YANMAR

APPLICATION MANUAL

INDUSTRIAL ENGINES

3TNV88C
3TNV86CT
4TNV88C
4TNV86CT
4TNV98C
4TNV98CT

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.

California
Proposition 65 Warning

Battery posts, terminals, and related accessories contain lead and lead compounds, chemicals known to the state of California to cause cancer and reproductive harm.
Wash hands after handling.

Disclaimers:

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APPLICATION MANUAL	MODEL	3TNV88C, 3TNV86CT, 4TNV88C, 4TNV86CT, 4TNV98C, 4TNV98CT
	CODE	0DTN4-G00400

Section 1

APPLICATION STANDARD

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The engine operating environment and driven machine conditions must be studied carefully when selecting an engine in order to make the most of the engine performance, extend the service life and improve the machine capacity.

This manual describes the items that must be considered when selecting an engine and determining the specifications to ensure that the engine is not used beyond its capacity.

Application Standard

<table>
<tr><th>No.</th><th>Item</th><th colspan="4">Application standard</th><th>Remarks</th></tr>
<tr><td>1</td><td>Engine type</td><td colspan="4">Direct injection system engines (DI-CR engines)</td><td>TNV series</td></tr>
<tr><td rowspan="5">2</td><td rowspan="5">Output/rpm</td><td colspan="2">Output/rpm</td><td colspan="2">Refer to Specifications on page 3-5.</td><td></td></tr>
<tr><td rowspan="3">Output setting conditions</td><td>Ambient temperature</td><td colspan="2">25 °C</td><td rowspan="4">Same as in JIS and ISO</td></tr>
<tr><td>Atmospheric pressure</td><td colspan="2">100 kPa (750 mmHg)</td></tr>
<tr><td>Relative humidity</td><td colspan="2">30 %</td></tr>
<tr><td colspan="2">Output power correction</td><td colspan="2">Refer to Power Corrections on page 4-3.</td></tr>
<tr><td rowspan="5">3</td><td rowspan="5">Special operating environment</td><td colspan="2">Precautions against sand dust</td><td colspan="2" rowspan="5">Refer to Special Operating Environment on page 1-5.</td><td rowspan="5"></td></tr>
<tr><td colspan="2">Precautions for outdoor installation</td></tr>
<tr><td colspan="2">Precautions against sea air and snow melting agents</td></tr>
<tr><td colspan="2">Precautions against cold environment</td></tr>
<tr><td colspan="2">Precautions against hot environment</td></tr>
<tr><td rowspan="10">4</td><td rowspan="10">Fuel oil</td><td colspan="2">Fuel oil</td><td>Ambient temperature (°C)</td><td>Equivalent fuel</td><td rowspan="10">Refer to Diesel Fuel on page 10-10.</td></tr>
<tr><td colspan="2" rowspan="4">Diesel fuel</td><td>≥ -5</td><td>JIS No. 2</td></tr>
<tr><td>-5 to -15</td><td>JIS No. 3</td></tr>
<tr><td>-15 ≥</td><td>JIS special No. 3</td></tr>
<tr><td colspan="2">Note: If JIS No. 2 is used near -5 °C, note that there is a risk of waxing due to the dispersion of fuel.</td></tr>
<tr><td colspan="2">Kerosene</td><td colspan="2">Not allowed</td></tr>
<tr><td colspan="2">Heavy oil</td><td colspan="2">Not allowed</td></tr>
<tr><td colspan="2">JP-4</td><td colspan="2">Not allowed</td></tr>
<tr><td colspan="2">JP-8, JP-5</td><td colspan="2">Not allowed</td></tr>
<tr><td colspan="2">Bio fuel</td><td colspan="2">Allowed up to density B7</td></tr>
</table>

<table>
<tr><th>No.</th><th>Item</th><th colspan="3">Application standard</th><th>Remarks</th></tr>
<tr><td rowspan="4">5</td><td rowspan="4">Engine oil</td><td colspan="3">Refer to Engine Oil on page 11-5.</td><td rowspan="3">The initial replacement of the lubricating oil and lubricating oil filter should be done at 50 hours of service.</td></tr>
<tr><td>Lubricating oil class</td><td>Lubricating oil replacement interval (hr)</td><td>Lubricating oil filter replacement interval (hr)</td></tr>
<tr><td>DH-2, CJ-4, E6</td><td>Every 250</td><td>Every 250</td></tr>
<tr><td>Allowable maximum engine oil temperature</td><td colspan="2">≤ 120 °C</td><td rowspan="2">At the specified maximum ambient temperature.</td></tr>
<tr><td rowspan="6">6</td><td rowspan="6">Engine coolant</td><td>Allowable cooling water temperature at engine outlet</td><td>≤ 105 °C</td><td>Refer to Cooling System on page 9-1.</td></tr>
<tr><td>Water quality</td><td colspan="2">Soft water</td><td>Refer to Engine Coolant on page 9-4.</td></tr>
<tr><td>Antifreeze mixing ratio (%)</td><td colspan="2">Atmospheric temperature (°C)</td><td rowspan="4">Refer to Radiator on page 9-8.</td></tr>
<tr><td>30</td><td colspan="2">0 to -15</td></tr>
<tr><td>40</td><td colspan="2">-15 to -25</td></tr>
<tr><td>50</td><td colspan="2">-25 to -40</td></tr>
<tr><td>7</td><td>Power take-off (PTO)</td><td colspan="3">Refer to P.T.O. Systems on page 16-1.</td><td></td></tr>
<tr><td>8</td><td>Low-temperature startability</td><td colspan="3">Refer to Low-temperature Startability on page 1-7.</td><td></td></tr>
<tr><td rowspan="2">9</td><td rowspan="2">Allowable inclination angle</td><td>Continuous operation</td><td>All directions</td><td>≤ 30°</td><td rowspan="2">Refer to Crankcase Breather System on page 11-15. (YANMAR standard deep oil pan)</td></tr>
<tr><td>Instantaneous operation (within 3 minutes)</td><td>All directions</td><td>≤ 35°</td></tr>
<tr><td>10</td><td>Allowable exhaust back pressure</td><td colspan="3" rowspan="2">Refer to Allowable Air Intake Restriction and Exhaust Back Pressures on page 1-14.</td><td></td></tr>
<tr><td>11</td><td>Allowable air restriction at intake manifold</td><td></td></tr>
</table>

Special Operating Environment

The engine performance depends greatly on the operating and environmental conditions.

Please consult with YANMAR when unusual operating conditions exist.

Precautions against dusty conditions

Condition	Part	Countermeasure
Wear due to dusty or sandy condition	Air cleaner	The following measures and cleaning are necessary to prevent dust from entering the engine: Use double element (safety element) Use evacuator valve Use dust indicator
	Cooling fan	to improve the wear resistance, a fan made of nylon 6 (reinforced with glass fiber) may be required.
	V-belt	To counteract belt wear, a reinforced type V-belt may be required.
	Radiator	Changing the core type and adding the screen may be required. Heat balance check after the modification is required.
	Fuel filter	Specification of the main fuel filter with improved filtration accuracy may be required to prevent entry of sand and dust to the common rail parts.
	Lubricating oil filter	A large capacity lubricating oil filter may be required to prevent entry of sand and dust into the engine.

Precautions for outdoor installation

Condition	Part	Countermeasure
Rain, snow, etc.	Rain cap (for both air cleaner and exhaust silencer)	Entry of rainwater, snow, etc. must be prevented.
	Electrical parts	Since electrical parts correspond to level R2* in JIS D 0203, either install them where they will not be splashed with water, or provide covers.
Location	–	Flat and well-ventilated place
Cleaning	–	High pressure cleaning not allowed

* *Level R2: A water spraying test level for checking the performance of the portion subject to indirect exposure to rainwater or splashing water.*

Precautions against salty conditions (air, sea water, road salt)

Condition	Part	Countermeasure
Location exposed to salt air or road salt	Electrical parts	Since corrosion may occur, careful maintenance is necessary.
	Exhaust manifold bolts	
	Radiator	
Location where salt water may splash directly onto the engine	–	Do not install engine where it can be splashed with salt water.

Precautions against cold environment

Environmental temperature	Part	Countermeasure	Remarks
-Below -21 °C	Battery (high CCA)	Specification must be changed.	Refer to *Low-temperature Startability on page 1-7* for startability.
	Starting motor		
Below -30 °C	Cooling water hose	Special rubber may be required to prevent rubber parts from being damaged by hardening. Choose components that will maintain flexibility at this temperature range.	
	Intake air hose		
	O-rings		
	Oil seal		
	Fuel hose		
	Starting aid	A block heater should be used.	
-40 °C or below		Not recommended.	

Precautions against hot environment

Environmental Temperature	Part	Countermeasure
Above 40 °C	Radiator	A large capacity radiator and fan must be used to prevent the cooling water and lubricating oil temperatures from getting too hot.
	Cooling fan	
	Oil cooler	Increase capacity or install as standard equipment.
	Electrical parts	The temperature inside the engine hood must be kept below 80 °C to protect the electrical parts. Provide ventilation around electrical parts.

Indoor use

Condition	Part	Countermeasure
Operation in the enclosed space such as indoors	–	There is a possibility that CO and HC may be generated at the Diesel Particulate Filter regeneration period. Be sure to ventilate the enclosed space such as indoors.

Others

Condition	Part	Countermeasure
Location where explosive, flammable or toxic gas exists	–	Engine is not designed for installation where explosive, flammable or toxic gas exists.

Low-temperature Startability

The lowest temperature guaranteed for starting the engine with standard specifications is -15 °C without load. This low-temperature startability when connected with the driven machine is greatly affected by the machine coupling method, moment of inertia of the driven machine and the capacity of the hydraulic equipment. Since the mounted devices vary with the manufacturer, the low-temperature startability of the engine loaded with the driven machine varies even when the purpose of the driven machine is the same.

The combination of the starting motor, battery and starting aid in each of the following tables is a guideline. Check the engine startability in the actual machine at the required starting conditions with the machine manufacturer.

“Standard” or “Hydrostatic” (HST) specification in the tables refers to the standard combination of various systems required for satisfying the startability at each temperature shown in the table.

“Standard specification” is for the driven machines that do not have parasitic load when engine starts, for example, mower, tractor (with mechanical clutch), combine and so on. “Specification with large parasitic load” refers to the driven machines that have parasitic load when engine starts, for example, tractor (with clutch), excavator, loader (with direct coupled hydraulic pump), generator, and so on.

Note: “Standard” in this section is different from the standard specification in estimating the F-F cost. F-F cost refers to the standard cost when equipped from the fan to the flywheel. Accessories such as the air cleaner, Diesel Particulate Filter (DPF) and radiator are not included. Please contact YANMAR for further details.

Combination of Starting Devices for Each Driven Machine

3TNV88C, 3TNV86CT

Standard specification: For driven machines with less parasitic load when the engine starts. E.g. mower, tractor (with mechanical clutch), or combine and others.

Item	Temperature t (°C)	-5 < t	-15 < t ≤ -5	*-20 ≤ t ≤ -15	t < -20
Starter	12V 1.2 kW, 129129-77010 DENSO				Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.4 kW, 129608-77010 HITACHI				
	12V 1.4 kW, 129207-77010 DENSO				
	12V 1.7 kW, 129242-77010 HITACHI	✔	✔	✔	
	12V 2.3 kW, 129136-77011 HITACHI				
Battery (Fully-charged new battery)	80D26 (NX110-5) CCA: 413	✔	✔	✔	
	75D31 (N70Z) CCA: 447				
	95D31 (NX120-7) CCA: 622				
	115D31				
	130E41 (NX200-10) CCA: 799				
Starting aid	Without energizing glow plug (only simultaneous energizing)	✔			
	Energizing glow plug 15 sec		✔	✔	
Battery cable	Total allowable resistance (YIS G30-7900J)	0.002 Ω			
F.O.	Fuel oil	JIS 2nd.	JIS 3rd.	JIS 3rd. Sp.	
L.O.	Lubricating oil	10W-30			

** Standard specification shown in Specifications of Standard Engines for Driven Machines on page 2-7.*

3TNV88C, 3TNV86CT

Large parasitic load specification: For driven machines with parasitic load when the engine starts. E.g. tractor (with HST), backhoe, vibrating roller, loader, generator and others.

Item	Temperature t (°C)	-5 < t	-15 < t ≤ -5	*-20 ≤ t ≤ -15	t < -20
Starter	12V 1.2 kW, 129129-77010 DENSO				Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.4 kW, 129608-77010 HITACHI				
	12V 1.4 kW, 129207-77010 DENSO				
	12V 1.7 kW, 129242-77010 HITACHI	✔	✔	✔	
	12V 2.3 kW, 129136-77011 HITACHI				
Battery (Fully-charged new battery)	80D26 (NX110-5) CCA: 413				
	75D31 (N70Z) CCA: 447				
	95D31 (NX120-7) CCA: 622	✔	✔	✔	
	115D31				
	130E41 (NX200-10) CCA: 799				
Starting aid	Without energizing glow plug (only simultaneous energizing)	✔			
	Energizing glow plug 15 sec		✔	✔	
Battery cable	Total allowable resistance (YIS G30-7900J)	0.0012 Ω			
F.O.	Fuel oil	JIS 2nd.	JIS 3rd.	JIS 3rd. Sp.	
L.O.	Lubricating oil	10W-30			

** Standard specification shown in Specifications of Standard Engines for Driven Machines on page 2-7.*

4TNV88C, 4TNV86CT

Standard specification: For driven machines with less parasitic load when the engine starts. E.g. mower, tractor (with mechanical clutch), or combine and others.

Item	Temperature t (°C)	-5 < t	-15 < t ≤ -5	*-20 ≤ t ≤ -15	t < -20
Starter	12V 1.2 kW, 129129-77010 DENSO				Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.4 kW, 129608-77010 HITACHI				
	12V 1.4 kW, 129207-77010 DENSO				
	12V 1.7 kW, 129242-77010 HITACHI	✔	✔	✔	
	12V 2.3 kW, 129136-77011 HITACHI				
Battery (Fully-charged new battery)	80D26 (NX110-5) CCA: 413				
	75D31 (N70Z) CCA: 447				
	95D31 (NX120-7) CCA: 622	✔	✔	✔	
	115D31				
	130E41 (NX200-10) CCA: 799				
Starting aid	Without energizing glow plug (only simultaneous energizing)	✔			
	Energizing glow plug 15 sec		✔	✔	
Battery cable	Total allowable resistance (YIS G30-7900J)	0.002 Ω			
F.O.	Fuel oil	JIS 2nd.	JIS 3rd.	JIS 3rd. Sp.	
L.O.	Lubricating oil	10W-30			

** Standard specification shown in Specifications of Standard Engines for Driven Machines on page 2-7.*

4TNV88C, 4TNV86CT

Large parasitic load specification: For driven machines with parasitic load when the engine starts.
E.g. tractor (with HST), backhoe, vibrating roller, loader, generator and others.

