal.

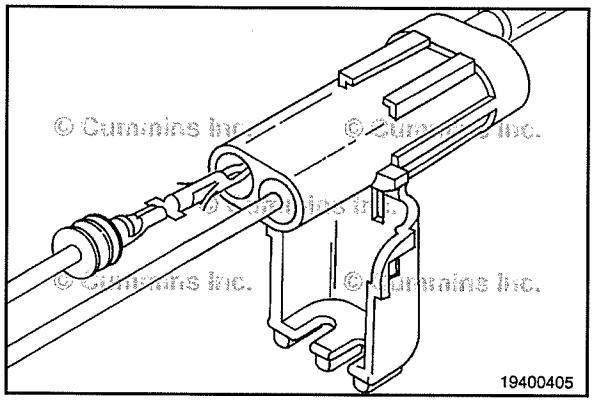
Open the wire lock.



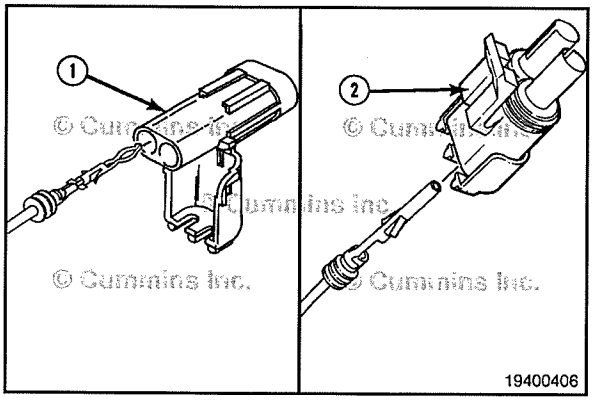


⚠CAUTION⚠
This tool can be easily broken. Care must be taken when using this tool. Do not force the tool into place.

Insert Weather-Pack extraction tool, Part Number 3822608, over the terminal. Use a twisting motion to push the tool to the bottom of the cavity.



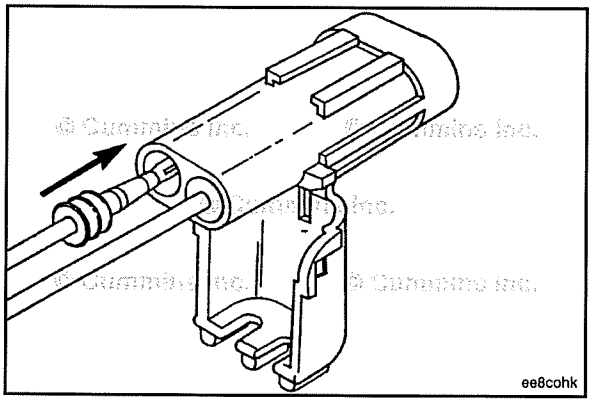
Pull the wire and the terminal out of the connector body.



Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

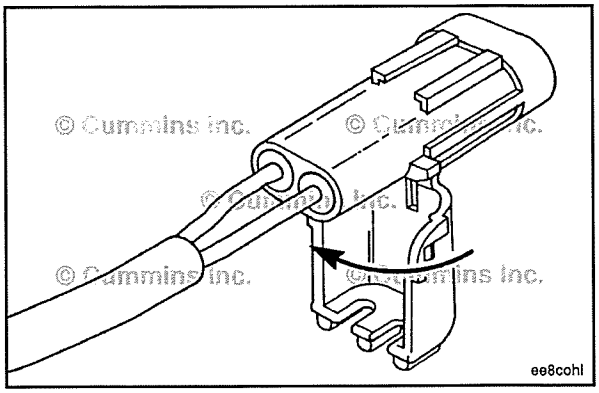
Replace one contact wire at a time. If more than one wire needs replaced, attached a lettered tag to each wire removed.



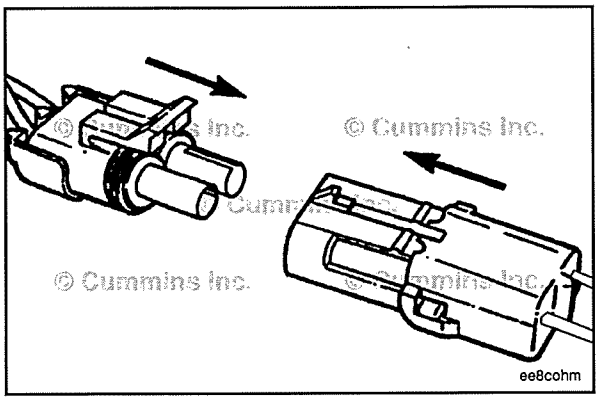
⚠CAUTION⚠
If more that one wire is repaired or if the connector body is replaced, make sure to insert the wires into the same locations as they were in. Electrical problems can occur if wires are switched.

Insert the terminal into the connector body. The terminal locking lances **must** click and hold the terminal in the body.

Close and latch the wire lock on the connector body.



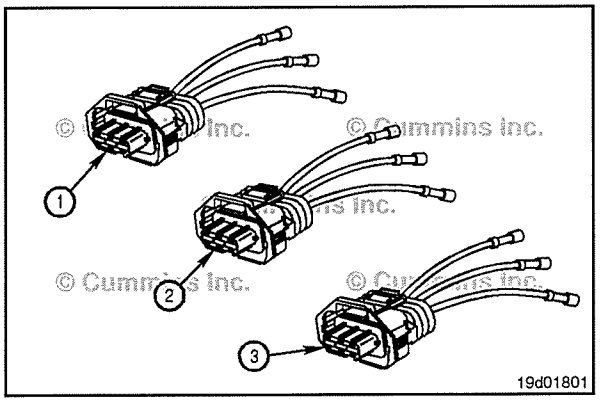
Insert the two connector halves together.



Metripack Connector Series (019-202)

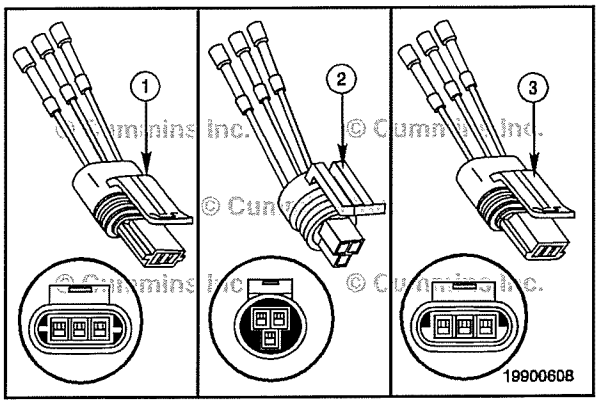
Pin Replacement

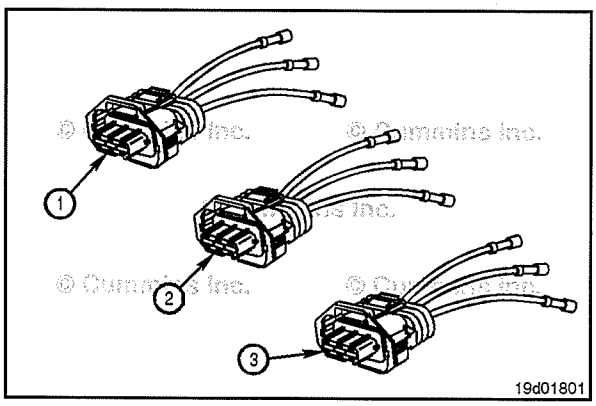
The connector can have multiple pin configurations. All types of connectors are repaired in the same manner.



The connector pins can **not** be repaired or replaced. The connector **must** be replaced as a unit.

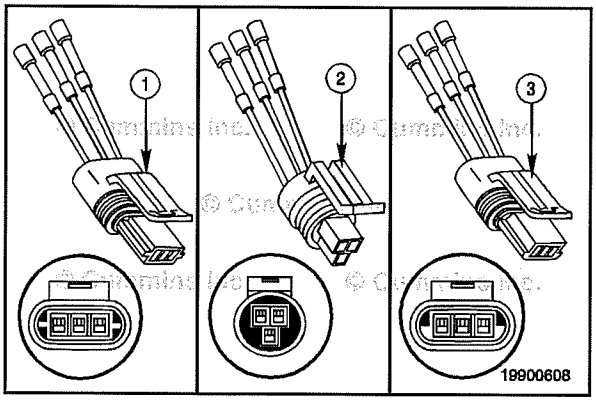
Refer to the connector replacement procedure for replacement instructions.





Connector Replacement

The connector can have multiple pin configurations. All types of connectors are repaired in the same manner.



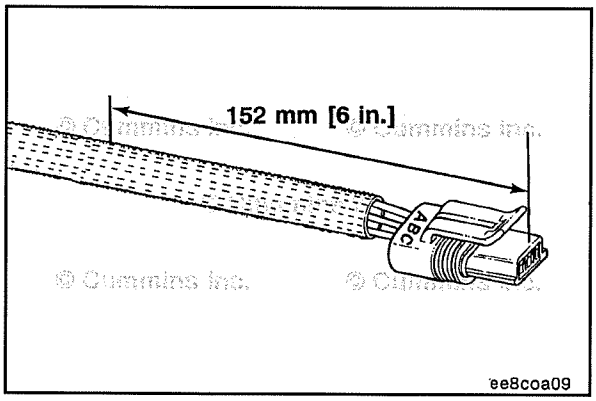
The connectors have different keying and can **not** be interchanged with each other.

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

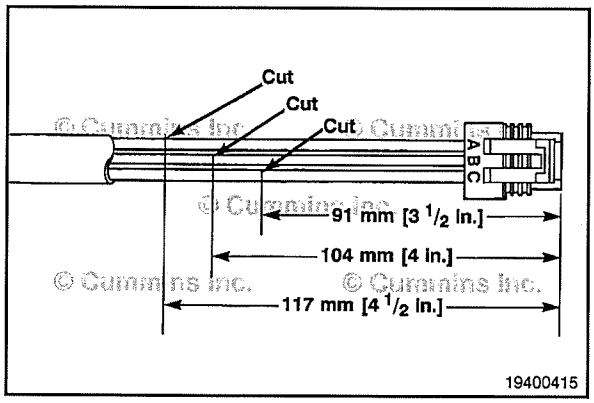
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.



Measure 152 mm [6 in] back from the face of the connector, and remove the wiring harness protective cover.



Before cutting the wires, measure and tag the wires.

Use wire cutters to cut wire A 117 mm [4-½ in] from the face of the connector.

Use wire cutters to cut wire B 104 mm [4 in] from the face of the connector.

Use wire cutters to cut wire C 91 mm [3-½ in] from the face of the connector.

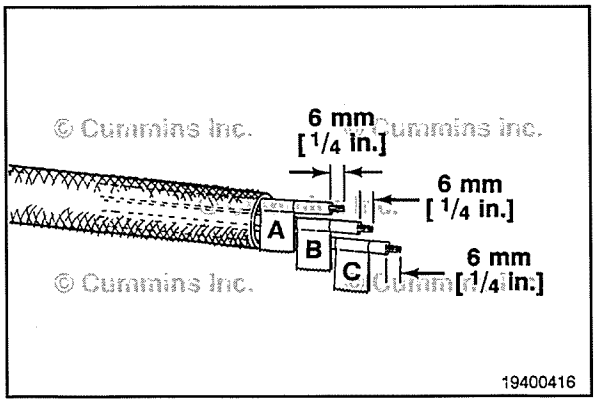
Use crimping tool, Part Number 3822930, to remove 6 mm [¼ in] of insulation from all electrical wires.

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

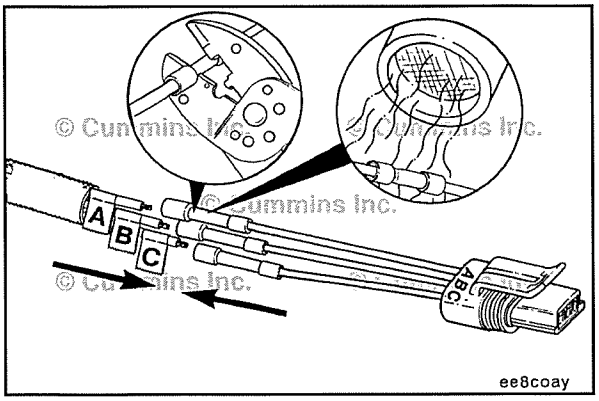
Refer to Section E for pin locations.

Replace one contact at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

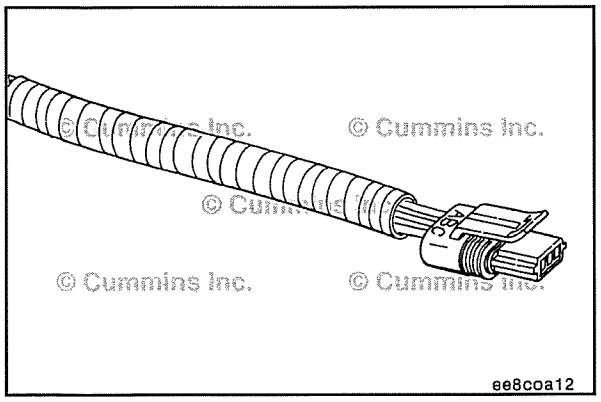


Install the terminal repair wires on the bare wires and use wire crimping tool, Part Number 3822930, to crimp the terminals.

Use heat gun, Part Number 3822860, to heat the shrink tubing. The tubing will shrink and make the connection waterproof.



Wrap the wires with tape, for added protection to complete the repair.



AMP Connector Series (019-203)

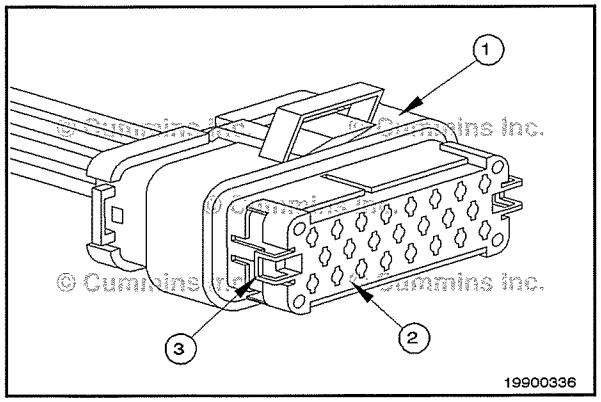
Pin Replacement

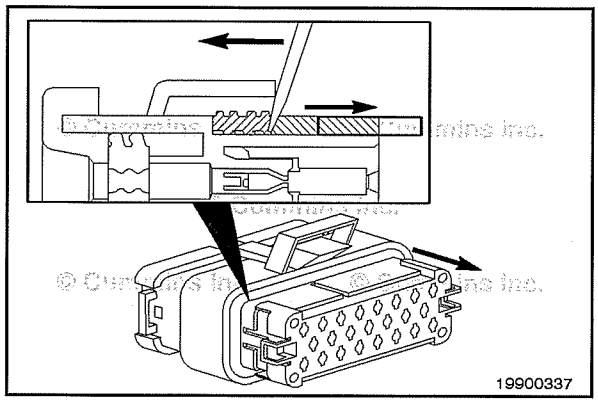
⚠CAUTION⚠

Use care in handling the AMP connectors. They are very fragile and easily damaged. Follow the steps outlined in this procedure to avoid damage.

Check to be sure the connector wedge lock is in the open position.

NOTE: The connector assembly is shipped in one piece, with the wedge lock in the open position. It is possible that during adverse shipping conditions that some wedge locks can get bumped into the closed position.





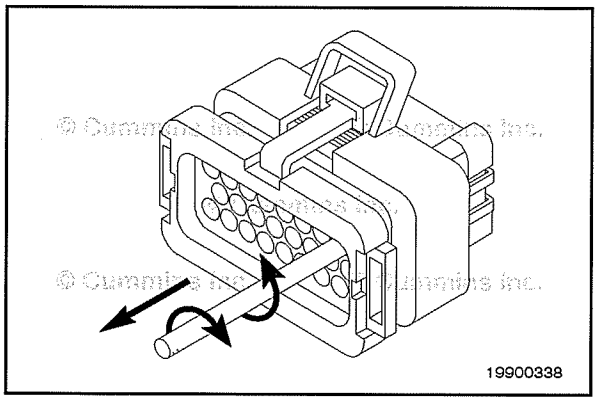
If the wedge lock is closed, perform the following:

Insert screwdriver blade (flat) between the matting seal and one of the red wedge lock tabs.

Depress the lock tabs (Item 3 in the figure in the previous step).

Pry open the wedge lock to the open position.

NOTE: The wedge lock **must not** be removed from the housing for insertion or removal of the contacts.

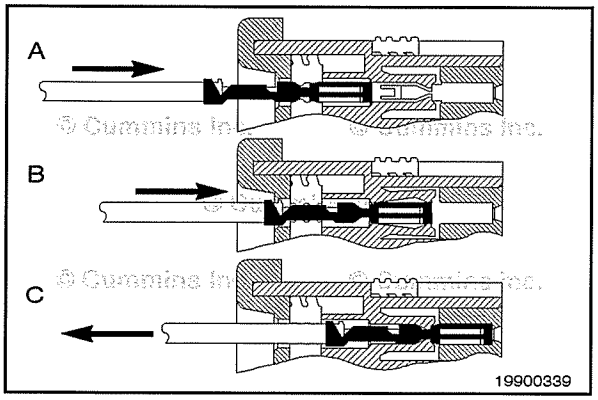


Remove the damaged contacts, rotate the contact wire back and forth over a half turn (¼ turn in each direction). Gently pull the wire until the contact is removed.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

NOTE: Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.



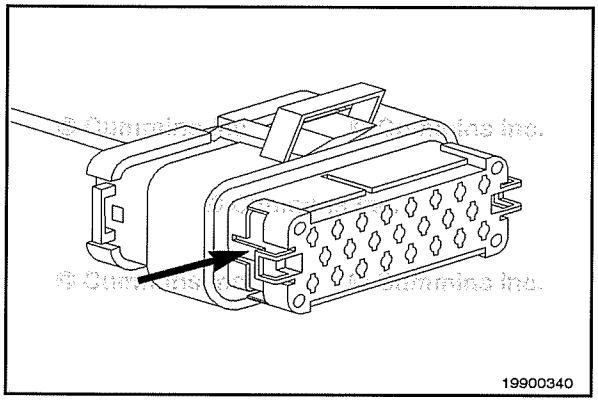
Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

Install a new wire and contact.

Insert wire straight into the appropriate circuit cavity.

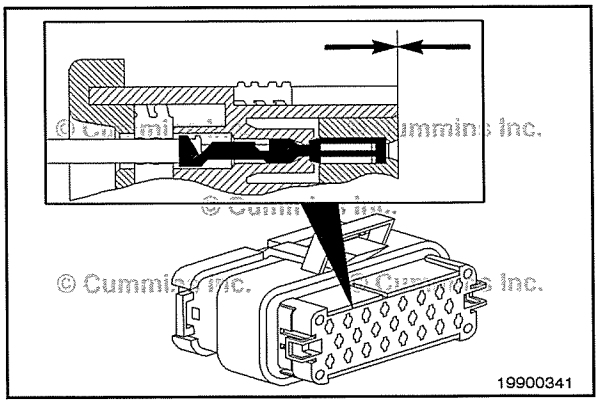
Insert the wire until the pin bottoms out.

Pull back gently to be sure the retention fingers are holding the contact.



After all of the required contacts have been replaced, the wedge lock **must** be closed to its LOCKED position. Release the locking latches by squeezing them inward.

Slide the wedge lock into the housing until it is flush with the housing.

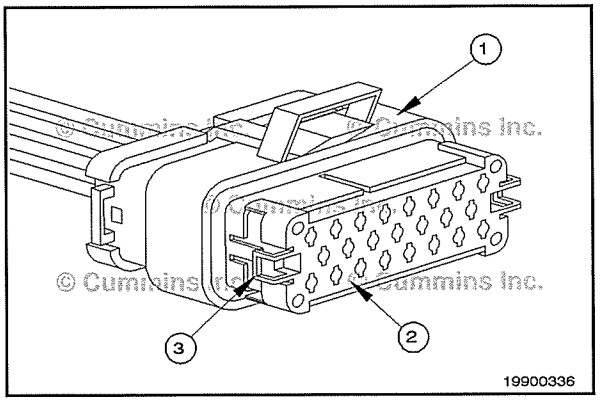


Connector Replacement

⚠CAUTION⚠
Use care in handling the AMP connectors. They are very fragile and easily damaged. Follow the steps outlined in this procedure to avoid damage.

NOTE: The connector assembly is shipped in one piece, with the wedge lock in the open position. It is possible that during adverse shipping conditions that some wedge locks can get bumped into the closed position.

Check to be sure the connector wedge lock is in the open position.



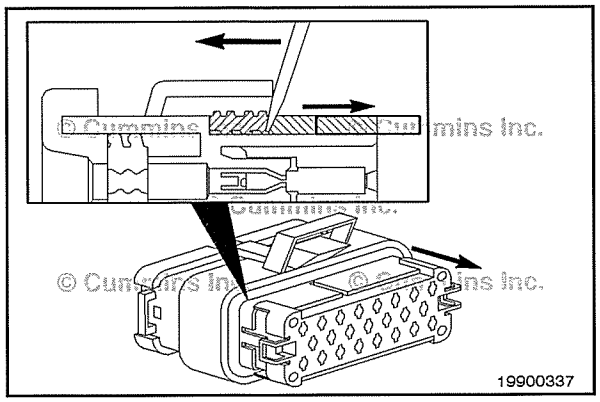
NOTE: The wedge lock **must not** be removed from the housing for insertion or removal of the contacts.

If the wedge lock is closed, perform the following:

Insert screwdriver blade (flat) between the matting seal and one of the red wedge lock tabs.

Depress the lock tabs (Item 3 in the figure in the previous step).

Pry open the wedge lock to the open position.



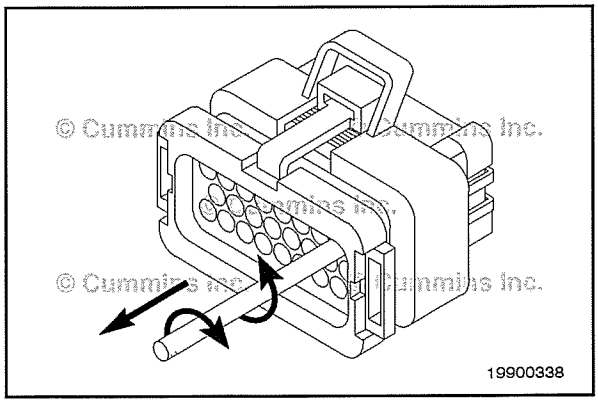
Replace one contact wire at a time. Attach a lettered tag to each wire removed.

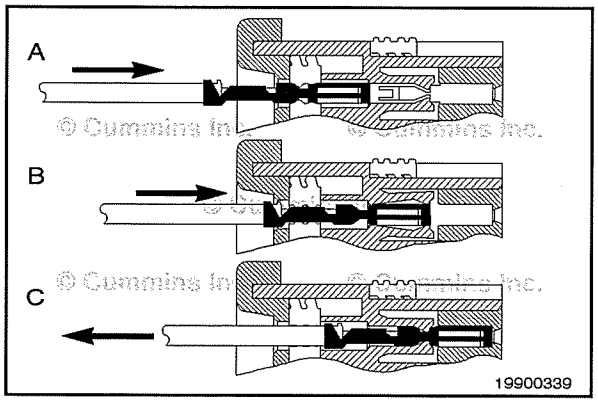
Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Remove all of the contacts. Rotate the contact wires back and forth over a half turn (¼ turn in each direction). Gently pull the wire until the contact is removed.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.



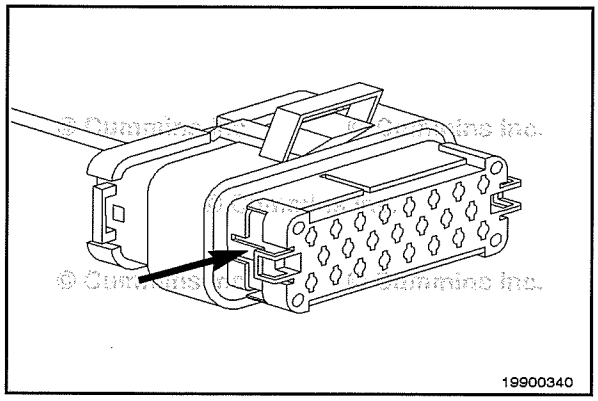


Install a new wire and contact by:

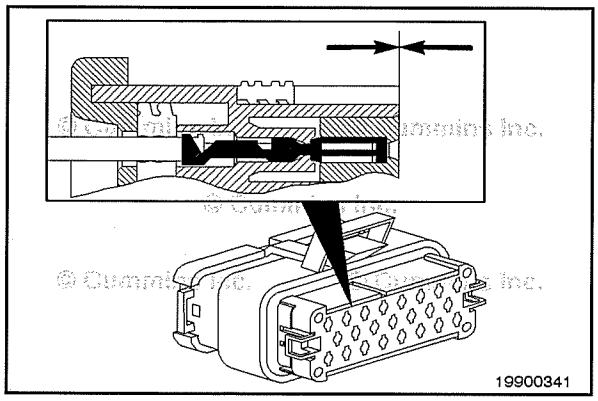
Insert wire straight into the appropriate circuit cavity.

Insert the wire until the pin bottoms out.

Pull back gently to be sure the retention fingers are holding the contact.



After all of the required contacts have been replaced, the wedge lock **must** be closed to its LOCKED position. Release the locking latches by squeezing them inward.



Slide the wedge lock into the housing until it is flush with the housing.

Deutsch DRC Connector Series (019-204)

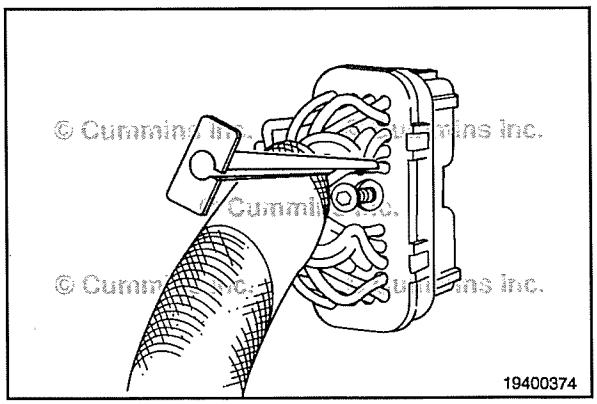
Pin Replacement

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

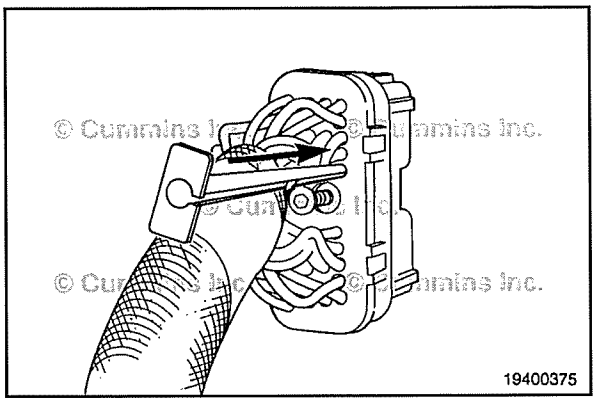
Refer to the wiring diagram for pin locations.

Use the Deutsch extraction tool, listed in the table below, to remove a pin from the connector.

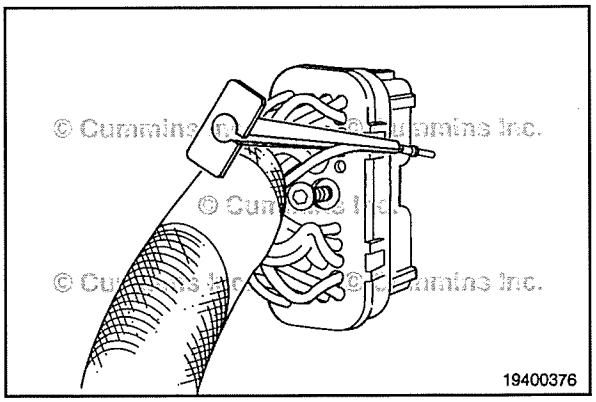
Tool Part Number	Wire Size
3824815	20 gauge
3822760	16 gauge
3824816	12 gauge

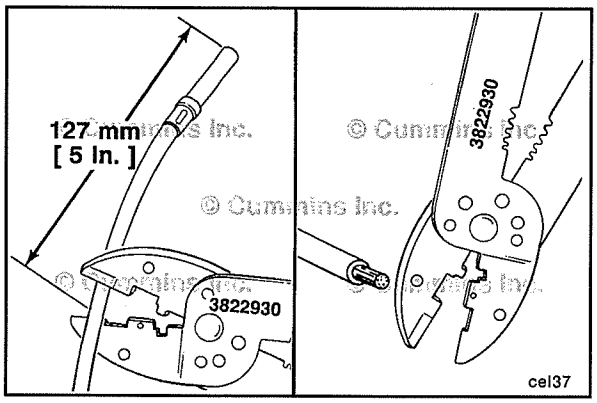


Push the tool into the connector approximately 25 mm [1 in] until it bottoms on the terminal flange.



Hold the tool on the terminal flange and pull the wire and connecting pin out of the connector. Note and record the hole from which the pin is removed.

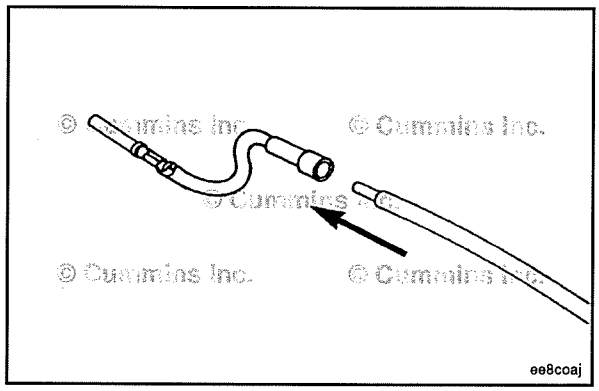




NOTE: The repair wire is 127 mm [5 in] long.

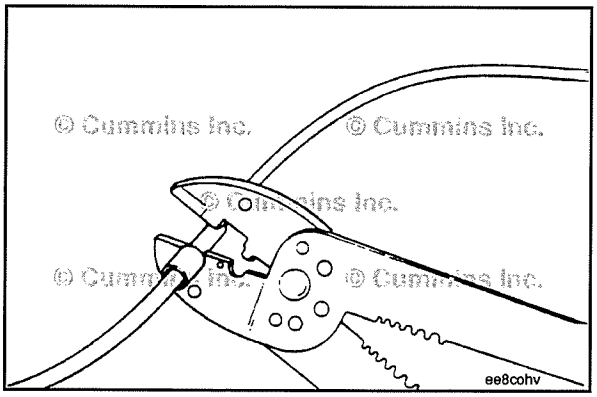
Use wire crimping tool, Part Number 3822930, to cut 127 mm [5 in] off the wire and pin.

Use the crimping tool to remove 6 mm [¼ in] of insulation from the wire.

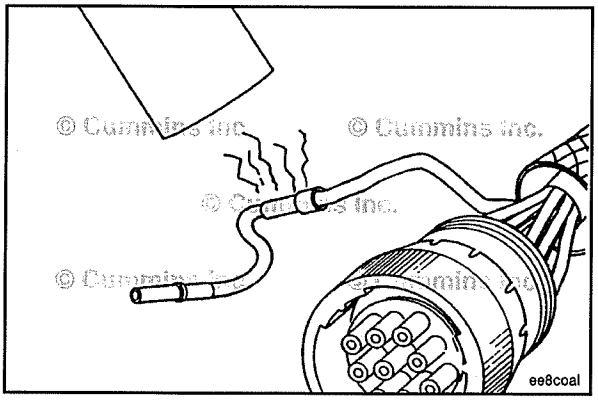


Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

Install the correct repair wire on the bare wire, make sure that the bare wire extends into the splice connector.



Use the wire crimping tool to crimp the repair wire onto the bare wire.

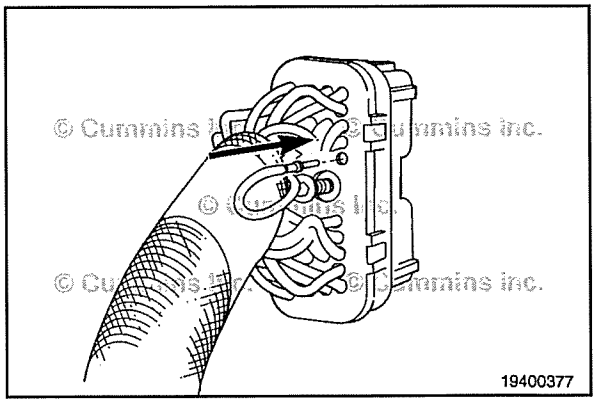


Use heat gun, Part Number 3822860, or an open flame to heat the shrink tubing around the wire. The tubing will shrink and make the connector waterproof.

Insert the pin into the correct hole of the connector.

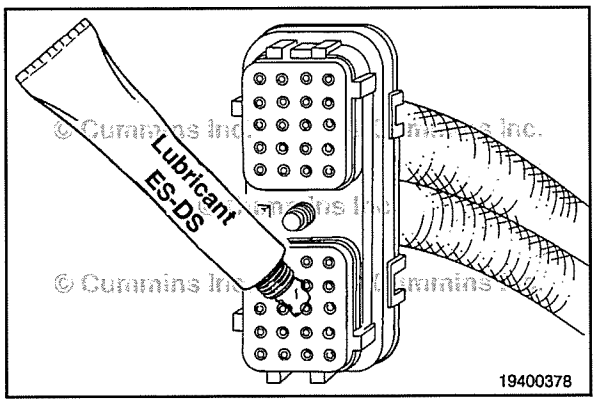
The pin **must** click into place and hold the wire in the connector.

Pull the wire gently to make sure it is seated in the connector.



△CAUTION△
Use only Cummins recommended lubricant DS-ES, Part Number 3822934. Other lubricants, such as lubricating oil or grease, in the connectors can cause Electronic Control Unit damage, poor performance, or premature connector pin wear.

Apply a small amount of lubricant to the connector terminals. Do **not** fill the entire connector cavity with the lubricant.



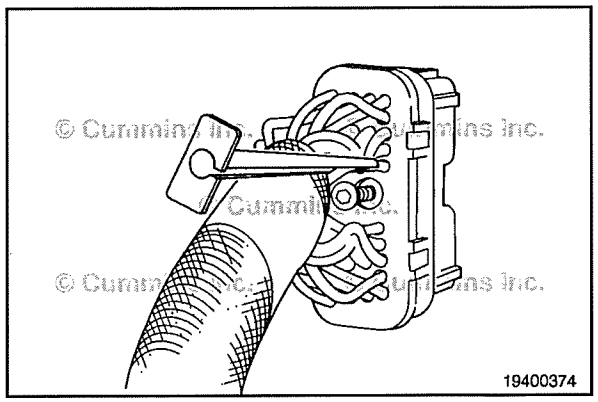
Connector Replacement

Use the Deutsch extraction tool, listed in the table below, to remove a pin from the connector.

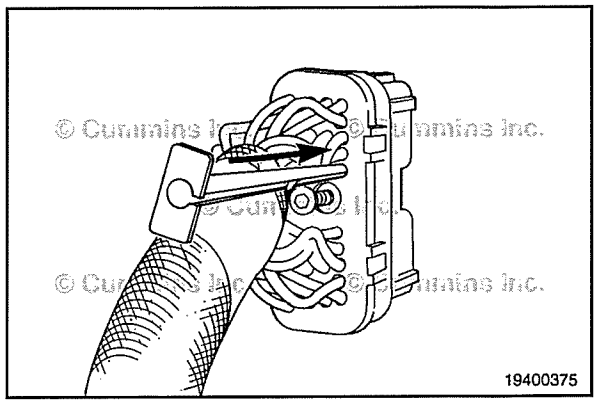
Tool Part Number	Wire Size
3824815	20 gauge
3822760	16 gauge
3824816	12 gauge

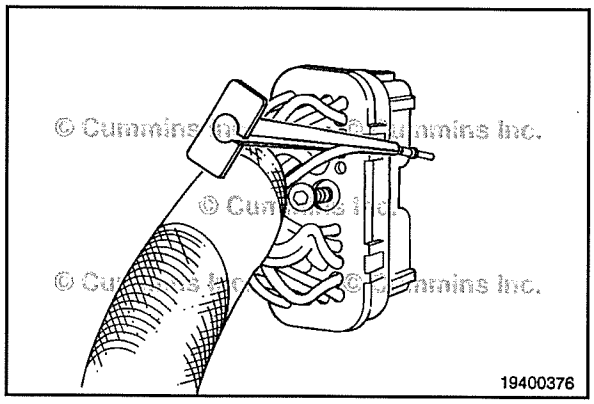
Replace one wire at a time. Attach a lettered tag to each wire removed.

Refer to the wiring diagram for pin locations.



Push the tool into the connector approximately 25 mm [1 in] until it bottoms on the terminal flange.



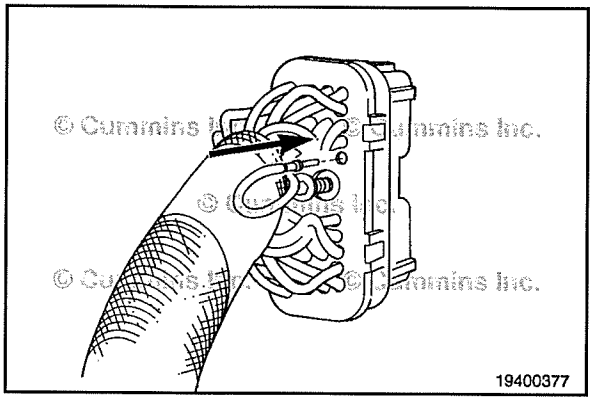


Hold the tool on the terminal flange and pull the wire and the connecting pin out of the connector. Note and record the hole from which the pin is removed.

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

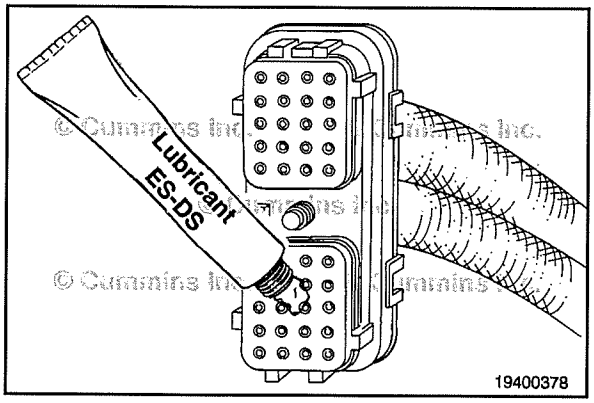
Refer to the wiring diagram for pin locations.



Insert the pins into the correct holes of the replacement connector.

Each pin **must** click into place and hold the wires in the connector.

Pull each wire gently to make sure it is seated in the connector.



△CAUTION△
Use only Cummins lubricant DS-ES, Part Number 3822934. Other lubricants such as lubricating oil or grease, in the connectors can cause Electronic Control Unit damage, poor performance or premature connector pin wear.

Apply a small amount of lubricant to the connector terminals. Do **not** fill the entire connector cavity with lubricant.

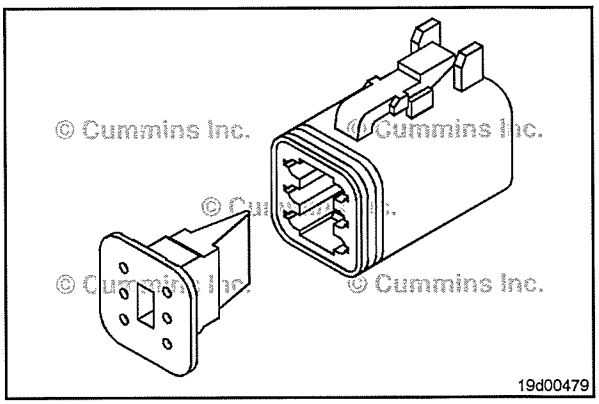
Deutsch DT Connector Series (019-205)

Pin Replacement

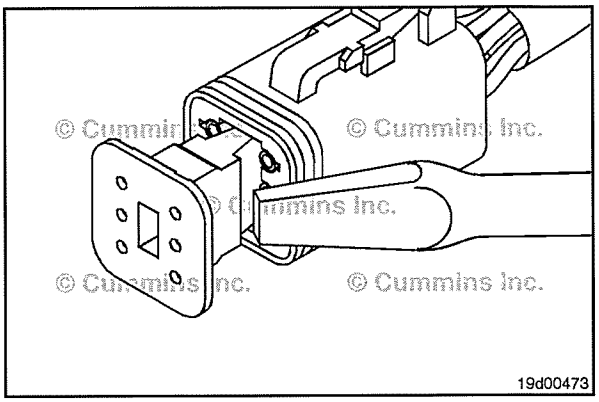
The connector can have multiple pin configurations. All type of connectors are repaired in the same manner.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

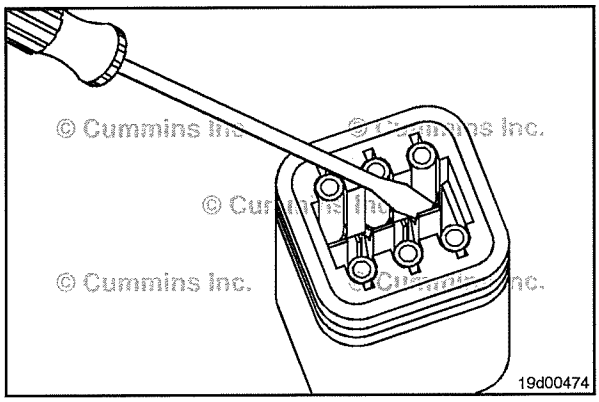


To replace the pin in the receptacle connector, remove the orange wedge using needle nose pliers or a hook-shaped wire to pull the wedge straight out.



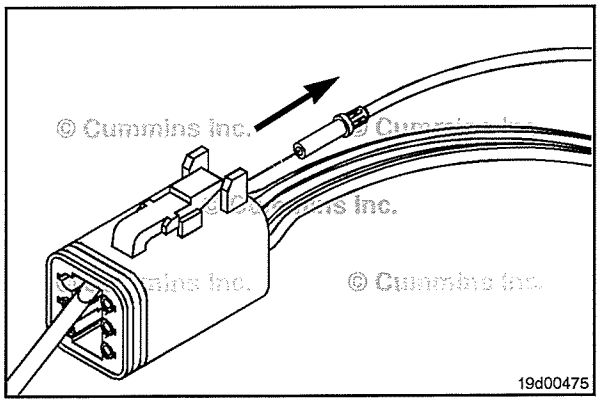
⚠CAUTION⚠
Locking finger can be easily broken. Care must be taken when using this tool. Do not force the tool into place.

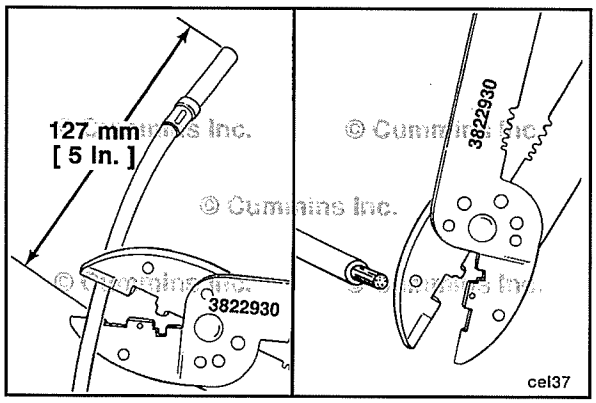
To remove the contact out of the connector body, gently pull wire backward, while at the same time releasing the locking finger by moving it away from the contact with a screwdriver.



⚠CAUTION⚠
If more than one wire is being repaired, tag each wire and install it in the original location. Electrical damage can occur if wire is installed in the incorrect location.

Pull the wire and the terminal out of the connector body.





Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

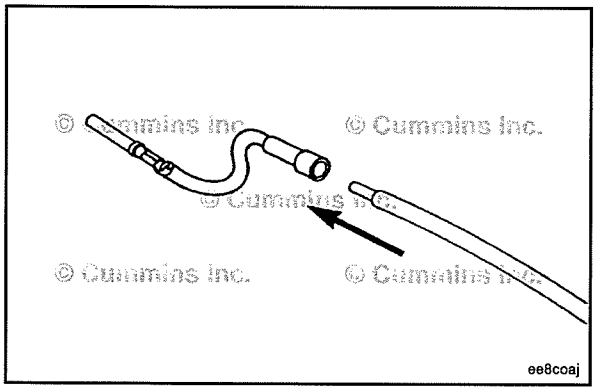
Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

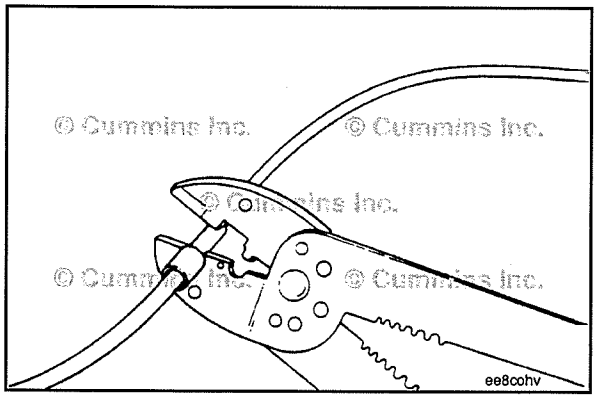
Use wire crimping tool, Part Number 3822930, to cut 127 mm [5 in] off the wire and pin.

Use wire crimping tool, Part Number 3822930, to remove 6 mm [¼ in] of insulation from the wire.

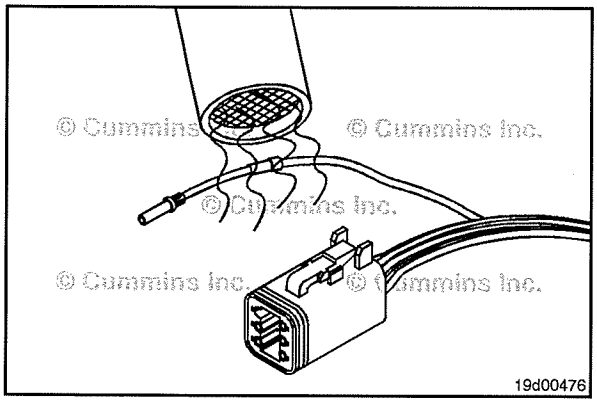


Install the correct repair wire on the bare wire.

Make sure the bare wire extends into the splice connector.



Use wire crimping tool, Part Number 3822930, to crimp the repair wire onto the bare wire.



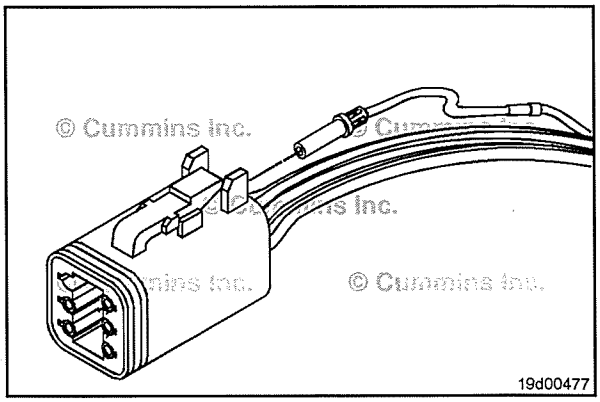
Use heat gun, Part Number 3822860, to heat shrink the tubing around the wire.

The tubing will shrink and make the connection waterproof.

⚠CAUTION⚠

If more than one wire is repaired or if the connector body is replaced, make sure to insert wires into the same locations as they are in the original connector. If wires are not in the original location electrical damage can occur.

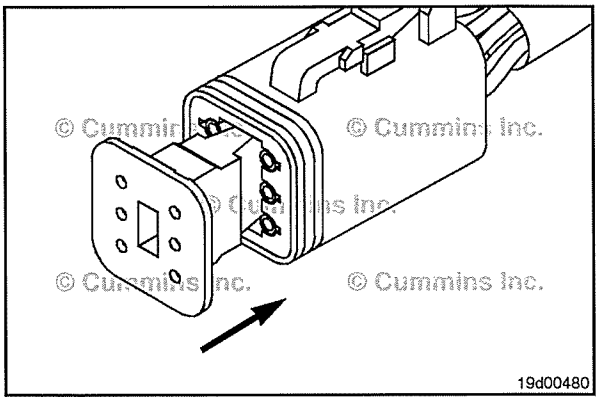
Replace the connector and install the wire and terminal into the connector body. Push the wire and terminal into the seal at the back of the connector. Push the wires straight in until a click is felt. A slight tug will confirm that it is properly locked in place.



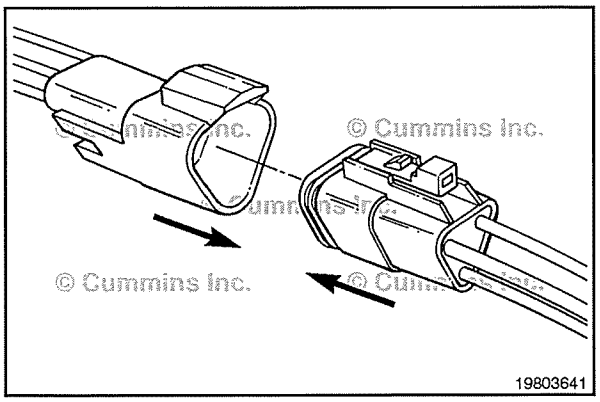
Once the wires are in place, insert the orange wedge with arrow pointing toward the exterior locking mechanism.

Push the orange wedge in until it snaps in place.

Make sure both seals are in place and the back of the connector plug and receptacle. Be sure the rubber seal has been installed on the connector plug.



Push the connector plug into the connector receptacle until the external locking clip snaps into place.



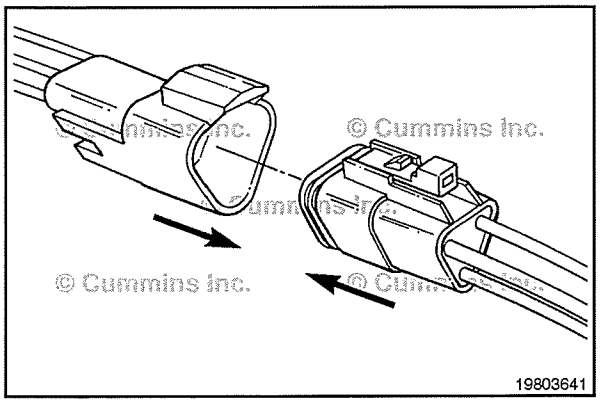
Connector Replacement

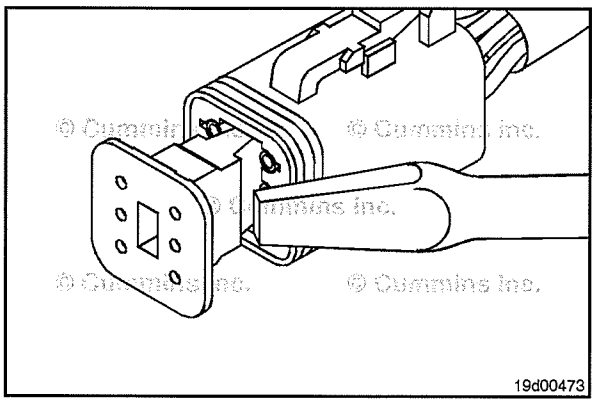
The connector can have multiple pin configurations. All types of connectors are repaired in the same manner.

Before installing the new connector perform a test fit to make sure the connector is keyed correctly.

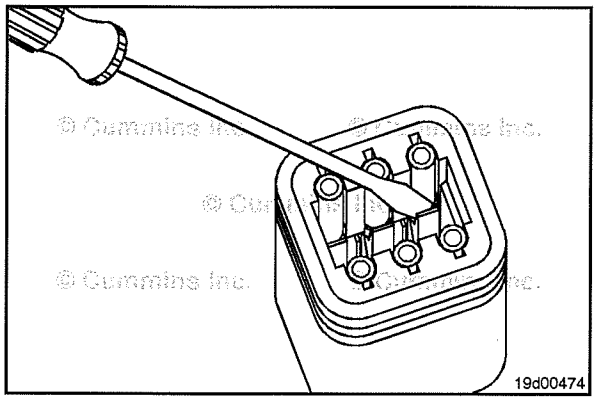
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.



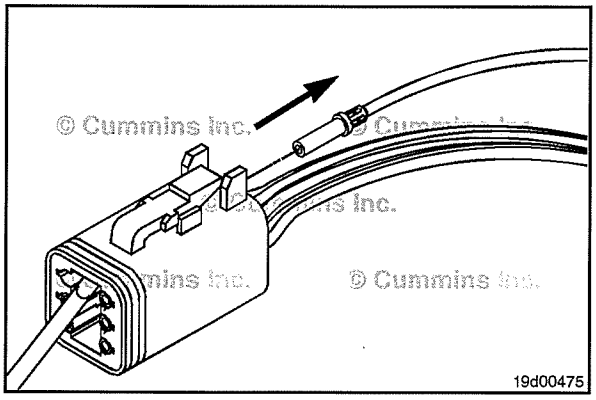


To replace the pin in the plug connector, grasp the orange wedge and pull the wedge straight out.



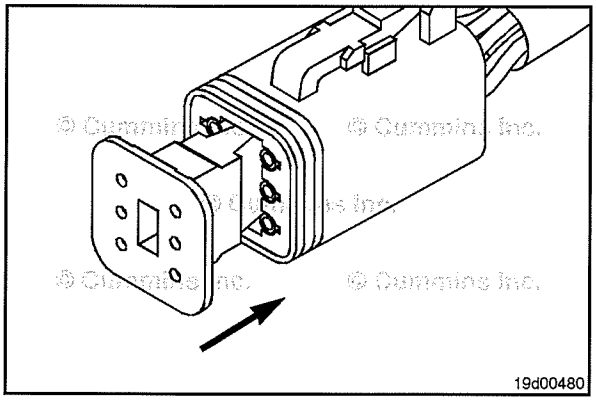
⚠CAUTION⚠
Locking finger can be easily broken. Care must be taken when using this tool. Do not force the tool into place.

To remove the contact out of the connector body, gently pull wire backward, while at the same time releasing the locking finger by moving it away from the contact with a screwdriver.



⚠CAUTION⚠
If more than one wire is repaired or if the connector body is replaced, be sure to insert the wires into the same location as they were in the original connector. If wires are not in the original location electrical damage can occur.

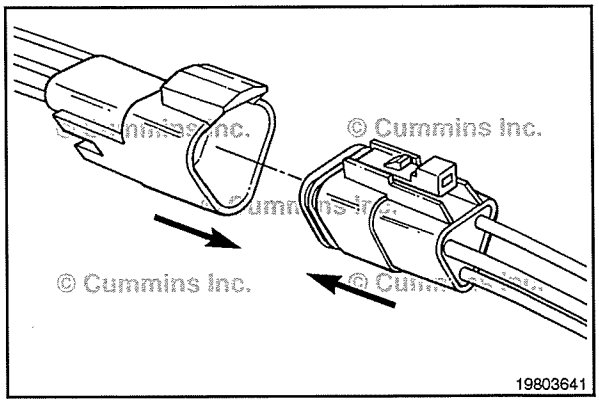
Replace the connector and install the wire and terminal into the seal at the back of the connector. Push the wires straight in until a click is felt. A slight tug will confirm that it is properly locked in place.



Once the wires are in place, insert the orange wedge with arrow pointing toward the exterior locking mechanism. Push the orange wedge in until it snaps in place.

Make sure both seals are in place at the back of the connector plug and receptacle. Make sure the rubber seal has been installed on the connector plug.

Push the connector plug into the connector receptacle until the external locking clip snaps into place.



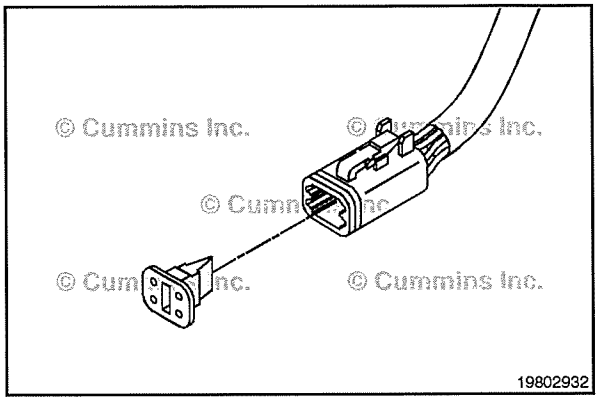
Deutsch DTM and DTP Connector Series (019-206)

Pin Replacement

The connector can have multiple pin configurations.

The connector pins can **not** be repaired or replaced. The connector **must** be replaced as a unit.

Refer to the connector replacement procedure for replacement procedures.



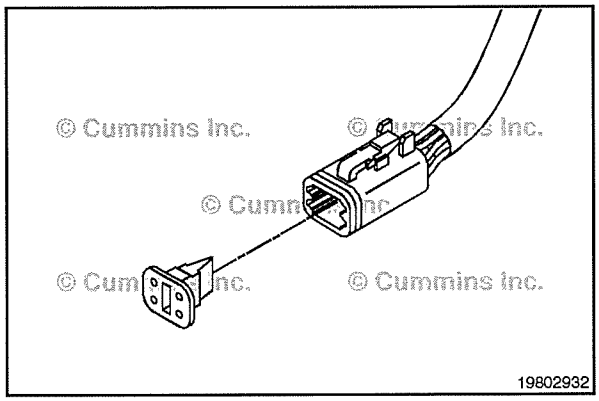
Connector Replacement

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

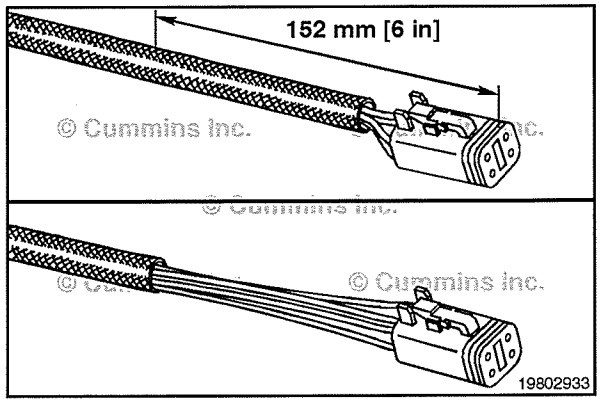
Refer to the appropriate wiring repair kit in the service tool table in the front of Section 19 for the correct repair connector.

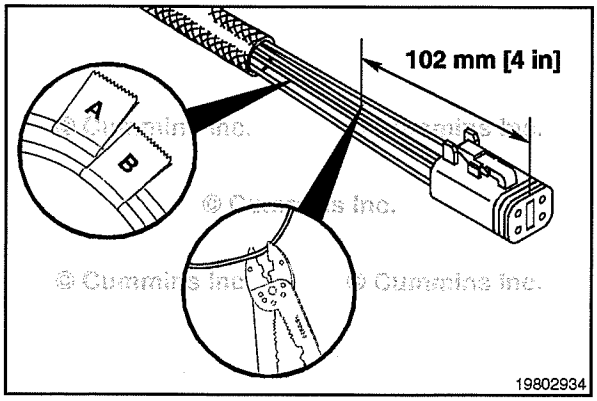
Refer to the wiring diagram in Section E for pin locations.

The replacement connector shown in the following procedure is a 4-pin Deutsch series. All sizes of DTM connectors are replaced in the same manner.



Measure 152 mm [6 in] back from the face of the connector and remove the wiring harness protective cover.



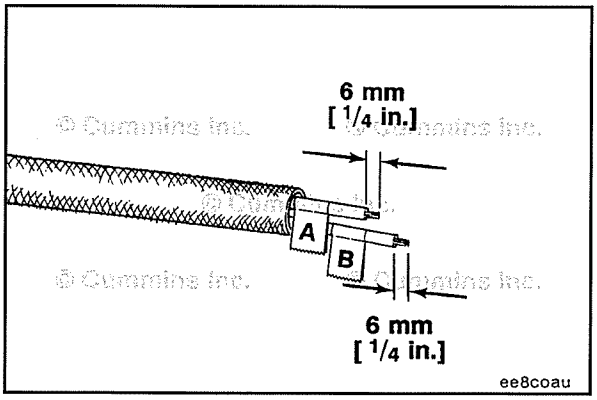


Before cutting the wires, measure and tag all wires.

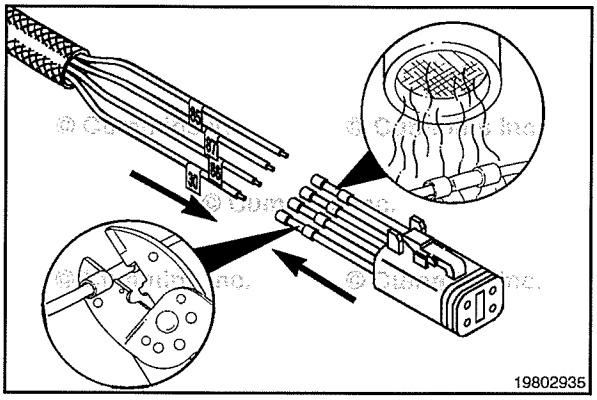
Use wire crimping tool, Part Number 3822930.

Cut wire A 102 mm [4 in] from the face of the connector.

Cut wire B 102 mm [4 in] from the face of the connector.

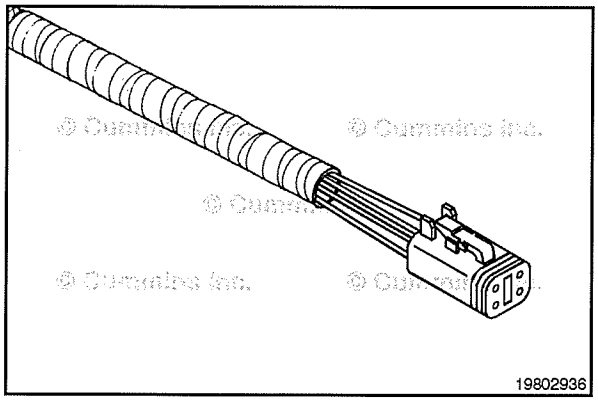


Use wire crimping tool, Part Number 3822930, to remove 6 mm [¼ in] of insulation from both electrical wires.



Install the connector repair wires and use wire crimping tool, Part Number 3822930, to crimp the terminals.

Use heat gun, Part Number 3822860, to heat the shrink tubing. The tubing will shrink and make the connection waterproof.



Wrap the wires with tape, for added protection, to complete the repair.

Deutsch HD10 Connector Series (019-207)

Pin Replacement

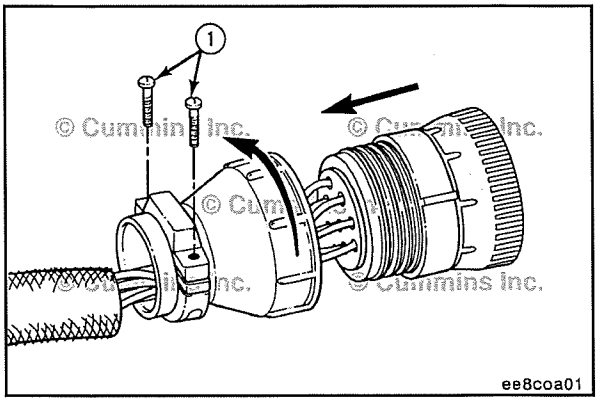
These connectors are available with multiple pin configurations.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire. Replace one contact at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

Unlock the connector. Rotate the locking tab **counterclockwise** by hand. Do **not** use pliers; they can damage the connector.

Remove the two clamp capscrews (1) from the rear of the connector. Turn the rear support of the connector **counterclockwise** until the two pieces are separated.



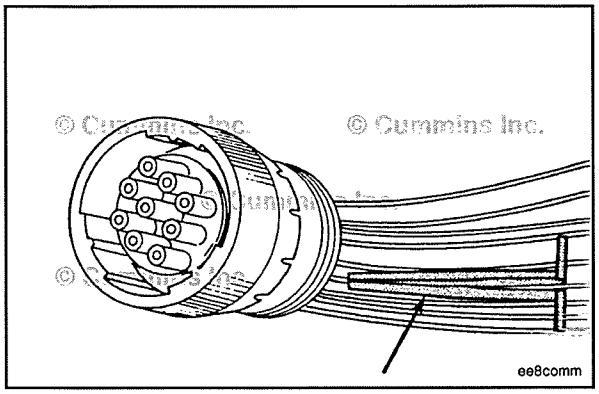
These connectors are available with multiple pin configurations.

Use the Deutsch extraction tool, listed in the table below, to remove a pin from the connector.

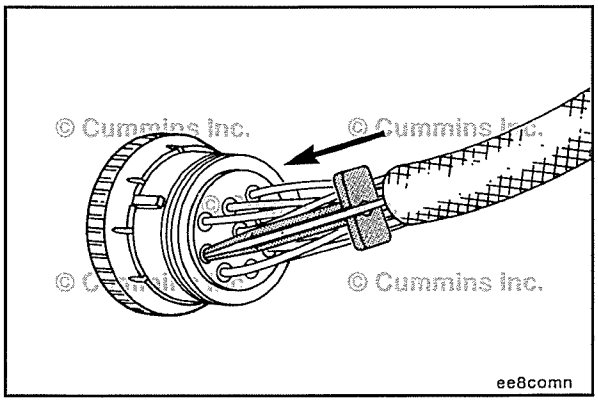
Tool Part Number	Wire Size
3824815	20 gauge
3822760	16 gauge
3824816	12 gauge

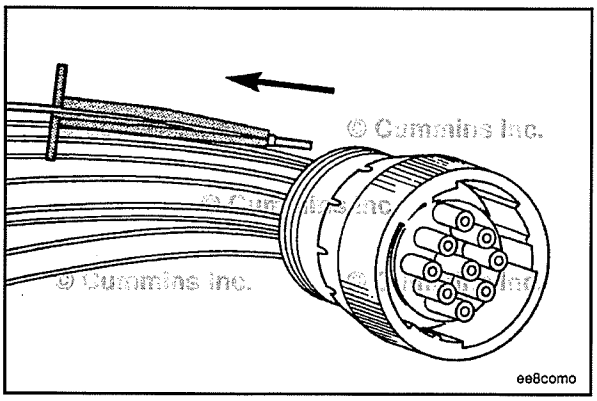
Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

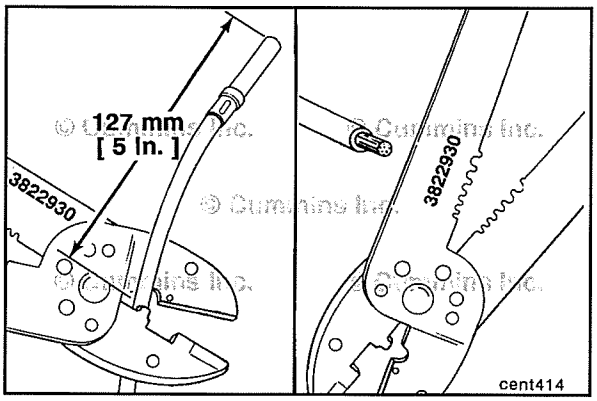


Push the tool into the connector approximately 25 mm [1 in] until it bottoms on the terminal flange.





Hold the tool on the terminal flange and pull the wire and the connecting pin out of the connector. Note and record the hole from which the pin is removed.



NOTE: The repair wire is 127 mm [5 in] long.

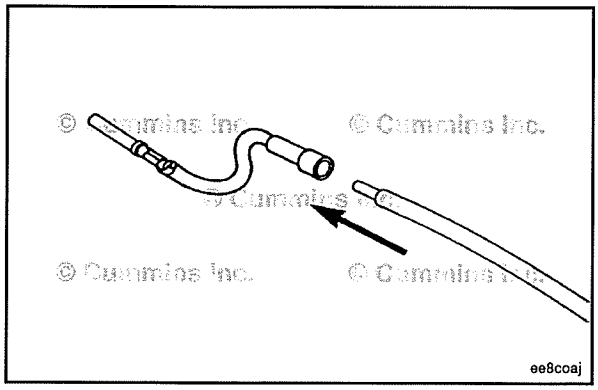
Remove about 6 mm [¼ in] of insulation from the wire.

Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

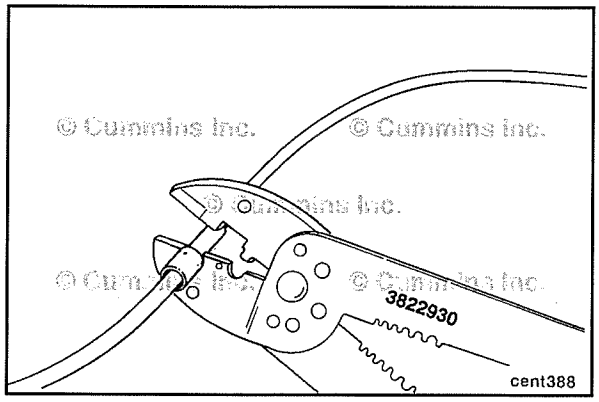
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.



Install a repair wire on the bare wire. Make sure the bare wire extends into the splice.

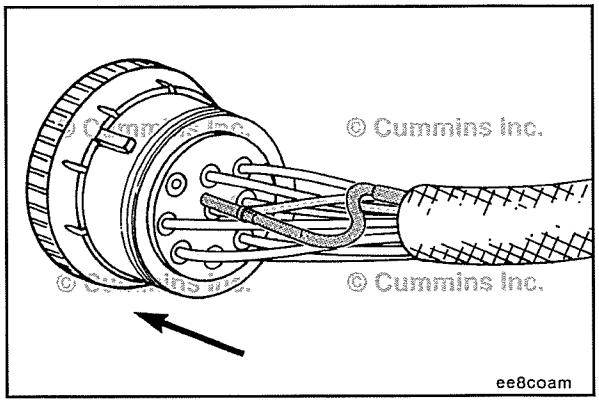


Use wire crimping tool, Part Number 3822930, to crimp the repair wire onto the bare wire.

Insert the pin into the correct hole of the connector.

The pin **must** lock into place and hold the wire in the connector.

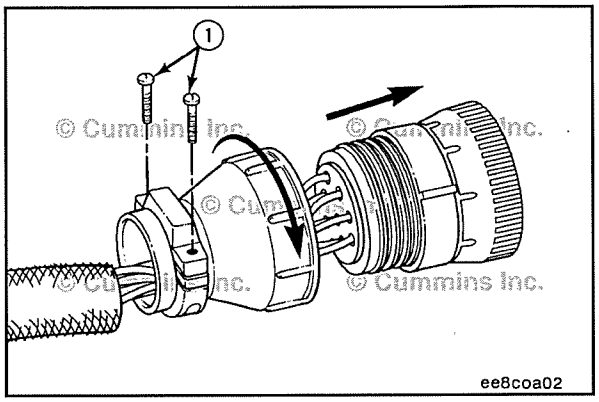
Pull the wire gently to make sure it is seated in the connector.



Install the rear connector support.

Tighten the two wire clamp capscrews.

Torque Value: 1 N•m [9 in-lb]



Connector Replacement

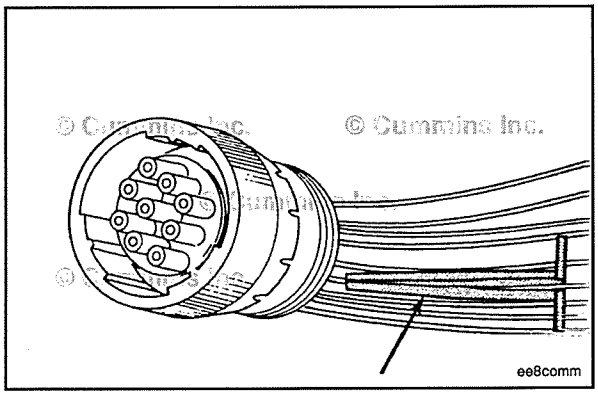
These connectors are available with multiple pin configurations.

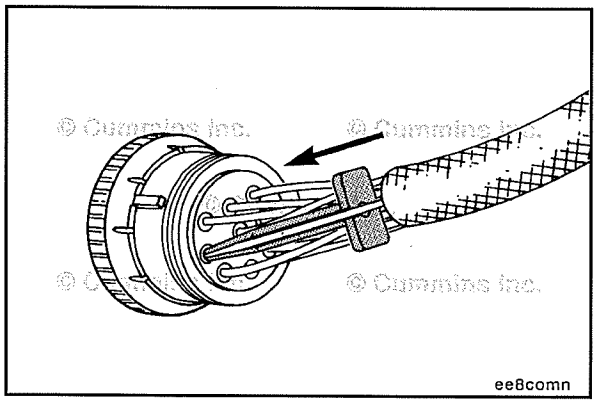
Use the Deutsch extraction tool, listed in the table below, to remove a pin from the connector.

Tool Part Number	Wire Size
3824815	20 gauge
3822760	16 gauge
3824816	12 gauge

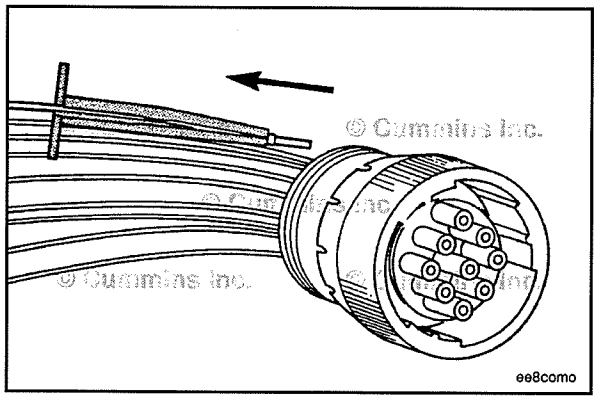
Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

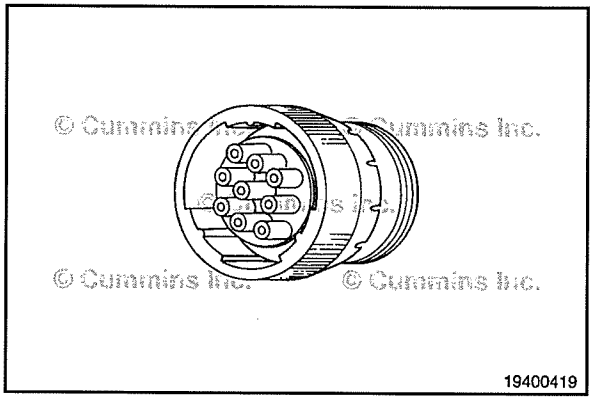




Push the tool into the connector approximately 25 mm [1 in] until it bottoms on the terminal flange.



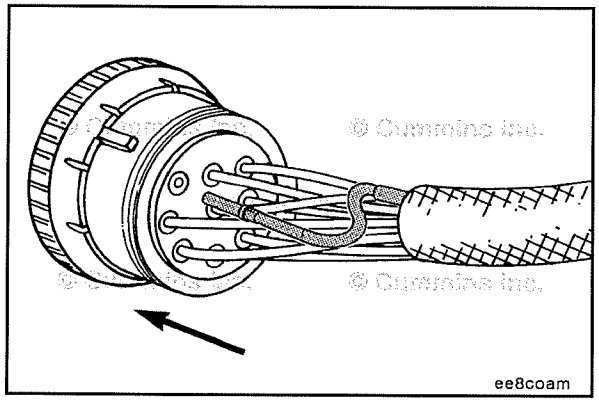
Hold the tool on the terminal flange and pull the wire and the connecting pin out of the connector. Note and record the hole from which the pin is removed.



Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.



Insert the pins into the correct holes of the replacement connector.

The pin **must** click into place and hold the wire in the connector.

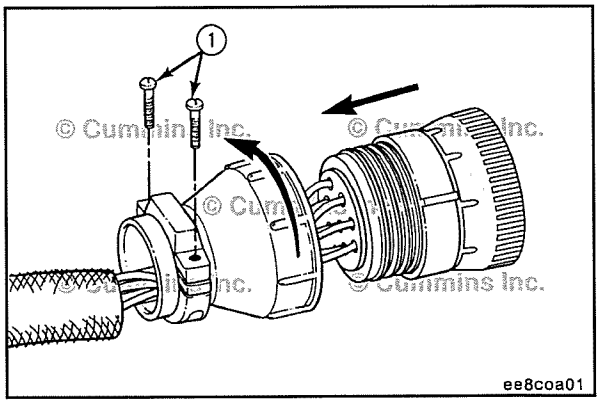
Pull the wire gently to make sure it is seated in the connector.

Deutsch HDP20 and HD30 Connector Series (019-208)

Pin Replacement

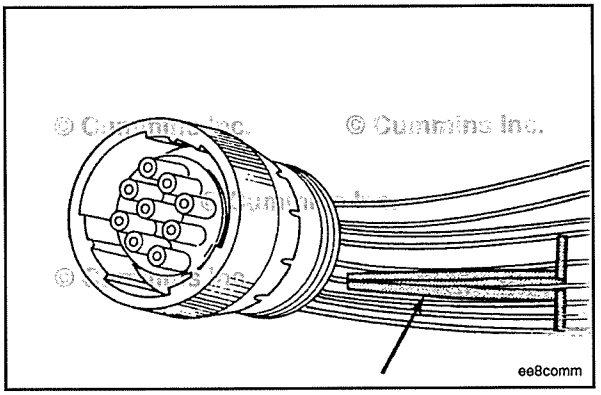
Remove the two clamp capscrews (1) from the rear of the connector.

Turn the retainer of the connector **counterclockwise** until the two pieces are separated.



Use the Deutsch extraction tool, listed in the table below, to remove a pin from the connector.

Tool Part Number	Wire Size
3824815	20 gauge
3822760	16 gauge
3824816	12 gauge



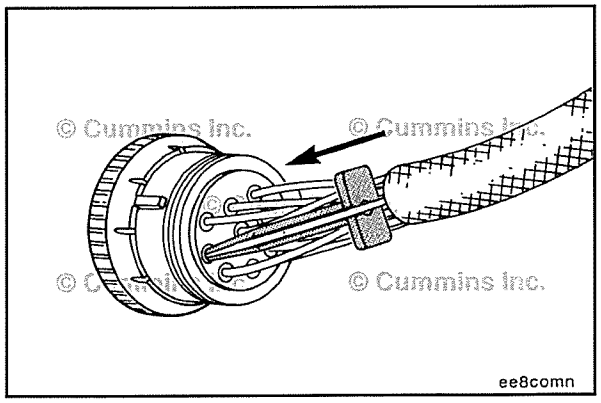
Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

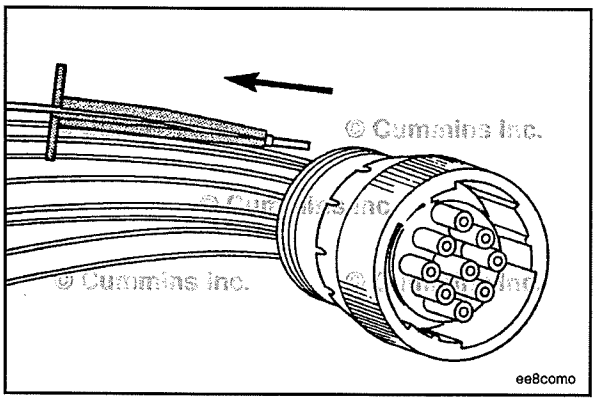
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

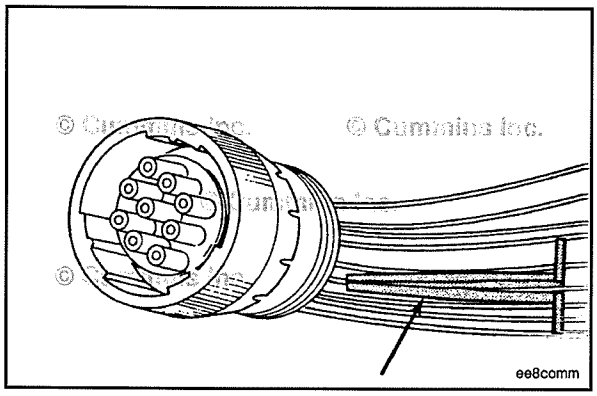
Refer to the wiring diagram in Section E for pin locations.

Push the tool into the connector about 25 mm [1 in] until it bottoms on the terminal flange.





Hold the tool on the terminal flange and pull the wire and the connecting pin out of the connector. Note and record the hole from which the pin is removed.



NOTE: The repair wire is 127 mm [5 in] long.

Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

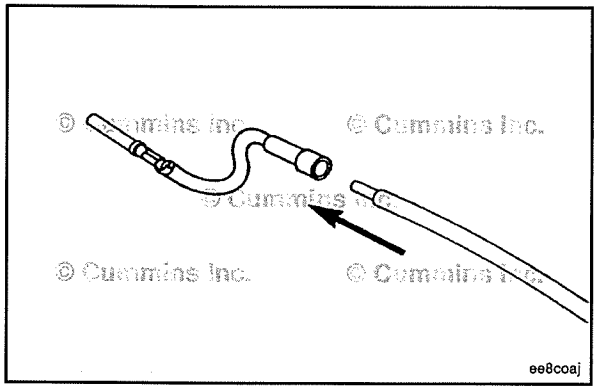
Refer to the appropriate wiring repair kit tools table in the front of Section 19 for the correct repair wire.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

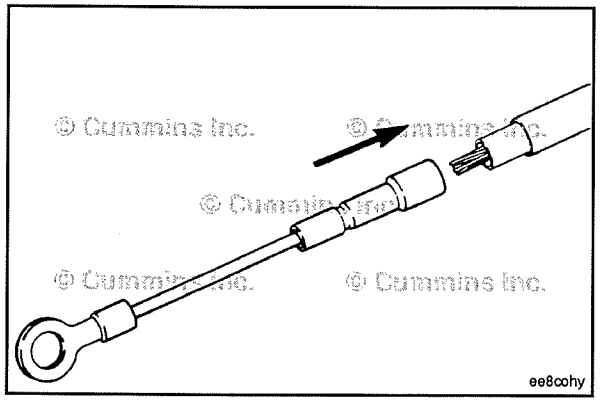
Use wire crimping tool, Part Number 3822930, to cut 127 mm [5 in] off the wire and pin.

Use the wire crimping tool to remove 6 mm [¼ in] of insulation from the wire.



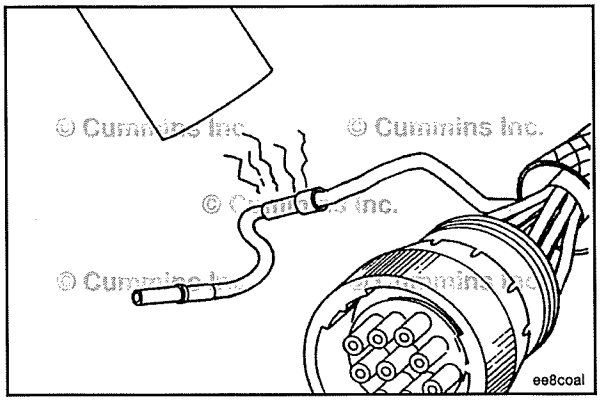
Install the correct repair wire on the bare wire.

Make sure the bare wire extends into the splice connector.



Use the wire crimping tool to crimp the repair wire onto the bare wire.

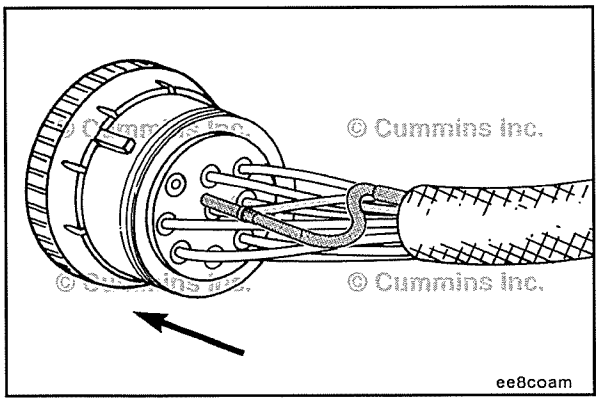
Use heat gun, Part Number 3822860, or an open flame to heat shrink the tubing around the wire. The tubing will shrink and make the connector waterproof.



Insert the pin into the correct hole of the connector.

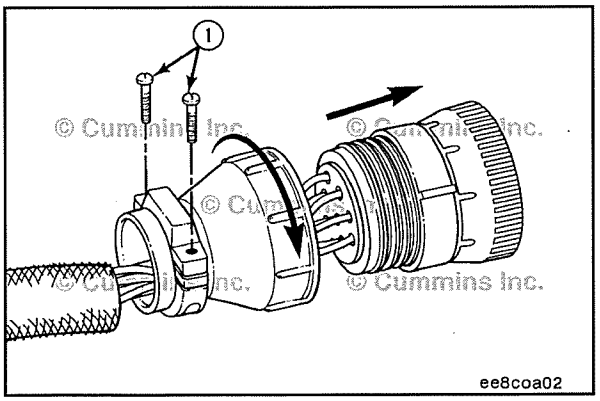
The pin **must** click into place and hold the wire in the connector.

Pull the wire gently to make sure it is seated in the connector.



Install the retainer. Tighten the two clamp capscrews.

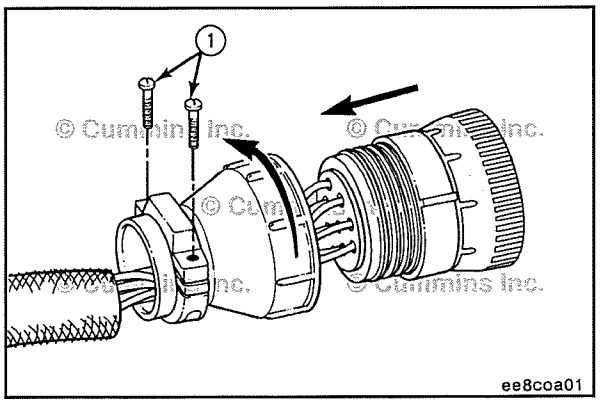
Torque Value: 1 N•m [9 in-lb]

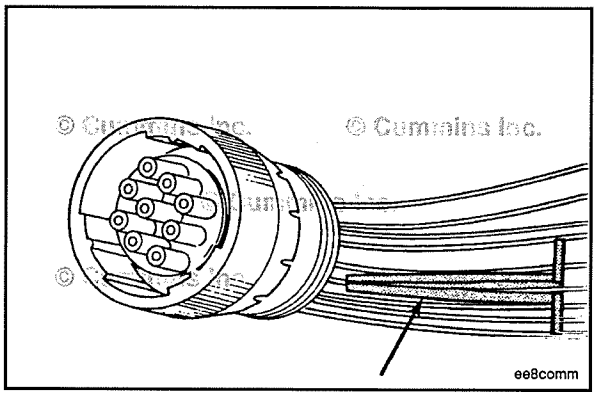


Connector Replacement

Remove the two clamp capscrews (1) from the rear of the connector.

Turn the retainer of the connector **counterclockwise** until the two pieces are separated.





Use the Deutsch extraction tool, listed in the table below, to remove a pin from the connector.

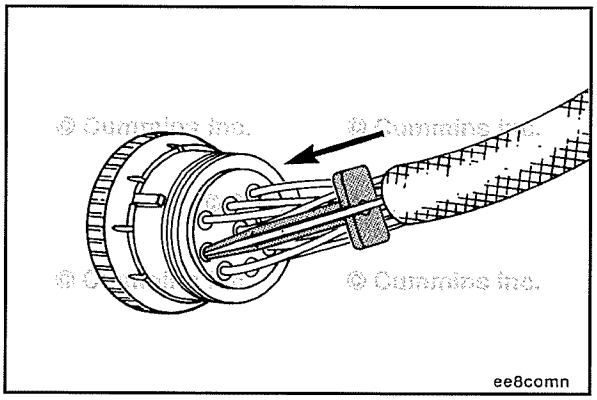
Tool Part Number	Wire Size
3824815	20 gauge
3822760	16 gauge
3824816	12 gauge

Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

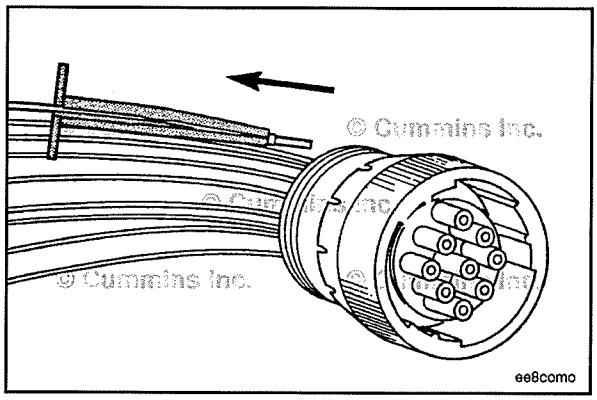
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

Refer to the wiring diagram in Section E for pin locations.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.



Push the tool into the connector about 25 mm [1 in] until it bottoms on the terminal flange.

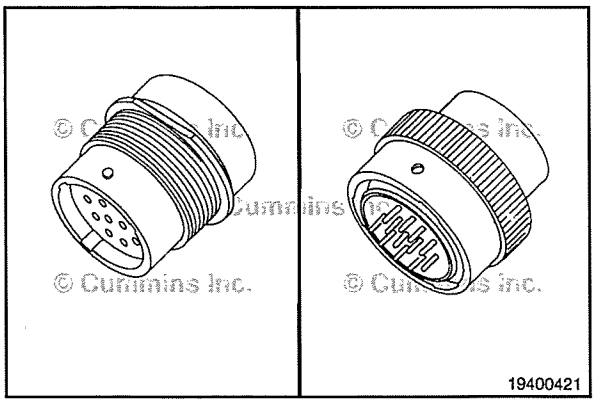


Hold the tool on the terminal flange and pull the wire and connecting pin out of the connector. Note and record the hole from which the pin is removed.

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

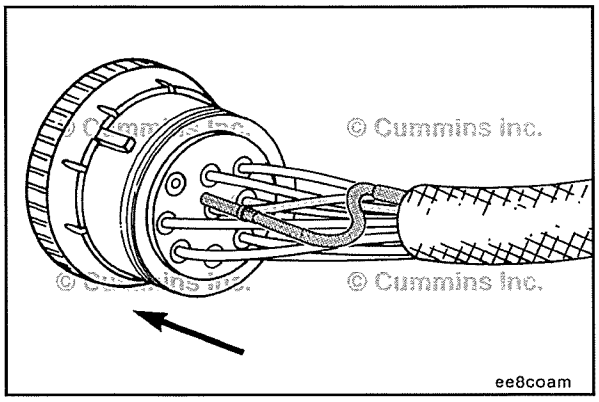
Refer to the wiring diagram in Section E for pin locations.



Insert the pins into the correct holes of the connector.

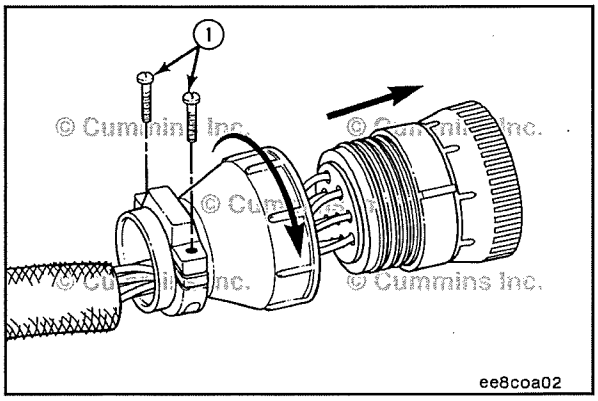
The pin **must** click into place and hold the wire in the connector.

Pull the wire gently to make sure it is seated in the connector.



Install the retainer. Tighten the two clamp capscrews

Torque Value: 1 N•m [9 in-lb]

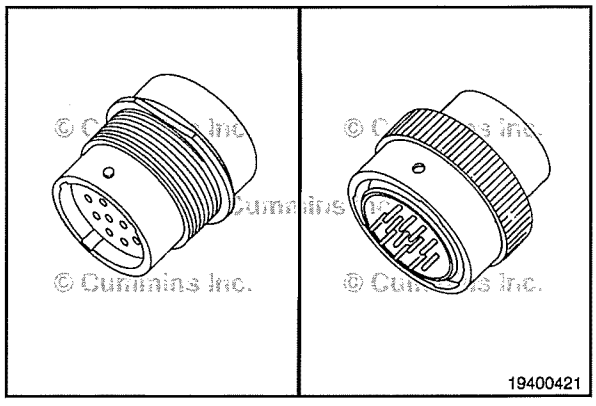


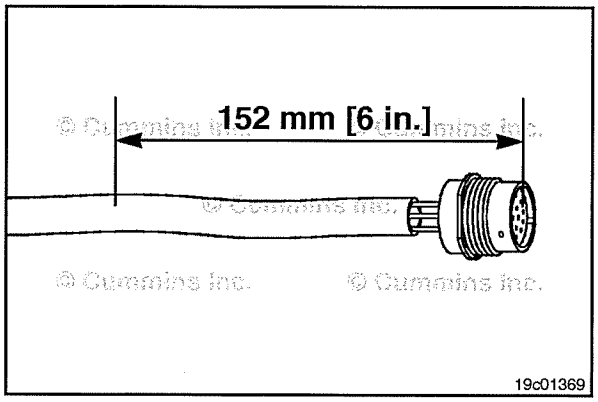
ITT Cannon Connector Series (019-209)

Pin Replacement

The connector pins can **not** be repaired or replaced. The connector **must** be replaced as a unit.

Refer to the Connector Replacement procedure for replacement instructions.