Item	Temperature t (°C)	-5 < t	-15 < t ≤ -5	*-20 ≤ t ≤ -15	t < -20
Starter	12V 1.2 kW, 129129-77010 DENSO				Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.4 kW, 129608-77010 HITACHI				
	12V 1.4 kW, 129207-77010 DENSO				
	12V 1.7 kW, 129242-77010 HITACHI				
	12V 2.3 kW, 129136-77011 HITACHI	✔	✔	✔	
Battery (Fully-charged new battery)	80D26 (NX110-5) CCA: 413				
	75D31 (N70Z) CCA: 447				
	95D31 (NX120-7) CCA: 622				
	115D31	✔	✔	✔	
	130E41 (NX200-10) CCA: 799				
Starting aid	Without energizing glow plug (only simultaneous energizing)	✔			
	Energizing glow plug 15 sec		✔	✔	
Battery cable	Total allowable resistance (YIS G30-7900J)	0.0012 Ω			
F.O.	Fuel oil	JIS 2nd.	JIS 3rd.	JIS 3rd. Sp.	
L.O.	Lubricating oil	10W-30			

** Standard specification shown in Specifications of Standard Engines for Driven Machines on page 2-7.*

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4TNV98C, 4TNV98CT

Standard specification: For driven machines with less parasitic load when the engine starts. E.g. mower, tractor (with mechanical clutch), or combine and others.

Item	Temperature t (°C)		-5 < t	-15 < t ≤ -5	*-20 ≤ t ≤ -15	t < -20
Starter	12V 2.3 kW, 129900-77040		✔	✔	✔	Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 3.0 kW, 129940-77011					
Battery (Fully-charged new battery)	80D26 (NX110-5)	CCA: 413				
	75D31 (N70Z)	CCA: 447				
	95D31 (NX120-7)	CCA: 622	✔	✔	✔	
	130E41 (NX200-10)	CCA: 799				
Starting aid	Without energizing glow plug (only simultaneous energizing)		✔			
	Energizing glow plug	15 sec		✔	✔	
Battery cable	Total allowable resistance (YIS G30-7900J)		0.0012 Ω			
F.O.	Fuel oil		JIS 2nd.	JIS 3rd.	JIS 3rd. Sp.	
L.O.	Lubricating oil		10W-30			

** Standard specification shown in Specifications of Standard Engines for Driven Machines on page 2-7.*

4TNV98C, 4TNV98CT

Large parasitic load specification: For driven machines with parasitic load when the engine starts. E.g. tractor (with HST), backhoe, vibrating roller, loader, generator and others.

Item	Temperature t (°C)	-5 < t	-15 < t ≤ -5	*-20 ≤ t ≤ -15	t < -20
Starter	12V 2.3 kW, 129900-77040				Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 3.0 kW, 129940-77011	✔	✔	✔	
Battery (Fully-charged new battery)	80D26 (NX110-5) CCA: 413				
	75D31 (N70Z) CCA: 447				
	95D31 (NX120-7) CCA: 622				
	130E41 (NX200-10) CCA: 799	✔	✔	✔	
Starting aid	Without energizing glow plug (only simultaneous energizing)	✔			
	Energizing glow plug 15 sec		✔	✔	
Battery cable	Total allowable resistance (YIS G30-7900J)	0.0012 Ω			
F.O.	Fuel oil	JIS 2nd.	JIS 3rd.	JIS 3rd. Sp.	
L.O.	Lubricating oil	10W-30			

** Standard specification shown in Specifications of Standard Engines for Driven Machines on page 2-7.*

Allowable Air Intake Restriction and Exhaust Back Pressures

Resistance to intake airflow and exhaust gas flow is generated in the intake and exhaust systems. Do not exceed the limits shown in the tables below to ensure proper engine performance.

The initial upper limit shown here refers to allowable resistances when new. As the engine is used, the resistances increase due to deposits in the air cleaner and DPF. The upper limits for air cleaner element replacement (or cleaning) and exhaust system usage process (including the exhaust tube and DPF) are the limit values for operation.

Allowable air intake restriction (provisional value)

Applicable model	Allowable depression at engine manifold ≤ kPa	
	Initial upper limit*1	Upper limit for air cleaner element replacement (or cleaning)
3TNV88C - 4TNV98CT	2.9*2	6.2

Allowable exhaust back pressure (provisional value)

Applicable model	Allowable exhaust back pressure ≤ kPa	
	Initial upper limit*1	Upper limit for exhaust system usage process
3TNV88C - 4TNV98CT	12.7*2	45*3

**1: Value when the EGR valve is closed (the SMARTASSIST Direct engine diagnosis tool (hereinafter referred to as SA-D) provides a function to close the EGR valve. Contact YANMAR for further details.*

**2: Intake/exhaust resistance in the rated power for the maximum speed specification of each model. Refer to "Note Point at the Intake/Exhaust Pressure Settings for the Engine with EGR".*

**3: Content is under close examination.*

The Necessity of Intake/Exhaust Pressure Settings for Engine with EGR

Engine with EGR controls the open level of EGR valve by engine speed and load and regulates the EGR gas volume. The EGR gas volume changes according to the difference of exhaust pressure even if the open level of the EGR valve is the same. (Refer to **Figure 1-1** below) Therefore the engine with EGR must be set the differential pressure between the intake and the exhaust in constant range. The range of the allowable intake/exhaust pressure for engine with EGR is as follows:

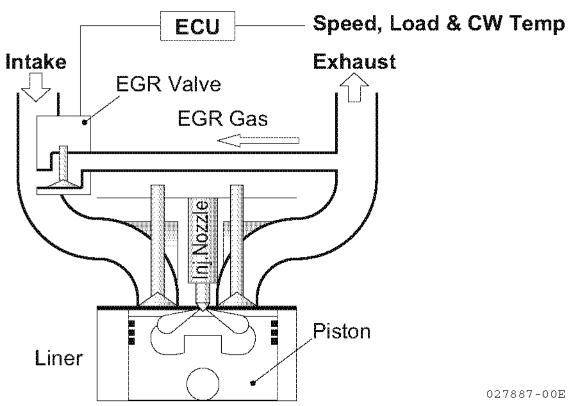

Figure 1-1

The Characteristics of Intake/Exhaust Pressure for the Engine with EGR

The Intake/Exhaust Pressure is changed because of changing the open level of EGR depending on the load rate for the engine with EGR. Refer to **Figure 1-2** below as the example. It is also changed depending on the engine rated speed.

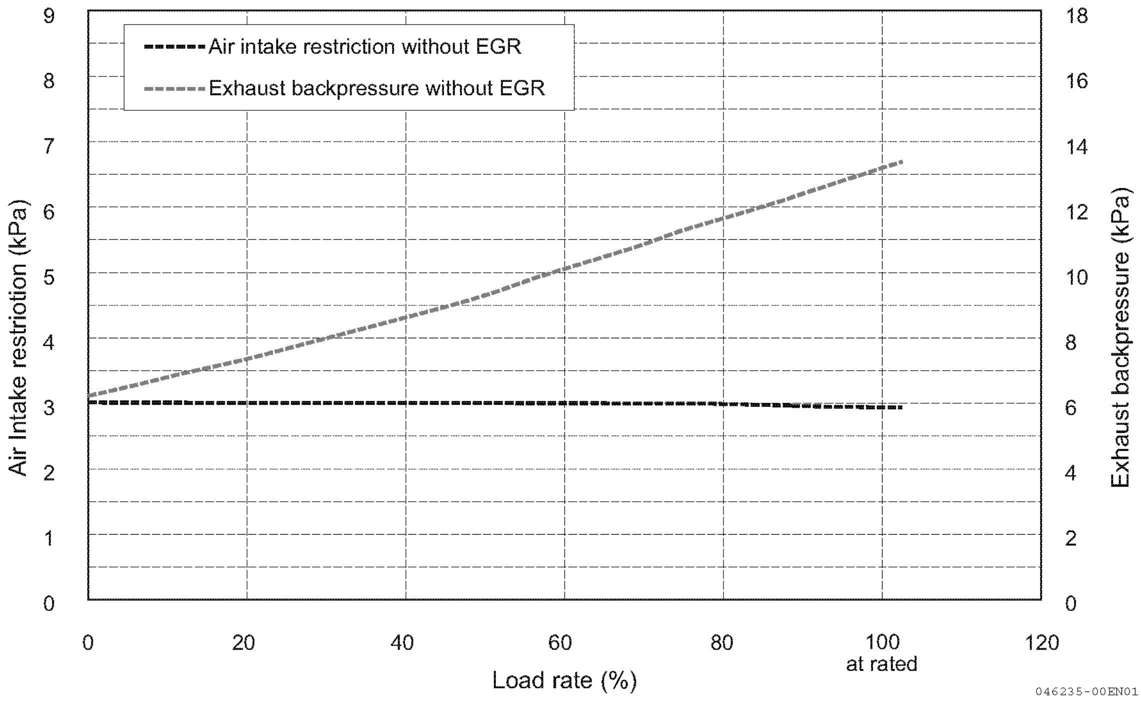

Figure 1-2

Note Point at the Intake/Exhaust Pressure Settings for the Engine with EGR

The point of the notes at the intake/exhaust pressure settings is shown.
The range of the allowable intake/exhaust pressure that YANMAR shows in the following material is in the condition of at rated speed and rated power. The volume of the EGR gas cannot be appropriately controlled beyond the limits of the this condition because the intake/exhaust pressure is changed depending on the engine speed and load factor for the engine with EGR. So please note the following points.

Measurement standard (For details, refer to "Installation Test Procedures" on page 12.)

- When doing the intake/exhaust pressure matching test, do the measurement with the speed and power as close as possible to their rated values and with the EGR valve closed.
- Please inform us engine speed and load factor at evaluation test if it is difficult to test engine at the rated speed and power. YANMAR will inform an appropriate range of intake/exhaust pressure.

The engine rotation speed and the load factor can be measured with an engine diagnosis tool (SA-D) supplied from YANMAR. Please inform YANMAR representative in detail.

3TNV88C Initial upper limit for intake/exhaust pressure (lower limit and usage process upper limit are shown separately)

Initial upper limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}				
			2400	2500	2600	2800	3000
EGR valve closed	Intake restriction	kPa	2.2	2.3	2.4	2.6	2.9
	Exhaust back pressure	kPa	8.0	8.7	9.5	11.0	12.7

4TNV88C (low speed specification) Initial upper limit for intake/exhaust pressure (lower limit and usage process upper limit are shown separately)

Initial upper limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}		
			2200	2400	2500
EGR valve closed	Intake restriction	kPa	2.5	2.8	2.9
	Exhaust back pressure	kPa	9.8	11.7	12.7

4TNV88C (high speed specification) Initial upper limit for intake/exhaust pressure (usage process upper limit is shown separately)

Initial upper limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}		
			2600	2800	3000
EGR valve closed	Intake restriction	kPa	2.4	2.6	2.9
	Exhaust back pressure	kPa	9.6	11.1	12.7

Initial lower limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}		
			2600	2800	3000
EGR valve closed	Intake restriction	kPa	1.9	2.1	2.3
	Exhaust back pressure	kPa	7.1	8.5	9.9

Usage process upper limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}		
			2600	2800	3000
EGR valve closed	Intake restriction	kPa	TBD	TBD	6.2
	Exhaust back pressure	kPa	TBD	TBD	45.0

3TNV86CT Initial upper limit for intake/exhaust pressure (lower limit and usage process upper limit are shown separately)

Initial upper limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}			
			2500	2600	2800	3000
EGR valve closed	Intake restriction	kPa	2.2	2.3	2.6	2.9
	Exhaust back pressure	kPa	8.4	9.1	11.0	12.7

4TNV86CT Initial upper limit for intake/exhaust pressure (lower limit and usage process upper limit are shown separately)

Initial upper limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}			
			2400	2600	2800	3000
EGR valve closed	Intake restriction	kPa	2.1	2.4	2.6	2.9
	Exhaust back pressure	kPa	7.9	9.0	10.7	12.7

4TNV98C Initial upper limit for intake/exhaust pressure (lower limit and usage process upper limit are shown separately)

Initial upper limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}					
			2000	2100	2200	2300	2400	2500
EGR valve closed	Intake restriction	kPa	2.1	2.3	2.4	2.5	2.7	2.8
	Exhaust back pressure	kPa	8.0	8.6	9.4	10.2	11.0	11.8

4TNV98CT Initial upper limit for intake/exhaust pressure (lower limit and usage process upper limit are shown separately)

Initial upper limit for intake/exhaust pressure (at rated power)			Rated speed min^{-1}					
			2000	2100	2200	2300	2400	2500
EGR valve closed	Intake restriction	kPa	2.1	2.3	2.4	2.6	2.8	2.9
	Exhaust back pressure	kPa	8.7	9.6	10.1	10.8	11.7	12.7

Emission Control Regulations for Non-road Diesel Engine (Requirements for the Driven Machine Manufacturers)

TNV series engine has cleared the emission control regulations including EPA regulations in the United States, NRMM in Europe, and latest regulations in Japan. These regulations apply to non-road compression-ignition engines or driven machines, and enforce regulations concerning new and in use engines that are produced on or after the implementation date.

The manufacturers of driven machine must confirm the conditions presented by YANMAR in order to comply with the emission control regulations (including EPA regulations) for their driven machines by submitting the installation evaluation. The following is a brief description of the responsibilities introduced by the regulation.

Contact YANMAR for details.

Engine output

Engine output is properly limited for not only the engines with approved emission control, but all engines at the time of shipment from YANMAR. The limit cannot be changed by the manufacturer of driven machines or the user. Engine output is based on ISO 1585 “Gross Power Rating”.

“Gross Power Rating” refers to power measured with the engine equipped only with the necessary accessories for operation on the test bench.

For the engines with other load demanded by driven machine manufacturers (such as cooling fan/fan pulley ratio and hydraulic pump load), the “net power rating” which can be obtained by subtracting the load from gross power rating is transmitted to the power line of driven machines. It is recommended to set the maximum absorption load of driven machines to reserve 10 % allowance to this net power rating.The purpose of this allowance percentage is to consider and include the difference between the actual environmental conditions of driven machines (such as ambient temperature, fuel temperature, and/or altitude) and the standard conditions for engine output settings at shipment.

Confirmation of compliance

YANMAR Co. Ltd. and its regional headquarters will determine approval of applications to the guidelines of the application manual, including these emission-related installation instructions.

YANMAR will confirm the results in case the installation is performed by the manufacturer of driven machines.

To ensure engine performance and exhaust emissions compliance YANMAR will review net rated output based on engine build, intake air restriction, exhaust back pressure, and any other operational characteristic required under the engine installation evaluation process.

No modification for emission-related parts

You are not allowed to modify the emission-related parts without the permission of YANMAR.

The typical emission-related parts are as follows:

> Common rail system (fuel supply pump, rail, fuel injection nozzle), DPF, ECU, turbocharger, temperature sensor, pressure sensor.

If you are making modification from the specification confirmed in the installation evaluation, be sure to contact YANMAR in advance to have a re-evaluation.

Failing to follow these instructions when installing a certified engine in a piece of non-road equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act.

In regard to installation position and piping of DPF in particular, exchange of an agreement with YANMAR prior to production is required. If installation position or piping is modified, the exhaust gas emissions will not be guaranteed.

Engine maintenance

Equipment manufacturers are responsible for relaying all emission-related service intervals to the final user of the product.