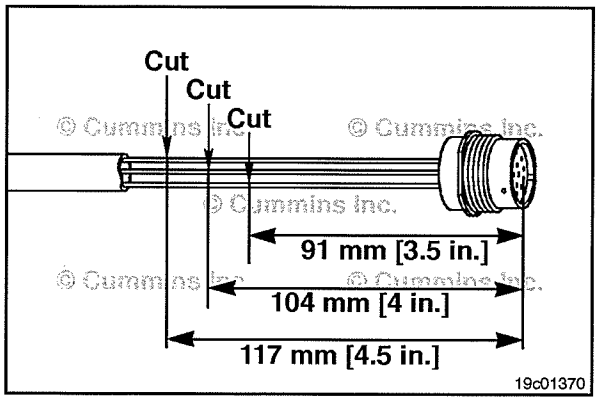
Connector Replacement

Measure 152 mm [6 in] back from the face of the connector and remove the wiring harness protective cover.

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

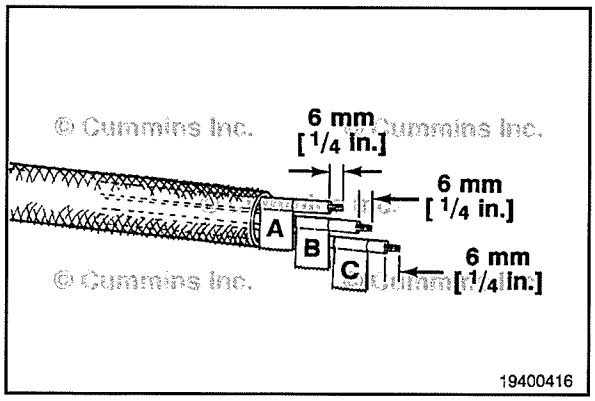
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

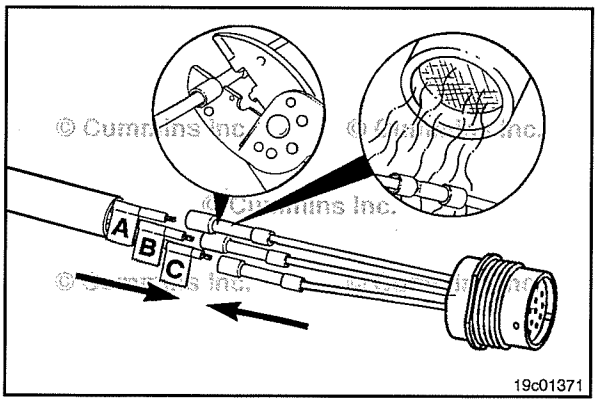


Use wire crimping tool, Part Number 3822930, to cut the wires. Cut the first wire 91 mm [3-½ in] from the face of the connector.

Cut the remaining seven wires in increments of 12 mm [½ in] back from the previous cut.



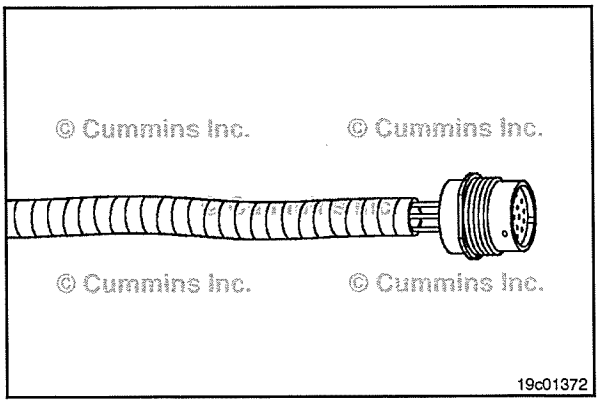
Use the wire crimping tool to remove 6 mm [¼ in] of insulation from all eight electrical wires.



Install the terminal repair wires on the bare wires and use the wire crimping tool to crimp the terminal.

Use heat gun, Part Number 3822860, or an open flame to heat the shrink tubing. The tubing will shrink and make the connection waterproof.

For added protection, wrap the wire with tape to complete the repair.



Packard Relay Connector (019-211)

Pin Replacement

The connector pins can **not** be replaced. The connector **must** be replaced as a unit.

Refer to the Connector Replacement procedure for replacement instructions.

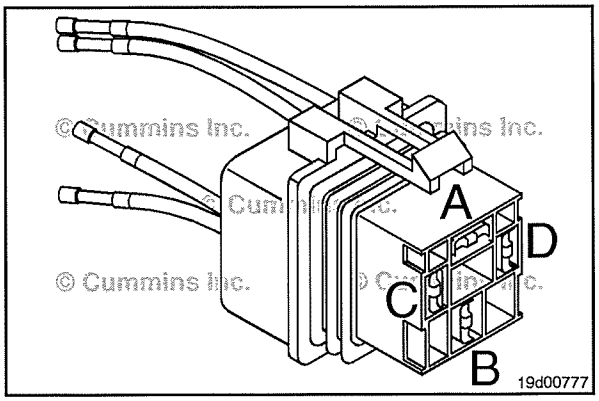
Connector Replacement

Before installing the new connector, perform a test fit to make sure the connector is keyed properly.

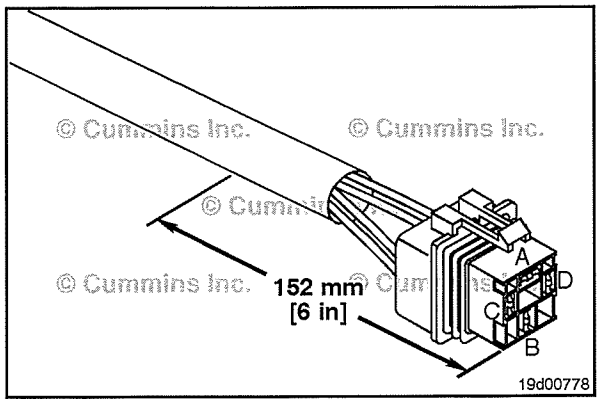
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

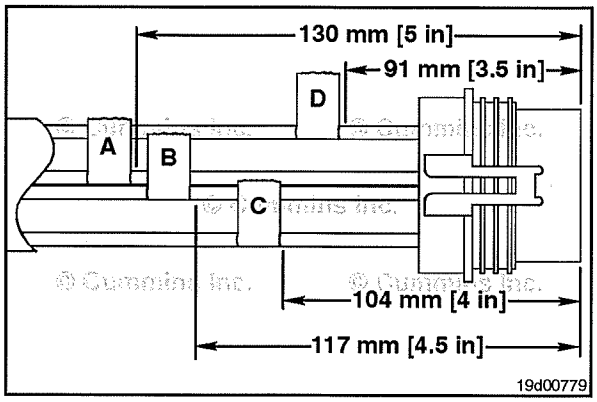
Refer to the wiring diagram for pin locations.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.



Measure 152 mm [6 in] from the face of the connector, and remove the wiring harness protective cover.





Before cutting the wires measure and tag them.

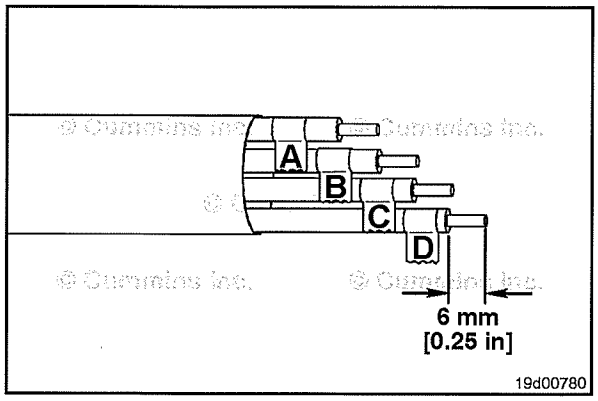
Use wire crimping tool, Part Number 3822930.

Cut wire A 130 mm [5 in] from the face of the connector.

Cut wire B 117 mm [4-½ in] from the face of the connector.

Cut wire C 104 mm [4 in] from the face of the connector.

Cut wire D 91 mm [3-½ in] from the face of the connector.



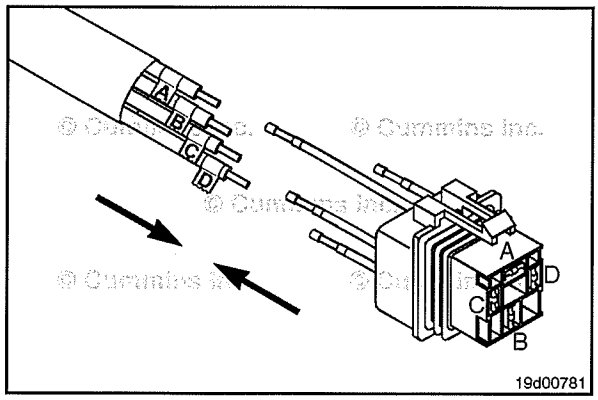
Use crimping tool, Part Number 3822930, to remove 6 mm [¼ inch] of insulation from the electrical wires.

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

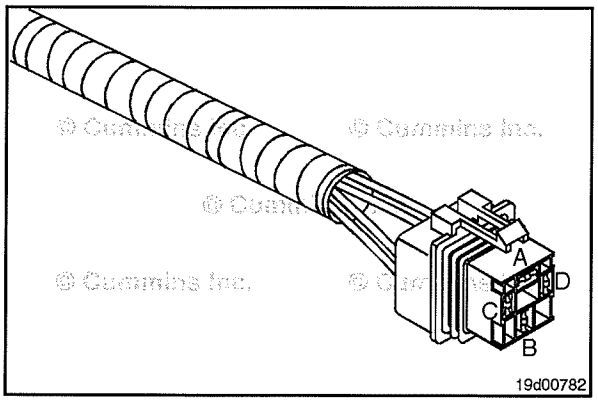
Refer to the wiring diagram for pin locations.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.



Install the terminal repair wires on the bare wires. Use wire crimping tool, Part Number 3822930, to crimp the terminals.

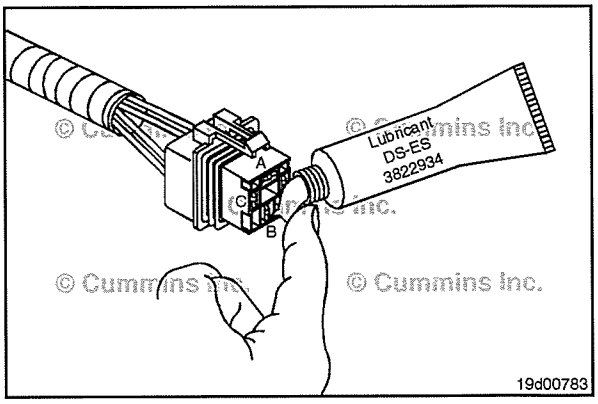
Use heat gun, Part Number 3822860, or an open flame to heat the shrink tubing. The tubing will shrink and make the connection waterproof.



Wrap the wires with tape, for added protection, to complete the repair.

⚠CAUTION⚠
Use only Cummins-recommended lubricant DS-ES, Part Number 3822934, other lubricants, such as lubricating oil or grease, in the connectors can cause electronic control unit damage, poor performance, or premature connector pin wear.

Apply a small amount of lubricant to the connector terminals. Before installing, fill the entire connector cavity with lubricant.

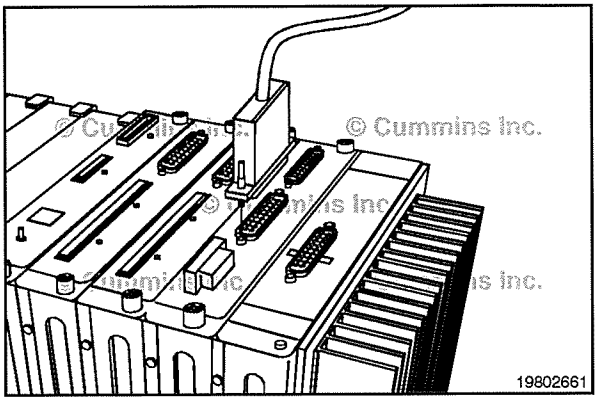


D-Sub Miniature Connector Series (019-213)

Pin Replacement

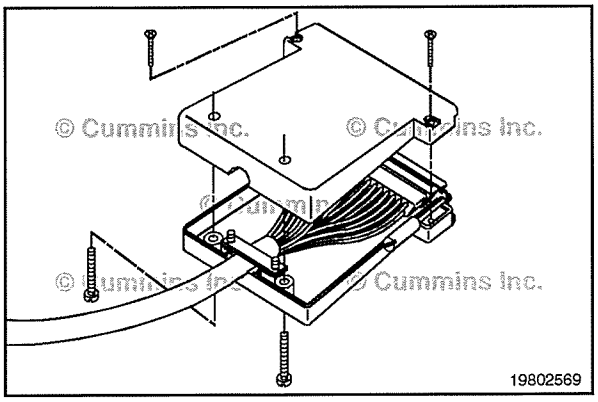
The D-sub miniature connector is used to attach the appropriate harnesses to the ECM.

Remove the connector.

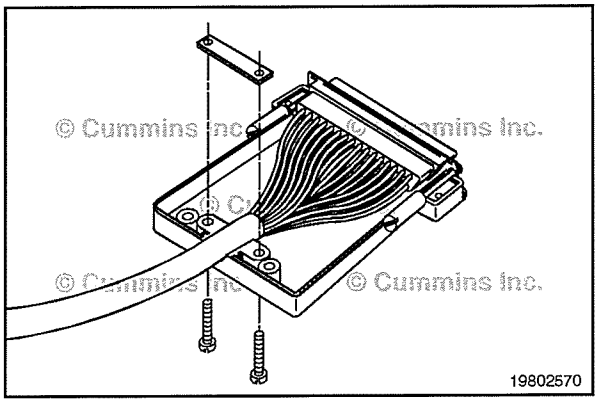


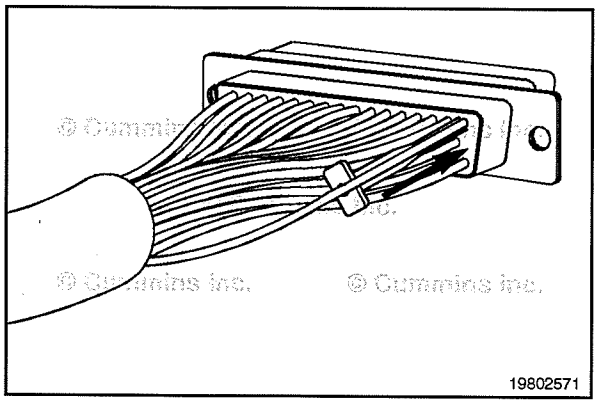
Remove the backshell from the connector.

Locate the damaged pin or wire.



Remove the strain relief to be able to work with the damaged pin.





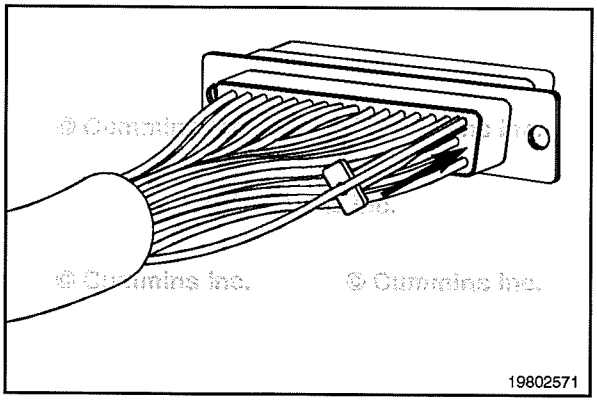
Use the D-sub miniature extraction tool, Part Number 3163971, place over the wire to remove a pin from the connector.

Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

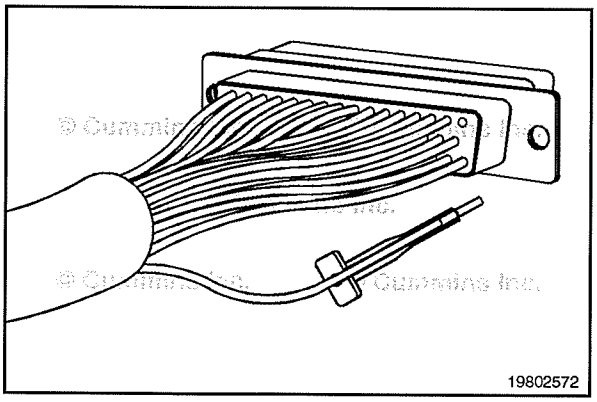
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

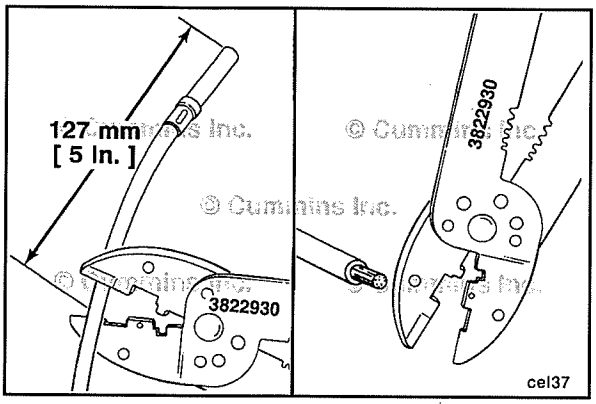
Refer to the wiring diagram in Section E for pin locations.



With a twisting motion, push the pin extraction tool into the connector approximately 25 mm [1 in] until it bottoms on the terminal flange. A click will be heard when the extraction tool is in place.



Hold the tool on the terminal flange and pull the wire and connecting pin out of the connector. Note and record the hole from which the pin is removed.

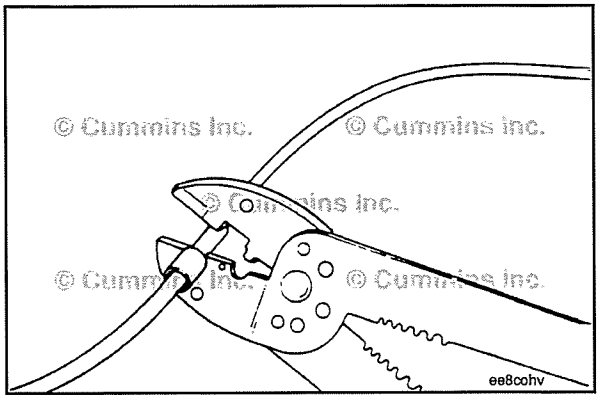


NOTE: The repair wire is 127 mm [5 in] long.

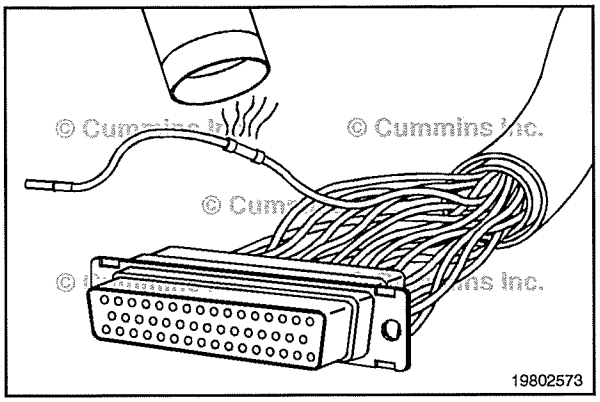
Use wire crimping tool, Part Number 3822930, to cut 127 mm [5 in] off the wire and pin.

Use the crimping tool to remove 6 mm [¼ in] of insulation from the wire.

Use the wire crimping tool to crimp the repair wire onto the bare wire.



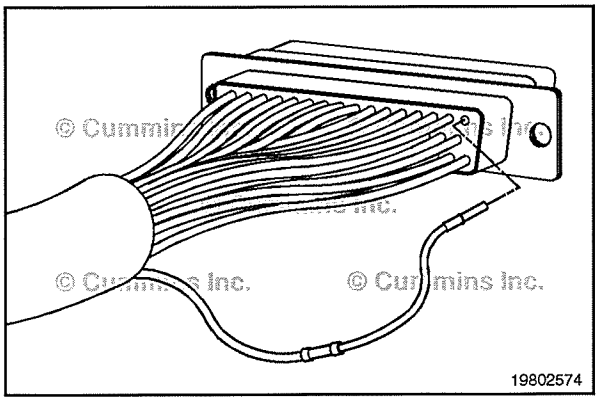
Use heat gun, Part Number 3822860, to heat shrink the tubing around the wire. The tubing will shrink and make the connection waterproof.



Insert the pin into the correct hole of the connector.

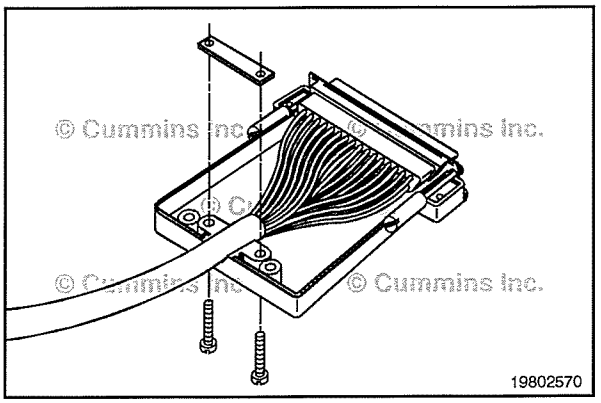
The pin **must** click into place and hold the wire in the connector.

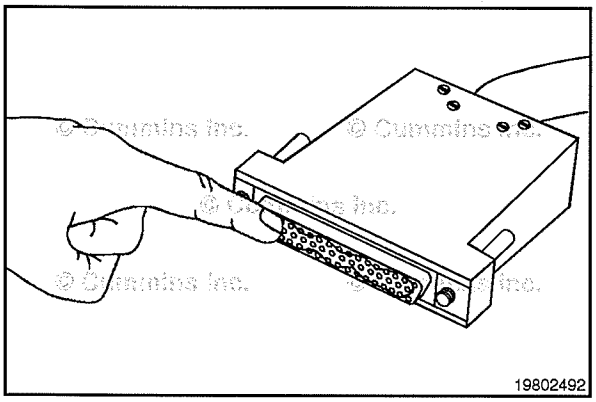
Pull the wire gently to make sure it is seated in the connector.



Tighten the strain relief.

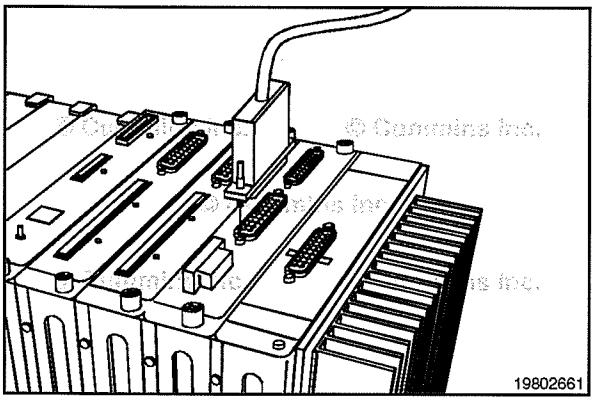
Complete the assembly of the backshell by placing the two halves together and tightening the screws.





⚠CAUTION⚠
Use only Cummins-recommended lubricant DS-ES, Part Number 3822934. Other lubricants, such as lubricating oil or grease, in the connectors can cause ECM damage, poor engine performance, or premature connector pin wear.

Apply a small amount of lubricant to the connector terminals. Do **not** fill the entire connector cavity with lubricant.



Connector Replacement

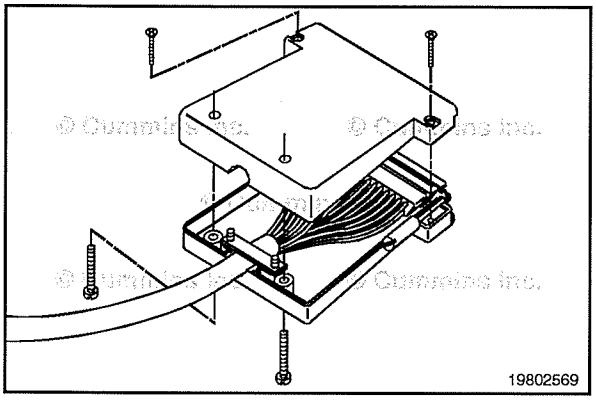
The 50-pin D-sub miniature connector is used to attach the appropriate harnesses to the ECM.

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.



Remove the backshell from the connector. Remove the stain relief.

To replace the connector use the D-sub miniature extraction tool, Part Number 3163971, place over each wire to remove all pins from the connector.

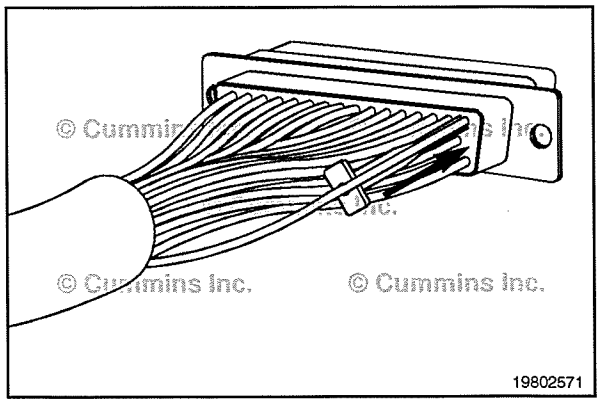
Before installing the new connector, perform a fit test to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

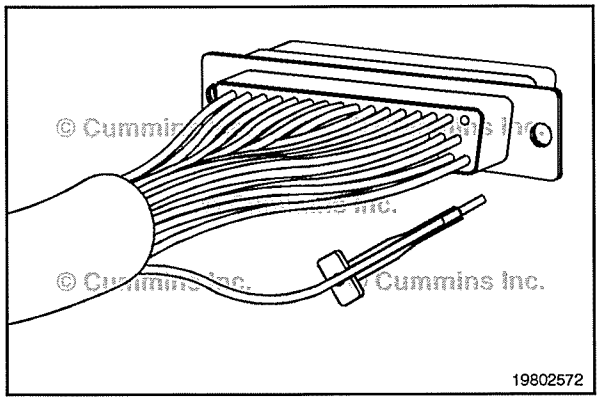
Refer to the wiring diagram in Section E for pin locations.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

With a twisting motion, push the pin extraction tool into the connector approximately 25 mm [1 in] until it bottoms on the terminal flange. A click will be heard when the extraction tool is in place.



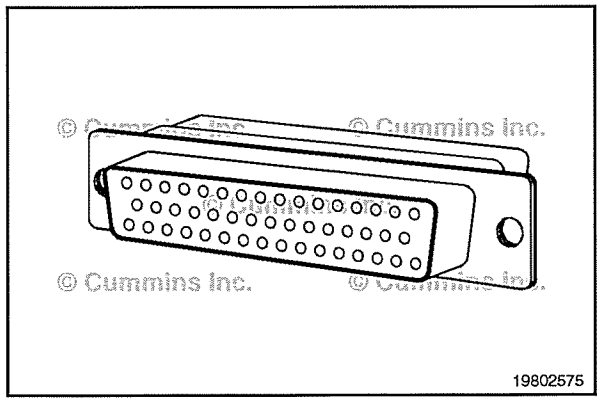
Hold the tool on the terminal flange and pull the wire and connecting pin out of the connector. Note and record the hole from which the pin was removed.

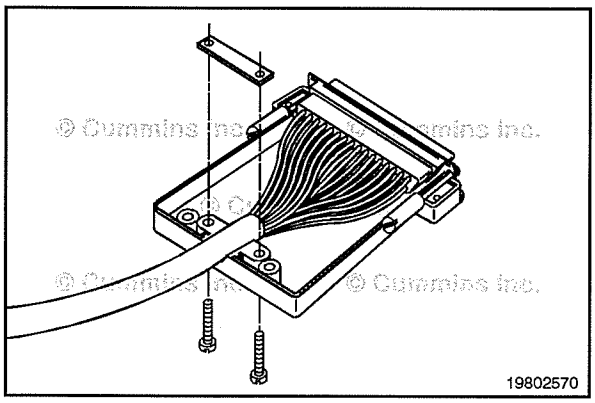


Insert the pins into the correct holes of the replacement connector.

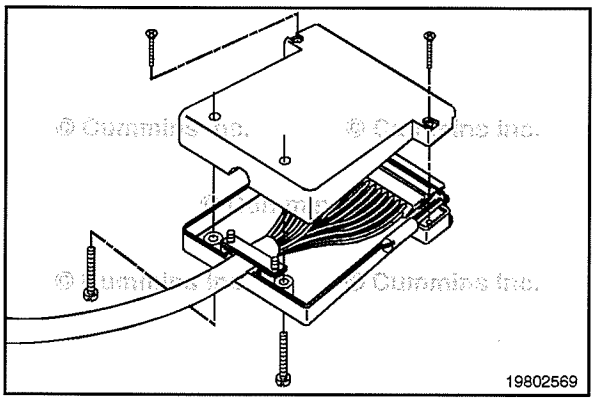
Each pin **must** click into place and hold the wires in the connector.

Pull each wire gently to make sure it is seated in the connector.

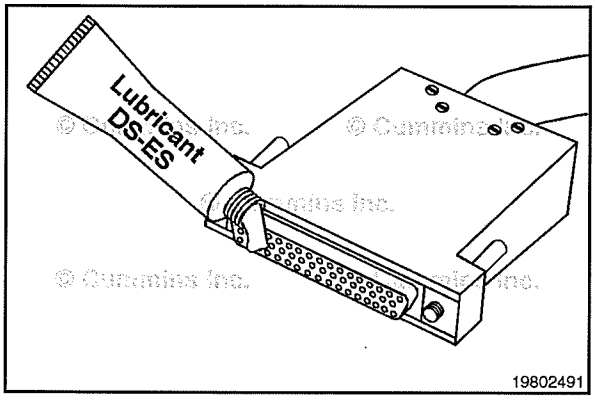




Place the connector pin block onto the lower half of the backshell. Place all wires within the strain relief and tighten the strain relief.

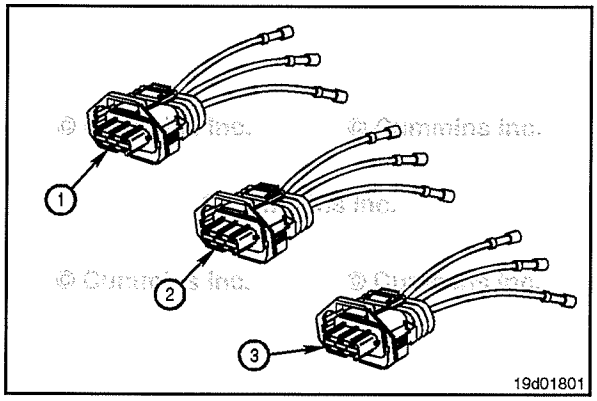


Complete the assembly of the connector by placing the upper half of the backshell onto the lower half and tightening the screws.



ΔCAUTIONΔ
Use only Cummins-recommended lubricant DS-ES, Part Number 3822934. Other lubricants, such as lubricating oil or grease, in the connectors can cause ECM damage, poor engine performance, or premature connector pin wear.

Apply a small amount of lubricant to the connector terminals. Do **not** fill the entire connector cavity with lubricant.



Bosch™ Actuator and Sensor Connector Series (019-214)

Pin Replacement

The connector is **not** repairable. If any part of the connector becomes damaged, replace the connector with the appropriate repair connector.

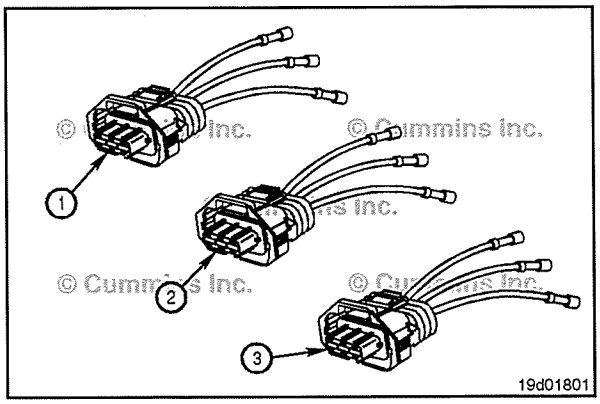
Connector Replacement

Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

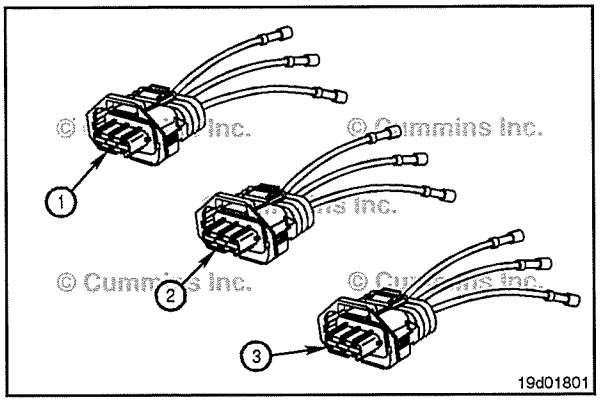
Refer to the wiring diagram in Section E for pin locations.

The connector is **not** repairable. If any part of the connector becomes damaged, replace the connector with the appropriate repair connector.

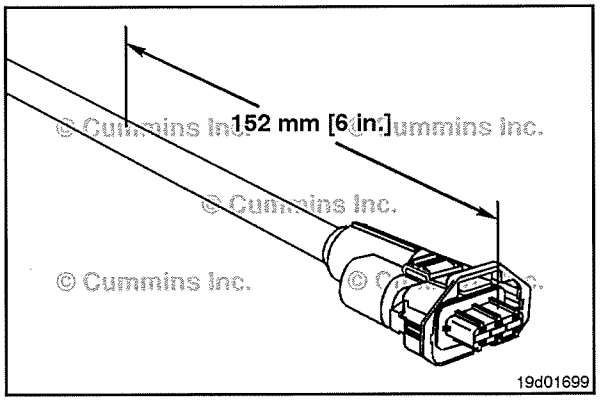


The connectors have different keying and can **not** be interchanged with each other.

Make sure the correct wires are connected to pin 1, pin 2, and pin 3, when replacement is necessary.



Measure 152 mm [6 in] back from the face of the connector, and remove the wiring harness protective cover.

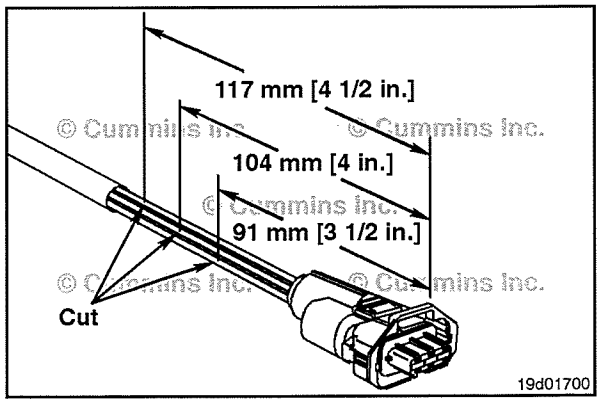


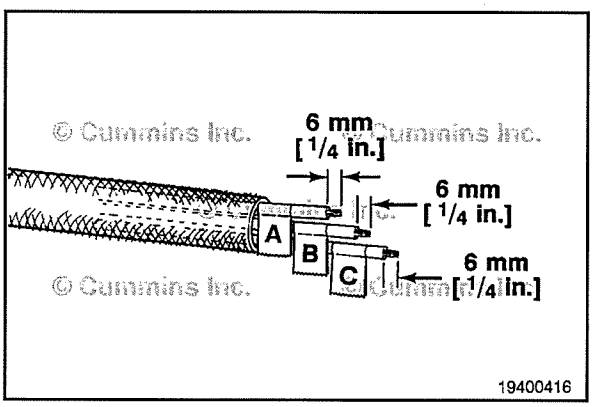
Before cutting the wires, measure and tag the three wires.

Use wire cutters to cut wire 1 117 mm [4-½ in] from the face of the connector.

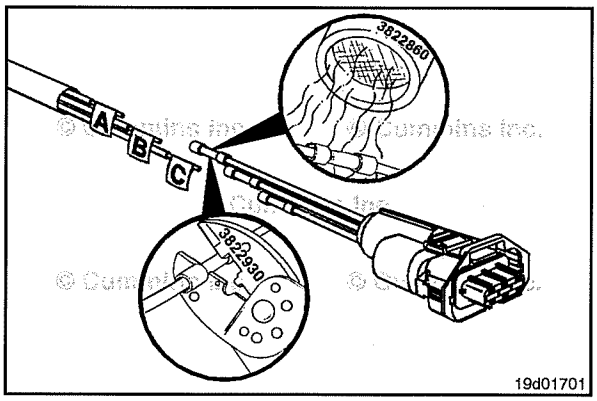
Use wire cutters to cut wire 2 104 mm [4 in] from the face of the connector.

Use wire cutters to cut wire 3 91 mm [3-½ in] from the face of the connector.



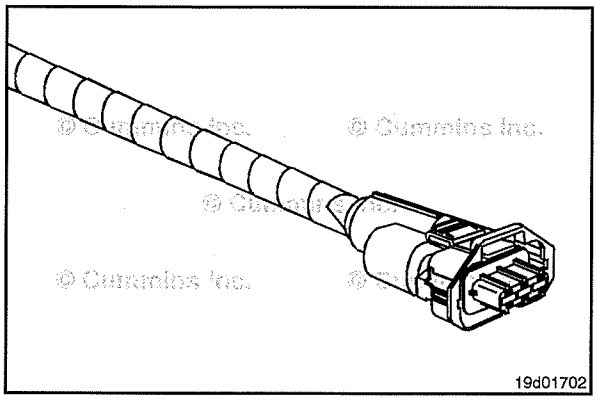


Use wire crimping tool, Part Number 3822930, to remove 6 mm [¼ in] of insulation from all electrical wires.

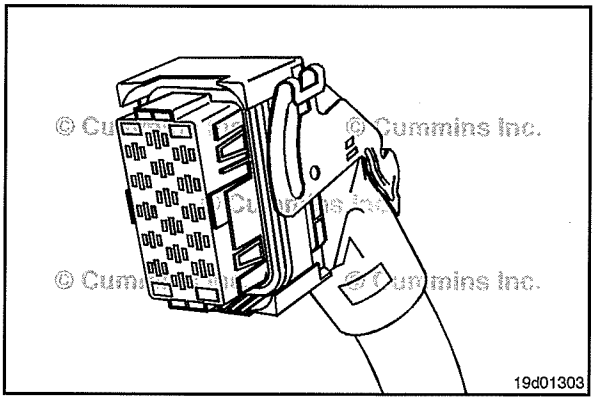


Install the pin repair wires and connector onto the bare wires of the harness and use the wire crimping tool to crimp each repair wire onto the harness.

Use heat gun, Part Number 3822860, to shrink the tubing. The tubing will shrink and make the connection waterproof.



Wrap the wires with tape, for added protection, to complete the repair.



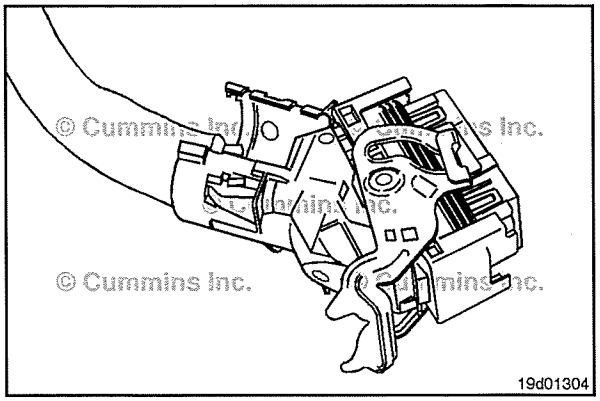
Bosch™ ECM Injector Driver Connector Series (019-215)

Pin Replacement

This connector is used to attach the appropriate harness to the ECM.

Remove the connector shell by slightly bending the connector shell (black) away from the two tangs that hold the shell to the ECM connector (red).

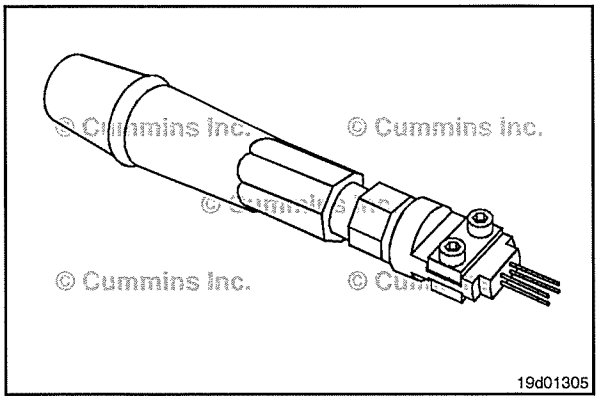
Before pins can be removed, they **must** be unlocked. Slide the purple tabs on the edges of the connector sideways at the same time. When unlocked, the purple tab will align with a slot, making the entire length of the purple tab visible.



Use Bosch® extraction tool, Part Number 3164091, place over the wire to remove a pin from the connector.

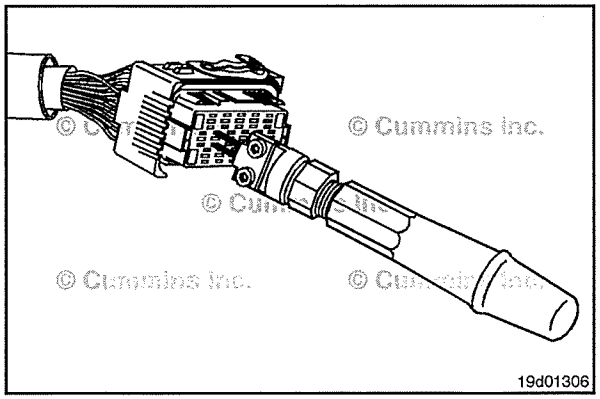
Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

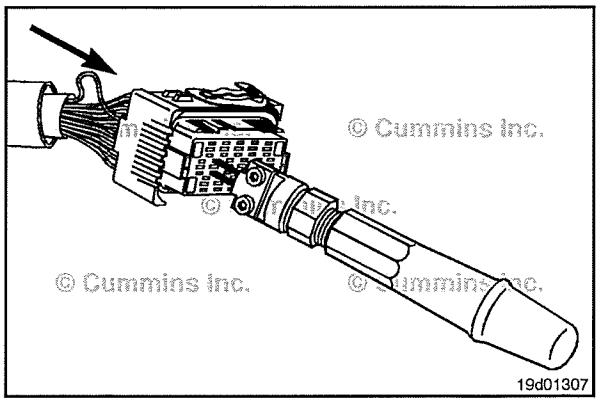


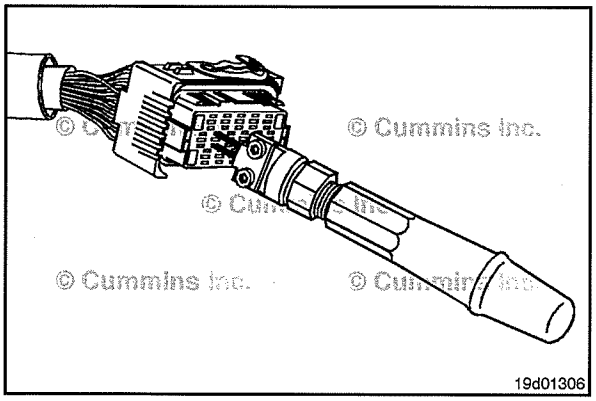
Insert the pin extraction tool into the unlocking holes in the connector.

Do **not** push the tool all the way into the connector.

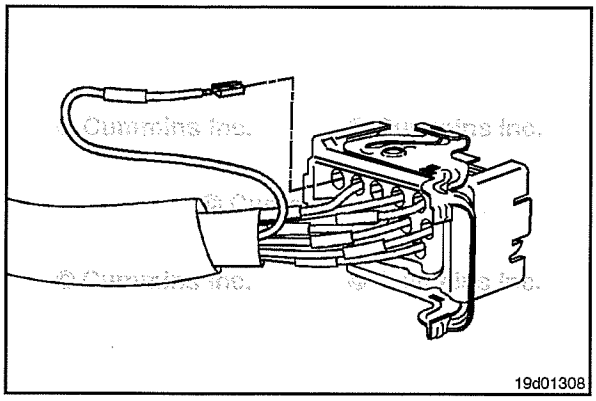


Push the corresponding wire toward the pin extraction tool.



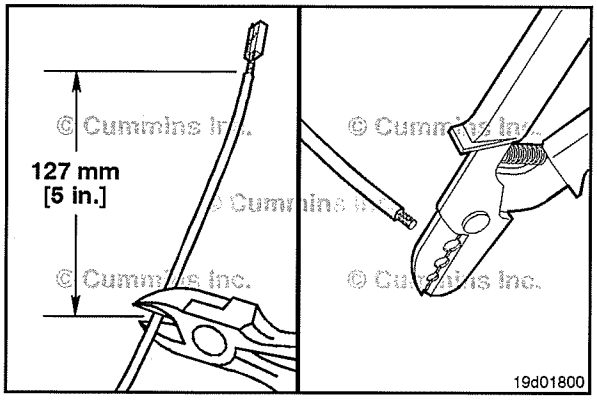


Press the pin extraction tool all the way into the connector.



⚠CAUTION⚠
If the wire is difficult to remove, do not pull hard on wire; the locking tang of the wire terminal will stick or the terminal will pull off the wire and remain in the connector.

Carefully pull the wire out of the connector. If it is difficult to remove, repeat the entire procedure.

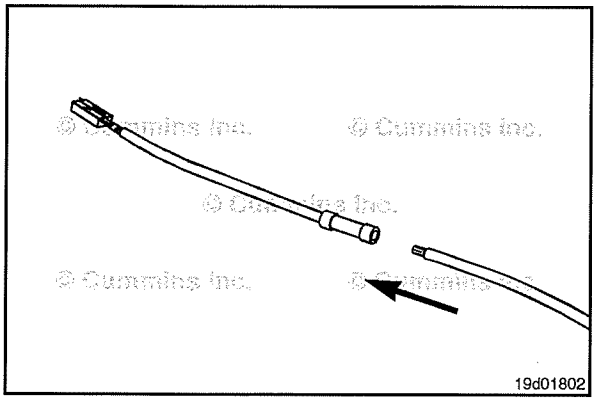


NOTE: The repair wire is 127 mm [5 in] long.

Use wire cutters to cut 127 mm [5 in] off the wire and pin.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

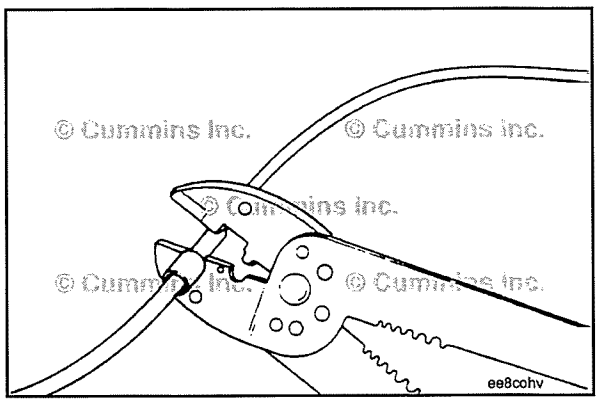
Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.



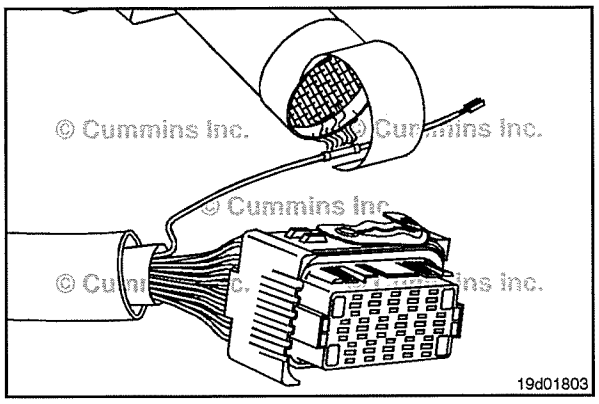
Install the repair wire on the bare wire.

Make sure the bare wire extends into the splice connector.

Use the wire crimping tool, Part Number 3822930, to crimp the repair wire onto the bare wire.



Use heat gun, Part Number, 3822860, to heat the shrink tubing around the wire. The tubing will shrink and make the connection waterproof.



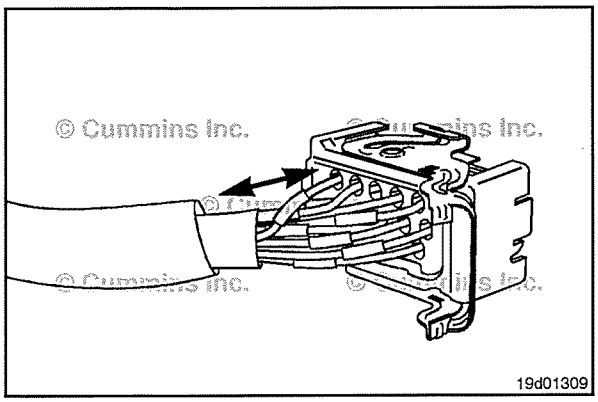
The wire terminal has locating pins that **only** allow it to be inserted in a certain orientation.

Insert the wire from the backside of the connector.

Pull the wire into the connector.

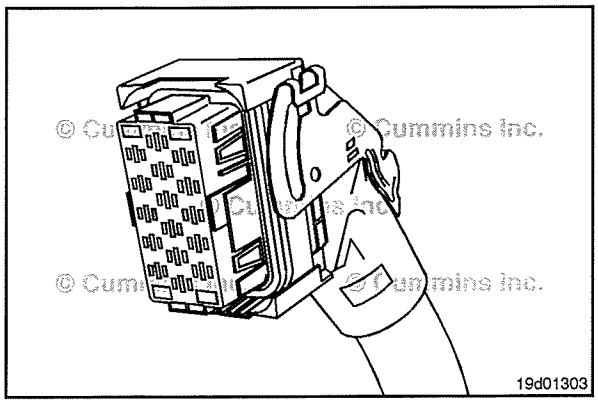
Pull the wire gently to make sure it is locked into the connector.

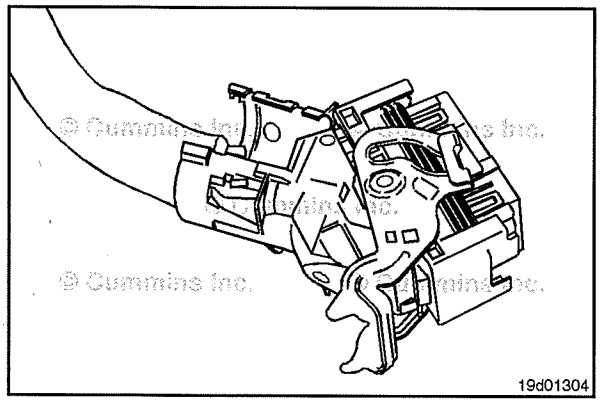
NOTE: If the wire's locking tang did **not** latch, then remove the wire and pry the tang away from the terminal and repeat this step.



Connector Replacement

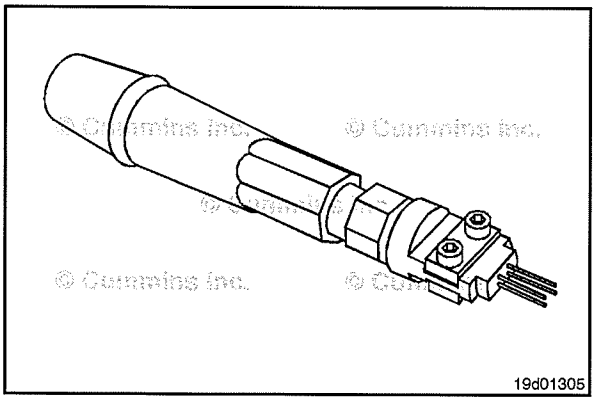
This connector is used to attach the harness to the ECM.





Remove the connector shell by slightly bending the connector shell (black) away from the two tangs that hold the shell to the ECM connector (red).

Before pins can be removed, they **must** be unlocked. Slide the purple tabs on the edges of the connector sideways at the same time. When unlocked, the purple tab will align with a slot, making the entire length of the purple tab visible.

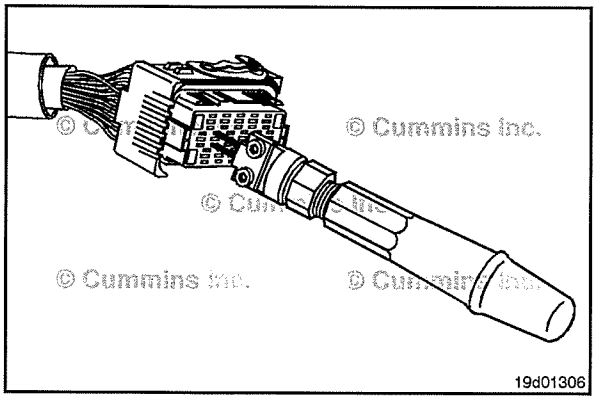


Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

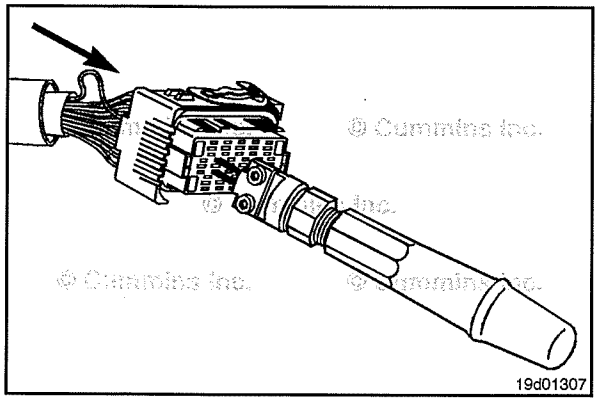
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

To replace the connector, use Bosch® extraction tool, Part Number 3164091, over each wire to remove all pins from the connector.



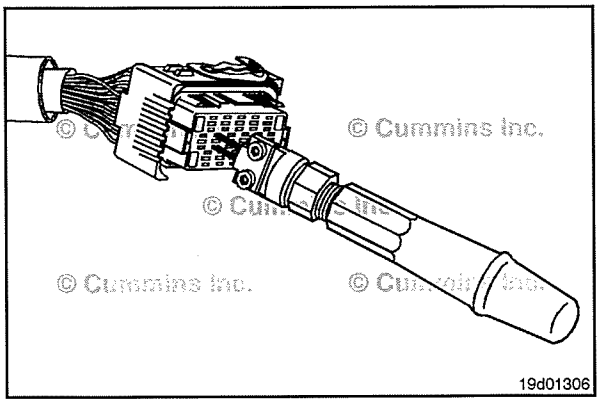
Insert the pin extraction tool into the unlocking holes in the connector.

Do **not** push the tool all the way into the connector.



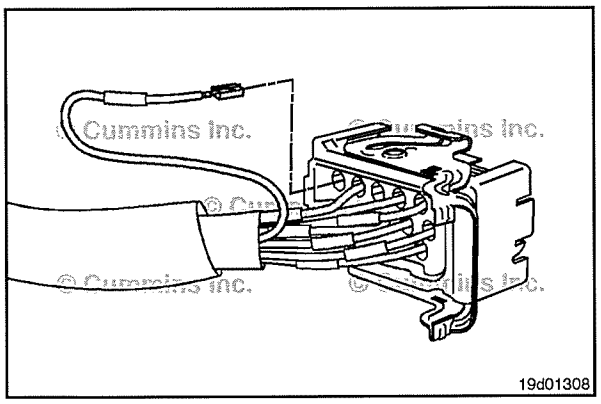
Push the corresponding wire toward the pin extraction tool.

Press the pin extraction tool all the way into the connector.



⚠CAUTION⚠
If the wire is difficult to remove, do not pull hard on the wire; otherwise, the locking tang of the wire terminal will stick or the terminal will pull off the wire and remain in the connector.

Carefully pull the wire out of the connector and record the hole from which the pin is removed. If it is difficult to remove, repeat the procedure.



Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

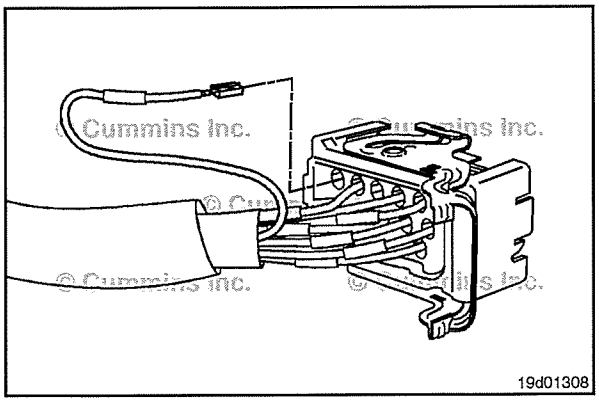
Refer to the wiring diagram in Section E for pin locations.

The wire terminal has locating pins that allow it to be inserted in **only** a certain orientation.

Insert the pins into the correct holes of the replacement connector.

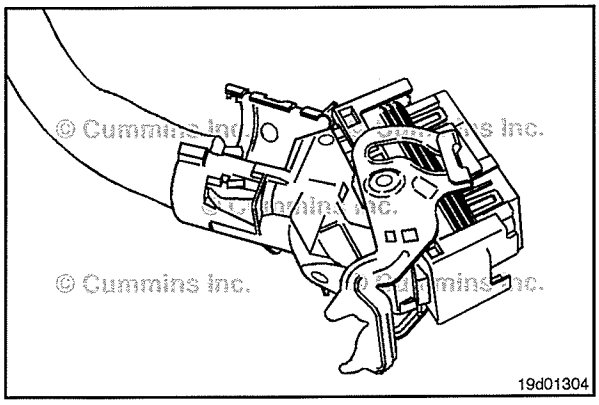
Each pin **must** click into place and hold the wires in the connector.

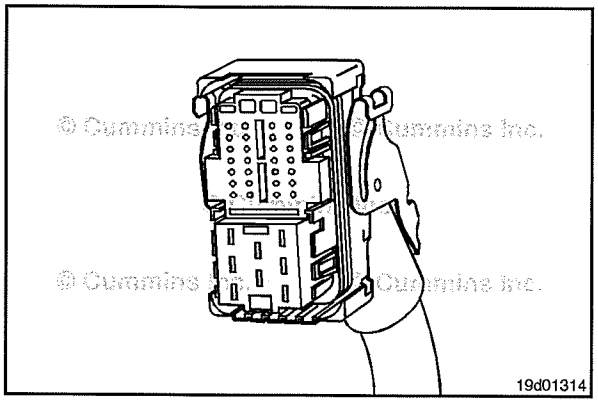
Pull each wire gently to make sure it is seated in the connector.



Replace the connector shell by inserting the hinge of the connector shell (black) into the hinge of the connector (red).

Close the connector shell onto the connector and wiring harness by pressing it onto the tang of the connector until a click is heard.

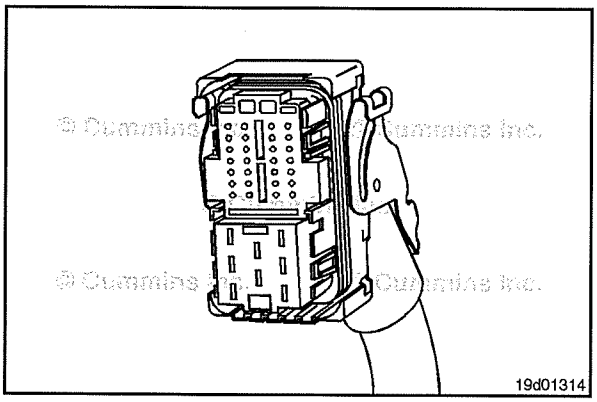




Bosch™ ECM Actuator and Sensor Connector Series (019-216)

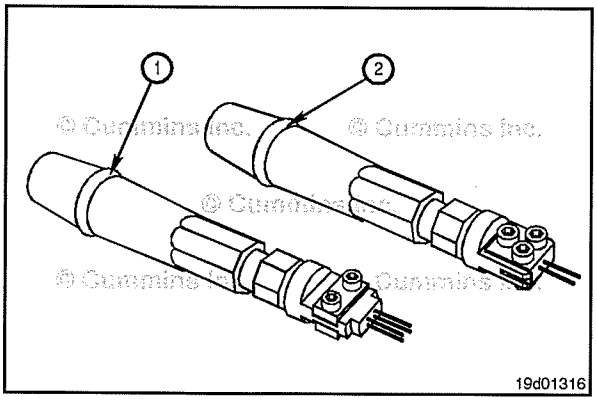
Pin Replacement

The connector is used to attach the appropriate harness to the ECM.



Remove the connector shell by slightly bending the connector shell (black) away from the two tangs that hold the shell to the ECM connector (red).

Before pins can be removed, they **must** be unlocked. Slide the purple tabs on the edges of the connector sideways at the same time. When unlocked, the purple tab will align with a slot, making the entire length of the purple tab visible.

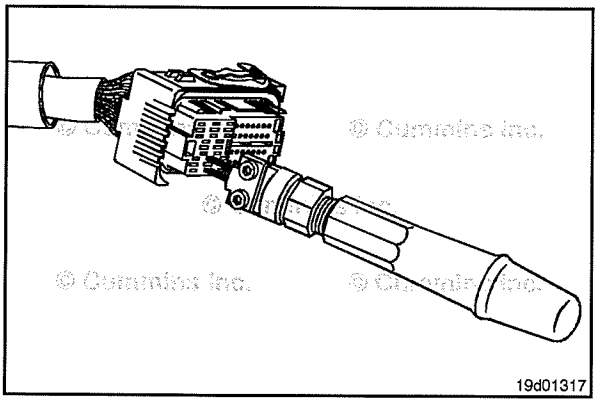


Use Bosch® extraction tool (2), Part Number 3164093, (small terminals), or use Bosch® extraction tool (1), Part Number 3164091 (large terminals), over the wire to remove a pin from the connector.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

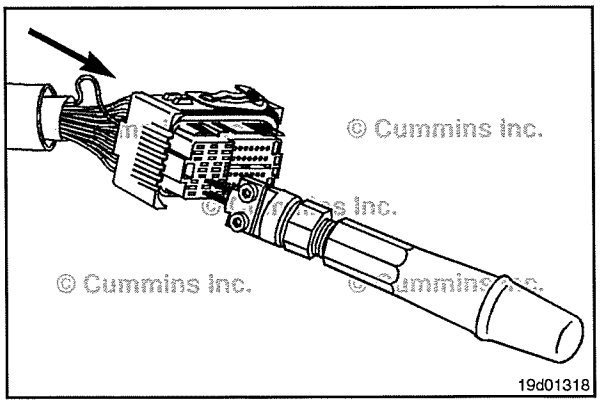
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.



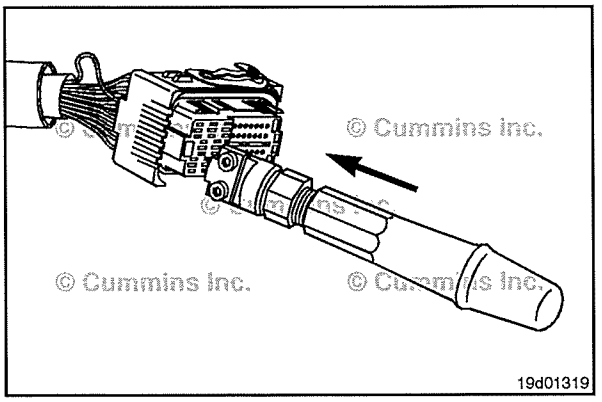
Insert the pin extractor tool into the unlocking holes in the connector.

Do **not** push the tool all the way into the connector.

Push the corresponding wire toward the pin extraction tool.

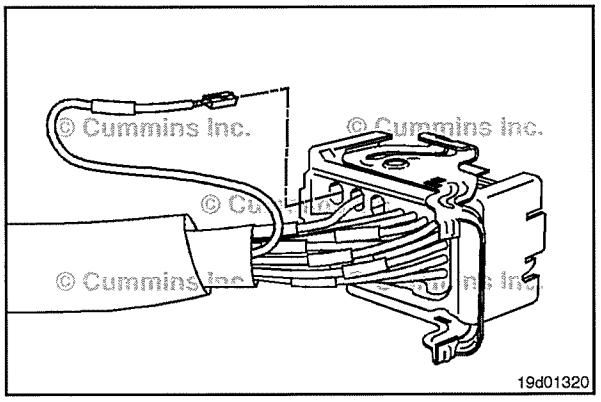


Press the pin extraction tool all the way into the connector.



⚠CAUTION⚠
If the wire is difficult to remove, do not pull hard on the wire; otherwise, the locking tang of the wire terminal will stick or the terminal will pull off the wire and remain in the connector.

Carefully pull the wire out of the connector. If it is difficult to remove, repeat the entire procedure.



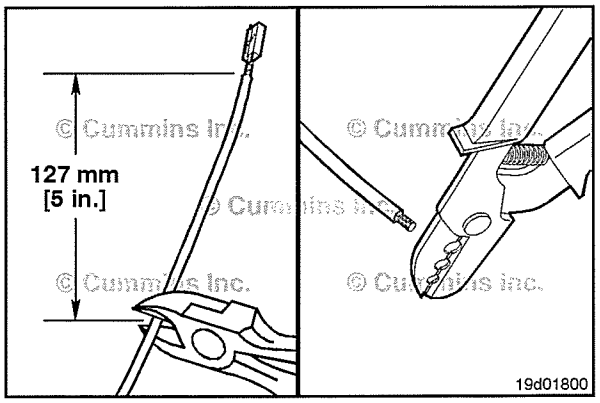
NOTE: The repair wire is 127 mm [5 in] long.

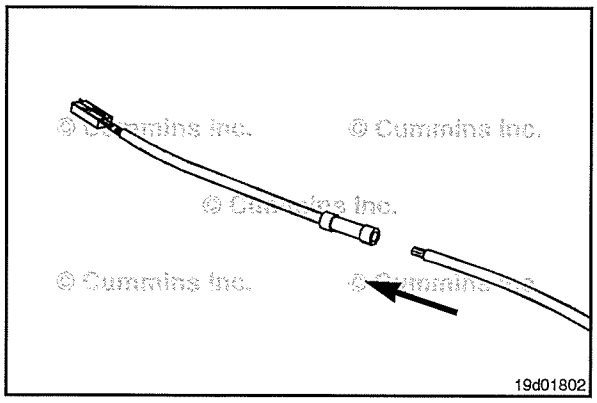
Use wire cutters to cut 127 mm [5 in] of the wire and pin.

Use wire crimping tool, Part Number 3822930, to remove 6 mm [¼ in] of insulation from the wire.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

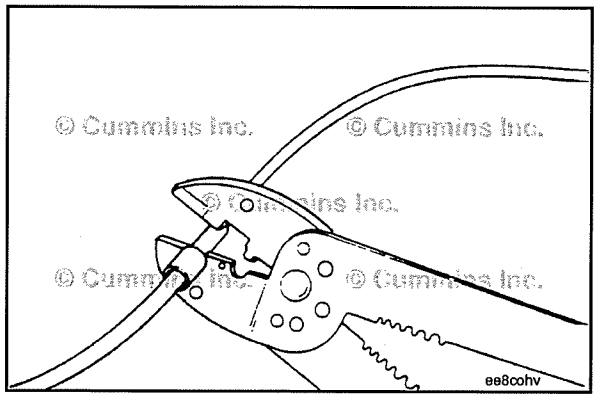
Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.



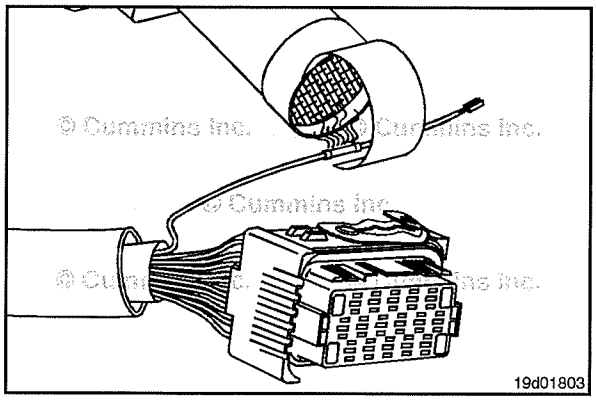


Install the repair wire on the bare wire.

Make sure the bare wire extends into the splice connector.

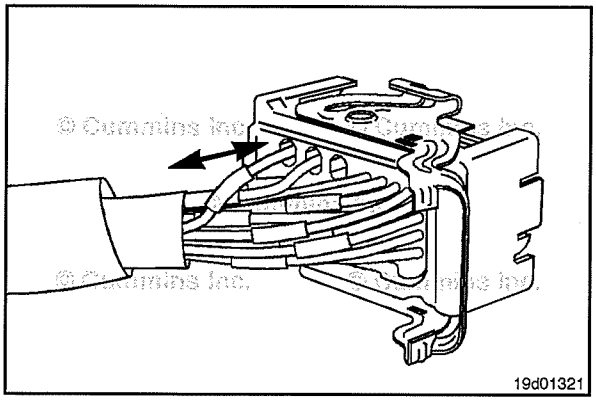


Use wiring crimping tool, Part Number 3822930, to crimp the repair wire onto the bare wire.



Use heat gun, Part Number 3822860, to heat the shrink tubing around the wire.

The tubing will shrink and make the connection waterproof.



The wire terminal has locating pins that **only** allow it to be installed in a certain orientation.

Insert the wire from the backside of the connector.

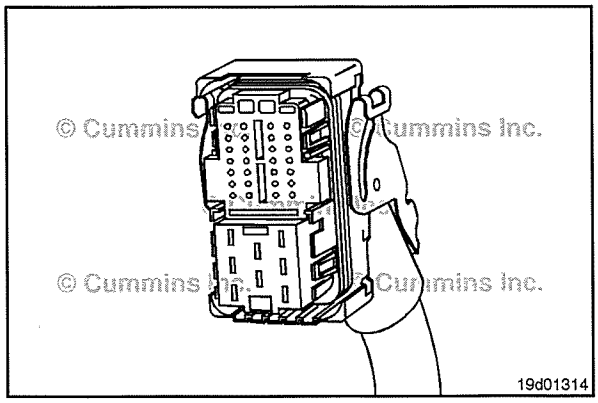
Push the wire into the connector.

Pull the wire gently to make sure it is locked into the connector.

NOTE: If the wire's locking tang has **not** latched, then remove the wire, pry the tang away from the terminal, and repeat this step.

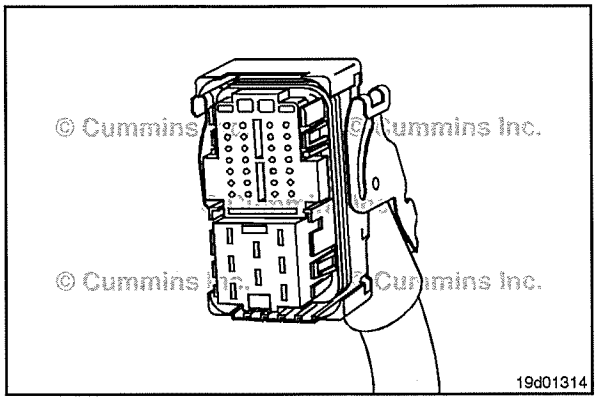
Connector Replacement

This connector is used to attach the engine harness to the ECM.



Remove the connector shell by slightly bending the connector shell (black) away from the two tangs that hold the shell to the ECM connector (red).

Before pins can be removed, they **must** be unlocked. Slide the purple tabs on the edges of the connector sideways at the same time. When unlocked, the purple tab will align with a slot, making the entire length of the purple tab visible.

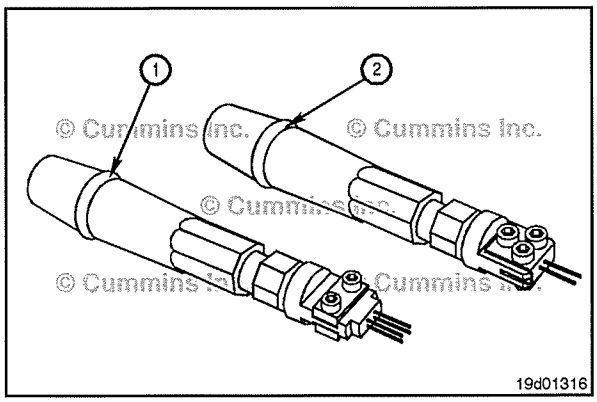


Use Bosch® extraction tool (2), Part Number 3164093, (small terminals), or use Bosch® extraction tool (1), Part Number 3164091 (large terminals), over the wire to remove a pin from the connector.

Remove one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

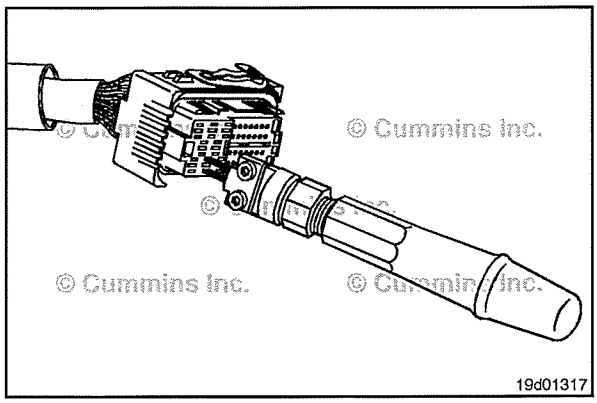
Refer to the wiring diagram in Section E for pin locations.

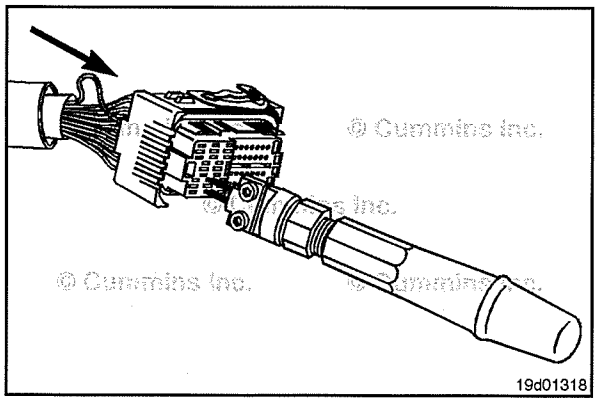
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.



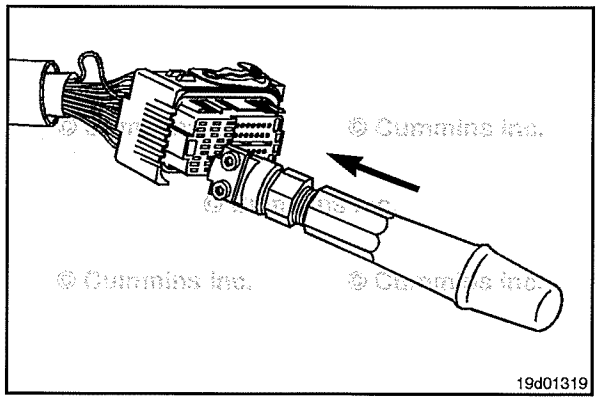
Insert the pin extraction tool into the unlocking holes in the connector.

Do **not** push the tool all the way into the connector.

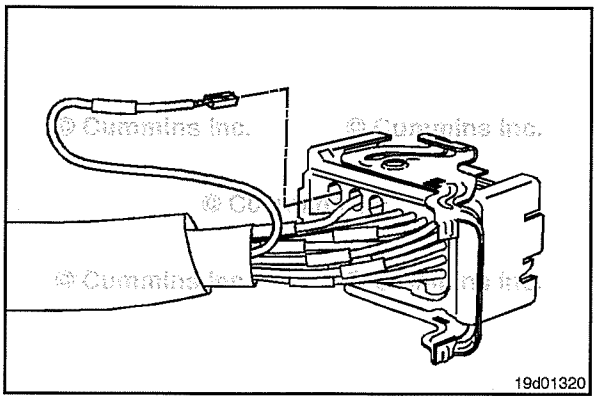




Push the corresponding wire toward the pin extraction tool.



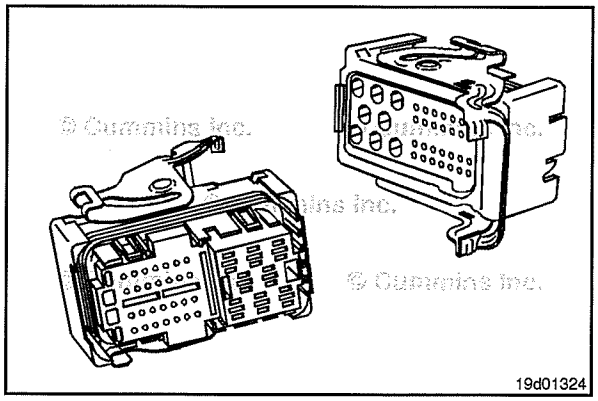
Press the pin extraction tool all the way into the connector.



ΔCAUTIONΔ

If the wire is difficult to remove, do not pull hard on the wire; otherwise, the locking tang of the wire terminal will stick or the terminal will pull off the wire and remain in the connector.

Carefully pull the wire out of the connector and record the hole from which the pin is removed. If it is difficult to remove, repeat the entire procedure.



Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

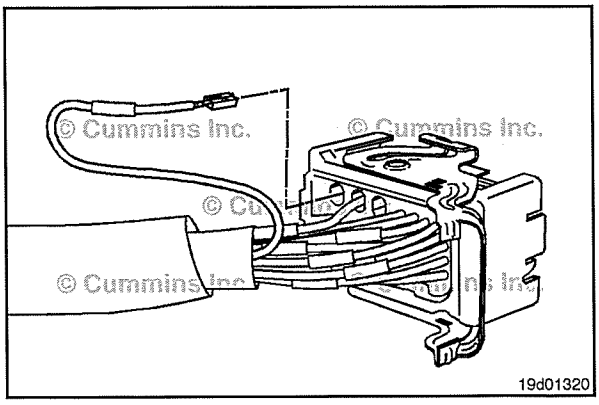
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.

Insert the pins into the correct hole of the replacement connector.

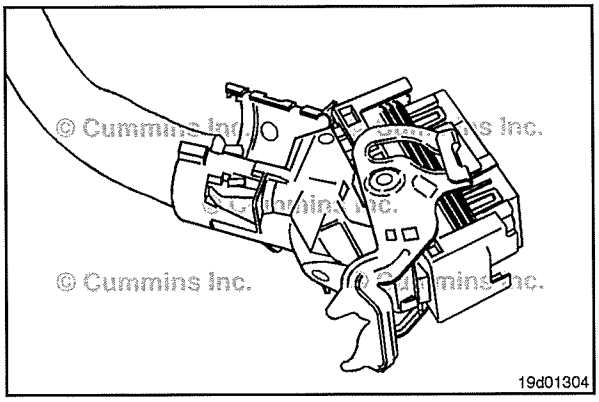
Each pin **must** click into place and hold the wires in the connector.

Pull each wire gently to make sure it is seated in the connector.



Replace the connector shell by inserting the hinge of the connector shell (black) into the hinge of the connector (red).

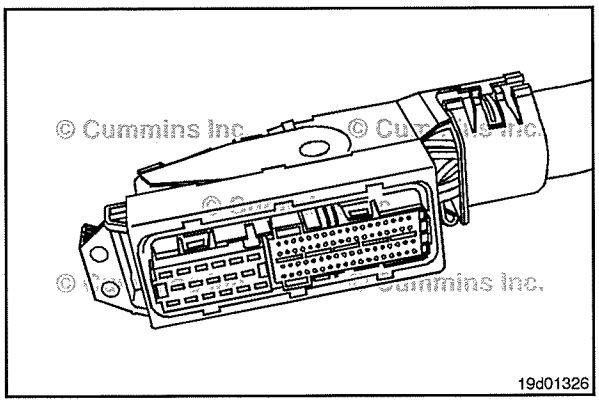
Close the connector shell onto the connector and wiring harness by pressing it on the tang of the connector until a click is heard.



Bosch™ ECM OEM Connector Series (019-217)

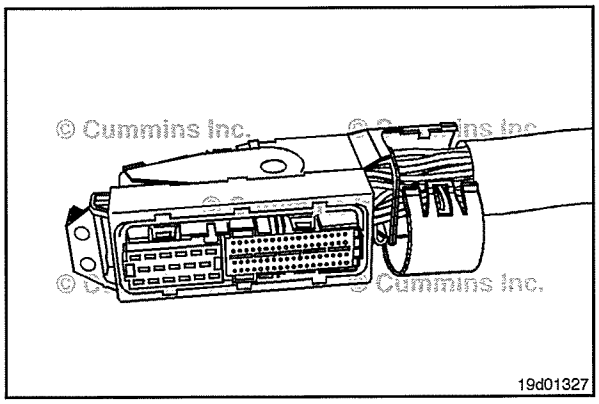
Pin Replacement

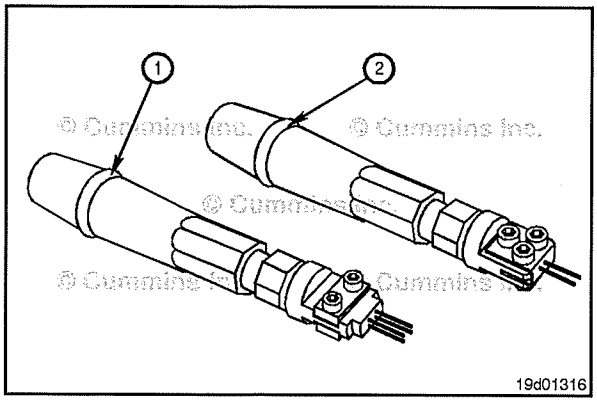
This connector is used to attach the appropriate harness to the ECM.



Remove the connector shell by slightly bending the connector shell (black) away from the two tangs that hold the shell to the ECM connector (red).

Before pins can be removed, they **must** be unlocked. Slide the purple tabs on the edges of the connector sideways at the same time. When unlocked, the purple tab will align with a slot, making the entire length of the purple tab visible.



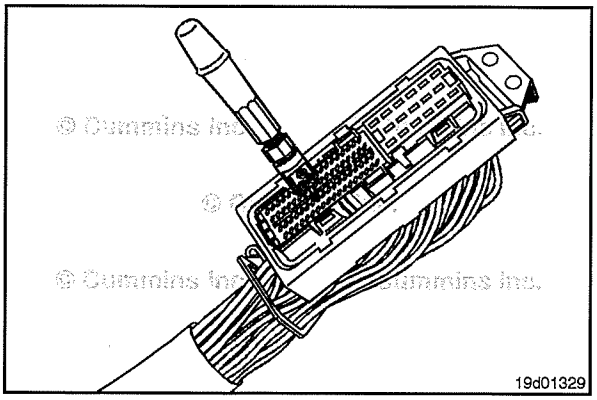


Use Bosch® extraction tool (2), Part Number 3164093, (small terminals), or use Bosch® extraction tool (1), Part Number 3164091 (large terminals), over the wire to remove a pin from the connector.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

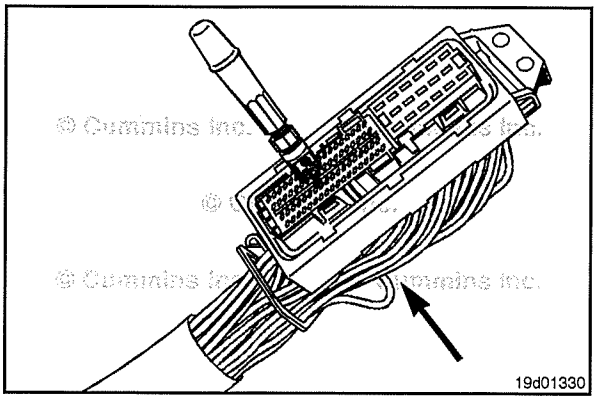
Refer to the wiring diagram in Section E for pin locations.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

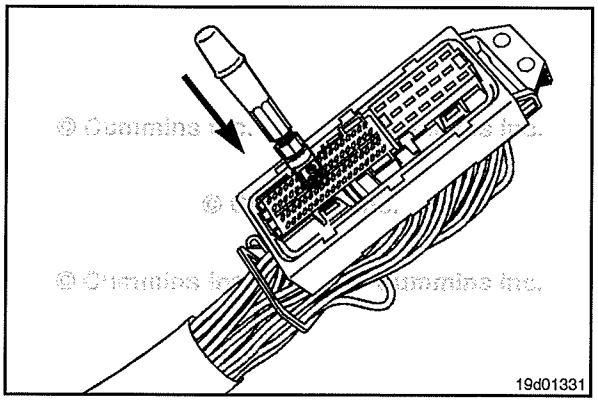


Insert the pin extraction tool into the unlocking holes in the connector.

Do **not** push the tool all the way into the connector.



Push the corresponding wire toward the pin extraction tool.

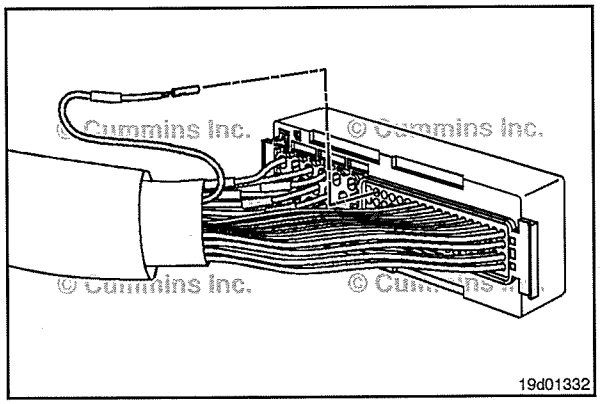


Press the pin extraction tool all the way into the connector.

⚠CAUTION⚠

If the wire is difficult to remove, do not pull hard on the wire; otherwise, the locking tang of the wire terminal will stick or the terminal will pull off the wire and remain in the connector.

Carefully pull the wire out of the connector. If it is difficult to remove, repeat the entire procedure.



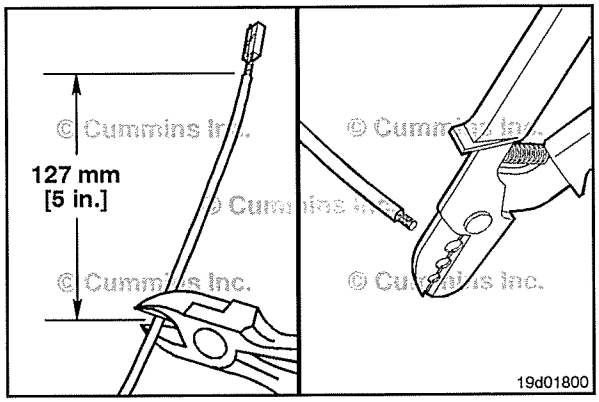
NOTE: The repair wire is 127 mm [5 in] long.

Use wire cutters to cut 127 mm [5 in] of the wire and pin.

Use wire crimping tool, Part Number 3822930, to remove 6 mm [¼ in] of insulation from the wire.

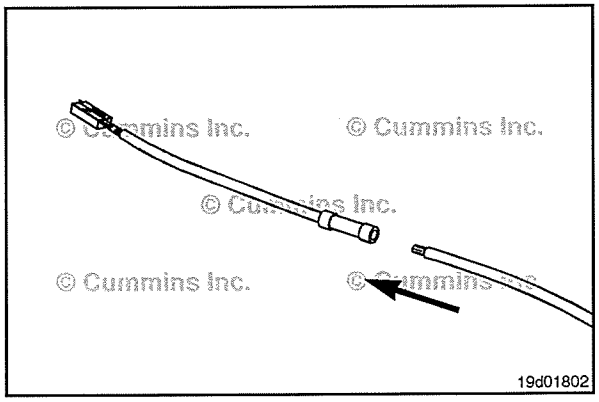
Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

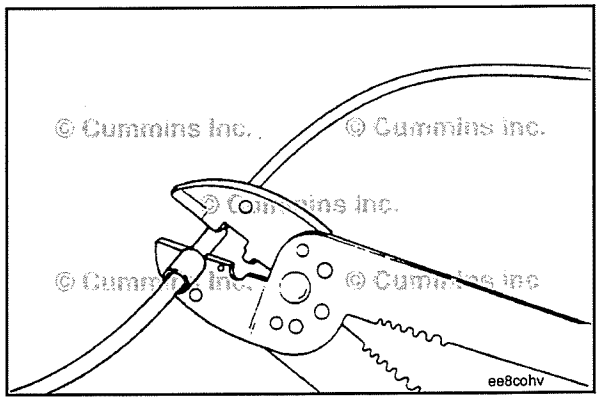


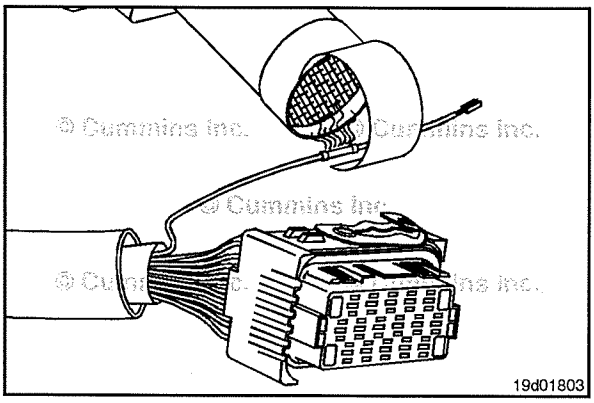
Install the repair wire on the bare wire.

Make sure the bare wire extends into the splice connector.



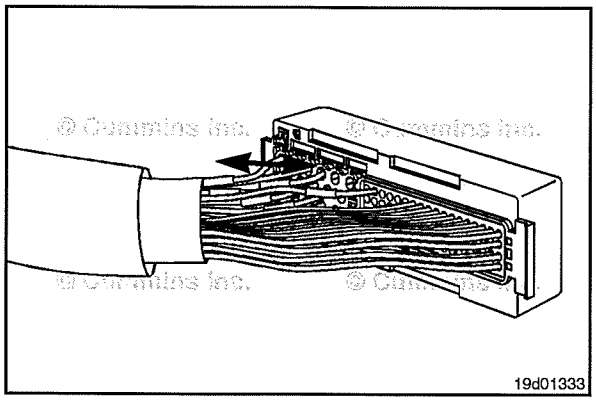
Use wire crimping tool, Part Number 3822930, to crimp the repair wire onto the bare wire.





Use heat gun, Part Number 3822860, to heat the shrink tubing around the wire.

The tubing will shrink and make the connection waterproof.



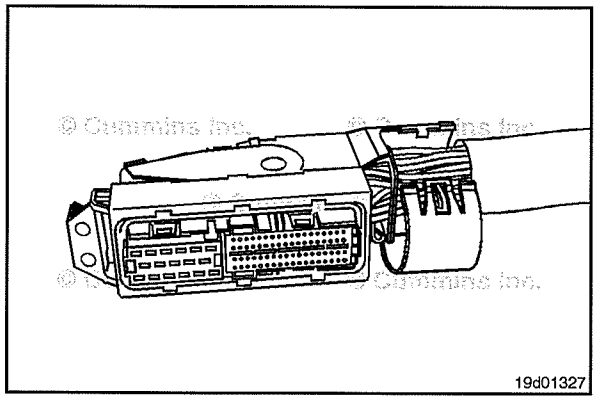
The wire terminal has locating pins that **only** allow it to be installed in a certain orientation.

Insert the wire from the backside of the connector.

Push the wire into the connector.

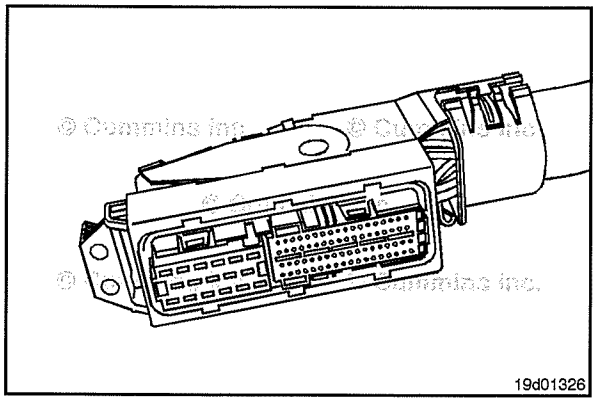
Pull the wire gently to make sure it is locked into the connector.

NOTE: If the wire's locking tang has **not** latched, then remove the wire, pry the tang away from the terminal, and repeat this step.



Replace the connector shell by inserting the hinge of the connector shell (black) into the hinge of the connector (red).

Close the connector shell onto the connector and wiring harness by pressing it onto the tang of the connector until you hear it click.

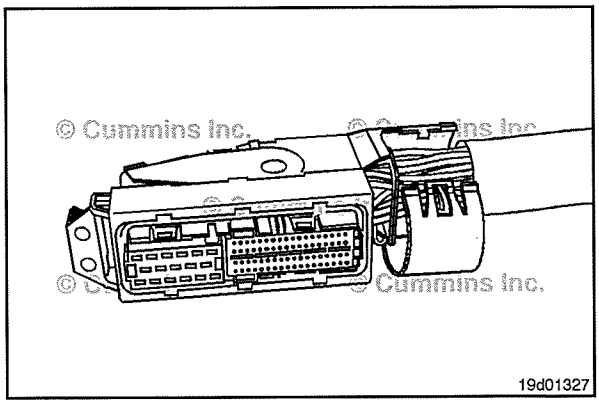


Connector Replacement

This connector is used to attach the appropriate harness to the ECM.

Remove the connector shell by slightly bending the connector shell (black) away from the two tangs that hold the shell to the ECM connector (red).

Before pins can be removed, they **must** be unlocked. Slide the purple tabs on the edges of the connector sideways at the same time. When unlocked, the purple tab will align with a slot, making the entire length of the purple tab visible.

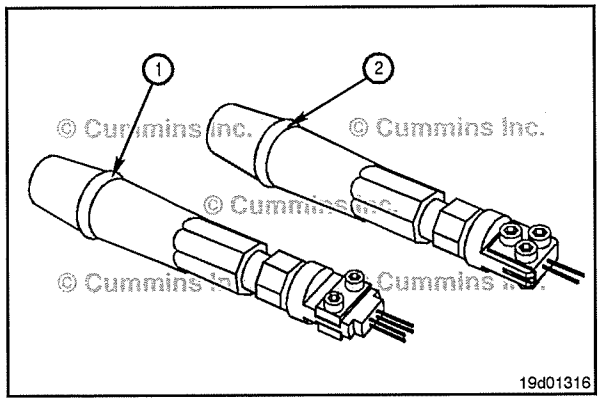


Use Bosch® extraction tool (2), Part Number 3164093, (small terminals), or use Bosch® extraction tool (1), Part Number 3164091 (large terminals), over the wire to remove a pin from the connector.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

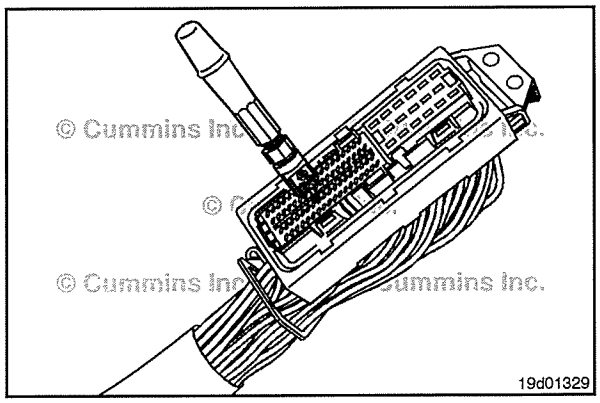
Refer to the wiring diagram in Section E for pin locations.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair wire.

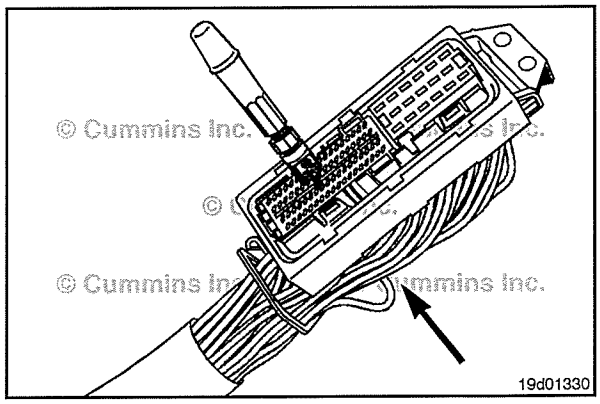


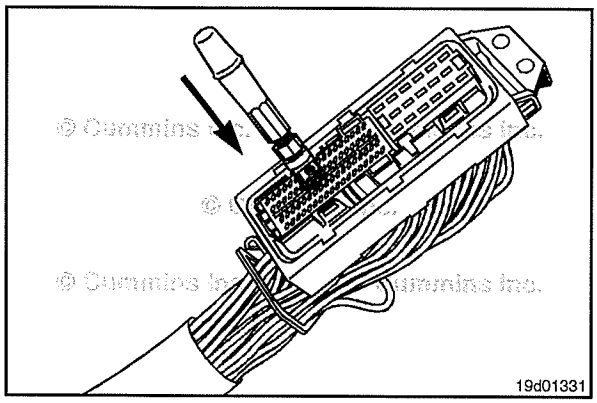
Insert the pin extraction tool into the unlocking holes in the connector.

Do **not** push the tool all the way into the connector.

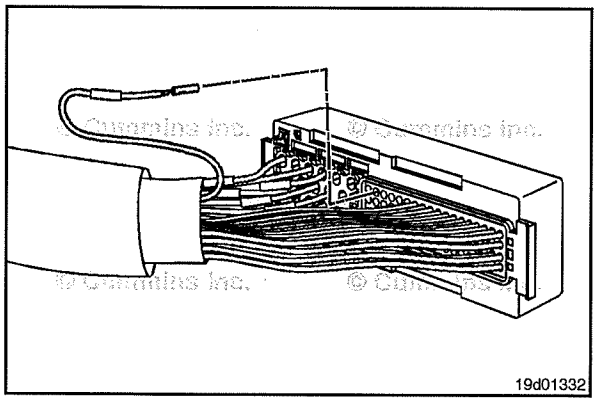


Push the corresponding wire toward the pin extraction tool.





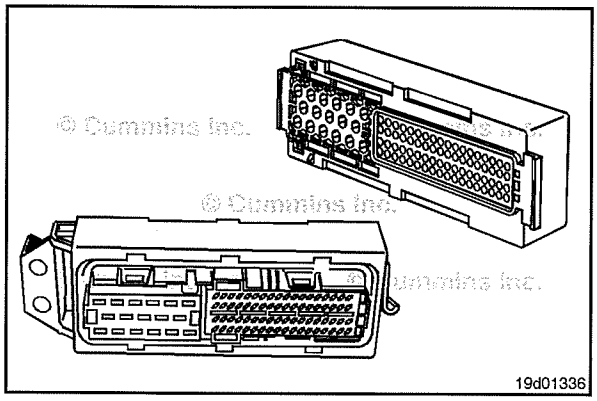
Press the pin extraction tool all the way into the connector.



ΔCAUTIONΔ

If the wire is difficult to remove, do not pull hard on the wire; otherwise, the locking tang of the wire terminal will stick or the terminal will pull off the wire and remain in the connector.

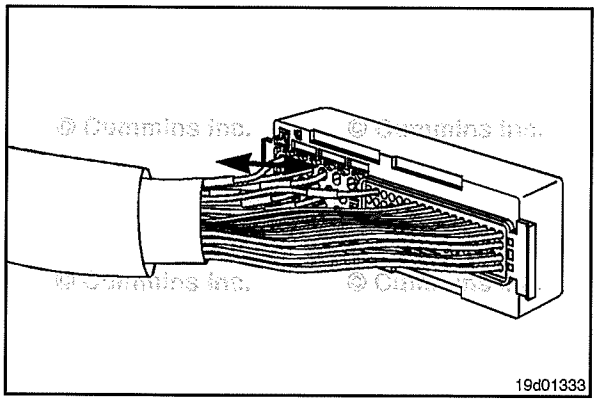
Carefully pull the wire out of the connector. If it is difficult to remove, repeat the entire procedure.



Before installing the new connector, perform a test fit to make sure the connector is keyed correctly.

Refer to the appropriate wiring repair kit in the service tools table in the front of Section 19 for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.



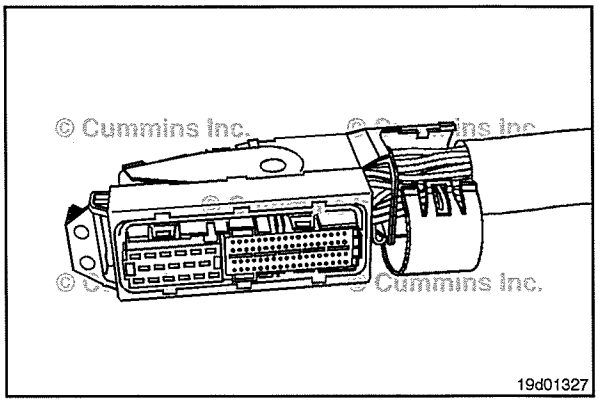
Insert the pins into the correct hole of the replacement connector.

Each pin **must** click into place and hold the wires in the connector.

Pull each wire gently to make sure it is seated in the connector.

Replace the connector shell by inserting the hinge of the connector shell (black) into the hinge of the connector (red).

Close the connector shell onto the connector and wiring harness by pressing it onto the tang of the connector until you hear it click.



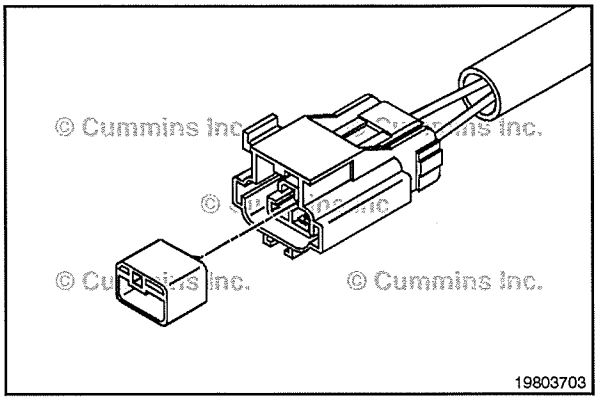
Framatome Connector Series (019-218)

Pin Replacement

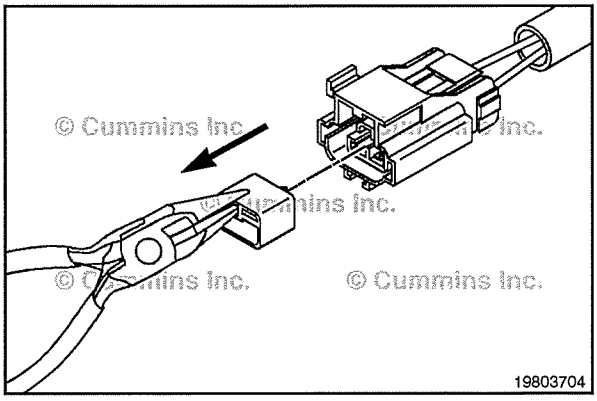
The connector can have multiple pin configurations. All type of connectors are repaired in the same manner.

Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

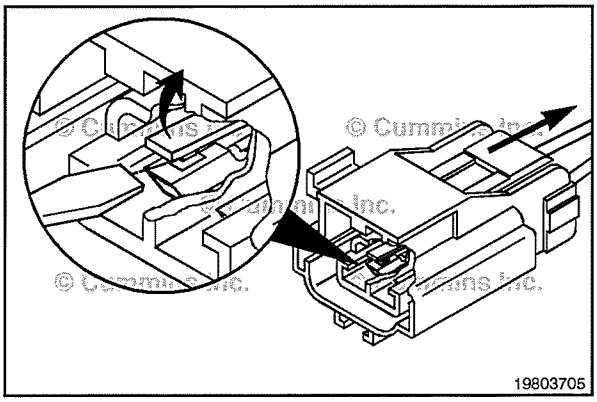


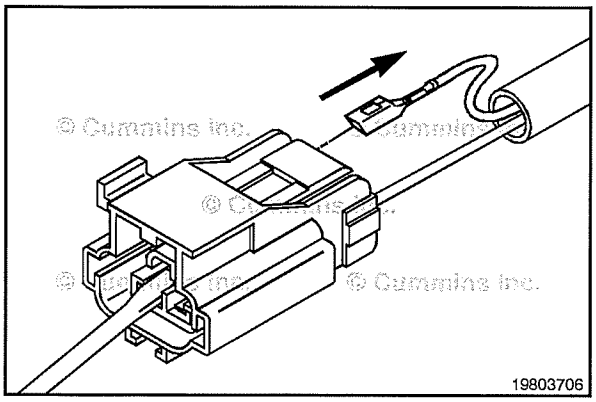
To replace the pin in the receptacle connector, remove the blue inter connector lock using needle nose pliers.



⚠CAUTION⚠
The locking finger can be easily broken. Care must be taken when using this tool. Do not force the tool into place.

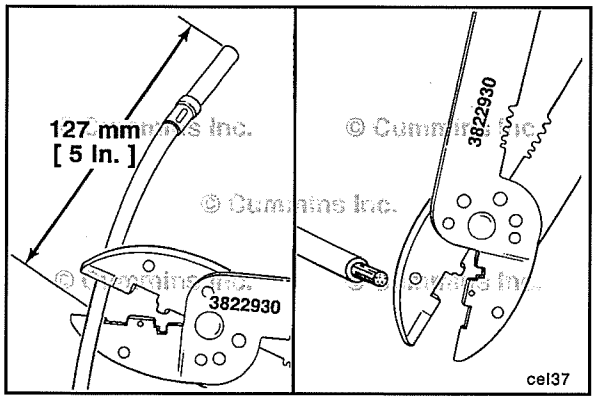
To remove the contact out of the connector body, gently pull wire backward, while at the same time releasing the locking finger by moving it away from the contact with a screwdriver.





△CAUTION△
If more than one wire is being repaired, tag each wire and install it in the original location. Electrical damage can occur if a wire is installed in the incorrect location.

Pull the wire and the terminal out of the connector body.



Refer to the appropriate wiring repair kit in the service tools table in the front of this section for the correct repair wire.

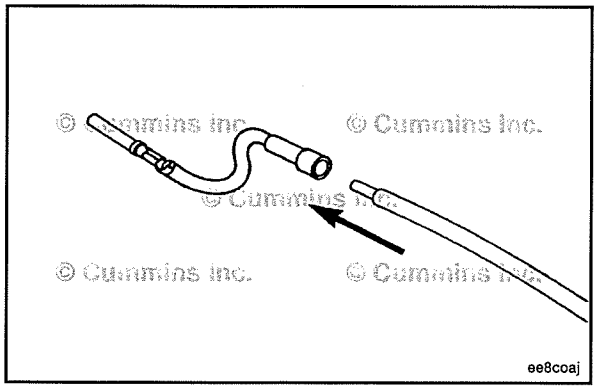
Replace one contact wire at a time. If more than one wire needs replaced, attach a lettered tag to each wire removed.

Refer to the wiring diagram in Section E for pin locations.

Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

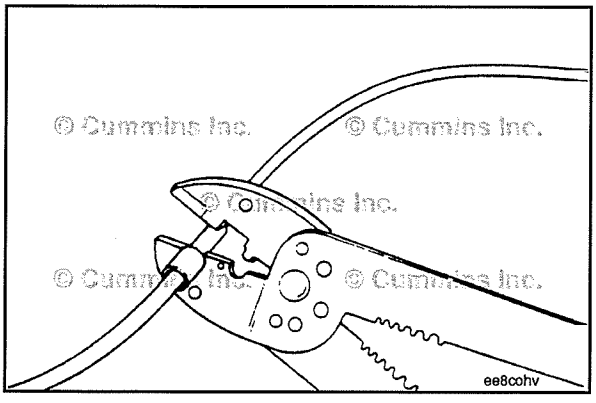
Use wire crimping tool, Part Number 3822930, to cut 127 mm [5 in] off the wire and pin.

Use wire crimping tool, Part Number 3822930, to remove 6 mm [¼ in] of insulation from the wire.



Install the correct repair wire on the bare wire.

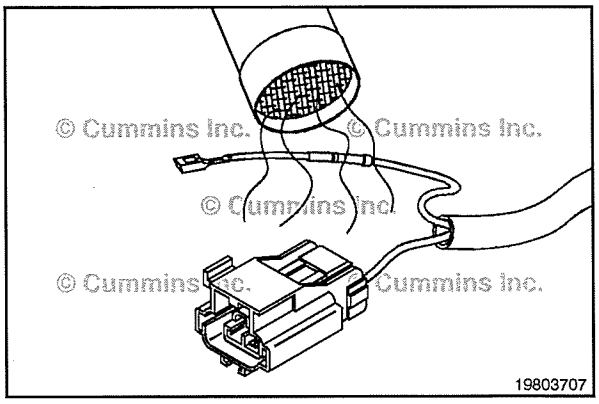
Make sure the bare wire extends into the splice connector.



Use wire crimping tool, Part Number 3822930, to crimp the repair wire onto the bare wire.

Use heat gun, Part Number 3822860, to heat shrink the tubing around the wire.

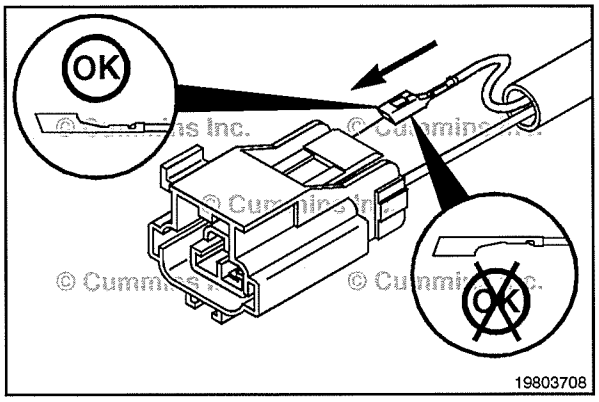
The tubing will shrink and make the connection waterproof.



⚠CAUTION⚠
If more than one wire is repaired or if the connector body is replaced, make sure to insert wires into the same locations as they are in the original connector. If wires are not in the original location, electrical damage can occur.

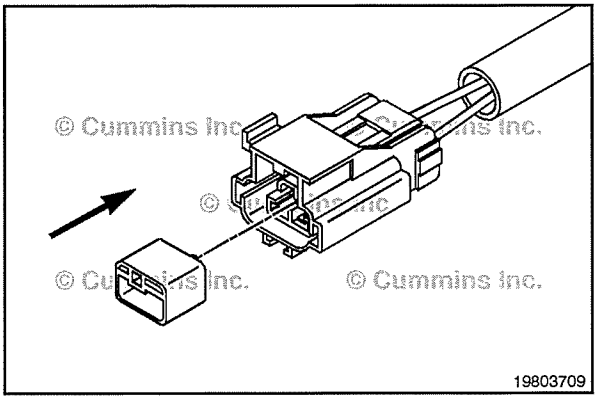
Install the wire and terminal into the connector body. Push the wire and terminal into the seal at the back of the connector. Install the replacement terminal and wire so that the longest point of the terminal is closest to the connector locking tab.

Push the wires straight in until a click is felt. A slight tug will confirm that it is properly locked in place.



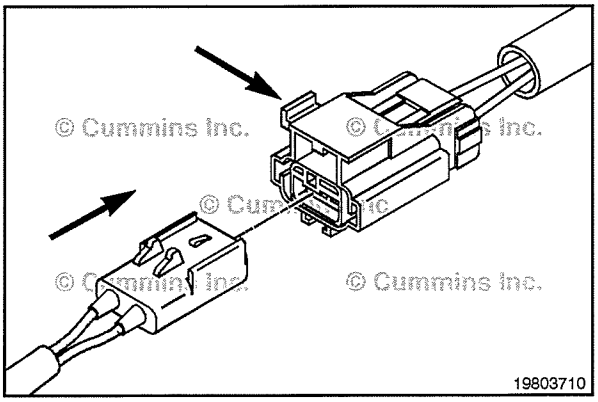
Once the wires are in place, insert the blue inter connector lock with the locking tab positioned towards the connector locking tab.

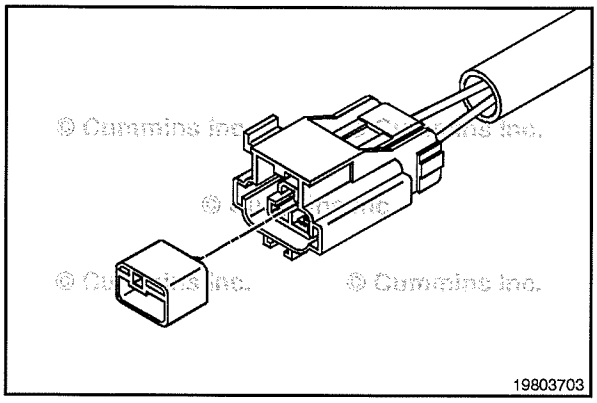
Push the blue inter connector lock in until it snaps in place.



Push the connector plug into the connector receptacle until the external locking clip snaps into place.

Slide the connector locking tab to the locked position.





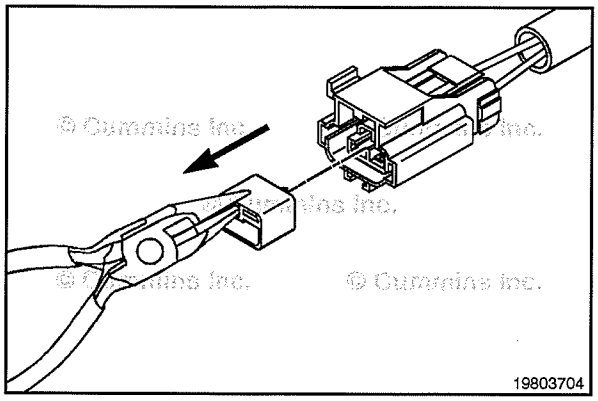
Connector Replacement

The connector can have multiple pin configurations. All types of connectors are repaired in the same manner.

Before installing the new connector perform a test fit to make sure the connector is keyed correctly.

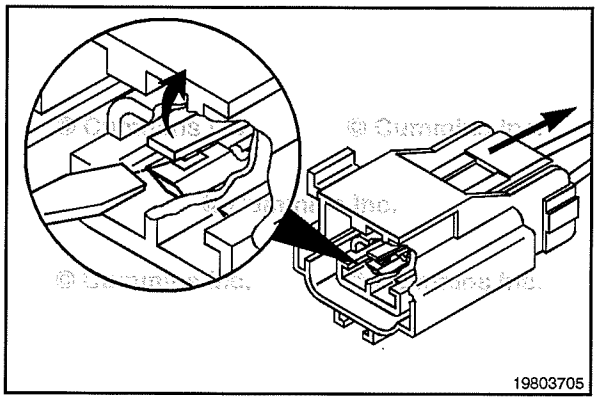
Refer to the appropriate wiring repair kit in the service tools table in the front of this section for the correct repair connector.

Refer to the wiring diagram in Section E for pin locations.



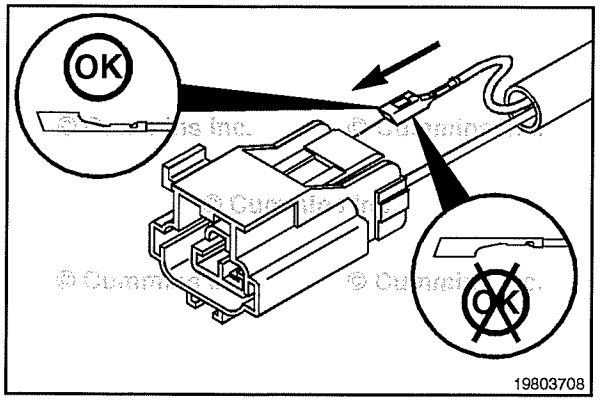
⚠CAUTION⚠
If more than one wire is repaired or if the connector body is replaced, be sure to insert the wires into the same location as they were in the original connector. If the wires are not in the original location, electrical damage can occur.

To replace the connector, grasp the blue inter connector and pull it straight out.



⚠CAUTION⚠
The locking finger can be easily broken. Care must be taken when using this tool. Do not force the tool into place.

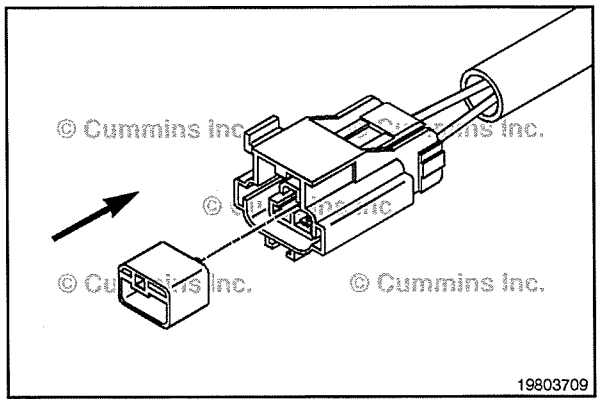
To remove the contact out of the connector body, gently pull wire backward, while at the same time releasing the locking finger by moving it away from the contact with a screwdriver.



Replace the connector and install the wires and terminals into the seal at the back of the connector. Push the wires straight in until a click is felt. A slight tug will confirm that it is properly locked in place.

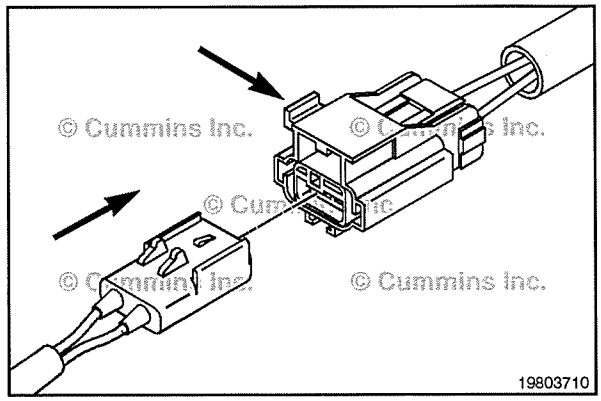
Once the wires are in place, insert the blue inter connector lock with the locking tab positioned towards the connector locking tab.

Push the blue inter connector lock in until it snaps in place.



Push the connector plug into the connector receptacle until the external locking clip snaps into place.

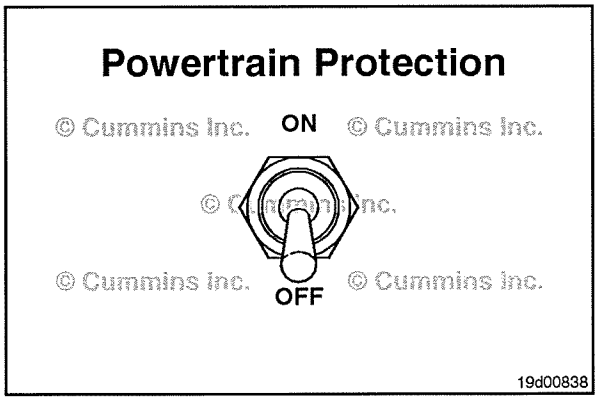
Slide the connector locking tab to the locked position.



Power Train Protection Switch (019-253)

General Information

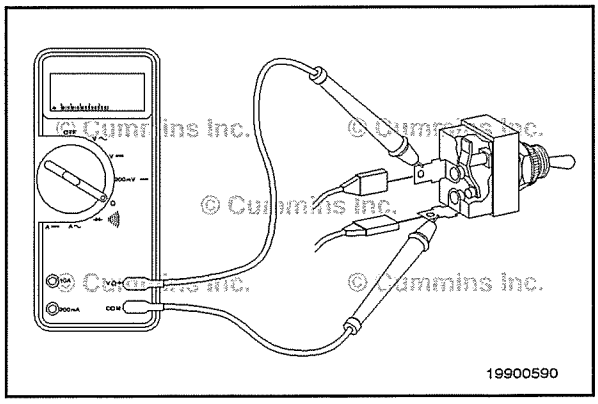
The powertrain protection switch circuit signals the system to protect the drivetrain when lower gears are engaged. The powertrain protection feature can limit engine output torque depending upon transmission gear ratio. Engine torque limits based on transmission gear ratio can be adjusted using the INSITE™ electronic service tool.

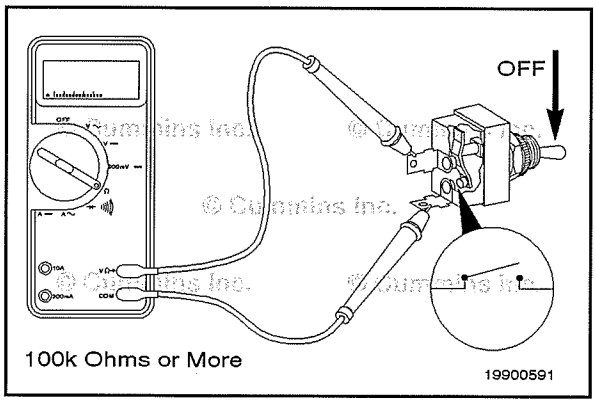


Resistance Check

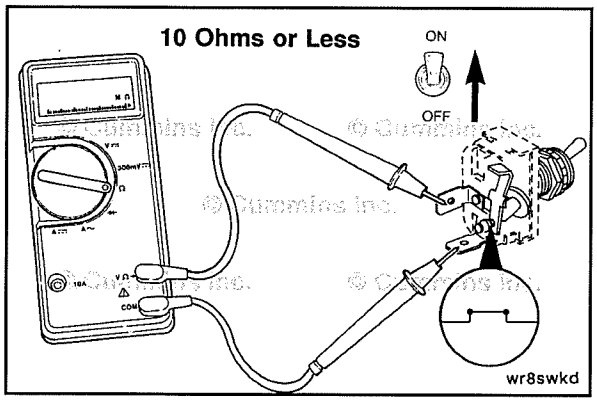
If INSITE™ electronic service tool is available, monitor the powertrain protection switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Locate the powertrain protection switch. Remove and tag the two connectors from the terminals on the switch. Touch the multimeter probes to the terminals on the switch.



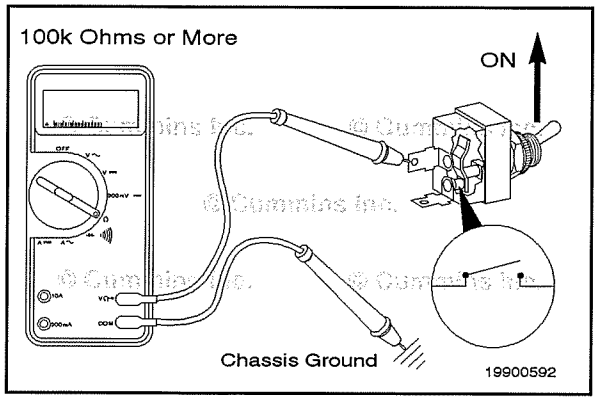


Move the switch to the OFF position, and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the original equipment manufacturer (OEM) troubleshooting and repair manual for the replacement instructions.



Move the switch to the ON position, and measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, the switch has failed. Refer to the OEM troubleshooting and repair manual for the replacement instructions.

If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the ON position, and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures.

Check for Short Circuit to External Voltage Source

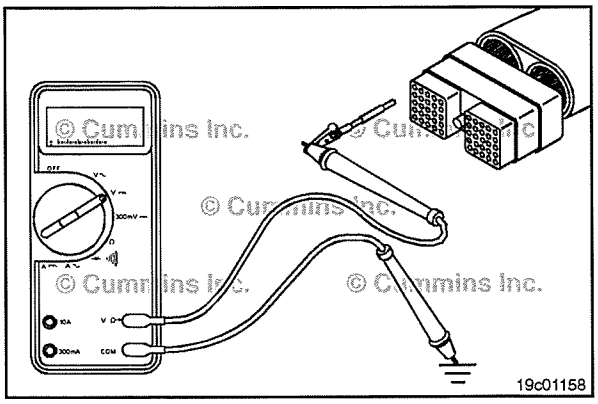
⚠CAUTION⚠
The leads must fit tightly in the connector without expanding the pins in the connector otherwise the connector will be damaged.

Isolate the powertrain protection switch circuit. Turn the vehicle keyswitch to the ON position. Adjust the multimeter to measure VDC.

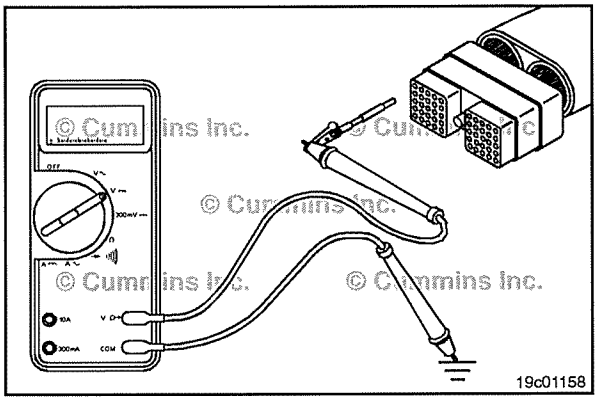
Insert the test lead connected to the positive (+) multimeter probe into the powertrain protection switch signal pin of the OEM harness.

Disconnect the negative (-) multimeter probe from the test lead, touch it to the engine block ground, and measure the voltage. The voltage **must** be 1.5 VDC or less.

NOTE: An external voltage source is any wire in the OEM harness wiring that carries the voltage.



If the voltage value is more than 1.5 VDC, there is a short circuit between the wire connected to the powertrain protection switch signal pin and a wire carrying power in the OEM harness. Repair the OEM harness according to the vehicle manufacturer's procedures.

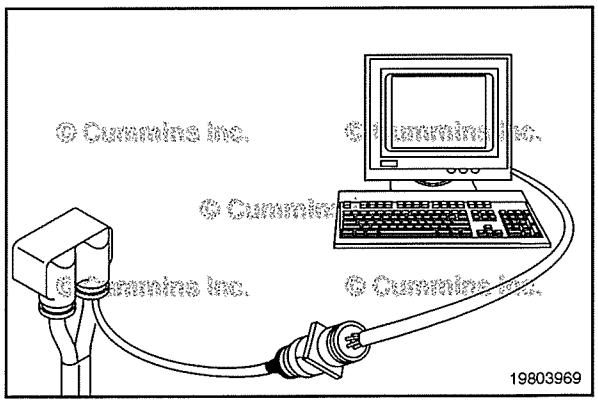


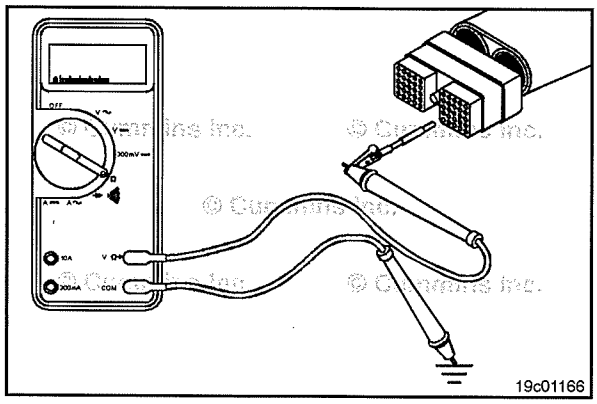
Power Train Protection Switch Circuit (019-254)

Resistance Check

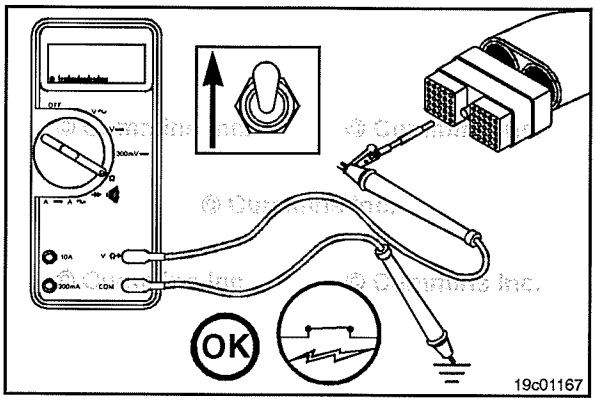
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the powertrain protection switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.

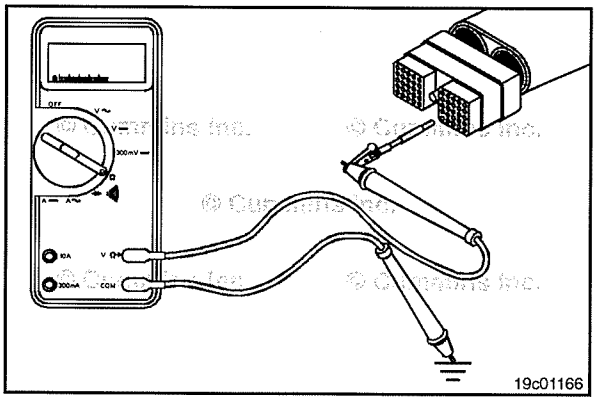




Disconnect the original equipment manufacturer (OEM) harness from the electronic control module (ECM). Insert the multimeter probe into powertrain protection switch signal pin in the OEM harness. Touch the other probe to the engine block ground.



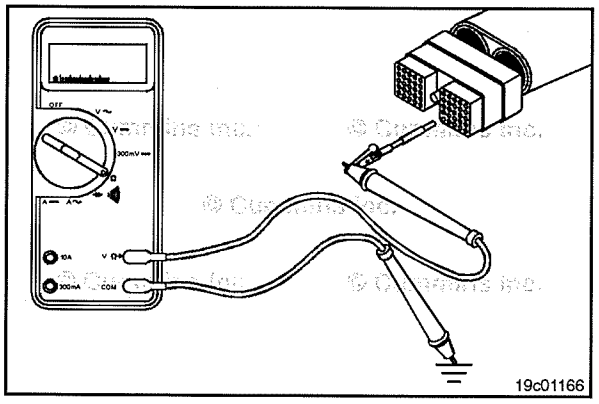
Move the powertrain protection switch to the ON position. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the signal wire for an open circuit. Refer to the OEM troubleshooting and repair manual. If the resistance is within specification, the signal pin **must** be checked for a short circuit to ground, a short circuit from terminal to terminal, and a short circuit to an external voltage source.



Check for Short Circuit to Ground

Isolate the powertrain protection switch circuit.

Touch multimeter probe to the engine block. With the other electrical lead inserted into powertrain protection switch signal pin, measure the resistance.

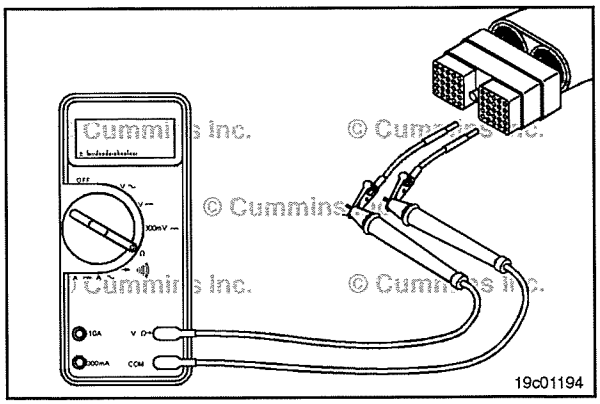


The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the powertrain protection switch circuit, provided that the switch has been previously checked. Repair or replace the wire connected to powertrain protection switch signal pin according to the vehicle manufacturer's instructions.

Check for Short Circuit from Pin to Pin

Isolate the powertrain protection switch circuit. Place one of the leads into power train protection switch signal pin. Insert the pin of the other lead into pin 1. Connect the alligator clips to the multimeter probes. Measure the resistance.

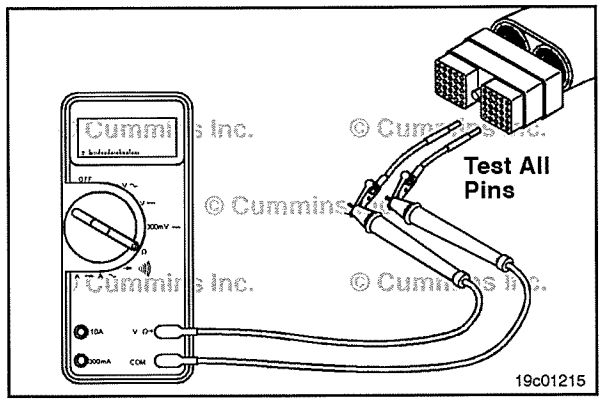
The multimeter **must** show an open circuit (100k ohms or more).



Remove the lead from pin 1, and check all other pins. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit from the wire connected to powertrain protection switch signal pin and any pin that measured less than 100k ohms.

Repair or replace the wires in the OEM harness according to the vehicle manufacturer's instructions.



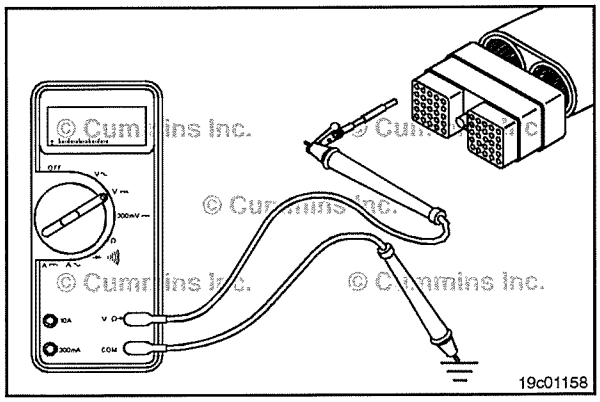
Check for Short Circuit to External Voltage Source

Isolate the powertrain protection switch circuit. Turn the vehicle keyswitch to the ON position. Set the multimeter to measure VDC.

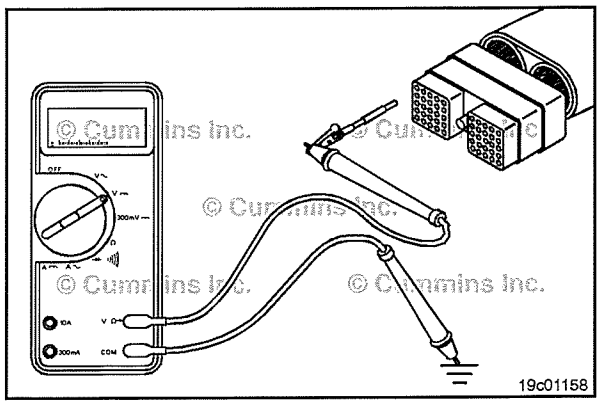
Insert the test lead connected to the positive (+) multimeter probe into powertrain protection switch signal pin of the OEM harness.

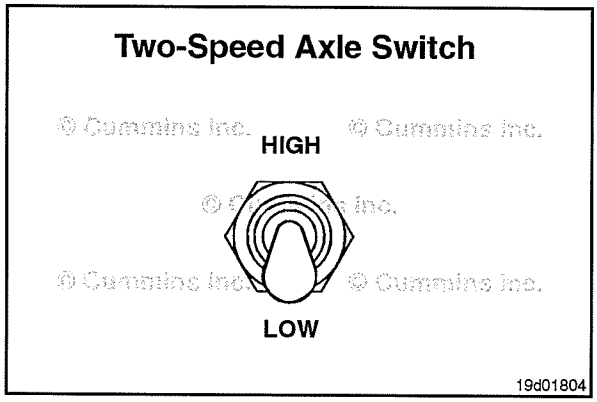
Disconnect the negative (-) multimeter probe from the test lead, touch it to the engine block ground, and measure the voltage. The voltage **must** be 1.5 VDC or less.

NOTE: An external voltage source is any wire in the OEM harness wiring that carries the voltage.



If the voltage value is more than 1.5 VDC, there is a short circuit between the wire connected to powertrain protection switch signal pin and a wire carrying power in the OEM harness. Repair the OEM harness according to the vehicle manufacturer's procedures.

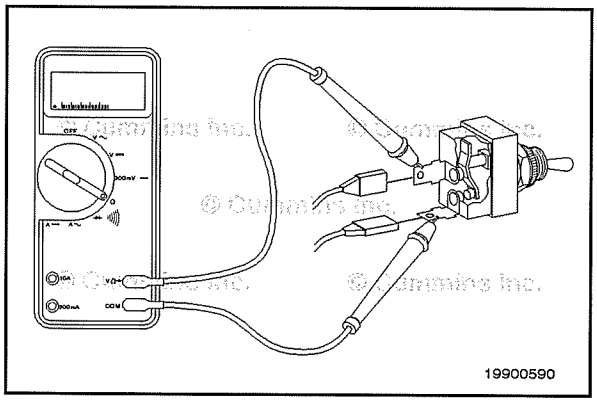




Two-Speed Axle Switch (019-255)

General Information

The 2-speed axle switch allows the operator the capability of switching from one axle to another. The ECM can then calculate the vehicle speed correctly.



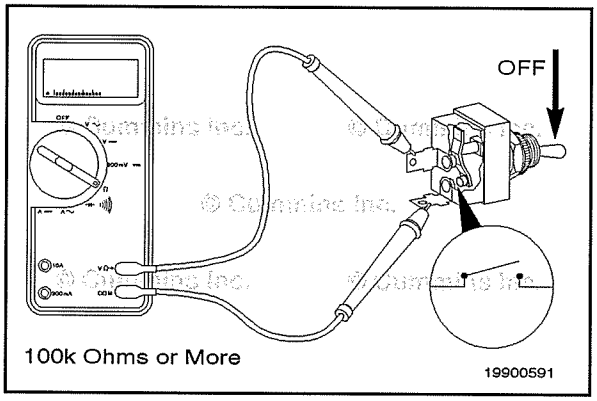
Resistance Check

If INSITE™ electronic service tool is available, monitor the 2-speed axle switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Locate the 2-speed axle switch.

Remove and tag the two connectors from the terminals on the switch.

Touch the multimeter probes to the terminals on the switch.

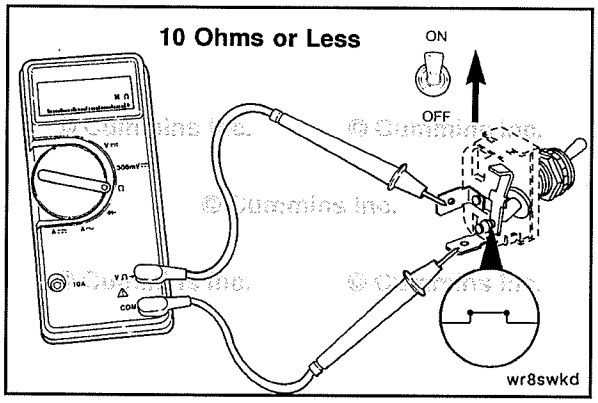


Move the switch to the OFF position, and measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, the switch is damaged and **must** be replaced.

Refer to the OEM troubleshooting and repair manual for the replacement instructions.



Move the switch to the ON position, and measure the resistance.

The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, the switch is damaged and **must** be replaced.

Refer to the OEM troubleshooting and repair manual for the replacement instructions.

If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.

Check for Short Circuit to Ground

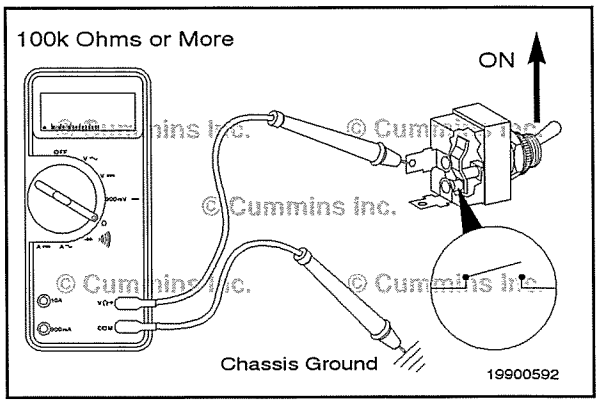
Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground.

Move the switch to the ON position, and measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, the switch is damaged and **must** be replaced.

Refer to the OEM repair manual for replacement procedures.



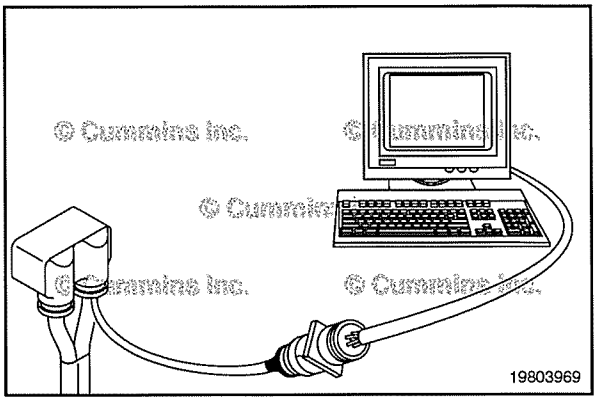
Two-Speed Axle Switch Circuit (019-256)

Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the 2-speed axle switch circuit for proper operation.

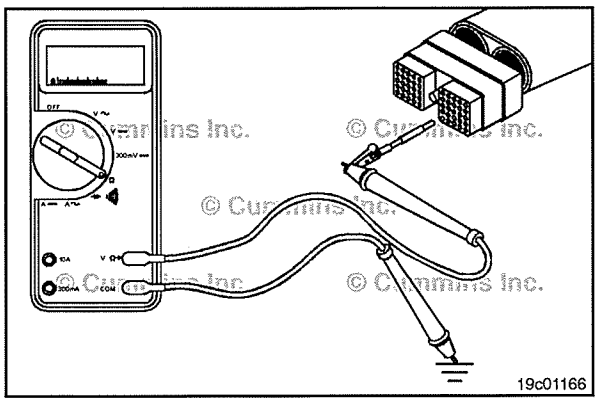
If **not**, follow the troubleshooting procedures in this section.



Disconnect the OEM harness from the ECM connector.

Insert a test lead into the 2-speed axle switch signal pin of the OEM harness connector, and attach it to a multimeter probe.

Touch the other multimeter probe to the engine block ground.

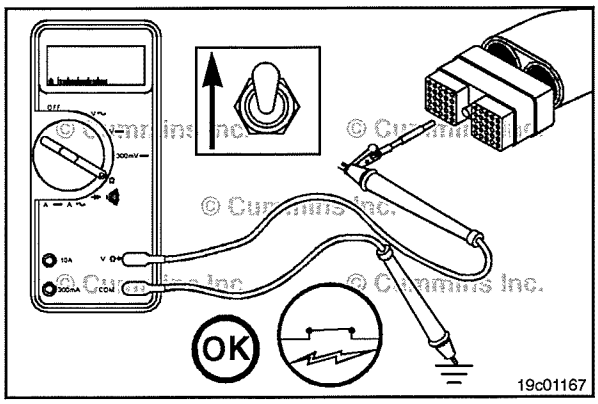


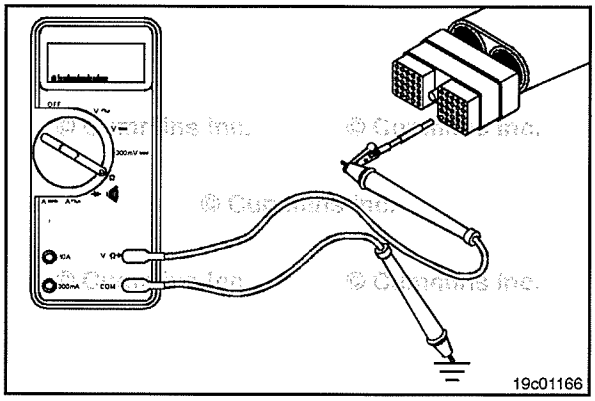
Move the 2-speed axle switch to the ON position.

The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, inspect the 2-speed-axle-switch signal wire for an open circuit. Refer to the OEM troubleshooting and repair manual.

If the resistance is within specification, the 2-speed axle switch signal pin **must** be checked for a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.



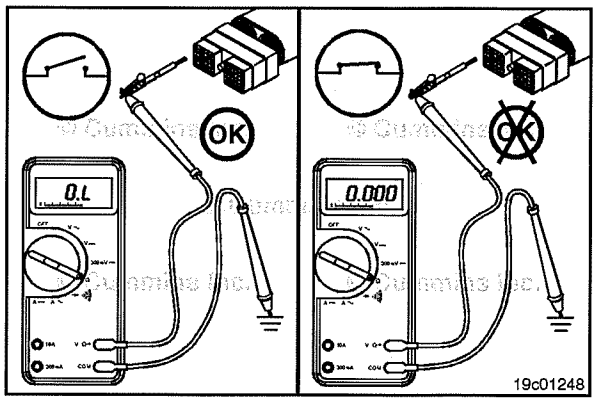


Check for Short Circuit to Ground

Isolate the 2-speed axle switch circuit.

Insert the test lead attached to the multimeter probe into the 2-speed axle switch signal pin of the OEM harness connector.

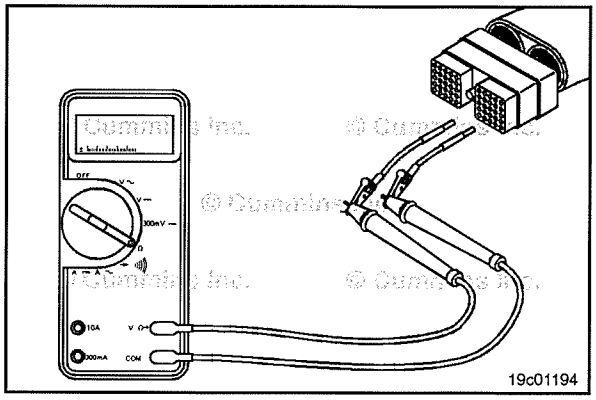
Touch the other multimeter probe to the engine block, and measure the resistance.



The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit to ground in the 2-speed axle switch circuit, provided that the switch has been previously checked.

Repair or replace the wire connected to the 2-speed axle switch signal pin according to the vehicle manufacturer's instructions.



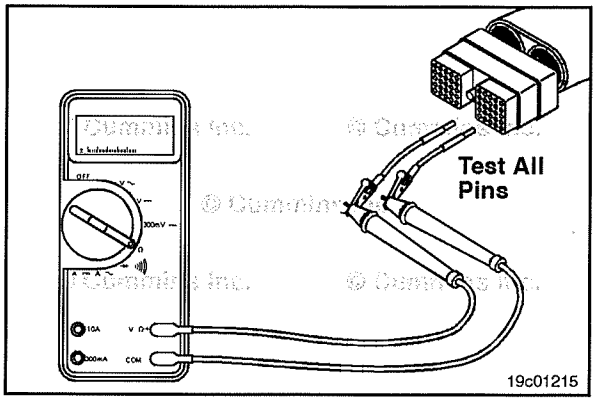
Check for Short Circuit from Pin to Pin

Isolate the 2-speed axle switch circuit.

Insert the appropriate test lead into the 2-speed axle switch signal pin of the OEM harness connector.

Insert the other appropriate test lead into one of the other pins of the connector. Connect the alligator clips to the multimeter probes. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).



Remove the lead and check all other pins.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, there is a short circuit from the wire connected to the 2-speed axle switch signal pin to any pin that measured less than 100k ohms.

Repair or replace the wires in the OEM harness according to the vehicle manufacturer's instructions.

Check for Short Circuit to External Voltage Source

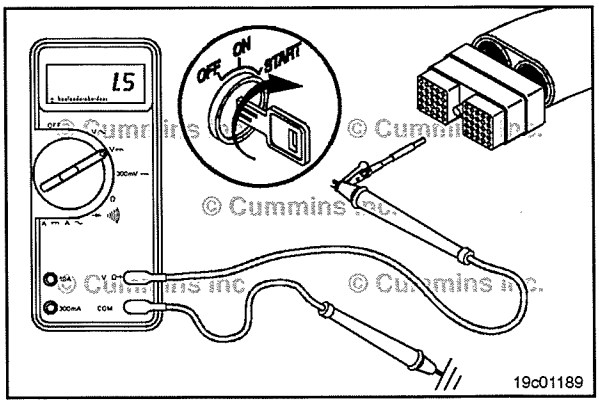
Isolate the 2-speed axle switch circuit. Turn the keyswitch to the ON position. Set the multimeter to measure VDC.

Insert the test lead connected to the positive (+) multimeter probe into the 2-speed axle switch signal pin of the OEM harness connector.

Disconnect the negative (-) multimeter probe from the test lead, touch it to the engine block ground, and measure the voltage.

The voltage **must** be 1.5-VDC or less.

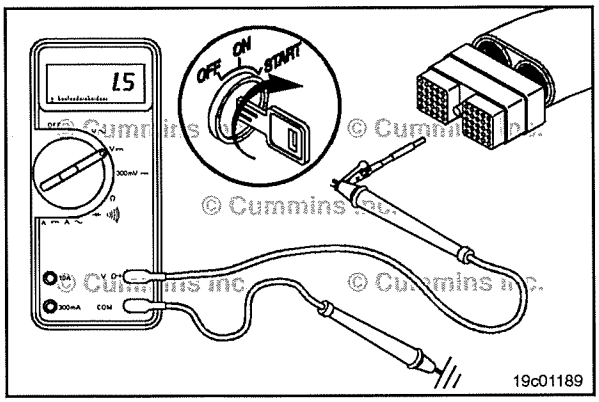
NOTE: An external voltage source is any wire in the OEM harness wiring that carries the voltage.



If the voltage value is more than 1.5-VDC, there is a short circuit between the wire connected to the 2-speed axle switch signal pin and a wire that is carrying power in the OEM harness.

Repair or replace the OEM harness. Refer to Procedure 019-071.

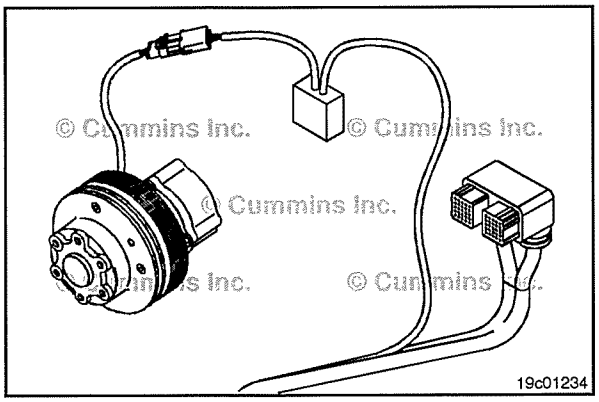
Connect all components after completing the repairs.



Air Conditioning Pressure Switch (019-261)

General Information

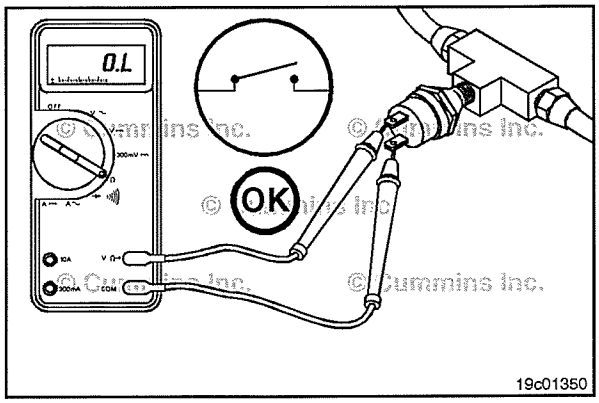
The air conditioning pressure switch circuit signals the system that the air conditioner head pressure is high and the engine fan **must** be engaged. The air conditioning pressure circuit consists of the air conditioning pressure switch signal pin and switch return pin. This circuit is considered "fail safe", meaning when the circuit is open, the engine fan will be engaged by the electronic control module (ECM).

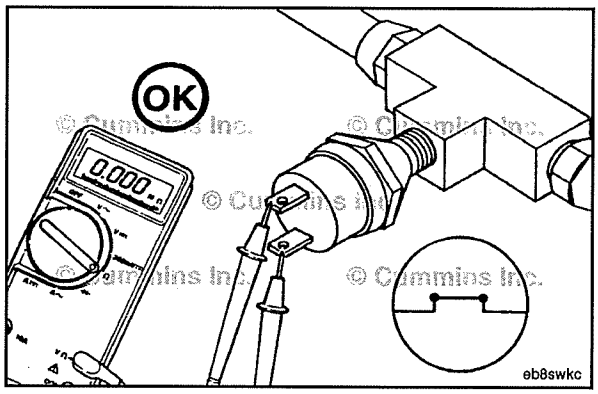


Resistance Check

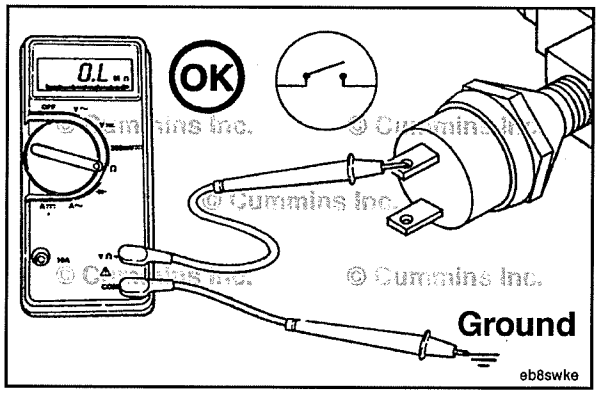
Locate the air conditioning pressure switch. Remove the electrical connection from the switch. Adjust the multimeter to measure resistance. Touch one multimeter probe to one of the terminals on the switch. Touch the other multimeter probe to the other terminal of the switch.

When the system head pressure is high, the multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the original equipment manufacturer (OEM) troubleshooting and repair manual for replacement procedures.



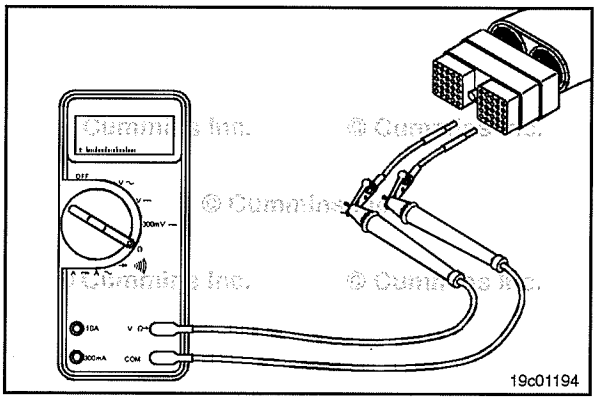


When the system head pressure is low, the multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

When the system head pressure is low, touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.



Air Conditioning Pressure Switch Circuit (019-262)

Resistance Check

△CAUTION△
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM). Insert one of the test leads into the switch return of the OEM harness connector and connect the alligator clip to the multimeter probe. Insert the other lead into the air conditioning pressure switch signal pin of the harness connector and connect the alligator clip to the other multimeter probe.

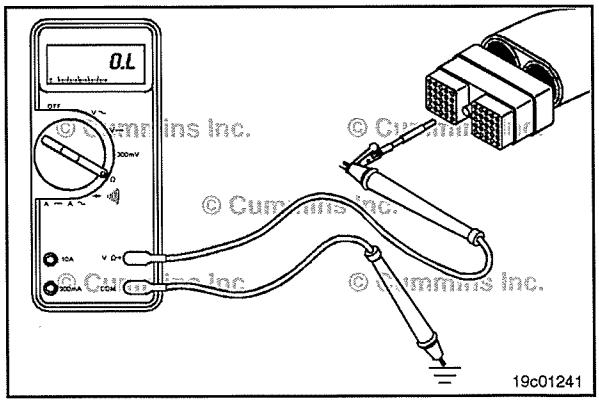
When the system head pressure is low, the multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the switch return and the air conditioning pressure switch signal wire for an open circuit, provided that the switch has been previously checked. Refer to the OEM troubleshooting and repair manual for repair procedures. If the resistance is within the specification, the switch return and the air conditioning pressure switch wire **must** be checked for a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.

Check for Short Circuit to Ground

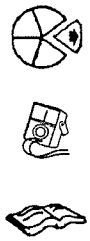
To isolate the air conditioning switch circuit when checking for an electrical short, disconnect the OEM harness from the ECM.

Adjust the multimeter to measure resistance. When the system head pressure is low, insert a test lead into the air conditioning pressure switch signal pin of the OEM harness connector and connect it to a multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the air conditioning switch circuit, provided that the switch has been previously checked. Repair or replace the wire connected to the air conditioning pressure switch signal pin in the OEM harness. Refer to Procedure 019-071.

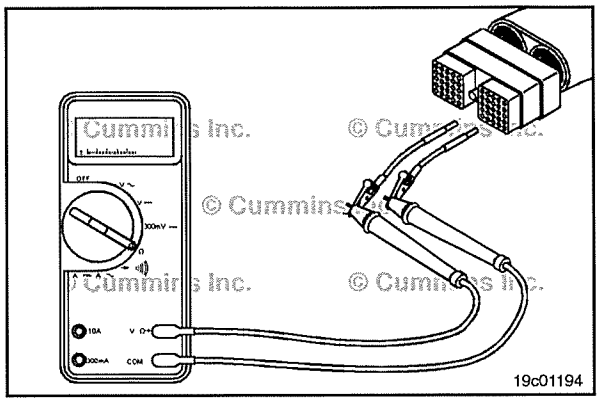


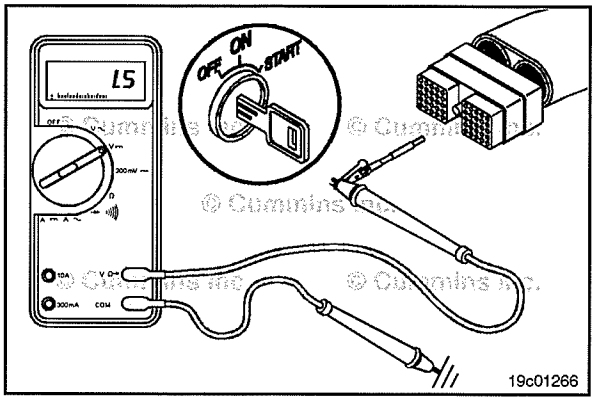
Check for Short Circuit from Pin to Pin



Check for a short circuit from pin-to-pin. Isolate the air conditioning circuit by removing the OEM harness from the ECM. Insert the lead into the air conditioning pressure switch signal pin. Connect the alligator clip to the multimeter. With the other lead inserted into the switch return pin, measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

Allow the head pressure to drop and remove the lead from the air conditioning pressure switch signal pin and check all other pins. When the system head pressure is low, measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit between the air conditioning pressure circuit and any pin that shows a closed circuit. Repair or replace the wires in the engine harness. Refer to Procedure 019-043. Repair or replace the wires in the OEM harness. Refer to Procedure 019-071.





Check for Short Circuit to External Voltage Source

Turn the keyswitch to the ON position. When the system head pressure is low, adjust the multimeter to measure VDC. Insert a test lead into the air conditioning pressure switch signal pin of the OEM connector and attach it to a multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the voltage. The voltage **must** be 1.5 VDC or less. If the voltage is **not** correct, there is an external voltage source connected to the circuit, or there is a short circuit between the air conditioning pressure switch circuit and a wire carrying power in the engine or OEM harness. Remove the voltage source, or repair or replace the wiring in the OEM harness. Refer to Procedure 019-071. Remove the voltage source or repair or replace the wires in the engine harness. Connect all components after completing the repair.

NOTE: If the air conditioning pressure switch circuit was approved in all of the previous tests, it is functioning properly.

Accelerator Interlock Switch (019-264)

General Information

The accelerator interlock switch inhibits the operation of the cab accelerator and the remote accelerator. For example, busses inhibit the accelerator as passengers embark and disembark, to ensure the bus remains stationary. The accelerator interlock feature, available **only** on special transit and vocational calibrations, uses this switch. Installation varies; busses commonly use a door-actuated switch.

Accelerator Interlock Switch Circuit (019-265)

Resistance Check

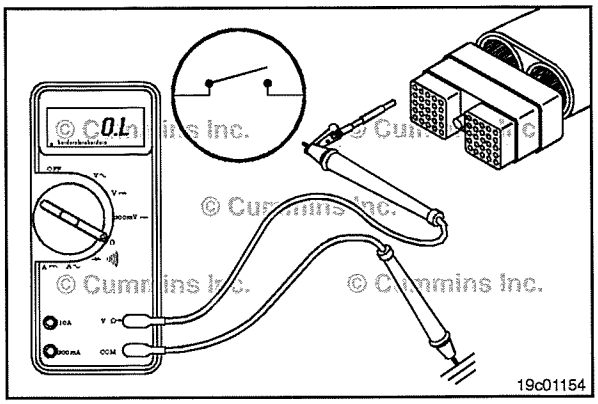
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

The accelerator interlock switch is programmable. Check the setting with INSITE™ electronic service tool before continuing with the troubleshooting steps.

If INSITE™ electronic service tool is available, monitor the accelerator interlock switch for proper operation. If **not**, follow the procedure below.

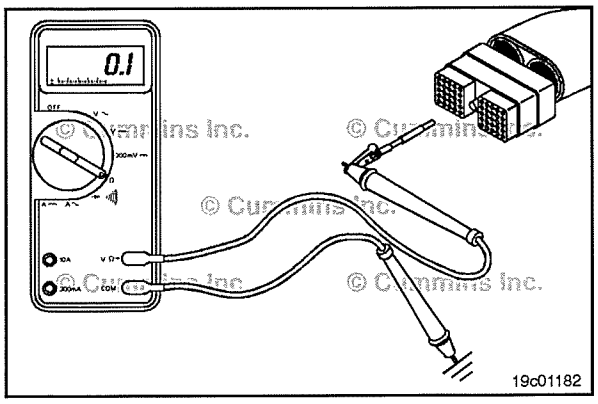
NOTE: The accelerator interlock signal input can also be used as the engine torque limit switch signal as well.

Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM). Insert a test lead into the accelerator interlock switch signal pin. Touch the other multimeter probe to engine block ground. With the switch in the inhibit position, the multimeter **must** read an open circuit (100k ohms or more).



With the switch in the normal position, the multimeter **must** read a closed circuit (10 ohms or less).

If the circuit is **not** closed, inspect the accelerator interlock switch signal line for an open circuit.

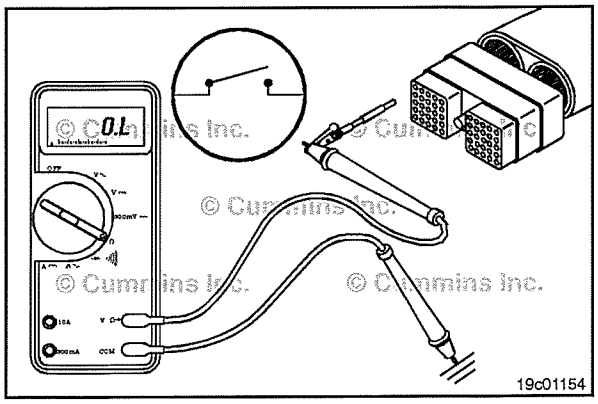


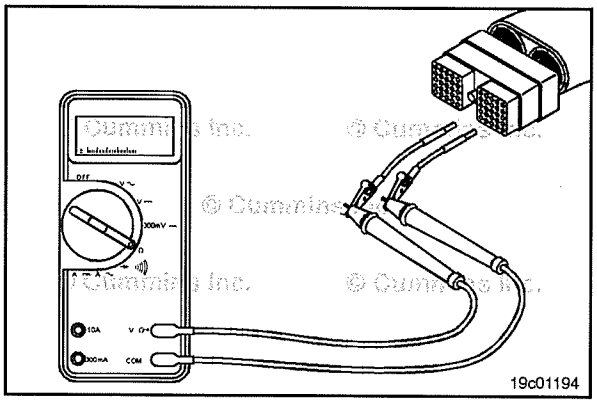
Check for Short Circuit to Ground

Connect one of the multimeter probes to the accelerator interlock switch signal wire. Touch the other probe to chassis ground. Move the switch to the inhibit position and measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more). If the circuit does **not** show an open circuit then there is a short to ground in the circuit somewhere.

Repair or replace the OEM harness. Refer to Procedure 019-071.



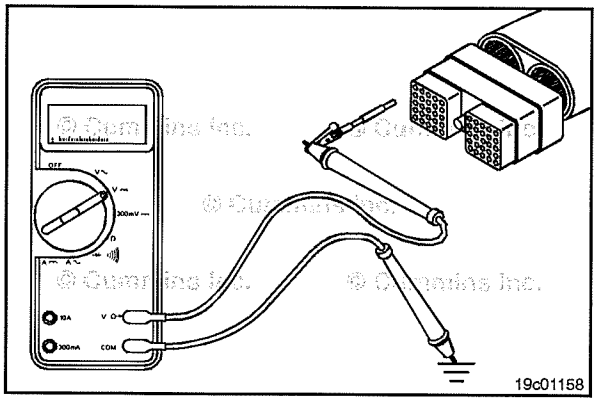


Check for Short Circuit from Pin to Pin

Check for a short circuit from pin-to-pin. Insert a test lead into the accelerator interlock switch signal pin. Insert the other test lead into the switch return pin. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

Remove the test lead from the switch return pin and test all other pins in the connector. The multimeter **must** show an open circuit on all pins.

Repair any pin circuits that show a closed circuit with the accelerator governor switch signal pin.

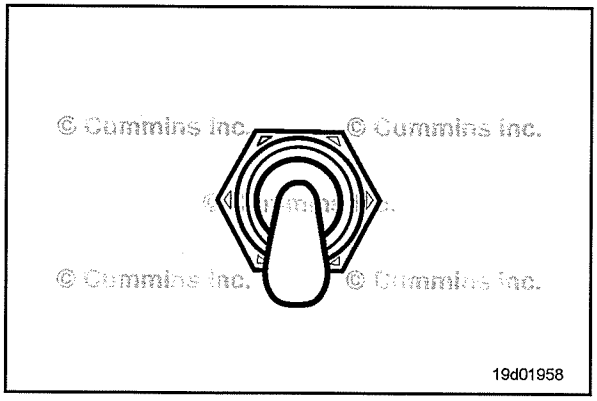


Check for Short Circuit to External Voltage Source

Set the switch to normal position and set the multimeter to read VDC. Insert one test lead into the accelerator interlock switch signal pin and connect a multimeter lead to it. Touch the other multimeter lead to engine block ground. Measure the voltage.

The voltage **must** read 1.5 VDC or less.

If the voltage is **not** correct, there is an external voltage source connected to the circuit. Repair or replace the OEM wiring. Refer to Procedure 019-071.



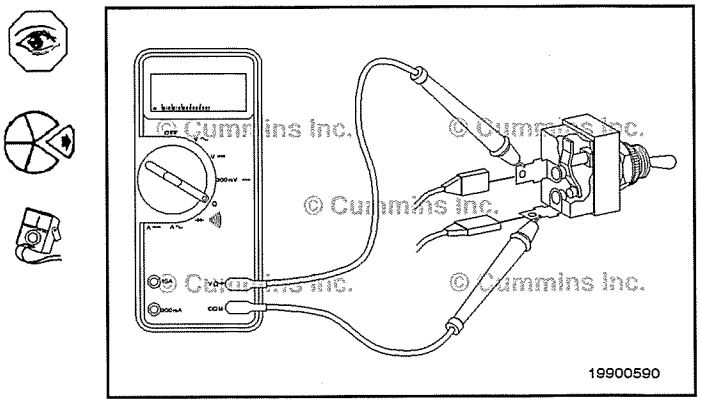
Cab Switchable Governor Switch (019-266)

General Information

The cab switchable governor switch selects between variable speed (VS) and automotive accelerator governors. Governor selection often occurs while changing operation modes: for example, between cab accelerator and remote accelerator. When the OEM enables the switchable accelerator type of feature, the automotive or VS governing feature uses the accelerator governor switch.

The accelerator governor switch has two positions: ALTERNATE and PROGRAMMABLE. The PROGRAMMABLE position allows the accelerator-type parameter, VS or automotive, to choose the governor. The ALTERNATE position chooses the opposite governor from that selected by the accelerator-type parameter.

Resistance Check



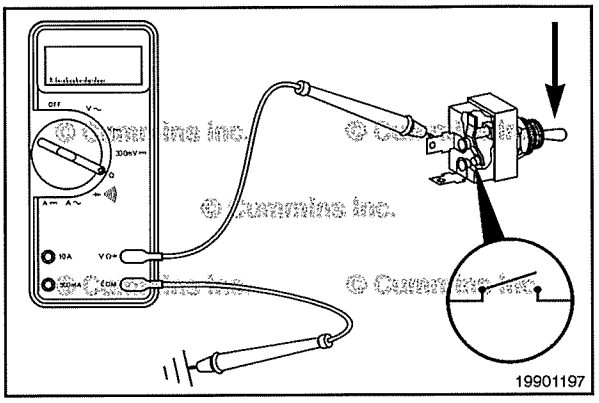
If INSITE™ electronic service tool is available, monitor the switch for proper operation. If **not**, follow the following procedure.

Locate the switch. Disconnect the connectors and label the wires. Touch a multimeter probe to each switch terminal and measure the resistance with the switch set to both positions.

The multimeter **must** show a value of 100k ohms or more (open circuit) while the switch is in one position and a value of 10 ohms or less (closed circuit) in the other position.

If the switch does **not** transition from an open to a closed circuit when flipped from one position to the other, the switch is defective. Replace the switch. Refer to the original equipment manufacturer (OEM) troubleshooting and repair manual.

Check for Short Circuit to Ground

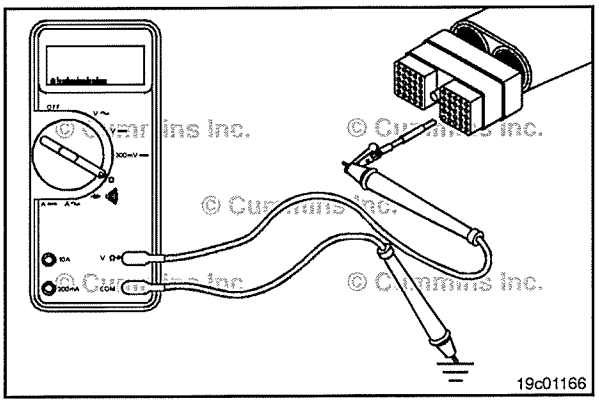


Locate the switch. Disconnect the connectors and label the wires. Touch one of the multimeter probes to one of the switch terminals and touch the other multimeter to engine block ground. Move the switch from one position to the other.

The multimeter **must** show a value of 100k ohms or more (open circuit) with the switch in both positions. If the switch does not show an open circuit, the switch is defective. Replace the switch. Refer to the original equipment manufacturer (OEM) troubleshooting and repair manual.

Cab Switchable Governor Switch Circuit (019-267)

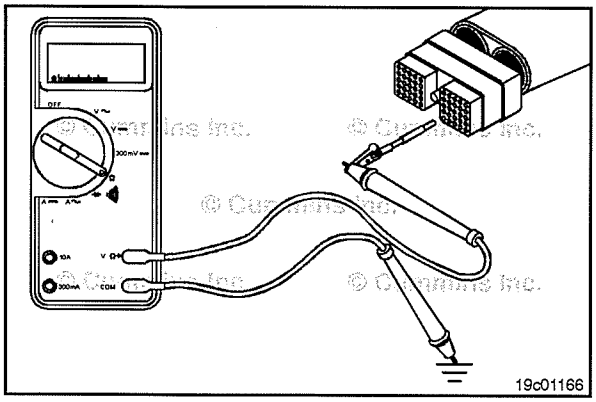
Resistance Check



⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

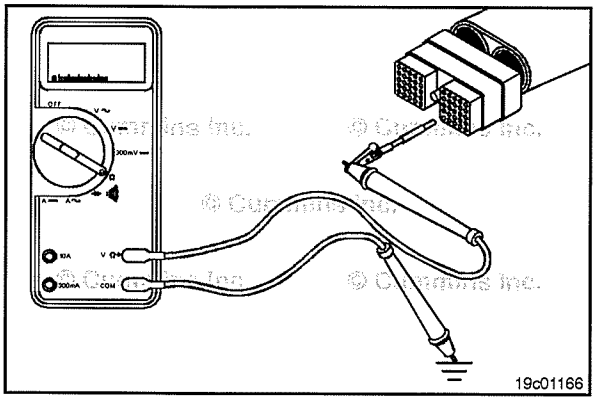
If INSITE™ electronic service tool is available, monitor the switch for proper operation. If **not**, follow the following procedure.

Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM). Set the multimeter to measure resistance. Insert a test lead into the accelerator governor switch input pin of the OEM harness connector, and attach the alligator clip to a multimeter probe. Touch the other multimeter probe to engine block ground.



Transition the switch from one position to the other and measure the resistance at both positions. The multimeter **must** show a value of 100k ohms or more (open circuit) while the switch is in one position, and a value of 10 ohms or less (closed circuit) in the other position.

If the switch does **not** transition from an open to a closed circuit when flipped from one position to the other, there is an open circuit in the input wire. If the specification is correct, the circuit **must** still be checked for a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.



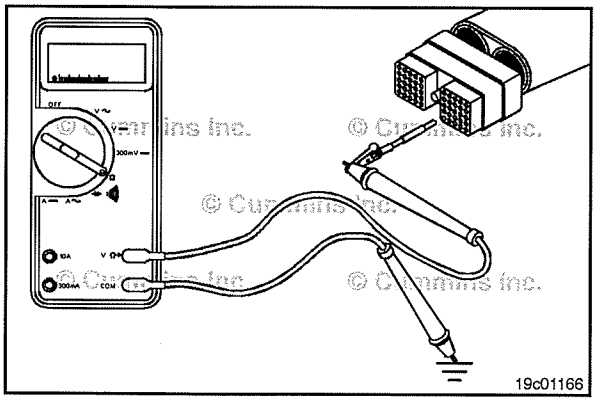
Check for Short Circuit to Ground

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECM. Set the multimeter to measure resistance.

Insert a test lead into the accelerator governor switch input pin of the OEM harness connector, and attach the alligator clip to a multimeter probe.

Touch the other multimeter probe to engine block ground. Move the switch from its present position to the other position, and measure the resistance.



The multimeter **must** show a value of 100k ohms or more (open circuit).

If the multimeter does **not** show an open circuit, there is a short circuit to ground in the circuit.

Repair or replace the OEM harness. Refer to Procedure 019-071.

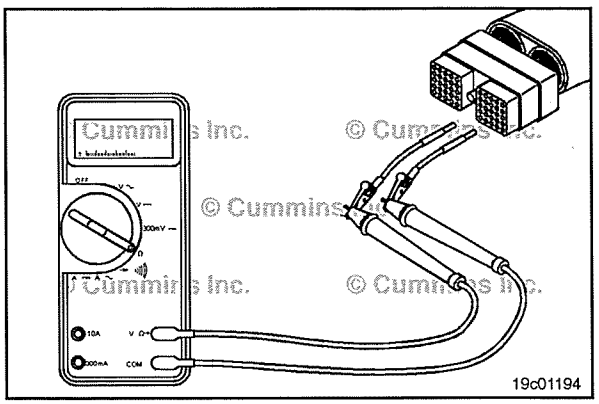
Check for Short Circuit from Pin to Pin

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECM. Set the multimeter to measure resistance.

Insert a test lead into the accelerator governor switch input pin of the OEM harness connector, and attach the alligator clip to a multimeter probe.

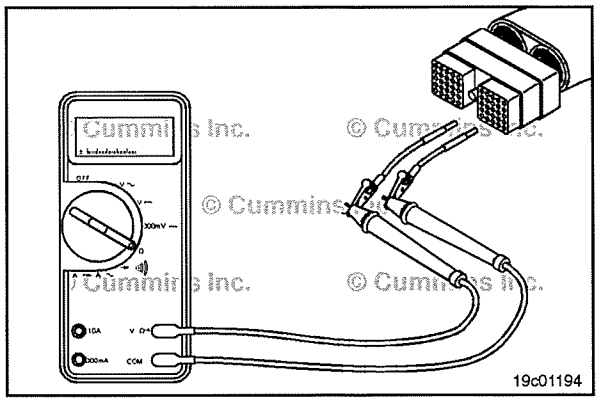
Touch the other multimeter probe with attached test lead to all other pins in the connector. Measure the resistance.



The multimeter **must** show a value of 100k ohms or more (open circuit) at all pins.

If any circuit is **not** open, there is a short circuit between the input pin and the applicable pin.

Repair or replace the OEM harness. Refer to Procedure 019-071.



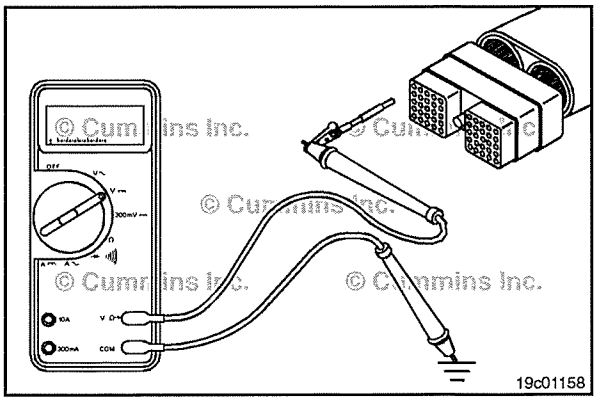
Check for Short Circuit to External Voltage Source

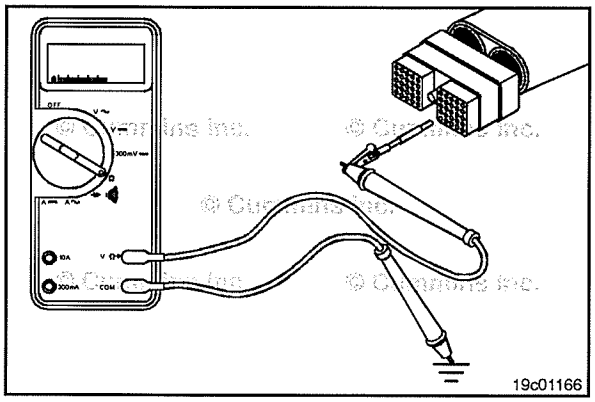
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECM. Set the multimeter to measure VDC. Turn the keyswitch to the ON position.

Insert a test lead into the accelerator governor switch input pin of the OEM harness connector, and attach the alligator clip to a multimeter probe.

Touch the other multimeter probe to engine block ground and measure the voltage.

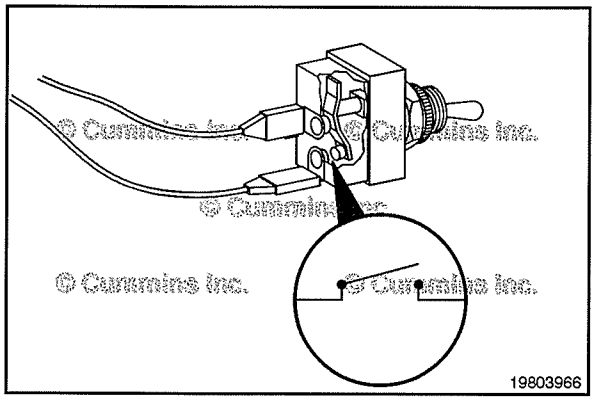




The multimeter **must** show a value of 1.5 VDC or less.

If the voltage is more than 1.5 VDC, there is a short circuit to an external voltage source.

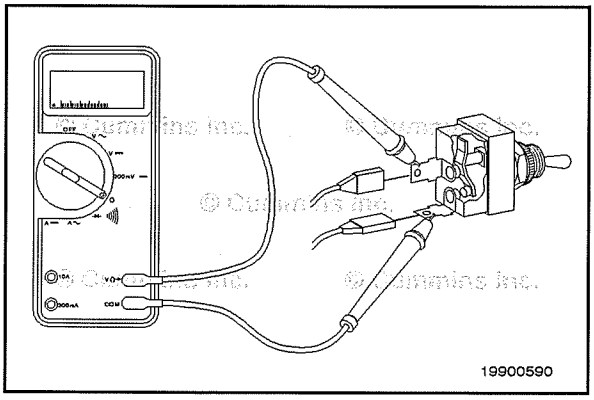
Remove the external voltage source.



Multi Unit Synchronization Switch (019-270)

General Information

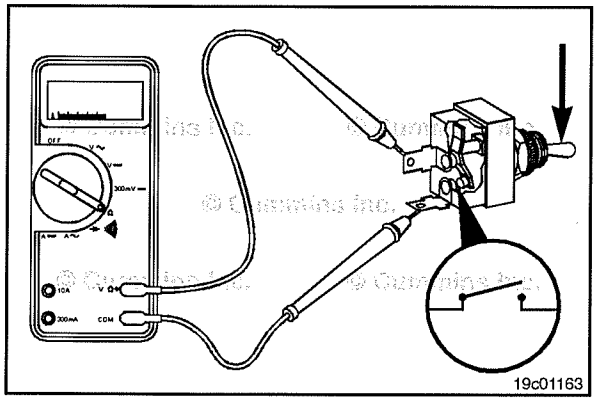
The Multiple Unit Synchronization feature allows two or more engines to be controlled by a single throttle input. One engine is configured as the primary engine, all other engines **must** be configured as secondary.



Resistance Check

If INSITE™ electronic service tool is available, monitor the switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Locate the desired ON/OFF toggle switch. Remove and tag the two connectors from the terminals on the switch. Touch the multimeter probes to the terminals on the switch.



Move the switch to the OFF position and measure the resistance.

The multimeter **must** show an open circuit (100K ohms or more).

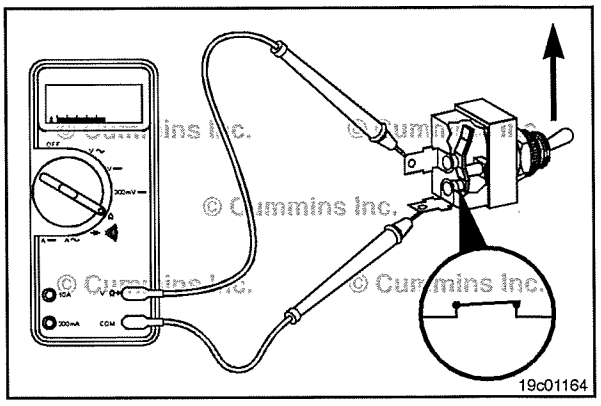
If the circuit is **not** open, the switch is damaged and **must** be replaced. Refer to the OEM troubleshooting and repair manual for the replacement procedures.

Move the switch to the ON position and measure the resistance.

The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, the switch is damaged and **must** be replaced. Refer to the OEM troubleshooting and repair manual for the replacement procedures.

If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



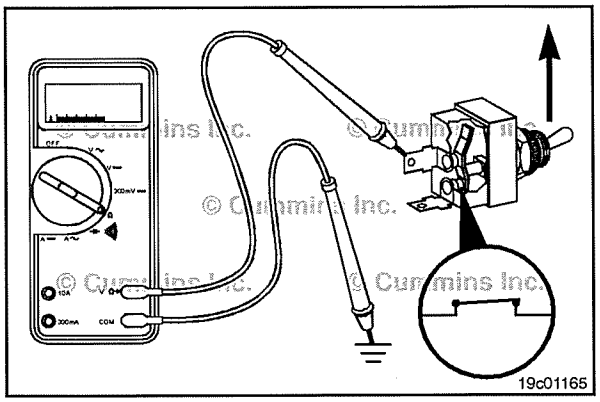
Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the ON position and measure the resistance.

The multimeter **must** show an open circuit (100K ohms or more).

If the circuit is **not** open, the switch is damaged and **must** be replaced. Refer to the OEM troubleshooting and repair manual for replacement procedures.

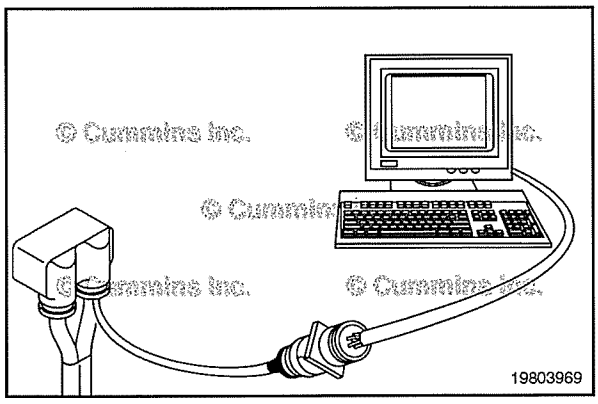
If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.



Engine Protection Override Switch (019-327)

General Information

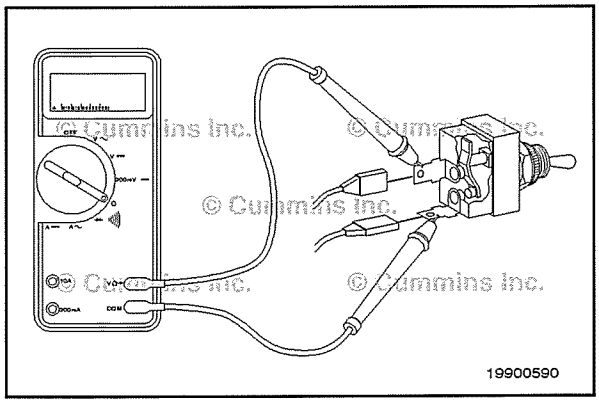
The engine protection override switch is an original equipment manufacturer (OEM) installed switch that allows a driver to abort a pending engine protection shutdown. The switch is **only** active when it is properly wired by the OEM and the engine protection shutdown override feature is enabled in the calibration. If the switch is **not** preventing a shutdown from occurring, check the feature with the electronic service tool to see if it is enabled in the calibration.

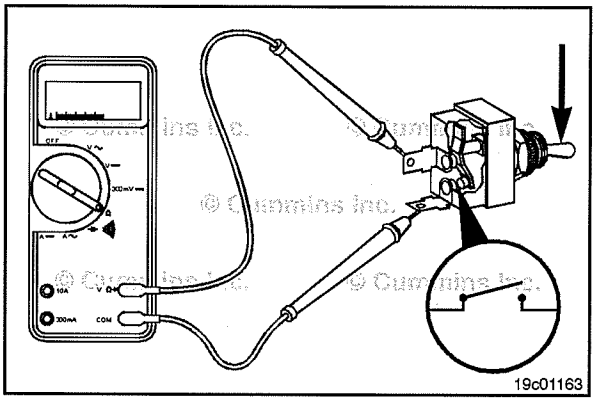


Resistance Check

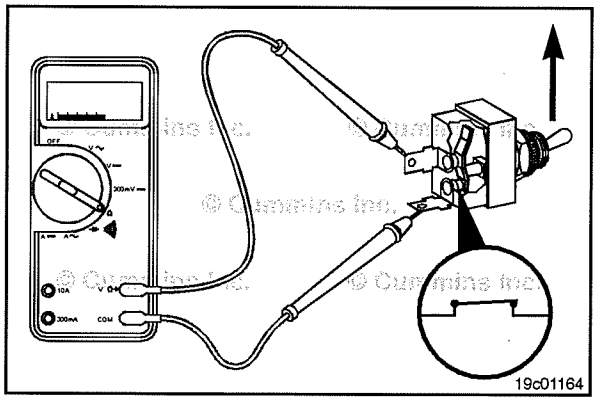
If INSITE™ electronic service tool is available, monitor the engine protection override switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Locate the engine protection override switch. Label the wires with the location on the switch or the wire number. Remove the electrical connectors from the switch. Adjust the multimeter to measure resistance. Touch one multimeter probe to one of the terminals on the switch. Touch the other multimeter probe to the other terminal of the switch.