For equipment manufacturers who prepare their own warranty cards, owner's manuals, service manuals, operation manuals and any related documents; they must reference the emission-related service intervals and procedures indicated in YANMAR's technical documents:

Warranty statement, operation manual, service manual and application manual.

Emission control label

As an evidence of receiving the approval for the emission control regulation, attach the emission control label on the engine. If you install the engine in a way that makes the engine's EPA and NRMM label hard to read during normal engine maintenance in the driven machine installed condition, you must place a duplicate label on the equipment.

Fuel inlet label

In accordance with the EPA emission control regulations 40CFR1039 104, it is a requirement to attach a fuel inlet label near the fuel inlet of the driven machine.

As it can be supplied as an accessory from YANMAR, contact YANMAR as required.

EPA REGULATION
USE ULTRA LOW SULFUR FUEL ONLY

114110-07761

Report on sales in the USA

According to 40CFR1039 250, the EPA requires YANMAR to obtain and report the production quantity for sales in the United States. The machine manufacturer must inform YANMAR of the actual sales quantity in the United States when it differs from the quantity of YANMAR engines produced.

In such cases, the creation of an additional new engine model to sell exclusively in the United States is requested to help in reporting the sales quantity without informing YANMAR.

Audit by testing the market service machine (in-use regulation)

In accordance with 40CFR1039, audit by emission testing may be conducted, using the driven machine installed with the engine that is within its service life. YANMAR will contact you as needed. We ask you for your cooperation including borrowing of your driven machine.

Recall - EPA

Whenever YANMAR conducts a recall program, the schedule scheme shall be reported to the authority in advance. The remedy program shall be done accordingly. After completing the remedy work, the report shall also be reported to the authority.

YANMAR requires the end purchaser's information, such as name, address and machine model to proceed with the recall program.

Section 2

ENGINE MODEL SELECTION

Page

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Model Designation

O TNV O O C (T) – O O O

- Configuration code
- Turbocharger
- Model name category C: ≥ 19 kW Tier 4
- Cylinder bore (mm)
- Model code
- Number of cylinders (3 to 4)

Configuration code = Engine Speed code and Driven Machine code. (Refer to *Engine model nomenclature on page 2-5.)*

Engine Classification

Engines are classified with (1) Injection system, (2) Displacement and (3) Engine speed as follows.
For engine performance. Refer to *Specifications on page 3-5*.

Classification with injection system

Abbreviation	Means
DI	Direct injection system

Classification with displacement

Abbreviation	Means
NV2	Engine displacement is roughly 2 liters
NV3	Engine displacement is roughly 3 liters

Classification with engine speed

Classification symbol	Speed range	Applicable driven machines
CL (Constant, low speed)	1500 or 1800 min^{-1}	4 pole generators and others
VM (Variable, medium speed)	2000 to 3000 min^{-1}	Agriculture machines, construction machines and other general machines

Engine classification with above mentioned conditions

No.	Model	Combustion chamber type	Group	Classification	
				CL	VM
1	3TNV88C	DI	NV2	–	○
2	3TNV86CT			–	○
3	4TNV88C			○	○
4	4TNV86CT			○	○
5	4TNV98C		NV3	○	*○
6	4TNV98CT			○	*○

** Engine speed up to 2500 min^{-1}*

Standard Engines for Driven Machines

Industrial engines are used as drives for various machines such as construction machines, agricultural machines and generators. Many driven machine applications based on standard TNV engine configurations for domestic and overseas markets have been developed. After YANMAR receives your inquiry, our staff in charge will quickly setup a conference with you to review your specifications and prepare an estimate. YANMAR proposes the best specification that you consider using a standard engine as standard specification for your application to help make the process of preparing a cost estimate as efficient as possible.

Advantages of preparing an estimate based on standard engines for driven machine applications

- The engine design considers past quality issues specific to individual driven machine applications. Quality check points enable preventive measures to be easily taken.
- Applying standard engine specifications make the process of submitting and preparing cost estimates more efficient.
- Standard engine specifications basically use standard YANMAR components which provide cost advantages for manufacturers of driven machines.

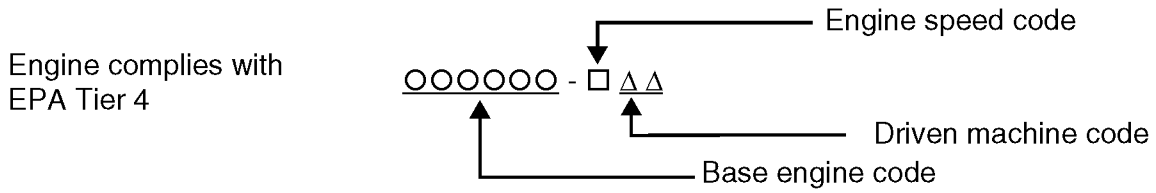
Classification of Standard Engines for Driven Machines

The classification of standard engines is based on the driven machine application and the speed the engine runs at (in rpm). The machine model name and principal differences are described below.

Engine model nomenclature

The engine model nomenclature of the standard engines for driven machines is as described below. However, note that the nomenclature of engine models is different between engines which comply with EPA emission control regulation Tier 3 and engines which comply with next regulations such as Tier 4 (Interim Tier 4 (> 56 kW), and Tier 4 (19 - 56 kW)).

Configuration code = Engine Speed code and Driven Machine code. (Refer to *Model Designation on page 2-3.)*



Engine speed or special spec. code	Engine speed (min^{-1})
G	1500/1800
W	2000
V	2100
S	2200
Q	2300
P	2400
N	2500
M	2600
L	2700
K	2800
D	3000

Model Name of Engine by Driven Machines and Category

The names of the standard engines for machines and their application are as follows:

No.	Model name	Model category	Typical applicable machines
1	BK	Construction use, at lower speed	Excavators, forklifts, refrigerators
2	WL	Construction use, at higher speed	Wheel loaders, SSLs, carriers, air compressors
3	GE	Constant speed	4P Generators (low speed) 2P Generators (high speed), Welders
4	MW	Utility use, at high speed	Mowers, utility vehicles, Speed sprayers, pumps
5	U1	Agricultural use	Tractor 1
6	U2	Agricultural use	Tractor 2 with integral monocoque frame
7	SA	Utility use	Full SAE housings
8	SA2		Semi SAE housings

Specifications of Standard Engines for Driven Machines

Machine standard engine (NV2 to complies with EPA Tier 4)

●: Specification changeable ○: Specification not changeable –: No engine model established

Category	Model name	Model category	Applicable machine	Parasitic load	Main specification	NV2							
						3TNV88C		3TNV86CT		4TNV88C		4TNV86CT	
						Rated speed		Rated speed		Rated speed		Rated speed	
Machine standard engine	BK	Construction use at lower speed	• Backhoe • Crane • Carrier • Forklift • Refrigerator	Heavy	• Semi SAE 5 housing • Deep oilpan • Puller fan • Larger starter	●	2400	–	–	●	2400	–	–
	WL	Construction machine at higher speed	• Wheel loader • SSL • Dozer • Damper • Carrier • Vibrator • Compressor • Snow blower	Heavy	• Semi SAE 5 housing • Deep oilpan • Extension type dipstick • Pusher fan • Oil cooler • Larger starter	●	3000	–	–	●	3000	●	3000
	GE	Constant speed use at lower speed	• 4P Generator	Small	• Semi SAE 4 housing • Deep oilpan • Pusher fan	–	–	–	–	●	1500 / 1800	●	1500 / 1800
		Constant speed use at higher speed	• 2P Generator	Small	–	–	–	–	–	–	–	–	–
	MW	Utility use at high speed	• Mower • Utility vehicle • Speed sprayer • Pump	Medium	• Semi SAE 5 housing • Shallow oilpan • HO-P • Oil cooler • Puller fan	●	–	●	3000	–	–	–	–
	U1	Agricultural use	• Tractor 1	Medium	• Backplate • Shallow oilpan • HO-P • Puller fan	●	–	–	–	●	–	–	–
	U2	Agricultural use	• Tractor 2 Mono-cock frame	Medium	• Backplate • Cast iron oilpan • Balancer for 4 cylinder • HO-P • Puller fan	●	2700	–	–	●	2700	–	–
General use	SA	Utility use		Medium	• Full SAE 5 housing • Deep oilpan • HO-P flange • Puller fan	○	3000	○	2800	○	3000	○	3000
	SA2				• Semi SAE 5 housing • Deep oilpan • HO-P flange • Oil cooler • Puller fan	○	3000	○	2800	○	3000	○	3000

Machine standard engine (NV3 to complies with EPA Tier 4, interim Tier 4)

●: Specification changeable ○: Specification not changeable –: No engine model established

Category	Model name	Model category	Applicable machine	Parasitic load	Main specification	NV3			
						4TNV98C		4TNV98CT	
						Rated speed		Rated speed	
Machine standard engine	BK	Construction use at lower speed	• Backhoe • Wheel loader • SSL • Vibrator • Dozer • Crane • Damper • Carrier • Forklift • Refrigerator • Compressor • Snow blower	Heavy	• Semi SAE 4 housing • Deep oilpan • Puller fan • Larger starter	●	2200	●	2200
	WL	Construction machine at higher speed		Heavy	• Semi SAE 4 housing • Deep oilpan • Pusher fan • Larger starter	●	2500	●	2500
	GE	Constant speed use at lower speed	• 4P Generator	Small	• Semi SAE 3 housing • Deep oilpan • Pusher fan	●	1500/1800	●	1500/1800
		Constant speed use at higher speed		Small	–	–	–	–	–
	MW	Utility use at high speed		Medium		–	–	–	–
	U1	Agricultural use	• Tractor 1	Medium		–	–	–	–
	U2	Agricultural use	• Tractor 2 Mono-cock frame	Medium		–	–	–	–
General use	SA	Utility use		Medium	• Full SAE 4 housing • Deep oilpan • Puller fan	○	2500	○	2500
	SA2				• Semi SAE 4 housing • Deep oilpan • Puller fan	○	2500	○	2500

Section 3

SPECIFICATIONS

Page

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DI Series 3-5

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Atmospheric conditions and the engine configuration affect the rated output of a TNV engine. TNV engines are tested using the methods established by the International Organization for Standardization (ISO) 3046/1. These standards state that engine output should be determined under the standard conditions (atmospheric pressure: 100 kPa, atmospheric temperature: 25 °C, relative humidity: 30 %). If the operating environment differs from these standard conditions. Refer to *Correcting Observed Power on page 4-1*.

The engine output specified in *Specifications on page 3-5* shows the gross power rating without a cooling fan. In addition, the other equipment including Diesel Particulate Filter and air cleaner assume that YANMAR standard products are equipped. Refer to the *YANMAR Option Menu* for the list of standard YANMAR components. If a TNV engine has all of these standard components installed, the engine output is called “net brake output.” Optional equipment is available from YANMAR. If your application uses optional equipment, please tell your YANMAR representative the fan type, pulley ratio and engine rpm range (refer to the *YANMAR Option Menu*) so the engineer can determine the engine’s output (net).

Engine output is roughly classified for industrial use or generator use. The handling method varies accordingly.

Engine output for industrial use

The engine output for industrial use is called the net rated output, which applies to the driven machine conforming to the VM specifications in *Engine Classification on page 2-3*. Most driven machines conforming to VM specifications use the maximum output requirement either intermittently or infrequently. The output applied in this case is the rated output. The engine should be selected, or the driven machine size should be determined, so the maximum output requirement in the driven machine operation pattern will not exceed the rated engine output.

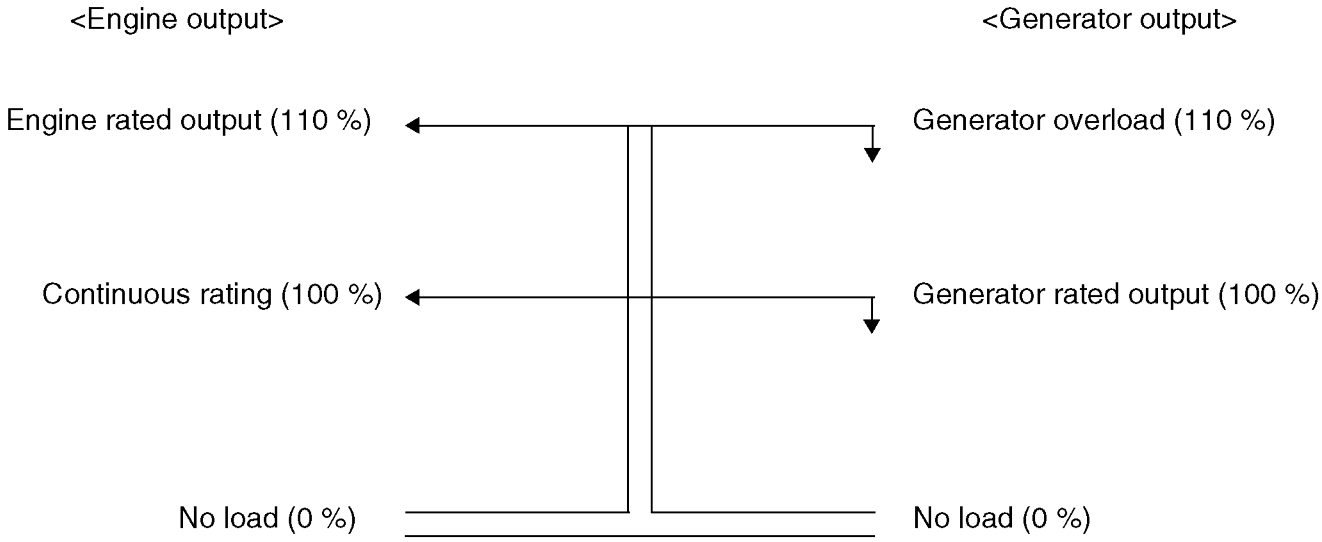
Some driven machines require the maximum output for a long period because of a fixed revolution range. In this case, select an engine so 90 % of its rated output equals the continuous maximum output requirement of the driven machine.

Engine output for generator use

Engine output for generator use applies when the engine is used to drive a generator or other applications that require a constant speed (such as a compressor, water pump or welder). In this classification the engine output is by the rated output (1-hour rating) and continuous rating.

The generator rated output must be selected so it is equal to or less than the continuous rated output of the engine. The engine must also be capable of sustaining a generator overload of 10 % for one hour in every twelve hours of operation. The corresponding capacity of the generator is called the overload. The generator capacity should be selected so the overload is equal to or less than the 1 hour rating of the engine output.

These output relationships are illustrated below:



Though the rated output is a term common to the engine and generator, the meaning is completely different. Use caution when selecting the engine or determining the generator capacity.

This method of determining the generator capacity is for generators used in an industrial capacity. Select the engine according to the respective standard and specifications when generators are used for disaster prevention or emergencies.