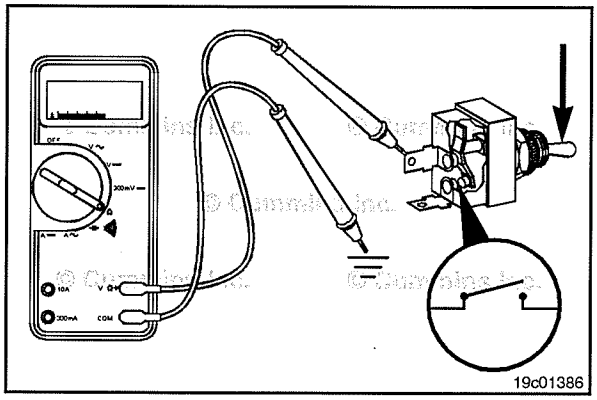




Place the switch in the non-override (released) position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch is defective. Refer to the original equipment manufacturer (OEM) troubleshooting and repair manual for replacement procedures.



Place the switch in the override (pressed) position and measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, the switch is defective. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the non-override (released) position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

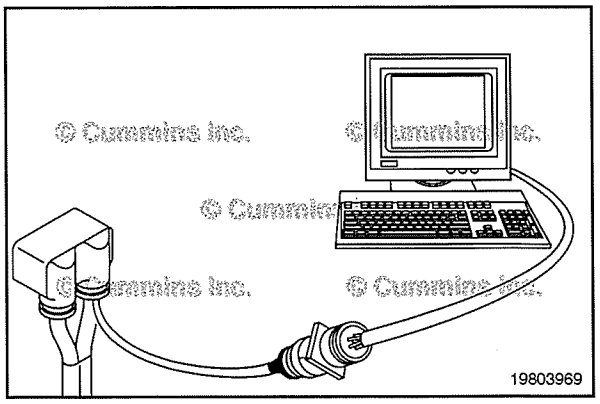
If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures.

If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.

Engine Protection Override Switch Circuit (019-328)

Resistance Check

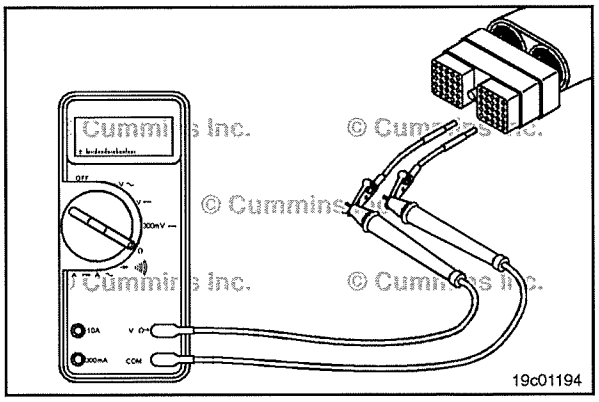
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.



If INSITE™ electronic service tool is available, monitor the engine protection override switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.

Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM). Insert one of the test leads into the switch return negative (-) pin of the OEM harness connector and connect the alligator clip to the multimeter probe. Insert the other lead into the engine protection override switch signal pin of the OEM harness connector and connect the alligator clip to the other multimeter probe.

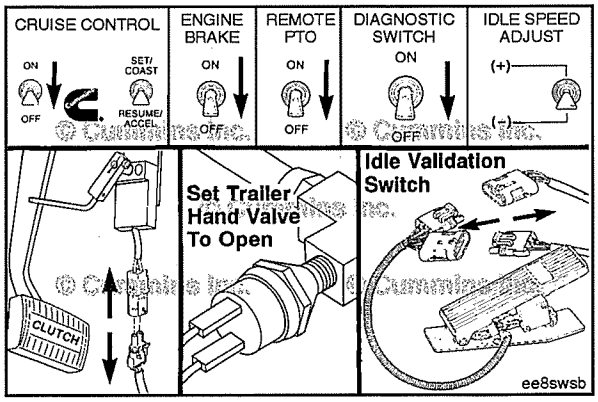
Move the engine protection override switch to the override (pressed) position. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the switch return negative (-) wire and the engine protection override switch wire for an open circuit, provided that the switch has been previously checked. Refer to the OEM troubleshooting and repair manual for repair procedures.

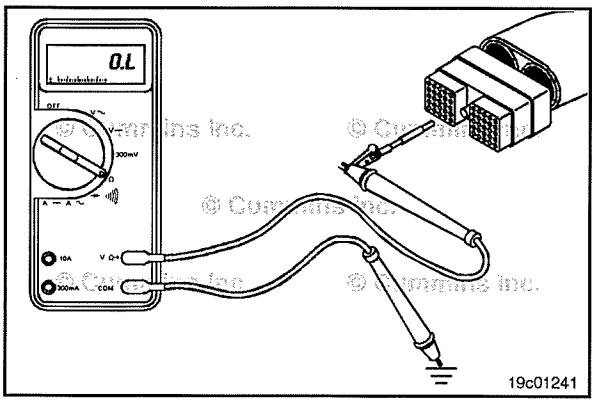


If the resistance is within the specification, the cab switch return negative (-) wire and the engine protection override switch wire **must** be checked for a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.

Check for Short Circuit to Ground

To isolate the engine protection override switch circuit when checking for an electrical short, disconnect the OEM harness from the ECM connector and the OEM harness from the engine protection override switch. Disconnect the idle validation switch. Set all cab panel switches to the OFF or neutral position. Set the service brake using the trailer brake hand valve.

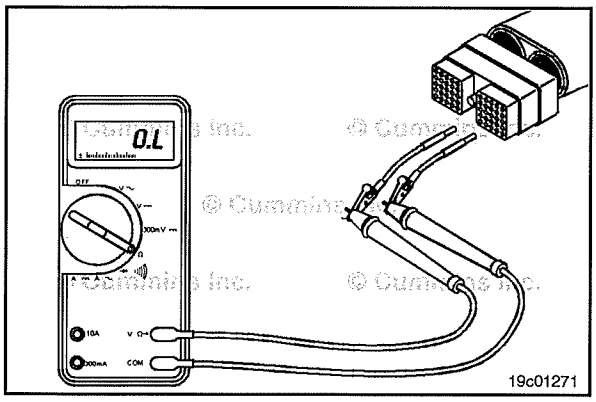




Adjust the multimeter to measure resistance. Insert a test lead into the engine protection override switch pin of the OEM harness connector and connect it to a multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the resistance.

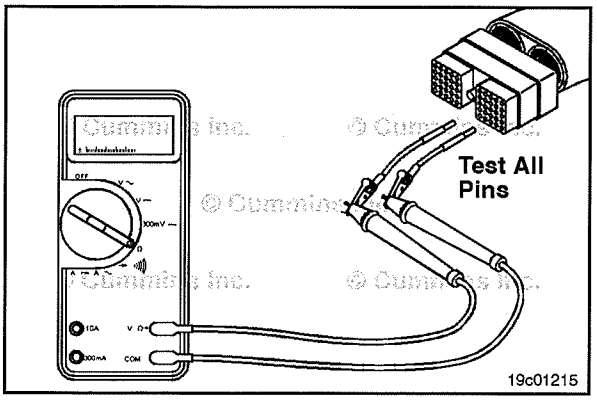
The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the engine protection override switch circuit, provided that the switch has been previously checked.

Repair or replace the wire connected to cruise control input wire in the OEM harness according to the vehicle manufacturer's procedure.



Check for Short Circuit from Pin to Pin

Check for a short circuit from pin-to-pin. Isolate the engine protection override circuit by setting the switches as in the previous section. Set the engine protection override switch to the override position. Insert the lead into the engine protection override switch pin. Connect the alligator clip to the multimeter. With the other lead inserted into the cab switch return negative (-) pin, measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).



Remove the lead from the engine protection override switch pin and check all other pins. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit between the engine protection override switch circuit and any pin that shows a closed circuit, provided the switch has previously been checked.

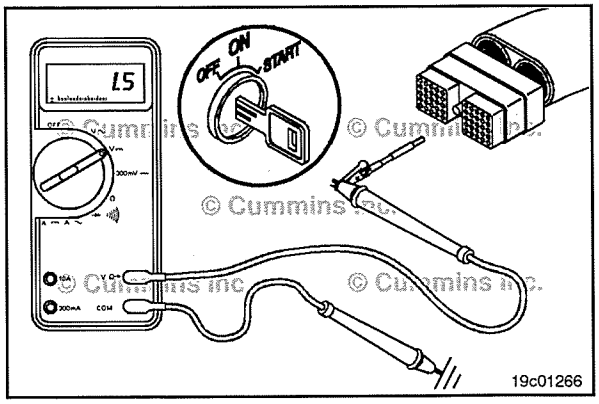
Repair or replace the wires in the OEM harness. Refer to Procedure 019-071.

Check for Short Circuit to External Voltage Source

Turn the keyswitch to the ON position. Set the engine protection override switch to the override position. Adjust the multimeter to measure VDC. Insert a test lead into the engine protection override switch pin and attach it to a multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the voltage. The voltage **must** be 1.5 VDC or less.

If the voltage is **not** correct, there is an external voltage source connected to the circuit, or there is a short circuit between the engine protection override switch circuit and a wire carrying power in the OEM harness. Remove the voltage source or repair the wiring in the OEM harness. Refer to Procedure 019-071. Connect all components after completing the repair.

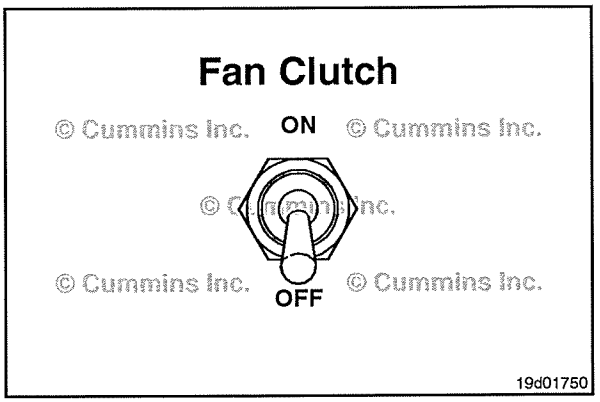
NOTE: If the engine protection override switch circuit was approved in all of the previous tests, it is functioning properly.



Fan Clutch Switch (019-329)

General Information

The fan clutch switch allows the driver to control the operation of the engine's fan.

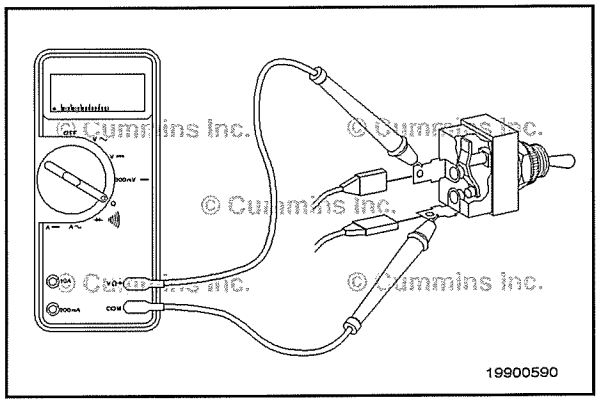


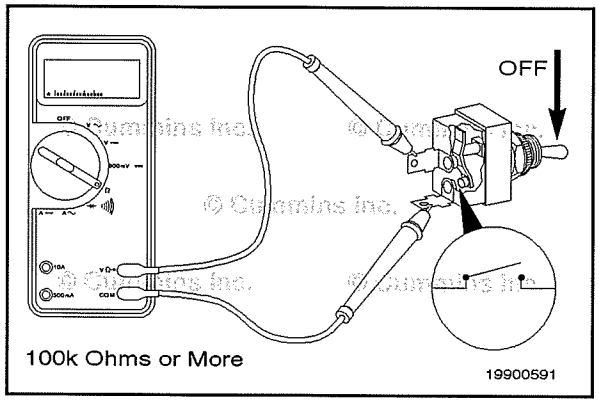
Resistance Check

If INSITE™ electronic service tool is available, monitor the fan clutch switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

Locate the fan clutch switch. Remove and tag the two connectors from the terminals on the switch.

Touch the multimeter probes to the terminals on the switch.



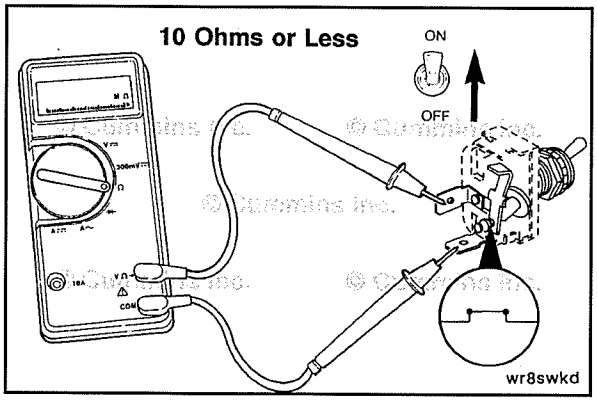


Move the switch to the OFF position, and measure the resistance.

The multimeter **must** show 100k ohms or more (open circuit).

If the circuit is **not** open, the switch has failed.

Replace the switch. Refer to the OEM troubleshooting and repair manual for the replacement instructions.

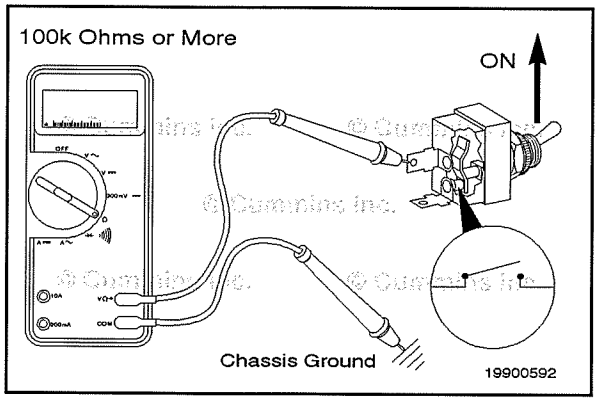


Move the switch to the ON position, and measure the resistance.

The multimeter **must** show 10 ohms or less (closed circuit).

If the circuit is **not** closed, the switch is damaged and **must** be replaced. Refer to the OEM repair manual for the replacement instructions.

If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



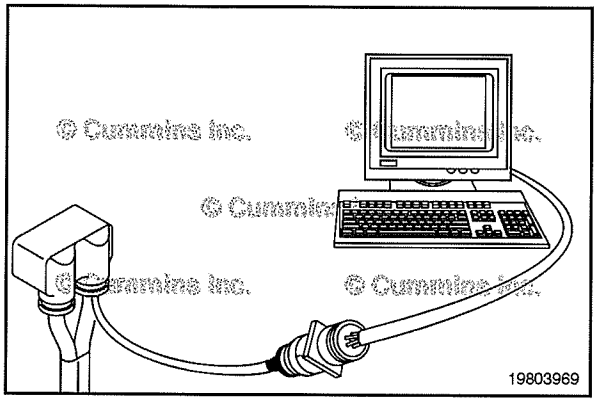
Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground.

Move the switch to the ON position, and measure the resistance.

The multimeter **must** show 100k ohms or more (open circuit).

If the circuit is **not** open, the switch is damaged and **must** be replaced. Refer to the OEM repair manual for replacement procedures.



Fan Clutch Switch Circuit (019-330)

Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

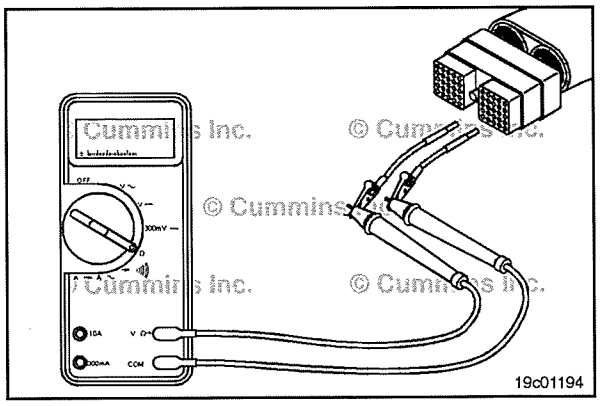
If INSITE™ electronic service tool is available, monitor the switch for proper operation. If **not**, follow the following procedure.

Disconnect the OEM harness connector from the ECM connector. Set the multimeter to measure resistance.

Insert a test lead into the manual fan clutch switch input pin of the OEM harness connector, and attach the alligator clip to a multimeter probe.

Insert the other lead attached to the multimeter probe to the switch return (-) pin of the OEM harness connector.

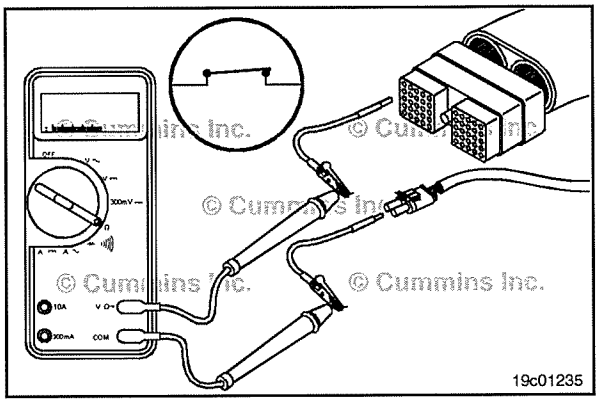
Set the manual fan clutch switch to the OFF position and measure the resistance.



The multimeter **must** show a value of 10 ohms or less (closed circuit).

If the specification is **not** correct, there is an open circuit in the return (-) wire or input wire, provided the switch has previously been checked.

If the resistance is within specification, the return (-) wire and switch wire **must** still be checked for a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.



Check for Short Circuit to Ground

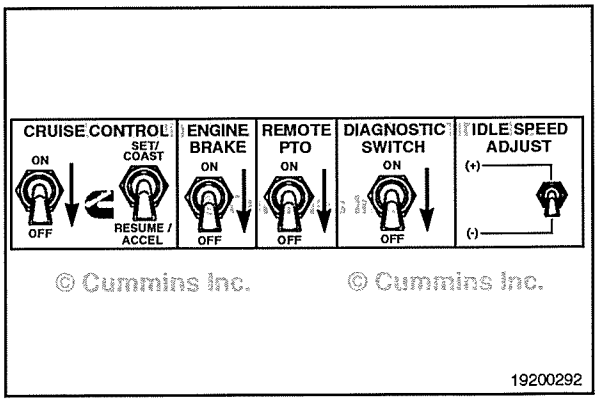
Disconnect the OEM harness connector from the ECM connector.

Disconnect the manual fan clutch switch from the OEM harness.

Disconnect the clutch switch and the idle validation switch.

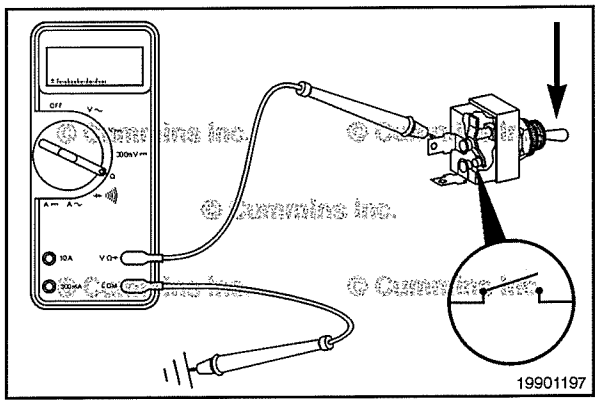
Set all cab switches to the OFF or neutral position.

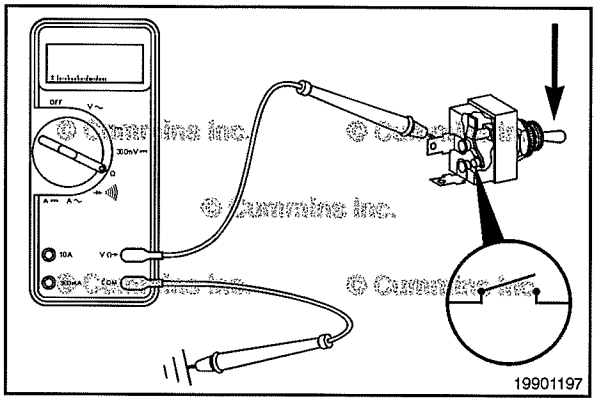
Set the service brake using the trailer brake hand valve. Set the multimeter to measure resistance.



Insert a test lead into the manual fan clutch switch input pin of the OEM harness connector, and attach the alligator clip to a multimeter probe.

Touch the other multimeter probe to engine block ground and measure the resistance.

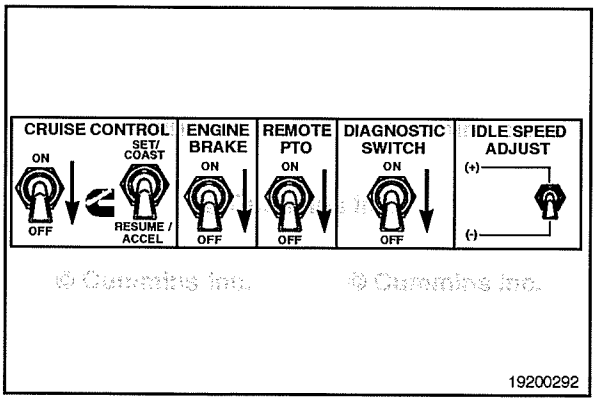




The multimeter **must** show a value of 100k ohms or more (open circuit).

If the circuit is **not** open, there is a short circuit to ground in the manual fan clutch circuit, provided the switch has been previously checked and is good.

Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.



Check for Short Circuit from Pin to Pin

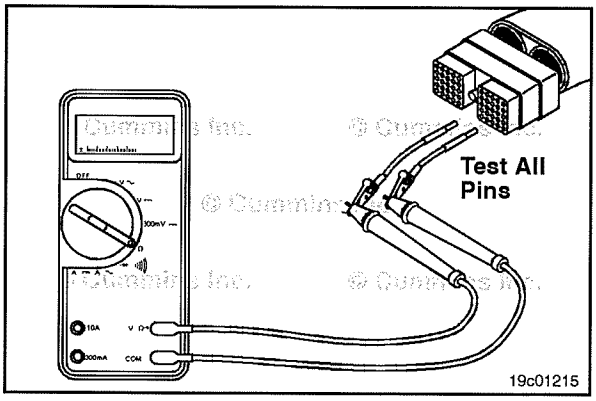
Disconnect the OEM harness connector from the ECM connector.

Disconnect the manual fan clutch switch from the OEM harness.

Disconnect the clutch switch and the idle validation switch.

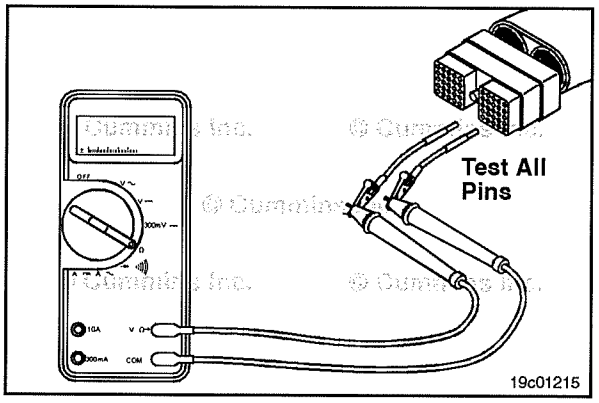
Set all cab switches to the OFF or neutral position.

Set the service brake using the trailer brake hand valve. Set the multimeter to measure resistance.



Insert a test lead into the manual fan clutch switch input pin of the OEM harness connector, and attach the alligator clip to a multimeter probe.

Touch the other multimeter probe with attached test lead to all other pins in the connector. Measure the resistance.



The multimeter **must** show a value of 100k ohms or more (open circuit) at all pins.

If any circuit is **not** open, there is a short circuit between the input pin and the applicable pin, provided the switch has been checked and is good.

Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

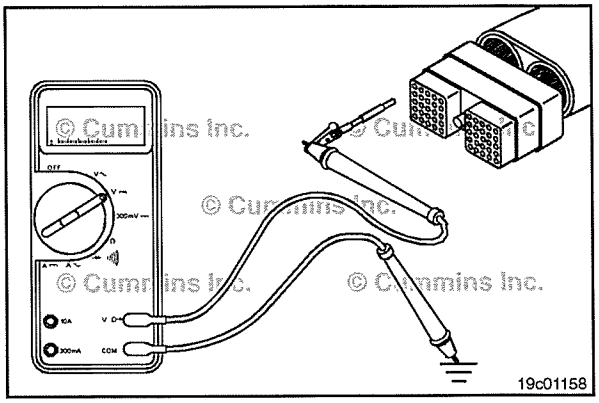
Check for Short Circuit to External Voltage Source

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECM connector. Set the multimeter to measure VDC. Turn the keyswitch to the ON position.

Insert a test lead into the manual fan clutch switch input pin of the OEM harness connector, and attach the alligator clip to a multimeter probe.

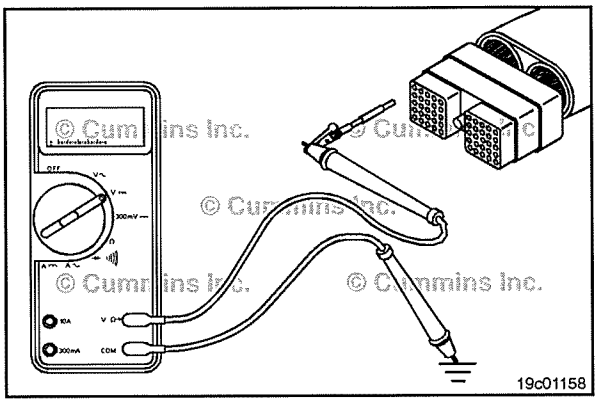
Touch the other multimeter probe to engine block ground and measure the voltage.



The multimeter **must** show a value of 1.5-VDC or less.

If the voltage is more than 1.5-VDC, there is a short circuit to an external voltage source.

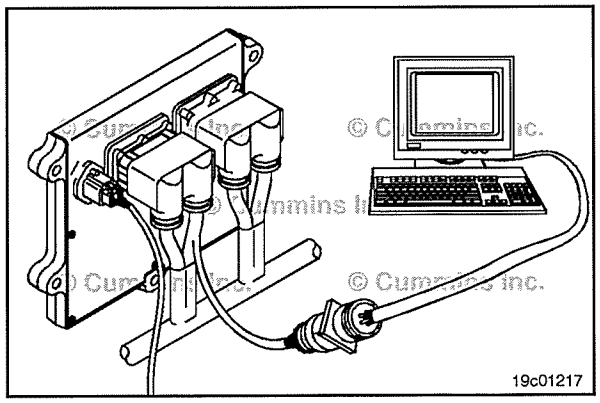
Remove the external voltage source.

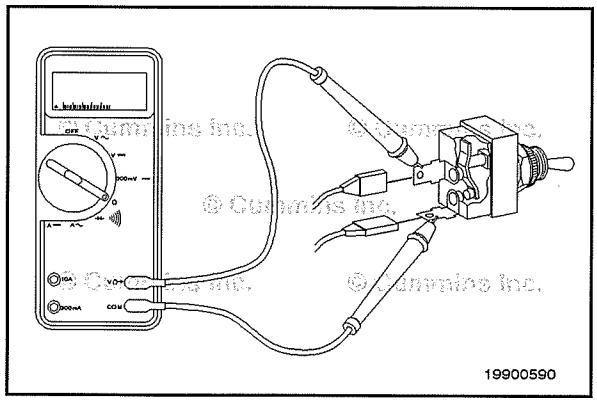


Remote Accelerator Switch (019-333)

General Information

The remote accelerator switch enables and disables the remote accelerator feature. When enabled, the remote accelerator feature allows an operator to control the fueling of the engine from a remote location. Often, the remote accelerator switch is located on a remote panel very close to the remote accelerator sensor.

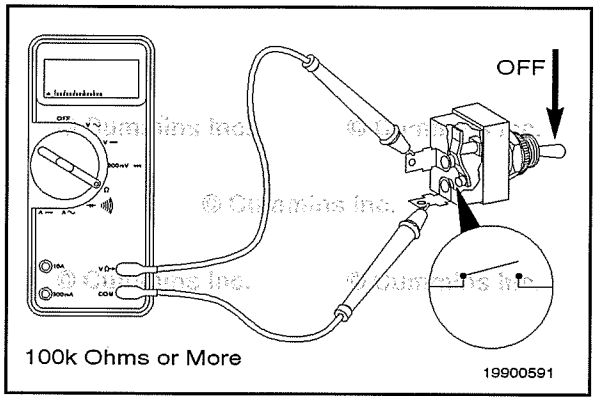




Resistance Check

If INSITE™ is available, monitor the switch for proper operation. If INSITE™ is **not** available, follow the troubleshooting procedures in this section.

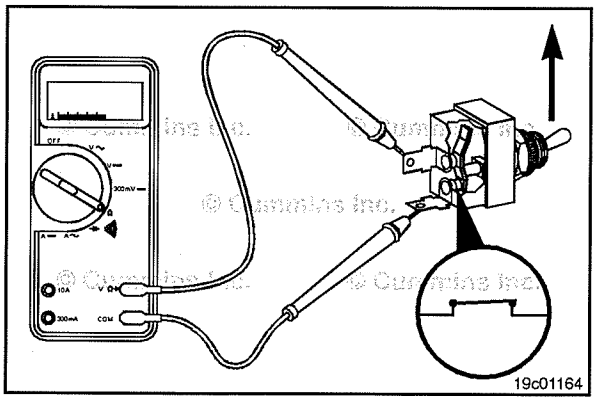
Locate the remote accelerator switch. Remove and tag the two connectors from the terminals on the switch.



Touch the multimeter probes to the terminals on the switch.

Move the switch to the OFF position and measure the resistance. The multimeter **must** show an open circuit (100K ohms or more).

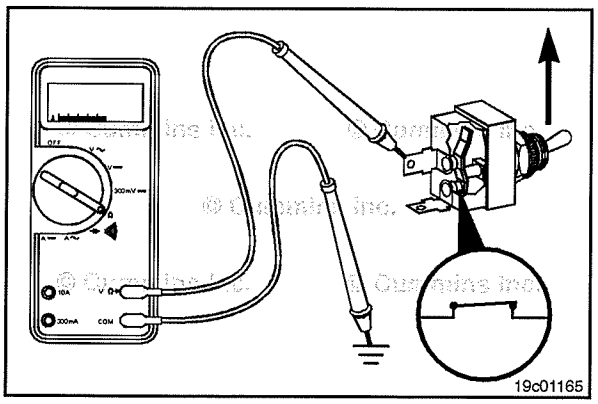
If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for the replacement procedures.



Move the switch to the ON position and measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures.

If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the ON position and measure the resistance. The multimeter **must** show an open circuit (100K ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures.

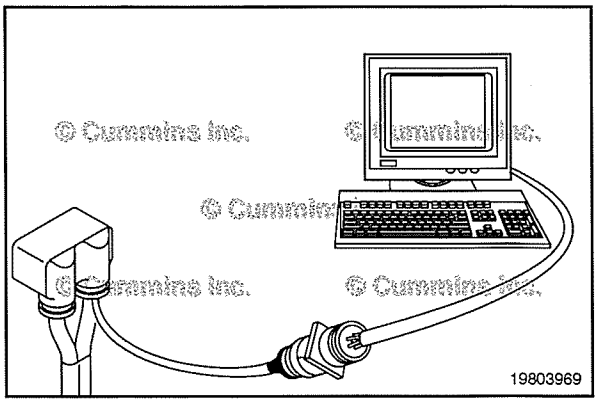
If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin to pin and a short circuit to an external voltage source.

Remote Accelerator Switch Circuit (019-334)

Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.

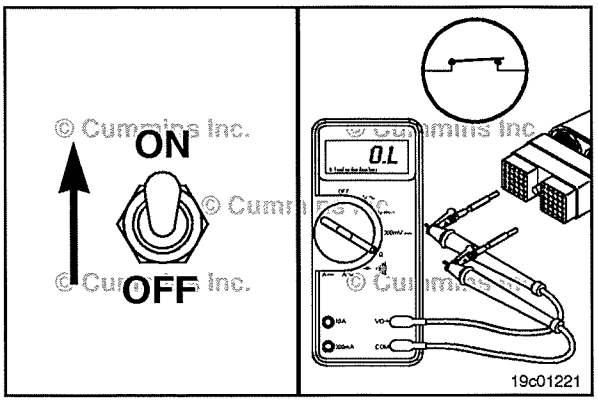


Disconnect the original equipment manufacturer (OEM) harness from the electronic control module (ECM).

Insert a test lead into the remote accelerator switch signal of the OEM harness connector and attach it to the multimeter probe. Touch the other probe to engine block ground. Move the remote accelerator switch to the ON position. The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, inspect the remote accelerator switch signal line wire for an open circuit. Refer to the OEM troubleshooting and repair manual.

If the resistance is within specification, the remote accelerator switch signal wire **must** be checked for short circuit to ground, short circuit from pin-to-pin, and a short circuit to an external voltage source.



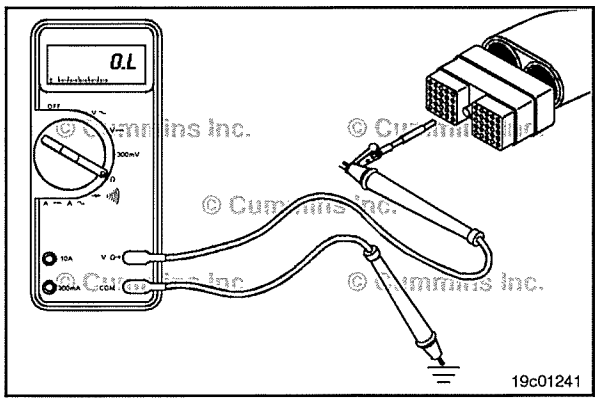
Check for Short Circuit to Ground

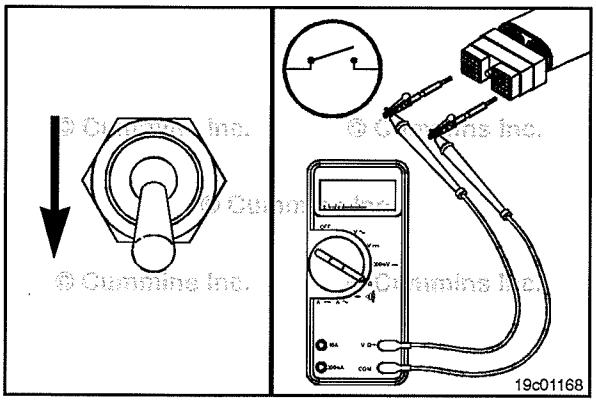
To isolate the remote accelerator switch circuit when checking for a short circuit, disconnect the OEM harness connector from the ECM and the OEM harness from the remote accelerator switch.

Adjust the multimeter to measure resistance. Insert a test lead into the remote accelerator switch signal wire of the OEM harness connector and attach it to a multimeter probe. Touch the other multimeter probe to engine block ground. Measure the resistance.

The multimeter **must** show an open circuit (100K ohms or more). If the circuit is **not** open, there is a short circuit to ground in the remote accelerator switch circuit, provided the switch has already been checked.

Repair or replace the wire connected to the remote accelerator switch signal. Refer to the OEM troubleshooting and repair manual.



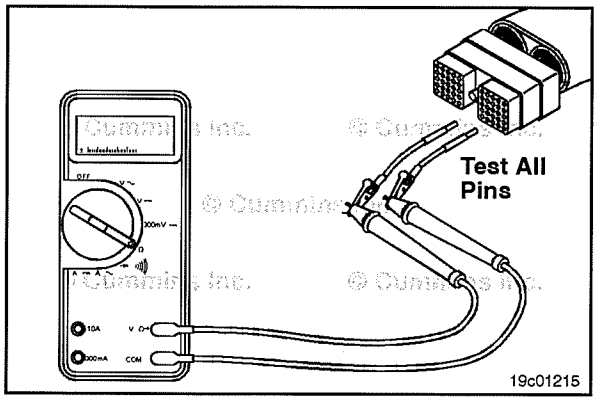


Check for Short Circuit from Pin to Pin

Turn the remote accelerator switch to the OFF position. Insert a test lead into the remote accelerator switch signal wire at the OEM harness connector.

Connect the multimeter probe to the test lead. Insert the other multimeter probe with a test lead attached into the switch return wires within the OEM harness connector. Measure the resistance.

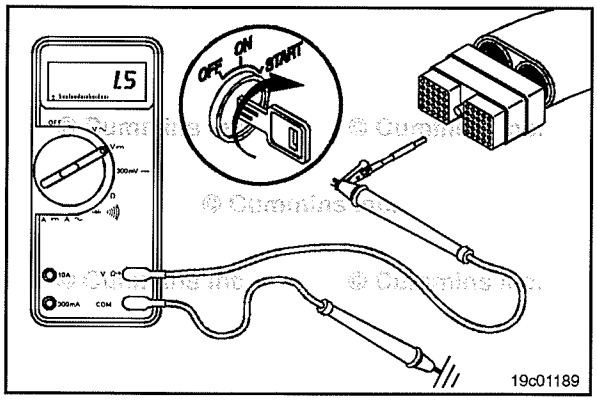
The multimeter **must** show an open circuit (100K ohms or more).



Remove the test lead from the remote accelerator switch signal wire and check all other pins. The multimeter **must** show an open circuit (100K ohms or more).

If the circuit is **not** open, there is a short circuit between the remote accelerator switch signal pin and any other pin that shows a closed circuit, provided the switch has previously been checked.

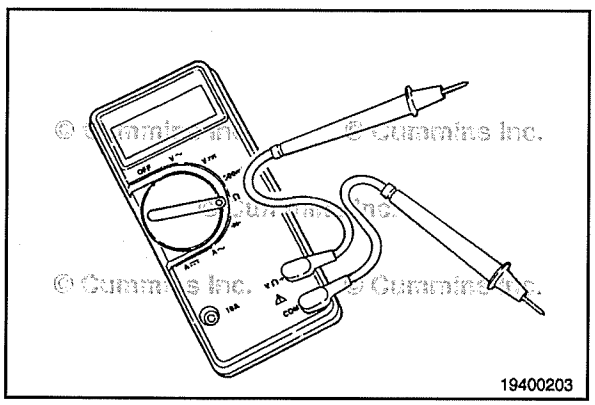
Repair or replace the wires in the OEM harness. Refer to Procedure 019-071.



Check for Short Circuit to External Voltage Source

Turn the vehicle keyswitch to the ON position. Set the remote accelerator switch to the ON position. Set the multimeter to measure VDC. Insert a test lead into the remote accelerator switch signal wire and attach it to a multimeter probe. Touch the other multimeter probe to engine block ground. Measure the voltage, the voltage **must** be 1.5 volts or less.

If the voltage is **not** correct, there is an external voltage source connected to the circuit, or there is a short circuit between the remote accelerator switch circuit and a wire carrying power in the OEM harness. Repair or replace the OEM harness. Refer to Procedure 019-071.



Multimeter Usage (019-359)

General Information

How to Use a Multimeter

On most meters, the negative (-), (black) meter probe **must** be plugged into the COM position and the positive (+), (red) meter probe **must** be plugged into one of the positions marked for amperage, resistance, or voltage. Refer to the manufacturer's procedures for more detail.

NOTE: When measuring to a block or chassis ground, use a clean, unpainted metal surface to make sure a good measurement exists.

Use of Special Test Leads

⚠CAUTION⚠

To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit for this control system.

Refer to the appropriate wiring repair kit for specific test leads used on this application.

How to Measure Amperage

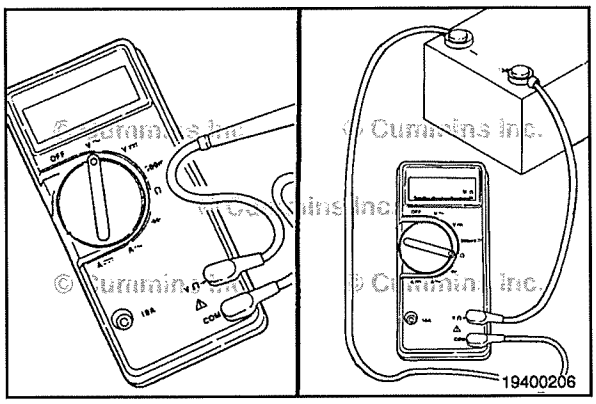
Make an open circuit at the place where the current is to be measured.

Select the AC current (A ~) or DC current (A-) function on the meter.

Turn on the power in the circuit being measured.

Put the probes of the meter across the open circuit to measure the amperage.

Read the displayed measurement.



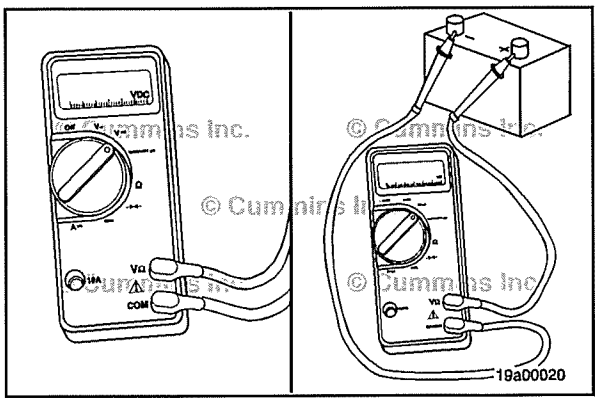
How to Measure Voltage

Select the AC voltage (V ~) or DC voltage (V-) function on the meter.

Turn on the power in the circuit being measured.

Touch the positive (+) probe of the multimeter to the terminal or pin that is being measured for voltage. Touch the other probe to a clean, unpainted metal surface that is connected to battery ground or to the negative (-) post of the battery.

Read the displayed measurement.



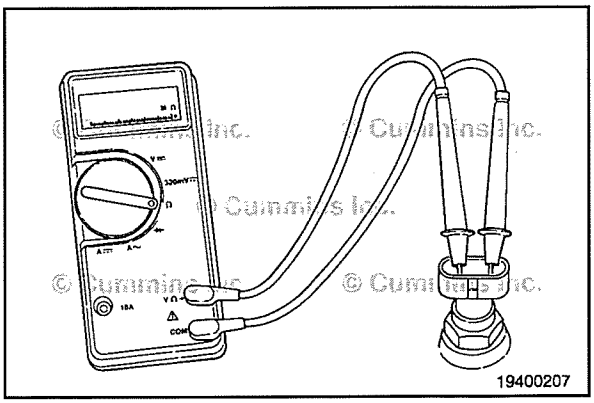
How to Measure Resistance

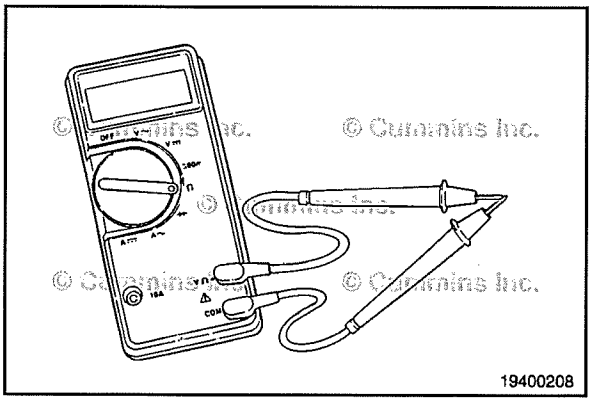
Select the resistance function on the meter.

Verify that there is no power to the components being tested.

Disconnect both ends of the circuit or component to be measured. Touch one probe to one end of the circuit or component terminal. Touch the other probe to the other end of the circuit or the other component terminal.

Read the displayed measurement.





How to Find the Internal Resistance of the Meter

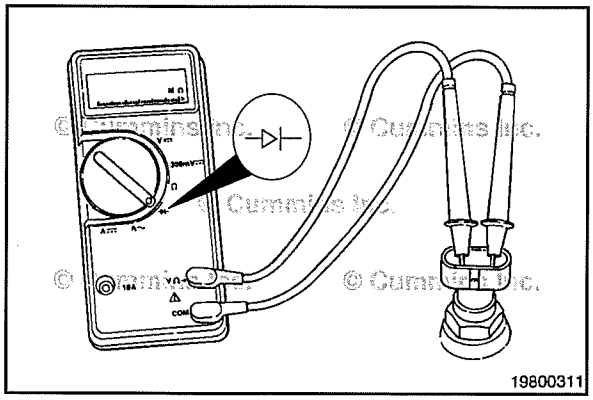
It is important to know the internal resistance of the meter when measuring small resistances. To measure small resistances accurately, the internal resistance of the meter **must** be subtracted from the measured resistance.

Turn the meter ON.

Set the meter to the lowest ohm scale.

Measure the resistance of the meter by touching the test probes together and reading the resistance value (including special test leads, if they are being used).

ZERO the meter or subtract this value when taking measurements.



How to Test for Continuity

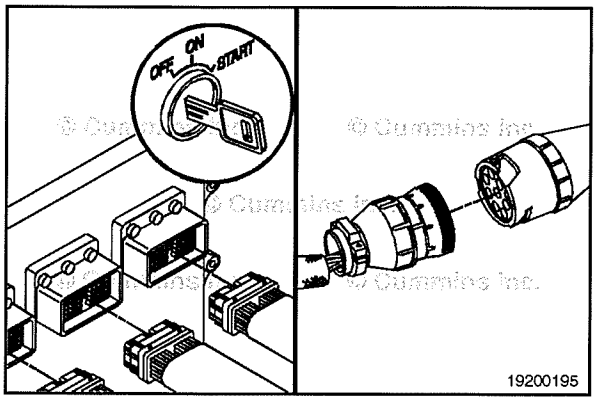
Select the continuity function on the meter (usually marked with a diode symbol).

Make sure there is no power to the component being measured.

Disconnect both ends of the circuit or component to be measured. Touch one probe to one end of the circuit or component terminal. Touch the other probe to the other end of the circuit or the other component terminal.

Read the displayed measurement.

The meter will beep if the resistance is less than about 150 ohms. If there is an open circuit, the meter does **not** beep.

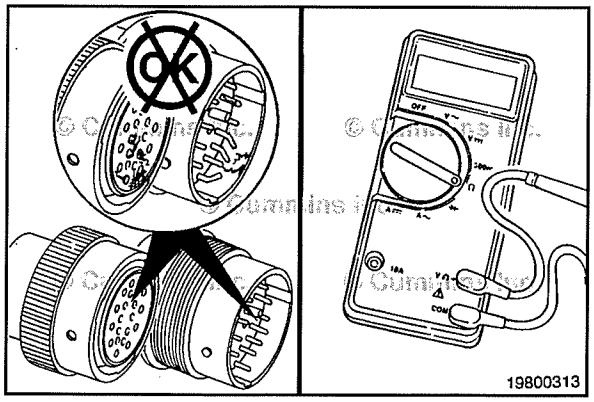


Short Circuit to Ground - Check

Short circuit to ground is a condition where a connection from a circuit to ground exists when it is **not** intended.

The procedure for checking for a short circuit to ground is as follows:

- Turn keyswitch OFF.
- Disconnect the connectors that are to be tested.



When testing a sensor, **only** the sensor connection is required to be disconnected.

When testing a harness, the harness connector at the electronic control unit and the connector at the sensor or multiple sensors should be disconnected.

Identify the pins that need to be tested.

Inspect the connector pins. 019-361.

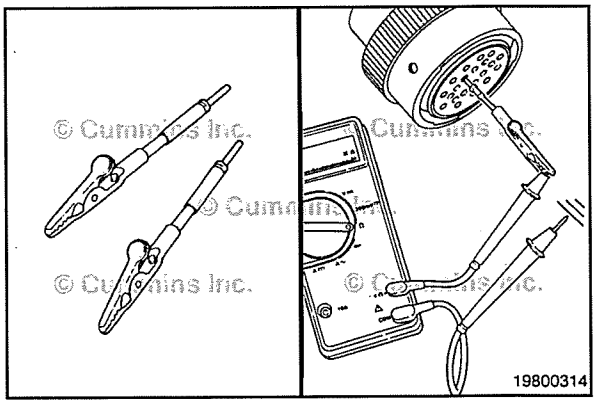
Adjust the multimeter to measure resistance.

⚠CAUTION⚠
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit for this control system.

Touch one of the multimeter probes to the correct pin to be tested.

Touch the other probe of the multimeter to a clean, unpainted surface on the engine block or chassis ground.

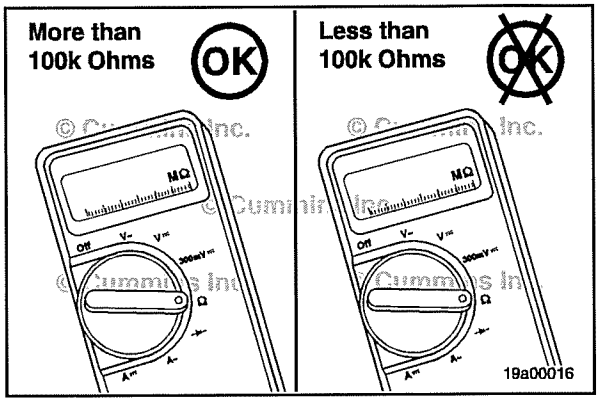
Read the value on the multimeter display.



The multimeter **must** read greater than 100k ohms, which is an open circuit.

If the circuit is **not** open, the wire being checked has a short circuit to ground, engine block or chassis ground.

Repair or replace the component or wire.

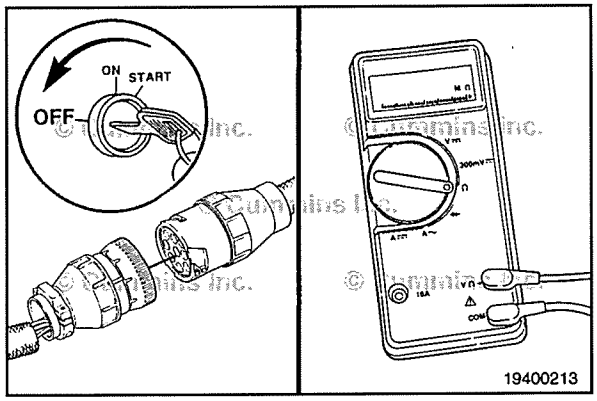


Short Circuit from Pin to Pin - Check

Short circuit from pin to pin is a condition in which an electrical path exists between two pins where it is **not** intended to exist.

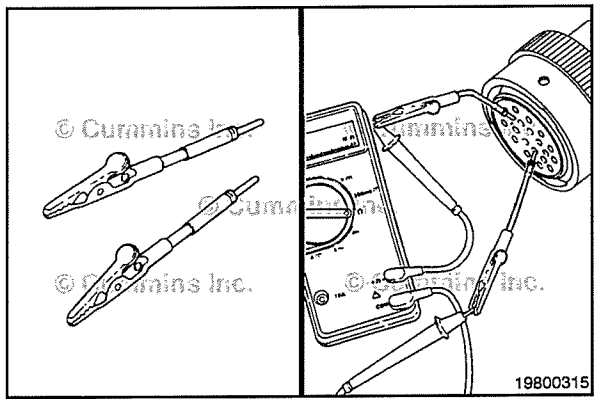
The procedure for checking short circuit from pin to pin is as follows:

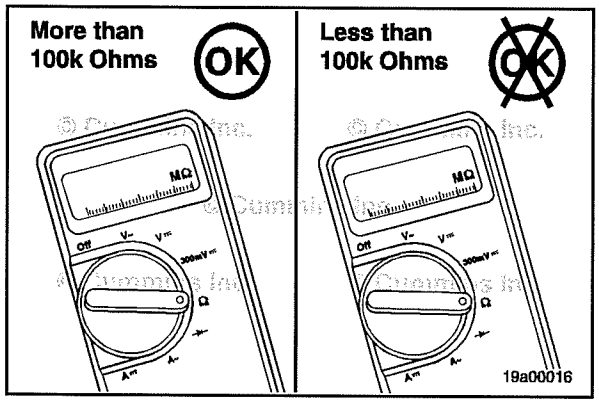
1 Turn keyswitch OFF.
2 Disconnect the connector that is to be tested.
3 Identify the pins that are to be tested.
4 Adjust the multimeter to measure resistance.



⚠CAUTION⚠
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit for this control system.

1 Touch one of the multimeter probes to the correct pin to be tested on the harness side of the connector.
2 Touch the other probe of the multimeter to all other pins on the harness side of the connector.





1 Read the value on the multimeter display.

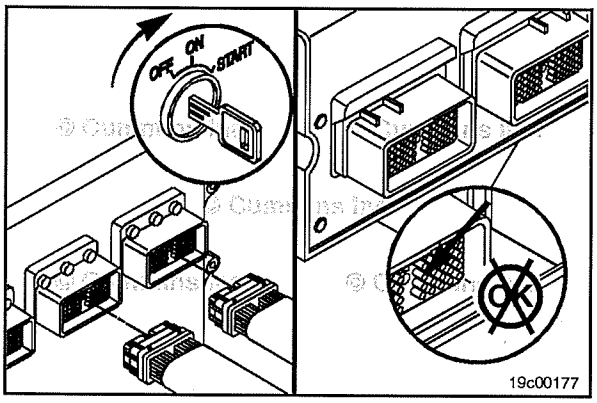
2 The multimeter **must** read greater than 100k ohms, which is an open circuit.

3 If the circuit is **not** open, the pins being checked are electrically connected.

NOTE: Refer to the wiring diagram to verify that the wires in question are **not** supposed to be connected.

1 Inspect the harness connectors for moisture that can be the cause of an inappropriate electrical connection.

2 Repair or replace the harness.



Voltage Checking

Voltage check is a procedure to measure the difference in voltage potential between two points.

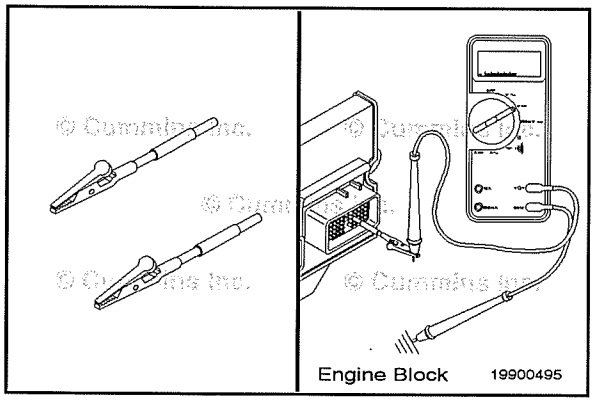
The procedure for checking voltage is as follows:

1 Disconnect the connectors that are to be tested.

2 Turn keyswitch ON.

3 Identify the pins that are to be tested.

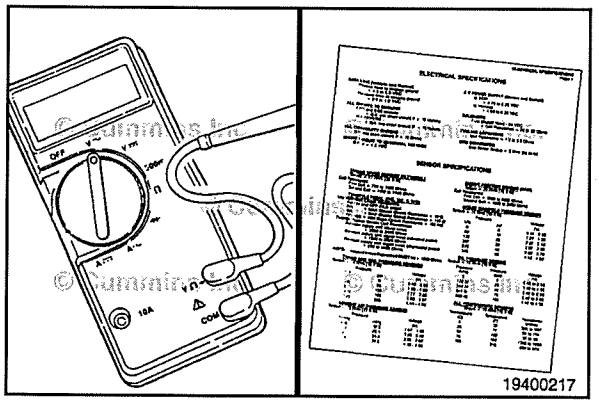
4 Adjust the multimeter to AC voltage (V ~) or DC voltage (V-).



⚠CAUTION⚠
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit for this control system.

1 Touch one of the multimeter test probes to the correct lead to be tested.

2 Touch the other multimeter probe to a clean, unpainted surface on the engine block, chassis ground or to the appropriate return pin.



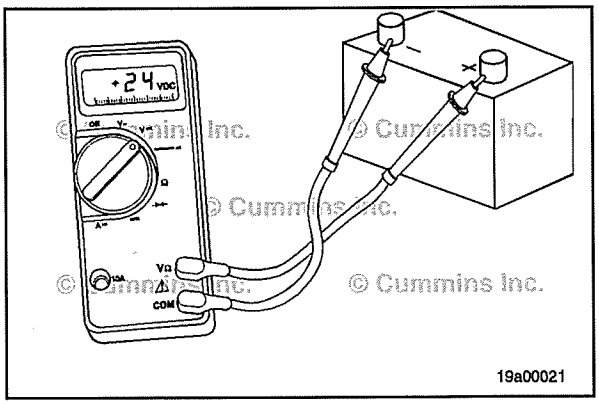
1 Read the value on the multimeter display. Compare the measured value to the range of voltage given in the specifications.

2 If the measured value falls outside of the specified range, check the repair procedure for the electrical system that is being checked for the appropriate action.

Polarity Check

A battery will be used as an example to check polarity of a circuit.

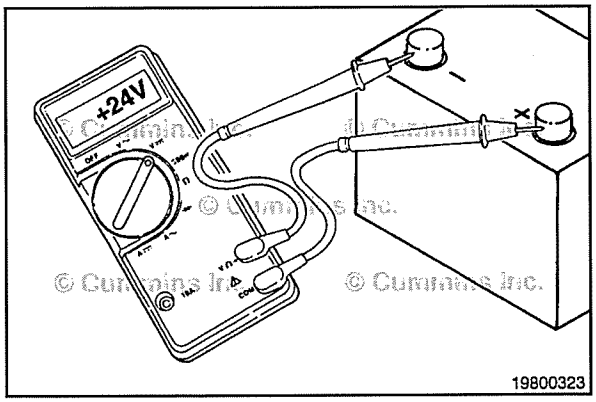
The terminals of a battery are marked for polarity. The multimeter displays the voltage difference of the positive (+) probe (red) to the negative (-) probe (black).



The polarity is correct when the positive (red) probe of the multimeter is on the positive (+) terminal of the battery and the negative (black) probe of the multimeter is on the negative (-) terminal of the battery.

The multimeter will display positive voltage if the polarity is correct.

If the multimeter probes are reversed, the multimeter displays a negative voltage.

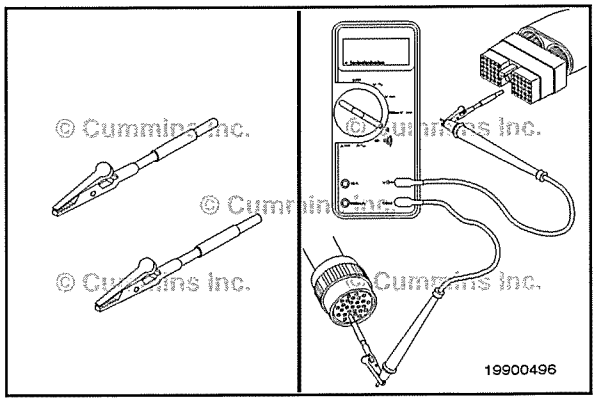


Continuity Check

⚠CAUTION⚠

To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit for this control system.

Continuity is an electrical connection between two pins that is less than a certain resistance value. For harness wires, the specification is less than 10 ohms.

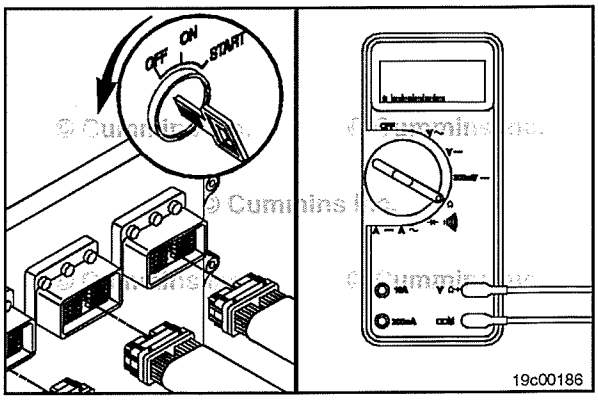


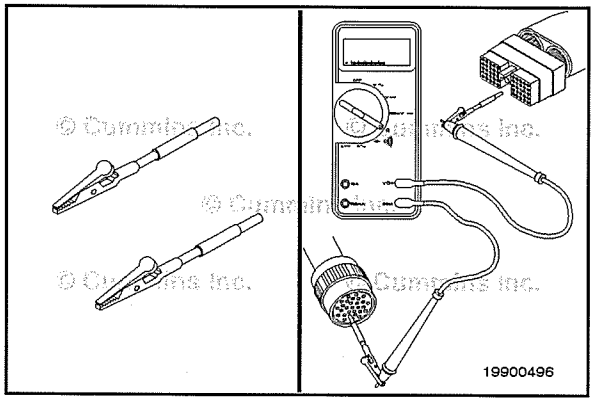
The procedure for checking continuity is as follows:

1 Turn keyswitch OFF.

2 Disconnect the harness connectors that are to be tested.

3 Adjust the multimeter to measure resistance.



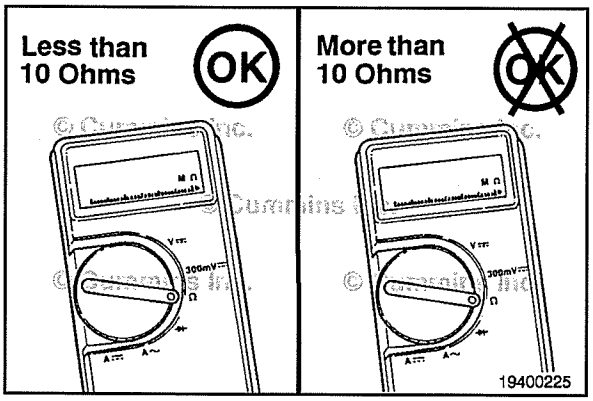


⚠CAUTION⚠
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit for this control system.

1 Insert test lead to the pin of the wire being tested and connect the alligator clip to the multimeter probe.

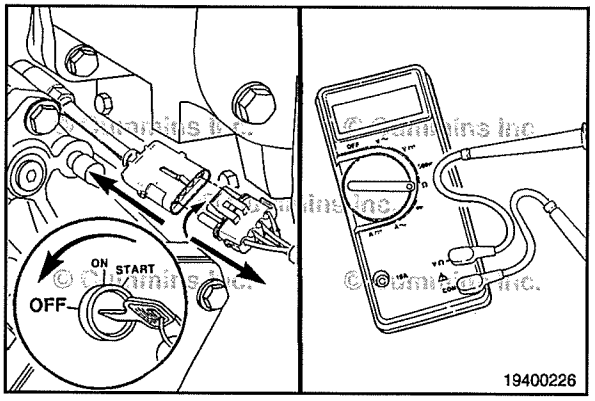
2 Insert the other test lead to the pin at the other end of the wire being tested and connect the alligator clip to the other multimeter probe.

3 Read the value on the multimeter display.



The multimeter **must** display less than 10 ohms for wire continuity.

If the multimeter displays greater than 10 ohms, the wire **must** be repaired or the harness replaced.



Resistance Check - Coil

Turn keyswitch OFF.

Disconnect the harness from the coil.

Adjust the multimeter to measure resistance.

⚠CAUTION⚠
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit for this control system.

Insert test lead to the coil connector pin, and connect the alligator clip to the multimeter probe.

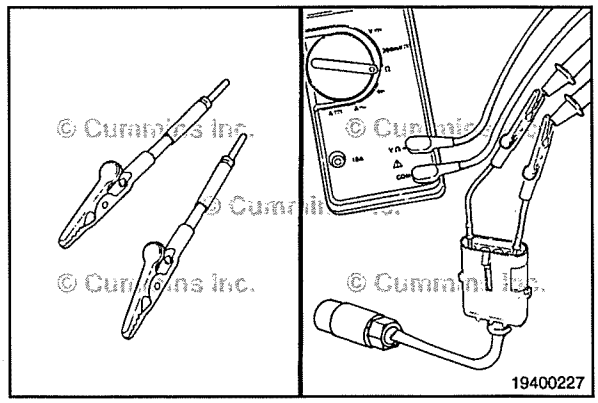
Insert the other test lead to the other coil connector pin, and connect the alligator clip to the other multimeter probe.

NOTE: For internally grounded coils, touch one multimeter lead to the coil terminal and the other multimeter lead to a clean, unpainted surface on the engine block.

Read the measured resistance on the multimeter display.

Check the measured resistance against the resistance specification for the coil.

NOTE: The internal resistance of the multimeter is significant in some coil resistance checks.



Resistance Measurement Using a Multimeter (019-360)

General Information

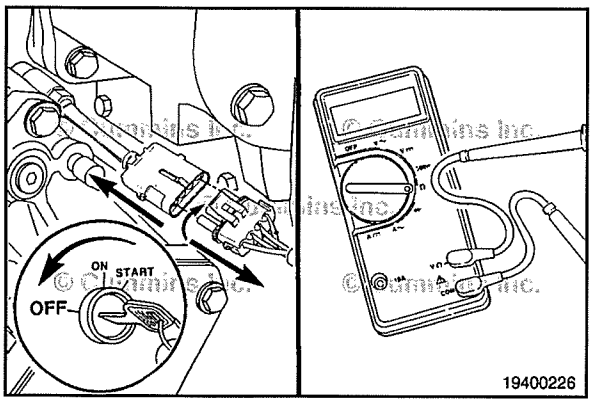
Use this procedure **only** if the harness or connector can be repaired.

After performing any of the checks below, and it is necessary to repair or replace a harness or connector, refer to the table of contents in section 19 for the appropriate repair or replacement procedure.

Fault code troubleshooting trees will refer to this procedure when it is necessary to measure resistance on a harness, connector, or component that the fault code applies to. Each fault code troubleshooting tree will troubleshoot a particular component and the associated circuitry such as a pressure sensor, wiring harness and connectors that connect the sensor to the electronic control unit.

When troubleshooting to determine if a short or open exists in a particular circuit, all of the associated connectors, pins, circuit names and connections that apply to this component can be viewed on the applicable wiring diagram.

Use the following procedures to determine how to make the necessary resistance checks on components, connectors and circuits that apply to the fault code that referred you to this procedure.



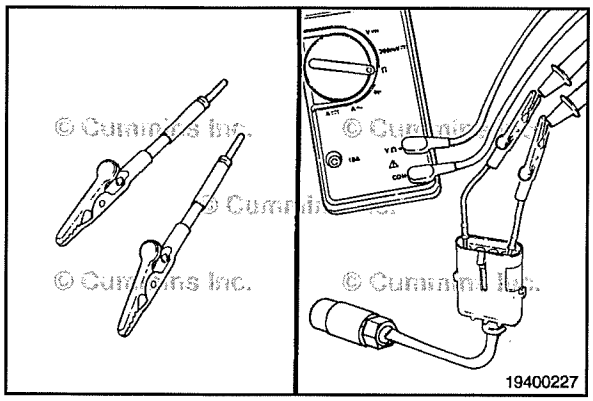
Resistance Check

Turn the key switch off.

Disconnect the appropriate connector from the component.

Adjust the multimeter to measure resistance.

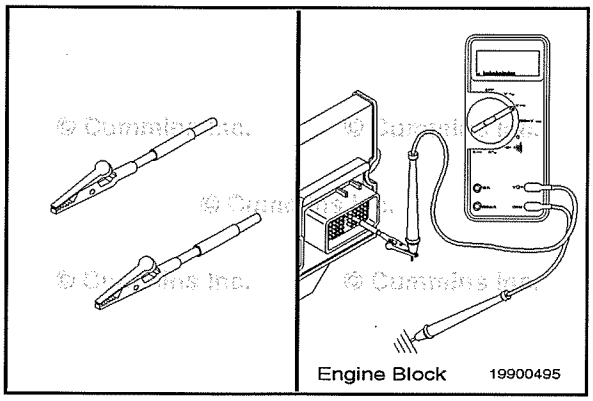
Use the wiring diagram to determine the pins that apply to the component you are measuring.



△CAUTION△
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit.

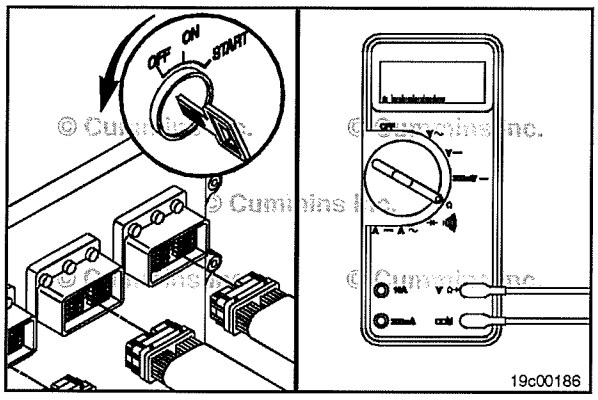
Connect the appropriate connector test leads to the connector pins and connect the alligator clips to the multimeter probe. Measure the resistance.

Compare this value to the applicable fault code specification or applicable Electrical or Sensor Specification on the wiring diagram. If the value is not correct, the component is malfunctioning. Refer to the applicable fault code procedure for instructions.



Continuity Check

Continuity is an electrical connection between two pins that is less than a certain value. For harness wires, the specification is less than 10 ohms.



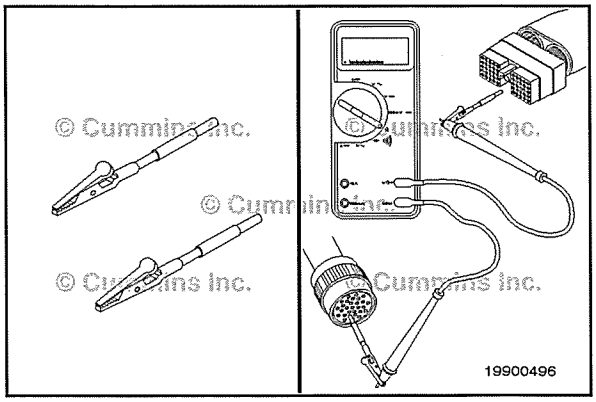
Turn the key switch to the OFF position.

Disconnect the harness connectors that are to be tested.

Adjust the multimeter to measure resistance.

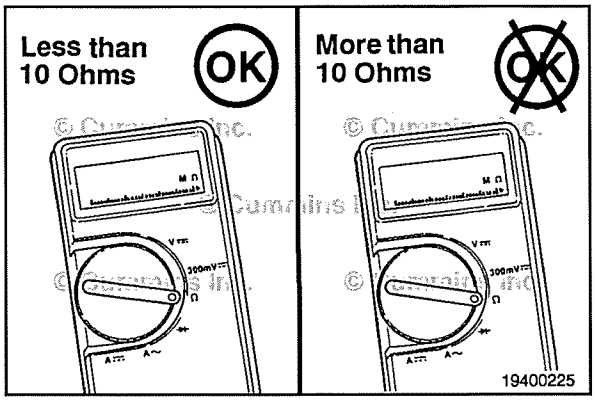
⚠CAUTION⚠
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit.

Connect the appropriate connector test leads to the connector pins and connect the alligator clips to the multimeter probe. Measure the resistance.



The multimeter **must** display less than 10 ohms for wire continuity. If the multimeter displays greater than 10 ohms, the wire **must** be repaired or the harness replaced.

Refer to the applicable fault code procedure for instructions.



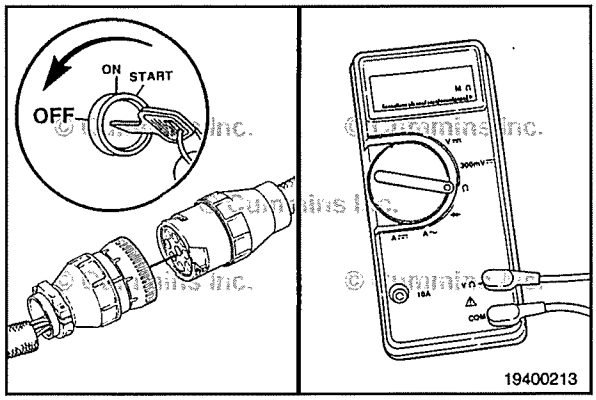
Check for Short Circuit from Pin to Pin

Short circuit from pin to pin check is a condition in which an electrical connection exists between two pins where it is **not** intended to exist.

Turn the key switch to the OFF position.

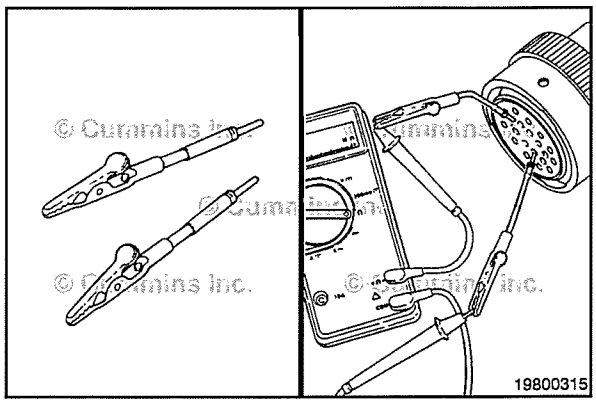
Disconnect the harness connectors that are to be tested.

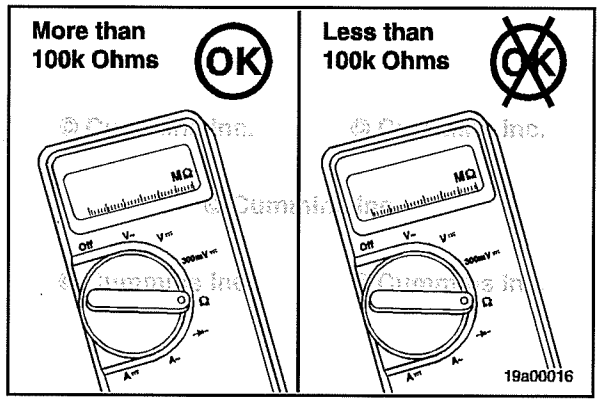
Adjust the multimeter to measure resistance.



⚠CAUTION⚠
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit.

Connect the appropriate connector test leads to the connector pins and connect the alligator clips to the multimeter probes. Measure the resistance.

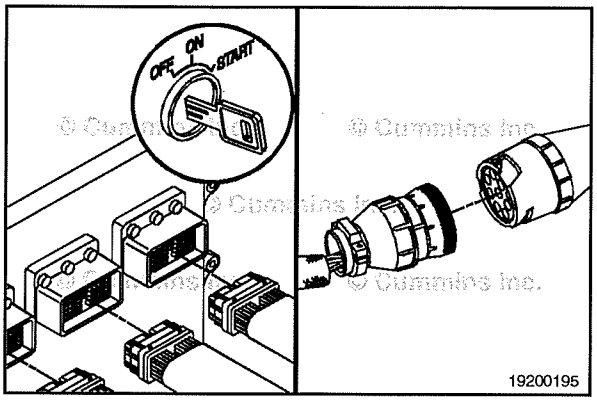




The multimeter **must** read greater than 100k ohms, which is an open circuit. If the circuit is **not** open, the pins being checked are electrically connected. Refer to the wiring diagram to verify that the wires are intended to be connected.

Inspect the harness connectors for moisture that can cause an inappropriate electrical connection.Refer to Procedure procedure 019-361.

Refer to the applicable fault code procedure for instructions.

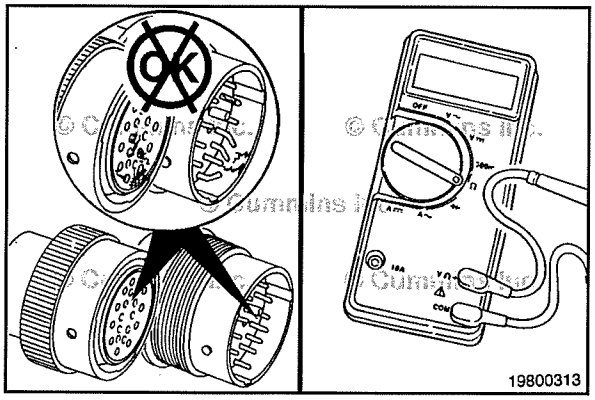


Check for Short Circuit to Ground

Short circuit to ground is a condition where a connection from a circuit to ground exists when it is not intended.

Turn the key switch to the OFF position.

Disconnect the harness connectors that are to be tested.

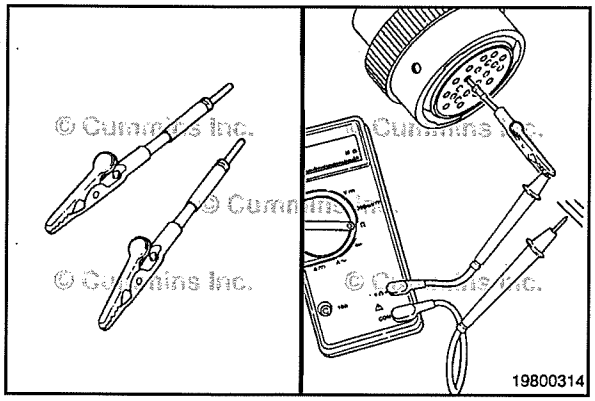


When testing a sensor, **only** the sensor connection is required to be disconnected.

When testing a harness, the harness connector at the electronic control unit and the connector at the sensor or multiple sensors **must** be disconnected.

Identify the pins that need to be tested.

Inspect the connector pins.Refer to Procedure procedure 019-361.



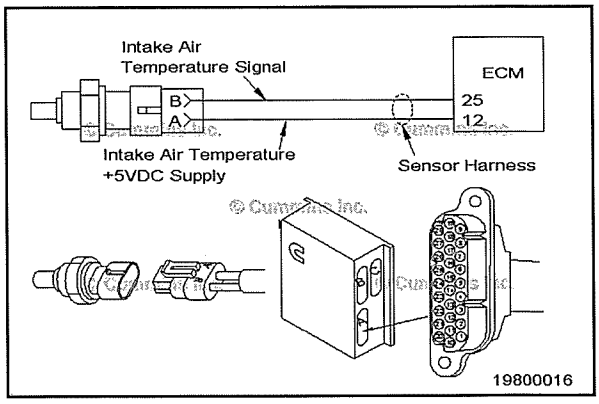
⚠CAUTION⚠
To reduce the possibility of pin and harness damage, use the appropriate test lead for the connector. Refer to the Service Tools listing or the appropriate wiring repair kit.

Connect the appropriate connector test lead to a connector pin and connect the alligator clip to the multimeter probe.

Touch the other multimeter probe to a clean, unpainted surface on the engine block or chassis ground. Measure the resistance.

The multimeter **must** read greater than 100k ohms, which indicates an open circuit. If the circuit is **not** open, the wire being checked has a short circuit to ground, the engine block or chassis ground.

Refer to the applicable fault code procedure for instructions.



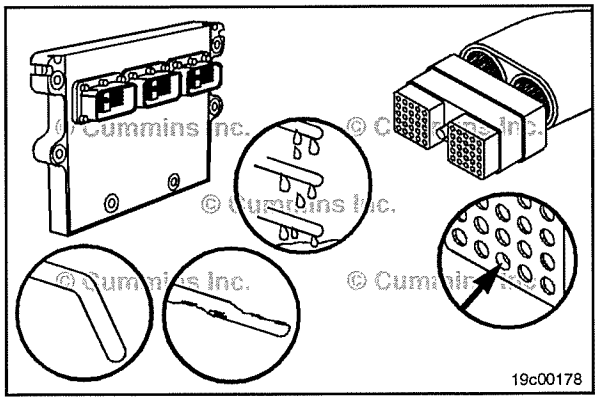
Component Connector and Pin Inspection (019-361)

General Information

The following inspection procedures should be used for any component, connector, or harness connector to ensure there is no pin damage.

Inspect for Reuse

When disconnecting connectors during troubleshooting, **always** check for loose connectors (gently pull the wires at the back of the connector) and inspect the pins to make sure they are **not** the cause of a bad connection. The things to look for are bent, corroded, and pushed back pins.



Moisture in Connector

Moisture in a connector can also cause system performance issues. Many times it is difficult to see moisture in a connector. If moisture is suspected, the connector **must** be dried by applying contact cleaner, Part No. 3824510, to the connector. A heat gun can also be used on a low heat setting so that it will **not** damage the connector or wires.

NOTE: Do **not** blow compressed air in the electronic control unit ports or connector. Compressed air can contain moisture due to condensation.

Bent or Expanded Pins

Inspect the male terminals of the connector. If any of the terminals are bent, so that they will **not** easily mate with the other side of the connector, or if the male terminals are expanded, that is, bulged out or squashed so as to make them too large to mate with the other side of the connector, then the pin **must** be replaced. Refer to the repair section for the specific connector in question.

Corroded Pins

Inspect both the male and female terminals for corrosion, which can cause a poor electrical connection within the connector. If any corrosion is evident on the pins, then the corroded pins **must** be replaced. Refer to the repair section for the specific connector in question.

Pushed Back Pins

Inspect both the male and female terminals for pins that can **not** be making contact because they are pushed back in the connector. To repair, push the pin into the connector body from the back of the connector. Make sure the terminal locks into place. If the terminal will **not** lock into place, then replace it. Refer to the repair section for the specific connector in question.

Inactive or Intermittent Fault Code (019-362)

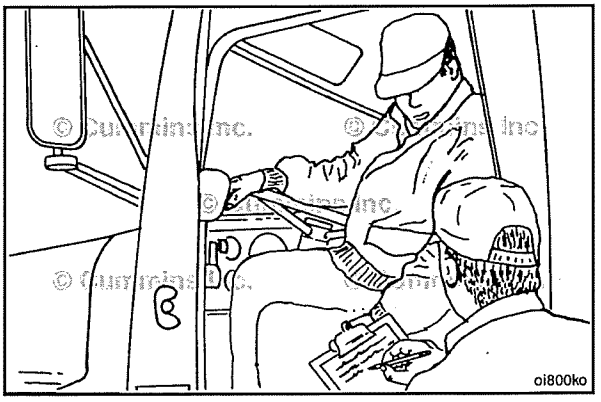
General Information

This procedure is designed to troubleshoot electrical circuit faults that are intermittent and are currently inactive. This procedure can also be used to troubleshoot high inactive counts of circuit related fault codes.

If multiple fault codes are present, use a wiring diagram to check for common sensor supplies and ground circuits that may be shared between sensors, actuators, and switches. Pressure sensors may share a common 5 volt supply and ground circuit. Temperature sensors and actuators may share a common ground circuit. If either a sensor supply or a ground circuit has an intermittent connection, fault codes related to all the sensors may be active or have high counts of inactive fault codes.

If the conditions for a fault code to trigger exist and then the conditions are no longer present, an inactive fault code is created. When conditions are intermittent, there may be multiple inactive counts for a given fault code. If there are more than 10 inactive counts, the fault code should be troubleshot as an active fault code. Troubleshooting priority should be given to fault codes that are associated engine performance components such as the turbocharger, EGR valve, or any system related fault code.

Initial Check

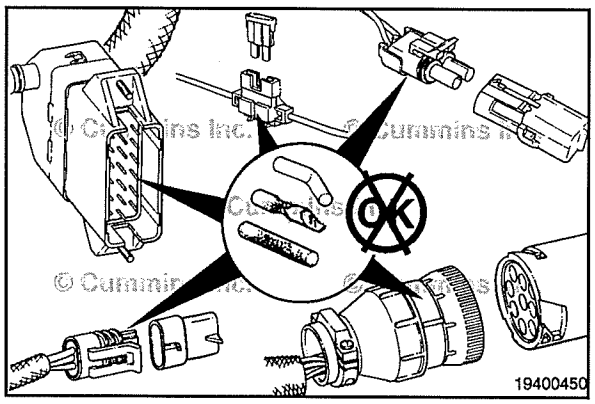


Interview the operator and determine the engine operating conditions when the fault occurs and what symptoms occur when the fault is active.

Determine if there have been any recent service repairs or maintenance performed that may be related to the intermittent condition.

Review the “Shop Talk” section of the fault code troubleshooting tree. Shop Talk will give additional troubleshooting information and will list possible causes for the fault code.

Verify the electronic control module (ECM) calibration is correct. Check the calibration revision history found on QuickServe® Online for applicable fixes to the calibration stored in the ECM. If necessary, recalibrate the ECM. 019-032 (ECM Calibration Code) in Section 19 in the corresponding Troubleshooting and Repair Manual for the engine being serviced.



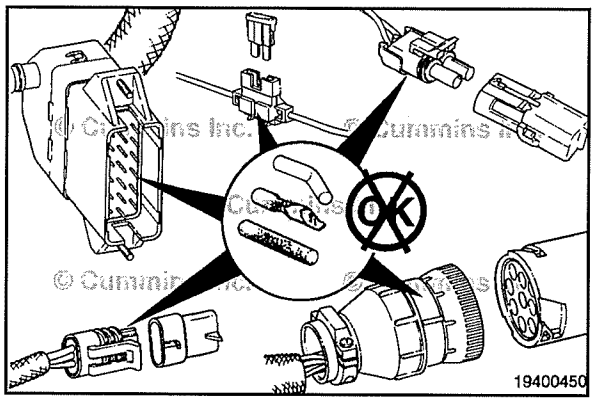
Disconnect the sensor or actuator related to the intermittent condition.

Inspect the wiring harness and connector for the following:

- Loose connector (gently pull the wires at the back of the connectors)
- Corroded pins
- Bent or broken pins
- Pushed back or expanded pins
- Moisture in or on the connectors
- Dirt or debris in, or on, the connector pins
- Missing or damaged connector seals
- Wire insulation damage
- Connector shell broken
- Damaged locking tab connector
- Pin wear (close visual inspection)
- Rusty, painted, corroded, or loose grounds.

Thoroughly inspect the wiring harness between the suspected component and ECM connection. Check for the proper strain relief on the wiring harness.

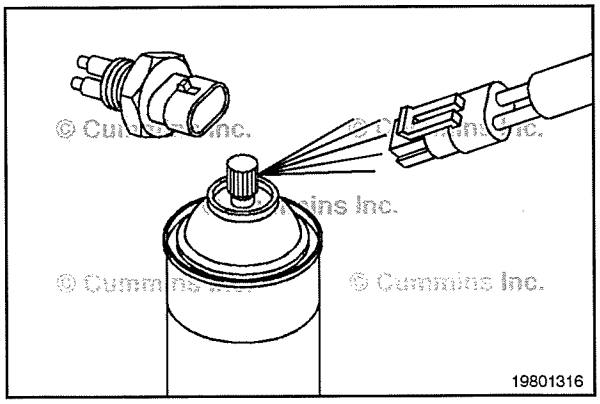
A dark powder found inside the connector may be a sign of pin fretting. Clean the pin contacts and reconnect the connector.



Disconnect the wiring harness connector from the ECM. Inspect the ECM connector for the following:

- Loose connector (gently pull the wires at the back of the connectors)
- Corroded pins
- Bent or broken pins
- Pushed back or expanded pins
- Moisture in or on the connectors
- Dirt or debris in, or on, the connector pins
- Missing or damaged connector seals
- Wire insulation damage
- Connector shell broken
- Damaged locking tab connector
- Pin wear (close visual inspection)
- Rusty, painted, corroded, or loose grounds.

Clean connector(s) of suspect components and clear the fault code.

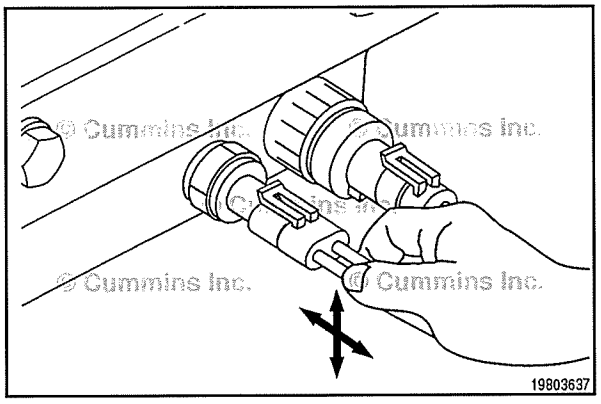


Connect INSITE™ and open the Data Monitor/Logger feature. Monitor the sensor signal voltage for the appropriate sensor. Also monitor the actual value of the sensor or component.

Beginning at the component in question and working back through the harness to the ECM, gently twist, bend and pull at each connection and in between connections in the harness.

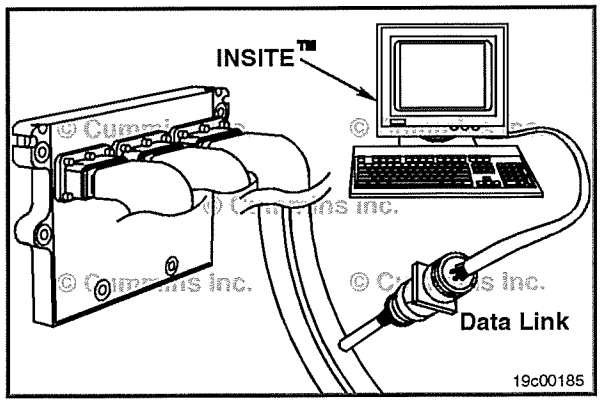
While performing the Harness Shake Test, the sensor signal voltage that INSITE™ displays should remain between steady. A typical reading should be between 0.5 and 5.12 volts.

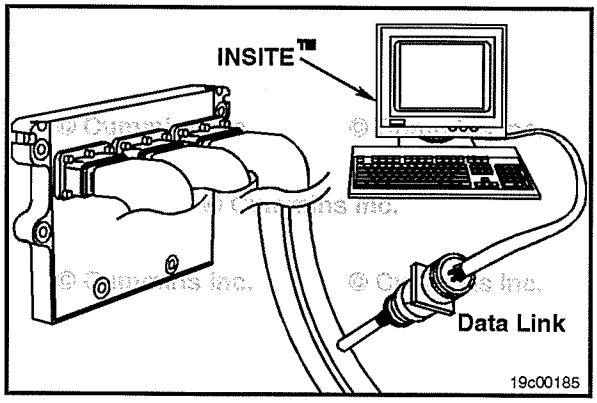
NOTE: This procedure can also be used to check for loose or damaged wires for switches. Switch status can be monitored with INSITE™. Look for switch changes when performing the Harness Shake Test.



If the fault code goes active, if inactive counts increase, the sensor signal voltage fluctuates, or the switch status changes, there is a loose connection or damaged wire at that specific location. Refer to Procedure 019-361, Component Connector and Pin Inspection, and inspect the pins at the connectors in question. Repair or replace as necessary.

NOTE: The ECM will **not** change the status of switches and faults instantaneously. Approximately 10 to 15 seconds should be used to gently twist the harness and see a reading change from the ECM. Trying to monitor too many parameters at one time with INSITE™ will slow down the update rate on the screen. Keep the number of parameters monitored with INSITE™ to minimum to increase the update rate.





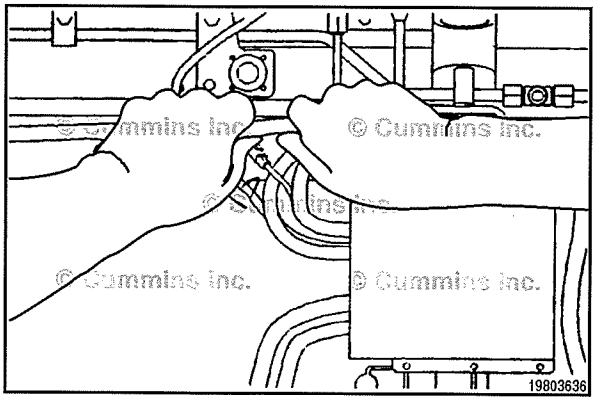
Start the engine.

With the engine running, connect to INSITE™ and open up the Data Monitor/Logger feature. Monitor the sensor signal voltage for the appropriate sensor. Also monitor the actual value of the sensor or component.

While performing the Harness Shake Test, the sensor signal voltage that INSITE™ displays should remain between steady. A typical reading should be between 0.5 and 5.12 volts.

Now gently bend, twist, and pull the connections and in between connections in the harness while monitoring the sensor signal voltage.

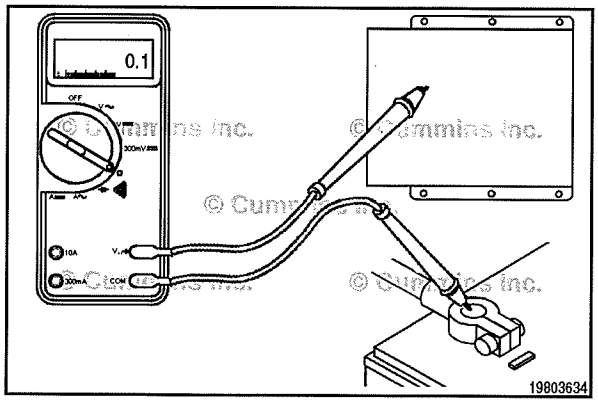
If the sensor signal voltage fluctuates during the test, then there is a loose connection or damaged wire at that specific location. Inspect the pins at the connectors in question.



Check for poor battery and chassis grounds. Firmly pull on ground wires or cables checking for loose connections. Check the following grounds making sure they are secure, clean, and on a non-painted surface:

- engine block grounds
- chassis (or frame rail) grounds
- ECM grounds
- alternator and starter negative posts

While performing this step, check to see if the fault code goes active, or if inactive counts increase. If this happens, there is a loose connection or damaged wire at that location. Disconnect, clean grounding cables and grounding surfaces, then reconnect. Repair or replace grounding cables or wires if necessary.

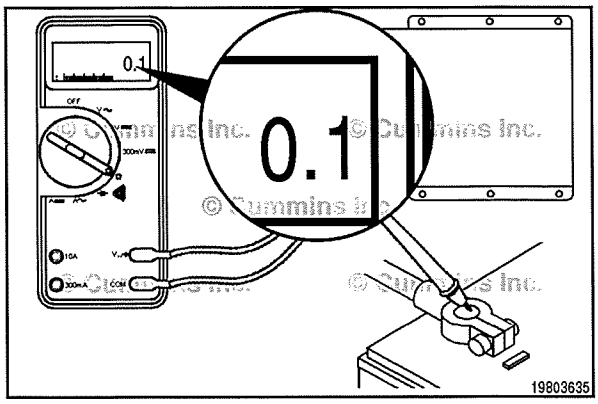


Measure resistance from the battery negative (-) post to:

- ECM casing (clean, non-painted surface)
- Engine Block (clean, non-painted surface)
- Starter (-) post
- Alternator (-) post
- Firewall grounding post
- Cab ground (dash switches, common ground)
- Vehicle frame rail.

All resistance values should measure less than 1 ohm. If resistance values exceed 1 ohm, clean grounding cables and grounding surfaces, then reconnect. Repair or replace grounding cables or wires if necessary.

NOTE: Refer to Procedure 019-359, "General Multimeter Usage", for the correct use of a multimeter.



Finishing Steps

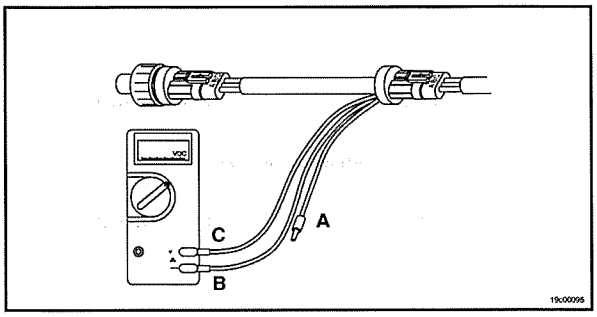
Voltage Drop Check

This test **must** be performed with the actuator connected to the wiring harness.

With the sensor or actuator disconnected from the wiring harness, measure the voltage at the engine harness connector of the component.

Connect the sensor or actuator to the wiring harness and measure the voltage with all the components connected. Use a breakout cable or back-probe the connector with the multimeter leads when performing this check.

The voltage to the component should be within 0.5 volts of the original voltage measured. If the voltage drops more than 0.5 volts, check for intermittent connections, cut wires, or corroded relay connections between the actuator and the ECM.



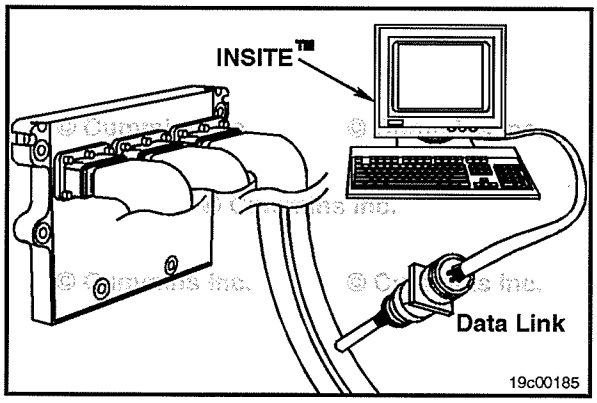
Finishing Steps

Sensor Default Values

When a sensor circuit is shorted high or shorted low, the sensor value will be locked to a default value when the fault code is active. The default value will usually be set to a value that is within the standard operating range of the sensor. When monitoring the sensor values with a service tool it will appear as if the sensor is reading a correct value even when the fault code is active. Some typical global default sensor values are as follows:

- Engine Coolant Temperature = 104.4°C [219.9°F]
- Intake Manifold Temperature = 21.3°C [70.3°F]
- Intake Manifold Pressure = 2.4 kpa [0.7 inHg]
- EGR Temperature = 37.8°C [100°F]
- Engine Oil Pressure = 73.1 kPa [10.6 psi]

Be aware when troubleshooting intermittent circuit fault codes that the value displayed with a service tool could be a default sensor reading. Always use the sensor signal voltage measurement when troubleshooting intermittent circuit fault codes.

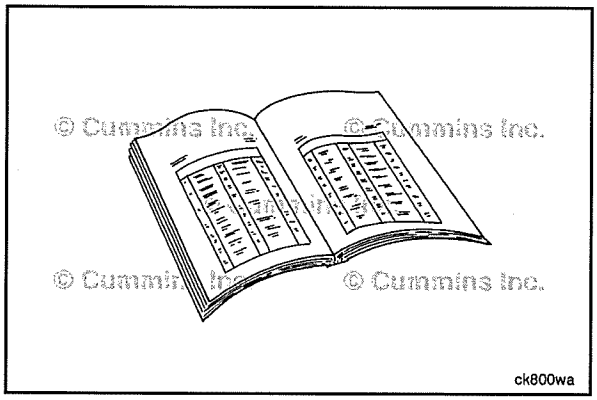


If further investigation is necessary, use the Data Monitor/ Logger feature in INSITE™ to monitor the inputs and outputs of a running engine and to capture data to a log file. The Logger feature in INSITE™ will allow for information to be captured during the intermittent event and can reviewed at a later time.

Camshaft Position Sensor (019-363)

General Information

The camshaft position sensor reports the speed and position of the camshaft to the engine control module (ECM). The camshaft position sensor is located on the front of the engine near the camshaft. Refer to Procedure 100-002 in Section E.

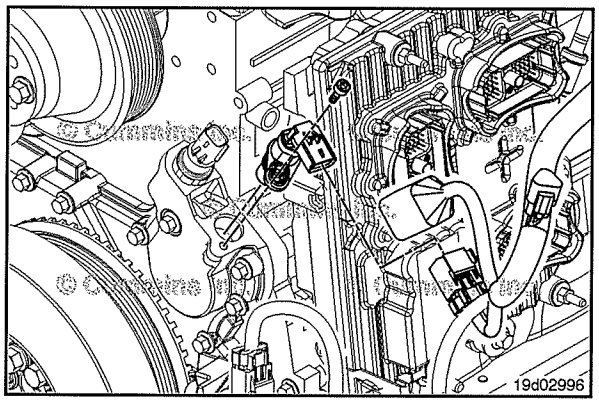


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.



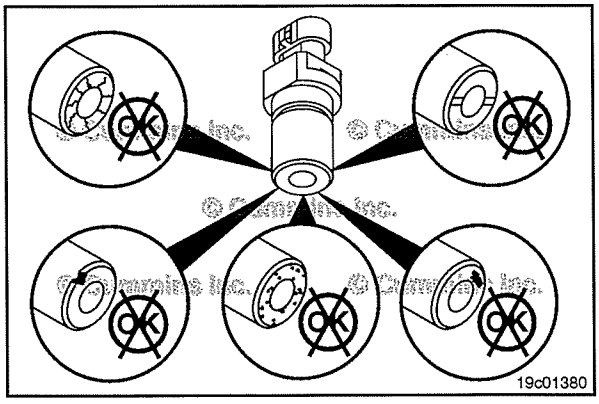
Remove

Disconnect the sensor from the engine harness.

Remove the capscrew that secures the sensor to the engine.

Remove the sensor from the mounting location.

Clean and Inspect for Reuse



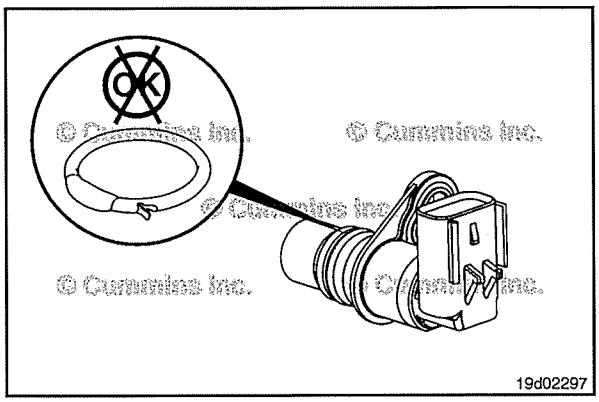
Inspect the camshaft position sensor for debris, cracks, or damage from contact with the tone wheel.

If there is debris on the camshaft position sensor, clean the sensor.

Inspect the engine harness connector and sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded or damaged sensor.

Repair or replace parts as necessary.

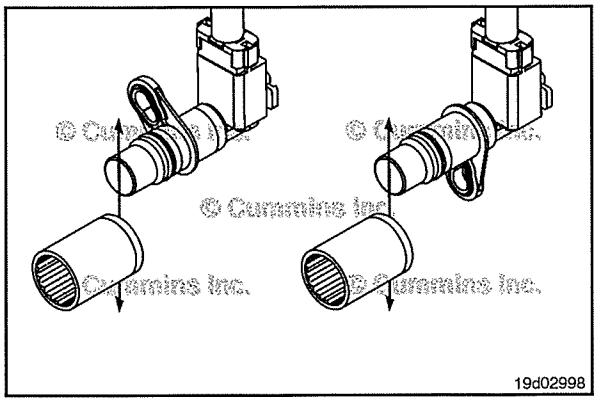


Inspect the camshaft position sensor o-ring for the following:

- Swollen o-ring
- Nicks or cuts in or on the o-ring.

Replace the o-ring if any damage is found.

Test



Connect the camshaft position sensor to the engine harness.

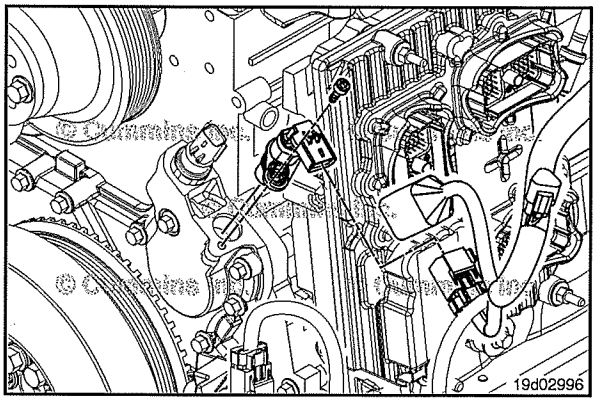
Use an electronic service tool to monitor the value of the camshaft position sensor with the key in the ON position and the engine off.

Place the ratchet drive side of the socket tool that was used to remove the sensor from the engine, flush on the sensor so the edge of the socket is on the edge of the sensor. Slowly slide the socket along the edge of the sensor as shown.

NOTE: The tool or part used for this **must** be of a ferrous material (a magnet would stick to it).

Monitor the sensor state while passing the socket over the sensor. Verify that the state changes from high to low or low to high.

If the sensor state does **not** change, replace the camshaft position sensor.



Install

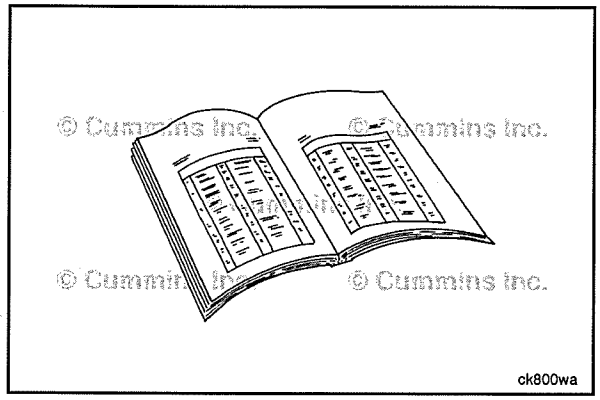
Lubricate the o-ring with clean engine oil before installation.

Install the camshaft position sensor by pressing firmly on the top of the sensor until the o-ring is fully seated.

Install and tighten the mounting capscrew.

Torque Value: 10 N•m [89 in-lb]

Connect the engine harness to the sensor.



Finishing Steps

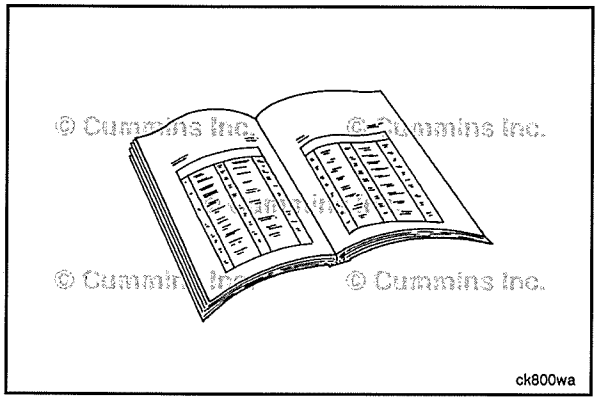
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Crankshaft Position Sensor (019-365)

General Information

The crankshaft position sensor reports the speed and position of the crankshaft to the engine control module (ECM). The crankshaft position sensor is located at the front of the engine near the vibration damper. Refer to Procedure 100-002 in Section E.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

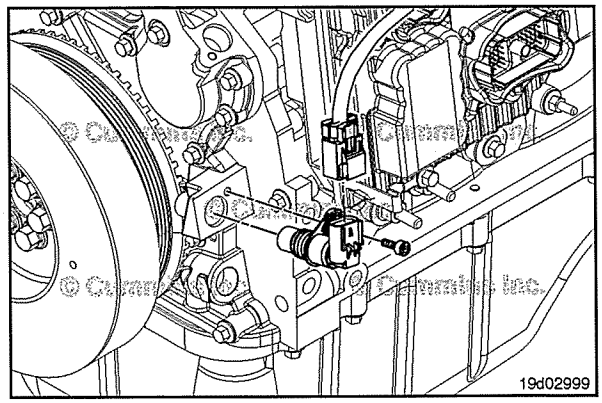
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.

Remove

Disconnect the sensor from the engine harness.

Remove the capscrew that secures the sensor to the engine.

Remove the sensor from the mounting location.



Clean and Inspect for Reuse

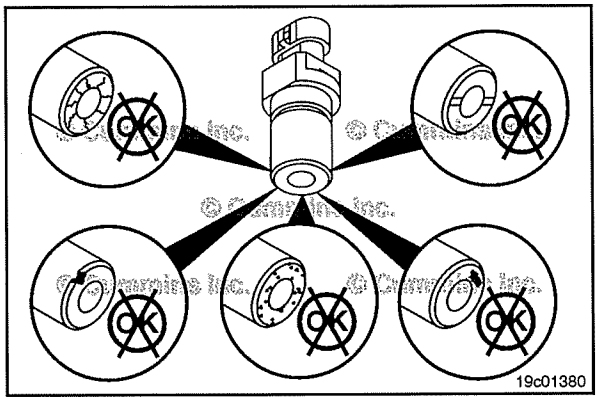
Inspect the crankshaft position sensor for debris, cracks, or damage from contact with the tone wheel.

If there is debris on the crankshaft position sensor, clean the sensor.

Inspect the engine harness connector and sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded or damaged sensor.

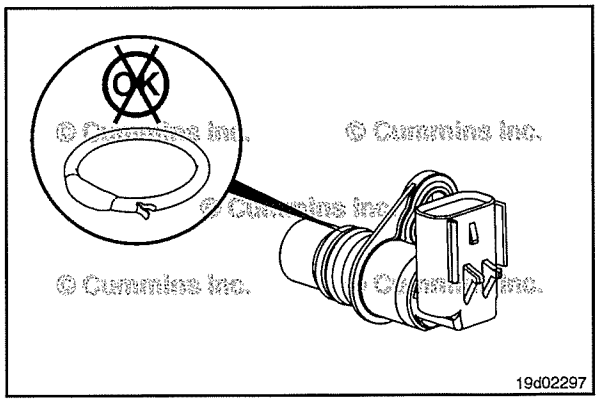
Repair or replace parts as necessary.

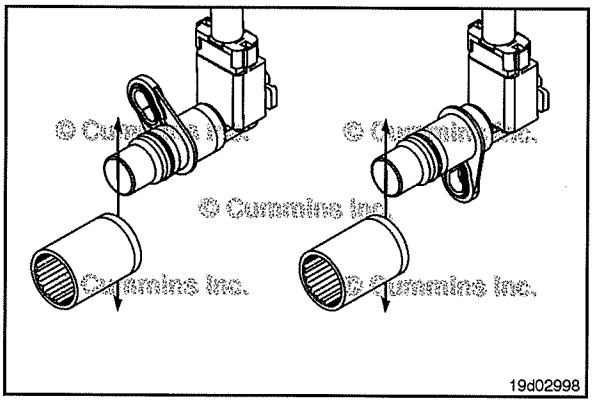


Inspect the crankshaft position sensor o-ring for the following:

- Swollen o-ring
- Nicks or cuts in or on the o-ring.

Replace the o-ring if any damage is found.





Test

Connect the crankshaft position sensor to the engine harness.

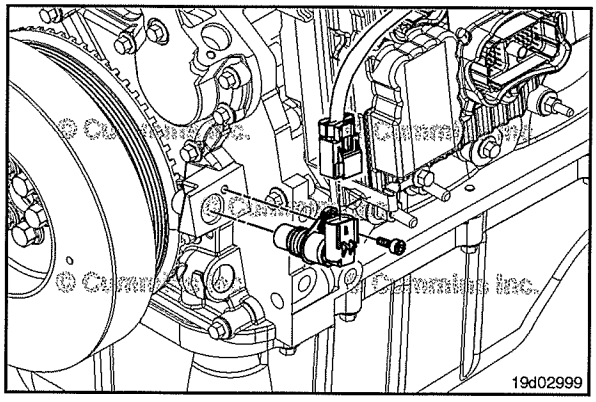
Use an electronic service tool to monitor the value of the crankshaft position sensor with the key in the ON position and the engine off.

Place the ratchet drive side of the socket tool that was used to remove the sensor from the engine, flush on the sensor so the edge of the socket is on the edge of the sensor. Slowly slide the socket along the edge of the sensor as shown.

NOTE: The tool or part used for this must be of a ferrous material (a magnet would stick to it).

Monitor the sensor state while passing the socket over the sensor. Verify that the state changes from high to low or low to high.

If the sensor state does **not** change, replace the crankshaft position sensor.



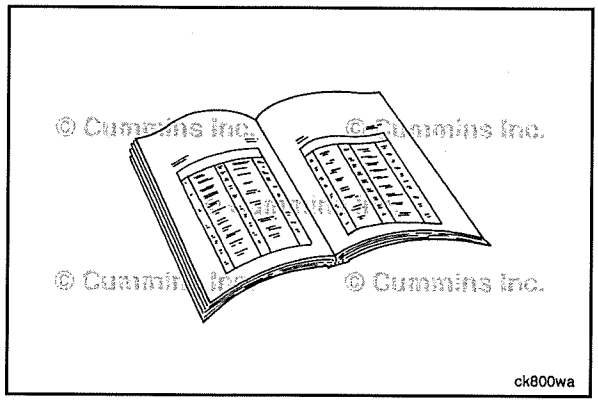
Install

Lubricate the o-ring with clean engine oil before installation.

Install the crankshaft position sensor by pressing firmly on the top of the sensor until the o-ring is fully seated.

Install and tighten the mounting capscrew.

Torque Value: 10 N•m [89 in-lb]



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

EGR Differential Pressure Sensor (019-370)

General Information

The exhaust gas recirculation (EGR) valve differential pressure sensor has two ports that sense a pressure drop across the EGR gas entrance to the intake connection.

The EGR valve differential pressure sensor is mounted on the intake side of the engine, near the EGR valve. Refer to Procedure 100-002 in Section E.

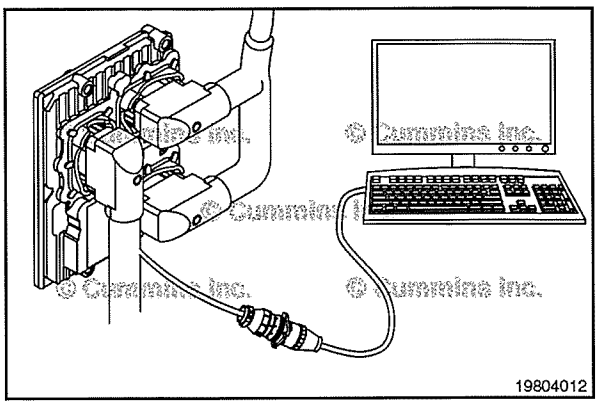
Initial Check

Use an electronic service tool to monitor the value of the EGR differential pressure sensor with the key in the ON position and the engine off.

The sensor should meet the following specification:

EGR Differential Pressure		
kPa		in Hg
± 3	NOM	± 0.90

If the value is **not** within specification, remove the EGR differential pressure sensor and inspect the EGR supply ports in the intake connection for blockage. Refer to Procedure 010-080 in Section 10.

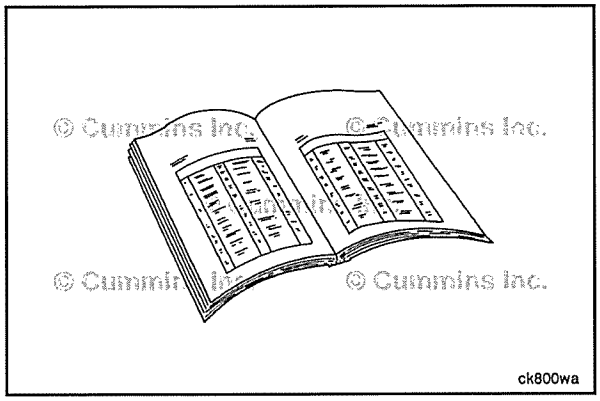


Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

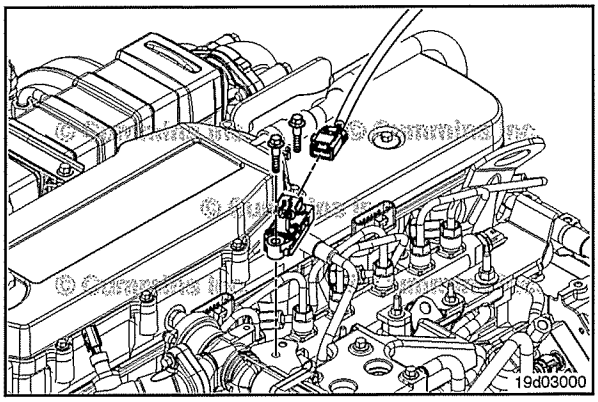
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area around the EGR differential pressure sensor.



Remove

Disconnect the EGR differential pressure sensor from the engine harness.

Remove the two capscrews from the base of the sensor and remove the sensor from the engine.

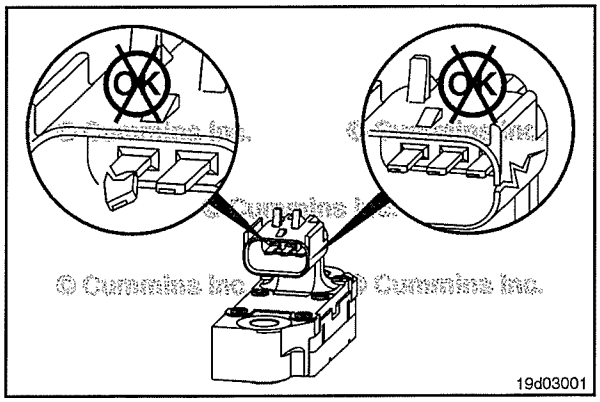


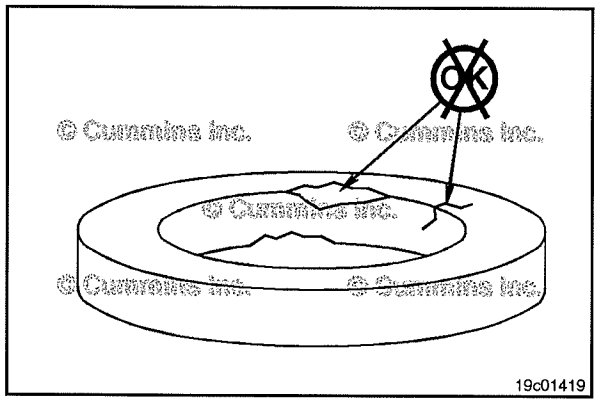
Clean and Inspect for Reuse

Inspect the engine harness connector and sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.

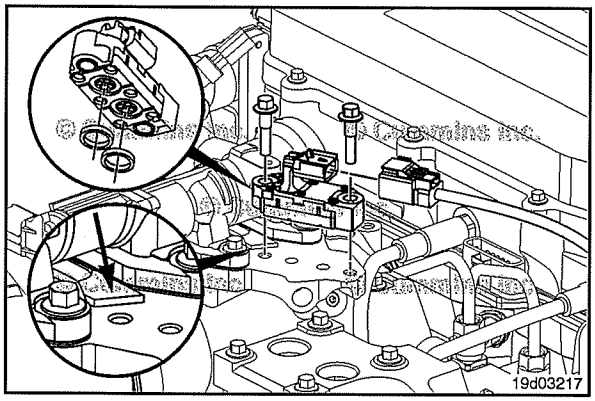
Repair or replace parts as necessary.





Inspect the o-rings for cracks and other damage.

Replace the o-rings if cracks or other damage is found.



Install

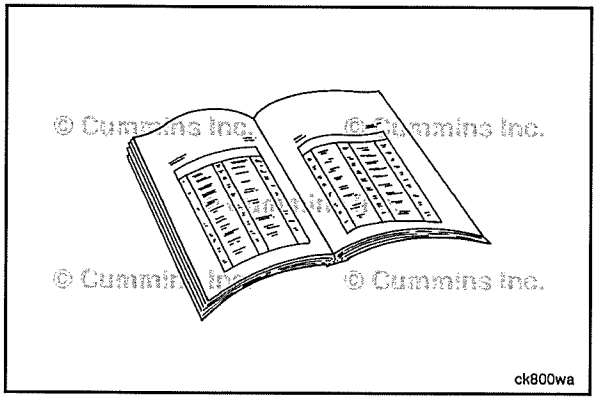
Make sure the new sensor has an o-ring in each of the two grooves at the base of the sensor.

Install the sensor onto the engine.

NOTE: For proper orientation, verify the ridge of the sensor mounting surface on the air intake connection to avoid backward installation.

Tighten the mounting capscrews.

Torque Value: 25 N•m [221 in-lb]



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Exhaust Gas Pressure Sensor (019-376)

General Information

The exhaust gas pressure sensor monitors the pressure in the exhaust manifold.

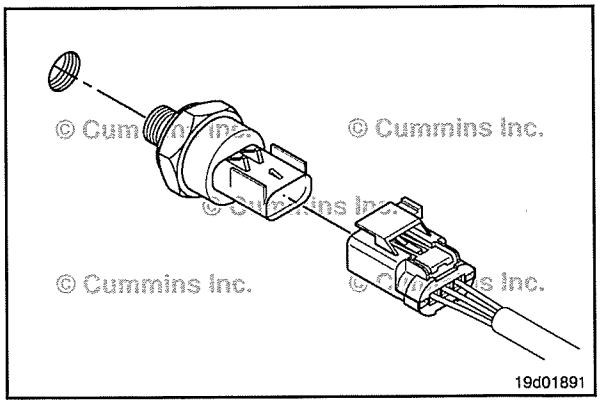
The exhaust gas pressure sensor is located near the exhaust gas recirculation (EGR) cooler on the exhaust side of the engine. Refer to Procedure 100-002 in Section E.

Remove

Slide the locking tab on the connector sideways. Push down on the button toward the rear of the connector and disconnect it from the sensor.

Remove the exhaust pressure sensor insulation tube. Do **not** peel apart the adhesive of the tube to remove.

Remove the sensor from the engine.



Install

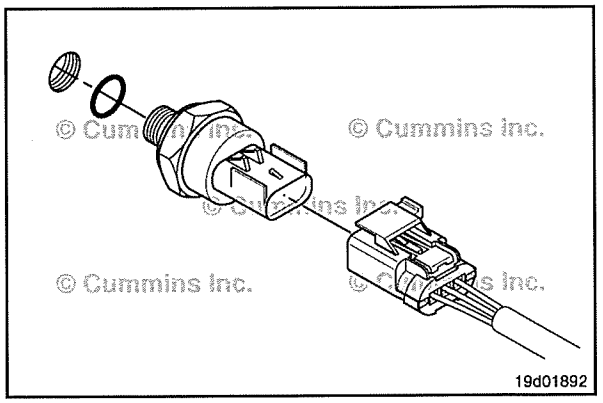
NOTE: Make sure the new sensor has an o-ring.

Lubricate the o-ring with clean engine oil.

Install the sensor into the engine. Tighten the sensor.

Use a deep well socket, being careful **not** to overtighten the sensor.

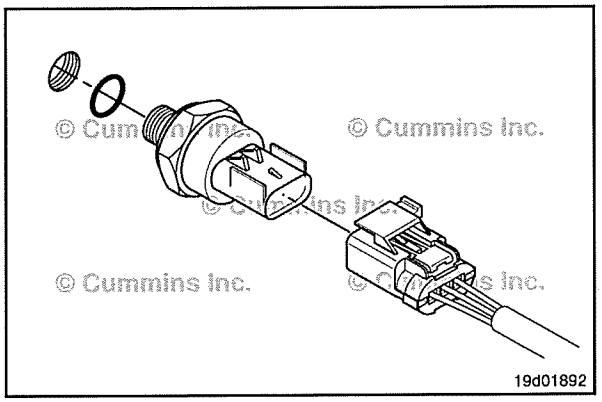
Torque Value: 18 N•m [159 in-lb]



Install the exhaust pressure sensor insulation tube.

Push the connectors together until they lock.

Slide the locking tab to the lock position.

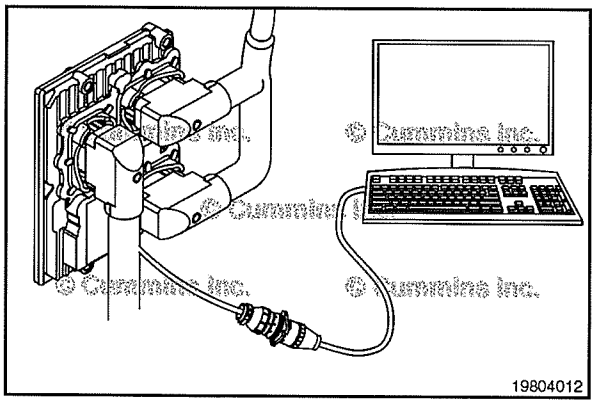


EGR Temperature Sensor (019-378)

General Information

The exhaust gas recirculation (EGR) temperature sensor is used to measure the temperature of the exhaust gas that exits the EGR cooler.

The EGR temperature sensor is located on the EGR crossover tube. Refer to Procedure 100-002 in Section E.



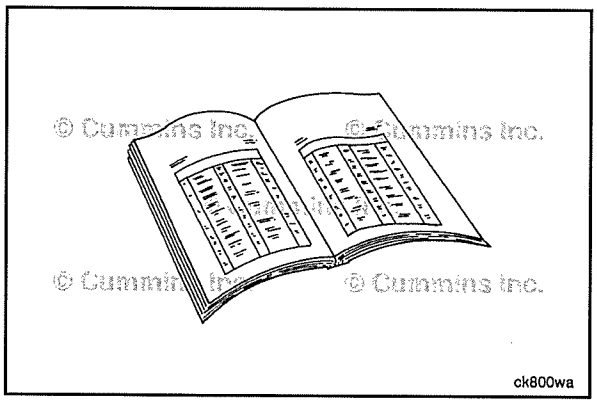
Initial Check

Use an electronic service tool to monitor the value of the EGR temperature sensor with the key in the ON position and the engine off.

NOTE: The value of the EGR temperature sensor should be checked when the engine is cold.

The value of the EGR temperature sensor should read within 5.5°C or 10°F of the local ambient air temperature.

Replace the EGR temperature sensor if the value is out of specification.

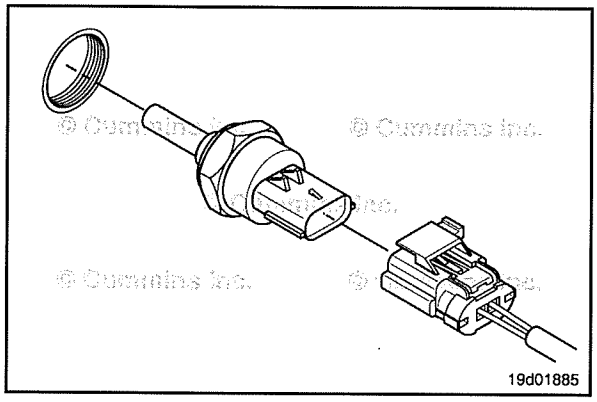


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

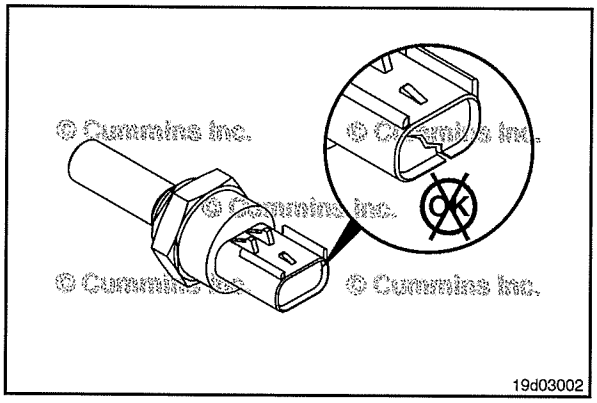
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area around the EGR temperature sensor.



Remove

Disconnect the EGR temperature sensor from the engine harness.

Remove the sensor from the engine.



Clean and Inspect for Reuse

Inspect the engine harness connector and sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.

Repair or replace parts as necessary.

Install

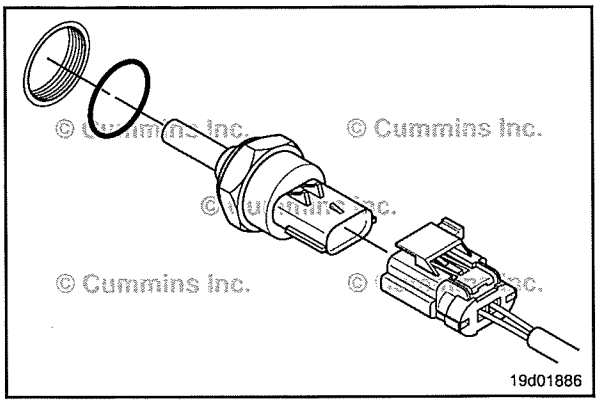
Check to make sure the sensor has a metal sealing washer.

Install the sensor into the EGR crossover tube.

Tighten the sensor.

Torque Value: 34 N•m [25 ft-lb]

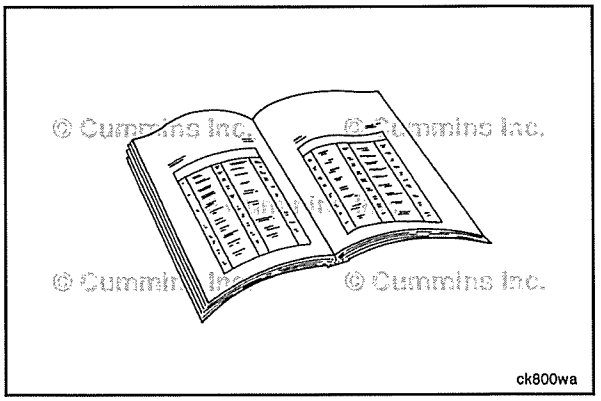
Connect the engine harness connector to the sensor.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

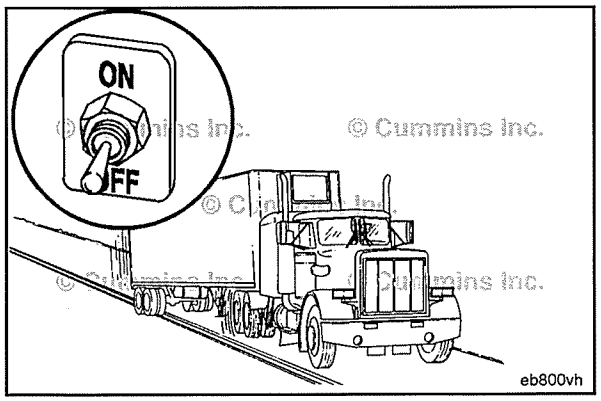


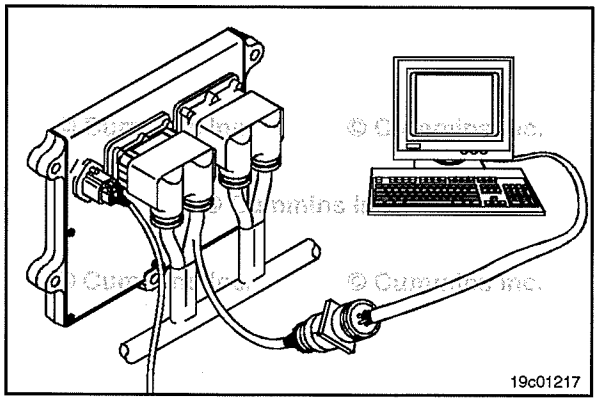
Fan Control Switch (019-380)

General Information

The fan control switch circuit signals the system that the operator is requesting the engine fan to be engaged. The fan on and off circuit consists of the fan control switch signal, the switch return, and the OEM cab-mounted toggle switch. This circuit is considered "fail safe", meaning when the circuit is open, the engine fan will be engaged by the ECM.

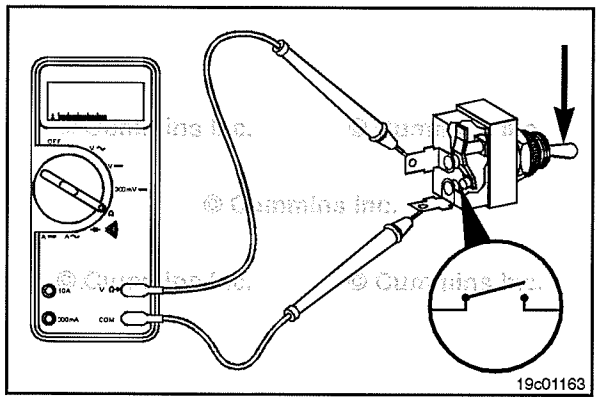
NOTE: This procedure is **only** valid if the fan control switch is wired through the ECM and the feature manual fan switch is enabled in the ECM. If the fan control switch is wired in series with the fan control relay, the ECM could log fan circuit errors during normal operation. Please verify the circuit is wired properly before performing this procedure.





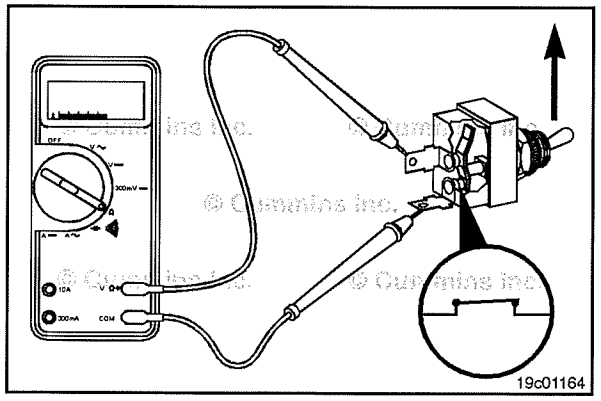
Resistance Check

If INSITE™ is available, monitor the fan control switch for proper operation. If **not** operating properly, follow the troubleshooting procedures in this section.

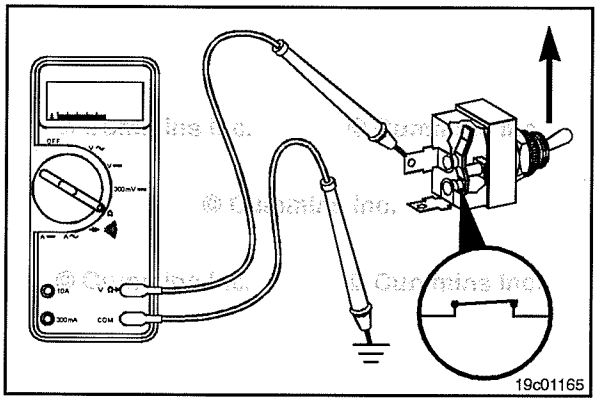


Locate the fan control switch. Label the wires with the location of the switch or the wire number. Remove the electrical connectors from the switch. Adjust the multimeter to measure resistance. Touch one multimeter probe to one of the terminals on the switch. Touch the other multimeter probe to the other terminal of the switch.

Move the switch to the ON position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures.



Place the switch in the OFF position and measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

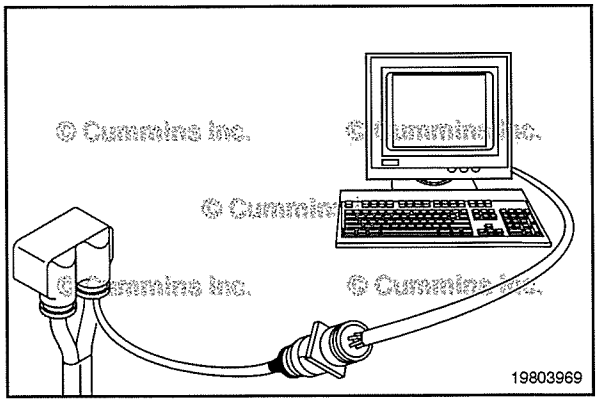
Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the OFF position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.

Fan Control Switch Circuit (019-381)

Resistance Check

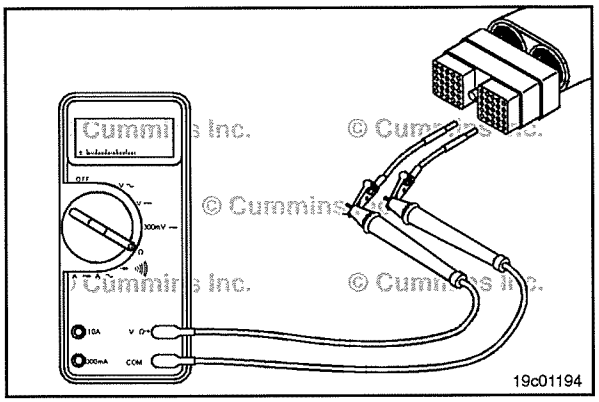
⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the fan control switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.



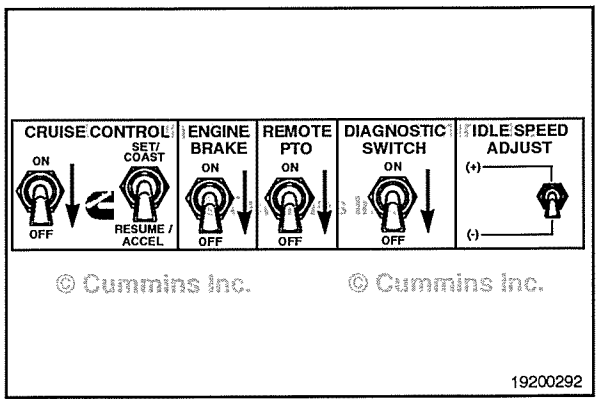
Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM). Insert one of the test leads into the switch return pin of the OEM harness connector and connect the alligator clip to the multimeter probe. Insert the other lead into the fan control switch signal pin of the OEM harness connector and connect the alligator clip to the other multimeter probe.

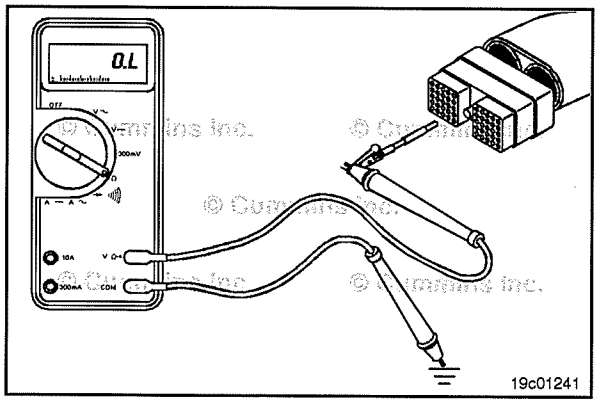
Move the fan control switch to the OFF position. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the fan control switch, switch return wire, and the fan control switch signal wire for an open circuit, provided that the switch has been previously checked. Refer to the OEM troubleshooting and repair manual for repair procedures. If the resistance is within the specification, the fan control switch, switch return (-) wire, and the fan control signal wire **must** be checked for a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.



Check for Short Circuit to Ground

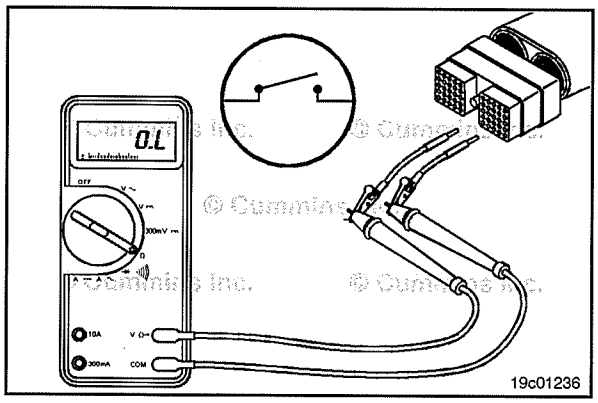
To isolate the fan control switch circuit when checking for an electrical short, disconnect the OEM harness from the ECM and fan control switch. Disconnect the clutch position switch/engine protection override switch and the accelerator pedal assembly. Set all cab panel switches to the OFF or neutral position. Set the service brake using the trailer brake hand valve.





Adjust the multimeter to measure resistance. Insert a test lead into the fan control switch signal pin of the OEM harness connector and connect it to a multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the resistance.

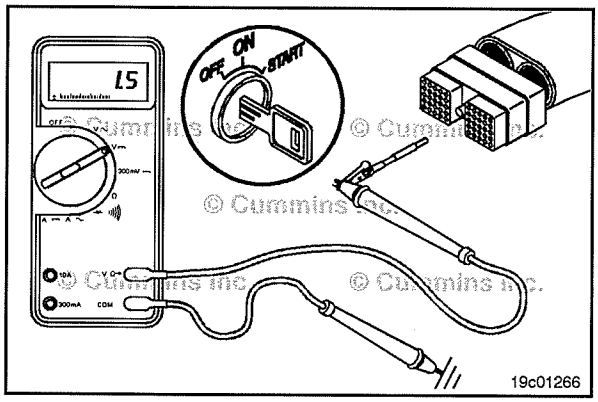
The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the fan switch control circuit, provided that the switch has been previously checked. Repair or replace the wire connected to the fan control switch signal in the OEM harness according to the vehicle manufacturer's procedure.



Check for Short Circuit from Pin to Pin

Isolate the fan control switch circuit by setting the switches as in the previous section. Set the fan control switch to the ON position. Insert the lead into the fan control switch signal pin. Connect the alligator clip to the multimeter. With the other lead inserted into the switch return pin, measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

Remove the lead from the fan control switch signal pin and check all other pins. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit between the fan control switch circuit and any pin that shows a closed circuit, provided the switch has previously been checked. Repair or replace the wires in the OEM harness. Refer to Procedure 019-071.



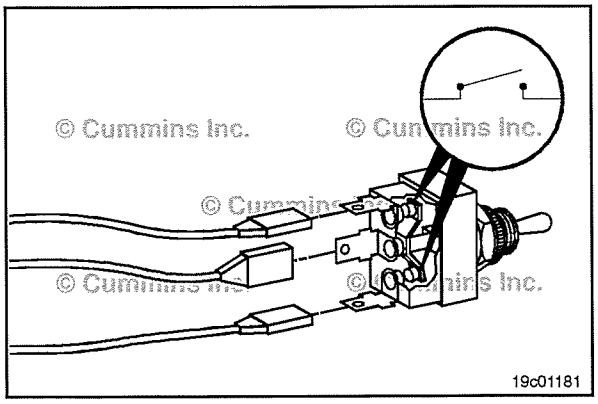
Check for Short Circuit to External Voltage Source

Turn the keyswitch to the ON position. Set the fan control switch to OFF. Adjust the multimeter to measure VDC. Insert a test lead into the fan control switch signal pin and attach it to a multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the voltage. The voltage **must** be 1.5 VDC or less.

If the voltage is **not** correct, there is an external voltage source connected to the circuit, or there is a short circuit between the fan control switch circuit and a wire carrying power in the OEM harness. Remove the voltage source or repair the wiring in the OEM harness according to the vehicle manufacturer's procedures.

Connect all components after completing the repair.

NOTE: If the fan control switch circuit was approved in all of the previous tests, it is functioning correctly.

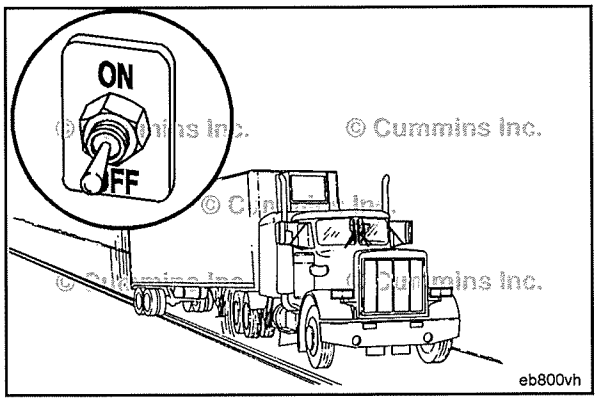


Maximum Engine Speed Switch (019-382)

General Information

The maximum engine speed switch is an OEM installed switch that allows a driver to select a lower, programmable maximum engine speed. Certain applications such as one that uses a hydraulic system may need to be protected from an overspeed condition. The operator may toggle this switch and limit the maximum engine RPM to a lower value that is safe for the hydraulic system to operate in.

NOTE: The switch is now programmable, meaning the speed limit and normal positions can either be open or closed depending on the configuration. Confirm which configuration the specific switch is and adjust the troubleshooting failure criteria before deeming the switch failed.

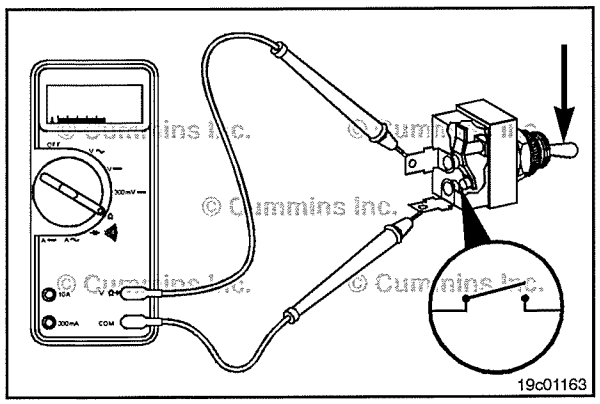


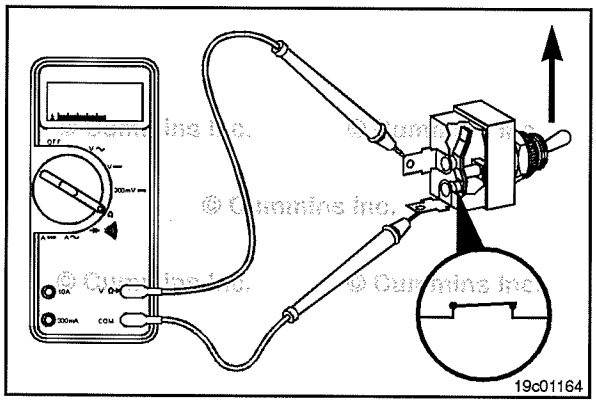
Resistance Check

If INSITE™ is available, monitor the maximum engine speed switch for proper operation. If **not**, follow the troubleshooting procedures in this section.

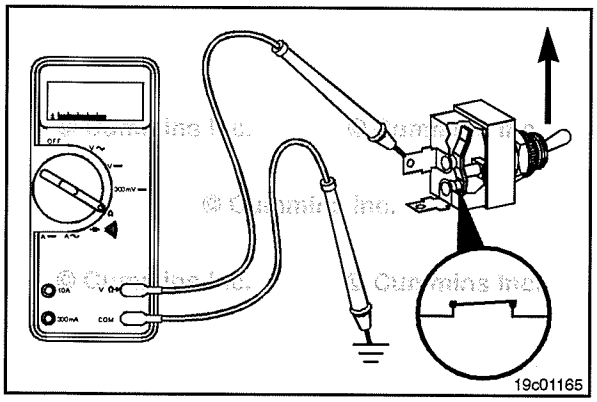
Locate the maximum engine speed switch. Label the wires with the location of the switch or the wire number. Remove the electrical connectors from the switch. Adjust the multimeter to measure resistance. Touch one multimeter probe to one of the terminals on the switch. Touch the other multimeter probe to the other terminal of the switch.

Place the switch in the open position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures.



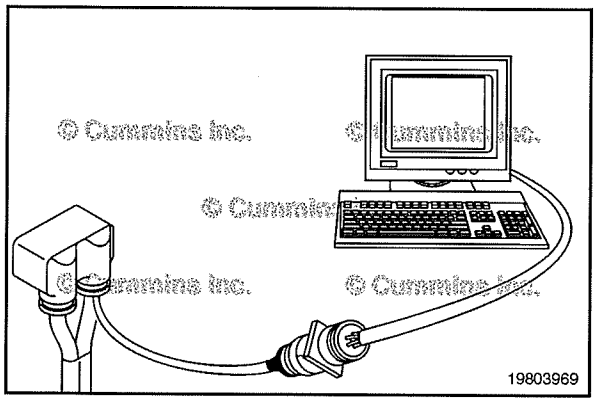


Place the switch in the closed position and measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the resistance value is correct, the switch **must** still be checked for a short circuit to ground.



Check for Short Circuit to Ground

Touch one of the multimeter probes to one of the switch terminals. Touch the other probe to chassis ground. Move the switch to the closed position and measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, the switch has failed. Refer to the OEM troubleshooting and repair manual for replacement procedures. If the switch passes all of the previous checks, the circuit **must** be checked for an open circuit, a short circuit to ground, a short circuit from pin to pin, and a short circuit to an external voltage source.



Maximum Engine Speed Switch Circuit (019-383)

Resistance Check

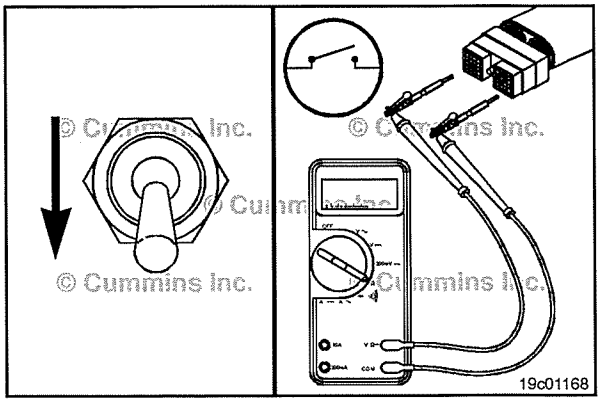
△CAUTION△
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

If INSITE™ electronic service tool is available, monitor the maximum engine speed switch circuit for proper operation. If **not**, follow the troubleshooting procedures in this section.

Disconnect the original equipment manufacturer (OEM) harness connector from the electronic control module (ECM). Insert one of the test leads into the switch return pin of the OEM harness connector and connect the alligator clip to the multimeter probe. Insert the other lead into the maximum engine speed switch signal pin of the OEM harness connector and connect the alligator clip to the other multimeter probe.

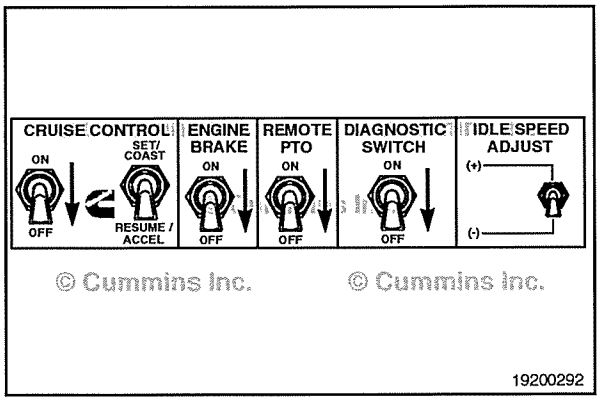
NOTE: The maximum engine speed switch is programmed by the OEM. The open or closed position of the switch can represent "Normal" or "Speed Limit" depending on how the OEM programs the switch. Before continuing to troubleshoot refer to the OEM troubleshooting and repair manual to determine how the switch is programmed and apply the defective switch criteria accordingly when performing the troubleshooting.

Move the maximum engine speed switch to the normal position. The multimeter **must** show a closed circuit (10 ohms or less). If the circuit is **not** closed, inspect the switch return wire and the maximum engine speed switch signal wire for an open circuit, provided that the switch has been previously checked. Refer to the OEM troubleshooting and repair manual for repair procedures. If the resistance is within the specification, the switch return wire and the maximum engine speed switch signal wire **must** be checked for a short circuit to ground, a short circuit from pin-to-pin, and a short circuit to an external voltage source.



Check for Short Circuit to Ground

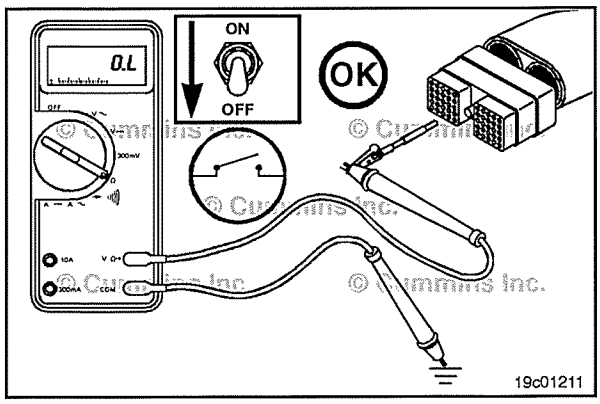
To isolate the maximum engine speed switch circuit when checking for an electrical short, disconnect the OEM harness from the ECM and the OEM harness from the maximum engine speed switch. Disconnect the clutch pedal position switch/engine protection override switch and the accelerator pedal assembly switch. Set all cab panel switches to the OFF or neutral position. Set the service brake using the trailer brake hand valve.

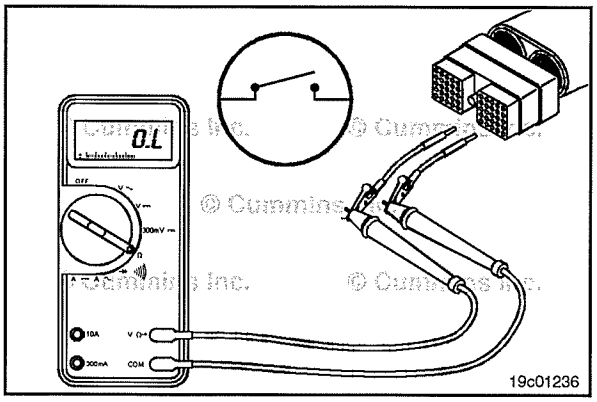


Adjust the multimeter to measure resistance. Insert a test lead into the maximum engine speed switch signal pin of the OEM harness connector and connect it to a multimeter probe. Touch the other multimeter probe to the engine block ground.

Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit to ground in the maximum engine speed switch circuit, provided that the switch has been previously checked.

Repair or replace the wire connected to the maximum engine speed switch signal pin in the OEM harness according to the vehicle manufacturer's procedure.



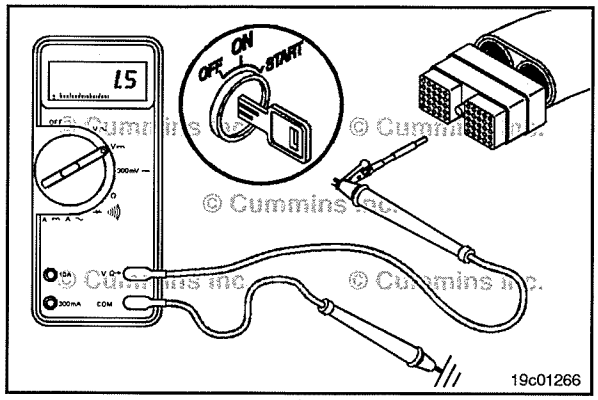


Check for Short Circuit from Pin to Pin

Isolate the maximum engine speed switch circuit by setting the switches as in the previous section. Set the maximum engine speed switch to the normal position. Insert the lead into the maximum engine speed switch signal pin. Connect the alligator clip to the multimeter. With the other lead inserted into the switch return pin, measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

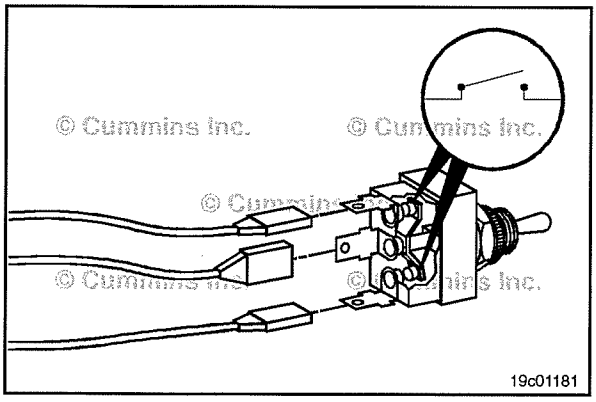
Remove the lead from the maximum engine speed switch signal pin and check all other pins. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more). If the circuit is **not** open, there is a short circuit between the manual fan switch circuit and any pin that shows a closed circuit, provided the switch has previously been checked.

Repair or replace the wires in the OEM harness. Refer to Procedure 019-071.



Check for Short Circuit to External Voltage Source

Turn the keyswitch to the ON position. Set the maximum engine speed switch to the normal position. Adjust the multimeter to measure VDC. Insert a test lead into the maximum engine speed switch signal pin and attach it to a multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the voltage. The voltage **must** be 1.5 VDC or less.



If the voltage is **not** correct, there is an external voltage source connected to the circuit, or there is a short circuit between the maximum engine speed switch circuit and a wire carrying power in the OEM harness.

Remove the voltage source or repair the wiring in the OEM harness according to the OEM troubleshooting and repair manual. Connect all components after completing the repair.

NOTE: If the maximum engine speed switch circuit was approved in all of the previous tests, it is functioning correctly.

Turbocharger Speed Sensor (019-390)

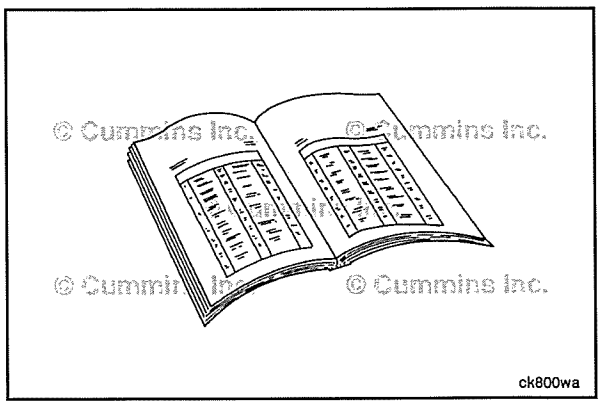
General Information

The turbocharger speed sensor is located on the turbocharger between the compressor and the turbine housings. Use the following procedure for a detailed component location view. Refer to Procedure 100-002 in Section E.

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area around the turbocharger speed sensor.



Remove

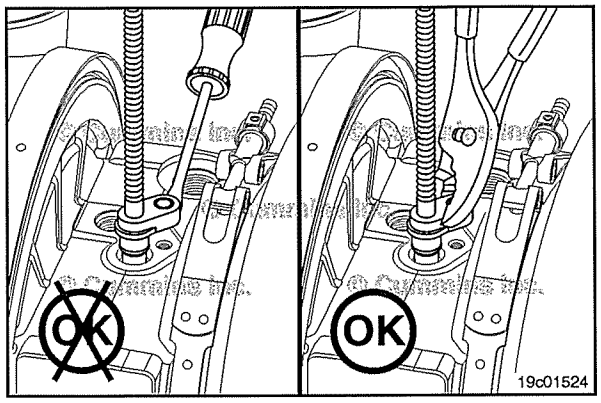
△CAUTION△
When removing the turbocharger speed sensor, use a twisting motion while pulling upward. Prying on the sensor body with a screwdriver can lead to broken sensors and could result in unwarranted turbocharger replacement. Pliers are recommended for turbocharger speed sensor removal.

NOTE: Take note of the proper routing of the harness when removing for proper installation,

Lift up on the locking tab and pull the electrical connectors apart.

Remove the mounting capscrew.

Use pliers to remove the turbocharger speed sensor. Apply a twisting motion while pulling upward.



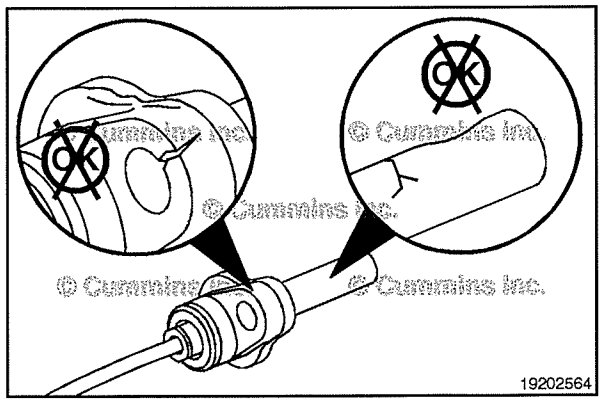
Clean and Inspect for Reuse

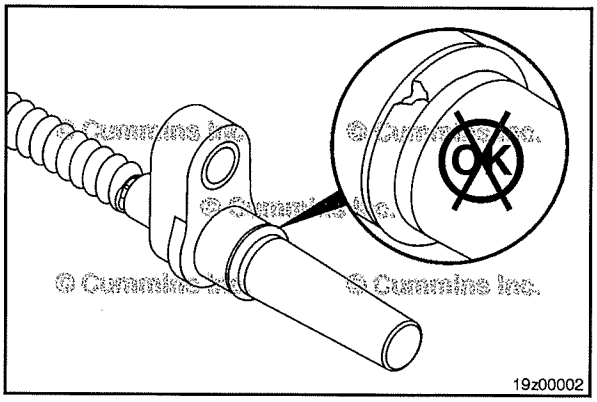
Inspect the turbocharger speed sensor body and wiring harness for signs of melting or damage.

Inspect the engine harness connector and sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor.

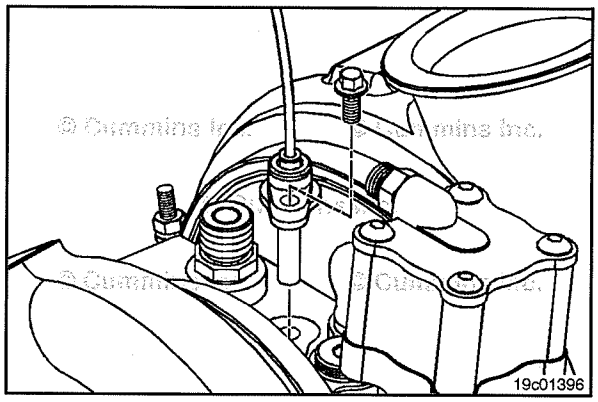
Repair or replace parts as necessary.





If the turbocharger speed sensor is being removed due to an oil leak, inspect the turbocharger speed sensor o-ring for signs of damage. If the o-ring is cut or damaged, the o-ring **must** be replaced.

If there are no cuts or damage evident to the o-ring, it is possible to reseal and prevent oil leaks. To do this, apply Loctite™ 5699, or equivalent, to the o-ring and the area where the o-ring sits on the speed sensor, prior to assembly.



Install

If installing a new turbocharger speed sensor, make sure the new turbocharger speed sensor has a new o-ring installed.

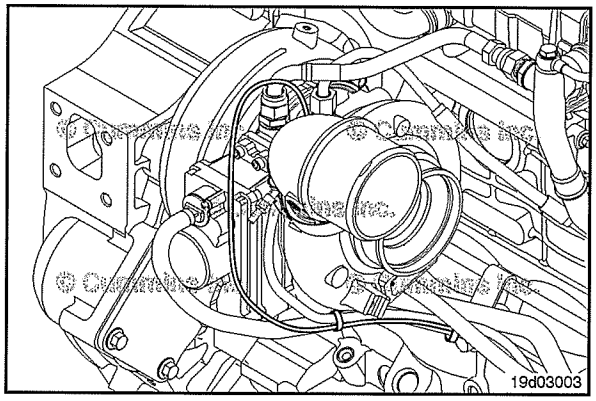
If the turbocharger speed sensor was removed due to an oil leak, it is possible to reuse the turbocharger speed sensor and either replace or inspect the o-ring for reuse (as described in the Inspection section above).

Apply Loctite™ 5699, or equivalent, to the o-ring. This helps seal and prevent oil leaks.

Install the turbocharger speed sensor onto the turbocharger.

Tighten the mounting capscrew.

Torque Value: 9 N•m [80 in-lb]



⚠CAUTION⚠
The turbocharger speed sensor harness must be tied up and away from any heat sources and hard or sharp surfaces. Failure to do so will cause damage to the harness.

⚠CAUTION⚠
Do not install cable ties directly over the sensor connector. Doing so can damage the connector. Tie the speed sensor wiring harness on either side of the connectors.

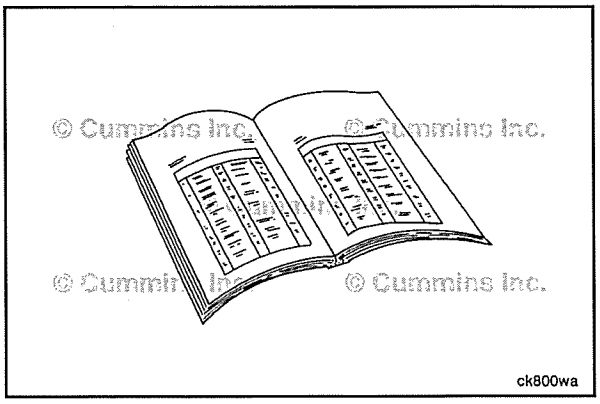
NOTE: Use the same routing that was noted during harness removal.

Secure the turbocharger speed sensor wiring harness to the turbocharger actuator harness.

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



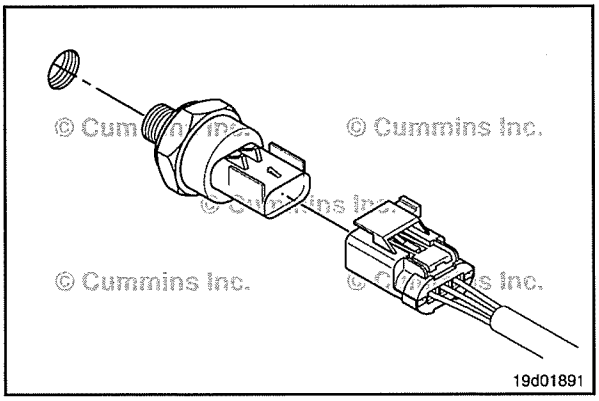
OEM Pressure Sensor (019-400)

General Information

Some original equipment manufacturers (OEMs) can choose to install an additional pressure sensor.

The OEM pressure sensor monitors an OEM-defined pressure and passes that information on to the electronic control module (ECM) through the OEM harness. The ECM uses this information to determine the state of an OEM switched output device.

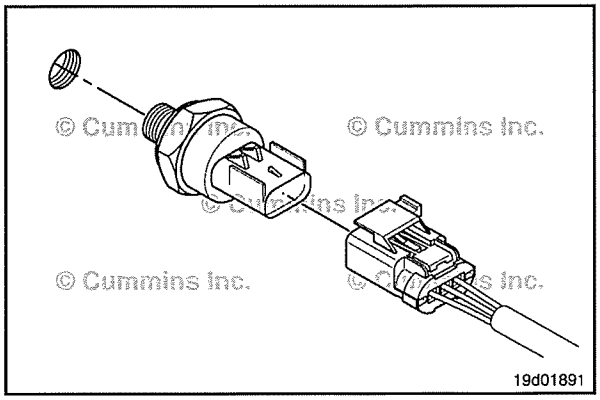
Refer to the OEM troubleshooting and repair manual for the location of the OEM pressure sensor.



Inspect for Reuse

Inspect the OEM pressure sensor for damaged or broken connector pins.

Refer to the OEM troubleshooting and repair manual for removal and installation instructions.

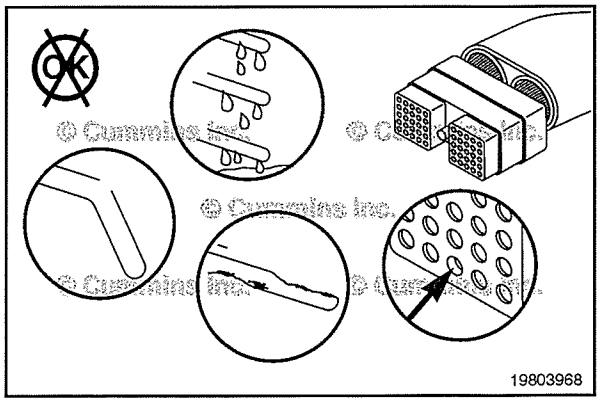


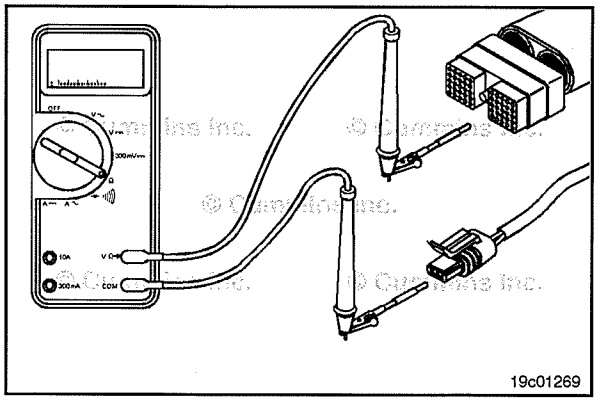
OEM Pressure Sensor Circuit (019-401)

Initial Check

Disconnect the original equipment manufacturer (OEM) pressure sensor connector from the OEM harness. Disconnect the OEM harness connector from the electronic control module (ECM).

Check the OEM pressure sensor connector and OEM harness connectors for broken, bare, or melted wires; loose, dirty, damaged, or missing pins; and other visible signs of damage.



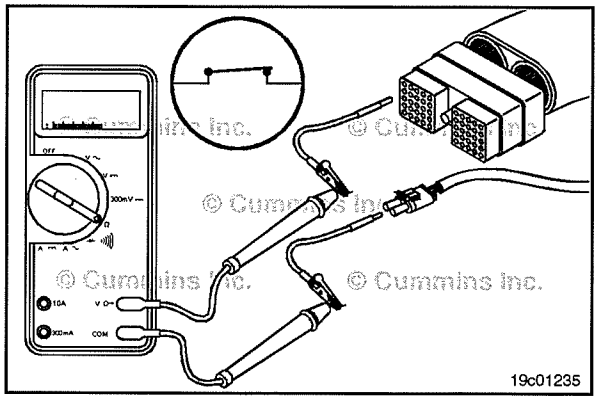


Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECM. Disconnect the OEM pressure sensor from the OEM harness. Set the multimeter to measure resistance.

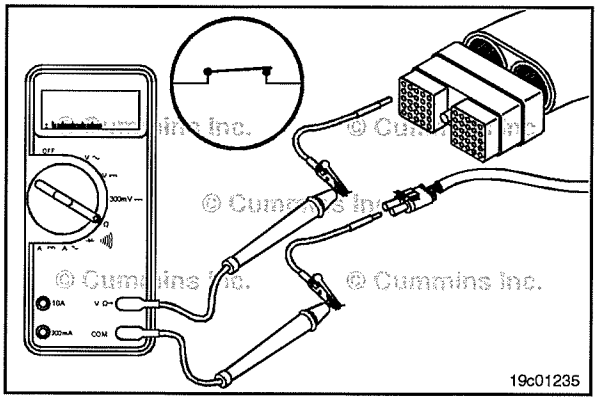
Insert a test lead into the OEM pressure sensor signal pin of the OEM harness connector. Connect the alligator clip to a multimeter probe. Insert the second test lead to the signal pin of the OEM pressure sensor harness connector and connect the clip to the other multimeter probe. Measure the resistance.



The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the signal wire.

Repair or replace the OEM harness. Refer to Procedure 019-071.



Repeat the resistance check for the return wire. Measure the resistance from the OEM pressure sensor return pin of the OEM harness connector to the OEM pressure sensor return pin of the harness connector.

The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the return wire.

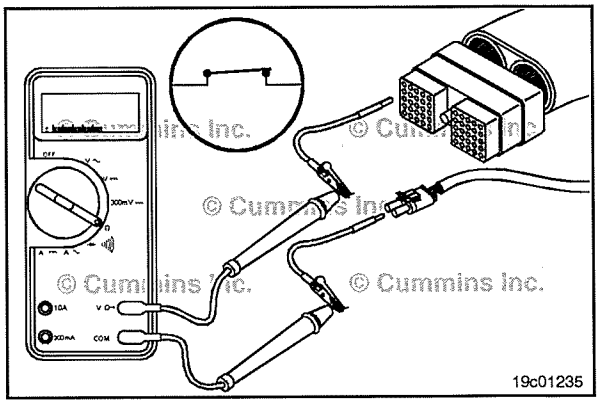
Repair or replace the OEM harness. Refer to Procedure 019-071.

Repeat the resistance check for the 5 volt supply wire. Measure the resistance from the OEM pressure sensor 5 volt supply pin of the OEM harness connector to the OEM pressure sensor 5 volt supply pin of the harness connector.

The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the 5 volt supply wire.

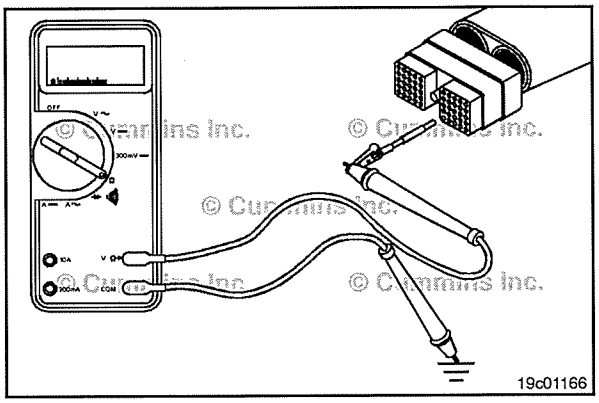
Repair or replace the OEM harness. Refer to Procedure 019-071.



Check for Short Circuit to Ground

Disconnect the OEM harness connector from the ECM. Disconnect the OEM pressure sensor from the OEM harness. Set the multimeter to measure resistance.

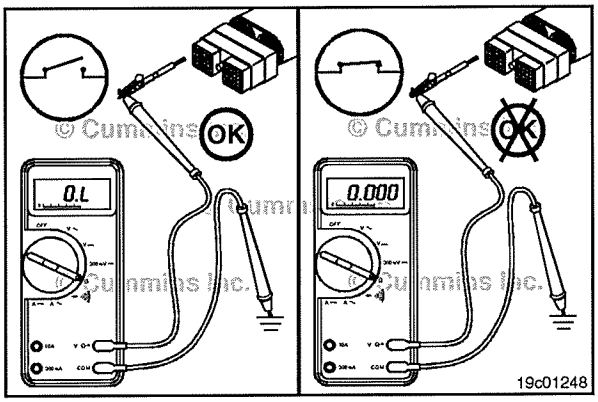
Insert the test lead into the OEM pressure sensor signal pin of the OEM harness connector. Touch the other multimeter probe to engine block ground. Measure the resistance.



The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the signal wire.

Repair or replace the OEM harness. Refer to Procedure 019-071.

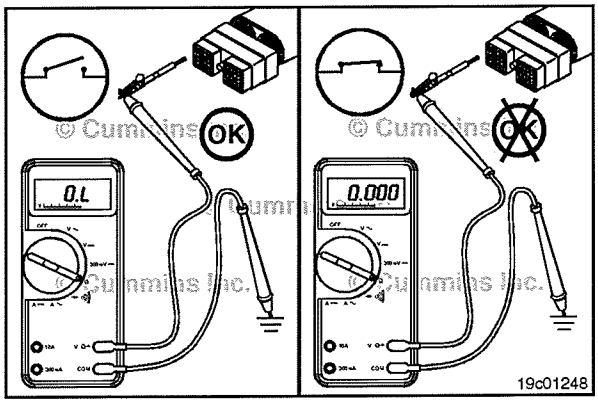


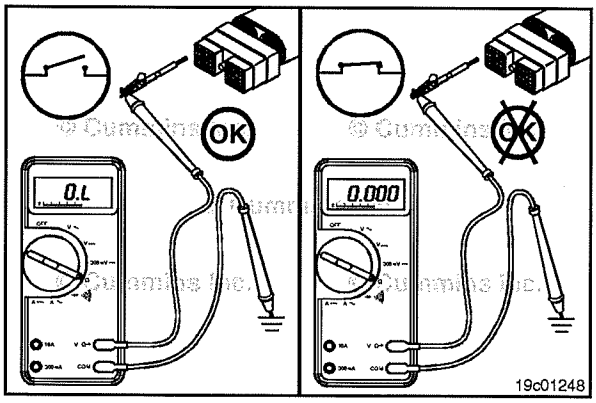
Repeat the short-to-ground check for the return wire. Measure the resistance from the OEM pressure sensor return pin of the OEM harness connector to engine block ground.

The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the return wire.

Repair or replace the OEM harness. Refer to Procedure 019-071.



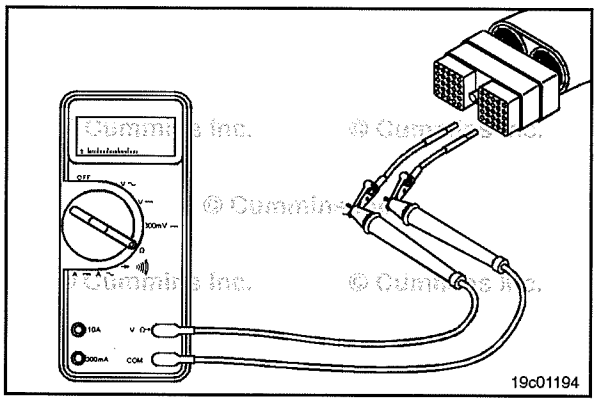


Repeat the short-to-ground check for the 5 volt supply wire. Measure the resistance from the OEM pressure sensor 5 volt supply pin of the OEM harness connector to engine block ground.

The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the 5 volt supply wire.

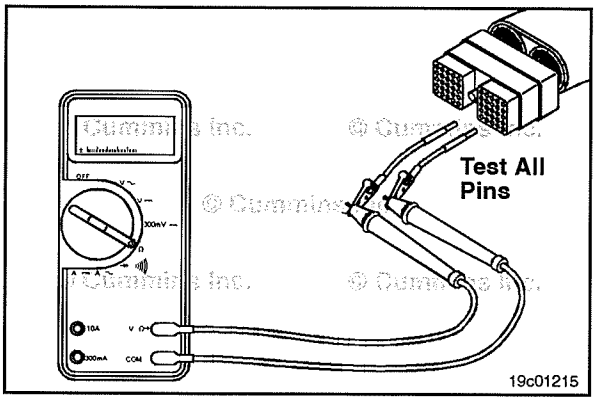
Repair or replace the OEM harness. Refer to Procedure 019-071.



Check for Short Circuit from Pin to Pin

Disconnect the OEM harness connector from the ECM. Disconnect the OEM pressure sensor from the OEM harness. Set the multimeter to measure resistance.

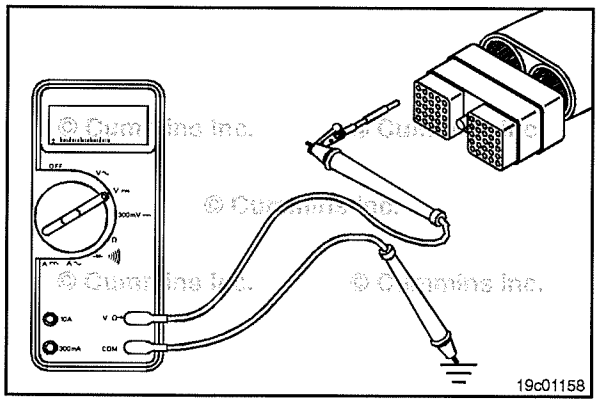
Measure the resistance from the OEM pressure sensor signal pin in the OEM harness connector to all other pins in the connector.



The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit between the signal wire and any other pin that measured a closed circuit.

Repair or replace the OEM harness. Refer to Procedure 019-071.



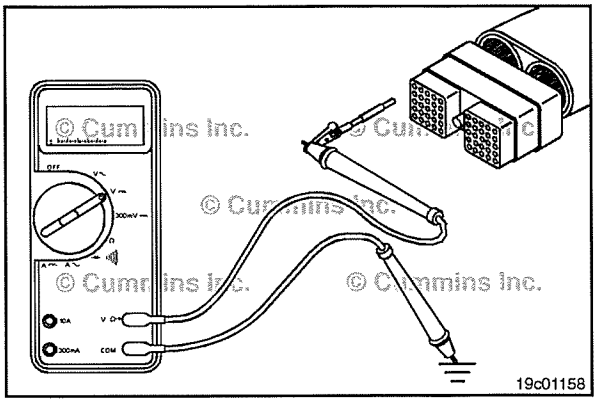
Check for Short Circuit to External Voltage Source

Disconnect the OEM harness connector from the ECM. Disconnect the OEM pressure sensor from the OEM harness. Set the multimeter to measure VDC. Turn the vehicle keyswitch to the ON position.

Insert the test lead connected to the positive (+) multimeter probe into the OEM pressure sensor signal pin of the OEM harness connector. Touch the negative (-) multimeter probe to engine block ground and measure the voltage.

If there is voltage present, there is a short circuit from the signal wire to an external voltage source.

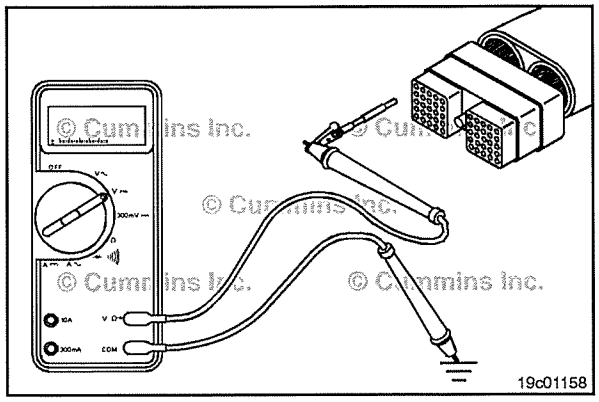
Repair or replace the OEM harness. Refer to Procedure 019-071.



Repeat the short to external voltage source check for the return wire. Measure the voltage from the OEM pressure sensor return pin of the OEM harness connector to engine block ground.

If there is voltage present, there is a short circuit from the return wire to an external voltage source.

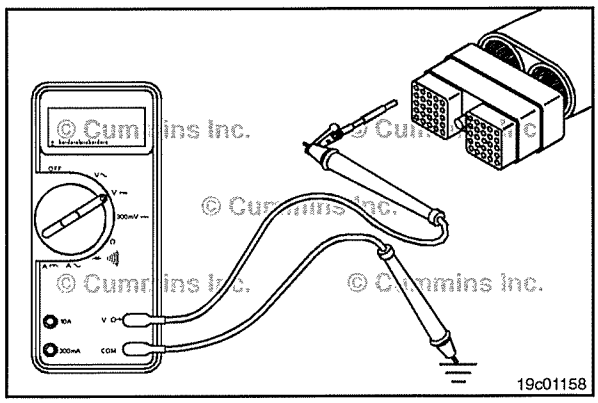
Repair or replace the OEM harness. Refer to Procedure 019-071.



Repeat the short to external voltage source check for the 5 volt supply wire. Measure the voltage from the OEM pressure sensor 5 volt supply pin of the OEM harness connector to engine block ground.

The multimeter **must** show a voltage of less than 5.5 VDC. If the voltage is greater than 5.5 VDC, there is a short circuit from the 5 volt supply wire to an external voltage source.

Repair or replace the OEM harness. Refer to Procedure 019-071.



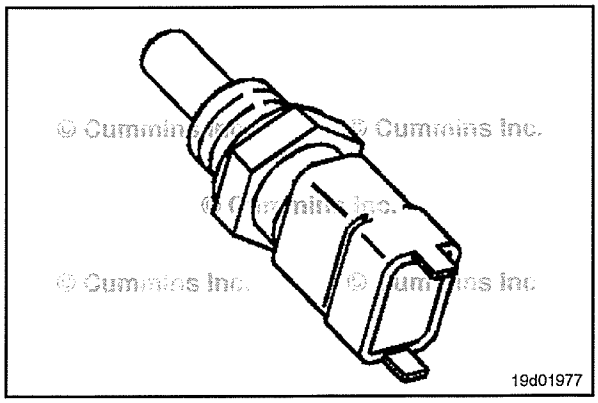
OEM Temperature Sensor (019-402)

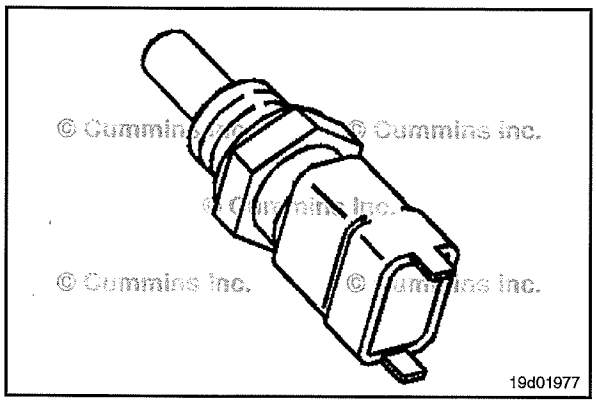
General Information

Some original equipment manufacturers (OEMs) can choose to install an additional temperature sensor.

The OEM temperature sensor monitors an OEM-defined temperature and passes that information on to the electronic control module (ECM) through the OEM harness. The ECM uses this information to determine the state of an OEM switched output device.

Refer to the OEM troubleshooting and repair manual for the location of the OEM temperature sensor.

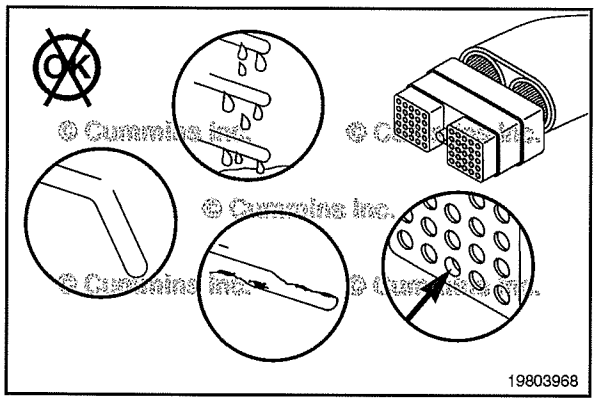




Inspect for Reuse

Inspect the OEM temperature sensor for damaged or broken connector pins.

Refer to the OEM troubleshooting and repair manual for removal and installation instructions.

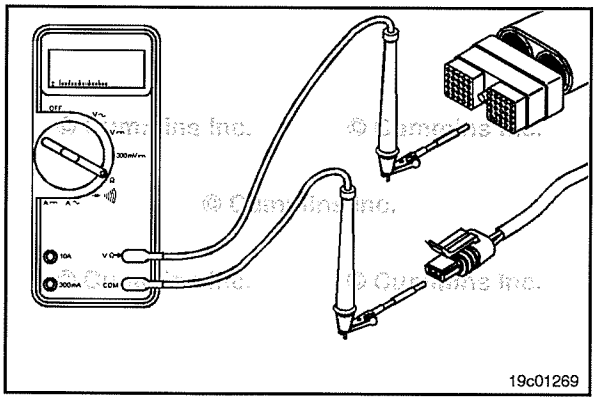


OEM Temperature Sensor Circuit (019-403)

Initial Check

Disconnect the original equipment manufacturer (OEM) temperature sensor connector from the OEM harness. Disconnect the OEM harness connector from the electronic control module (ECM).

Check the OEM temperature sensor connector and OEM harness connectors for broken, bare, or melted wires; loose, dirty, damaged, or missing pins; and other visible signs of damage.



Resistance Check

△CAUTION△
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

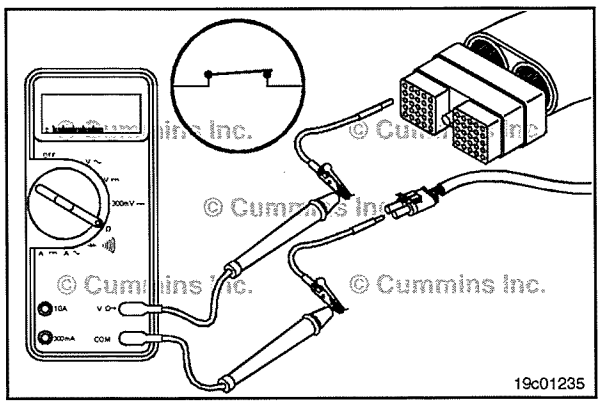
Disconnect the OEM harness connector from the ECM. Disconnect the OEM temperature sensor from the OEM harness. Set the multimeter to measure resistance.

Insert a test lead into the OEM temperature sensor signal pin of the OEM harness connector. Connect the alligator clip to a multimeter probe. Insert the second test lead to the signal pin of the OEM temperature sensor harness connector and connect the clip to the other multimeter probe. Measure the resistance.

The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the signal wire.

Repair or replace the OEM harness. Refer to Procedure 019-071.

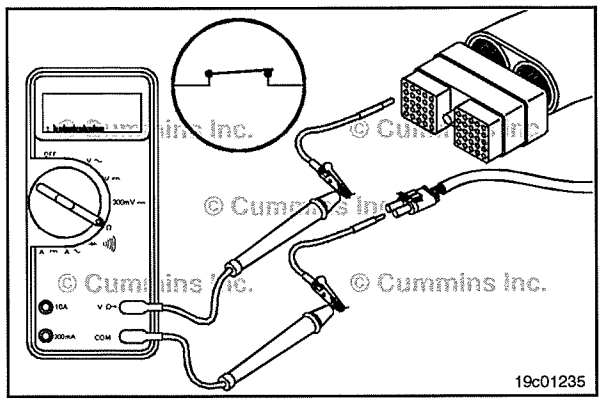


Repeat the resistance check for the return wire. Measure the resistance from the OEM temperature sensor return pin of the OEM harness connector to the OEM temperature sensor return pin of the harness connector.