Specifications

DI Series

3TNV88C (complies with EPA Tier 4)

Engine model				3TNV88C											
Engine classification				CL		VM									
1	Type		–	Vertical, 4-cycle water-cooled diesel engine											
2	Combustion system		–	Direct injection (DI)											
3	No. of cylinders - Bore × stroke		n - mm × mm	3 - 88 × 90											
4	Displacement		ℓ	1.642											
5	Rated engine speed		min^{-1}							2400	2500	2600		2800	3000
	Output (gross)	Cont. rating	kW												
		Rated output	kW							21.8	22.8	23.7		25.5	27.5
6	Maximum idling speed		min^{-1}							2550	2650	2750		2950	3150
7	Compression ratio		–	19.1											
8	Main shaft side		–	Flywheel side											
9	Rotation direction		–	Counterclockwise (viewed from flywheel side)											
10	Injection system		–	Common rail system											
11	Aspiration		–	Natural aspiration											
12	Cooling system		–	Radiator type											
13	Lubricating system		–	Forced lubrication with trochoid pump											
14	Starting system		–	Electric starting											
15	Charging system		–	Alternator											
16	Starting aid device		–	Glow plug											

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SPECIFICATIONS

3TNV86CT (complies with EPA Tier 4)

Engine model				3TNV86CT											
Engine classification				CL		VM									
1	Type		–	Vertical, 4-cycle water-cooled diesel engine											
2	Combustion system		–	Direct injection (DI)											
3	No. of cylinders - Bore × stroke		n - mm × mm	3 - 86 × 90											
4	Displacement		ℓ	1.568											
5	Rated engine speed		min^{-1}								2500	2600		2800	3000
	Output (gross)	Cont. rating	kW												
		Rated output	kW								27.4	28.5		31	32.4
6	Maximum idling speed		min^{-1}								2650	2750		2950	3150
7	Compression ratio		–	19.2											
8	Main shaft side		–	Flywheel side											
9	Rotation direction		–	Counterclockwise (Viewed from flywheel side)											
10	Injection system		–	Common rail system											
11	Aspiration		–	Exhaust turbine turbocharger											
12	Cooling system		–	Radiator type											
13	Lubricating system		–	Forced lubrication with trochoid pump											
14	Starting system		–	Electric starting											
15	Charging system		–	Alternator											
16	Starting aid device		–	Glow plug											

4TNV88C (complies with EPA Tier 4)

Engine model				**4TNV88C**										
Engine classification				CL	VM									
1	Type		–	Vertical, 4-cycle water-cooled diesel engine										
2	Combustion system		–	Direct injection (DI)										
3	No. of cylinders - Bore × stroke		n - mm × mm	4 - 88 × 90										
4	Displacement		ℓ	2.189										
5	Rated engine speed		min^{-1}				2200		2400	2500	2600		2800	3000
	Output (gross)	Cont. rating	kW											
		Rated output	kW				26.7		29.1	30.5	31.7		34.3	35.5
6	Maximum idling speed		min^{-1}				2350		2550	2650	2750		2950	3150
7	Compression ratio		–	19.1										
8	Main shaft side		–	Flywheel side										
9	Rotation direction		–	Counterclockwise (Viewed from flywheel side)										
10	Injection system		–	Common rail system										
11	Aspiration		–	Natural aspiration										
12	Cooling system		–	Radiator type										
13	Lubricating system		–	Forced lubrication with trochoid pump										
14	Starting system		–	Electric starting										
15	Charging system		–	Alternator										
16	Starting aid device		–	Glow plug										

4TNV86CT (complies with EPA Tier 4)

Engine model				4TNV86CT										
Engine classification				CL	VM									
1	Type		–	Vertical, 4-cycle water-cooled diesel engine										
2	Combustion system		–	Direct injection (DI)										
3	No. of cylinders - Bore × stroke		n - mm × mm	4 - 86 × 90										
4	Displacement		ℓ	2.091										
5	Rated engine speed		min^{-1}	1800					2400	2500	2600		2800	3000
	Output (gross)	Cont. rating	kW	(25.2)										
		Rated output	kW	(27.7)					35.5	36.6	37.9		41.1	44
6	Maximum idling speed		min^{-1}	1895					2550	2650	2750		2950	3150
7	Compression ratio		–	19.2										
8	Main shaft side		–	Flywheel side										
9	Rotation direction		–	Counterclockwise (Viewed from flywheel side)										
10	Injection system		–	Common rail system										
11	Aspiration		–	Exhaust turbine turbocharger										
12	Cooling system		–	Radiator type										
13	Lubricating system		–	Forced lubrication with trochoid pump										
14	Starting system		–	Electric starting										
15	Charging system		–	Alternator										
16	Starting aid device		–	Glow plug										

Note: Rated output value (gross value) may be changed.

4TNV98C (complies with EPA Tier 4)

Engine model				4TNV98C						
Engine classification				CL	VM					
1	Type		–	Vertical, 4-cycle water-cooled diesel engine						
2	Combustion system		–	Direct injection (DI)						
3	No. of cylinders - Bore × stroke		n - mm × mm	4 - 98 × 110						
4	Displacement		ℓ	3.318						
5	Rated engine speed		min^{-1}	1800	2000	2100	2200	2300	2400	2500
	Output (gross)	Cont. rating	kW	(36.4)						
		Rated output	kW	(41.5)	42.4	44.3	46.2	48.1	49.9	51.7
6	Maximum idling speed		min^{-1}	1895	2150	2250	2350	2450	2550	2650
7	Compression ratio		–	18.3						
8	Main shaft side		–	Flywheel side						
9	Rotation direction		–	Counterclockwise (Viewed from flywheel side)						
10	Injection system		–	Common rail system						
11	Aspiration		–	Natural aspiration						
12	Cooling system		–	Radiator type						
13	Lubricating system		–	Forced lubrication with trochoid pump						
14	Starting system		–	Electric starting						
15	Charging system		–	Alternator						
16	Starting aid device		–	Glow plug						

Note: Rated output value (gross value) may be changed.

4TNV98CT (complies with EPA Tier 4)

Engine model				4TNV98CT						
Engine classification				CL	VM					
1	Type		–	Vertical, 4-cycle water-cooled diesel engine						
2	Combustion system		–	Direct injection (DI)						
3	No. of cylinders - Bore × stroke		n - mm × mm	4 - 98 × 110						
4	Displacement		ℓ	3.318						
5	Rated engine speed		min^{-1}	1800	2000	2100	2200		2400	2500
	Output (gross)	Cont. rating	kW	(46.4)						
		Rated output	kW	(51)	51.6	53.7	53.7		53.7	53.7
6	Maximum idling speed		min^{-1}	1895	2150	2250	2350		2550	2700
7	Compression ratio		–	17.9						
8	Main shaft side		–	Flywheel side						
9	Rotation direction		–	Counterclockwise (Viewed from flywheel side)						
10	Injection system		–	Common rail system						
11	Aspiration		–	Exhaust turbine turbocharger						
12	Cooling system		–	Radiator type						
13	Lubricating system		–	Forced lubrication with trochoid pump						
14	Starting system		–	Electric starting						
15	Charging system		–	Alternator						
16	Starting aid device		–	Glow plug						

Note: Rated output value (gross value) may be changed.

Section 4

CORRECTING OBSERVED POWER

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Engine output basically depends on the oxygen concentration in the air, which varies with atmospheric conditions such as atmospheric pressure, atmospheric temperature and relative humidity.

When discussing engine output, it is important to specify the atmospheric conditions. Conversely, the maximum level of engine output at a given atmospheric pressure, atmospheric temperature and relative humidity are also important when considering the engine application.

The output correction formula shows the relationship between atmospheric conditions and the engine output.

Also note the applicable formula varies with the degree of difference between actual and standard conditions. The concept and formulas are the same in the JIS and ISO.

In addition, the estimated value of output reduction which is determined by the correction formulas can be different compared to the actual measurement value. The possible causes for this difference can be the variables which are not included in the correction formulas, such as changes in combustion temperature or fan loss.

Power Corrections

The following two power correction formulas are provided for selection according to the actual or specified atmospheric conditions:

- Use the power correction formula (A) in *Correction formula (A)...JIS B8003 (ISO 15550: 2002) on page 4-4* when atmospheric conditions are judged to be relatively close to standard conditions:

Standard atmospheric conditions	: 25 °C, 100 kPa, 30 %
Engine intake air temperature	: 10 to 40 °C (283 to 313 K)
Dry intake air pressure	: 90 to 110 kPa
Correction factor α_c	: 0.96 to 1.06 (Refer to calculation in Obtain correction factor α_c.)

- Use the power calculation formula (B) in *Correction formula (B)...JIS B8002-1 (ISO 3046-1: 2002) on page 4-7* when atmospheric conditions are much different from standard atmospheric conditions.

Correction formula (A)...JIS B8003 (ISO 15550: 2002)

Use correction formula (A) when the actual test conditions are judged to be relatively close to the standard atmospheric conditions.

1. Obtain atmospheric factor f_a. This factor is calculated by the two formulas shown below depending on whether a turbocharger is used.
   - For a naturally aspirated engine

$$f_a = \left(\frac{p_r - \phi_r \times p_{sr}}{p_y - \phi_y \times p_{sy}}\right)\left(\frac{T_y}{T_r}\right)^{0.7}$$

   - For a turbocharged engine

$$f_a = \left(\frac{p_r - \phi_r \times p_{sr}}{p_y - \phi_y \times p_{sy}}\right)^{0.7}\left(\frac{T_y}{T_r}\right)^{1.2}$$

Subscript "r" represents the value under standard atmospheric conditions, and "y" the value under actual test conditions.

p_r	: Standard atmospheric pressure	100 kPa
$ø_r$	: Relative humidity under standard atmospheric conditions	0.30 (30 %)
T_r (t_r)	: Intake air temperature under atmospheric standard conditions	298 K (t_r = 25 °C)
p_{sr}	: Saturation vapor pressure under standard atmospheric conditions	3.170 kPa (Obtain from the table *Relationship between Atmospheric Temperature and Saturation Vapor Pressure on page 4-10.*)
p_y	: Atmospheric pressure under actual test conditions	kPa
$ø_y$	: Relative humidity under actual test conditions	
T_y (t_y)	: Intake air temperature under actual test conditions	K (°C)
p_{sy}	: Saturation vapor pressure under actual test conditions	kPa (Obtain from the table *Relationship between Atmospheric Temperature and Saturation Vapor Pressure on page 4-10.*)

Pay attention to the unit of each value in actual calculation.

If kPa is used for standard atmospheric pressure p_r, all of p_{sr}, p_y and p_{sy} must also be expressed in kPa. The relationship between hPa and kPa is as follows:

kPa = hPa/10

Always use absolute temperature in K for representing the intake air temperatures T_r and T_y. The relationship between °C on ordinary thermometers- meters and absolute temperature K is as follows:

$K = 273 + °C$

Obtain engine factor f_m

Engine factor f_m for each engine should be calculated in a matching test for which high precision is required. In most cases the important point is how the rated output changes under the actual test conditions. Estimate the f_m using the output and empirical average fuel consumption derived from the Engine Factor: f_m at Rated Output of TNV Engines' table.

Table 4-1 Engine factor: f_m at rated output of TNV engines

Model	Rated speed (min^{-1})								
	For industrial use							For generators	
	2000	2200	2400	2500	2600	2800	3000	1500	1800
3TNV88C	–	–	–	0.410	0.416	0.471	0.516	–	–
3TNV86CT	–	–	–	0.200	0.200	0.200	0.200	–	–
4TNV88C	–	0.350	0.391	0.404	0.396	0.445	0.411		
4TNV86CT	–	–	0.200	–	0.200	0.200	0.200	–	
4TNV98C	0.541	0.564	0.565	0.579	–	–	–	–	
4TNV98CT	0.241	–	0.200	0.200	–	–	–	–	

2. Obtain correction factor α_c.

   $\alpha_c = f_a^{fm}$

   Proceed with the calculation if the value of α_c satisfies the condition $0.96 \le \alpha_c \le 1.06$.

3. Obtain the corrected output under the actual test conditions as follows:

   $P = P_0 / \alpha_c$

P_0	:	Rated output under standard atmospheric conditions	(kW)
P	:	Output under actual test conditions	(kW)
α_c	:	Correction factor	

Example:

The rated output of the 4TNV88C engine under standard atmospheric conditions is 35.5 kW at 3,000 min^{-1}.

What will be the output under actual test conditions of 98 kPa (approximately 200 m), intake air temperature of 313 K (40 °C), atmospheric temperature of 309 K (36 °C) and relative humidity of 40 %?

First determine the power correction formula to be applied according to *Correction formula (A)...JIS B8003 (ISO 15550: 2002) on page 4-4* or *Correction formula (B)...JIS B8002-1 (ISO 3046-1: 2002) on page 4-7*.

Since the engine intake air temperature and dry atmospheric pressure are in the ranges of 10 to 40 °C and 90 to 110 kPa, respectively, the correction formula (A) in *Correction formula (A)...JIS B8003 (ISO 15550: 2002) on page 4-4* applies.

The atmospheric temperature is not taken into consideration in selecting the power correction formula to be applied.

p_r	: Standard atmospheric pressure	100 kPa
$ø_r$	: Relative humidity under standard atmospheric conditions	0.30 (30 %)
T_r (t_r)	: Intake air temperature under standard atmospheric conditions	298K (t_r = 25 °C)
p_{sr}	: Saturation vapor pressure under standard atmospheric conditions	3.170 kPa (Obtain from the table *Relationship between Atmospheric Temperature and Saturation Vapor Pressure on page 4-10.*)
p_y	: Atmospheric pressure under actual test conditions	98 kPa
$ø_y$	: Relative humidity under actual test conditions	0.40 (40 %)
T_y (t_y)	: Intake air temperature under actual test conditions	313 K (40 °C)
p_{sy}	: Saturation vapor pressure under actual test conditions	7.385 kPa (Obtain from the table *Relationship between Atmospheric Temperature and Saturation Vapor Pressure on page 4-10.*)

1. Obtain atmospheric factor f_a. Since 4TNV88C is a naturally aspirated engine,

$$f_a = \left(\frac{p_r - \phi_r \times p_{sr}}{p_y - \phi_y \times p_{sy}}\right)\left(\frac{T_y}{T_r}\right)^{0.7}$$

$$= \frac{100 - 0.30 \times 3.170}{98 - 0.40 \times 7.385}\left(\frac{313}{298}\right)^{0.7}$$

$$= \frac{99.049}{95.046} \times 1.0350$$

$$= 1.0786$$

2. Obtain engine factor f_m.

   It is 0.411 for 4TNV88C at 3,000 min^{-1} from the engine factor table.

3. Obtain correction factor α_c.

   $\alpha_c = f_a^{fm} = 1.0786^{0.411} = 1.0316$

   Since this value of α_c satisfies the condition $0.96 \leq \alpha_c \leq 1.06$ for application of the example formula, proceed with the calculation.

4. Obtain the corrected output under the actual test conditions as follows:

   $P = P_0 / \alpha_c = 35.5 / 1.0316$

   $= 34.4\ kW$

   Therefore, the output is down by 1.1 kW or approximately 3.1 % in this example.

Correction formula (B)...JIS B8002-1 (ISO 3046-1: 2002)

Use correction formula (B) when the actual test conditions are very different from the standard atmospheric conditions.

1. First obtain the K value expressed as follows for the cases with and without the turbocharger.
   - For naturally aspirated engine

$$K = \frac{p_x - \phi_x \times p_{sx}}{p_r - \phi_r \times p_{sr}} \left(\frac{T_r}{T_x}\right)^{0.75}$$

   - For turbocharged engine

$$K = \left(\frac{p_x}{p_r}\right)^{0.7} \left(\frac{T_r}{T_x}\right)^{2.0}$$

   Subscripts "r" and "x" represent the values under standard atmospheric conditions and actual test conditions, respectively.

p_r	:	Standard atmospheric pressure	100 kPa
ϕ_r	:	Relative humidity under standard atmospheric conditions	0.30 (30 %)
T_r (t_r)	:	Intake air temperature under standard atmospheric conditions	298 K (t_r = 25 °C)
p_{sr}	:	Saturation vapor pressure under standard atmospheric conditions	3.170 kPa (Obtain from the table *Relationship between Atmospheric Temperature and Saturation Vapor Pressure on page 4-10*.)
p_x	:	Atmospheric pressure under actual test conditions	kPa
ϕ_x	:	Relative humidity under actual test conditions	
T_x (t_x)	:	Intake air temperature under actual test conditions	K (°C)
p_{sx}	:	Saturation vapor pressure under actual test conditions	kPa (Obtain from the table *Relationship between Atmospheric Temperature and Saturation Vapor Pressure on page 4-10*.)
T_{cr} (t_{cr})		Atmospheric temperature at standard atmospheric conditions	K (°C)
T_{cx} (t_{cx})		Atmospheric temperature at test conditions	K (°C)

2. Obtain correction factor α as follows:

   $\alpha = K - 0.7\,(1 - K)\,(1 / \eta m - 1)$ $\eta m = 0.8$ (machine efficiency)
   $= K - 0.175\,(1 - K)$

3. Obtain the corrected output under the actual test conditions.

   $P_y = \alpha \cdot P_r$

   Where,

P_r	:	Rated output under standard conditions	kW
P_y	:	Output under actual test conditions	kW
a	:	Correction factor	

Atmospheric Pressure Calculation for Change in Altitude

$P_x = (3.731444 - 0.841728 \times 10^{-4} \times H)^{5.255880} / 10$...JIS W0201 (ISO 2533-1975)

Where,

p_x : Atmospheric pressure in kPa at H (m) above sea level

p_r : Standard atmospheric pressure 101.3 kPa at 0 (m) above sea level

H : Altitude (m)

Atmospheric Temperature Calculation for Change in Altitude

$t_x = t_r - 0.0065 \times H$

Where,

t_x : Atmospheric temperature (°C) at H (m) above sea level

t_r : Atmospheric temperature (25 °C) at 0 (m) above sea level

H : Altitude (m)

Relationships among Altitude, Atmospheric Pressure and Atmospheric Temperature

Altitude (m)	Atmospheric pressure (kPa)	Altitude (m)	Atmospheric pressure (kPa)
0	101.3	2600	73.7
100	100.1	2800	71.9
200	99.0	3000	70.1
400	96.6	3200	68.3
600	94.3	3400	66.6
800	92.1	3600	64.9
1000	89.9	3800	63.3
1200	87.7	4000	61.6
1400	85.6		
1600	83.5		
1800	81.5		
2000	79.5		
2200	77.5		
2400	75.6		

[In accordance with JIS W0201]

How to Obtain Relative Humidity by Dry and Wet-bulb Thermometer

Even if the wet bulb temperature becomes lower than 0 °C, the wet bulb is not frozen (excessive engine coolant is provided)

Relative humidity (%)

Dry bulb °C	Difference between dry and wet bulb temperatures																			
	0.0	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**	**5.5**	**6.0**	**6.5**	**7.0**	**7.5**	**8.0**	**8.5**	**9.0**	**9.5**	**10.0**
40	100	97	94	91	88	85	82	80	77	74	72	69	67	64	62	59	57	55	53	51	48
35	100	97	93	90	87	84	81	78	75	72	69	67	64	61	59	56	54	51	49	47	44
30	100	96	93	89	96	83	79	76	73	70	67	64	61	58	55	52	50	47	44	42	39
25	100	96	92	88	84	81	77	74	70	67	63	60	57	53	50	47	44	41	38	35	33
20	100	96	91	87	83	78	74	70	66	62	59	55	51	48	44	40	37	34	30	27	24
15	100	95	90	85	80	75	70	66	61	57	52	48	44	40	35	31	27	23	19	16	12
10	100	94	88	82	76	71	65	60	54	49	44	39	33	28	23	19	14				
5	100	93	86	78	72	65	58	51	45	38	32	25	19	13							
0	100	91	82	73	64	56	47	39	31	22	14										
-5	100	88	77	65	54	43	32	21													
-10	100	84	69	54	38	23															

[In accordance with JIS Z8806]

The wet bulb at a temperature lower than 0 °C is frozen

Relative humidity (%)

Dry bulb °C	Difference between dry and wet bulb temperatures																			
	0.0	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**	**5.5**	**6.0**	**6.5**	**7.0**	**7.5**	**8.0**	**8.5**	**9.0**	**9.5**	**10.0**
40	100	97	94	91	88	85	82	80	77	74	72	69	67	64	62	59	57	55	53	51	48
35	100	97	93	90	87	84	81	78	75	72	69	67	64	61	59	56	54	51	49	47	44
30	100	96	93	89	86	83	79	76	73	70	67	64	61	58	55	52	50	47	44	42	39
25	100	96	92	88	84	81	77	74	70	67	63	60	57	53	50	47	44	41	38	35	33
20	100	96	91	87	83	78	74	70	66	62	59	55	51	48	44	40	37	34	30	27	24
15	100	95	90	85	80	75	70	66	61	57	52	48	44	40	35	31	27	23	19	16	12
10	100	94	88	82	76	71	65	60	54	49	44	39	33	28	23	19	14				
5	100	93	86	78	72	65	58	51	45	38	32	30	24	18							
0	100	91	82	74	65	57	49	41	33	25	17										
-5	95	84	73	63	52	42	31	21													
-10	91	76	62	48	35	21															

[In accordance with JIS Z8806]

Relationship between Atmospheric Temperature and Saturation Vapor Pressure

Atmospheric temperature K (°C)	Saturation vapor pressure kPa	Atmospheric temperature K (°C)	Saturation vapor pressure kPa
263 (-10)	0.260	295 (22)	2.645
265 (-8)	0.310	297 (24)	2.986
267 (-6)	0.369	298 (25)	3.170
269 (-4)	0.437	299 (26)	3.364
271 (-2)	0.518	301 (28)	3.783
273 (0)	0.611	303 (30)	4.247
275 (2)	0.706	305 (32)	4.760
277 (4)	0.814	307 (34)	5.125
279 (6)	0.935	309 (36)	5.948
281 (8)	1.073	311 (38)	6.633
283 (10)	1.228	313 (40)	7.385
285 (12)	1.403	315 (42)	8.210
287 (14)	1.599	317 (44)	9.112
289 (16)	1.819	319 (46)	10.100
291 (18)	2.065	321 (48)	11.178
293 (20)	2.339	323 (50)	12.353

Note: A temperature lower than 0 °C indicates saturation vapor pressure of ice.

Corrections for High Altitudes

As described in *Power Corrections on page 4-3*, the output decreases at higher altitudes, and the exhaust gas density increases.

Under the Tier 4 standard, exhaust gas emissions must be guaranteed up to a high altitudes of 5,500 ft (1676.4 m).

To guarantee engine performance and durability at high altitudes, high altitude correction control is applied.

Regarding details on engine performance at high altitudes, please contact YANMAR.

Output Correction

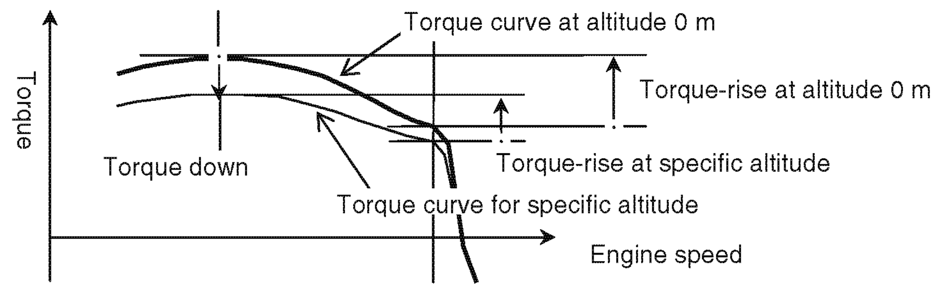
Reduction of output with regard to increase and decrease of altitude is summarized below, on the basis of actual measurement.

Altitude (m)		0	1000	2000	3000
Reduction of rated output (%)	Naturally aspirated engines	0	10	20	30
	Turbocharged engines	0	7	10	15

Torque Correction

The operating altitude of an engine affects the maximum torque because the excess air ratio is too low to allow the engine to attain the rated output. The reduction of maximum torque is described below based on the measured value.

Altitude (m)		0	1000	2000	3000
Reduction of maximum torque (%)	Naturally aspirated engines	0	20	30	35
	Turbocharged engines	0	10	15	20



Exhaust white Smoke

White smoke generation immediately after starting the engine increases and lasts longer at higher altitudes due to ignition delay caused by the decreased air density and temperature.

The following measures are available for these problems.

- Use of diesel fuel with higher cetane number: 52 or greater
- Energization of glow plug after starting

Misfire at High Altitude

If the engine is operated at high speed immediately after starting at high altitudes, a misfire is likely to occur due to ignition delay caused by the decreased air density and outdoor temperature.

Actions similar to those against white smoke generation in *Exhaust white Smoke on page 4-12* are required in order to reduce misfire. Sufficient warming up of the engine (at least 5 minutes) at medium or lower speed is also required.

Others

In addition to the above, the following problem can occur.

Increased heat load due to rise of exhaust temperature

Altitude (m)		0	1000	2000	3000
Rise of exhaust temperature at rated output (%)	Naturally aspirated engines	0.0	2.0	3.0	3.0
	Turbocharged engines	0.0	0.0	1.0	4.0

Section 5

ENGINE PERFORMANCE

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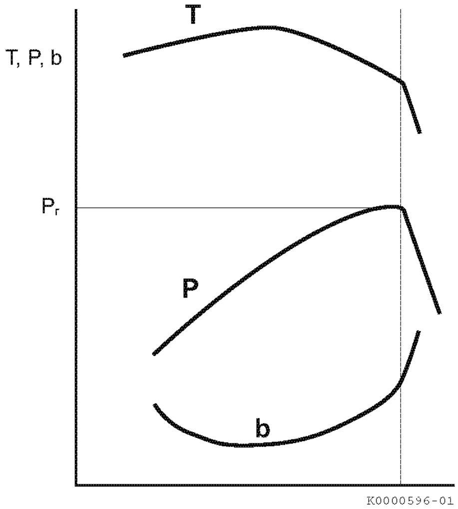
Performance Curves

Engine performance is generally expressed with three curves: output, specific fuel consumption and torque curves, as shown in the figure below:



T: Torque (N·m)

P: Output (kW)

b: Specific fuel consumption (g/kWh)

n: Engine speed (min^{-1})

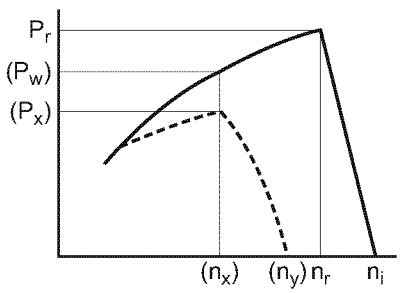
P_r: Rated output (kW)

n_r: Rated speed (min^{-1})

The engine performance curves represent the performance of an engine at rated speed n_r that produces rated output P_r. The output of the same engine at another speed cannot be read from these curves. Consequently, the performance curves shown in a catalog or this manual show a rated output only at a specific rated speed. If you need performance curves at other rated speeds, please contact YANMAR.

Each of the performance curves has the following meaning.

Output curve: *P*



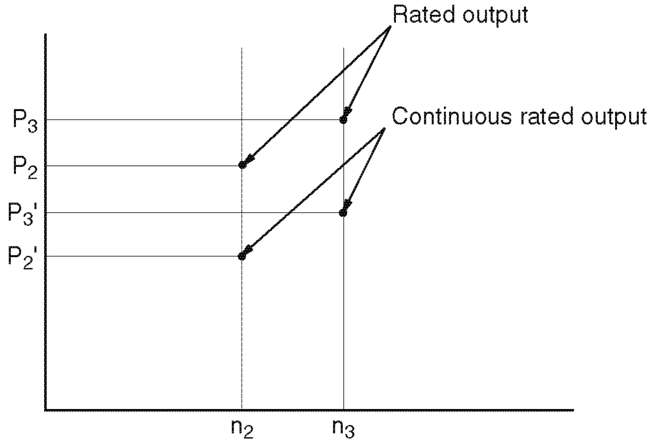
The figure to the left shows a performance curve of an engine set to rated speed n_r and rated output P_r. It shows the maximum speed is n_i at no load.

For example, the output curve of a 4TNV88C diesel engine shows the no-load maximum speed n_i of 2750 min^{-1} and the rated output P_r of 31.7 kW when the rated speed is set to 2600 min^{-1}.

When you look at the performance curves make sure that you do not confuse the values of Rated Speed (n_r) and Rated Output (P_r) with Output (P_w) if the rated speed is set to (n_x). For example, if you run a 4TNV88C engine at a rated speed (n_x) of 2400 min^{-1}, what will be the rated output (P_x) in kW? The rated output will be 29.1 kW. This is shown as the “broken line” in the performance curve. The no-load maximum speed (n_y) is 2550 min^{-1} from the specification tables in 4TNV88C.

Refer to the catalog and/or the specifications of this manual for the rated output at various rated engine speeds. Note that rated output at the flywheel must be reduced for fan and other auxiliary loads.

The arrows on the following output curves show the rated output of a 2P (or 4P) generator and continuous rated output, respectively. They apply to engines used exclusively for driving generators.

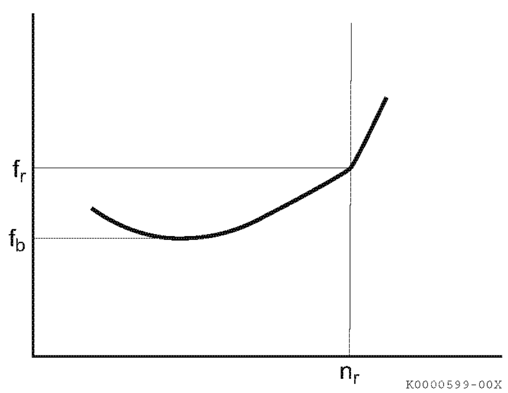


Generators are often driven continuously under load. The engine output to meet this demand is termed the continuous rated output. The rated output of a generator should be less than or equal to the continuous rated output of the engine (P_2', P_3'). Generators frequently work under an overload condition that is 10 % greater than the continuous rated output. They must be capable of sustaining this overload for one hour out of every twelve hours. The engine output at this overload condition is called the rated output (P_2, P_3).

The rated engine speeds of n_2 and n_3 correspond to the generator frequencies of 50 Hz and 60 Hz. The rated engine speed must be either fixed or adjusted to n_2 or n_3 during operation.