The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the return wire.

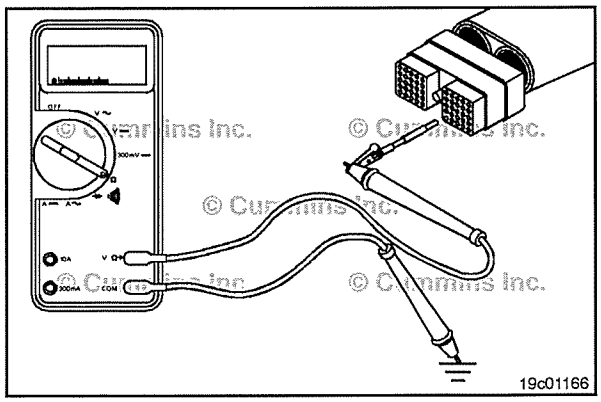
Repair or replace the OEM harness. Refer to Procedure 019-071.



Check for Short Circuit to Ground

Disconnect the OEM harness connector from the ECM. Disconnect the OEM temperature sensor from the OEM harness. Set the multimeter to measure resistance.

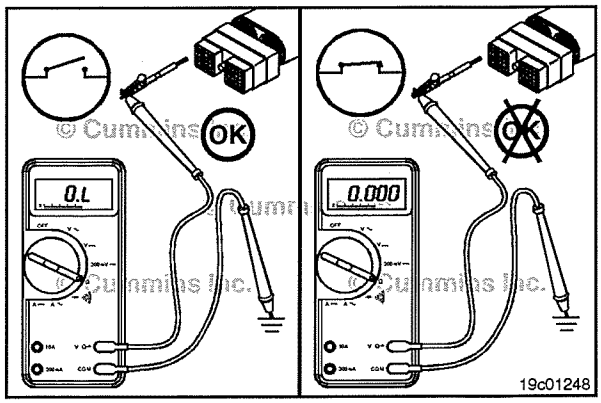
Insert the test lead into the OEM temperature sensor signal pin of the OEM harness connector. Touch the other multimeter probe to engine block ground. Measure the resistance.

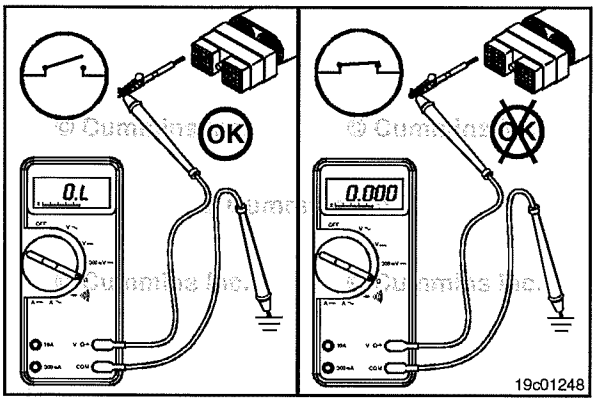


The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the signal wire.

Repair or replace the OEM harness. Refer to Procedure 019-071.



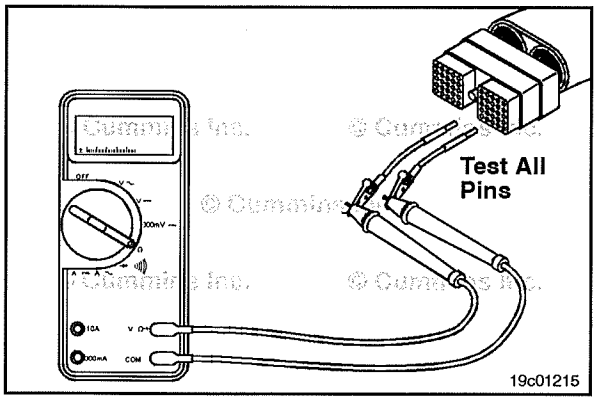


Repeat the short-to-ground check for the return wire. Measure the resistance from the OEM temperature sensor return pin of the OEM harness connector to engine block ground.

The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the return wire.

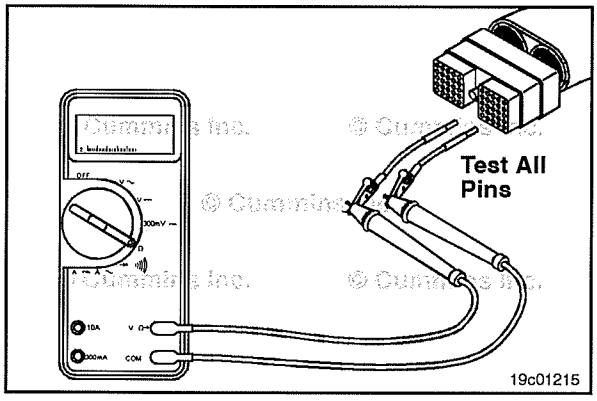
Repair or replace the OEM harness. Refer to Procedure 019-071.



Check for Short Circuit from Pin to Pin

Disconnect the OEM harness connector from the ECM. Disconnect the OEM temperature sensor from the OEM harness. Set the multimeter to measure resistance.

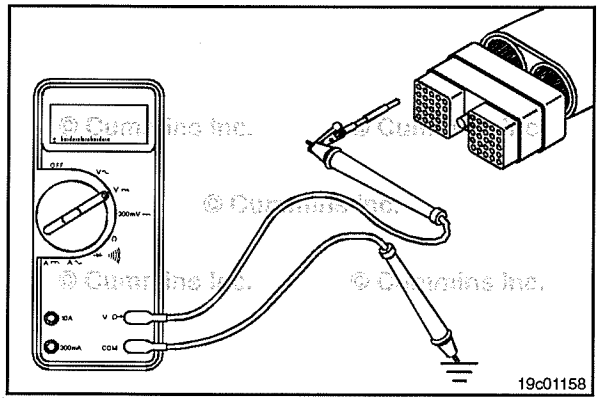
Measure the resistance from the OEM temperature sensor signal pin in the OEM harness connector to all other pins in the connector.



The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit between the signal wire and any other pin that measured a closed circuit.

Repair or replace the OEM harness. Refer to Procedure 019-071.



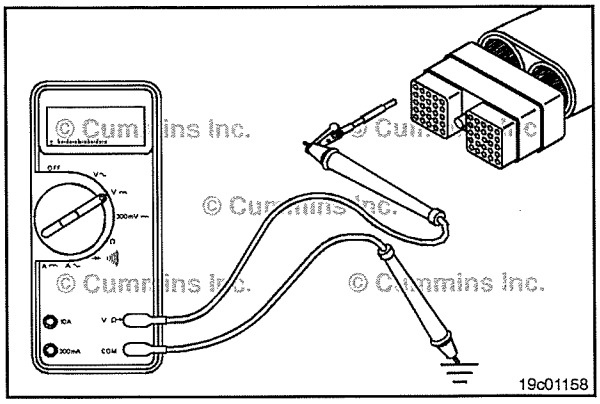
Check for Short Circuit to External Voltage Source

Disconnect the OEM harness connector from the ECM. Disconnect the OEM temperature sensor from the OEM harness. Set the multimeter to measure VDC. Turn the vehicle keyswitch to the ON position.

Insert the test lead connected to the positive (+) multimeter probe into the OEM temperature sensor signal pin of the OEM harness connector. Touch the negative (-) multimeter probe to engine block ground and measure the voltage.

The multimeter **must** show voltage of 5.5 VDC or less. If the voltage is incorrect, there is a short circuit from the signal wire to an external voltage source.

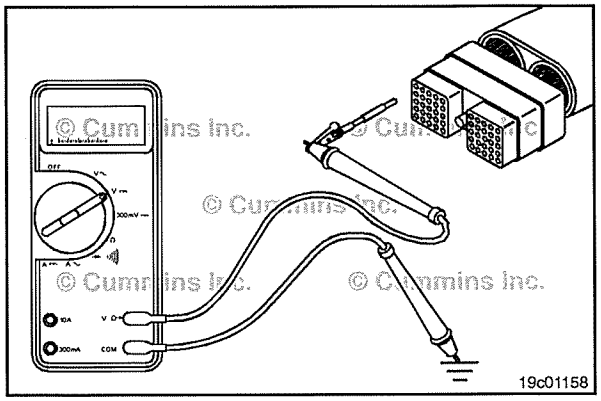
Repair or replace the OEM harness. Refer to Procedure 019-071.



Repeat the short to external voltage source check for the return wire. Measure the voltage from the OEM temperature sensor return pin of the OEM harness connector to engine block ground.

The multimeter **must** show voltage of 5.5 VDC or less. If the voltage is incorrect, there is a short circuit from the return wire to an external voltage source.

Repair or replace the OEM harness. Refer to Procedure 019-071.



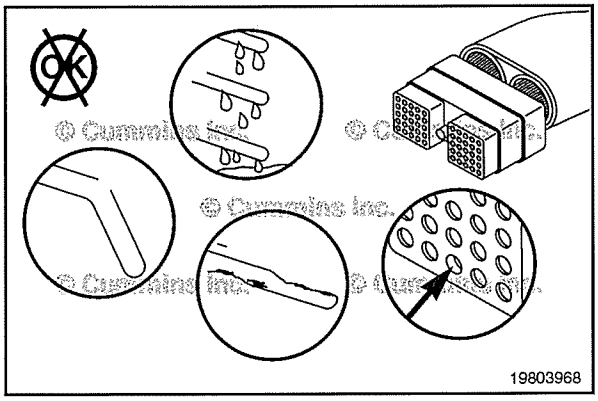
Intake Air Heater Control Relay Circuit (019-408)

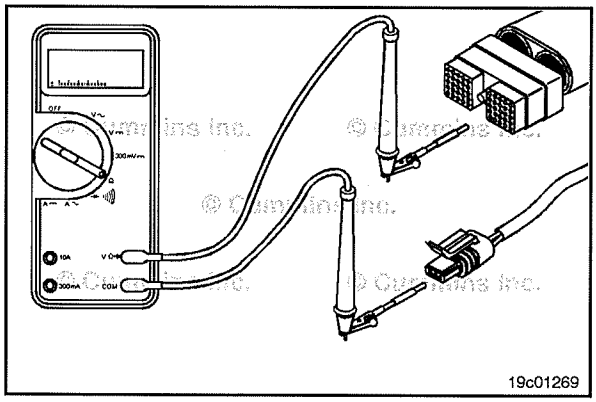
Initial Check

Disconnect the intake air heater control relay from the OEM harness.

Disconnect the OEM harness connector from the ECM connector.

Check the intake air heater control relay and harness connector for broken, bare, or melted wires; loose, dirty, damaged, or missing pins; and other visible signs of damage.





Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECM connector. Disconnect the intake air heater control relay from the OEM harness. Set the multimeter to measure resistance.

Insert a test lead into the intake air heater control relay signal pin of the OEM harness connector. Connect the alligator clip to a multimeter probe. Insert the second test lead to the signal pin of the intake air heater control relay harness connector and connect the clip to the other multimeter probe. Measure the resistance.

The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

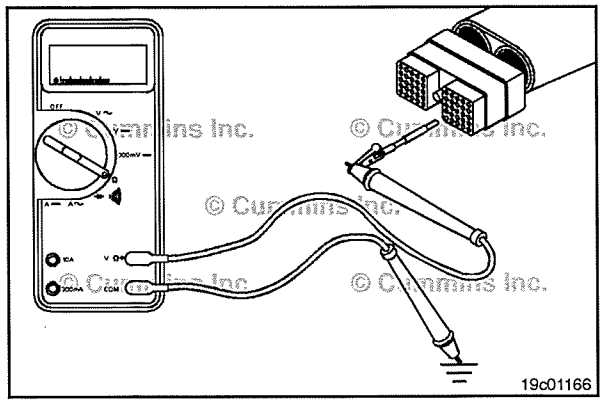
If the measured value is more than 10 ohms, there is an open circuit in the signal wire. Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

Repeat the resistance check for the return wire. Measure the resistance from the intake air heater control relay return pin of the OEM harness connector to the intake air heater control relay return pin of the harness connector.

The multimeter **must** show a measurement of 10 ohms or less (closed circuit).

If the measured value is more than 10 ohms, there is an open circuit in the return wire. Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

Check for Short Circuit to Ground



Disconnect the OEM harness connector from the ECM connector. Disconnect the intake air heater control relay from the OEM harness. Set the multimeter to measure resistance.

Insert the test lead into the intake air heater control relay signal pin of the OEM harness connector. Touch the other multimeter probe to engine block ground. Measure the resistance.

The multimeter **must** show a measurement of 100k ohms or more (open circuit).

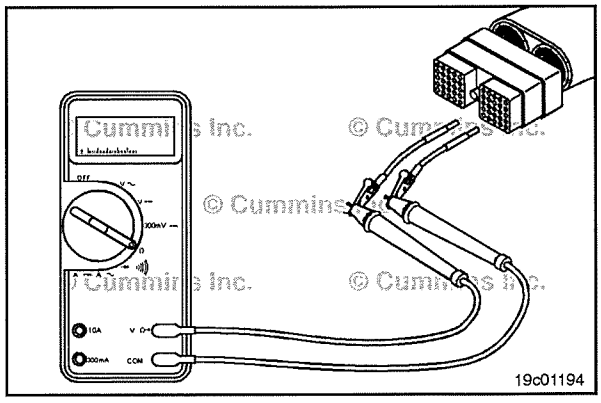
If the measured value is less than 100k ohms, there is a short circuit to ground in the signal wire. Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

Repeat the short to ground check for the return wire. Measure the resistance from the intake air heater control relay return pin of the OEM harness connector to engine block ground.

The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit to ground in the return wire. Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

Check for Short Circuit from Pin to Pin

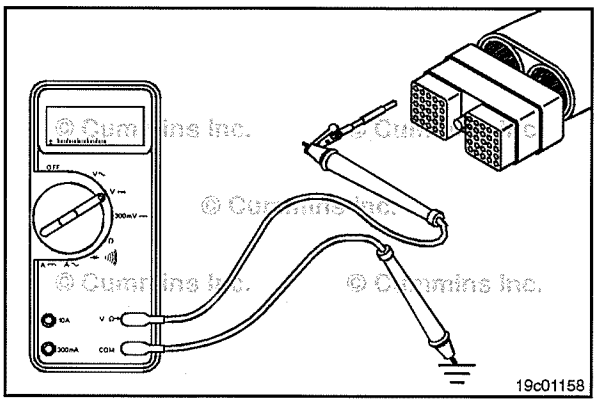


Disconnect the OEM harness connector from the ECM connector. Disconnect the intake air heater control relay from the OEM harness. Set the multimeter to measure resistance.

Measure the resistance from the intake air heater control relay signal pin in the OEM harness connector to all other pins in the connector.

The multimeter **must** show a measurement of 100k ohms or more (open circuit).

If the measured value is less than 100k ohms, there is a short circuit between the signal wire and any other pin that measured a closed circuit. Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.



Check for Short Circuit to External Voltage Source

Disconnect the OEM harness connector from the ECM connector. Disconnect the intake air heater control relay from the OEM harness.

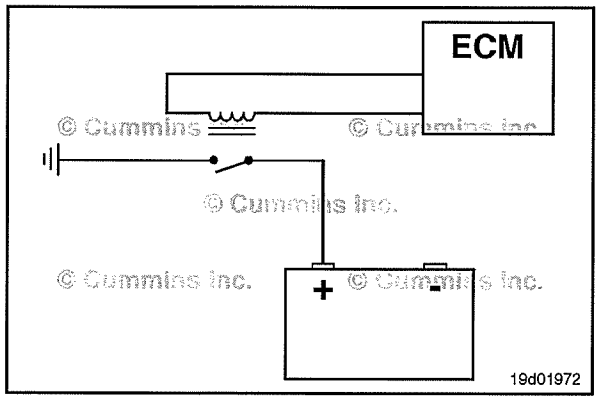
Set the multimeter to measure VDC. Turn the keyswitch to the ON position.

Insert the test lead connected to the positive (+) multimeter probe into the intake air heater control relay signal pin of the OEM harness connector. Touch the negative (-) multimeter probe to engine block ground and measure the voltage.

If voltage is present, there is a short circuit from the signal wire to an external voltage source. Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.

Repeat the short to external voltage source check for the return wire. Measure the voltage from the intake air heater control relay return pin of the OEM harness connector to engine block ground.

If voltage is present, there is a short circuit from the return wire to an external voltage source. Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.



Starter Lockout/Switched Outputs Relay Circuit (019-419)

General Information

The ECM can control a starter lockout relay or an OEM relay.

Refer to the vehicle manufacturer's publications for more information on troubleshooting and repair of the starter lockout relay or OEM relay.

Resistance Check

⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

Disconnect the OEM harness connector from the ECM connector. Disconnect the OEM wiring at the starter lockout or OEM relay. Set the multimeter to measure resistance.

Insert a test lead into the starter lockout relay signal/switched output relay number 1 signal pin of the OEM harness connector and connect the alligator clip to a multimeter probe. Touch the other test lead to the starter lockout relay signal/switched output relay number 1 signal terminal at the component. Measure the resistance.

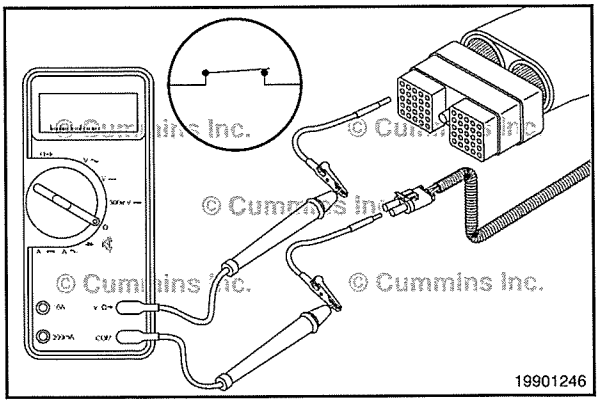
The multimeter **must** show 10 ohms or less (closed circuit).

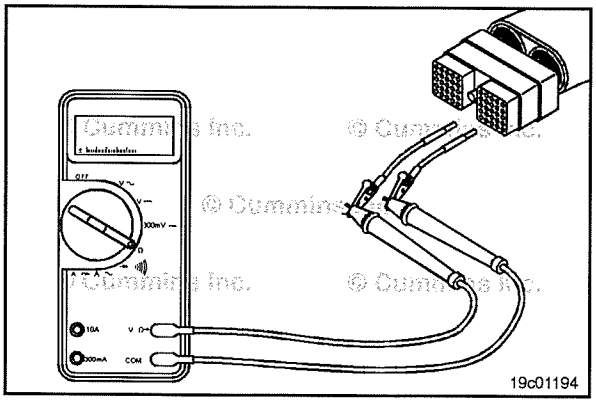
Check the return pin. Insert a test lead into the starter lockout relay signal/switched output relay number 1 return pin of the OEM harness connector and connect the alligator clip to a multimeter probe. Touch the other test lead to the starter lockout relay signal/switched output relay number 1 return terminal at the component. Measure the resistance.

The multimeter **must** show 10 ohms or less (closed circuit).

If the circuit is closed, it **must** still be checked for a short circuit from pin to pin.

If the circuit is **not** closed, there is a connection problem or an open circuit in the harness.





Check for Short Circuit from Pin to Pin

Check for a short circuit between the starter lockout relay signal/switched output relay number 1 signal pin and all other pins in the OEM harness connector.

Disconnect the OEM harness connector from the ECM connector.

Set the multimeter to measure resistance.

Disconnect the starter lockout or OEM relay from the OEM harness.

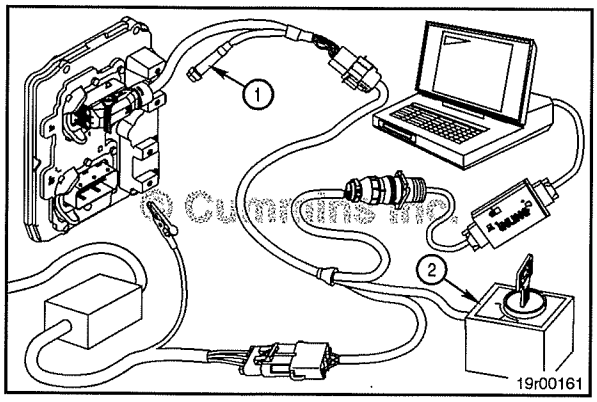
Insert a test lead into the signal pin of the OEM harness connector, and connect the alligator clip to a multimeter probe. Insert the second test lead to the first pin in the OEM harness connector, and connect the alligator clip to the other multimeter probe.

Measure the resistance from the signal pin to all other pins in the connector, one at a time.

The multimeter **must** show 100k ohms or more (open circuit) at all pins.

If any pin-to-pin check shows a closed circuit, there is a short circuit between the applicable pins that measured a closed circuit.

Repair or replace the OEM harness. Refer to the OEM troubleshooting and repair manual.



Engine Control Module ROM Boot (019-427)

General Information

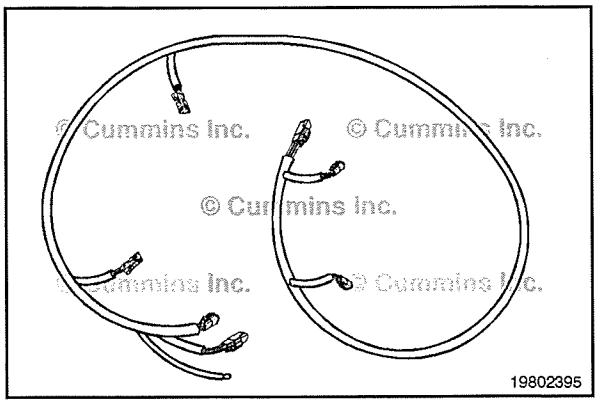
Engine Control Module (ECM) ROM Boot Procedure:

- Install the calibration cable with ROM boot switch.
- With the keyswitch (2) in the OFF position, press the ROM boot switch (1), located on the ECM-specific calibration adapter harness, and hold.
- Switch the keyswitch to the ON position while holding the ROM boot switch down, wait for five seconds.
- Release the ROM boot switch.
- Recalibrate the ECM. Refer to Procedure 019-032 in Section 19.
- Remove the ROM boot cable from the ECM.

For general tool information, including the correct installation configuration, see the ECM-specific calibration adapter cable with ROM boot switch in the ECM Bench Calibration Base Harness, Bulletin 3377791.

Engine Datalinks (019-428)

General Information



⚠CAUTION⚠
Proper leads and/or a Cummins® approved circuit testing tool must be used when working with electrical connectors to prevent pin expansion and damage to the connector.

The engine data link consists of circuitry located in the engine wiring harness. On older engines, the engine data link circuitry supports J1587/J1708 protocol. On newer engines, the engine data link circuitry supports J1939 protocol.

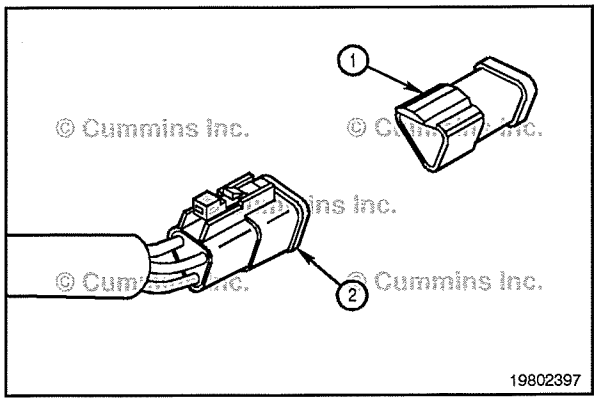
The purpose of the engine data link is to provide an access point for a service tool, such as INSITE™ electronic service tool, to communicate with the engine control module (ECM). A service tool can communicate with the ECM on the engine data link free from data link traffic from other electronic devices that can be present on the OEM data link.

SAE J1939 Backbone Harness Overview:

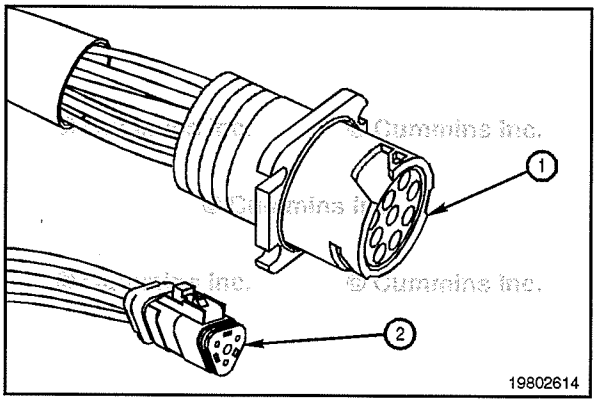
SAE J1939 has strict guidelines that **must** be followed for successful communication. Understanding some fundamentals about SAE J1939 will help make sure these guidelines are followed.

The main component of an SAE J1939 system is a backbone harness. The harness can be up to 40 m [131 ft] long. The backbone harness is terminated at each end with 120 ohm resistors.

A maximum of 30 different devices can be attached to the SAE J1939 backbone at once. Each device, such as the data link adapter, is connected to the backbone through a stub which can be up to 1 m [3.2 ft] in length. The stub connector is a 3-pin plug.



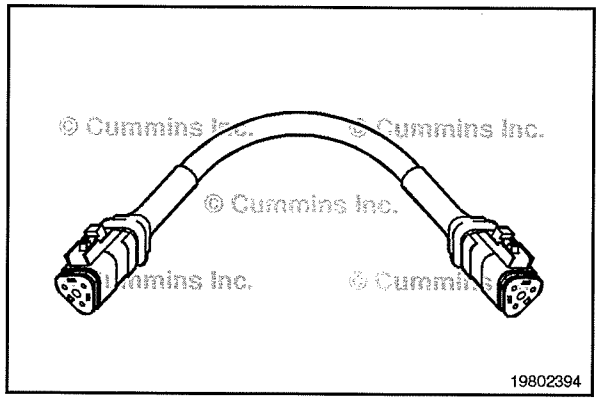
The terminating resistor caps (1) **must** be in place on the OEM backbone harness plugs (2) to maintain proper communication. Each resistor is 120 ohms and is located in a removable cap. This resistance is required when communicating with INSITE™ electronic service tool over the J1939 data link.



Some engine harnesses include a complete SAE J1939 backbone harness. If this is supplied, connection to INSITE™ electronic service tool is accomplished either by a 9-pin data link connector (1), Part Number 4918416, or a 3-pin receptacle (2), Part Number 3165141.

To check for the J1939 backbone, turn the keyswitch to the OFF position. Measure the resistance from the SAE J1939 data link positive (+) pin to the SAE J1939 data link negative (-) pin of the 3-pin Deutsch™ connector.

The multimeter will show 60 ohms when the engine harness has provided a backbone on the data link bus.



If the engine harness does **not** supply the J1939 backbone harness and the data link connector is a 3-pin receptacle, a mini-backbone harness will have to be added.

Engine Data Link Connectors

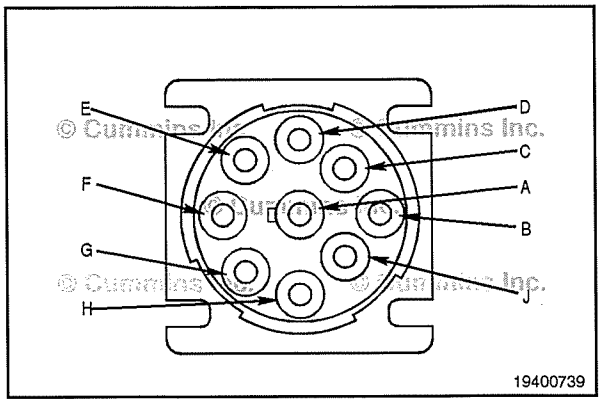
The engine data link connector available on the engine harness will depend upon the data link circuitry in the engine harness and the vintage of the engine. Engine data link connectors available on Cummins® engines are summarized in the table below.

Connector Type	Data Link Protocols Supported
2-pin Weather Pack™	J1587/J1708
3-pin Deutsch™	J1939
6-pin Deutsch™	J1587/J1708
9-pin Deutsch™	J1587/J1708, J1939

Each connector type is described in more detail in the following information.

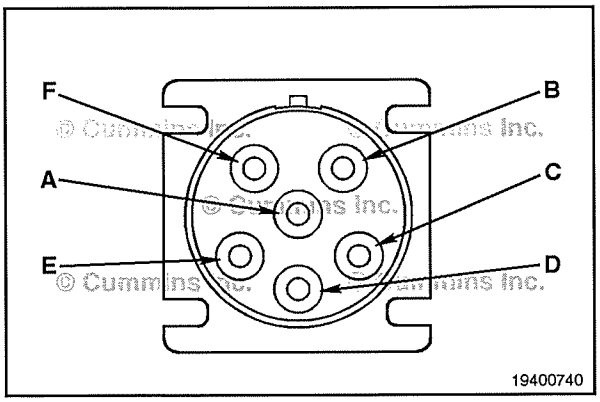
The 9-pin Deutsch™ connector, Part Number 3824018, connector can supply SAE J1587/SAE 1708 and SAE J1939 communications, and battery voltage. The following are pin-outs for the 9-pin connector:

Pin	Signal
A	Ground
B	Unswitched Battery
C	J1939 data link (+)
D	J1939 data link (-)
E	J1939 data link (shield) (**not** applicable for Marine)
F	J1708 data link (+)
G	J1708 data link (-)
H	Open
J	Open

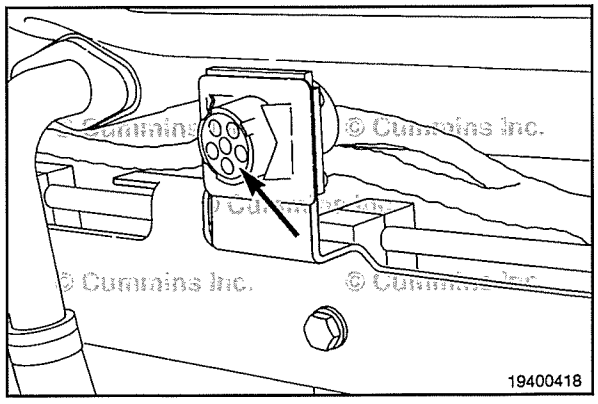


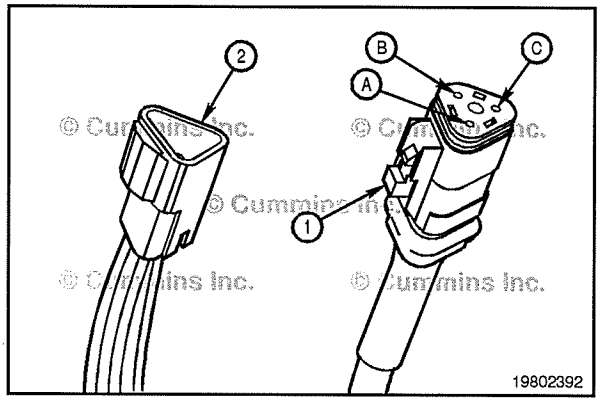
The 6-pin Deutsch™ connector, Part Number 3824805, is found on some engines. This connector supplies SAE J1587/J1708, as well as the battery voltage. The following are pin-outs for the 6-pin connector:

Pin	Signal
A	J1708 data link (+)
B	J1708 data link (-)
C	Unswitched battery (+)
D	Open
E	Ground
F	Open



NOTE: For CELECT Plus™ engines, do **not** use the in-cab 6-pin data link connector to calibrate the ECM. Use the data link connector found on the engine.





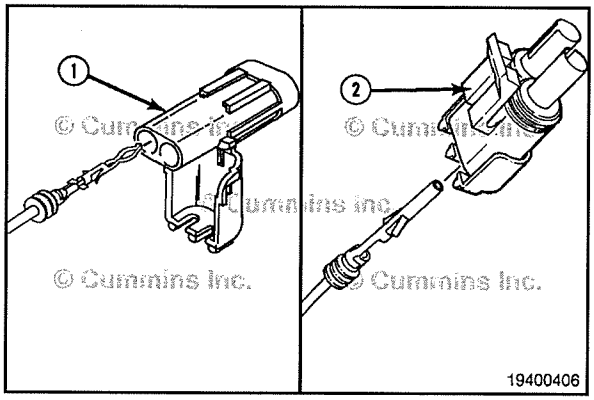
The 3-pin SAE J1939 Deutsch™ connectors are also found on some Cummins® engine harnesses. Two possible types of 3-pin connectors can be present: A 3-pin plug (1), Part Number 3824288; and a 3-pin receptacle (2), Part Number 3824290. The following are the pin-outs for the 3-pin connector:

Pin	Signal
A	J1939 data link (+)
B	J1939 data link (-)
C	J1939 data link (shield)

The 3-pin connector **only** supports the SAE J1939 data link.

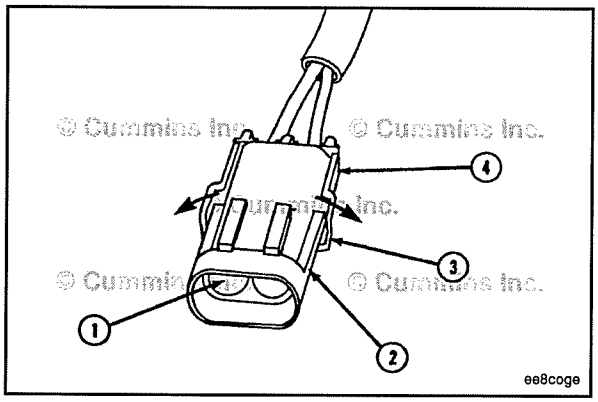
To meet the SAE J1939 standard, the 3-pin receptacle connector **must** be within 0.66 m [2.16 ft] of the ECM. Use of the J1939 mini-backbone harness, Part Number 3163096, may be required for proper termination resistance. The mini-backbone harness is required when **no** backbone is provided on the data link. Gender changer cable, Part Number 3163597, may be required to connect the mini-backbone harness to the engine harness or service tool cable.

NOTE: If there is 60 ohm resistance measured between pins A and B of the 3-pin connector, a backbone is on the data link.



The 2-pin connector is on many older engines, and **only** supplies SAE J1587/J1708 support (no battery voltage supply). The following are the pin-outs for the 2-pin connector:

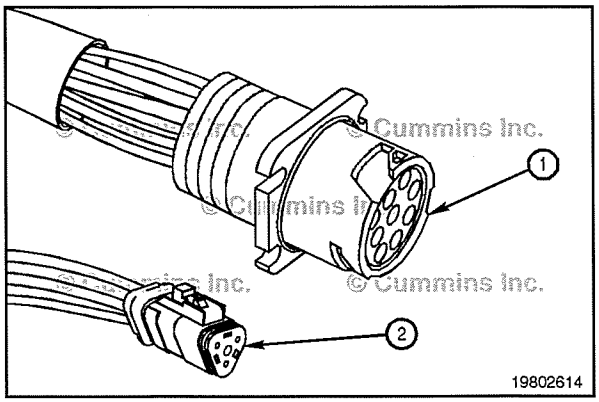
Pin	Signal
A	J1587/J1708 data link (+)
B	J1587/1708 data link (-)



Some engines have a 2-pin service tool power supply Weather Pack™ receptacle located in the engine harness. It can be used to power up any service tool device.

Pin	Signal
A	Unswitched battery (+)
B	Ground (-)

Resistance Check

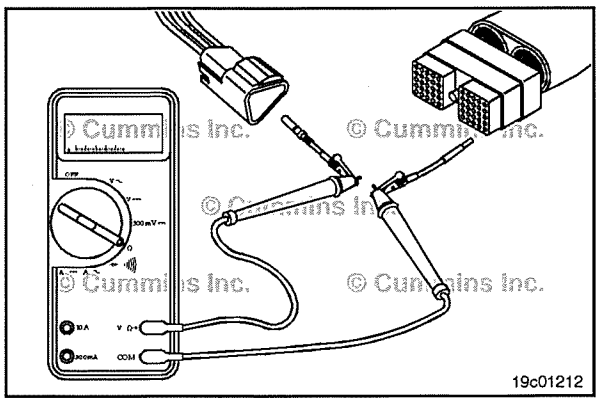


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠
For the J1939 engine data link, use test lead, Part Number 3822758, on the ECM connector to avoid damage to the connector pins. Use test lead, Part Number 3824811, for the 9-pin Deutsch™ connector. Use test lead, Part Number 3823993 for the 3-pin Deutsch™ connector pin receptacle or test lead, Part Number 3823994 for the 3-pin Deutsch™ connector.

⚠CAUTION⚠
For the J1587/J1708 engine data link, use test lead, Part Number 3622758, on the ECM connector to reduce the possibility of damage to the connector pins. Use test lead 3824800 for the 6-pin Deutsch™ connector. Use test lead 3823995 for the 2-pin Packard™ connector.

Determine the type of engine data link available on the engine, either J1939 or J1587/J1708. Follow the instructions provided to measure the resistance for the type of engine data link identified.



J1939 Engine Data Link

- Disconnect the batteries.
- Disconnect the engine harness connector from the ECM. Turn the keyswitch to the OFF position.

Insert a test led into the SAE J1939 data link positive (+) pin of the engine harness ECM connector, and connect it to the multimeter probe. Insert the other test lead into the SAE J1939 data link positive (+) pin of the 3-pin or 9-pin Deutsch™ connector, and connect it to the multimeter.

Measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less).

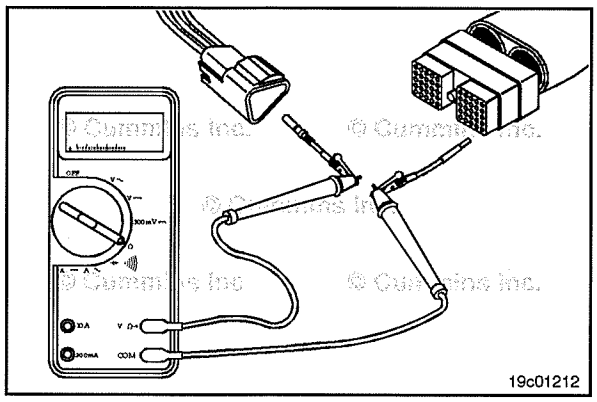
If the circuit is **not** closed, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

Insert the multimeter lead into the SAE J1939 data link negative (-) of the engine harness ECM connector. Touch the other lead to the SAE J1939 data link negative (-) pin of the 3-pin or 9-pin Deutsch™ connector. Measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, repair or replace the engine harness.

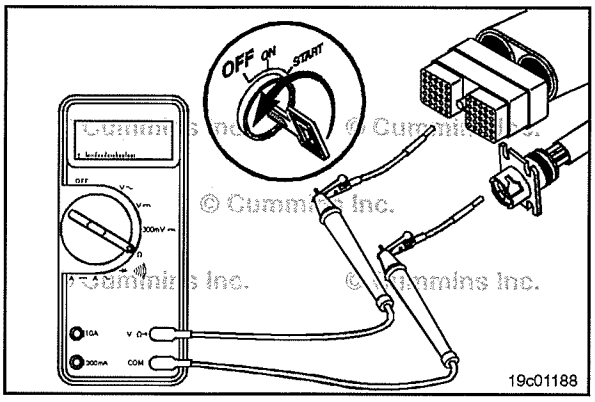
See the Troubleshooting and Repair manual for additional information.



If the values are correct, the circuit **must** still be checked for a short circuit to ground and a short circuit from pin-to-pin.

Remove the lead from the SAE J1939 data link negative (-) pin of the engine harness ECM connector and insert it into the SAE J1939 data link (shield) pin. Touch the negative multimeter lead to the SAE J1939 data link (shield) pin of the 3-pin or 9-pin Deutsch™ connector. Measure the resistance.

The multimeter **must** show a closed circuit (10 ohms or less). If more than 10 ohms are measured in any of these steps, there could be an open circuit in the SAE J1939 data link (shield) pin, the SAE J1939 data link negative (-) pin, or the SAE J1939 data link positive (+) pin, or the polarity is **not** correct.



J1587/J1708 Engine Data Link

Turn the keyswitch to the OFF position. Disconnect the engine harness from the ECM.

Insert a test lead into the SAE J1587 data link positive (+) pin of the engine harness ECM connector and connect it to a multimeter probe. Insert the other test lead into the SAE J1587 data link positive (+) pin of the 2-pin or 6-pin connector and connect it to the other multimeter probe. Measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

Remove the test lead from the SAE J1587 data link positive (+) pin and insert it into the SAE J1587 data link negative (-) pin of the ECM connector. Remove the other test lead from the SAE J1587 data link positive (+) pin and insert it into the SAE J1587 data link negative (-) pin of the 2-pin or 6-pin connector. Measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

Remove the test lead from the SAE J1587 data link negative (-) pin and insert it into the battery negative (-) pin of the 6-pin Deutsch™ connector. Remove the test lead from the SAE J1587 data link negative (-) pin of the engine connector and disconnect it from the multimeter probe. Touch the multimeter probe to the engine block ground. Measure the resistance. The multimeter should show a closed circuit (10 ohms or less).

If the circuit is not closed, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠
Use test lead, Part Number 3824811, for the 6-pin Deutsch™ connector.

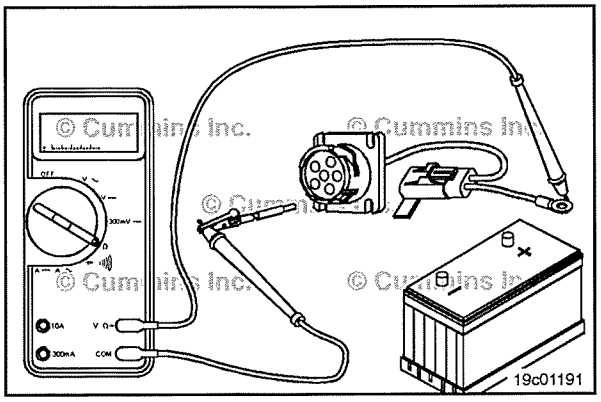
Disconnect the batteries.

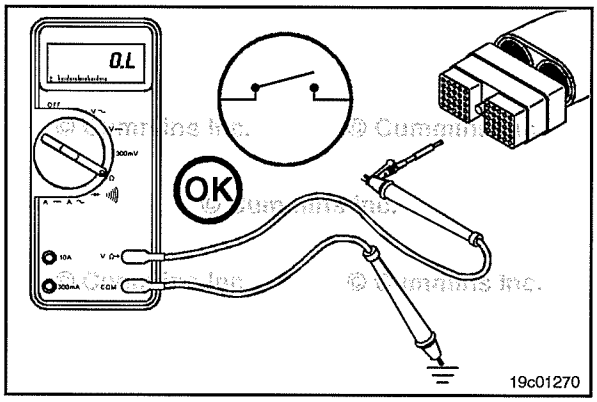
Measure the resistance from the positive (+) battery terminal to battery positive (+) of the 6-pin Deutsch™ connector. The multimeter **must** show a closed circuit (10 ohms or less).

If the circuit is **not** closed, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

If the values are correct, the circuit **must** still be checked for a short circuit to ground and a short circuit from pin-to-pin.





Check for Short Circuit to Ground

⚠CAUTION⚠
For the J1939 engine data link, use test lead, Part Number 3822758, on the ECM connector to avoid damage to the connector pins.

⚠CAUTION⚠
For the J1587/J1708 engine data link, use test lead, Part Number 3822758, on the ECM connector to avoid damage to the connector pins.

Determine the type of engine data link available on the engine, either J1939 or J1587/J1708. Follow the instructions provided for short circuit to ground check for the type of engine data link identified.

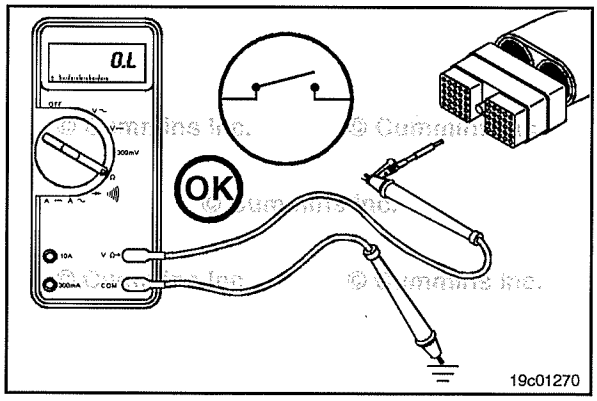
J1939 Engine Data Link

Disconnect the engine harness connector from the ECM. Insert a test lead into SAE J1939 data link positive (+) pin of the engine harness ECM connector and connect it to a multimeter probe. Touch the other multimeter probe to engine block ground.

Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.



Remove the test lead from the SAE J1939 data link positive (+) pin and insert it into the SAE J1939 data link negative (-) pin of the ECM connector. Measure the resistance from the SAE J1939 data link negative (-) pin of the engine harness ECM connector to the engine block ground. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

If less than 100k ohms is measured in any of the previous steps, there is a short to circuit to ground. Repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

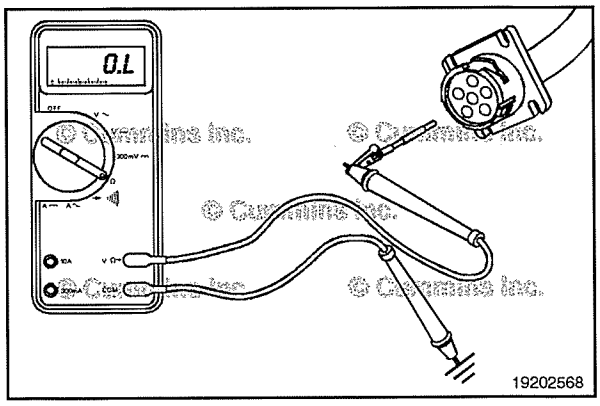
J1587/J1708 Engine Data Link

Disconnect the engine harness connector from the ECM.

Insert a test lead into the SAE J1587 data link positive (+) pin of the engine harness ECM connector and connect it to a multimeter probe. Touch the other multimeter probe to the engine block ground. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.



Remove the test lead from the SAE J1587 data link positive (+) pin and insert it into the SAE J1587 data link negative (-) pin of the engine harness ECM connector. Touch the other multimeter probe to the engine block ground. Measure the resistance from the SAE J1587 data link negative (-) pin of the engine harness ECM connector to the engine block ground. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

Check for Short Circuit from Pin to Pin

△CAUTION△
For the J1939 engine data link, use test lead, Part Number 3822758, on the ECM connector to avoid damage to the connector pins.

△CAUTION△
For the J1587/J1708 engine data link, use test lead, Part Number 3822758, on the ECM connector to avoid damage to the connector pins.

J1939 Engine Data Link

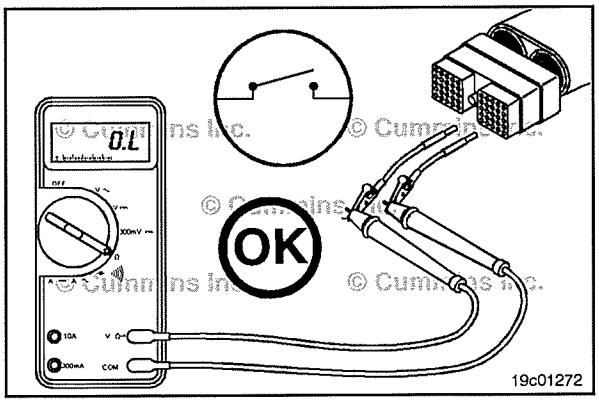
Disconnect the engine harness connector from the ECM.

Insert a test lead into the SAE J1939 data link positive (+) pin of the engine harness ECM connector and connect it to the multimeter probe. Insert the other test lead into another pin in the connector of the engine harness ECM connector and connect it to the other multimeter probe.

Measure the resistance from the SAE J1939 data link positive (+) pin to the first pin in the connector. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.



Remove the lead from the first pin in the connector and measure the resistance from the SAE J1939 data link positive (+) pin of the engine harness ECM connector to all other pins in the connector, one at a time. The multimeter **must** show an open circuit (100k ohms or more) at all pins.

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

Remove the test lead from the J1939 data link positive (+) pin and insert it into the J1939 data link (shield) pin of the engine harness ECM connector. Insert the other test lead into another pin in the connector. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

Measure the resistance from the SAE J1939 data link (shield) pin to all other pins in the connector, one at a time. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

Remove the test lead from the SAE J1939 data link (shield) pin and insert it into the SAE J1939 data link negative (-) pin of the engine harness ECM connector. Insert the other test lead into another pin in the connector. Measure the resistance.

The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

Measure the resistance from the SAE J1939 data link negative (-) pin of the engine harness connector to all other pins in the connector, one at a time. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

J1587/J1708 Engine Data Link

Disconnect the engine harness connector from the ECM.

Insert a test lead into the SAE J1587 data link positive (+) pin of the engine harness ECM connector and connect it to the multimeter probe. Insert the other test lead into another multimeter probe. Measure the resistance. The multimeter **must** show an open circuit (100k ohms or more).

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.

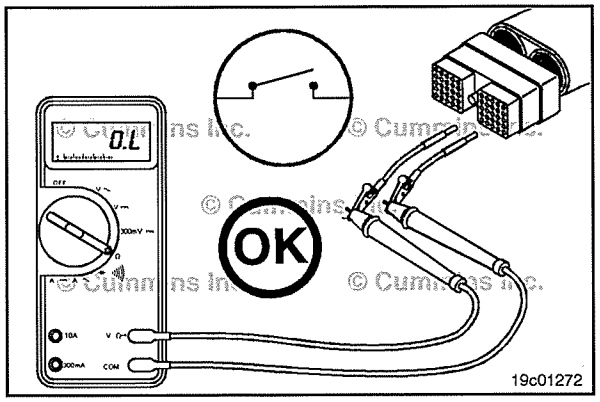
Remove the lead from the first pin in the connector and test all other pins in the connector. Measure the resistance from the SAE J1587 data link positive (+) pin of the engine harness ECM connector to all other pins in the connector, one at a time. The multimeter **must** show an open circuit (100k ohms or more).

Remove the test lead from the SAE J1587 data link positive (+) pin of the engine harness ECM connector and insert it into the SAE J1587 data link negative (-) pin.

Measure the resistance from the SAE J1587 data link negative (-) pin to all other pins in the connector. The multimeter **must** show an open circuit (100k ohms or more) at all pins.

If the circuit is **not** open, repair or replace the engine harness.

See the Troubleshooting and Repair manual for additional information.



Crankcase Pressure Sensor (019-445)

General Information

The crankcase pressure sensor is used to monitor the pressure in the crankcase.

The crankcase pressure sensor is located near the crankcase ventilation filter. Use the following procedure for a detailed component location view. Refer to Procedure 100-002 in Section E.

Depending on the breather system used, the crankcase pressure sensor will be located:

1 On top of the rocker lever cover

2 At the rear of the engine, on the external crankcase ventilation filter housing that mounts to the flywheel housing.

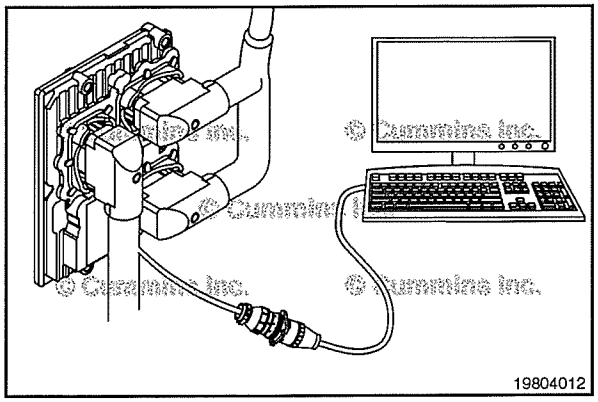
Initial Check

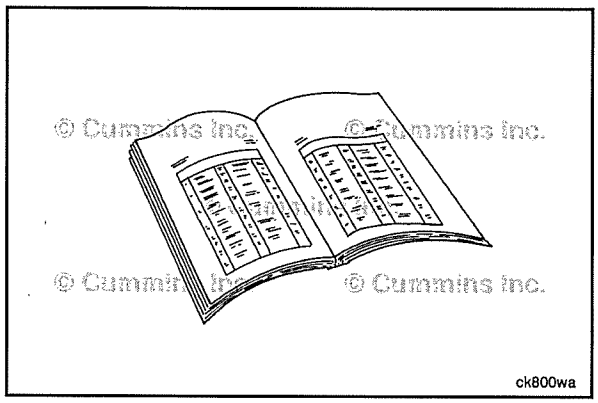
Use an electronic service tool to monitor the value of the crankcase pressure sensor with the key in the ON position and the engine off.

The crankcase pressure sensor value should meet the following specification.

Crankcase Pressure		
kPa		in Hg
0 ±0.63	NOM	0 ± 0.18

If the crankcase pressure value is out of specification, replace the crankcase pressure sensor.



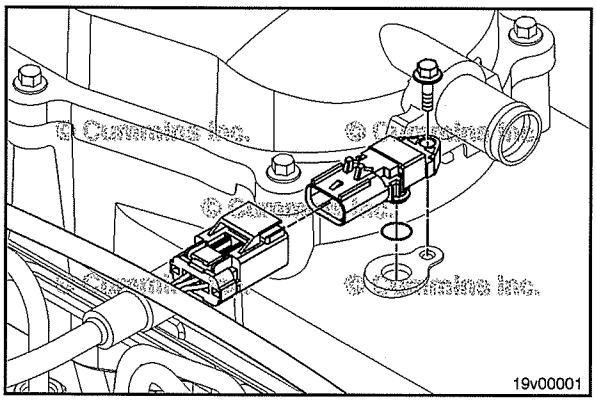


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean the area around the crankcase pressure sensor.

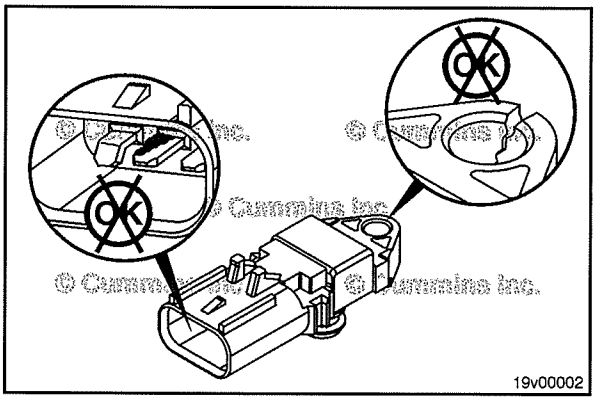


Remove

Disconnect the pressure sensor connector from the engine harness.

Remove the mounting capscrew.

Remove the sensor from the engine by pulling straight up on the sensor. Be careful **not** to damage the o-ring seal when removing the sensor.

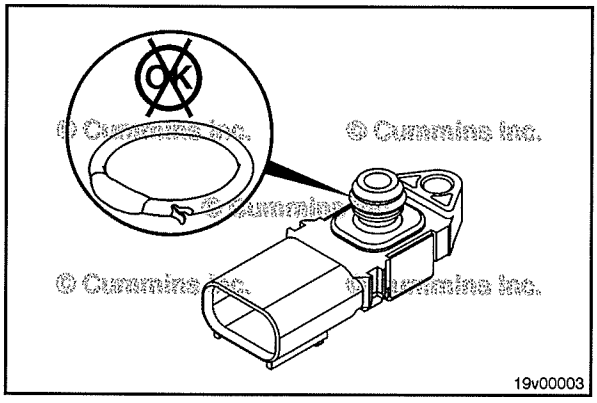


Clean and Inspect for Reuse

Inspect the engine harness connector and the crankcase pressure sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins
- Chipped, cracked, extruded, or damaged sensor
- Connector base between the sensor body and the connector shell.

Repair or replace parts as necessary.



Inspect the crankcase pressure sensor for the following:

- Swollen o-ring
- Nicks or cuts in or on the o-ring.

Install

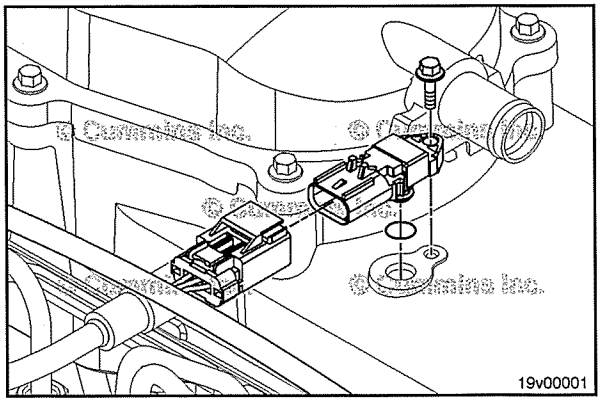
Lubricate the o-ring with clean engine oil before installation.

Install the crankcase pressure sensor by pressing firmly on the top of the sensor until the o-ring is fully seated.

Install and tighten the mounting capscrew.

Torque Value: 7 N•m [62 in-lb]

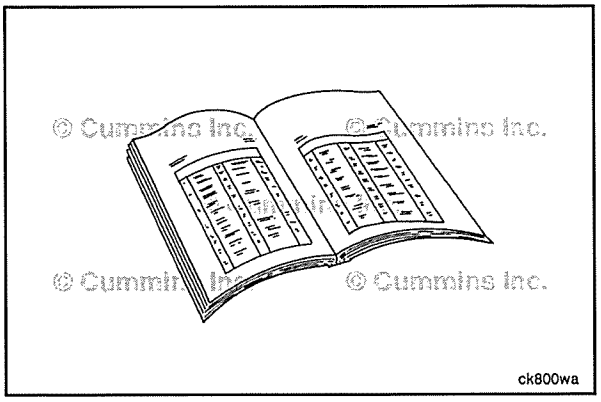
Connect the engine harness to the crankcase pressure sensor.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Aftertreatment Exhaust Gas Temperature Sensor (019-449)

General Information

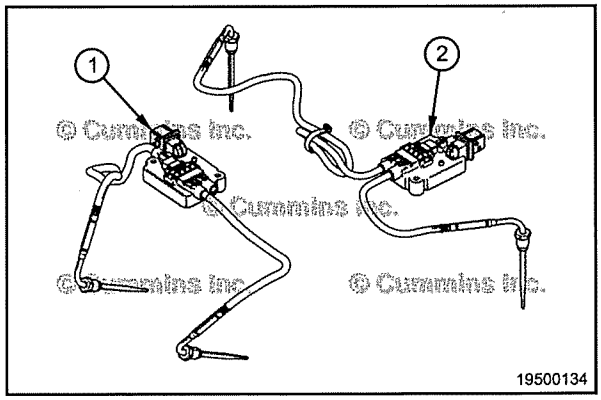
Due to the number of various aftertreatment configurations, this procedure has been written to be generic. **Not** all illustrations within this procedure will represent the application being serviced.

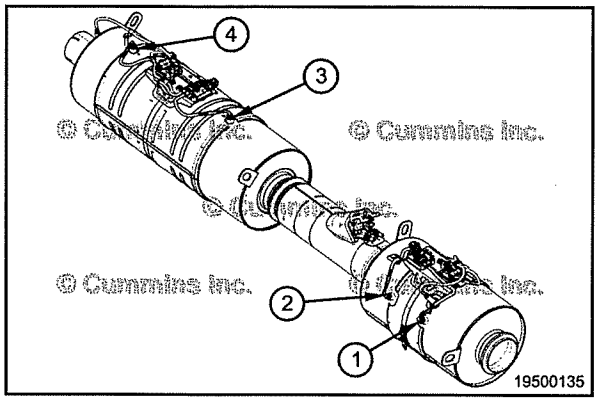
Due to the similarities between the aftertreatment diesel oxidation catalyst (DOC) temperature sensor assembly and the aftertreatment selective catalytic reduction (SCR) catalyst temperature sensor assembly, this procedure will cover both components.

The aftertreatment DOC temperature sensor assembly (1) is located on the aftertreatment DOC and consists of a module and two temperature sensor probes.

The aftertreatment SCR catalyst temperature sensor assembly (2) is located on the aftertreatment SCR catalyst and consists of a module and two temperature sensor probes.

The temperature sensor module and temperature sensor probes are **not** serviceable separately and must be replaced as an assembly.





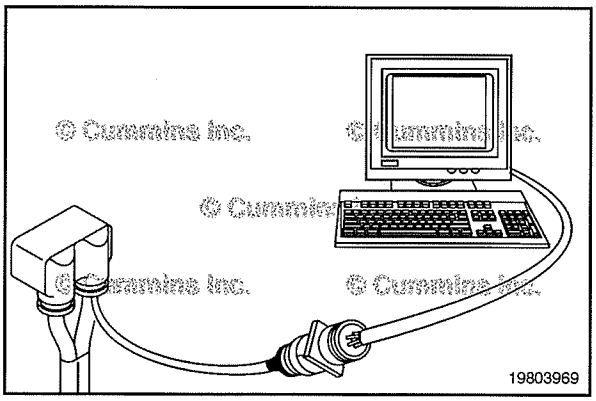
Aftertreatment exhaust gas temperature sensor assemblies are used to measure the temperature of exhaust gas in the aftertreatment system.

The aftertreatment DOC intake temperature sensor probe (1) is located closest to the turbocharger outlet.

The aftertreatment DOC outlet temperature sensor probe (2) is located in the outlet of the aftertreatment DOC.

The aftertreatment SCR catalyst intake temperature sensor probe (3) is located in the intake of the aftertreatment SCR catalyst.

The aftertreatment SCR catalyst outlet temperature sensor probe (4) is located in the outlet of the aftertreatment SCR catalyst.



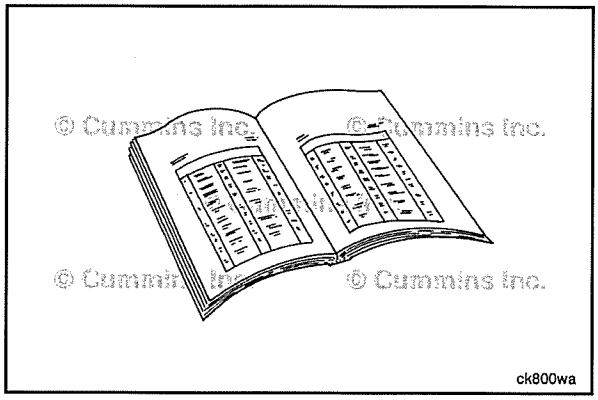
Initial Check

Use an electronic service tool to monitor the value of the aftertreatment exhaust gas temperature sensors with the key in the ON position and the engine OFF.

The engine **must** be off long enough for coolant temperature to be equal to the local ambient air temperature.

The aftertreatment exhaust gas temperature sensors should read within 10°C or 50°F of the present ambient air temperature on a cold engine.

Replace any aftertreatment exhaust gas temperature sensor assembly with values out of specification.



Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the sensor table heat shield, if equipped. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-032 in Section 11. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-032 in Section 11.

Remove

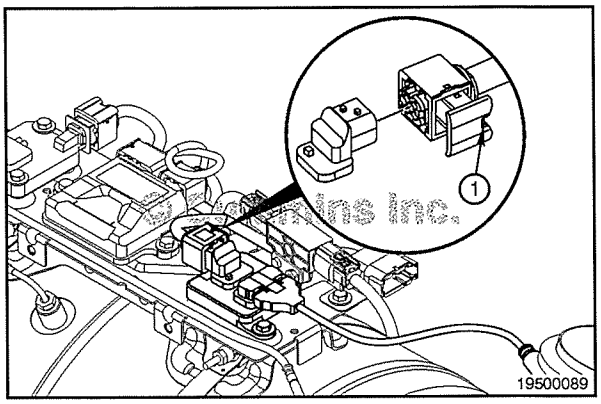
⚠WARNING⚠
During regeneration, exhaust gas temperature can reach 800°C [1500°F], and exhaust system surface temperature can exceed 700°C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

△CAUTION△
Excessive force applied to the locking slide will result in damage to the connector.

Disconnect the afterreatment exhaust gas temperature sensor from the aftertreatment interface harness.

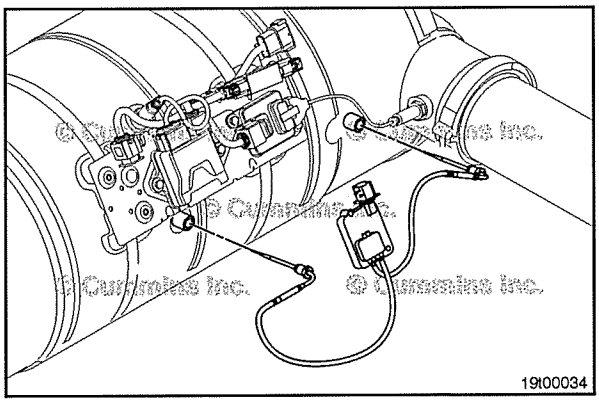
To assist in removing the connector, a small screwdriver can be inserted into the top notch (1) on the locking slide for leverage as the locking slide is pulled out by hand.

If the locking slide does **not** move freely, clean the connector using contact cleaner to free it of debris.



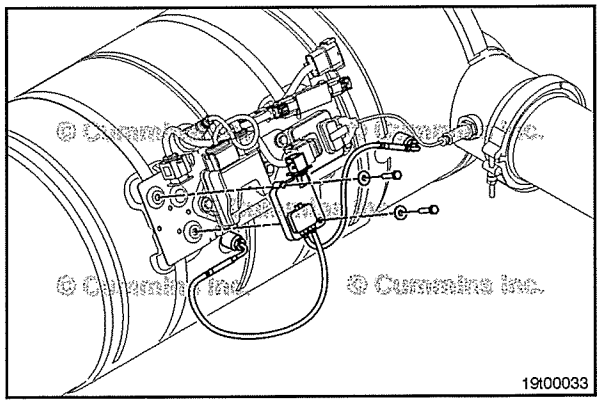
Loosen the retaining nut and remove the aftertreatment exhaust gas temperature sensor probe from the aftertreatment system.

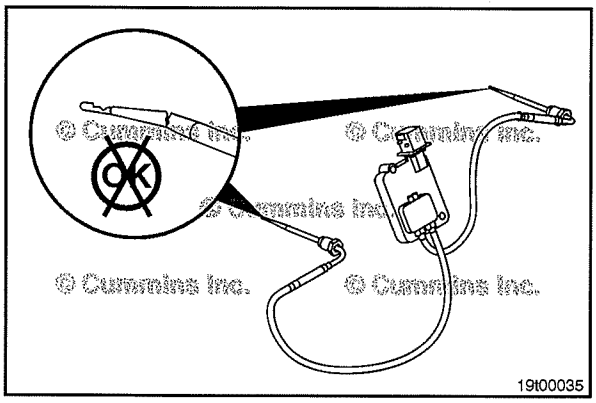
If removing more than one aftertreatment exhaust gas temperature sensor probe at a time, record the location where it was installed to make sure it is installed again in the same location.



Remove wire ties securing the exhaust gas temperature sensor probe wires to the sensor table.

Remove the bolts securing the exhaust gas temperature sensor assembly to the sensor table.





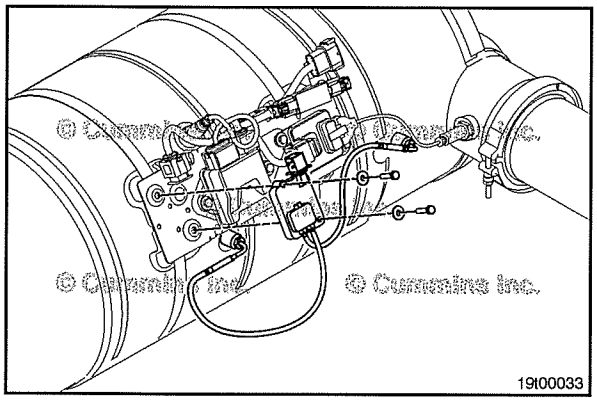
Clean and Inspect for Reuse

Inspect the exhaust gas temperature sensor assembly sensors for damaged or exposed wires, bent or broken pins, damaged connectors, or damaged threads.

Inspect the tip of the sensor for cracks, dents, kinks, and carbon buildup.

Inspect the exhaust gas temperature sensor module body for cracks or any other damage.

Replace the sensor assembly if damage is found.

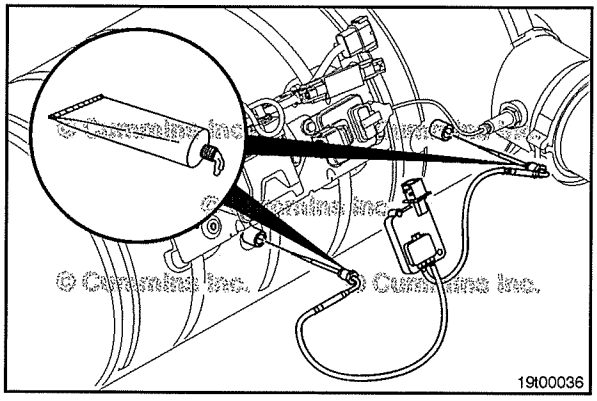


Install

Install the exhaust gas temperature sensor assembly to the sensor table.

Install and tighten the mounting bolts.

Torque Value: 14 N•m [124 in-lb]



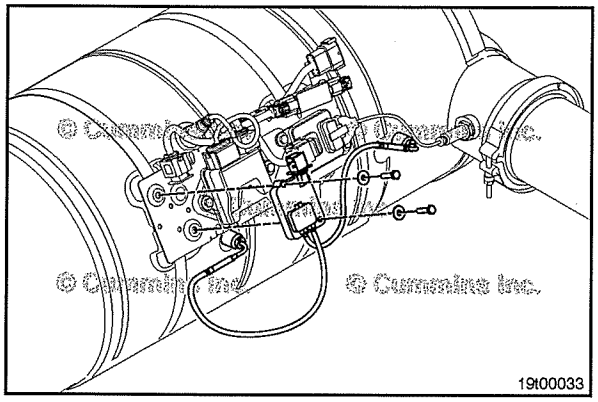
△CAUTION△
If the temperature sensor wire connectors are not connected to the proper locations after installation, damage can occur to the aftertreatment system.

Apply a coating of anti-seize, Cummins® Part Number 3824397 or equivalent, to the sensor probe threads prior to assembly.

Install the aftertreatment exhaust gas temperature sensor probe.

Tighten the nut that secures the sensor probe to the aftertreatment system.

Torque Value: 30 N•m [22 ft-lb]



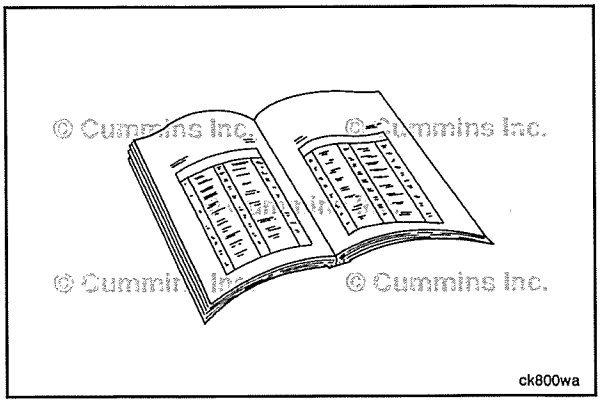
Install new wire ties securing the exhaust gas temperature sensor probe wires to the sensor table.

NOTE: Make sure the exhaust gas temperature sensor probe wires are properly secured so that they do **not** come into contact with hot components.

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Install the sensor table heat shield, if equipped. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 011-032 in Section 11. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 011-032 in Section 11.
- Operate the engine and check for fault codes.



Aftertreatment Outlet NOx Sensor (019-451)

General Information

⚠WARNING⚠
The aftertreatment system will stay hot to the touch for long periods of time after the engine has been shut down. To reduce the possibility of personal injury, avoid direct contact of hot components with your skin.

⚠WARNING⚠
The NOx sensor will stay hot to the touch for long periods of time after the engine has been switched off. The NOx sensor will also be hot if the engine keyswitch is ON.

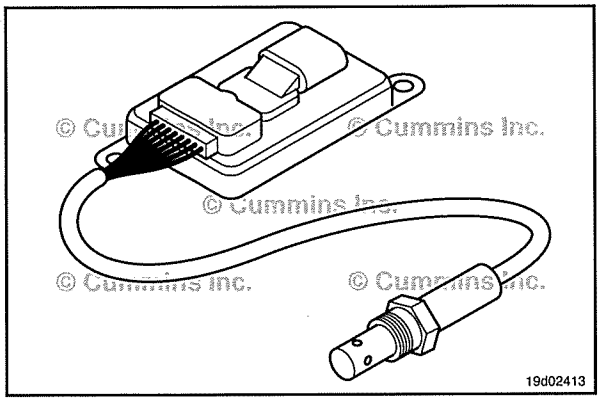
⚠WARNING⚠
Wear goggles and protective clothing to reduce the possibility of personal injury.

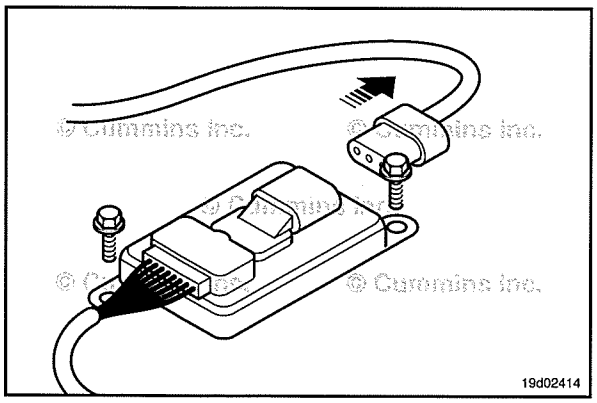
⚠CAUTION⚠
Do not underseal or coat/paint any part of the NOx sensor.

The aftertreatment outlet NOx sensor is located after the aftertreatment selective catalytic reduction (SCR) catalyst.

The aftertreatment outlet NOx sensor is made up of two parts: a small electronic module with a wired connection to the sensor body that is installed in the exhaust system. The two parts are permanently connected and **can not** be separated.

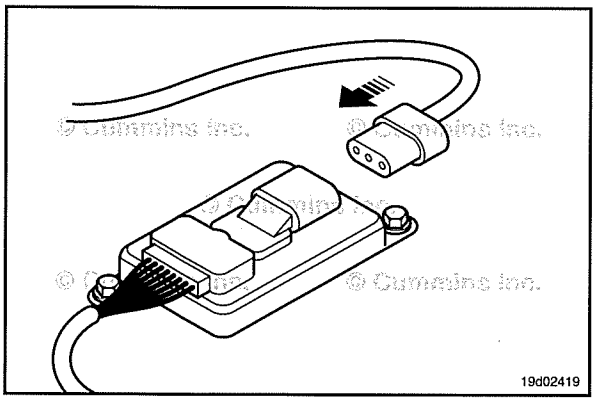
The aftertreatment outlet NOx sensor is available in both 12 volt and 24 volt configurations. The electronic module for the 24 volt version is larger than the module for the 12 volt version. The original equipment manufacturer (OEM) wiring harness connector on the aftertreatment outlet NOx sensor is **always** black in color.



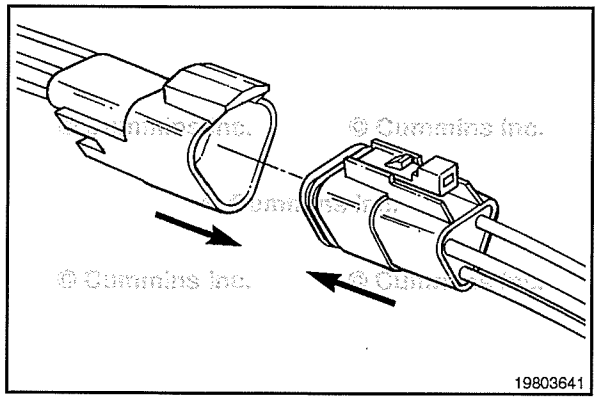


Test

Unplug the NOx sensor from the vehicle harness.



Connect the service tool, Part Number 2892467, to the NOx sensor module.



Connect the service tool data link (3-pin Deutsch™) to the engine SAE J1939 data link connection, located on the driver's side of the engine.

Use the vehicle 12-VDC to supply power to the service tool.

NOTE: Battery adapter cable, Part Number 3823955, can be used to provide power from the vehicle battery supply.

For Fault Codes 3681 and 3682, the following conditions **must** be met before checking the status of the active fault code:

Start the engine and allow the NOx sensor to reach operating temperature.

This diagnostic runs when the exhaust gas temperature of the aftertreatment intake or outlet NOx sensor is above 200° C [392° F] and the engine is running. Use INSITE™ electronic service tool to monitor exhaust gas temperature.

NOTE: For the aftertreatment outlet NOx sensor, there is also a 60 second delay after the exhaust gas temperature reaches 200° C [392° F].

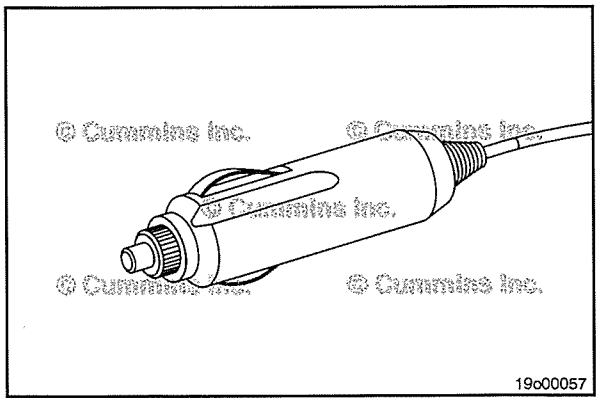
For Fault Codes 2771 and 3232, the following conditions **must** be met before checking the status of the active fault code.

This diagnostic runs continuously when the keyswitch is in the ON position

NOTE: If service tool is being used on 24 volt sensor, battery adapter cable, Part Number 3823955, will need to be used to provide power from the vehicle. battery supply.

Check inactive fault codes. After the above conditions have been met for the active fault code:

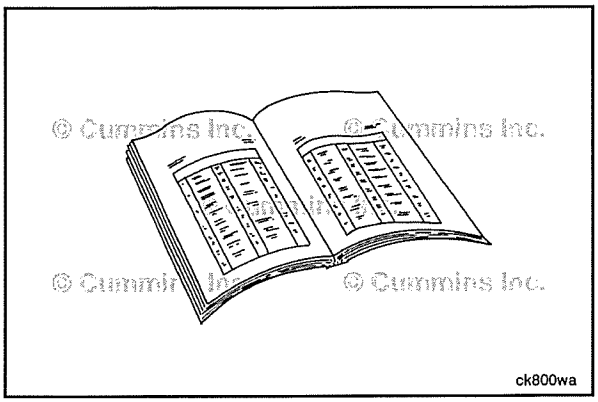
- Check to see if any of the active fault codes listed (2771, 3232, 3681, and 3682) now display as inactive.
- If the active fault codes now display as inactive, the sensor is operating normally and should **not** be replaced. The source of the fault code is located within the wiring that was isolated by the service tool.

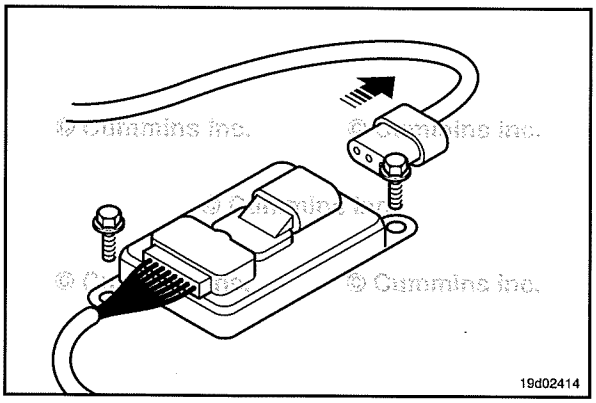


Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the OEM service manual.

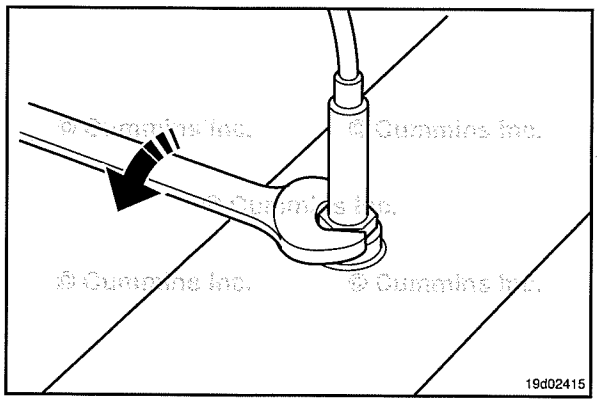




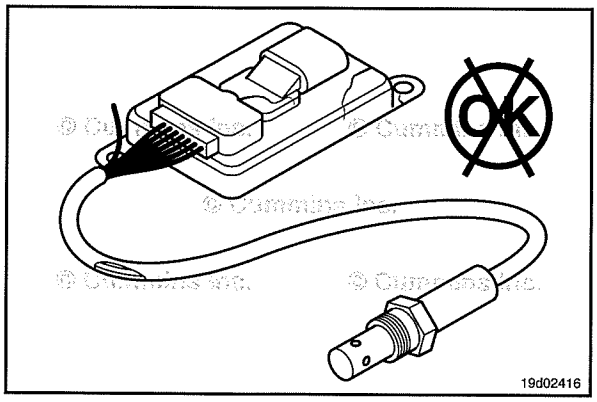
Remove

Disconnect the aftertreatment outlet NOx sensor from the OEM harness.

Remove the two retaining capscrews.



Loosen the retaining nut and remove the aftertreatment outlet NOx sensor from the exhaust.



Clean and Inspect for Reuse

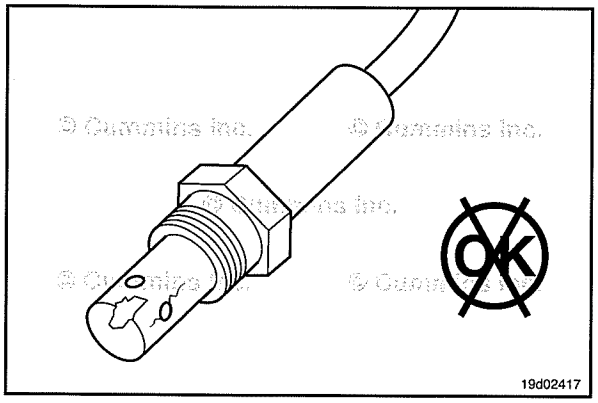
△CAUTION△
Do not clean the NOx sensor with any kind of fluid.

△CAUTION△
Do not immerse the NOx sensor in water or any kind of chemical wash.

△CAUTION△
Do not jet-wash or steam clean the NOx sensor.

Inspect the NOx sensor for damage to the wiring or to the body of the sensor.

Replace the aftertreatment outlet NOx sensor if any damage is found.



Inspect the tip of the NOx sensor for damage.

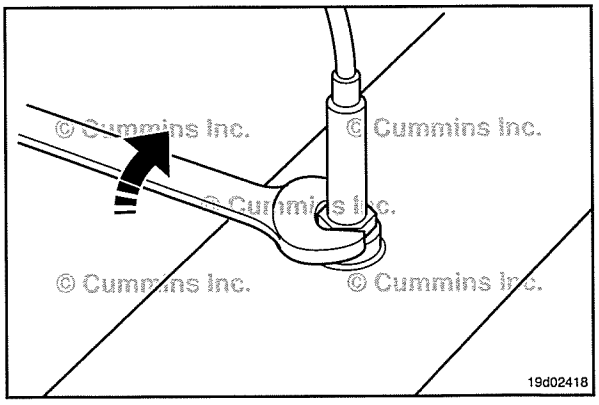
Replace the aftertreatment outlet NOx sensor if any damage is found.

Install

Apply a light coating of anti-seize compound, Part Number 3824879, to the threads of the NOx sensor.

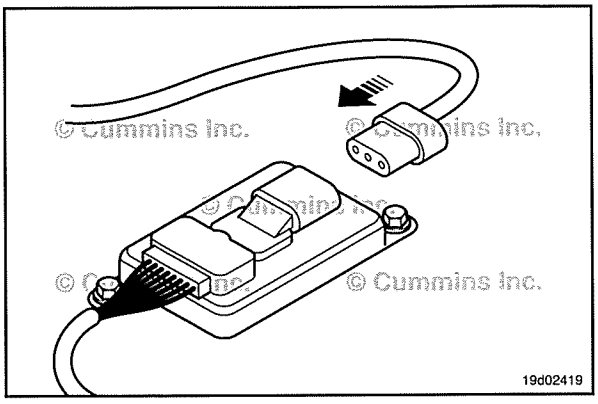
Install the NOx sensor to the exhaust system and tighten the retaining nut.

Torque Value: 50 N•m [37 ft-lb]



Connect the aftertreatment outlet NOx sensor to the OEM wiring harness.

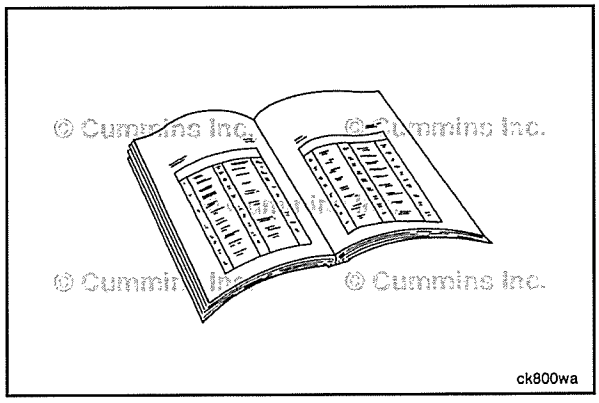
Install the retaining capscrews. Refer to the OEM service manual.

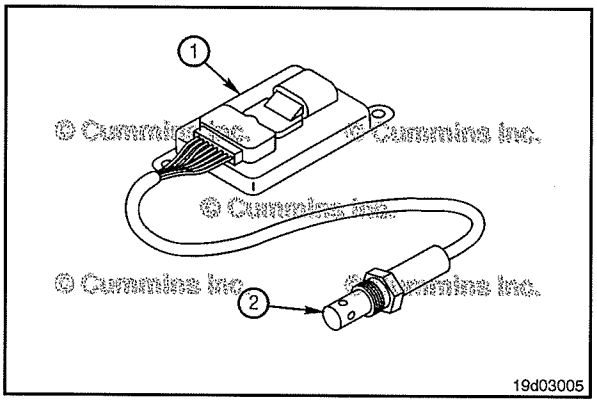


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.





Aftertreatment Intake NOx Sensor (019-463)

General Information

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair. Make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components.

⚠WARNING⚠
The NOx sensor will stay hot to touch for long periods of time after the engine has been switched off. The NOx sensor will also be hot if the engine keyswitch is on.

⚠WARNING⚠
Improper practices, carelessness, or ignoring the warnings can cause burns, cuts, mutilation, asphyxiation, or other personal injury or death.

△CAUTION△
Do not underseal or coat/paint any part of the NOx sensor. Failure to do so can result in sensor damage.

The aftertreatment intake nitrogen oxides (NOx) sensor is located after the turbocharger, and is mounted to the diesel oxidation catalyst (DOC) intake.

The aftertreatment intake NOx sensor is made up of two parts: (1) a small electronic module with a wired connection to the (2) sensor body that is installed in the exhaust system. These two parts are permanently connected and can **not** be separated.

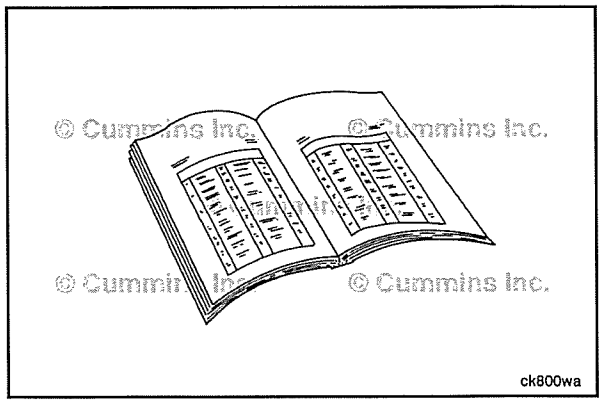
The aftertreatment intake NOx sensor is available in both 12-volt and 24-volt configurations. The electronic module for the 24-volt version is larger than the module on the 12-volt version.

Due to the number of different sensor mounting locations, this procedure has been written to be generic. The Remove and Install sections of this procedure are common regardless of the intake NOx sensor mounting configuration.

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the OEM service manual.



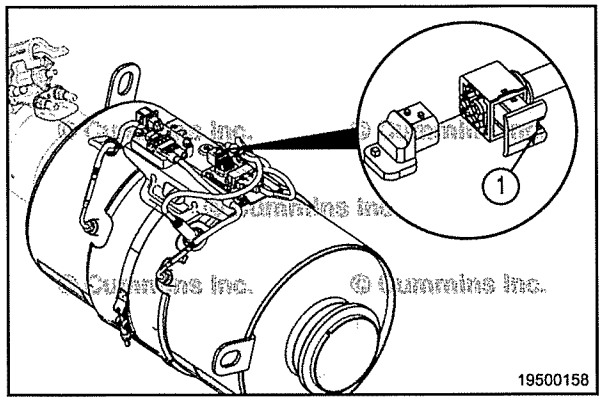
Remove

Disconnect the aftertreatment intake NOx sensor from the aftertreatment interface harness.

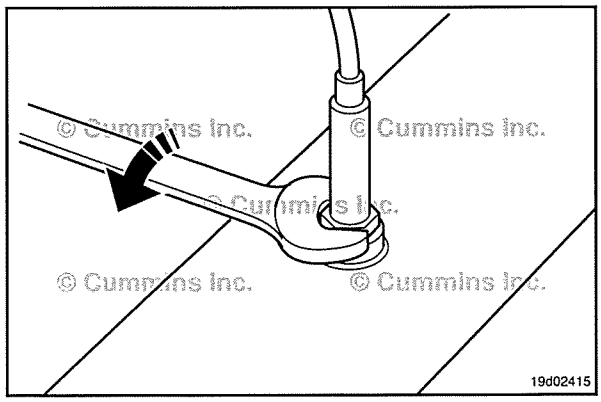
To assist in removing the connector, a small screwdriver can be inserted into the top notch (1) on the locking slide for leverage as the locking slide is pulled out by hand.

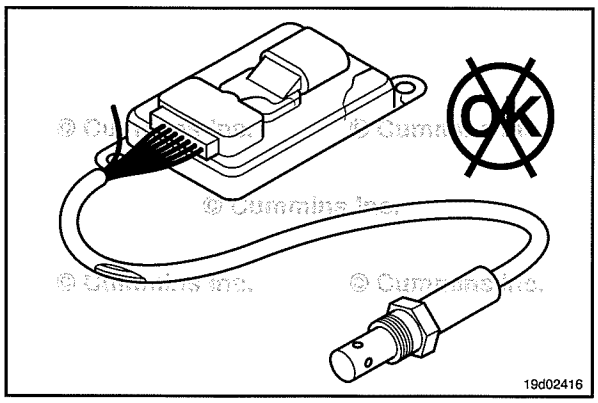
If the locking slide does **not** move freely, clean the connector using contact cleaner to free it of debris.

Remove the two retaining capscrews.



Loosen the retaining nut and remove the aftertreatment outlet NOx sensor from the exhaust system.





Clean and Inspect for Reuse

△CAUTION△
Do not clean the NOx sensor with any kind of fluid. Damage to the sensor can occur.

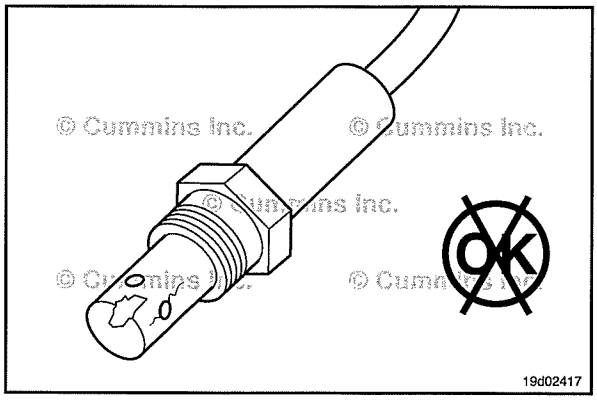
△CAUTION△
Do not immerse the NOx sensor in water or any kind of chemical wash. Damage to the sensor can occur.

△CAUTION△
Do not jet wash or steam clean the NOx sensor. Damage to the sensor can occur.

Inspect the NOx sensor for damage to the wiring or to the body of the sensor.

Inspect the electrical connector pins in the sensor for signs of corrosion.

Replace the aftertreatment intake NOx sensor if any damage is found.

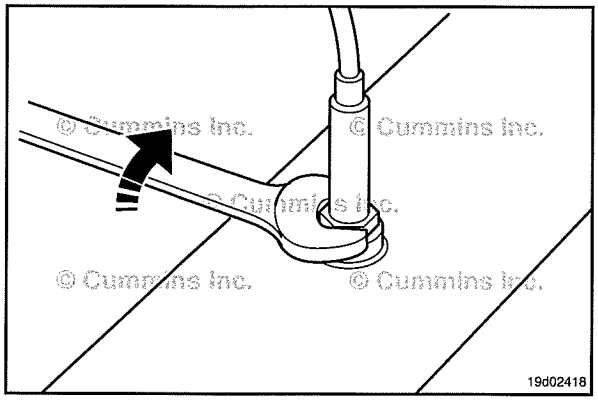


NOTE: It is **not** uncommon to have soot on the tip of the sensor. Do **not** try to clean the intake NOx sensor tip unless directed by fault codes or other troubleshooting symptoms.

Inspect the tip of the NOx sensor for damage.