Consequently, the performance curves for engines designed for generator applications will be the rated output and continuous rated output at the rated speeds n_2 and n_3 as indicated by the arrows shown in this example.

Specific diesel fuel consumption curve: *b*



The specific diesel fuel consumption described in the catalog and/or specification table represents a specific diesel fuel consumption b_r at a rated speed n_r and rated output P_r. In the case of a construction machine, b_b may be called the minimum specific diesel fuel consumption.

Torque Curve: *T*

One of the important characteristics of industrial machinery is the torque backup value expressed with the torque curve.

The curve should be smooth with a peak in the middle. The tenacity of the engine can be expressed with this torque backup value or torque backing ratio (torque rise) and the size of the torque range.

The greater those values, the better the tenacity of the engine. Ultimately, however, it is necessary to determine the level of torque characteristics in a matching test of the driven machine. An engine driving a generator has a smaller torque backup ratio (torque rise) than industrial machinery engines in general. This is because a generator does not require good tenacity on the part of the engine.

The engine torque curve is shown below.

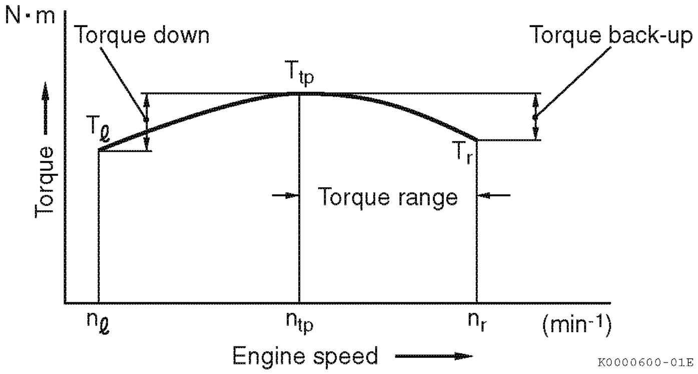


Figure 5-1

T_{ℓ}	:	Torque at low idling speed	N·m
T_{tp}	:	Maximum torque	N·m
T_r	:	Rated torque at rated output	N·m
n_{ℓ}	:	Low idling speed of rotation	min^{-1}
n_{tp}	:	Speed at maximum torque (T_{tp})	min^{-1}
n_r	:	Rated speed	min^{-1}

- Torque backup value refers to the difference between the maximum torque and the torque at rated output.

  Torque backup = Maximum torque (T_{tp}) – torque at rated output (T_r)

  Torque backup ratio (torque rise) = $\frac{T_{tp} - T_r}{T_r} \times 100$ (%)

- Torque down value refers to the difference between the maximum and minimum torque values.

  Torque down = $T_{tp} - T_{\ell}$

  Torque down ratio = $\frac{T_{\ell}}{T_{tp}} \times 100$ (%)

- Torque range refers to the difference ($n_r - n_{tp}$) between the speed (n_{tp}) at maximum torque (T_{tp}) and the rated speed (n_r),

Partial Recovery Ratio

Partial recovery ratio refers, for example, to the recovery of output expressed as a percentage to the maximum output curve at 80 % of the rated speed, when an engine set to a rated speed and rated output is loaded from 80 % of maximum no-load speed **(Figure 5-2)**.

The 80 % referred to above is a definition and does not have any practical significance, but if this characteristic is low, it may cause engine to stall when coupled with a driven machine that requires a wide range of engine speeds. **(Figure 5-2,** dashed line.**)**

The common rail engines that comply with Tier 4 have a partial recovery rate of 100 % because they have an electronic control governor, but the user must check the characteristics after installing it in the driven machine.

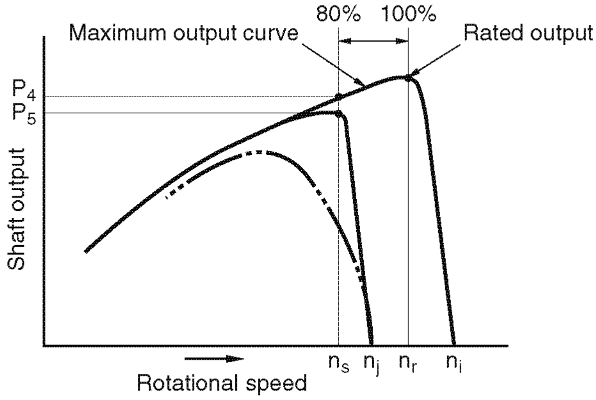


Figure 5-2 **Partial recovery ratio curve**

n_r : Rated engine speed
n_i : No-load maximum speed
n_s : $n_r \times 0.8$
n_j : $n_i \times 0.8$

Partial recovery ratio $= \frac{P_5}{P_4} \times 100\ (\%)$

Governor Performance...JIS B8002-4

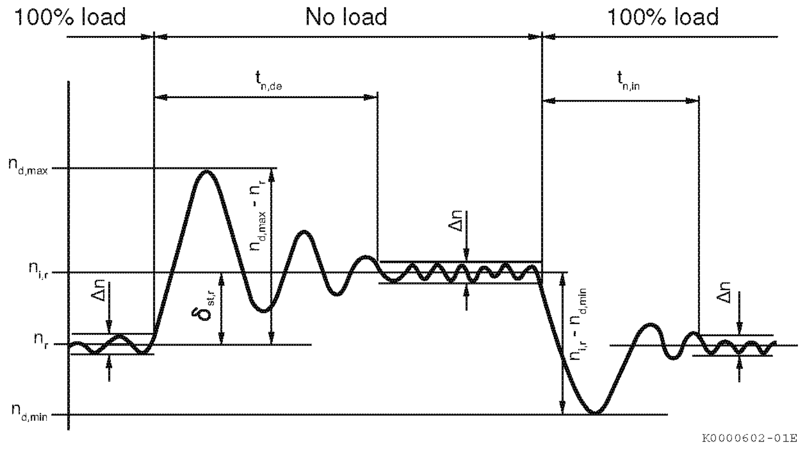


Figure 5-3

$n_{d,max}$ $n_{d,min}$	Transient engine speeds under varying loads
n_r	Rated speed
$n_{i,r}$	No-load speed
β_n	Steady-state governed speed band (range of speed variation in steady state Δn expressed as a percentage of the rated speed. The width of variation expressed in min^{-1} is called the speed variation.)
$t_{n,in}$, $t_{n,dc}$	Recovery time (time for steady-state governed speed band from the start of speed variation to the setting to the steady state in transient state, or the time after departure from band ν to entry to band ν.)
$\delta n_{st,r}$	Speed droop (deviation in speed after setting governor to rated output and rated speed until transition to no load, expressed by the ratio (%) to the rated speed. Also referred to as permanent speed change ratio in some cases.)

$$\delta n_{st,r} = \frac{n_{i,r} - n_r}{n_r} \times 100 \ (\%)$$

δn_{dyn}	Instantaneous speed difference (ratio (%) of maximum speed change to rated speed when the load is suddenly varied while the engine is running in the governed state. Also referred to as transient speed difference in some cases.)*

*1 When 100 % load is removed momentarily (in a naturally aspirated engine and turbo-charged engine)

$$\delta n^{+}_{st} = \frac{n_{d,max} - n_r}{n_r} \times 100 \ (\%)$$

*2 When a load is input momentarily (naturally aspirated engine)

$$\delta n^{-}_{dyn} \ \frac{n_{d,min} - n_{i,r}}{n_r} \times 100 \ (\%)$$

Governor performance of TNV series engines

Engines that comply with Tier 4 (common rail type engine)

		Constant speed specification	Variable speed specification
		DI	
		CL	VM
Instantaneous speed difference (transient speed difference) ratio (δn^{+}_{dyn}, δn^{-}_{dyn})	%	≤ 8 to 10	≤ 12
Permanent speed difference (steady state difference) ratio ($\delta n_{st,r}$)	%	≤ 1	≤ 4 to 6
Recovery time ($t_{n,de}$, $t_{n,in}$)	sec.	≤ 5	≤ 6
Speed variation (Δn)	min^{-1}	≤ 15	≤ 22

Section 6

COLD STARTING AIDS

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TNV series engines are equipped with cold starting aids.
If an optional block heater is applied, the engine can be started even at very low temperature.
For use of cold starting aids by ambient temperature. Refer to *Low-temperature Startability on page 1-7.*
This section describes the cold starting aids.
Refer to Electronic Control System on page 14-1 for control circuits.

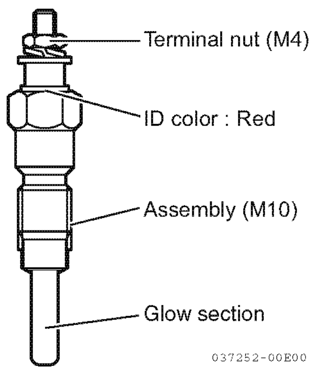
Glow Plug

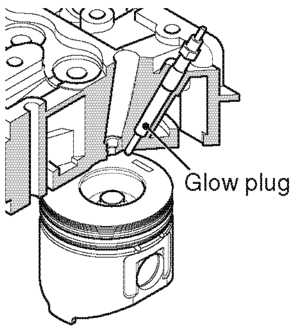
The glow plug is an electrically heated coil that is installed in the combustion chamber. The glow plug is heated by an electric current from the battery before starting the engine. The combustion chamber is heated by the red-hot glow plug for easier starting.

A glow plug is installed for each cylinder.

Applicable model		3TNV88C, 4TNV88C, 3TNV86CT, 4TNV86CT, 4TNV98C, 4TNV98CT
Nominal voltage	V	12
Type name		Standard glow plug
Part code		129008-77800
Standard preheating time	Sec	15
Rated capacity	V/A	11/7.0
Identification color		Black

Glow plug structure





DI engine

Figure 6-1

Engine Block Heater

An optional engine block heater may be installed on the cylinder block using the special screw mount provided with the unit. The engine block heater uses an AC power supply instead of a battery.

The engine block heater heats the engine coolant in the cylinder block jacket. It indirectly heats the engine oil, which lowers the viscosity of the oil to reduce drag torque. It also heats the cylinder head combustion chamber to make diesel fuel ignition easier and improve cold startability.

Connect the engine block heater to the AC power supply several hours prior to starting the engine depending on the ambient temperature condition and the engine size.

The engine block heater is quite effective in starting engines in cold weather (below -20 °C) for a driven machine with a large drag torque.

Engine block heaters are standard equipment on engines used for disaster prevention or for those mounted on emergency generators to ensure starting in case of an emergency. If the engine block heater is permanently connected to the power supply when the ambient temperature is high, the engine coolant may reach the boiling point or the heater life may be shortened.

Since alternating current is supplied at various voltages, the engine block heater can be set to meet the requirements of various voltages. The following table indicates parts frequently used for industrial engines:

Part name	Part code	Remarks
Block heater	171015-77900	Rated capacity: 115 V AC/400 W
	129908-77900	Rated capacity: 200 V AC/200 W
Connecting code	171015-77910	Approx. 300 mm long

NOTICE

- Never connect the engine block heater to the power supply without engine coolant - the engine block heater will overheat.
- Never use the engine block heater at ordinary temperature as the engine coolant will boil and the engine block heater will overheat.
- When the engine starts, turn the commercial power supply off and disconnect the cord from the engine.

Block heater configuration

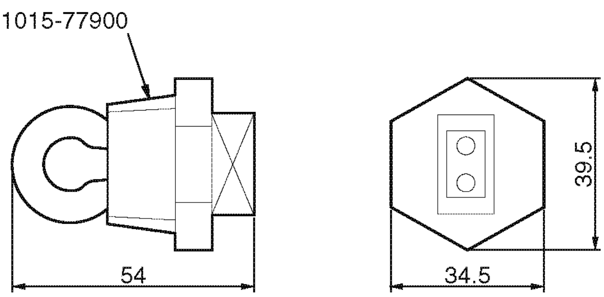


Figure 6-2

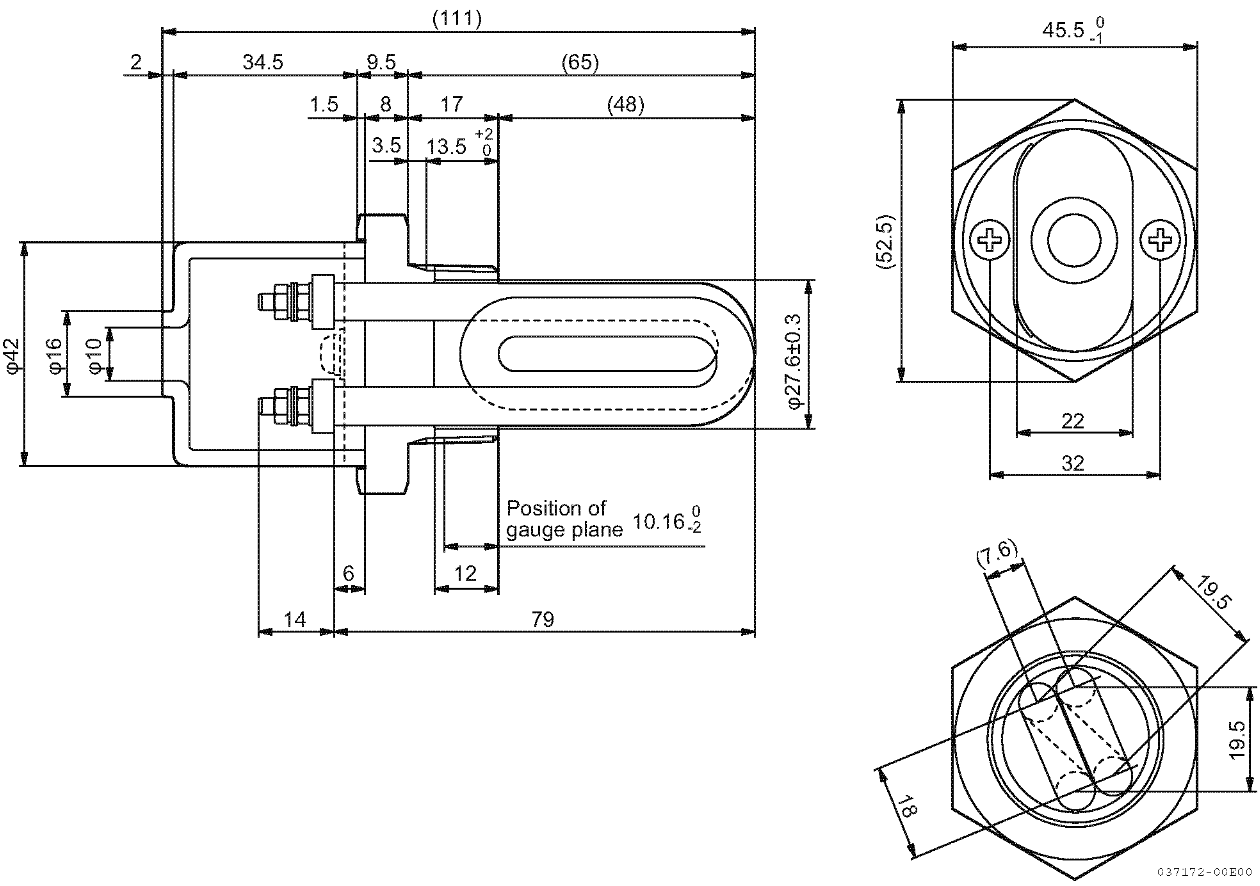


Figure 6-3

Block heater connection diagram

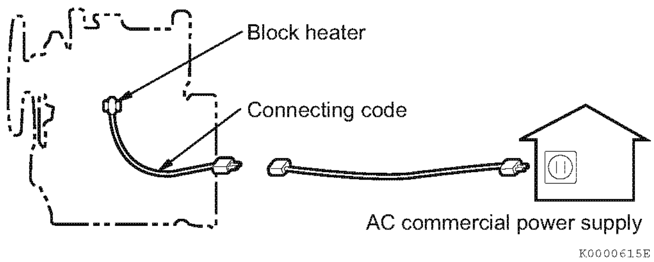


Figure 6-4

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Section 7

AIR INTAKE SYSTEM

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The amount of air supplied to the combustion chamber in the intake stroke of the engine is directly related to the combustion performance of the engine. The amount of air greatly affects basic engine performance such as engine output, specific diesel fuel consumption, exhaust system and engine service life. You must take these factors into consideration when you select the air intake system for your application.