Replace the NOx sensor if any damage is found.

Inspect the NOx sensor for oil spray on the tip of the sensor. Reference the following procedure for QSB6.7 CM2350 B105 engines. Refer to Procedure 010-033 in Section 10. Reference the following procedure for QSL9 CM2350 L102 engines. Refer to Procedure 010-033 in Section 10.



Install

Apply a light coating of anti-seize compound, Part Number 3824879, or equivalent, to the threads of the NOx sensor.

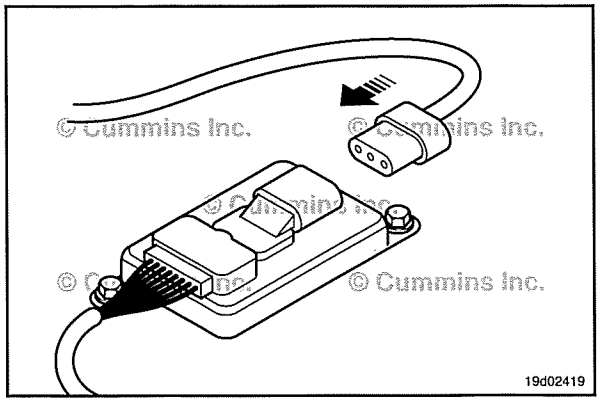
Install the NOx sensor to the exhaust system and tighten the retaining nut.

Torque Value: 50 N•m [37 ft-lb]

Connect the aftertreatment inlet NOx sensor to the aftertreatment interface harness.

Install and tighten the capscrews.

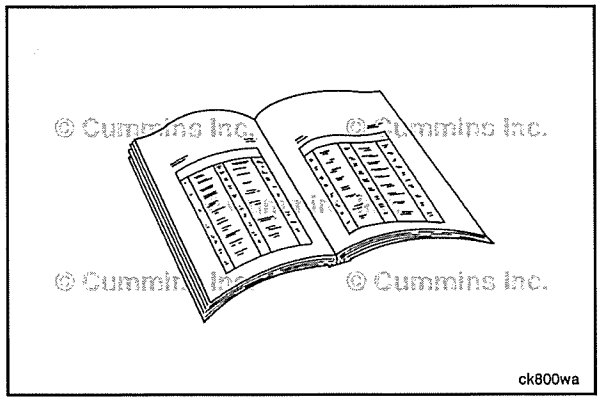
Torque Value: 14.4 N•m [127 in-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Turbocharger Compressor Intake Pressure/Temperature Sensor (019-466)

General Information

The turbocharger compressor intake pressure/temperature sensor is a combination sensor that monitors the temperature and pressure of the air entering the turbocharger.

The sensor is located in the original equipment manufacturer (OEM) intake piping, between the air cleaner and turbocharger.

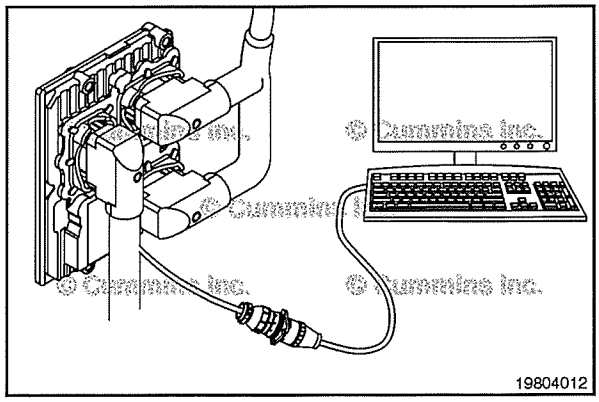
Initial Check

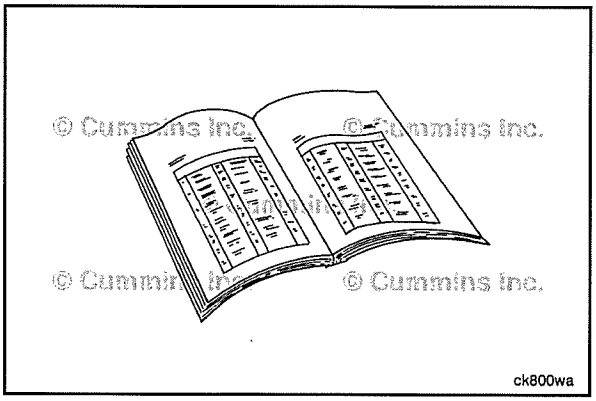
Use an electronic service tool to monitor the value of the turbocharger compressor intake pressure/temperature sensor with the key in the ON position and the engine off.

The value of the turbocharger compressor air intake temperature sensor should be checked when the engine is cold, and should read within 5.5°C or 10°F of the local ambient air temperature.

The value of the turbocharger compressor intake pressure should read within 1 kPa [0.3 in Hg] of the local barometric air pressure. Refer to Procedure 018-028 in Section V.

Replace the turbocharger compressor intake pressure/ temperature sensor if either value is out of specification.



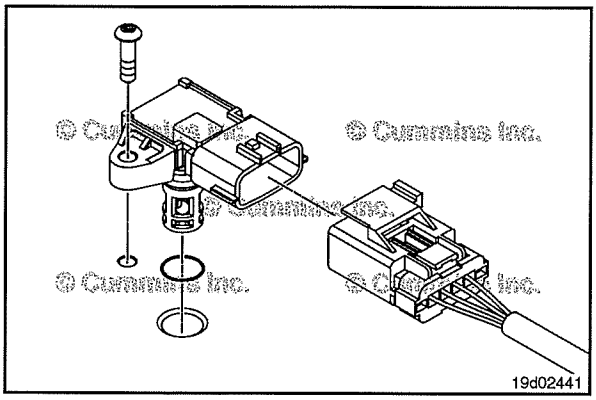


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the OEM service manual.
- Clean the area around the turbocharger compressor intake pressure/temperature sensor.



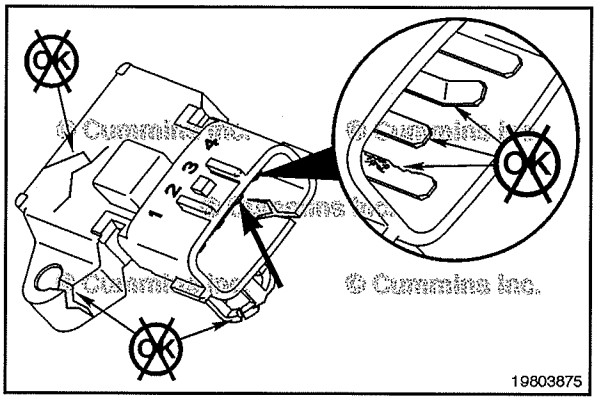
Remove

Disconnect the sensor connector from the engine harness.

Remove the mounting capscrew.

Remove the sensor from the engine by pulling straight up on the sensor.

Be careful **not** to damage the o-ring when removing the sensor.

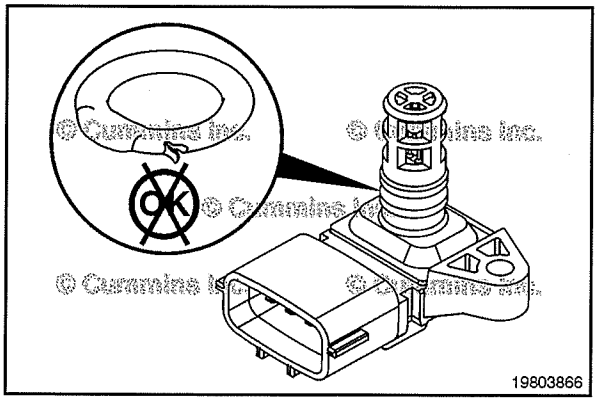


Clean and Inspect for Reuse

Inspect the engine harness connector and the turbocharger compressor intake pressure/temperature sensor for the following:

- Cracked or broken connector shell
- Missing or damaged connector seals
- Dirt, debris, or moisture in or on the connector pins
- Corroded, bent, broken, pushed back, or expanded pins.

Replace or repair the connector or turbocharger compressor intake pressure/temperature sensor as necessary.



Inspect the engine harness connector and the turbocharger compressor intake pressure/temperature sensor for the following:

Inspect the turbocharger compressor intake pressure/ temperature sensor o-ring the following:

- Swollen o-ring
- Nicks or cuts in or on the o-ring.

Replace the o-ring if any damage is found.

Install

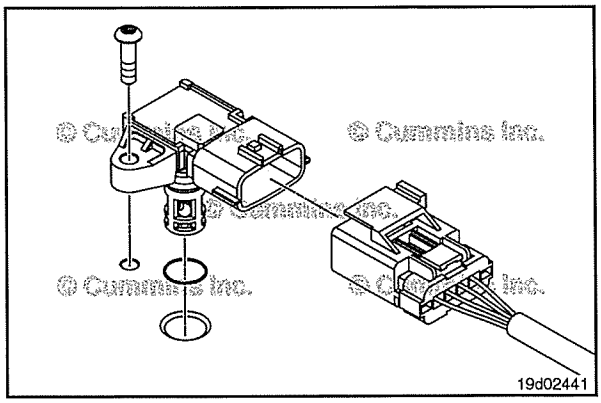
Lubricate the o-ring with clean engine oil before installation.

Install the turbocharger compressor intake pressure/temperature sensor by pressing firmly on the top of the sensor until the o-ring is fully seated.

Install and tighten the mounting capscrew.

Torque Value: 7 N•m [62 in-lb]

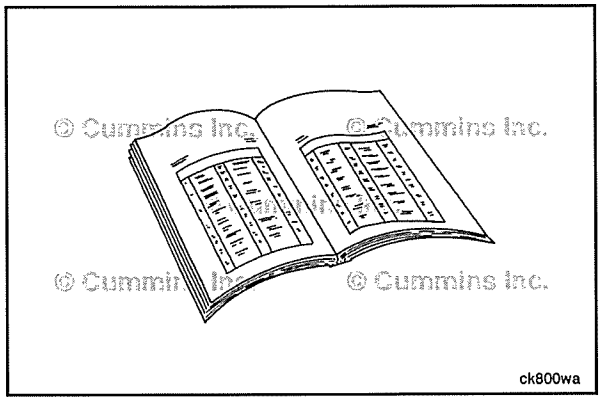
Connect the engine harness to the turbocharger compressor intake pressure/temperature sensor.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Aftertreatment Diesel Exhaust Fluid Quality Sensor (019-475)

General Information

The aftertreatment diesel exhaust fluid (DEF) quality sensor is part of the DEF tank head unit assembly.

The DEF quality sensor is original equipment manufacturer (OEM)-supplied. Refer to the OEM service manual for the location of the sensor. This procedure was written to be generic to multiple systems.

The DEF quality sensor is located in the DEF tank. Refer to the OEM service manual for the location of the DEF tank.

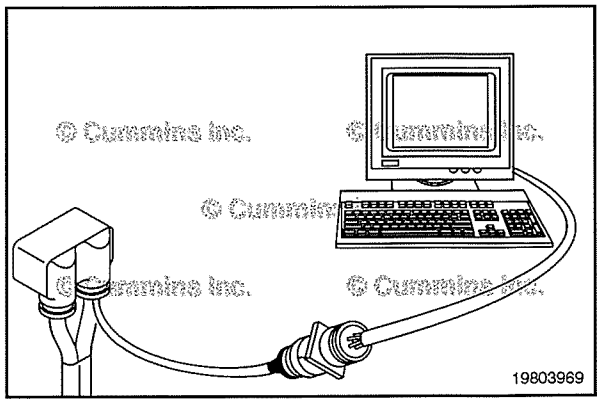
The aftertreatment DEF quality sensor monitors the fluid in the DEF tank and passes that information on to the engine control module (ECM).

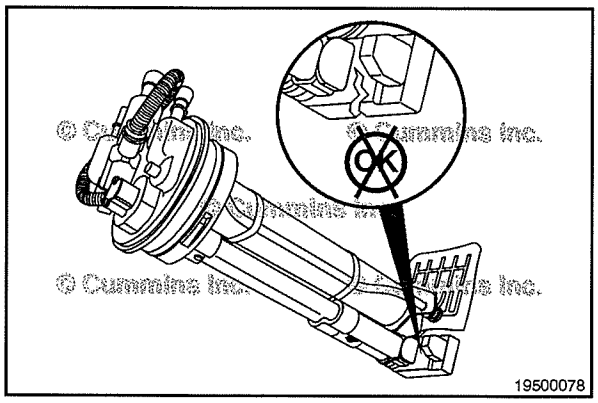
The ECM uses this information to determine if the liquid in the tank is the proper concentration of DEF or a foreign substance.

The DEF quality sensor reading can be monitored using the Datalogger/Monitor function in INSITE™ electronic service tool.

The DEF concentration should read 32.5 ± 4 percent at keyswitch ON.

If the DEF concentration is **not** within specification, see the following procedure to manually verify the concentration of DEF. Refer to Procedure 011-056 in Section 11.

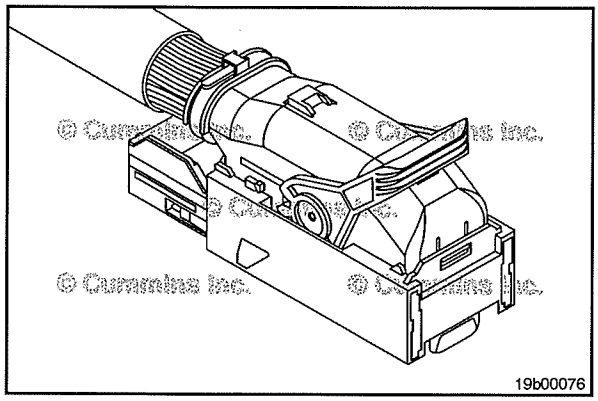




Inspect for Reuse

Inspect the aftertreatment DEF quality sensor for damaged or broken connector pins.

Refer to the OEM service manual for removal, installation, and inspection instructions.

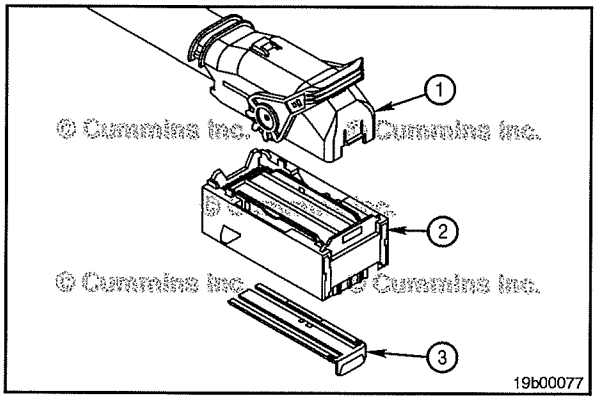


Delphi® 96 Way Engine Control Module Connector (019-505)

General Information

This connector is used to attach the engine wiring harness and the original equipment manufacturer (OEM) harness to the engine control module (ECM).

NOTE: The engine harness connector and the OEM connector are keyed differently, so they can **not** be used interchangeably.

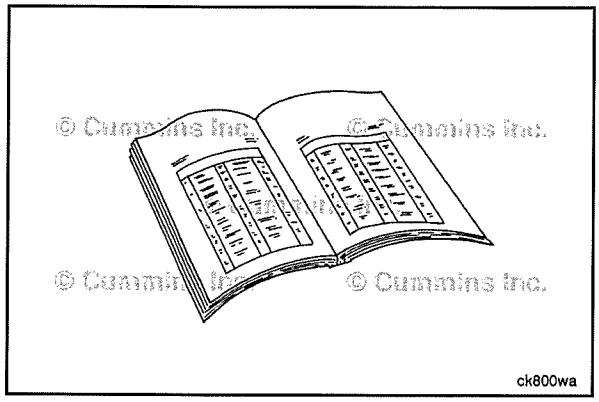


The Delphi® 96 Way engine control module (ECM) connector is made up of three components:

1 Backshell

2 Connector body

3 Locking comb.



Preparatory Steps

⚠WARNING⚠

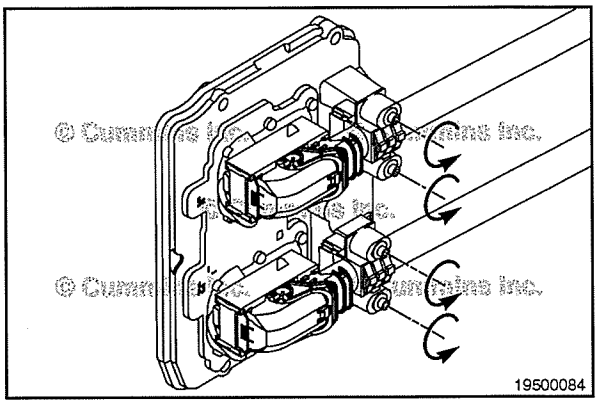
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the OEM service manual.

Remove

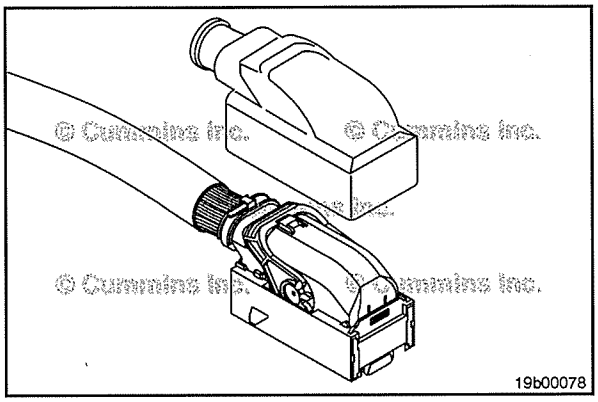
Unbolt the wire harness hold down clamp from the ECM.

NOTE: Do **not** remove wire ties securing the hold down clamp to the wire harness.



If equipped, fold the dust boot back to gain access to the ECM connector or remove it, if necessary.

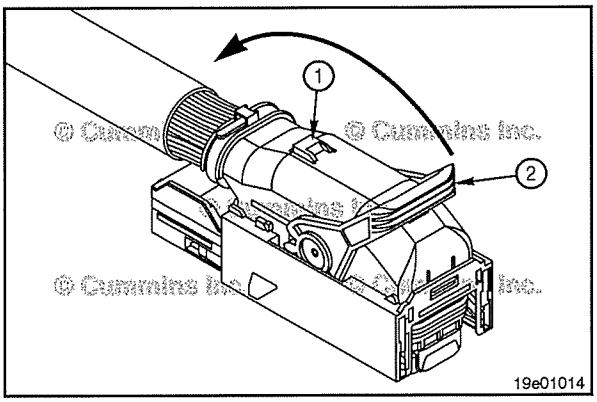
NOTE: If the dust boot is removed, the it **must** be re-installed at the conclusion of the repair.



⚠CAUTION⚠
Damage to the backshell will occur if the locking tab is not depressed prior to lifting of the lever.

Remove the connector from the ECM by pressing down on the locking tab (1) and pulling up on the lever (2).

NOTE: Do **not** close the lever after the connector has been removed from the ECM. Attempting to do so will cause damage.

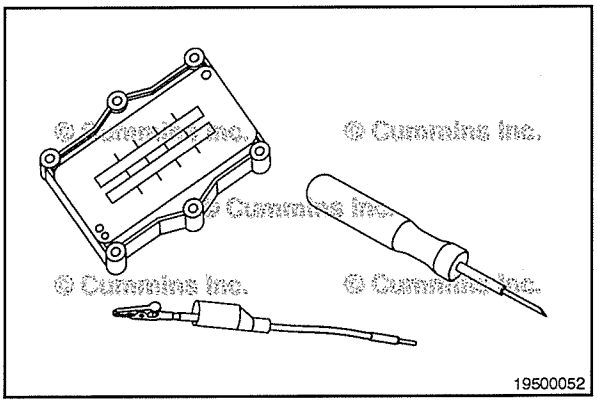


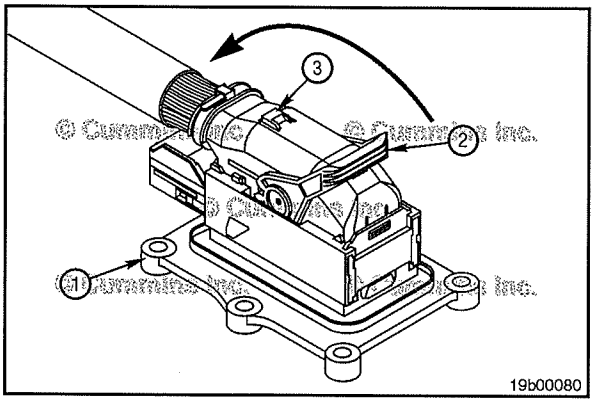
Test

⚠CAUTION⚠
Do not insert test leads into the ECM connector terminals. Doing so may cause terminals to spread and cause intermittent electrical connections.

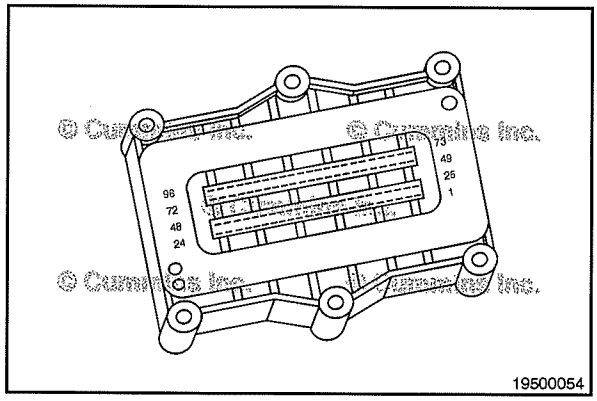
To perform pin-out diagnostic checks, use ECM connector electrical circuit tester, Part Number 2892510, and test lead, Part Number 3164113.

All diagnostic test leads, connector repair tools, and repair terminals can be found in CM2350 ECM Connector Repair Kit, Part Number 2892512.



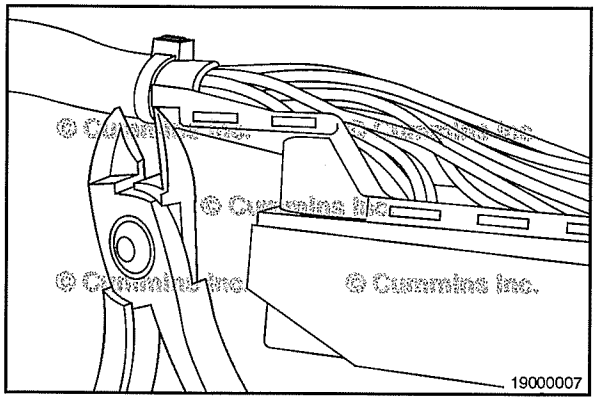


Attach the electrical circuit tester, Part Number 2892510, to the ECM (1) connector by placing the electrical circuit tester into the ECM connector and pulling back on the locking lever (2) until the connector is fully seated and the lever locking tab (3) is engaged.



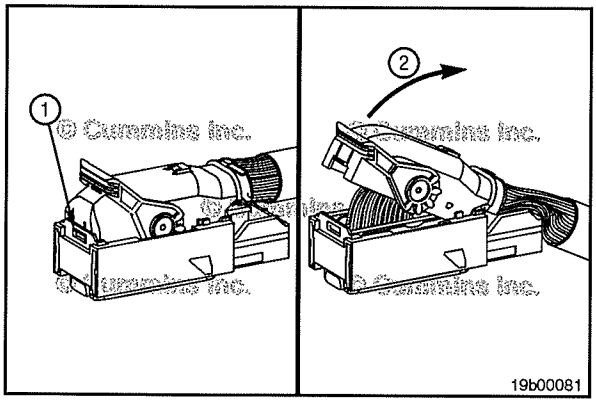
Use electrical circuit tester, Part Number 2892510, to help identify terminal number locations.

Reference the appropriate wiring diagram for circuit terminal locations.



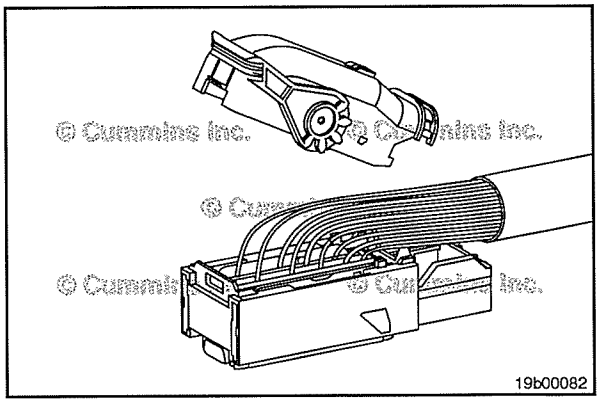
Pin Replacement

Cut the wire tie securing the wire bundle to the backshell.



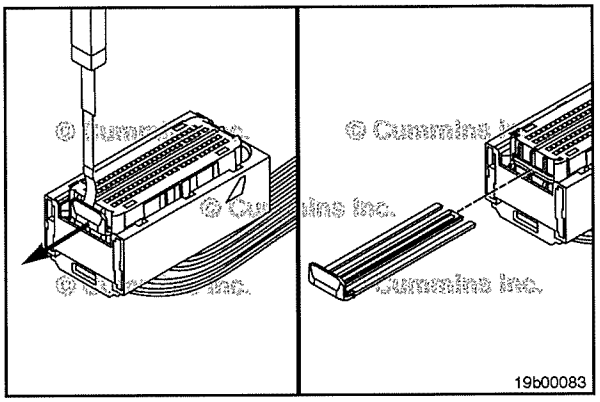
Remove the connector backshell by pressing in on the backshell locking tab (1) and pivot the front of the backshell upward (2).

Pull the backshell forward, then upward, to release the backshell mounting tabs from the connector body.



Gently release the locking comb by using retainer removal tool, Part Number 4918919, to separate the locking comb from the connector body.

Fully remove the locking comb by hand.



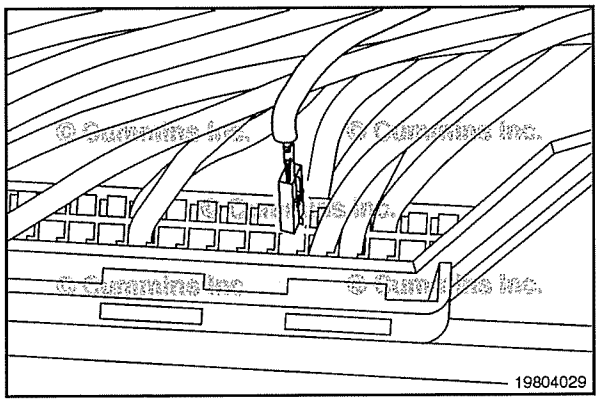
Removing Terminal

Replace one terminal wire at a time. If more than one terminal wire **must** be replaced, attach an identification tag to each wire removed.

If more than four terminals are damaged and need to be replaced, the engine wiring harness is to be replaced.

Reference the appropriate wiring diagram for terminal locations.

Reference the appropriate wiring harness repair kit in the Service Tools procedure in Section 19 for the correct repair wire.

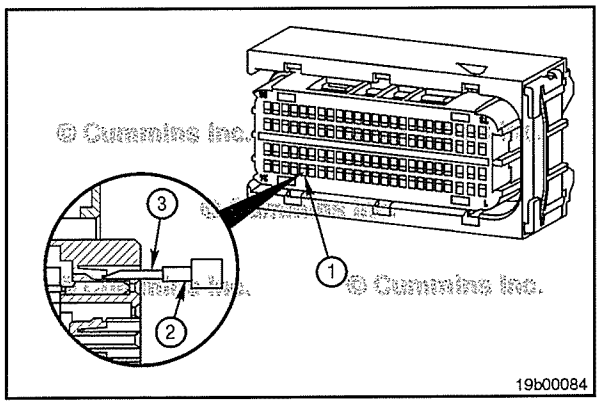


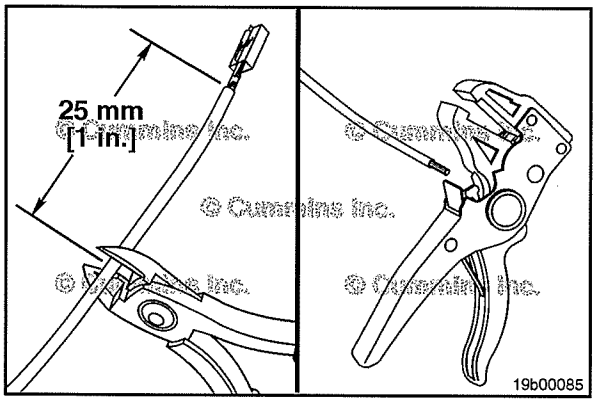
⚠CAUTION⚠
If the wire is difficult to remove, do not pull hard on the wire, otherwise, the locking tang of the terminal will stick or the terminal will pull off the wire and remain in the connector.

Insert terminal removal tool, Part Number 4918921, into the larger access cavity (1).

With the beveled side of the tool facing away from the terminal cavity (2), rotate the tool slightly to release the terminal from the locking tang (3).

Carefully pull the wire from the connector. If it is difficult to remove, repeat the entire process.

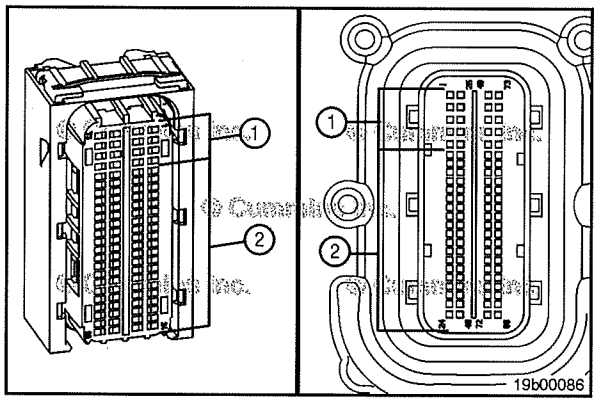




Use wire cutters to remove 25 mm [1 in.] of the terminal and wire to be replaced.

Use wire stripping tool, Part Number 3400045, or equivalent, to remove 6 mm [¼ in.] of insulation from the wire.

NOTE: It will be necessary to remove the wire ties securing the wire harness hold down clamps to the wire harness. Wire ties **must** be replaced at the conclusion of the repair.

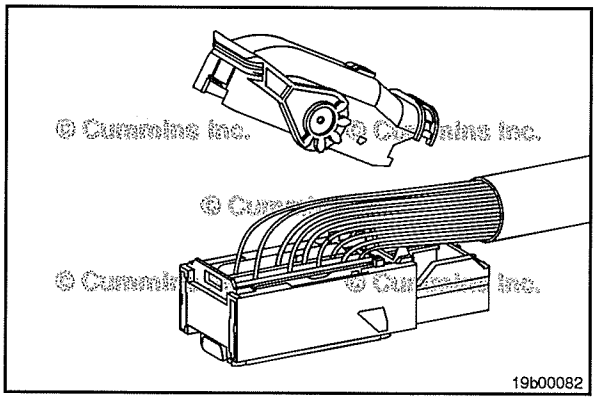


There are two electrical connector repair terminals available for the ECM connector.

Part Number 4918916, identified by a grey wire with a red stripe, is used to repair 16 gauge wires used in cavities 1-4, 25-28, 49-52, and 73-76 (1).

Part Number 2892507 is used to repair 20 gauge wires used in cavities 5-24, 29-48, 53-72, and 77-96 (2).

Reference CM2350 Wiring Harness Repair Kit, Part Number 5298734, for the appropriate repair terminal.

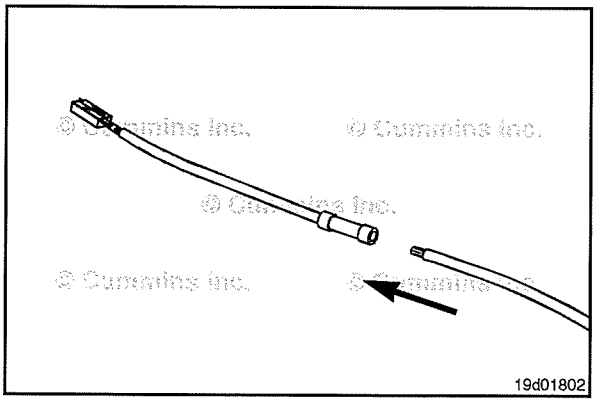


In some applications, there may **not** be enough clearance to route the repair terminal butt-splice connection into the wire harness convolute. The repair terminal will need to be cut to appropriate length to allow the butt-splice connection to be located under the backshell.

NOTE: The repair wire is 203mm [8 in] long.

Use a wire cutter to cut the electrical connector repair terminal to an appropriate length so that it can be attached to the original wire lead, using a butt-splice, under the connector backshell.

NOTE: If more than four terminals are damaged and need to be replaced, the wiring harness is to be replaced.

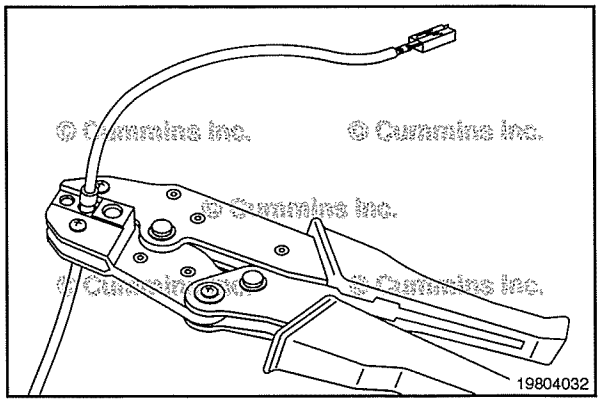


Before installing the new repair wire, perform a test fit to make sure the wire is the correct size.

Install the repair wire on the bare wire.

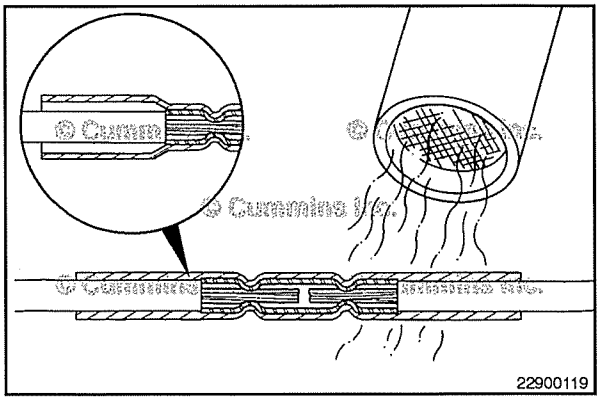
Make sure the bare wire extends into the splice connector properly.

Use wire crimping tool, Part Number 3163109, or equivalent, to crimp the repair wire onto the bare wire.



Use Heat Gun, Part Number 3822860, or equivalent, to heat the shrink tubing around the wire.

The tubing will shrink and make the connection waterproof.



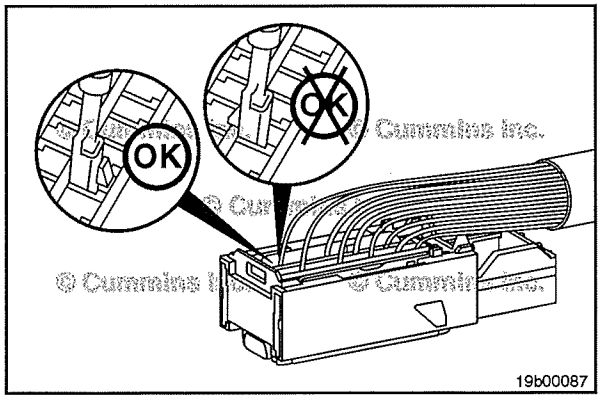
Inserting Terminal

The wire terminals have locating features that only allow the terminal to be inserted in one orientation.

Insert the wire from the top of the connector.

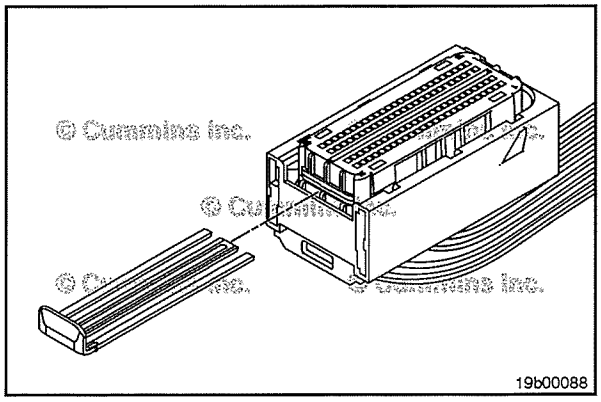
Push the wire into the connector until the terminal locks into place.

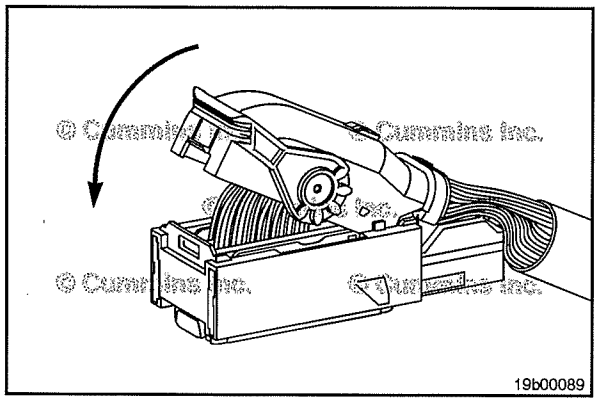
Pull on the wire gently to make sure the terminal is locked into the connector.



Insert the locking comb.

NOTE: The locking comb should slide into place without excessive force. If it is difficult to install the locking comb, check to ensure all pins are fully engaged.

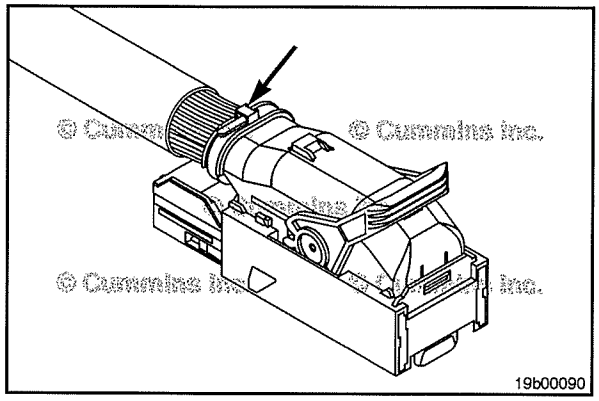




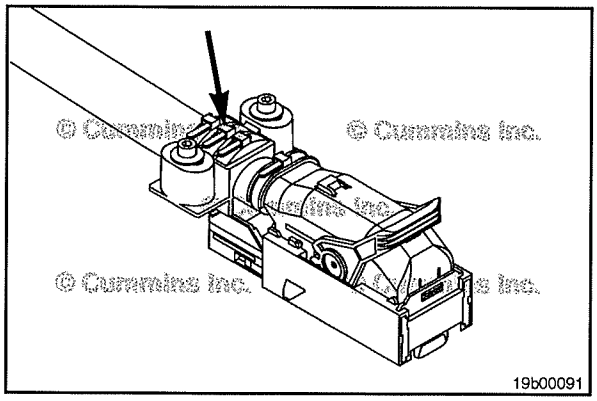
NOTE: Make sure the lever on the backshell is in the open position before installing the backshell onto the connector body.

Position the wire bundle into place and install the backshell mounting tabs into the connector body.

Pivot the front of the backshell downward until the locking tab engages with the connector body.

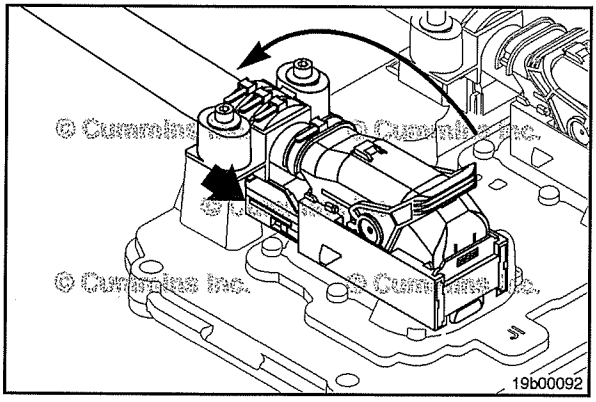


Install a wire tie to secure the wire bundle to the connector backshell.



If the harness hold down clamps were removed from the harness, loosely re-attach the hold down clamps to the wire harness using wire ties.

Once the connector has been re-attached to the ECM and the hold down clamp has been attached to the ECM, the wire ties can be pulled tight, securing the hold down clamp to the wire harness.

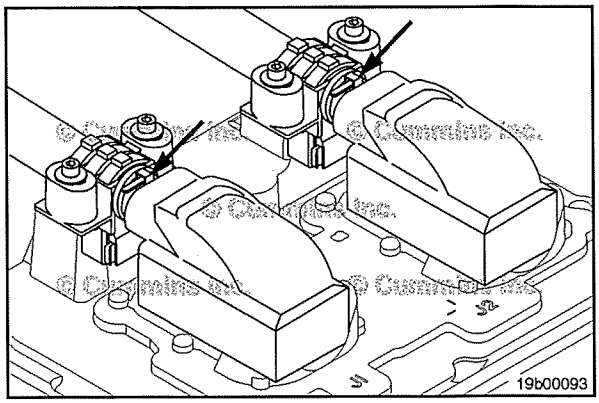


Install

Install the connector to the ECM by placing the connector into the ECM receptacle and pulling back on the locking lever until the connector is fully seated and the lever locking tab is engaged.

If equipped, fold the dust boot back into place over the ECM connector.

If the dust boot was removed, install it over the ECM connector and secure it to the harness using a wire tie. Replace the dust boots if torn or damaged.

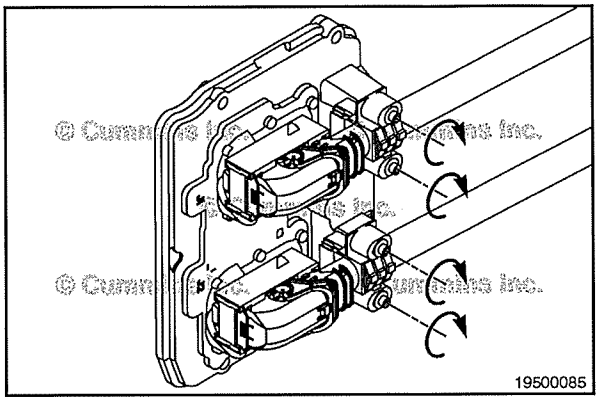


⚠CAUTION⚠
Do not over-tighten the harness hold-down clamp mounting screws or damage to the ECM will occur.

Install the harness hold-down clamps.

Torque Value: 8 N•m [71 in-lb]

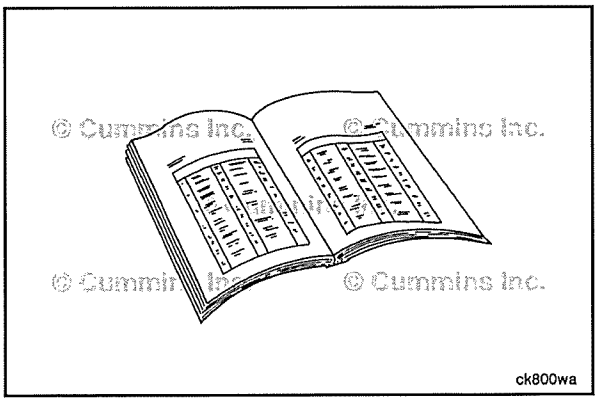
NOTE: If the wire ties securing the harness hold-down clamp to the wire harness were removed, new wire ties **must** be installed.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for loose components and fault codes.



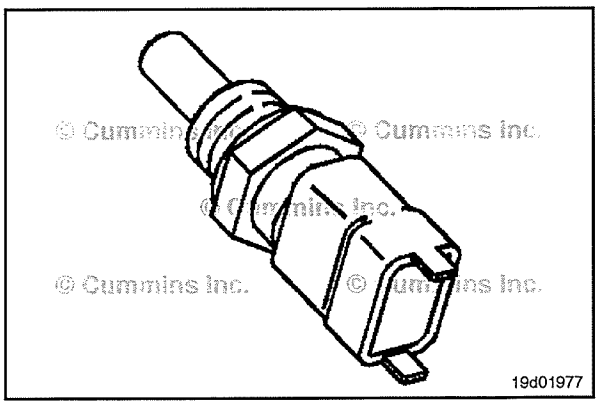
Engine Charge-Air Cooler Outlet Temperature Sensor (019-544)

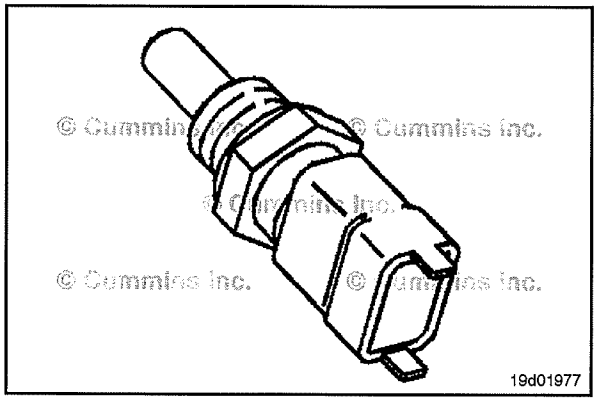
General Information

Original equipment manufacturers (OEMs) can optionally install a charge-air cooler (CAC) outlet temperature sensor.

The OEM CAC outlet temperature sensor monitors the CAC outlet air temperature and passes that information on to the engine control module (ECM) through the OEM harness.

Refer to the OEM service manual for the location of the CAC outlet temperature sensor.

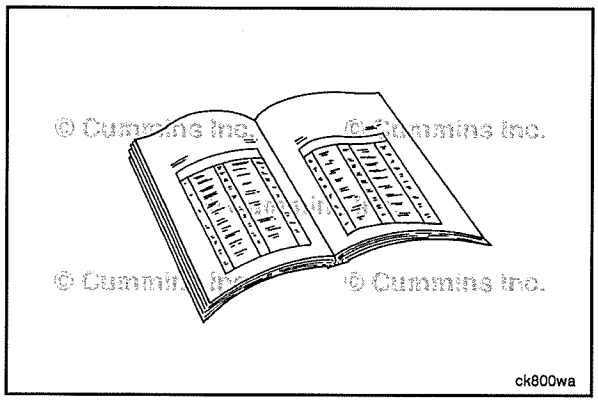




Inspect for Reuse

Inspect the CAC outlet temperature sensor for damaged or broken connector pins.

Refer to the OEM service manual for removal and installation instructions.



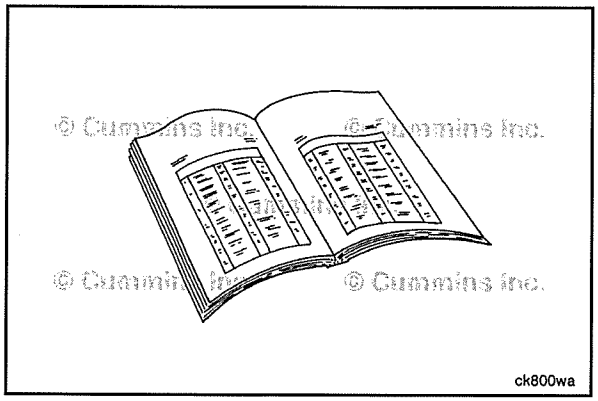
Machine Constrained Engine Operation Controller (019-545)

General Information

Some original equipment manufacturers (OEMs) constrain the operation of the engine based on the specific needs of the equipment.

By constraining the operation of the engine, it is possible to get a standard torque curve to have a higher torque rise and meet the specific demands for the equipment. All constraining **must** be done such that the standard torque curve is **not** modified. Refer to the OEM manual for the location and specification of the machine constrained engine operation controller.

NOTE: The OEM is to provide a secondary label regarding the machine constrained operations. It **must** be placed inside the engine compartment in a location which is clearly visible. Four items are included on this label: maximum constrained power (hp or Kw), maximum engine speed at which maximum power can be achieved (rpm), statement of compliance to government regulations, and machine manufacturer name.



Inspect for Reuse

The machine constrained engine operation controller uses standard J1939 data link commands. It **must** provide an indication to the engine control module (ECM) which indicates if the controller is in error because of a J1939 data link issue, machine controller software execution issue, or loss of machine controller power.

Refer to the OEM service manual for removal and installation instructions.

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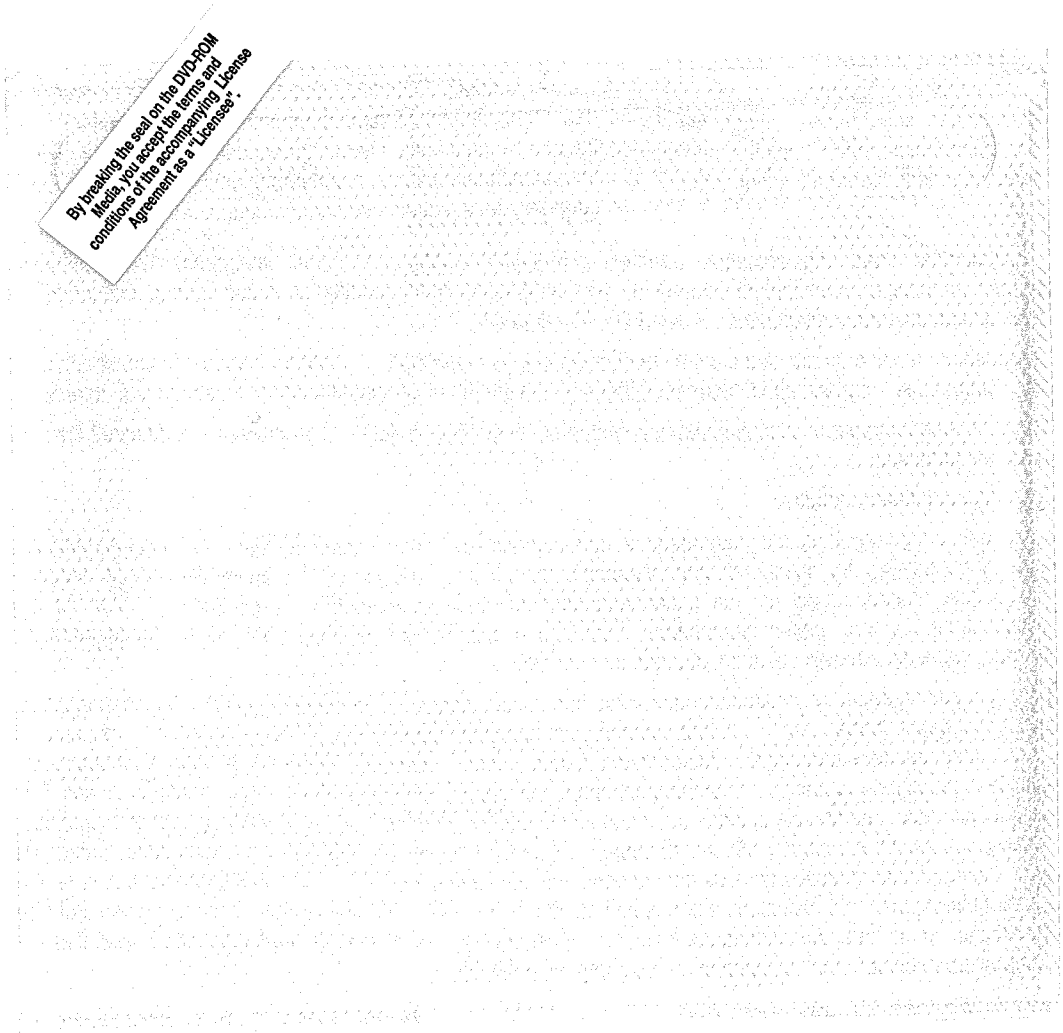

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- Color Monitor with at least 800x600 resolution graphics
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Section L - Service Literature

Section Contents

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Additional Service Literature

General Information

The following publications can be purchased:

Additional Service Literature	
4332778	QSB6.7 CM2350 B105 Service Manual
4332777	QSB6.7 CM2350 B105 Fault Code Troubleshooting Manual
4332776	QSB6.7 CM2350 B105 Wiring Diagram
4332779	QSB6.7 CM2350 B105 Operation and Maintenance Manual
4332780	QSB6.7 CM2350 B105 Owners Manual
3379000	Air for Your Engine
3379001	Fuels for Cummins® Engines
3379009	Operation of Diesel Engines in Cold Climates
3666132	Cummins® Coolant Requirements and Maintenance
3387266	Cold Weather Operation
3810340	Cummins® Engine Oil and Oil Analysis Recommendations

Service Literature Ordering Location
Contact Information

Region	Ordering Location
United States and Canada	Cummins Distributors or Credit Cards at 1-800-646-5609 or Order online at www.powerstore.cummins.com
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- Engine Configuration Data
- Table of Contents
- Separate Option and Parts Indexes
- Service Kits (when applicable)
- ReCon Part Numbers (when applicable)

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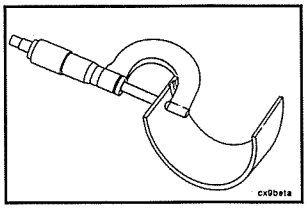
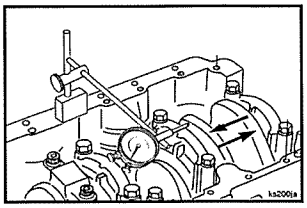
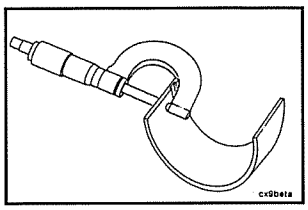
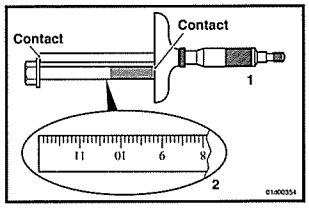
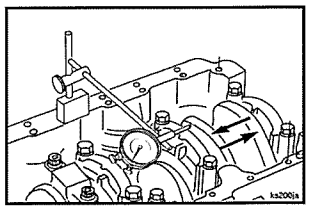
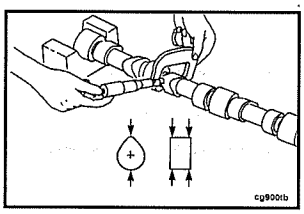
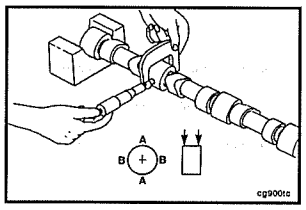
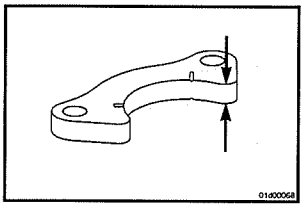
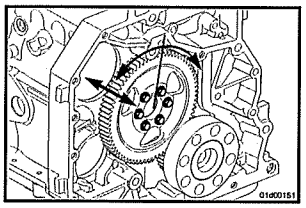
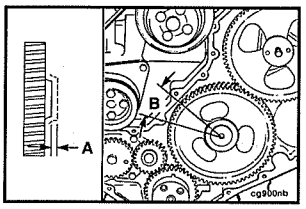
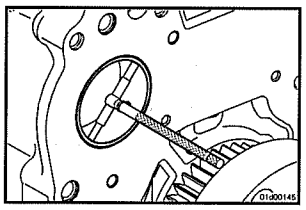
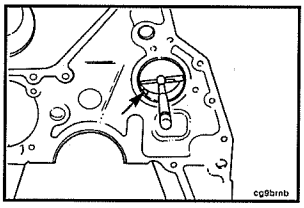
Notes

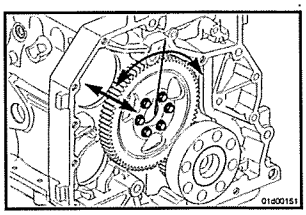
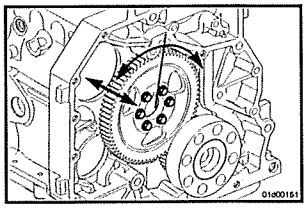
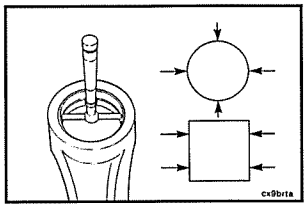
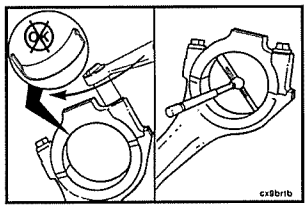
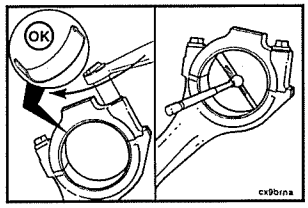
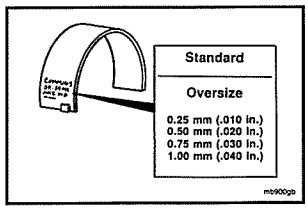
Section V - Specifications

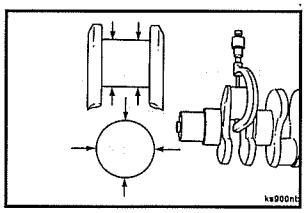
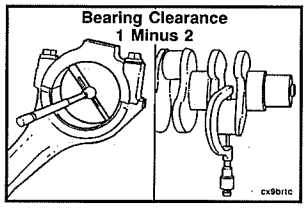
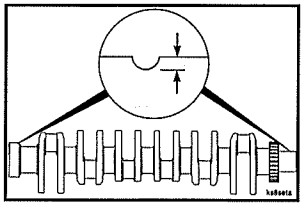
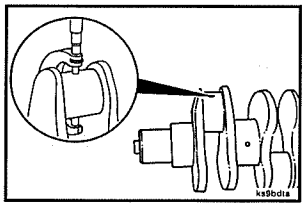
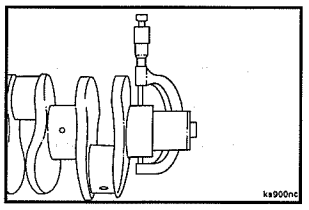
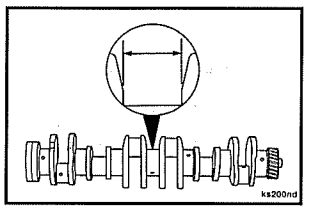
Section Contents

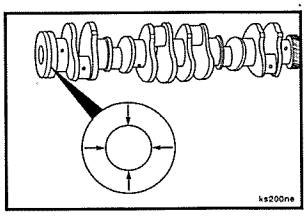
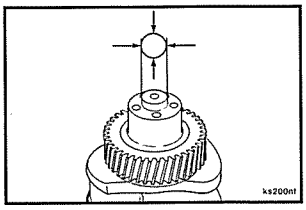
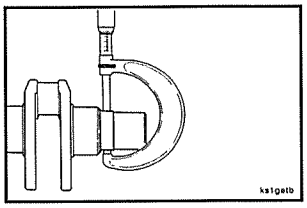
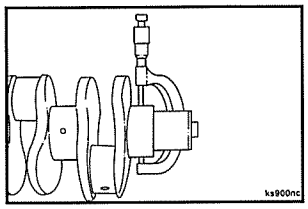
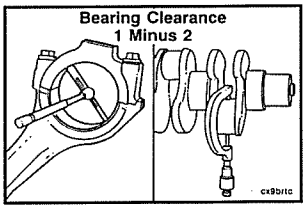
Cylinder Block - Group 01 - Specifications

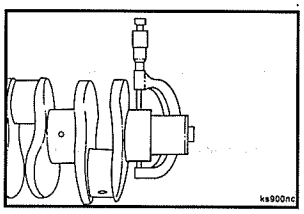
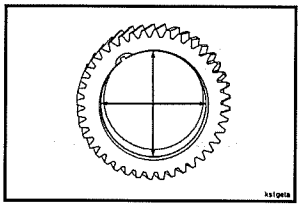
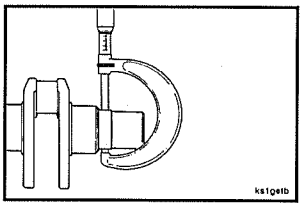
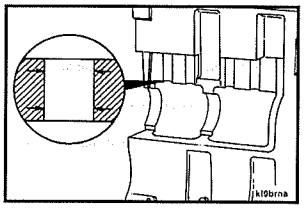
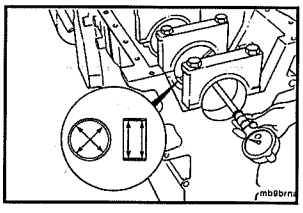
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Bearings, Connecting Rod (001-005)					
Standard		1.955	MIN	0.0770	
		1.968	MAX	0.0775	
0.25 mm [0.010 in]		2.080	MIN	0.0819	
		2.093	MAX	0.0824	
0.50 mm [0.020 in]		2.205	MIN	0.0868	
		2.218	MAX	0.0873	
0.75 mm [0.030 in]		2.330	MIN	0.0917	
		2.343	MAX	0.0922	
1.00 mm [0.040 in]		2.455	MIN	0.0967	
		2.468	MAX	0.0972	
Bearings, Main (001-006)					
Crankshaft End Clearance		0.102 mm	MIN	0.004 in	
		0.432 mm	MAX	0.017 in	
Standard		2.456	MIN	0.0967	
		2.464	MAX	0.097	
Oversize 0.25 mm [0.010 in]		2.706	MIN	0.1067	
		2.714	MAX	0.117	
Oversize 0.50 mm [0.020 in]		2.956	MIN	0.1167	
		2.964	MAX	0.117	
Oversize 0.75 mm [0.030 in]		3.206	MIN	0.1267	
		3.214	MAX	0.127	
Oversize 1.00 mm [0.040 in]		3.456	MIN	0.1367	
		3.464	MAX	0.137	
Main Bearing Underhead Capscrew Length		120.00 mm	MAX	4.724 in	
Crankshaft End Clearance		0.102 mm	MIN	0.004 in	
		0.432 mm	MAX	0.017 in	
Camshaft (001-008)					
Clearance from Rear Gear Housing		81.28 mm	MIN	32 in	

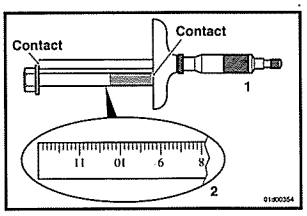
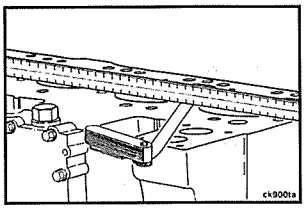
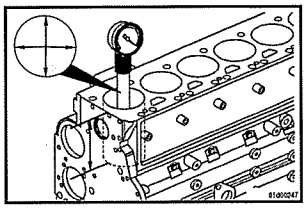
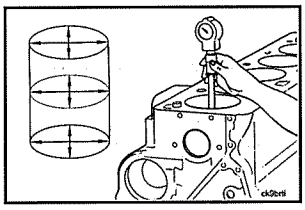
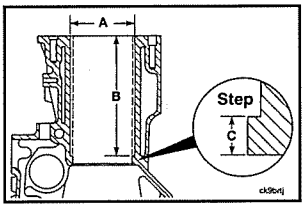
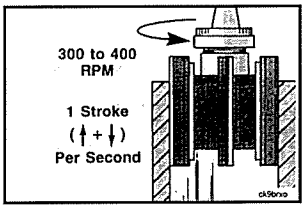
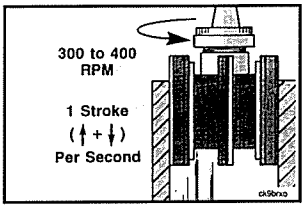
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Intake		47.175	MIN	1.857	
		47.855	MAX	1.884	
Exhaust		45.632	MIN	1.797	
		46.312	MAX	1.823	
Journal Diameter		53.095 mm	MIN	2.0904 in	
		54.045 mm	MAX	2.1278 in	
Camshaft Thrust Plate Thickness		5.25 mm	MIN	0.207 in	
		5.35 mm	MAX	0.211 in	
Camshaft End Play (A)		0.10 mm	MIN	0.004 in	
		0.36 mm	MAX	0.014 in	
Camshaft Gear Backlash Limits (B)		0.076 mm	MIN	0.003 in	
		0.280 mm	MAX	0.011 in	
Camshaft End Play (A)		0.12 mm	MIN	0.005 in	
		0.50 mm	MAX	0.020 in	
Camshaft Gear Backlash Limits (B)		0.08 mm	MIN	0.003 in	
		0.25 mm	MAX	0.010 in	
Camshaft Bushings (001-010)					
Camshaft Bore (Camshaft Bushing Previously Installed)		59.248	MAX	2.3326	
Camshaft Bore (Camshaft Bushing not Previously Installed)		54.164	MAX	2.1324	
Camshaft Bore (Bushing Installed)		54.083 mm	MIN	2.1293 in	
		54.147 mm	MAX	2.1318 in	

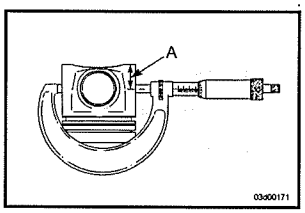
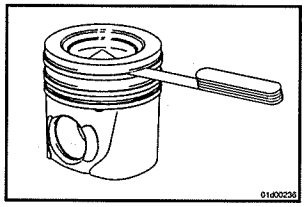
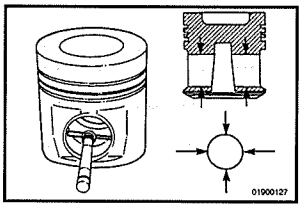
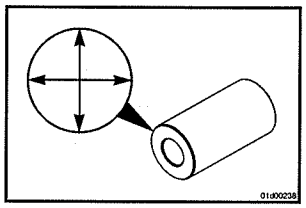
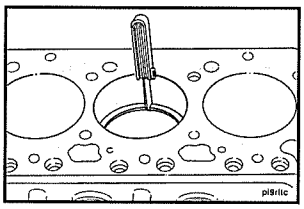
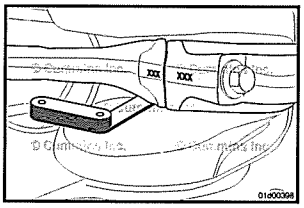
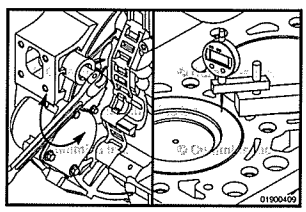
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Camshaft Gear (Camshaft Installed) (001-012)					
Camshaft End Play		0.100 mm 0.360 mm	MIN MAX	0.004 in 0.014 in	
Camshaft Backlash		0.076 mm 0.280 mm	MIN MAX	0.003 in 0.011 in	
Camshaft End Play		0.100 mm 0.360 mm	MIN MAX	0.004 in 0.014 in	
Camshaft Backlash		0.076 mm 0.280 mm	MIN MAX	0.003 in 0.011 in	
Connecting Rod (001-014)					
Connecting Rod Piston Pin Bushing Inside Diameter		40.019 mm 40.042 mm	MIN MAX	1.5756 in 1.5765 in	
Connecting Rod Crankshaft Bore Diameter, Bearings Removed		72.99 mm 73.01 mm	MIN MAX	2.873 in 2.875 in	
Standard		69.05 69.10	MIN MAX	2.719 2.720	
Oversize					
0.25 mm [0.010 in]		68.80 68.85	MIN MAX	2.709 2.711	
0.50 mm [0.020 in]		68.55 68.60	MIN MAX	2.699 2.701	
0.75 mm [0.030 in]		68.30 68.35	MIN MAX	2.689 2.691	
1.00 mm [0.040 in]		68.05 68.10	MIN MAX	2.680 2.681	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Standard		68.962 69.013	MIN MAX	2.7150 2.7170	
Undersize					
0.25 mm [0.010 in]		68.712 68.763	MIN MAX	2.7052 2.7072	
0.50 mm [0.020 in]		68.462 68.513	MIN MAX	2.6954 2.6974	
0.75 mm [0.030 in]		68.212 68.263	MIN MAX	2.6855 2.6875	
1.00 mm [0.040 in]		67.962 68.013	MIN MAX	2.6767 2.6787	
Connecting Rod to Crankshaft Bearing Clearance		0.04 mm 0.12 mm	MIN MAX	0.002 in 0.005 in	
Crankshaft (001-016) Crankshaft Front and Rear Oil Seal Wear Groove		0.25 mm	MAX	0.010 in	
Crankshaft Connecting Rod Journal Diameter		76.000 mm 76.026 mm	MIN MAX	2.9921 in 2.9931 in	
Crankshaft Connecting Rod Out-of-Roundness		0.050 mm	MAX	0.002 in	
Crankshaft Connecting Rod Journal Taper		0.013 mm	MAX	0.0005 in	
Crankshaft Main Bearing Journal Diameter		98.006 mm 98.032 mm	MIN MAX	3.8585 in 3.8595 in	
Crankshaft Main Bearing Journal Out-of-Roundness		0.050 mm	MAX	0.002 in	
Crankshaft Main Bearing Journal Taper		0.013 mm	MAX	0.0005 in	
Crankshaft Thrust Face Width (Standard)		37.475 mm 37.576 mm	MIN MAX	1.475 in 1.576 in	

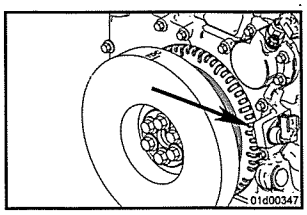
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Crankshaft Rear Oil Seal Flange Outside Diameter		129.98 mm	MIN	5.117 in	
		130.03 mm	MAX	5.119 in	
Crankshaft Damper Pilot Outside Diameter		23.92 mm	MIN	0.942 in	
		24.00 mm	MAX	0.945 in	
Crankshaft Gear Journal Outside Diameter		75.987 mm	MIN	2.9916 in	
		76.006 mm	MAX	2.9924 in	
0.25 mm [0.010 in]		68.712 mm	MIN	2.7052 in	
		68.763 mm	MAX	2.7072 in	
0.50 mm [0.020 in]		68.462 mm	MIN	2.6954 in	
		68.513 mm	MAX	2.6974 in	
0.75 mm [0.030 in]		68.212 mm	MIN	2.6855 in	
		68.263 mm	MAX	2.6875 in	
1.00 mm [0.040 in]		67.962 mm	MIN	2.6767 in	
		68.013 mm	MAX	2.6787 in	
Connecting Rod Crankshaft Bearing Clearance		0.04 mm	MIN	0.002 in	
		0.12 mm	MAX	0.005 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Standard Crankshaft Main Bearing Journal Diameter		82.962 mm	MIN	3.2662 in	
		83.013 mm	MAX	3.2682 in	
0.25 mm [0.010 in]		82.712 mm	MIN	3.2564 in	
		82.763 mm	MAX	3.2584 in	
0.50 mm [0.020 in]		82.462 mm	MIN	3.2465 in	
		82.513 mm	MAX	3.2485 in	
0.75 mm [0.030 in]		82.212 mm	MIN	3.2367 in	
		82.263 mm	MAX	3.2387 in	
1.00 mm [0.040 in]		81.962 mm	MIN	3.2268 in	
		82.013 mm	MAX	3.2289 in	
Crankshaft Gear, Front (Crankshaft Removed) (001-019)					
Crankshaft Gear Bore Inside Diameter		70.51 mm	MIN	2.776 in	
		70.55 mm	MAX	2.779 in	
Crankshaft Gear Journal Outside Diameter		70.59 mm	MIN	2.779 in	
		70.61 mm	MAX	2.780 in	
Cylinder Block (001-026)					
Tappet Bore Diameter		16.000 mm	MIN	0.630 in	
		16.055 mm	MAX	0.632 in	
Main Bearing Bore Diameter with Bearings Removed		87.983 mm	MIN	3.4639 in	
		88.019 mm	MAX	3.4653 in	

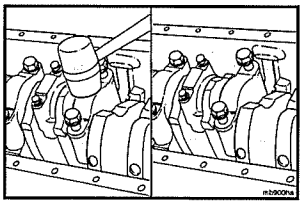
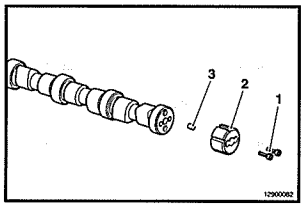
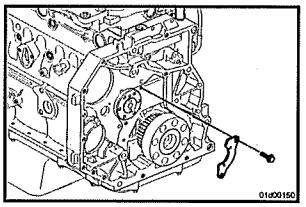
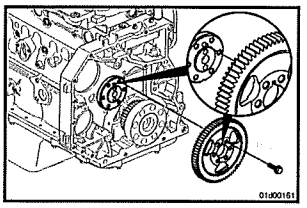
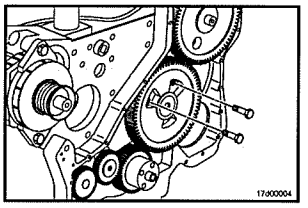
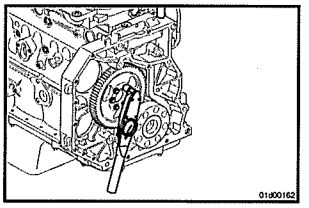
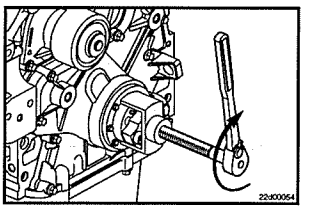
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Main Bearing Underhead Capscrew Length		120.00 mm	MAX	4.724 in	
End-to-End		0.076	MAX	0.003	
Side-to-Side		0.051	MAX	0.002	
Cylinder Bore Diameter - 6.7L Engines (New Cylinder Block)		106.990 mm	MIN	4.2122 in	
		107.010 mm	MAX	4.2130 in	
Cylinder Bore Diameter - 6.7L Engines (Used Cylinder Block)		106.990 mm	MIN	4.2122 in	
		107.030 mm	MAX	4.2138 in	
Out-of-Round		0.038 mm	MAX	0.0015 in	
Rebore		107.45	NOM	4.2303	
Cylinder Bore Depth (B)		192.65	MIN	7.5846	
Standard Bore/Repair Sleeve		102.000	MIN	4.0157	
		102.040	MAX	4.0173	
First Rebore		102.500	MIN	4.0354	
		102.540	MAX	4.0370	
Second Rebore		103.000	MIN	4.0551	
		103.040	MAX	4.0567	
Standard Bore/Repair Sleeve		106.990	MIN	4.2122	
		107.010	MAX	4.2130	
Rebore		107.490	MIN	4.2319	
		107.510	MAX	4.2327	
Rebore		107.490	MIN	4.2319	
		107.510	MAX	4.2327	

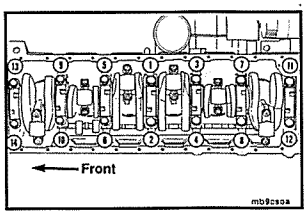
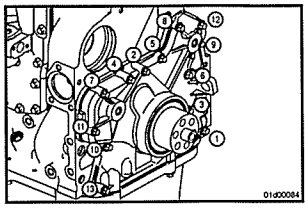
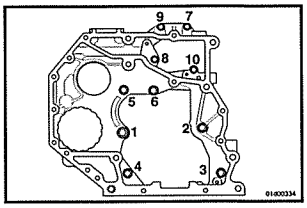
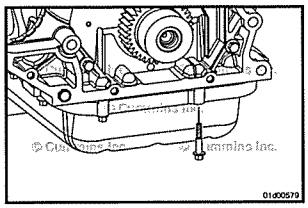
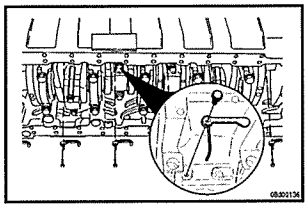
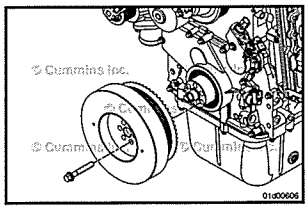
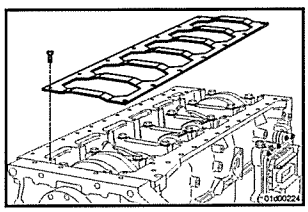
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Piston (001-043)					
Standard Piston Skirt Diameter		106.878 mm	MIN	4.2078 in	
		106.892 mm	MAX	4.2083 in	
Oversize Piston Skirt Diameter		107.378 mm	MIN	4.2275 in	
		107.392 mm	MAX	4.2280 in	
Intermediate		0.040	MIN	0.0016	
		0.110	MAX	0.0043	
Oil control		0.040	MIN	0.0016	
		0.085	MAX	0.0033	
Piston Pin Bore		40.006 mm	MIN	1.5750 in	
		40.012 mm	MAX	1.5753 in	
Piston Pin Diameter		39.997 mm	MIN	1.5747 in	
		40.003 mm	MAX	1.5749 in	
Piston Rings (001-047)					
Top		0.30	MIN	0.012	
		0.46	MAX	0.018	
Phosphate-Coated Intermediate		0.82	MIN	0.032	
		1.18	MAX	0.047	
Chrome-Faced Intermediate		0.52	MIN	0.021	
		0.88	MAX	0.034	
Oil		0.22	MIN	0.010	
		0.58	MAX	0.023	
Piston and Connecting Rod Assembly (001-054)					
Connecting Rod and Crankshaft Side Clearance		0.10 mm	MIN	0.004 in	
		0.33 mm	MAX	0.013 in	
Piston Protrusion		0.151 mm	MIN	0.006 in	
		0.485 mm	MAX	0.019 in	

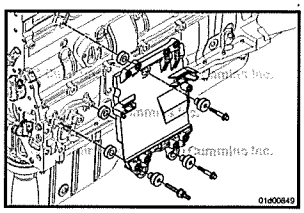
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Crankshaft Speed Indicator Ring (001-071)				
Crankshaft Speed/Position Sensor Air Gap		0.8 mm	MIN	0.032 in
		1.5 mm	MAX	0.060 in



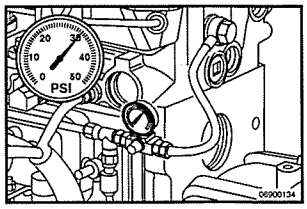
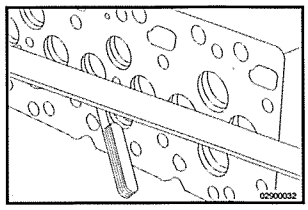
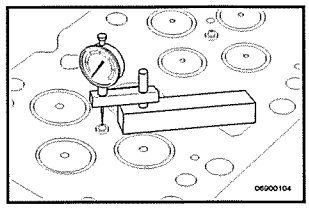
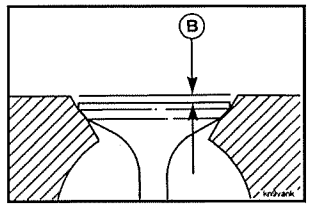
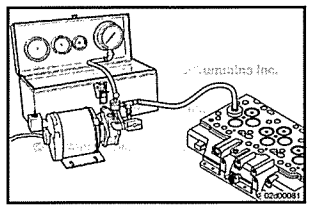
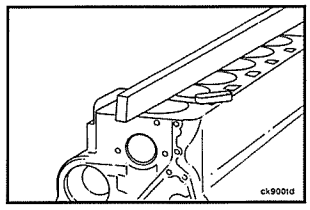
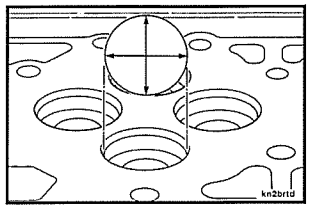
Cylinder Block - Group 01 - Torque Values

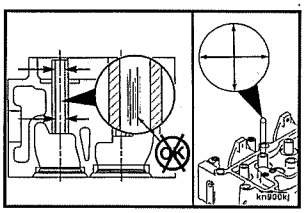
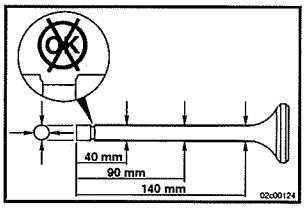
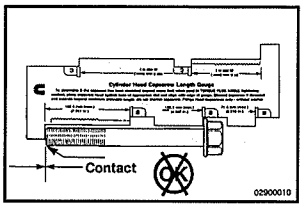
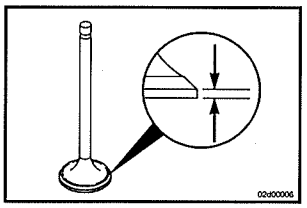
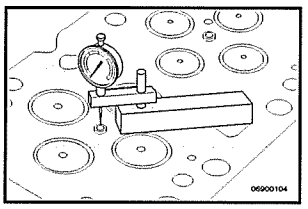
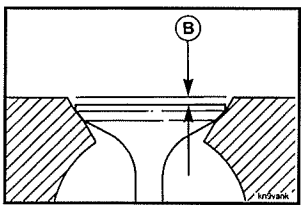
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Bearings, Main (001-006)				
Main Bearing Capscrews.		50 N•m	[37 ft-lb]	
Camshaft (001-008)				
Rear Gear Train Camshaft Speed Indicator Ring Capscrews.		10 N•m	[89 in-lb]	
Thrust Plate Capscrews		24 N•m	[212 in-lb]	
Camshaft Gear Capscrews		36 N•m	[27 ft-lb]	
Camshaft Thrust Plate Retaining Capscrews		24 N•m	[212 in-lb]	
Camshaft Gear (Camshaft Installed) (001-012)				
Camshaft Gear Capscrews		36 N•m	[27 ft-lb]	
Crankshaft Seal, Front (001-023)				
Crankshaft Seal Replacer Capscrews		33 N•m	[24 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Cylinder Block (001-026)		176 N•m	[130 ft-lb]	
Gear Cover, Front (001-031) Front Cover Capscrew		24 N•m	[212 in-lb]	
Gear Housing, Rear (001-034) Rear Gear Housing Capscrews		47 N•m 24 N•m	[35 ft-lb] [212 in-lb]	
		28 N•m	[248 in-lb]	
Piston Cooling Nozzle (001-046)		15 N•m	[133 in-lb]	
Crankshaft Wear Sleeve, Rear (001-067)		20 N•m	[177 in-lb]	
Block Stiffener Plate (001-089) Block Stiffener Plate Capscrew		43 N•m	[32 ft-lb]	

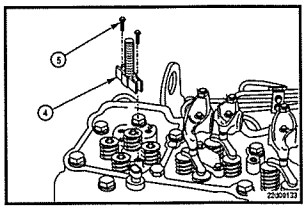
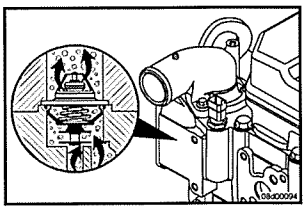
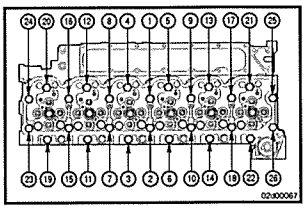
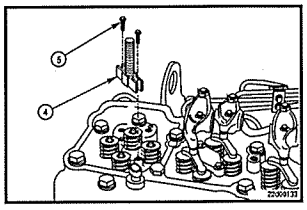
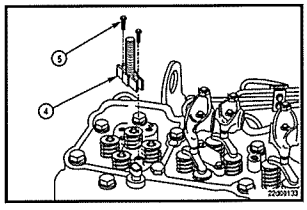
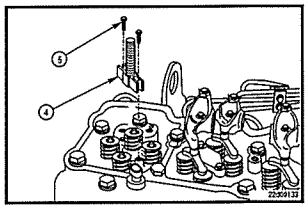
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Control Module Mounting Plate (001-103)				
Ecm Mounting Plate To Cylinder Block Mounting Capscrews.		24 N•m	[212 in-lb]	

Cylinder Head - Group 02 - Specifications

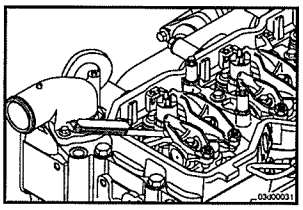
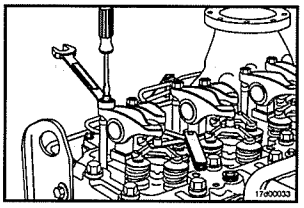
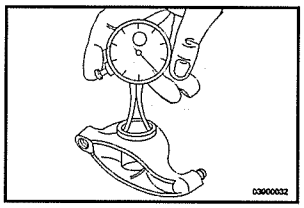
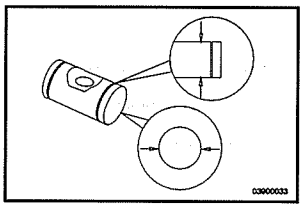
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder Head (002-004)					
End-to-End		0.305	MAX	0.012	
Side-to-Side		0.076	MAX	0.003	
Injector Protrusion		1.63 mm	MIN	0.064 in	
		1.98 mm	MAX	0.078 in	
Intake Valve Depth (Installed)		0.584 mm	MIN	0.023 in	
		1.092 mm	MAX	0.043 in	
Exhaust Valve Depth (Installed)		0.965 mm	MIN	0.038 in	
		1.473 mm	MAX	0.058 in	
Used		51	NOM	15	
New		69	NOM	20	
End-To-End		0.075	MAX	0.003	
Side-To-Side		0.075	MAX	0.002	
Cylinder Head Insert Bore Inside Diameter.		34.847 mm	MIN	1.3719 in	
		34.863 mm	MAX	1.3726 in	

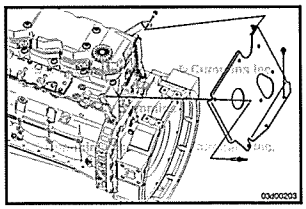
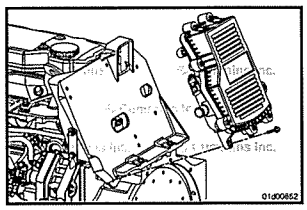
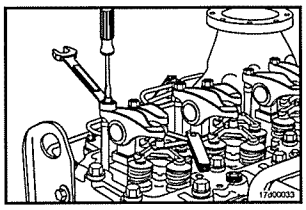
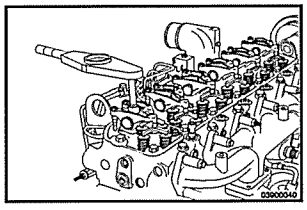
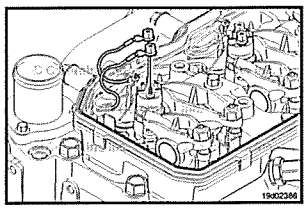
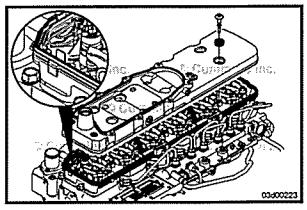
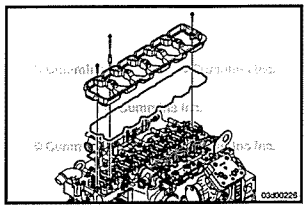
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Valve Guide Bore Diameter		7.027 mm 7.077 mm	MIN MAX	0.2767 in 0.2786 in	
Valve Stem Outside Diameter		6.96 mm 7.01 mm	MIN MAX	0.2740 in 0.2760 in	
Capscrew Free Length		152.1 mm	MAX	5.99 in	
Valve Rim Thickness Limit		0.79 mm	MIN	0.031 in	
Injector Protrusion		1.63 mm 1.98 mm	MIN MAX	0.064 in 0.078 in	
Intake Valve Depth (Installed)		0.584 mm 1.092 mm	MIN MAX	0.023 in 0.043 in	
Exhaust Valve Depth (Installed)		0.965 mm 1.473 mm	MIN MAX	0.038 in 0.058 in	

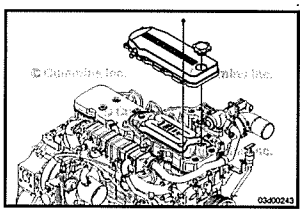
Cylinder Head - Group 02 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Cylinder Head (002-004)				
Valve Spring Compressor Capscrews.		5 N•m	[44 in-lb]	
Thermostat And Water Outlet Connection Capscrews		10 N•m 18 N•m	[89 in-lb] [159 in-lb]	
Pressure Test Fixture Nuts		80 N•m	[59 ft-lb]	
		5 N•m	[44 in-lb]	
Valve Guide Seal, Cylinder Head (002-016)		5 N•m	[44 in-lb]	
		5 N•m	[44 in-lb]	

Rocker Levers - Group 03 - Specifications

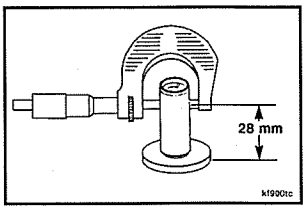
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Overhead Set (003-004)					
Intake		0.152	MIN	0.006	
		0.381	MAX	0.015	
Exhaust		0.533	MIN	0.021	
		0.863	MAX	0.034	
Intake		0.254	NOM	0.010	
Exhaust		0.508	NOM	0.020	
Rocker Lever (003-008)					
Rocker Lever Bore		22.027 mm	MAX	0.867 in	
Rocker Lever Shaft		21.965 mm	MIN	0.865 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Crankcase Breather (External) (003-001)		18 N•m	[159 in-lb]	
		18 N•m	[159 in-lb]	
Overhead Set (003-004)				
Rocker Lever Adjustment Locknut		24 N•m	[212 in-lb]	
Rocker Lever (003-008)		36 N•m	[27 ft-lb]	
Rocker Lever Cover (003-011)				
Injector Solenoid Terminal Nut		1.5 N•m	[13 in-lb]	
Rocker Lever Cover Capscrew		24 N•m	[212 in-lb]	
Rocker Lever Housing (003-013)				
Rocker Lever Housing Mounting Capscrew		24 N•m	[212 in-lb]	

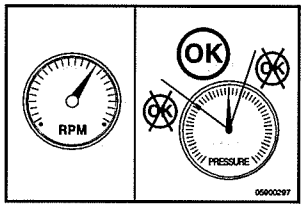
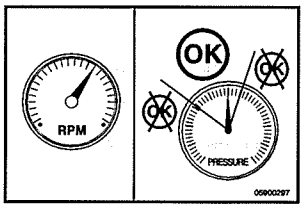
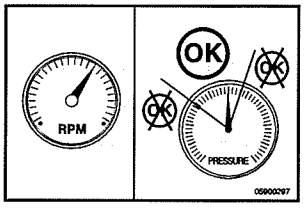
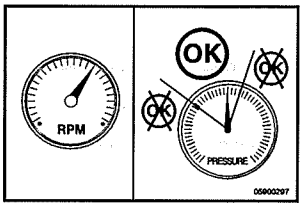
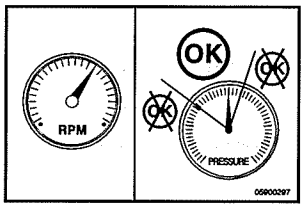
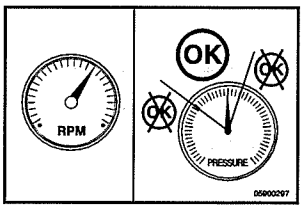
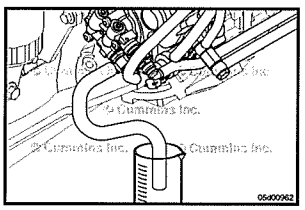
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Crankcase Ventilation Filter (003-021)				
Rocker Lever Cover Mounted Ventilation Filter Cover Capscrew		7 N•m	[62 in-lb]	

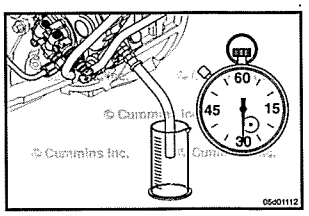
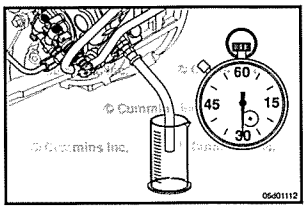
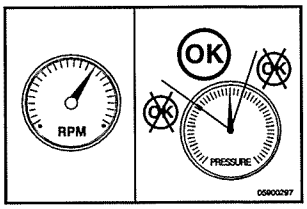
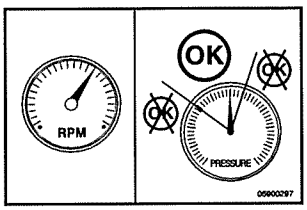
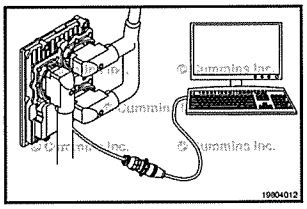
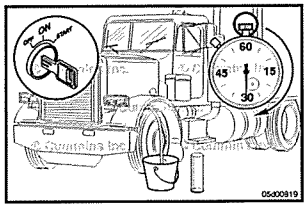
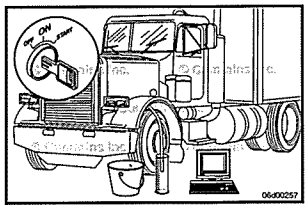
Cam Followers/Tappets - Group 04 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Tappet (004-015)				
Valve Tappet Stem Diameter		15.936 mm	MIN	0.627 in
		15.977 mm	MAX	0.629 in

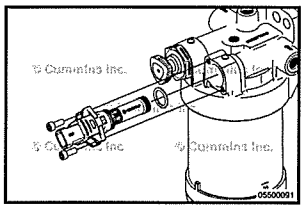
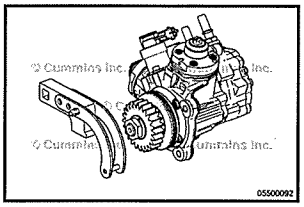
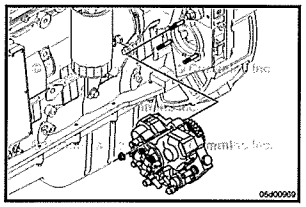
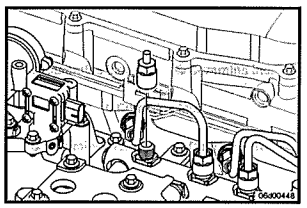