Air Capacity Required for Combustion

Theoretically, the minimum amount of air required for complete combustion of approximately 1 kg of diesel fuel is approximately 14.6 kg (about 12.5 m^3/standard atmospheric condition). This is not enough air, however, to ensure complete combustion. The ratio of extra air needed to the theoretical minimum amount of air for complete combustion is called the excess air ratio. In the case of a diesel engine, the excess air ratio at full load is 1.5 to 2.0. That means the engine requires 1.5 to 2.0 times the theoretical minimum amount of air for complete combustion. It is not true, however, that the greater the excess air ratio, the better. Excess air ratio is calculated to ensure optimal engine performance under near full load conditions (actual output is close to the rated output of the engine). For a smaller load, less diesel fuel is injected which increases the excess air ratio. This also causes a drop in combustion temperature and problems in the exhaust system. Therefore you should avoid low-load operation for an extended period of time.

Calculation of the Air Capacity

There are two types of air capacity, the air flow actually needed for combustion and the apparent intake air flow for checking air cleaner capacity. Different calculation formulas are used accordingly.

Air capacity required for combustion

There are a number of ways to determine the air capacity necessary for diesel fuel combustion. The simplest calculation method is based on engine displacement as follows:

$$Q_1 = \eta_V \times V_S \times N \times C \times 10^{-3}$$

Where,

Q_1	:	Required air capacity	m^3/min
η_V	:	Volumetric efficiency:	
		Naturally aspirated engine	0.85 to 0.9
		Turbocharged engine	1.3
V_S	:	Engine displacement	ℓ
N	:	Speed of engine	min^{-1}
C	:	Constant, 4-cycle engine:	1/2

Volumetric efficiency η_V differs slightly depending on the range of engine speeds encountered during actual use but η_V can assumed to be constant when you calculate air capacity. If η_V is 0.9 for the naturally aspirated engine, 1.3 for the turbocharged engine, and the engine speed N is a variable, then required air capacity for combustion in the respective engines is given by the following calculation formula:

N: Engine speed (min^{-1})

No.	Engine model	Engine displacement: (ℓ)	Required air capacity Q_1 for combustion: (m^3/min)
1	3TNV88C	1.642	$7.39 \times 10^{-4} \times N$
2	4TNV88C	2.190	$9.85 \times 10^{-4} \times N$
3	3TNV86CT	1.568	$1.02 \times 10^{-3} \times N$
4	4TNV86CT	2.091	$1.36 \times 10^{-3} \times N$
5	4TNV98C	3.319	$1.49 \times 10^{-3} \times N$
6	4TNV98CT	3.319	$2.16 \times 10^{-3} \times N$

Example:

How many cubic meters of air capacity will be required per minute for burning diesel fuel in a 3TNV88C diesel engine at 23.7 kW/2600 min^{-1}?

From the above table, the calculation formula for the air capacity required for burning diesel fuel in the 3TNV88C diesel engine is

$$Q_1 = 7.39 \times 10^{-4} N$$

The required air capacity can be obtained by substituting N with 2600 min^{-1}.

$$Q_1 = 7.39 \times 10^{-4} \times 2600$$
$$= 1.92\ (m^3/min)$$

Apparent air capacity

Apparent air capacity should be determined when selecting air cleaner capacity. The air capacity that is calculated using the formula in *Calculation of the Air Capacity on page 7-3*, *Air capacity required for combustion*, is called the mean air capacity. Since air flows into the engine once every two revolutions, considerable air flow pulsation is created. As the number of cylinders in the engine decreases, the amount of pulsation increases. To reduce the amount of air flow pulsation, it is necessary to increase the capacity of the air cleaner so it is slightly larger than the mean air capacity. This increase is called apparent air capacity.

Use the following formula to calculate the apparent air capacity. This formula applies to both naturally aspirated engines and turbocharged engines.

$$Q_2 = Q_1 \times K$$

Where,

Q_2	:	Apparent air capacity	m^3/min
Q_1	:	Required air capacity for combustion	m^3/min
K	:	Coefficient depending on the number of cylinders	
	:	3 cylinders	1.7
	:	4 cylinders	1.0

Air cleaner selection method

Air cleaner performance curve and apparent air capacity should be determined when selecting air cleaner capacity. Use the method in the following figure. Output setting is at YANMAR standard air intake negative pressure for TNV engines. As the air intake negative pressure increases, the engine output is reduced, select the air cleaner with appropriate size.

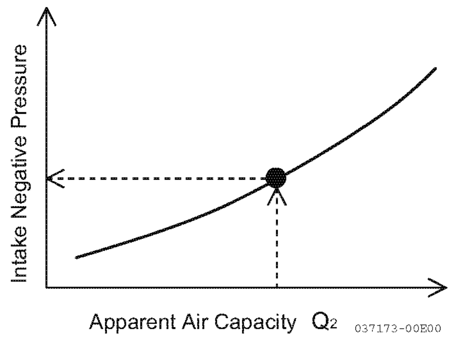

Figure 7-1 Air cleaner performance curve

Air Cleaner Selection Table

The intake air capacity of an engine is approximately proportional to the engine speed. YANMAR uses the following table when selecting the air cleaner for TNV engines. We may recommend an air cleaner that is one size larger depending on the intended use of the driven machine and its service environment.

<table>
<tr><th>Air cleaner</th><th colspan="12">Single element</th></tr>
<tr><th>Engine</th><th colspan="2">CL</th><th colspan="10">VM</th></tr>
<tr><td>min^{-1}</td><td>1500</td><td>1800</td><td>2000</td><td>2100</td><td>2200</td><td>2300</td><td>2400</td><td>2500</td><td>2600</td><td>2700</td><td>2800</td><td>3000</td></tr>
<tr><td>3TNV88C</td><td colspan="4">–</td><td colspan="8">5 inch</td></tr>
<tr><td>3TNV86CT</td><td colspan="7">–</td><td colspan="5">5 inch</td></tr>
<tr><td>4TNV88C</td><td colspan="8">5 inch</td><td colspan="4">6 inch</td></tr>
<tr><td>4TNV86CT</td><td colspan="12">7 inch</td></tr>
<tr><td>4TNV98C</td><td colspan="8">7 inch</td></tr>
<tr><td>4TNV98CT</td><td colspan="8">7 inch</td></tr>
</table>

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<tr><th>Air cleaner</th><th colspan="12">Double element</th></tr>
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<tr><td>3TNV88C</td><td colspan="4">–</td><td colspan="6">5 inch</td><td colspan="2">6 inch</td></tr>
<tr><td>3TNV86CT</td><td colspan="7">–</td><td colspan="5">6 inch</td></tr>
<tr><td>4TNV88C</td><td colspan="6">5 inch</td><td colspan="6">6 inch</td></tr>
<tr><td>4TNV86CT</td><td colspan="12">7 inch</td></tr>
<tr><td>4TNV98C</td><td colspan="8">7 inch</td></tr>
<tr><td>4TNV98CT</td><td colspan="8">7 inch</td></tr>
</table>

Refer to the *YANMAR TNV Option Menu* for details.

Air Cleaner

In the preceding subsection, the air capacity required for combustion was calculated. The purpose of the calculation was mainly to determine the air capacity for assuring the engine output performance.

For the engine to operate at full capacity, the intake air capacity should be sufficient, and the air has to be clean. Dust in the intake air has an adverse effect on the life of the main moving parts such as the piston, piston ring, cylinder block and the intake/exhaust valves. The air cleaner removes dust in before it gets into the engine. The air cleaner used for TNV series engine is called a cyclone paper element type and the element is a paper filter.

The air cleaner size is expressed by measuring its diameter in inches. Four types of air cleaners, 5, 6, 7, and 8 inches, are used for TNV series engines. Air cleaners of various configurations with different air intake/ exhaust port positions are available for various driven machines and mounting positions.
Refer to the *YANMAR TNV Option Menu* for details.

Although air cleaners are essential for general-purpose engines, if the application calls for indoor, emergency use purposes, and the engine will only run for short periods of time, no cleaner is generally provided. The chance that dust will degrade the life of the engine in these applications is minimal. In these types of applications, the air inlet must be covered with metal wire mesh or equivalent material.

Dust Removing Principle of the Air Cleaner

Dust is removed from the air as follows:

Air is sucked in the direction of the tangent from the air inlet (1) on the air cleaner body close to the circumference and is forced to swirl along the guides (vanes) on the inside of the main body. Larger particles of dust are separated by centrifugal force. The outer element (2) removes more than 99.9 % of dust and allows the clean air to enter the engine from the air cleaner outlet (3).

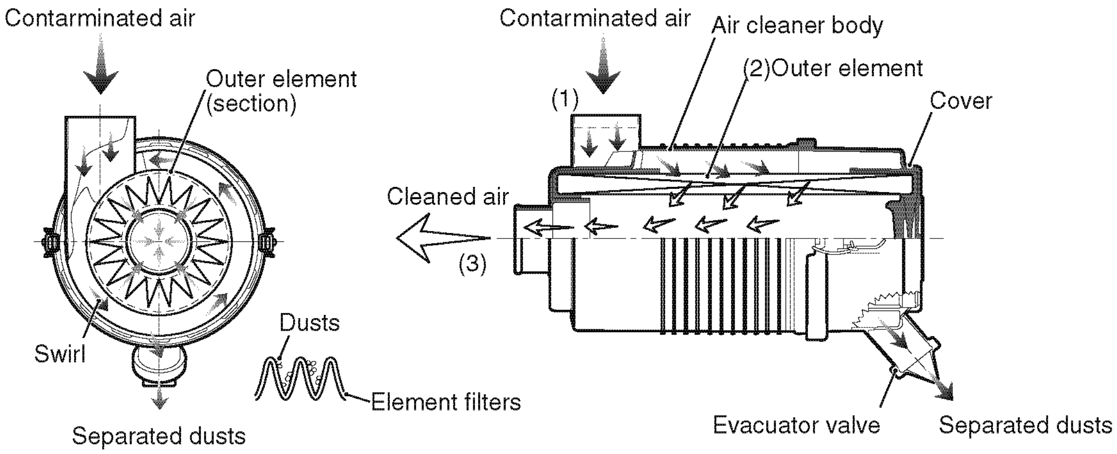

Figure 7-2

Structure of Air Cleaner

Types of air cleaner element

Two types of air cleaner are available as described below, depending not only on their size but also on the structure of the element inside the air cleaner:

- Single element type
- Double element (safety element) type

A double element type air cleaner has the inner element installed. This inner element is intended to prevent dust or foreign matters from entering inside the engine when the outer element is removed for cleaning and/or replacing the element. A double element type air cleaner is necessary to be applied especially when the engine is installed on driven machines which handle particulates (sands, cement, volcanic ashes, etc.) which will significantly accelerate the wear inside the engine, or when the engine is used in a dusty environment. However, please note that the capacity as an air cleaner and the maintenance period of a double element are the same as those of a single element which is the same size.

Precautions for air cleaners:

- Be sure to perform periodic maintenance/replacement for both element types.
- For the double element type, do not remove the inner element during a normal maintenance. (check the inner element if the dust indicator actuates soon after the outer element is replaced.)
- Also for the single element type, be careful not to allow the entrance of dust or foreign matters inside the engine during the maintenance.
- In general, the inner element can be installed even on a single element type air cleaner if the element is of the same manufacturer and the same size. (consult with manufacturer for more information.)

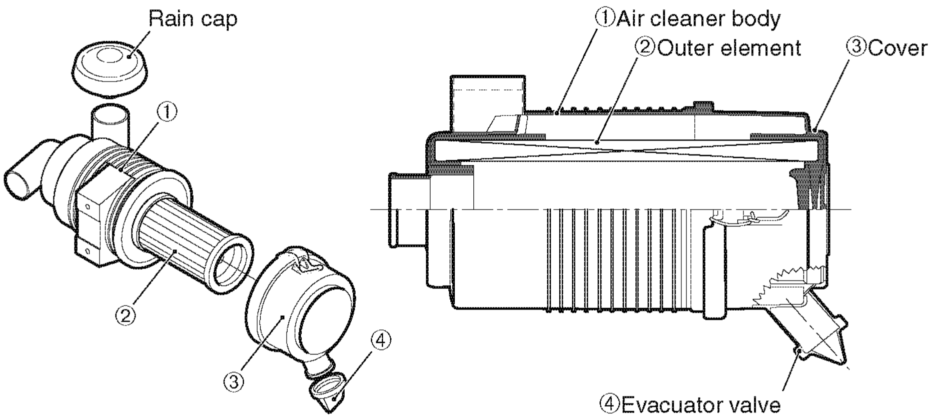

Figure 7-3 Structure of single element type

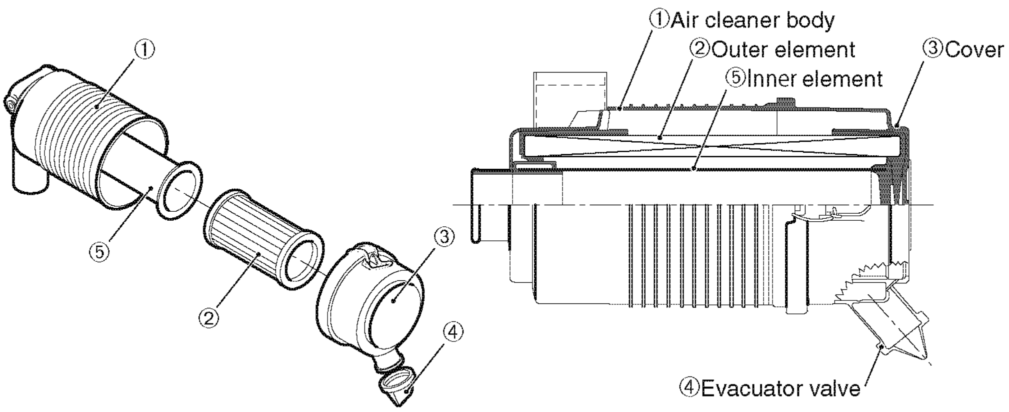

Figure 7-4 Structure of double element type

Dust Indicator

A dust indicator is mounted on the air outlet of the air cleaner to indicate the degree of air restriction and is available in a mechanical or electric type. Both types actuate when the intake air flow restriction reaches 6.23 kPa. When the mechanical type of dust indicator actuates, a "red band" appears inside of the indicator's body. The mechanical indicator has a latching feature and reset button. When the electric type of dust indicator actuates, an indicator lamp or LED comes on.