Fuel System - Group 05 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Fuel System Diagnostics (005-236)					
Drain Line Restriction at High Idle		18.6 kPa	MAX	2.7 psi	
Gear Pump Pressure at High Idle		255 kPa 758 kPa	MIN MAX	37 psi 110 psi	
Pressure Drop Across Fuel Filter at High Idle		81 kPa	MAX	11.7 psi	
Drain Line Restriction at Engine Cranking (150 rpm minimum)		18.6 kPa	MAX	2.7 psi	
Gear Pump Pressure at Engine Cranking (150 rpm minimum)		255 kPa 606 kPa	MIN MAX	37 psi 88 psi	
Pressure Drop Across Fuel Filter at Engine Cranking (150 rpm minimum)		81 kPa	MAX	11.7 psi	
Minimum High Pressure Fuel Pump Supply Flow with Engine Cranking (150 rpm minimum) in 30 Seconds		120 ml	MIN	4 fl-oz	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Maximum High Pressure Fuel Pump Return Flow with Engine Cranking (150 rpm minimum) in 30 Seconds		440 ml	MAX	15 fl-oz	
Maximum High Pressure Fuel Pump Return Flow at Standard Idle Conditions in 30 Seconds		440 ml	MAX	15 fl-oz	
Fuel Pressure Range at Fuel Filter with Engine Cranking (150 rpm minimum)		255 kPa	MIN	37 psi	
		606 kPa	MAX	88 psi	
Maximum Allowable Pressure Drop Across Fuel Filter while Cranking (150 rpm minimum)		81 kPa	MAX	11.7 psi	
Fuel Pressure Range at Fuel Filter with Engine at High Idle		255 kPa	MIN	37 psi	
		758 kPa	MAX	110 psi	
Maximum Allowable Pressure Drop Across Fuel Filter while Engine Running at High Idle		81 kPa	MAX	11.7 psi	
High Pressure Fuel Rail Return Flow at Standard Idle Conditions using INSITE™ electronic service tool "Fuel System Leakage Test" in 30 Seconds		8 ml	MAX	0.27 fl-oz	
Injector Return Flow at Engine Cranking (150 rpm minimum) for 30 Seconds		36 ml	MAX	1.2 fl-oz	
Injector Return Flow at Standard Engine Idle Conditions using INSITE™ electronic service tool "Fuel System Leakage Test" in 30 Seconds (less than 900 rpm idle speed)		36 ml	MAX	1.2 fl-oz	
Injector Return Flow at Standard Engine Idle Conditions using INSITE™ electronic service tool "Fuel System Leakage Test" in 30 Seconds (900 rpm and above idle speed)		54 ml	MAX	1.8 fl-oz	

Fuel System - Group 05 - Torque Values

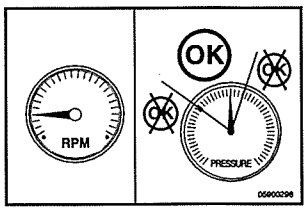
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Fuel Heater, Electric (005-008)				
Fuel Heater Bolts		9 N•m	[80 in-lb]	
Fuel Pump (005-016)				
Fuel Pump Drive Gear Nut		85 N•m	[63 ft-lb]	
Fuel Pump Mounting Fasteners		24 N•m	[212 in-lb]	
Fuel System Diagnostics (005-236)				
Injector Isolation Tool, Part Number 4918298		40 N•m	[30 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

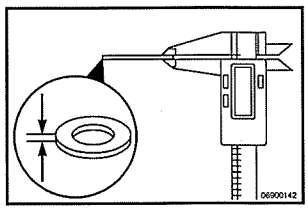
Injectors and Fuel Lines - Group 06 - Specifications

Fuel Drain Line Restriction (006-012)

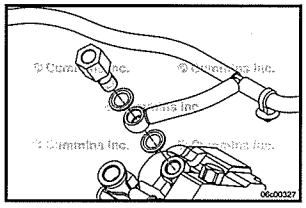
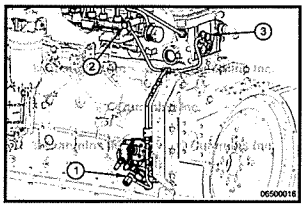
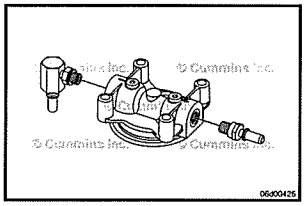
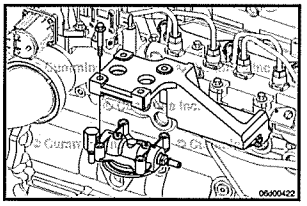
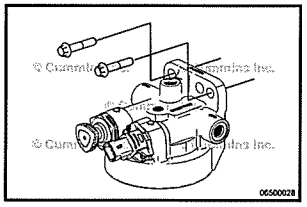
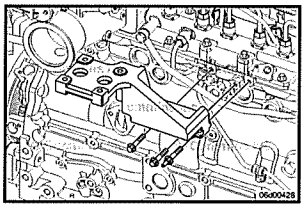
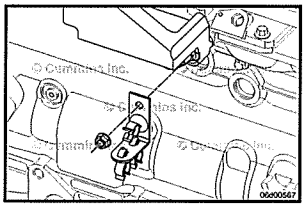
Drain Line Restriction	18.6 kPa	MAX	2.7 psi

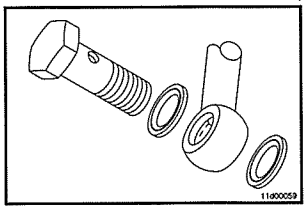
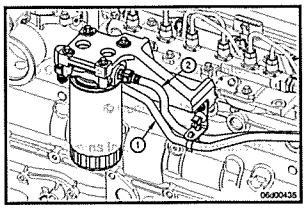
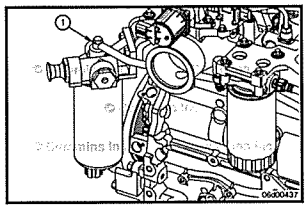
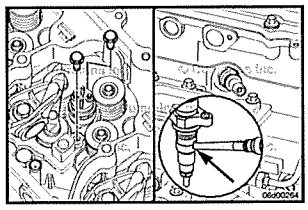
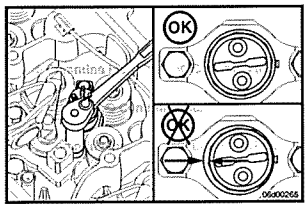
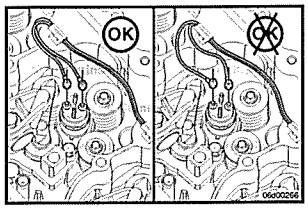
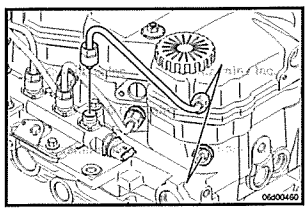


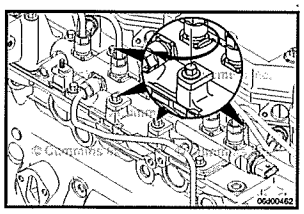
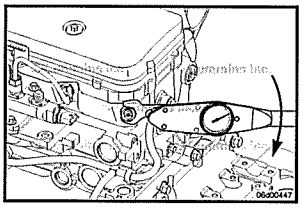
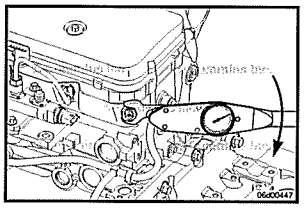
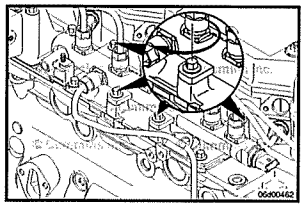
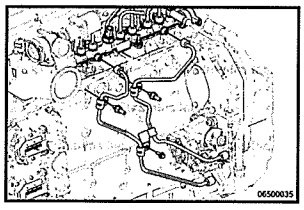
Injector (006-026)



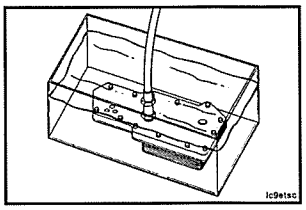
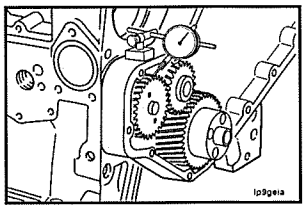
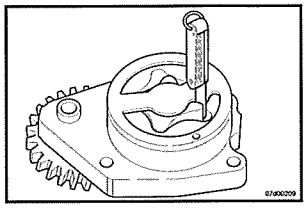
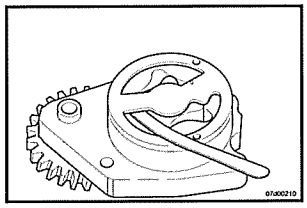
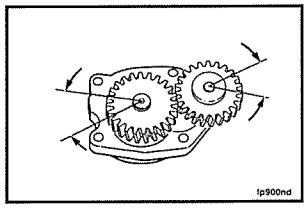
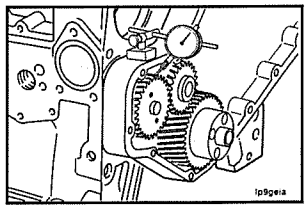
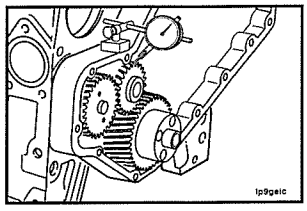
Injectors and Fuel Lines - Group 06 - Torque Values

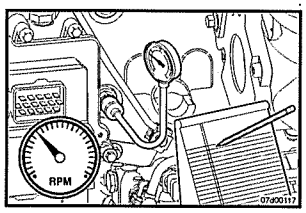
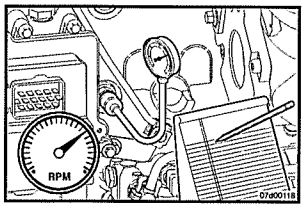
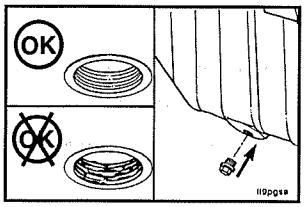
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Drain Lines (006-013)				
Fuel Drain Line Banjo Bolt Fitting		24 N•m	[212 in-lb]	
Fuel Drain Line Banjo Bolt Fitting		24 N•m	[212 in-lb]	
Fuel Filter Head (006-017)				
Fuel Filter Head Fitting		24 N•m	[212 in-lb]	
Rear Gear Train Fuel Filter Head Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Filter Head Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Filter Head Bracket (006-018)				
Fuel Filter Head Bracket Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Line Brace Fastener		24 N•m	[212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Supply Lines (006-024)				
Fuel Supply Line Banjo Bolt Fitting		24 N•m	[212 in-lb]	
Rear Gear Train P-Clip		24 N•m	[212 in-lb]	
Fuel Supply Line Banjo Bolt		24 N•m	[212 in-lb]	
Injector (006-026)				
Fuel Connector (Preliminary Torque)		15 N•m	[133 in-lb]	
Injector Hold-Down Clamp		8 N•m	[71 in-lb]	
Injector Terminal Nut		1.5 N•m	[13 in-lb]	
Injector Supply Lines (High Pressure) (006-051)				
Injector High-Pressure Supply Line		40 N•m	[30 ft-lb]	

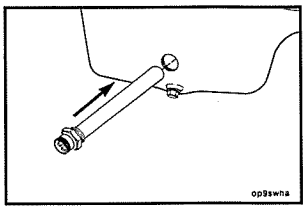
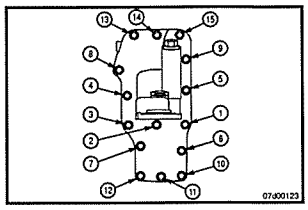
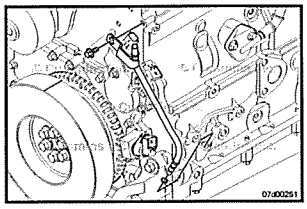
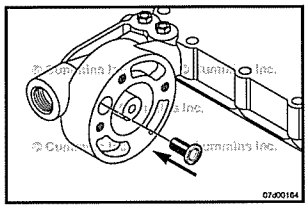
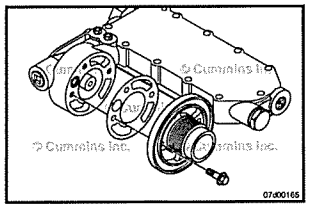
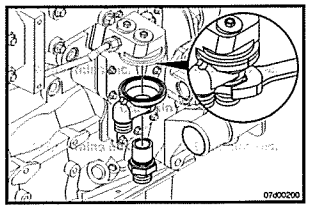
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Rail Mounting Capscrew		24 N•m	[212 in-lb]	
Fuel Connector (Head Mounted) (006-052)				
Fuel Connector Retaining Nut		55 N•m	[41 ft-lb]	
Fuel Connector Retaining Nut		55 N•m	[41 ft-lb]	
Fuel Rail (006-060)				
Fuel Rail Capscrews		24 N•m	[212 in-lb]	
Fuel Rail Supply Line (High Pressure) (006-071)				
Fuel Rail Supply Line Nut		40 N•m 24 N•m	[30 ft-lb] [212 in-lb]	

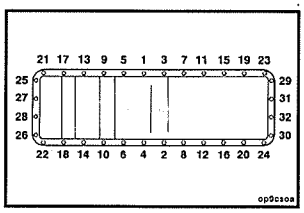
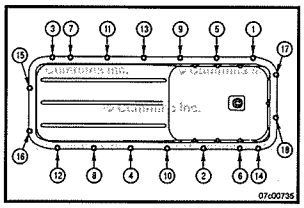
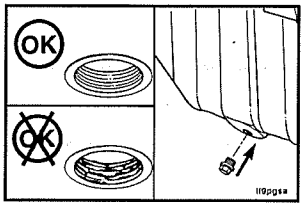
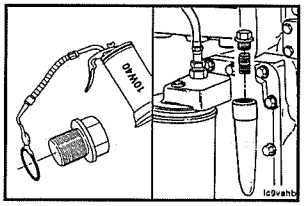
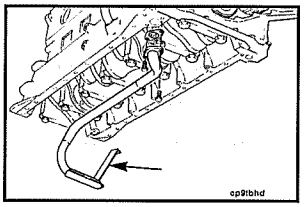
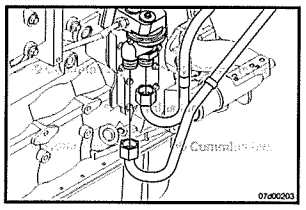
Lubricating Oil System - Group 07 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Lubricating Oil Cooler (007-003)					
Air Pressure Test		449 kPa 518 kPa	MIN MAX	65 psi 75 psi	
Lubricating Oil Pump (007-031)					
Lubricating Oil Pump Driven Gear Backlash Limits		0.170 mm 0.300 mm	MIN MAX	0.007 in 0.012 in	
Tip Limit		0.13 mm	MAX	0.005 in	
Gerotor Drive/Planetary to Port Plate Limit		0.126 mm	MAX	0.004 in	
Backlash Limits (used pump)		0.170 mm 0.300 mm	MIN MAX	0.007 in 0.012 in	
Lubricating Oil Pump Driven Gear Backlash Limits (new pump)		0.300 mm 0.500 mm	MIN MAX	0.012 in 0.019 in	
Lubricating Oil Pump Idler Gear Backlash Limits (new pump)		0.125 mm 0.205 mm	MIN MAX	0.004 in 0.008 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Lubricating Oil System (007-037)					
Oil Pressure at Low Idle		69 kPa	MIN	10 psi	
Oil Pressure at Rated Engine Speed		207 kPa	MIN	30 psi	
M18		60	NOM	44	
M22		80	NOM	59	
M22		60	NOM	44	

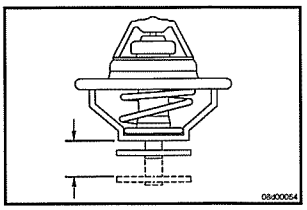
Lubricating Oil System - Group 07 - Torque Values

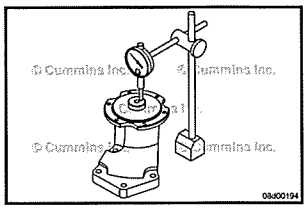
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Oil Heater (007-001)				
Heater Element		80 N•m	[59 ft-lb]	
Lubricating Oil Cooler (007-003)				
		17 N•m	[150 in-lb]	
		28 N•m	[248 in-lb]	
Lubricating Oil Dipstick Tube (007-011)				
Dipstick Tube Insert Capscrew		24 N•m	[212 in-lb]	
Lubricating Oil Filter Bypass Valve (007-014)				
Lubricating Oil Bypass Valve Pipe Plug		45 N•m	[33 ft-lb]	
Lubricating Oil Filter Head (007-015)				
Lubricating Oil Filter Head Mounting Capscrews		24 N•m	[212 in-lb]	
Lubricating Oil Filter Head Adapter (007-018)				
Lubricating Oil Filter Head Adapter		100 N•m	[74 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Lubricating Oil Pan (007-025)				
		28 N•m	[248 in-lb]	
Oil Pan Capscrew For 6-Cylinder Applications With A Suspended Oil Pan		28 N•m	[248 in-lb]	
Oil Pan Drain Plug		60 N•m 80 N•m 60 N•m	[44 ft-lb] [59 ft-lb] [44 ft-lb]	
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)				
Pressure Regulator Valve Plug		80 N•m	[59 ft-lb]	
Lubricating Oil Suction Tube (Block-Mounted) (007-035)				
Suction Tube Capscrews		24 N•m	[212 in-lb]	
Lubricating Oil Lines (007-092)				
Lubricating Oil Lines		76 N•m	[56 ft-lb]	

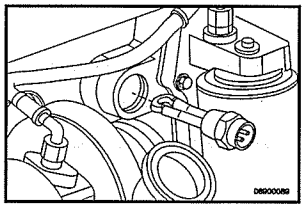
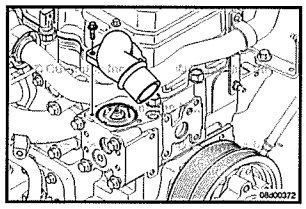
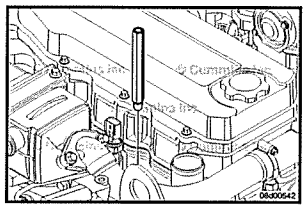
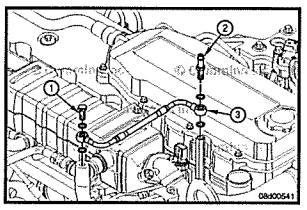
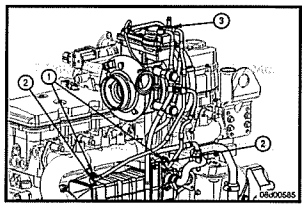
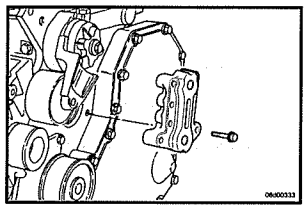
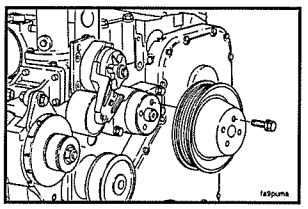
Cooling System - Group 08 - Specifications

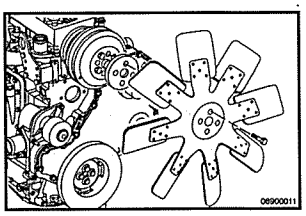
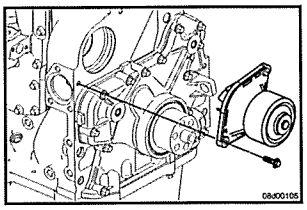
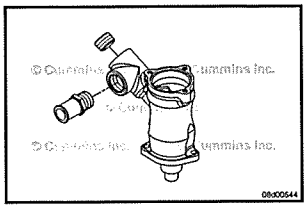
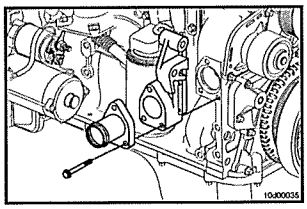
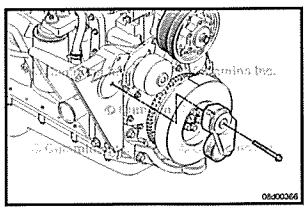
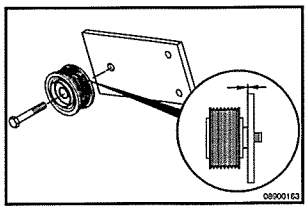
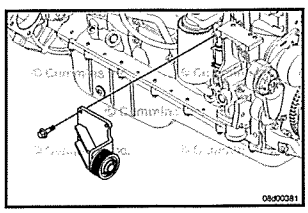
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Coolant Thermostat (008-013)				
Initial Opening		86	MIN	186
		89	MAX	193
Fully Opened		97	MAX	207
Fan Hub, Belt Driven (008-036)				
Fan Hub End Play		0.15 mm	MAX	0.006 in

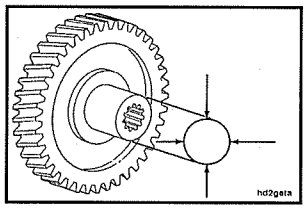
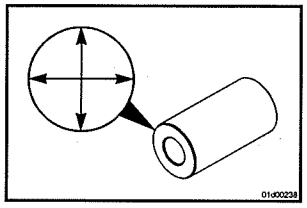
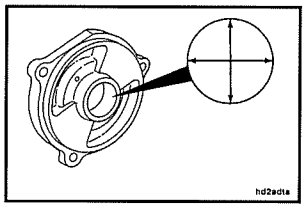
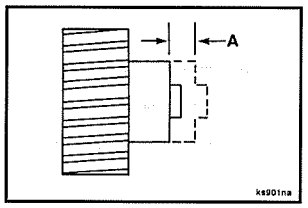


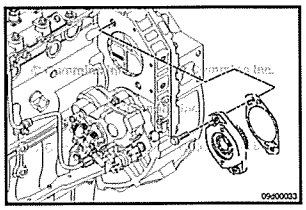
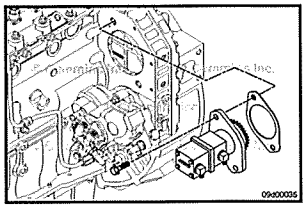
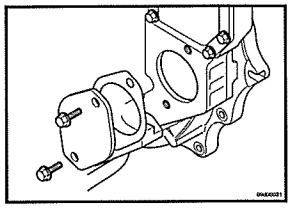
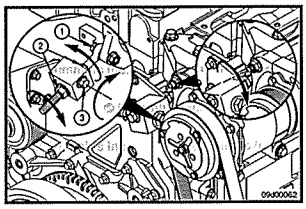
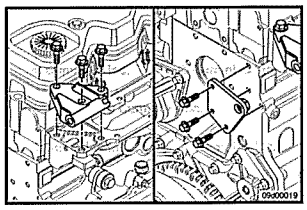


Cooling System - Group 08 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Coolant Heater (008-011)				
Coolant Heater Mounting (Threaded)		55 N•m	[41 ft-lb]	
Coolant Thermostat (008-013)				
Water Outlet Tube Mounting Capscrews		10 N•m	[89 in-lb]	
Coolant Vent Lines (008-017)				
Cylinder Head Adapter		25 N•m	[221 in-lb]	
Egr Cooler Banjo Bolt		7 N•m	[62 in-lb]	
		15 N•m 7 N•m	[133 in-lb] [62 in-lb]	
Fan Clutch, Electric (008-026)				
Fan Clutch Support Bracket Mounting Capscew Torque		33 N•m	[24 ft-lb]	
Fan Spacer and Pulley (008-039)				
Engine Driven Cooling Fan Mounting Capscrews		10 N•m 43 N•m 77 N•m	[89 in-lb] [32 ft-lb] [57 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Driven Cooling Fan Mounting Capscrews		77 N•m	[57 ft-lb]	
Water Pump (008-062) Water Pump 10.9 Grade Mounting Capscrew		30 N•m	[22 ft-lb]	
Torque Converter Cooler (008-065) 3/4 NPTF Fitting And Plug		75 N•m	[55 ft-lb]	
Water Inlet Connection (008-082) Water Inlet Connection		43 N•m 80 N•m	[32 ft-lb] [59 ft-lb]	
Cooling Fan Belt Tensioner (008-087) Belt Tensioner Mounting Bracket Capscrew		24 N•m 43 N•m	[212 in-lb] [32 ft-lb]	
Pulley, Fan Idler (008-111) Idler Pulley Mounting Capscrews		18 N•m	[159 in-lb]	
Idler Pulley Support Bracket Capscrews		18 N•m	[159 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Drive Units - Group 09 - Specifications					
Accessory Drive (009-001)					
Accessory Drive Gear Bore Inside Diameter (Accessory Drive Adapter)		38.920 mm	MIN	1.5323 in	
		38.945 mm	MAX	1.5333 in	
Accessory Drive Shaft Outside Diameter (Accessory Drive Adapter)		39.008 mm	MIN	1.5357 in	
		39.020 mm	MAX	1.5362 in	
Bearing Bore Inside Diameter (Accessory Drive Adapter)		67.759 mm	MIN	2.6755 in	
		67.983 mm	MAX	2.6765 in	
Accessory Drive Gear End Clearance		0.5 mm	MIN	0.020 in	

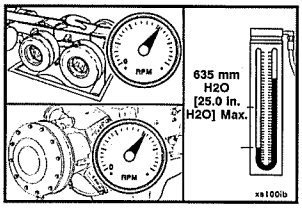
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Drive Units - Group 09 - Torque Values				
Accessory Drive (009-001)				
Accessory Drive To Rear Gear Housing Capscrews		62 N•m	[46 ft-lb]	
Hydraulic Pump Drive (009-016)				
Hydraulic Pump Mounting Capscrew		62 N•m	[46 ft-lb]	
Accessory Drive Cover (009-039)				
Accessory Drive Cover Capscrews		50 N•m	[37 ft-lb]	
Drive Belt, Refrigerant Compressor (000-052)				
		77 N•m 43 N•m	[57 ft-lb] [32 ft-lb]	
Refrigerant Compressor Mounting Bracket (009-055)				
Refrigerant Compressor Mounting Bracket		23 N•m 43 N•m	[204 in-lb] [32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

Air Intake System - Group 10 - Specifications

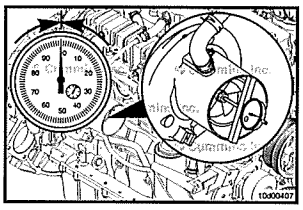
Air Intake Restriction (010-031)

Air Filter Restriction	635 mm H_2O	MAX	25 in H_2O

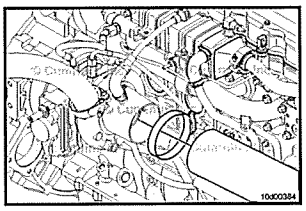
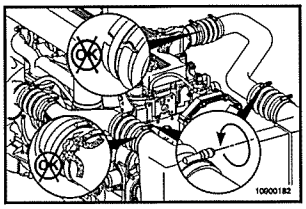
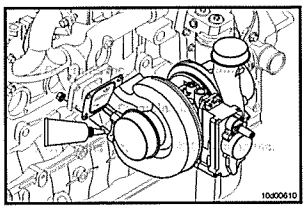
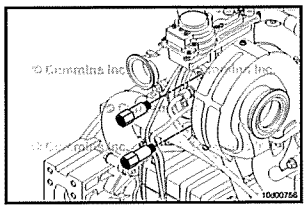
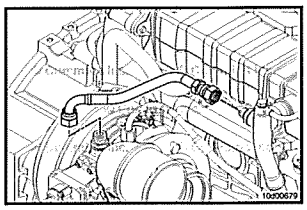
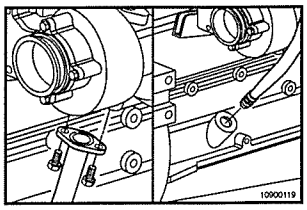
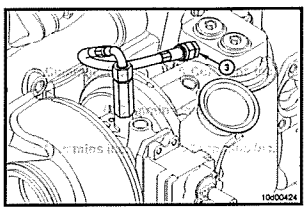


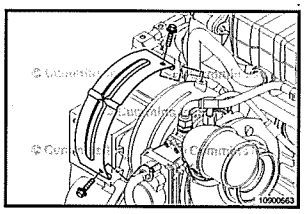
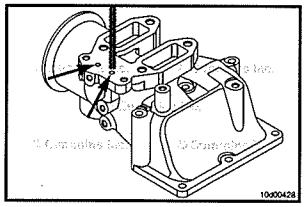
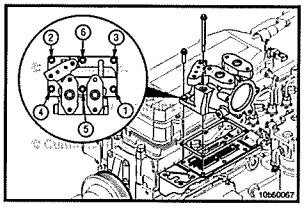
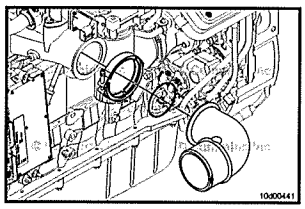
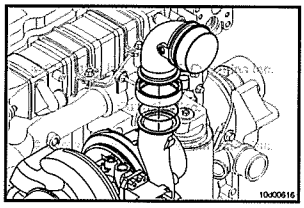
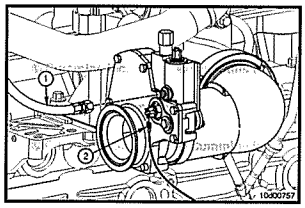
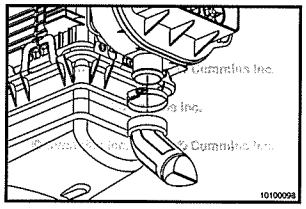
Turbocharger (010-033)

Axial Clearance (HE3xx Variable Geometry)	0.025 mm	MIN	0.001 in
	0.127 mm	MAX	0.005 in



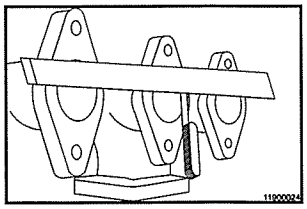
Air Intake System - Group 10 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Inlet Connection (010-022)				
Hose Clamp		8 N•m	[71 in-lb]	
Air Leaks, Air Intake and Exhaust Systems (010-024)				
Air Inlet Clamps		10 N•m	[89 in-lb]	
Turbocharger (010-033)				
Turbocharger Mounting Nuts		55 N•m	[41 ft-lb]	
Turbocharger Coolant Hoses (010-041)				
Turbocharger Bearing Housing Coolant Fitting		35 N•m	[26 ft-lb]	
Turbocharger Coolant Hose Banjo Fitting To Bearing Housing		35 N•m 25 N•m 35 N•m	[26 ft-lb] [221 in-lb] [26 ft-lb]	
Turbocharger Oil Drain Line (010-045)				
Turbocharger Oil Drain Line Capscrews		24 N•m	[212 in-lb]	
Turbocharger Oil Supply Line (010-046)				
Turbocharger Oil Supply Line		36 N•m	[27 ft-lb]	

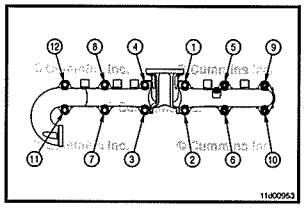
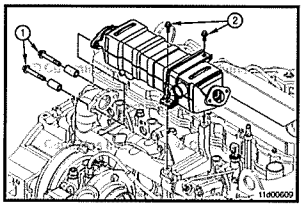
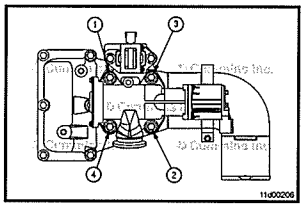
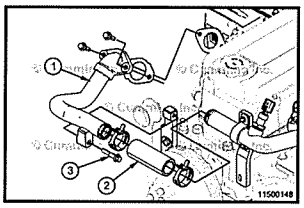
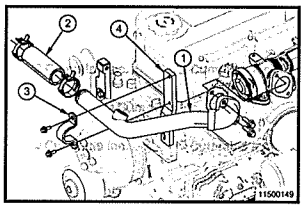
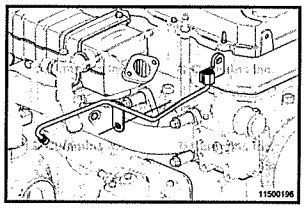
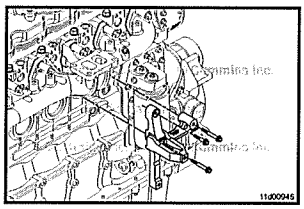
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger Heat Shield (010-076)				
Turbocharger Heat Shield Capscrews		25 N•m	[221 in-lb]	
Air Intake Connection (010-080)				
Pipe Plugs		10 N•m	[89 in-lb]	
Intake Manifold Cover Capscrews		24 N•m	[212 in-lb]	
Air Intake Connection Adapter (010-131)				
Air Intake Connection Adapter V Band Clamp		10 N•m	[89 in-lb]	
Turbocharger Compressor Outlet Connection (010-132)				
Turbocharger Compressor Outlet Connection Clamp.		10 N•m	[89 in-lb]	
Air Shutoff Valve (010-143)				
Intake Air Shutoff Valve Support Bracket Capscrew		24 N•m 20 N•m	[212 in-lb] [177 in-lb]	
Dust Ejection Valve (010-146)				
Dust Ejection Valve Hose Clamp		5 N•m	[44 in-lb]	

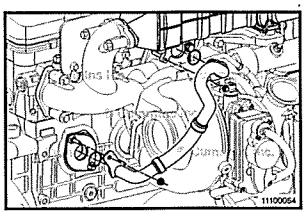
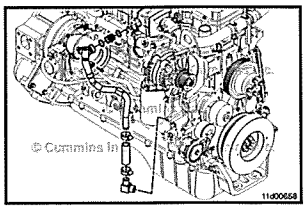
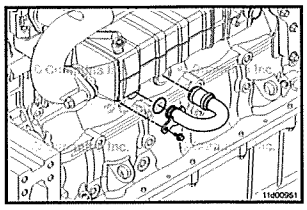
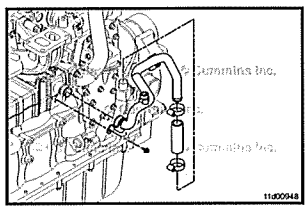
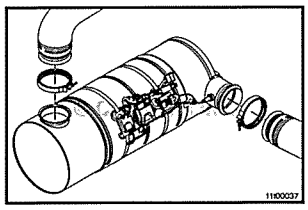
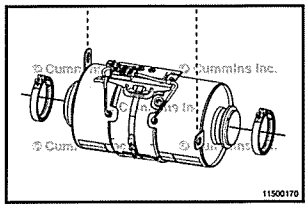
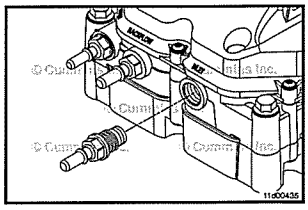
Exhaust System - Group 11 - Specifications

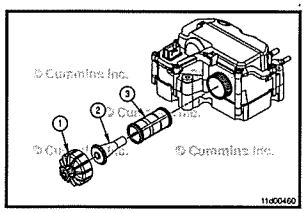
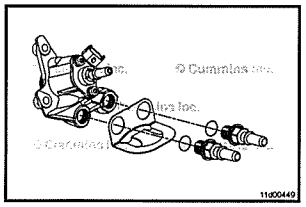
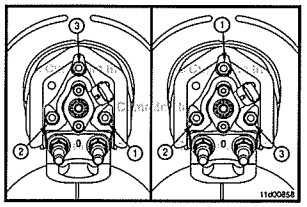
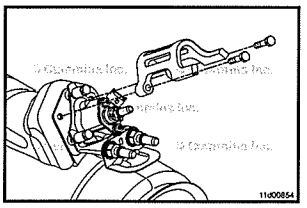
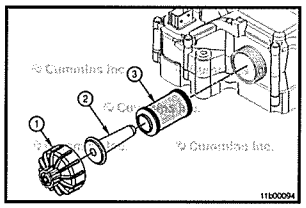
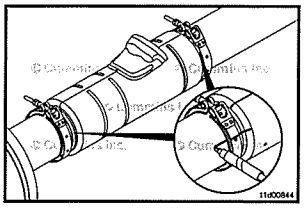
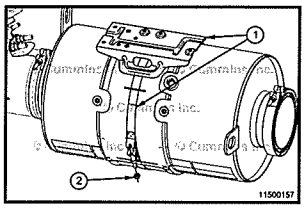
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Exhaust Manifold, Dry (011-007)				
Exhaust Manifold Flatness		0.20 mm	MAX	0.008 in



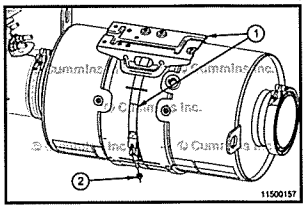
Exhaust System - Group 11 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Exhaust Manifold, Dry (011-007)				
Exhaust Manifold Mounting Capscrews		53 N•m	[39 ft-lb]	
EGR Cooler (011-019)				
Egr Cooler Inlet And Exhaust Capscrews		43 N•m 24 N•m	[32 ft-lb] [212 in-lb]	
EGR Valve (011-022)				
Egr Valve Mounting Capscrews		24 N•m	[212 in-lb]	
EGR Connection Tubes (011-025)				
EGR Connection Tube Brace Capscrew		24 N•m	[212 in-lb]	
Support Brace And EGR Tube Mounting Capscrew		24 N•m 10 N•m	[212 in-lb] [89 in-lb]	
Exhaust Gas Pressure Sensor Tube (011-027)				
Exhaust Gas Pressure Sensor Tube Mounting Fastener		24 N•m 24 N•m 18 N•m	[212 in-lb] [212 in-lb] [159 in-lb]	
EGR Cooler Mounting Bracket (011-029)				
		24 N•m	[212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
EGR Cooler Coolant Lines (011-031)				
Coolant Supply Line To Block Mounting Capscrew		24 N•m 10 N•m	[212 in-lb] [89 in-lb]	
Coolant Return Hose Clamp		5 N•m 10 N•m 10 N•m	[44 in-lb] [89 in-lb] [89 in-lb]	
EGR Cooler Supply Line To Transfer Connection Capscrew		24 N•m 10 N•m 5 N•m	[212 in-lb] [89 in-lb] [44 in-lb]	
EGR Cooler Coolant Return Hose Clamp		5 N•m 10 N•m 10 N•m	[44 in-lb] [89 in-lb] [89 in-lb]	
Aftertreatment Selective Catalytic Reduction (SCR) Catalyst (011-036)				
		55 N•m	[41 ft-lb]	
Aftertreatment Diesel Oxidation Catalyst (011-049)				
V-Band Clamp Inlet		13.5 N•m	[120 in-lb]	
Aftertreatment Diesel Exhaust Fluid Dosing Unit (011-058)				
		4.5 N•m	[40 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		20 N•m	[177 in-lb]	
Aftertreatment Diesel Exhaust Fluid Dosing Valve (011-059)		6 N•m	[53 in-lb]	
		9 N•m	[80 in-lb]	
		9 N•m	[80 in-lb]	
Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter (011-060)				
Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter Equalizing Element Cap		20 N•m	[177 in-lb]	
Aftertreatment Decomposition Tube (011-062)				
V-Band Clamps		14 N•m	[124 in-lb]	
Aftertreatment SCR Catalyst Temperature Sensor Interface Module Mounting Bracket (011-076)				
		7 N•m	[62 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
Aftertreatment Diesel Oxidation Catalyst Temperature Sensor Module Mounting Bracket (011-076)		7 N•m	[62 in-lb]

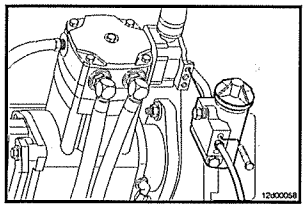


Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

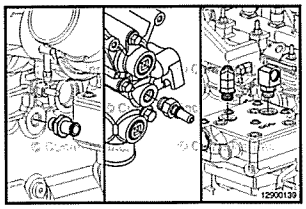
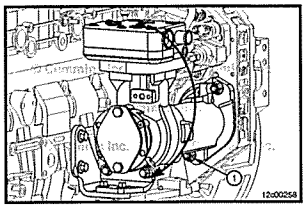
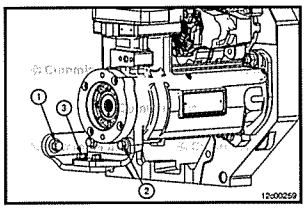
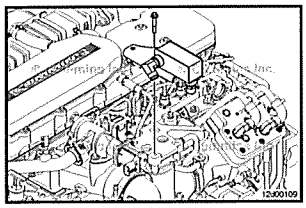
Compressed Air System - Group 12 - Specifications

Air Governor (012-016)

Air Governor Setting	724 kPa	MIN	105 psi
	1000 kPa	MAX	145 psi



Compressed Air System - Group 12 - Torque Values

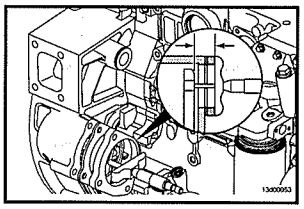
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Compressor Coolant Lines (012-004)				
Air Compressor Coolant Supply Line Fittings		18 N•m 20 N•m 24 N•m	[159 in-lb] [177 in-lb] [212 in-lb]	
Air Compressor (012-014)				
Air Compressor Upper Mounting Capscrews		77 N•m	[57 ft-lb]	
Wabco Air Compressor Mounting Capscrews		24 N•m 43 N•m 77 N•m	[212 in-lb] [32 ft-lb] [57 ft-lb]	
Air Compressor Discharge Lines (012-015)				
Fuel Filter Bracket Mounting Capscrews		24 N•m	[212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

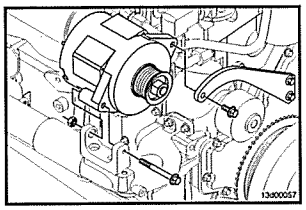
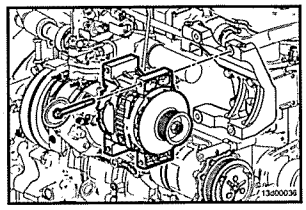
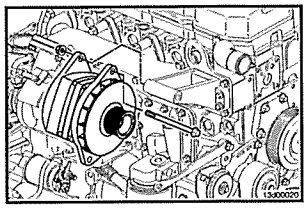
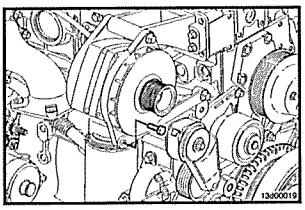
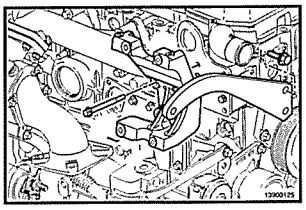
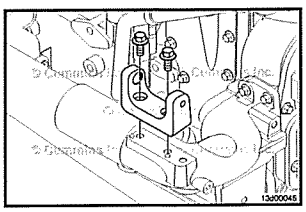
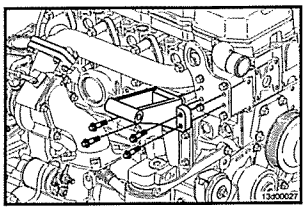
Electrical Equipment - Group 13 - Specifications

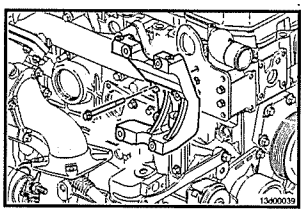
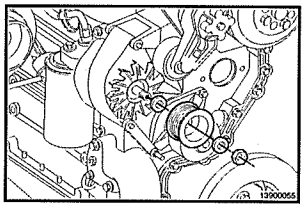
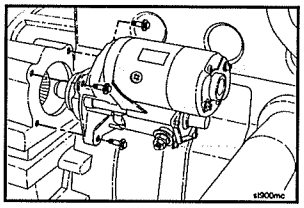
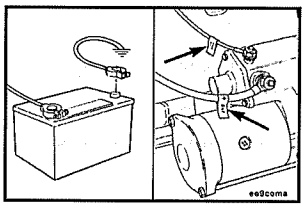
Starting Motor (013-020)

Starting Motor Spacing	49.28 mm	MIN	1.94 in
	52.32 mm	MAX	2.06 in



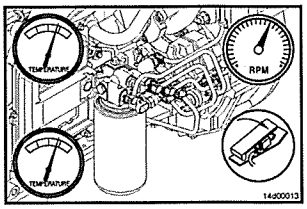
Electrical Equipment - Group 13 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Alternator (013-001)				
Spool Mount Alternator Link Capscrews		40 N•m 24 N•m	[30 ft-lb] [212 in-lb]	
Pad Mount Alternator Capscrews		64 N•m	[47 ft-lb]	
Alternator Capscrew		40 N•m	[30 ft-lb]	
Alternator Link Capscrew		24 N•m	[212 in-lb]	
Alternator Bracket (013-003)				
Alternator Bracket Mounting Capscrews		24 N•m 43 N•m	[212 in-lb] [23 ft-lb]	
Alternatorbracket Mounting Capscrews		54 N•m	[40 ft-lb]	
Alternator Bracket Upper And Lower Mounting Bracket Capscrews		24 N•m 43 N•m	[212 in-lb] [32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Alternator Bracket Mounting Capscrews		45 N•m	[33 ft-lb]	
Alternator Pulley (013-006)				
Alternator Pulley Mounting Fasteners		70 N•m 65 N•m 65 N•m 95 N•m 102 N•m 102 N•m 102 N•m	[52 ft-lb] [48 ft-lb] [48 ft-lb] [70 ft-lb] [75 ft-lb] [75 ft-lb] [75 ft-lb]	
Starting Motor (013-020)				
Starting Motor Mounting Capscrews		43 N•m	[32 ft-lb]	
Starter Motor Electrical Connection		21 N•m	[185 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

Engine Testing - Group 14 - Specifications



Engine Run-in (Engine Dynamometer) (014-006)

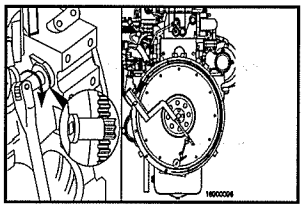
Lubricating Oil Temperature	90 °C	MIN	194 °F
Fuel Temperature	32 °C	MAX	90 °F

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

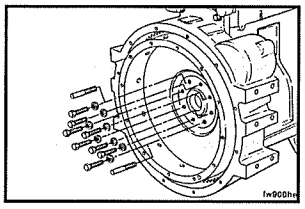
Mounting Adaptations - Group 16 - Specifications

Flywheel (016-005)

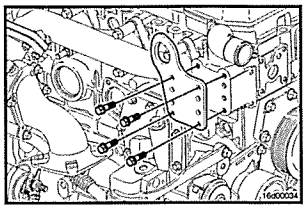
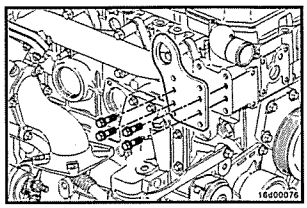
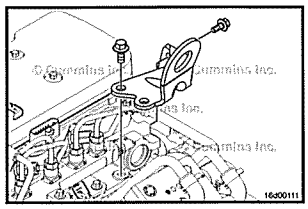
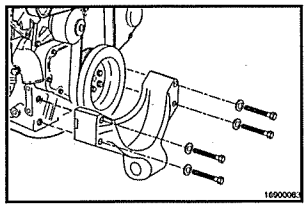
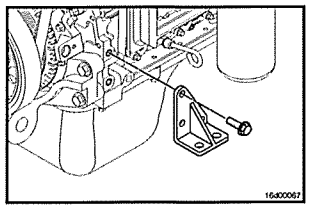
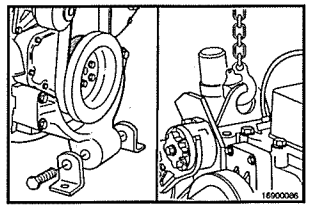
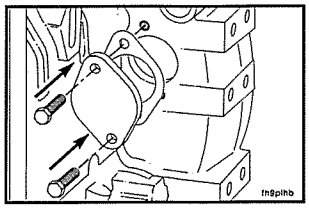
Flywheel Total Indicator Reading	0.127 mm	MAX	0.0050 in

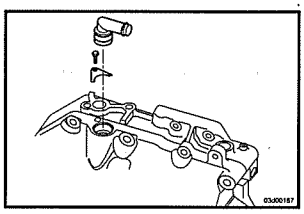
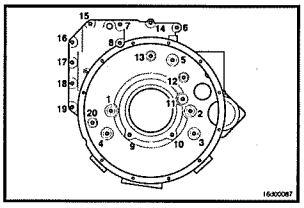
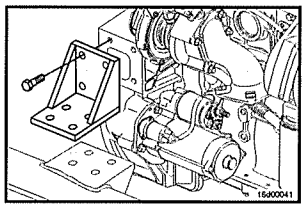


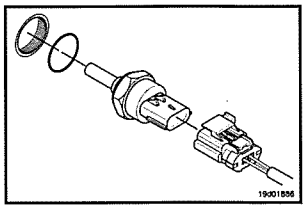
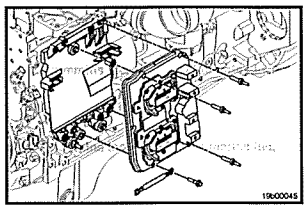
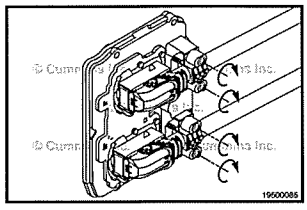
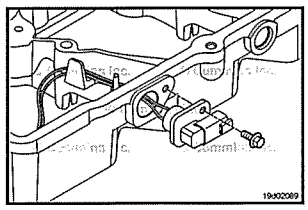
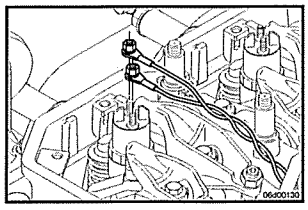
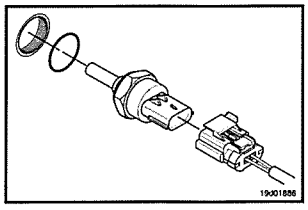
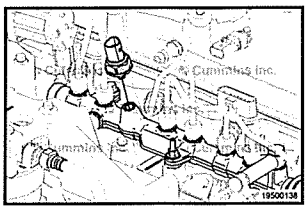
Flywheel Bore Runout	0.127 mm	MAX	0.005 in

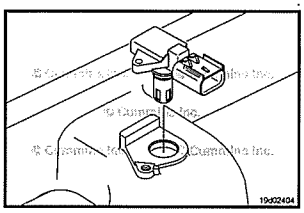
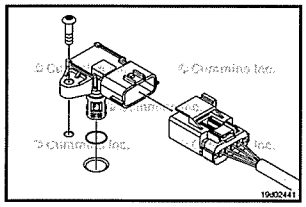
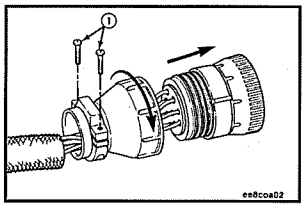
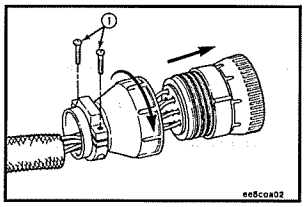
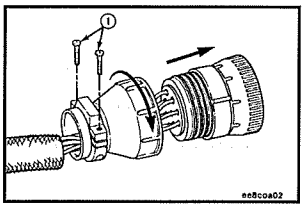
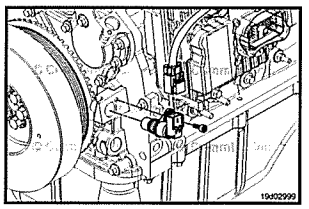
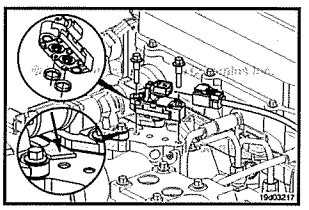


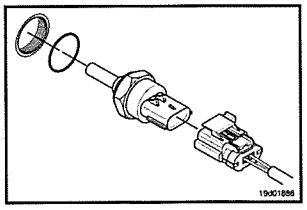
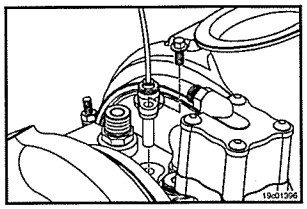
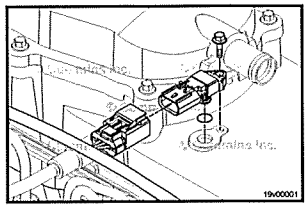
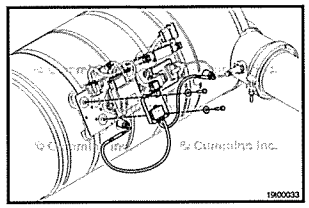
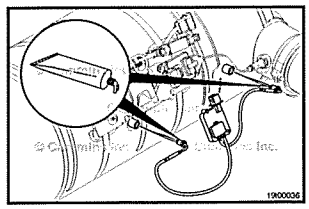
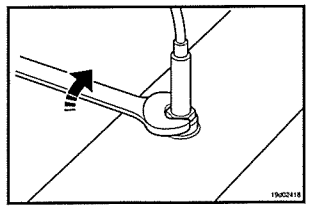
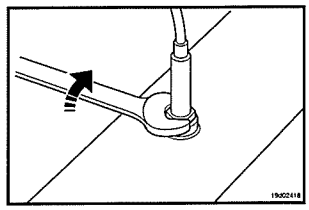
Mounting Adaptations - Group 16 - Torque Values

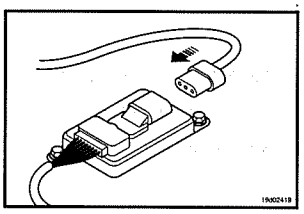
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Lifting Brackets (016-001)				
Front Engine Lifting Bracket (Non Pad-Mounted Alternator)		24 N•m 43 N•m	[212 in-lb] [32 ft-lb]	
Front Engine Lifting Bracket (Pad-Mounted Alternators)		32 N•m	[24 ft-lb]	
Rear Engine Lifting Bracket		43 N•m 77 N•m	[32 ft-lb] [57 ft-lb]	
Engine Support Bracket, Front (016-002)				
Front Mount Engine Support Bracket Mounting Capscrews		80 N•m 115 N•m 125 N•m	[60 ft-lb] [85 ft-lb] [95 ft-lb]	
Side Mount Engine Support Bracket Mounting Capscrews		80 N•m 115 N•m 125 N•m	[60 ft-lb] [85 ft-lb] [95 ft-lb]	
Cummins Engine Support Bracket Mounting Bolts		350 N•m	[258 ft-lb]	
Flywheel Housing (016-006)				
Access Cover Capscrews		24 N•m	[212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Breather Tube Adapter Bracket Capscrew		24 N•m	[212 in-lb]	
Flywheel Housing Capscrew		49 N•m 85 N•m	[36 ft-lb] [63 ft-lb]	
Rear Engine Support Bracket Capscrews		77 N•m	[57 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Electronic Controls - Group 19 - Torque Values				
Engine Coolant Temperature Sensor (019-019)				
Engine Coolant Temperature Sensor		18 N•m	[159 in-lb]	
Engine Control Module (019-031)				
Electronic Control Module (Ecm) Mounting Capscrews		18 N•m	[159 in-lb]	
Engine Wiring Harness (019-043)				
Engine Wiring Harness Ecm Connector		8 N•m	[89 in-lb]	
Internal Actuator Wiring Harness (019-063)				
Internal Wiring Harness Pass-Through Connector		10 N•m	[89 in-lb]	
Injector Pigtail Nuts		1.25 N•m	[11 in-lb]	
Engine Oil Pressure Sensor/Switch (019-066)				
Engine Oil Pressure Sensor		14 N•m 24 N•m	[124 in-lb] [212 in-lb]	
Rail Fuel Pressure Sensor (019-115)				
Rail Fuel Pressure Sensor		70 N•m	[52 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Ambient Air Temperature Sensor (019-134)				
Ambient Air Tempurature/Barometric Pressure Sensor		6 N•m	[53 in-lb]	
Intake Manifold Pressure/Temperature Sensor (019-159)				
Intake Manifold Pressure/Temperature Sensor		7 N•m	[62 in-lb]	
Deutsch HD10 Connector Series (019-207)				
		1 N•m	[9 in-lb]	
Deutsch HDP20 and HD30 Connector Series (019-208)				
Clamp Capscrews		1 N•m	[9 in-lb]	
Clamp Capscrews		1 N•m	[9 in-lb]	
Crankshaft Position Sensor (019-365)				
Crankshaft Position Sensor		10 N•m	[89 in-lb]	
EGR Differential Pressure Sensor (019-370)				
Egr Valve Differential Pressure Sensor		25 N•m	[221 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
EGR Temperature Sensor (019-378)				
Egr Temperature Sensor		34 N•m	[25 ft-lb]	
Turbocharger Speed Sensor (019-390)				
Turbocharger Speed Sensor Capscrew		9 N•m	[80 in-lb]	
Crankcase Pressure Sensor (019-445)				
Crankcase Pressure Sensor Mounting Capscrew		7 N•m	[62 in-lb]	
Aftertreatment Exhaust Gas Temperature Sensor (019-449)				
Exhaust Gas Temperature Sensor Probe Nut		14 N•m	[124 in-lb]	
Exhaust Gas Temperature Sensor Probe Nut		30 N•m	[22 ft-lb]	
Aftertreatment Outlet NOx Sensor (019-451)				
Nox Sensor Installation Torque		50 N•m	[37 ft-lb]	
Aftertreatment Intake NOx Sensor (019-463)				
Intake Nox Sensor		50 N•m	[37 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Intake Nox Sensor		14.4 N•m	[127 in-lb]	

General Engine

Specifications

Listed below are the general specifications for this engine.

Horsepower.....Reference the engine dataplate
Bore and Stroke.....107 mm [4.21 in] X 124 mm [4.88 in]
Displacement.....6.7 liters [409 C.I.D.]
Firing Order.....1-5-3-6-2-4
Approximate Engine Dry Weight (with standard accessories).....520 kg [1146 lb]
Crankshaft Rotation (viewed from the front of the engine).....Clockwise
Valve Clearance:
Intake.....0.254 mm [0.010 in]
Exhaust.....0.508 mm [0.020 in]
Maximum Overspeed Capability (15 seconds maximum).....3750 rpm
Minimum Ambient Air Temperature for Unaided Cold Start[1] .....-31°C [-24°F]
Minimum Ambient Air Temperature with Cold Starting Aid[2] .....-40°C [-40°F]
Minimum Engine Cranking Speed.....120 rpm
Engine Idle Speed.....Minimum 700 rpm to maximum 1200 rpm
Altitude Limit Before Derate is Applied.....3658 m [12,000 ft]

1. Engines covered by this manual meeting regulations for Tier 4 Final/Stage IV **must** be equipped with an intake air grid heater. Refer to Procedure 010-029 in Section 10.

2. Available cold starting aids include a block heater and an oil pan heater.

Fuel System

Specifications

For performance and fuel rate values, refer to the Engine Data Sheet.

Maximum Fuel Inlet Restriction (vacuum)*.....305 mm-hg [12 in-hg]
Rail Pressure Operating Range.....250 to 2200 bar [3626 to 31,908 psi]
Fuel Pressure Range at Fuel Filter Inlet and Outlet (Engine Cranking).....255 to 606 kPa [37 to 88 psi]
Fuel Pressure Range at Fuel Filter Inlet and Outlet (Engine Running).....255 to 758 kPa [37 to 110 psi]
Maximum Pressure Drop across Fuel Filter.....81 kPa [11.7 psi]
Maximum Fuel Drain Line Restriction.....19 kPa [2.7 psi]
Maximum Fuel Inlet Temperature.....80°C [176°F]

* Inlet restriction measured at the fuel gear pump inlet using a diagnostic test line and methods outlined in the following procedure. Refer to Procedure 006-020 in Section 6.

Lubricating Oil System

Specifications

Oil Pressure
- Low Idle (minimum allowed)....69 kPa [10 psi]
- At Rated Speed (minimum allowed)....207 kPa [30 psi]

Oil Regulating Valve Opening Pressure Range....448 kPa [65 psi] to 517 kPa [75 psi]
Oil Filter Differential Pressure to Open Bypass....345 kPa [50 psi]

Lubricating Oil Capacity of Standard Engine (Standard Oil Pan)
- Pan **Only** ....14.2 liters [15 qt]
- Total System....16.7 liters [17.6 qt]
- High to Low (on dipstick)....1.9 liters [2 qt]

Lubricating Oil Filter Capacity....0.950 liters [1 qt]

Lubricating Oil Capacity of Standard Engine (High Capacity Oil Pan)
- Pan **Only** ....17.2 liters [18.5 qt]
- Total System....19.7 liters [20.8 qt]
- High to Low (on dipstick)....2.8 liters [3 qt]

Lubricating Oil Filter Capacity....0.950 liters [1 qt]
Maximum Oil Temperature....138°C [280°F]

NOTE: If the type/oil capacity of each pan is **not** known:

- Contact a Cummins® Distributor/Dealer
- Determine the capacity of the oil pan option for the engine being serviced by using QuickServe™ Online and the engine serial number.
- Fill the lubricating oil pan to the smallest oil pan capacity listed for the engine being serviced. Then add 0.95 liters [1 qt] of oil at a time until it reaches the high mark on the dipstick. Record the number of liters/quarts added, so the capacity is known the next time the oil is drained.

Cooling System

Specifications

Coolant Capacity (Includes block, cylinder head, water pump volute, EGR cooler, and EGR plumbing)....11.5 liters [3.0 gal]
Standard Modulating Thermostat - Range.....86 to 97°C [186 to 207°F]
Maximum Allowed Operating Temperature.....107°C [225°F]
Minimum Recommended Operating Temperature.....71°C [160°F]
Minimum Recommended Pressure Cap.....90 kPa [13 psi]
Maximum Recommended Pressure Cap.....172 kPa [25 psi]

Air Intake System

Specifications

Maximum Intake Restriction (clean air filter element).....381 mm H_2O [15.0 in H_2O]
Maximum Intake Restriction (dirty air filter element).....635 mm H_2O [25.0 in H_2O]

Exhaust System

Specifications

Maximum Exhaust Restriction:

Exhaust System.....180 mm Hg [7 in Hg]

1 See the following procedure for more information. Refer to Procedure 011-009 in Section 11.

Electrical System

Specifications

Recommended Battery Capacity

System Voltage		Ambient Temperature		
-18°C [0°F]		-29°C [-20°F]		
	Cold Cranking Amperes	Reserve Capacity (minutes)[1]	Cold Cranking Amperes	Reserve Capacity (minutes)[1]
6 cylinder engines				
12-VDC	1500	260	1900	260
24-VDC[2]	750	130	950	130
4 cylinder engines				
12-VDC	1200	260	1500	260
24-VDC[2]	600	260	750	260
[1] The number of plates within a given battery size determines reserve capacity. Reserve capacity is the length of time for which a battery at 27°C [81°F] can supply 25 amperes at 10.5-VDC or greater.				
[2] Cold cranking amp(s)(CCA) ratings are based on two 12-VDC batteries in series.				

Batteries (Specific Gravity)

Specific Gravity at 27°C [81°F]	State of Charge
1.260 to 1.280	100%
1.230 to 1.250	75%
1.200 to 1.220	50%
1.170 to 1.190	25%
1.110 to 1.130	Discharged

Compressed Air System

Specifications

Air Compressor Part Number 3971519

Compressor Manufacturer/Model....Knorr-Bremse™ / 225CC
Number of Cylinders....1
Piston Displacement....225 cm [13.7 C.I.D.]
Bore....80 mm [3.15 in]
Stroke....45 mm [1.77 in]
Drive Ratio....1:1
Cooling....Water
Lubrication....Engine lubricating oil
Height, Overall (approximate)....262.03 mm [10.32 in]
Width, Overall (approximate)....Head: 116.8 mm [4.60 in]; Crankcase: 174 mm [6.85 in]
Length, Overall (approximate)....150 mm [5.91 in]
Weight (approximate)....9.613 kg [21.193 lb]

Plumbing Line Sizes

Coolant Inlet and Outlet....M16 x 1.5
Air Inlet....M26 x 1.5 x 16 Deep
Air Outlet....M22 x 1.5 x 15 Deep

Air Compressor Part Number 5301082

Compressor Manufacturer/Model....Wabco™ / 18.7 CFM
Number of Cylinders....1
Piston Displacement....318 cm [19.4 C.I.D.]
Bore....85 mm [3.35 in]
Stroke....56 mm [2.20 in]
Drive Ratio....1:1
Cooling....Water
Lubrication....Engine lubricating oil
Height, Overall (approximate)....304.75 mm [12.00 in]
Width, Overall (approximate)....Head: 144.1 mm [17.37 in]; Crankcase: 174 mm [6.85 in]
Length, Overall (approximate)....201 mm [7.91 in]
Weight (approximate)....16.423 kg [36.206 lb]

Plumbing Line Sizes

Coolant Inlet and Outlet....¾ - 16 UNF
Air Inlet....25.4 mm [1 in]
Air Outlet....M27 x 2
Unloader Port....M10 x 1
Governor Mounting Direct....M8 x 1.25

Air Compressor Part Number 5301080

Compressor Manufacturer/Model....Wabco™ / 18.7 CFM
Number of Cylinders....1
Piston Displacement....318 cm [19.4 C.I.D.]
Bore....85 mm [3.35 in]
Stroke....56 mm [2.20 in]
Drive Ratio....1:1
Cooling....Water
Lubrication....Engine lubricating oil
Height, Overall (approximate)....294.9 mm [11.61 in]
Width, Overall (approximate)....Head: 179.1 mm [7.05 in]; Crankcase: 137 mm [5.39 in]
Length, Overall (approximate)....334.5 mm [13.17 in]
Weight (approximate)....19.402 kg [42.774 lb]

Plumbing Line Sizes

Coolant Inlet and Outlet....¾ - 16 UNF
Air Inlet....25.4 mm [1 in]
Air Outlet....M27 x 2
Unloader Port....M10 x 1
Governor Mounting Direct....M8 x 1.25

Air Compressor Part Number 4940190

Compressor Manufacturer/Model....Knorr-Bremse™ / 225CC
Number of Cylinders....1
Piston Displacement....225 cm [13.7 C.I.D.]
Bore....80 mm [3.15 in]

Stroke.....45 mm [1.77 in]
Drive Ratio.....1:1
Cooling.....Water
Lubrication.....Engine lubricating oil
Height, Overall (approximate).....261.95 mm [10.31 in]
Width, Overall (approximate).....Head: 116.8 mm [4.60 in]; Crankcase: 174 mm [6.85 in]
Length, Overall (approximate).....160.6 mm [6.32 in]
Weight (approximate).....11.110 kg [24.493 lb]

Plumbing Line Sizes

Coolant Inlet and Outlet.....M16 x 1.5
Air Inlet.....M26 x 1.5 x 16 Deep
Air Outlet.....M22 x 1.5 x 15 Deep

Diesel Exhaust Fluid Recommendations and Specifications

General Information

⚠WARNING⚠

It is unlawful to tamper with or remove any component of the aftertreatment system. It is also unlawful to use a Diesel Exhaust Fluid (DEF) that does not meet the specifications provided or to operate the vehicle/ equipment with no Diesel Exhaust Fluid (DEF).

⚠WARNING⚠

Diesel Exhaust Fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow internally. In the event the diesel exhaust fluid is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

△CAUTION△

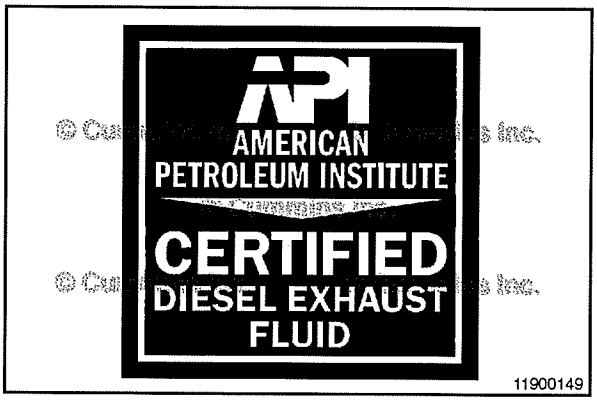
Never attempt to create Diesel Exhaust Fluid by mixing agricultural grade urea with water. Agricultural grade urea does not meet the necessary specifications required and the aftertreatment system may be damaged.

Cummins Inc. requires the use of Diesel Exhaust Fluid meeting ISO 22241-1. There is NO acceptable substitute.

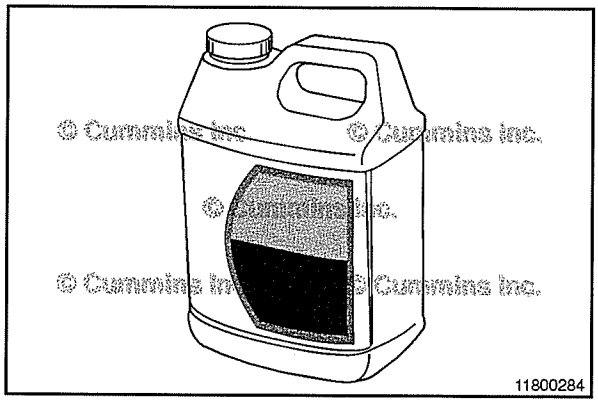
NOTE: Some locations may reference the DIN 70070 standard. Diesel Exhaust Fluid specification limits of this standard are identical to ISO 22241-1.

Cummins Inc. is not responsible for failures or damage resulting from what Cummins Inc. determines to be abuse or neglect, including but not limited to: operation without correctly specified Diesel Exhaust Fluid; lack of maintenance of aftertreatment; improper storage, or shutdown practices; unauthorized modifications of the engine and aftertreatment. Cummins is also not responsible for failures caused by incorrect Diesel Exhaust Fluid or by water, dirt or other contaminants in the Diesel Exhaust Fluid

For further details and discussion of Diesel Exhaust Fluid (DEF) for Cummins® engines. Refer to the Diesel Exhaust Fluid Specifications for Cummins® Selective Catalytic Reduction Systems, Service Bulletin Number 4021566.



For engines using SCR operating in the United States and Canada, it is also strongly recommended that the Diesel Exhaust Fluid (DEF) used be certified by the American Petroleum Institute (API). This would be indicated by a symbol on the container/dispensing system as shown.



To ensure the correct Diesel Exhaust Fluid (DEF) is used, Cummins Inc. recommends the use of Fleetguard® Diesel Exhaust Fluid. Fleetguard® carries different quantity options from small to bulk containers.

For customers located in the United States and Canada, for assistance locating Diesel Exhaust Fluid (DEF), contact the Cummins Customer Assistance Center: 1-800 DIESELS (1-800-343-7357).

For customers outside of the United States and Canada, contact you local Cummins authorized repair location for assistance in locating Diesel Exhaust Fluid (DEF).

The following are other common names used for Diesel Exhaust Fluid (DEF):

- Urea
- AUS 32 (Aqueous Urea Solution 32)
- AdBlue
- NOx Reduction Agent
- Catalyst Solution
- DEF

Regardless of what the Diesel Exhaust Fluid is called, the Diesel Exhaust Fluid must meet the specifications as outlined in the General Information section of this procedure.

Storage

NOTE: The following information is for reference and is to be used as a guideline only. There are many factors that determine Diesel Exhaust Fluid (DEF) shelf life, with temperature and duration being two of the major determining contributors. If in doubt, check the concentration of the Diesel Exhaust Fluid (DEF), refer to the Test step of this procedure, or replace the fluid with known quality Diesel Exhaust Fluid.

Diesel Exhaust Fluid has a limited shelf life, both in the vehicle's diesel exhaust fluid tank and in storage/bulk/ transportation containers.

The following conditions are ideal for maintaining DEF quality and shelf life during prolonged transportation and storage:

- Storage temperature between 23°F and 77°F (-5°C and 25°C)
- Store in sealed containers to avoid contamination
- Avoid direct sunlight

In these conditions, DEF has a minimum expected shelf life of 18 months. If stored at higher temperatures for extended periods of time, the shelf life will be reduced by approximately 6 months for every 5°C [9°F] above the highest storage temperature listed above.

Long term storage in a vehicle (in excess of 6 months) is not recommended. If long term storage is necessary, periodic testing of the Diesel Exhaust Fluid is recommended to be performed to ensure the concentration does not fall out of specification. Follow the Test step of this procedure.

NOTE: To assist in preventing Diesel Exhaust Fluid from deteriorating when stored in the vehicles DEF tank, locate and plug the tanks venting to seal the tank exposure to the atmosphere.

Handling

Diesel Exhaust Fluid is not harmful to handle, but can be corrosive to certain materials over time. Such as carbon steels, iron, zinc, nickel, copper, aluminum and magnesium.

- Make sure to only use approved containers to transport and store Diesel Exhaust Fluid. Containers made of polyethylene and polypropylene are recommended.
- If Diesel Exhaust Fluid is spilled, rinse and clean immediately with water.
- Avoid prolonged contact with skin. In case of contact, wash with immediately with soap and water. If not washed immediately, when the diesel exhaust fluid dries, a white film will be left that can be more difficult to wash off.

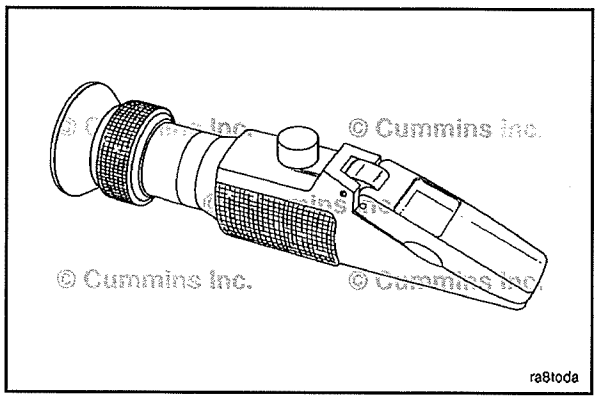
NOTE: Spilled Diesel Exhaust Fluid if left to dry or wiped away with a cloth only will leave a white residue. Failure to clean the spilled Diesel Exhaust Fluid may result in an incorrectly diagnosed leak of the Diesel Exhaust Fluid Dosing system.

Before using containers, funnels, etc. that will be used to dispense, handle or store Diesel Exhaust Fluid, make sure to wash thoroughly to remove any contaminants and then rinse with distilled water.

NOTE: Do not use tap water to rinse components that will be used to deliver diesel exhaust fluid. Tap water will contaminate the Diesel Exhaust Fluid. If distilled water is not available, rinse with tap water and then rinse with Diesel Exhaust Fluid.

Disposal

If disposing of Diesel Exhaust Fluid (DEF), always check with the local authority regulations on proper disposing process and requirements.



Test

Having the correct concentration of Diesel Exhaust Fluid is critical to the engine and aftertreatment system performing correctly.

To test the concentration of the Diesel Exhaust Fluid, use the Cummins Diesel Exhaust Fluid Refractometer, service tool part number 4919554. Follow the instructions provided with the service tool.

Percent Urea Concentration: 32.5 +/- 1.5%

The specification listed above takes into consideration the refractometer tool tolerances, varibility, and calibration when measuring Diesel Exhaust Fluid concentration.

If the Diesel Exhaust Fluid concentration is found to be outside of this specification, drain the Diesel Exhaust Fluid tank, flush with distilled water and fill with new and/or known good Diesel Exhaust Fluid. Recheck the Diesel Exhaust Fluid concentration.

Concentration of the Diesel Exhaust Fluid should be checked when:

- The vehicle has been stored for an extended period of time.
- It is suspected that water has been added to the Diesel Exhaust Fluid tank

Contamination/Incorrect Fluid

⚠CAUTION⚠

Never add water or any other fluid besides what is specified to the Diesel Exhaust Fluid (DEF) tank. The aftertreatment system may be damaged.

In the event that the incorrect fluid is added to the Diesel Exhaust Fluid tank, such as, but not limited to:

- Water
- Diesel Fuel
- Hydraulic Fluid
- Coolant
- Windshield Washer Fluid

Contact a local Cummins Authorized Repair location to determine the appropriate repair direction.

If only water has been added to the Diesel Exhaust Fluid (DEF) tank, drain the Diesel Exhaust Fluid (DEF) tank, flush with distilled water and refill with new and/or known good Diesel Exhaust Fluid (DEF). Check the Diesel Exhaust Fluid (DEF) concentration after completing the refill, follow to the Test step of this procedure.

Freezing

⚠CAUTION⚠

Do NOT add any chemicals/additives to the Diesel Exhaust Fluid in an effort to prevent freezing. If chemicals/ additives are added to the Diesel Exhaust Fluid, the aftertreatment system may be damaged.

Diesel Exhaust Fluid will freeze around -11°C [12°F]. The diesel exhaust fluid system on the vehicle is designed to accommodate this and does not require any intervention by the vehicle operator.

The Operating the Engine (101-015) procedure in Section 1 of the Owners and Operation and Maintenance Manual will provide information on proper cold weather set up for your engine/vehicle.

Drive Belt Tension

Tension Chart

SAE Belt Size	Belt Tension Gauge Part No.		Belt Tension New		Belt Tension Range Used*	
	Click-type	Burroughs	N	lbf	N	lbf
0.380 in	3822524		620	140	270 to 490	60 to 110
0.440 in	3822524		620	140	270 to 490	60 to 110
1/2 in	3822524	ST-1138	620	140	270 to 490	60 to 110
11/16 in	3822524	ST-1138	620	140	270 to 490	60 to 110
3/4 in	3822524	ST-1138	620	140	270 to 490	60 to 110
7/8 in	3822524	ST-1138	620	140	270 to 490	60 to 110
4 rib	3822524	ST-1138	620	140	270 to 490	60 to 110
5 rib	3822524	ST-1138	670	150	270 to 530	60 to 120
6 rib	3822525	ST-1293	710	160	290 to 580	65 to 130
8 rib	3822525	ST-1293	890	200	360 to 710	80 to 160
10 rib	3822525	3823138	1110	250	440 to 890	100 to 200
12 rib	3822525	3823138	1330	300	530 to 1070	120 to 240
12 rib K section	3822525	3823138	1330	300	890 to 1070	200 to 240
31 rib	-	3164750	1668	375	1330 to 1560	300 to 350

NOTE: This chart does not apply to automatic belt tensioners.

* A belt is considered used if it has been in service for ten minutes or longer.

* If used belt tension is less than the minimum value, tighten the belt to the maximum used belt value.

Fraction, Decimal, Millimeter Conversions

Conversion Chart

Fraction	inch	mm	Fraction	inch	mm
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.778	39/64	0.6094	15.478
1/8	0.1250	3.175	5/8	0.6250	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.859
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	0.2500	6.350	3/4	0.7500	19.050
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7969	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	0.3750	9.525	7/8	0.8750	22.225
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.019
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	0.5000	12.700	1	1.0000	25.400

Conversion Factor: 1 inch = 25.4 mm

Weights and Measures - Conversion Factors

Conversion Chart

Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbreviation	Unit Name	Abbreviation		
Area	sq. inch	in^2	sq. millimeters	mm^2	645.16	0.001550
			sq. centimeters	cm^2	6.452	0.155
	sq. foot	ft^2	sq. meter	m^2	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H_2O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H_2O	millimeters of water	mm H_2O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32) ÷1.8	(1.8 x °C) +32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in^3	liter	l	0.01639	61.02545
	cubic inch	in^3	cubic centimeter	cm^3	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

Newton-Meter to Foot-Pound Conversions

Conversion Chart

N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1	9 in-lb	55	41	155	114
5	44 in-lb	60	44	160	118
6	53 in-lb	65	48	165	122
7	62 in-lb	70	52	170	125
8	71 in-lb	75	55	175	129
9	80 in-lb	80	59	180	133
10	89 in-lb	85	63	185	136
11	97 in-lb	90	66	190	140
12	106 in-lb	95	70	195	144
14	124 in-lb	100	74	200	148
15	133 in-lb	105	77	205	151
16	142 in-lb	110	81	210	155
18	159 in-lb	115	85	215	159
20	15 ft-lb	120	89	220	162
25	18	125	92	225	165
30	22	130	96	230	170
35	26	135	100	235	173
40	30	140	103	240	177
45	33	145	107	245	180
50	37	150	111	250	184
NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.					

Capscrew Markings and Torque Values

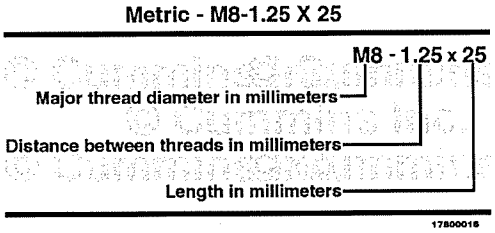
General Information

⚠CAUTION⚠

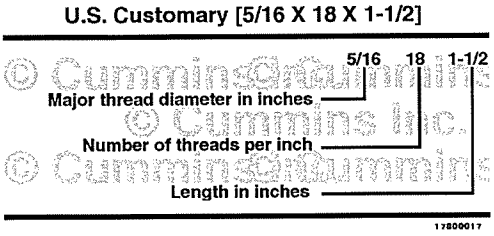
When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

Metric capscrews and nuts are identified by the grade number stamped on the head of the capscrew or on the surface of the nuts. U.S. Customary capscrews are identified by radial lines stamped on the head of the capscrew.

The following examples indicate how capscrews are identified:



- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.
- When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

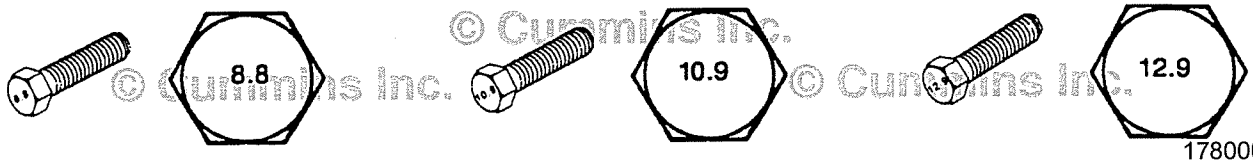


- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.
- When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

Capscrew Markings and Torque Values - Metric

Commercial Steel Class

8.8	10.9	12.9
Capscrew Head Markings		



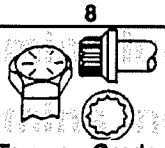
Body Size	Torque				Torque				Torque			
Diameter	Cast Iron		Aluminium		Cast Iron		Aluminium		Cast Iron		Aluminium	
mm	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
6	9	5	7	4	13	10	7	4	14	9	7	4
7	14	9	11	7	18	14	11	7	23	18	11	7

Body Size	Torque				Torque				Torque			
Diameter	Cast Iron		Aluminium		Cast Iron		Aluminium		Cast Iron		Aluminium	
mm	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
8	23	17	18	14	33	25	18	14	40	29	18	14
10	45	33	30	25	65	50	30	25	70	50	30	25
12	80	60	55	40	115	85	55	40	125	95	55	40
14	125	90	90	65	180	133	90	65	195	145	90	65
16	195	140	140	100	280	200	140	100	290	210	140	100
18	280	200	180	135	390	285	180	135	400	290	180	135
20	400	290	—	—	550	400	—	—	—	—	—	—

Capscrew Markings and Torque Values - U.S. Customary

SAE Grade Number 5 8

Capscrew Head Markings
These are all SAE Grade 5 (3 line)



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Capscrew Torque - Grade 5 Capscrew

Capscrew Body Size	Cast Iron		Aluminium		Cast Iron		Aluminium	
	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1/4 - 20	9	7	8	6	15	11	8	6
1/4 - 28	12	9	9	7	18	13	9	7
5/16 - 18	20	15	16	12	30	22	16	12
5/16 - 24	23	17	19	14	33	24	19	14
3/8 - 16	40	30	25	20	55	40	25	20
3/8 - 24	40	30	35	25	60	45	35	25
7/16 - 14	60	45	45	35	90	65	45	35
7/16 - 20	65	50	55	40	95	70	55	40
1/2 - 13	95	70	75	55	130	95	75	55
1/2 - 20	100	75	80	60	150	110	80	60
9/16 - 12	135	100	110	80	190	140	110	80
9/16 - 18	150	110	115	85	210	155	115	85
5/8 - 11	180	135	150	110	255	190	150	110
5/8 - 18	210	155	160	120	290	215	160	120
3/4 - 10	325	240	255	190	460	340	255	190
3/4 - 16	365	270	285	210	515	380	285	210
7/8 - 9	490	360	380	280	745	550	380	280
7/8 - 14	530	390	420	310	825	610	420	310
1 - 8	720	530	570	420	1100	820	570	420
1 - 14	800	590	650	480	1200	890	650	480

Pipe Plug Torque Values

Torque Table

Size		Torque		Torque	
Thread	Actual Thread O.D.	In Aluminum Components		In Cast Iron or Steel Components	
in	**in**	**N•m**	**ft-lb**	**N•m**	**ft-lb**
1/16	0.32	5	45 in-lb	15	10
1/8	0.41	15	10	20	15
1/4	0.54	20	15	25	20
3/8	0.68	25	20	35	25
1/2	0.85	35	25	55	40
3/4	1.05	45	35	75	55
1	1.32	60	45	95	70
1-1/4	1.66	75	55	115	85
1-1/2	1.90	85	65	135	100

Tap-Drill Chart - U.S. Customary and Metric

General Information

NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

Tap Size		Drill Size
60%	75%	
		48
		1.95mm
		5/64
	3-48	47
		2.00mm
	M2.5x.45	2.05mm
		46
3-48	3056	45
		2.10mm
M2.5x.45	M2.6x.45	2.15mm
3-56	4-36	44
		2.20mm
M2.6x.45		2.25mm
4-36	4-40	43
		2.30mm
		2.35mm
4-40	4-48	42
		3/32
	M3x.6	2.40mm
4-48		41
		2.45mm
		40
M3x.6	M3x.5	2.50mm
		39
	5-40	38
M3x.5		2.60mm
5-40	5-44	37
		2.70mm
5-44	6-32	36
		2.75mm
		7/64
		35
		2.80mm
		34
6-32	6-40	33
	M3.5x6	2.90mm
		32
M3.5x6		3.00mm
6-40		31
		3.10mm
		1/8
		3.20mm
	M4x.75	3.25mm
		30
	M4x.7	3.30mm
M4x.75		3.40mm
M4x.7	8-32	29
		3.50mm
	8-36	28
8-32		9/64
		3.60mm
8-36		27
		3.70mm
		26
	M4.5x.75	3.75mm
	10-24	25
		3.80mm
		24
M4.5x.75		3.90mm
		23
		5/32
10-24		22
	M5x1	4.00mm
	10-32	21
		20
	M5x.9	4.10mm
M5x1	M5x.8	4.20mm
10-32		19
M5x.9		4.25mm
M5x.8		4.30mm
		18
		11/64
		17

Tap Size		Drill Size
60%	75%	
		4.40mm
	12-24	16
		4.50mm
		15
	M5.5x.9	4.60mm
12-24	12-28	14
		13
		4.70mm
M5.5x.9		4.75mm
12-28		3/16
		12
		4.80mm
		11
		4.90mm
		10
		9
	M6x1	5.00mm
		8
		5.10mm
	1/4-20	7
		13/64
		6
M6x1		5.20mm
		5
	M6x.75	5.25mm
		5.30mm
1/4-20		4
M6x.75		5.40mm
	1/4-28	3
		5.50mm
		7/32
		5.60mm
1/4-28		2
		5.70mm
		5.75mm
		1
		5.80mm
		5.90mm
		A
		15/64
	M7x1	6.00mm
		B
		6.10mm
		C
M7x1		6.20mm
		D
	M7x.75	6.25mm
		6.30mm
		E
		1/4
M7x.75		6.40mm
		6.50mm
	5/16-18	F
		6.60mm
		G
		6.70mm
		17/64
	M8x1.25	6.75mm
5/16-18		H
		6.80mm
		6.90mm
	5.16-24	I
M8x1.25	M8x1	7.00mm
		J
		7.10mm
5/16-24		K
		9/32
M8x1		7.20mm
		7.25mm
		7.30mm
		L
		7.40mm
		M

Tap Size		Drill Size
60%	75%	
		7.50mm
		19/64
		7.60mm
		N
		7.70mm
	M9x1.25	7.75mm
		7.80mm
		7.90mm
	3/8-16	5/16
M9x1.25	M9x1	8.00mm
		O
		8.10mm
M9x1		8.20mm
		P
		8.25mm
		8.30mm
3/8-16	1/8-27NPT	21/64
		8.40mm
	3/8-24	Q
	M10x1.5	8.50mm
		8.60mm
		R
3/8-24		8.70mm
1/8-27NPT		11/32
	M10x1.25	8.75mm
M10x1.5		8.80mm
		S
		8.90mm
M10x1.25	M10x1	9.00mm
		T
		9.10mm
		23/64
M10x1		9.20mm
		9.30mm
	7/16-14	U
		9.40mm
	M11x1.5	9.50mm
		3/8
		V
		9.60mm
		9.70mm
		9.75mm
M11x1.5		9.80mm
7/16-14		W
		9.90mm
	7/16-20	25/64
		10.00mm
7/16-20		X
	M12x1.75	10.20mm
		Y
		13/32
		Z
M12x1.75	M12x1.5	10.50mm
	1/2-13	27/64
M12x1.5	M12x1.25	10.75mm
M12x1.25		11.00mm
1/2-13		7/16
1/4-18NPT		
		11.25mm
		11.50mm
		29/64
		11.75mm
		11.50mm
	1/2-20	29/64
	9/16-12	15/32
	M14x2	12.00m
		12.25mm
9/16-12		31/64
M14x2	M14x1.5	12.50mm
	9/16-18	1/2
M14x1.5	M14x1.25	12.75mm
M14x1.25		13.00mm
9/16-18		33/64

Tap Size		Drill Size
60%	75%	
		13.25mm
	5/8-11	17/32
	M15x1.5	13.50mm
M15x1.5		13.75mm
5/8-11		35/64
	M16x2	14.00mm
		14.25mm
	5/8-18	9/16
M16x2	M16x1.5	14.50mm
5/8-18		37/64
		14.75mm
M16x1.5		15.00mm
		19.32
		15.25mm
		39/64
		15.50mm
	M17x1.5	15.75mm
M17x1.5	M18x2.5	5/8
		16.00mm
M18x2.5	M18x2	16.25mm
M18x2		41/64
	3/4-10	16.50mm
	M18x1.5	21/32
3/4-10	M19x2.5	16.75mm
M18x1.5		17.00mm
M19x2.5		43/64
		17.25mm
	3/4-16	11/16
3/4-16	M20x2.5	17.50mm
		17.75mm
		45/64
M20x2.5	M20x2	18.00mm
M20x2		18.25mm
		23/32
	M20x1.5	18.50mm
		47/64
M20x1.5		18.75mm
		19.00mm
		3/4
		19.25mm
	7/8-9	49/64
	M22x2.5	19.50mm
7/8-9		25/32
		19.75mm
M22x2.5	M22x2	20.00mm
	7/8-14	51/64
M22x2		20.25mm
	M22x1.5	20.50mm
7/8-14		13/16
		20.75mm
M22x1.5	M24x3	21.00mm
		53/64
		21/25mm
		27/32
M24x3		21.50mm
		21.75mm
		55/64
	M24x2	22.00mm
	1"-8	7/8
M24x2		22.25mm
	M24x1.5	22.50mm
1"-8		57/64
M24x1.5		22.75mm
	M25x2	23.00mm
	1"-12	29/32
M25x2		23.25mm
1"x12	1"-14	59/64
	M25x1.5	23.50mm
M20x1.5		23.75mm
1"-14		15/16

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Barometric Pressure at Altitude

Specifications

Barometric Pressure at Altitude					
Pressure				Altitude	
kPa	PSI	mm Hg	in Hg	m	ft.
103.2	14.96	773.9	30.47	-152	-500
101.3	14.69	760.0	29.92	0	0
99.5	14.43	746.3	29.38	152	500
97.7	14.17	733.0	28.86	305	1000
96.0	13.92	719.8	28.34	458	1500
94.2	13.66	706.6	27.82	610	2000
92.5	13.42	693.9	27.32	762	2500
90.8	13.17	681.2	26.82	914	3000
89.2	12.93	668.8	26.33	1067	3500
87.5	12.69	656.3	25.84	1219	4000
85.9	12.46	644.3	25.37	1372	4500
84.3	12.23	632.2	24.89	1524	5000
82.8	12.01	620.7	24.44	1677	5500
81.2	11.78	609.1	23.98	1829	6000
79.7	11.56	597.8	23.54	1982	6500
78.2	11.34	586.5	23.09	2134	7000
76.7	11.13	575.5	22.66	2286	7500
75.2	10.91	564.4	22.22	2438	8000
73.8	10.71	553.8	21.80	2591	8500
72.4	10.50	543.1	21.38	2743	9000
71.1	10.31	532.8	20.98	2896	9500
69.7	10.11	522.5	20.57	3048	10,000
67.1	9.73	502.8	19.80	3353	11,000
64.4	9.34	483.1	19.02	3658	12,000
62.0	8.99	464.7	18.30	3963	13,000
59.5	8.63	446.3	17.57	4267	14,000
57.2	8.30	429.0	16.89	4572	15,000
54.9	7.96	411.7	16.21	4877	16,000

Notes