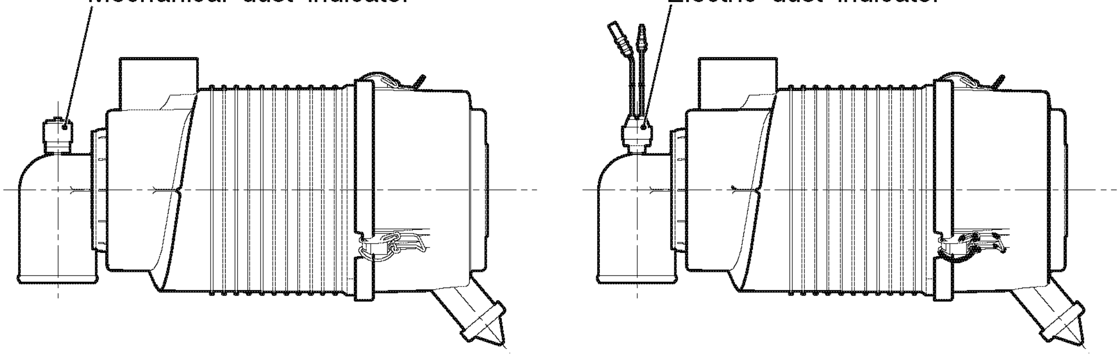

Figure 7-5

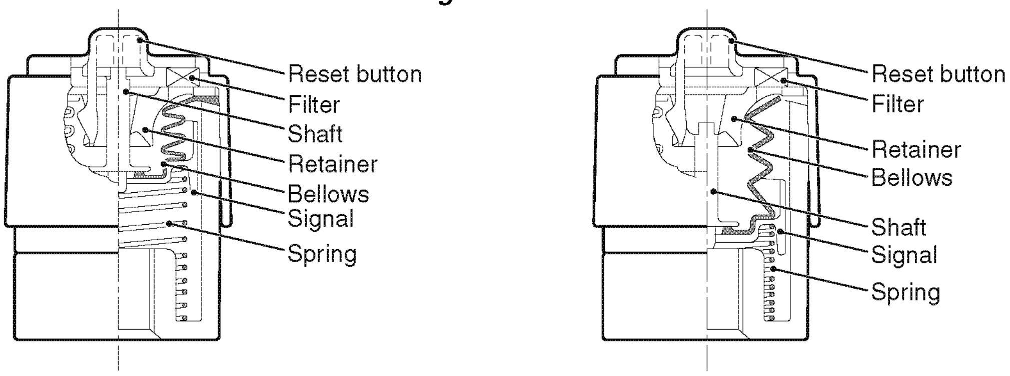

Figure 7-6 Mechanical dust indicator: Part code: 126650-12680

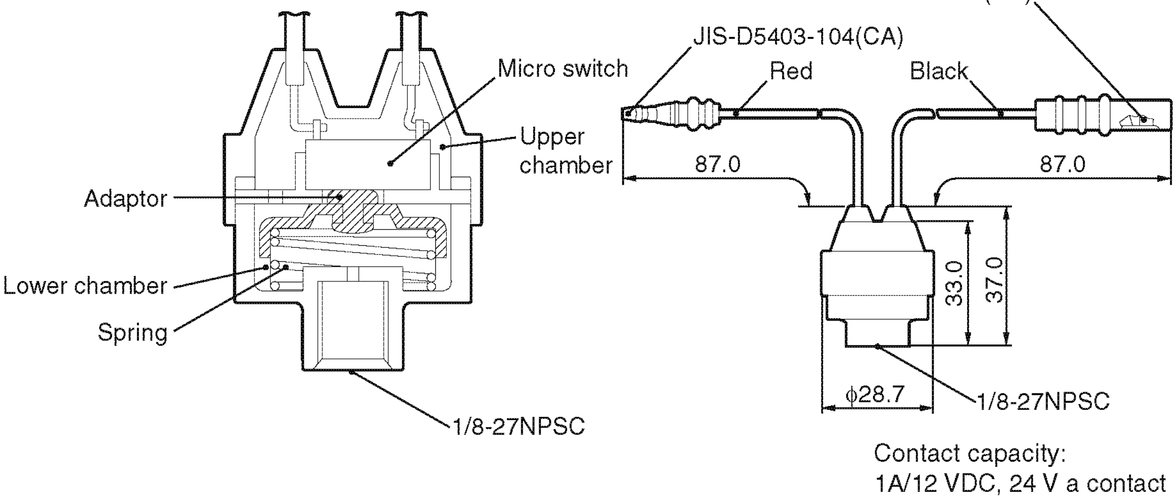

Figure 7-7 Electric dust Indicator: Part code: 119140-12680

Air Cleaner Installation

Maintenance of the air cleaner greatly affects engine service life. The air cleaner should be installed in a position that facilitates maintenance. Since the air cleaner requires space for element replacement, air cleaner layout must be considered carefully when designing a driven machine.

In addition, when installing an air cleaner on the engine body, select the bracket rigidity to keep vibration acceleration within 55 m/sec^2 [RMS] (low pass filter is set for 1 kHz) for an air cleaner made of resin. Make sure the air cleaner is installed to avoid resonance with the engine vibration isolators after the unit is installed on the driven machine. Check vibration and durability after the engine is installed. If vibration acceleration exceeds the target value, consider changing the position of the air cleaner.

Install the air cleaner body where the ambient air temperature is 80 °C (176 °F) or below.

Air Intake System Hose Routing

Carefully plan the location of the air cleaner and routing of the air intake hoses when you design a TNV engine application. Prevent vibration of the air intake hose and avoid contact with other components. If the intake air temperature is high according to *Cooling performance and heat resistance evaluation on page 12-13*, reconsider the air intake position. Make sure that no water, snow or dust can enter from the intake port.

Intake port position

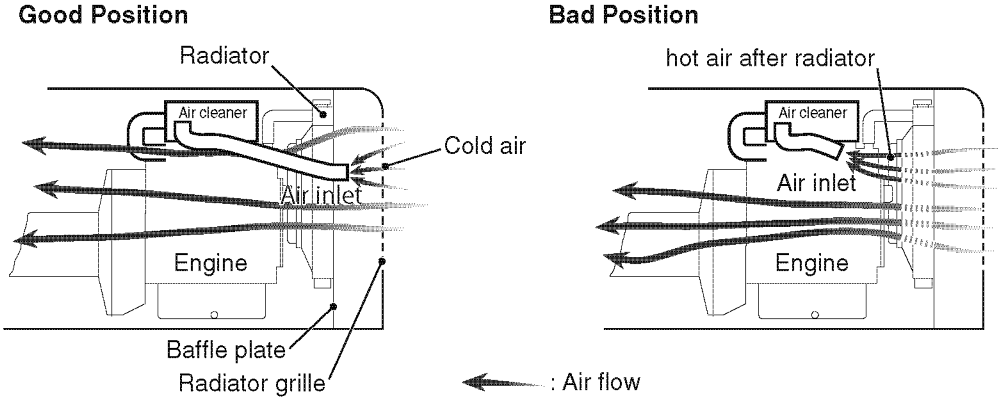

Figure 7-8

Inlet (a) of air hose should be lower than air cleaner inlet port (b) to keep water out of air cleaner canister.

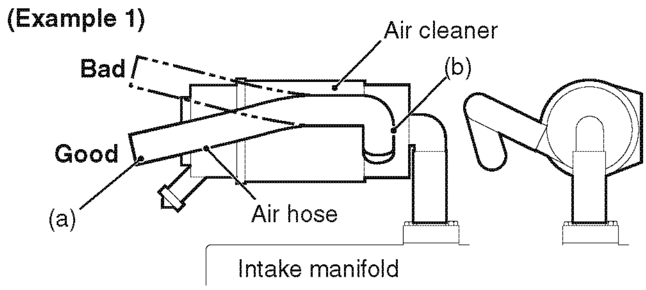

Figure 7-9

Select air intake hose materials that meet or exceed the following characteristics.

		Naturally aspirated engine	Turbocharged engine
Heat resistance		120 °C or higher	Turbocharged engine: 120 °C or above
Pressure resistance	Negative pressure	13 kPa or higher (air cleaner to air intake manifold)	29 kPa or higher (air cleaner to turbocharger)
	Positive pressure	–	196 kPa or higher (turbocharger to air intake manifold)
Materials		Ethylenepropylene rubber (EPDM)	Ethylenepropylene rubber (EPDM) (Air cleaner - blow-by gas circulation position) Oil resistant rubber (Ex. NBR + CSM coating) (Blow-by gas circulation position - turbocharger)

NOTICE

Do not use vinyl hose. It may be deformed under heat or intake negative pressure or become hard and brittle at low temperature.

Air Intake Throttle

Role and operation of air intake throttle

Air intake throttle is a device that controls the air volume of the engine intake. It is generally used in gasoline engine. For TNV engines, air intake throttle is used for burning the soot accumulated inside the DPF.
The figure below shows the schematic diagram of air intake throttle. Air intake throttle is driven by DC motor and the appropriate opening is indicated by the E-ECU (Electronic Engine Control Unit, refer to *Electronic Control Manual*) depending on engine speed or load conditions. Accordingly, the engine intakes the minimum required air volume and the exhaust temperature increases to burn the soot accumulated inside the DPF.

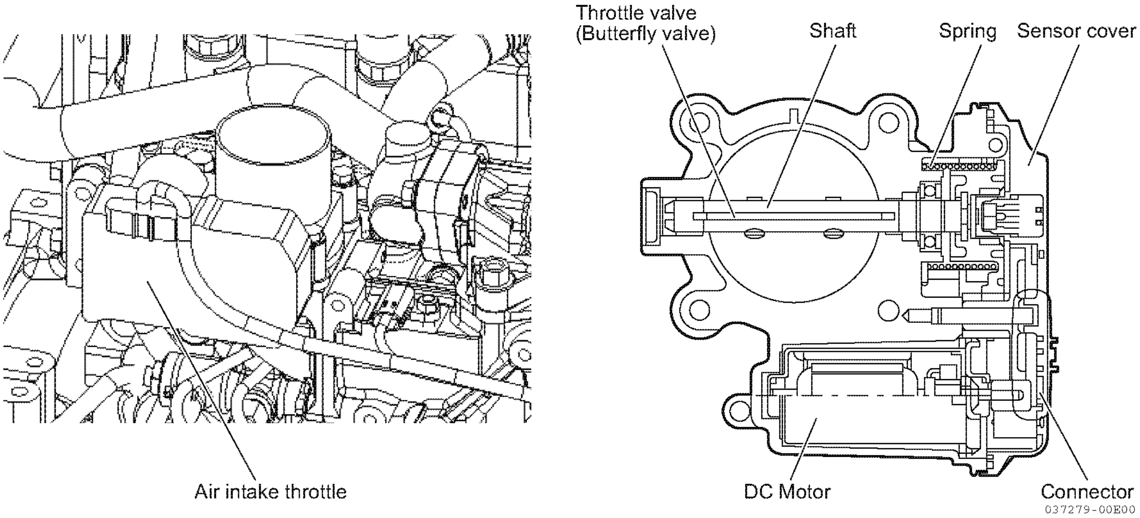

Figure 7-10

Air Intake Restriction

Factors that contribute to the increase or decrease of air intake restriction include the following:

(a) Engine intake air capacity

(b) Air cleaner capacity

(c) Length and diameter of the air intake hoses

(d) Number of air intake hose bends and the angles they are bent at

If these factors cause the air intake restriction to increase, it is impossible to obtain the necessary air capacity for proper combustion. This adversely affects engine combustion performance. If air intake restriction exceeds the allowable value, increased diesel fuel consumption, increased engine exhaust temperature, decreased engine output, increased emissions, and shorter engine life could result.

Reduction of air intake restriction requires proper engine and air intake system design. It is necessary to conduct a negative pressure test after installing the parts and components of the air intake system. If the test results exceed the allowable value, check factors (b), (c) or (d) listed previously to determine the cause.

Measurement of air intake restriction

Refer to *Installation Test Procedures on page 12-1* for the measurement of the air intake resistance.

Allowable air intake restriction

As output setting is at YANMAR standard air intake negative pressure for TNV engines, the air intake negative pressure increases, the engine output is reduced. If the output is significantly reduced due to the increase in the air intake negative pressure, it is required to review the intake system prior to starting the driven machine production.
Allowable resistance increases along with the operating time of air cleaner. Apply the initial upper limit value to the development stage of the driven machine and the upper limit for air cleaner replacement to the maintenance check stage.

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Section 8

EXHAUST SYSTEM

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* *In this material "DPF" means a filter designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine.*

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The purpose of an engine exhaust system is to release high temperature gases generated during fuel combustion to the air and to reduce exhaust noise using a muffler. The engine exhaust system has been playing important roles by adding functions such as EGR equipment for decreasing exhaust emissions/black smoke, DPF, or turbocharger equipment to improve engine performance and to provide high altitude capability. Components of the exhaust system, including the exhaust pipes and mufflers, produce resistance (exhaust back pressure) to the flow of exhaust gas. Excessive resistance can adversely affect engine performance including increase of fuel consumption, reduction of engine output, and worsened exhaust gas emissions/smoke density.

This section describes the considerations about the structures, functions, and applications of these major equipments, and the importance of exhaust back pressure which affects the engine performance together with the major equipments.

The surfaces of components in exhaust system become extremely hot, and the engine can be very dangerous especially after operation and immediately after shutdown. Be sure to check the heat shielding design and safety of the driven machine, and give instructions to the users.

In-use testing requirements

In order to meet future EPA requirements, Yanmar may request the equipment owner's cooperation for in-use testing. In addition, Yanmar may ask the equipment manufacturer's support to modify the original exhaust piping if necessary to satisfy the requirements in 40 CFR 1039.205(u).

For equipment that does not allow installation of an extension pipe, a connection must be designed into the exhaust system for temporary attachment of exhaust sampling equipment. An example of an approved connection would be internally threaded with standard pipe threads of a size not larger than one-half inch, and shall be closed by a pipe-plug when not in use.

EGR Equipment

Role and Operation of EGR

EGR (Exhaust Gas Recirculation) is a technology which has been widely used for automotive diesel engines. EGR lowers the combustion temperature and reduces NOx which is a composition subject to emission control regulations by introducing a part of exhaust gas into the intake air. By applying this EGR technology, we can now comply with emission control regulations in each country, including the emission control regulation Tier4 of the Environmental Protection Agency (EPA).

The figure below shows the schematic diagram of EGR equipment. There is an appropriate value for the circulating exhaust gas volume (referred as *EGR rate* below), and it is controlled by the EGR valve which is installed between the intake and exhaust flow. EGR valves are driven by DC brushless motors and they adjust the EGR rate according to the appropriate opening indicated by the E-ECU (Electronic Engine Control Unit, refer to *Electronic Control Manual*) depending on engine speed or load conditions.

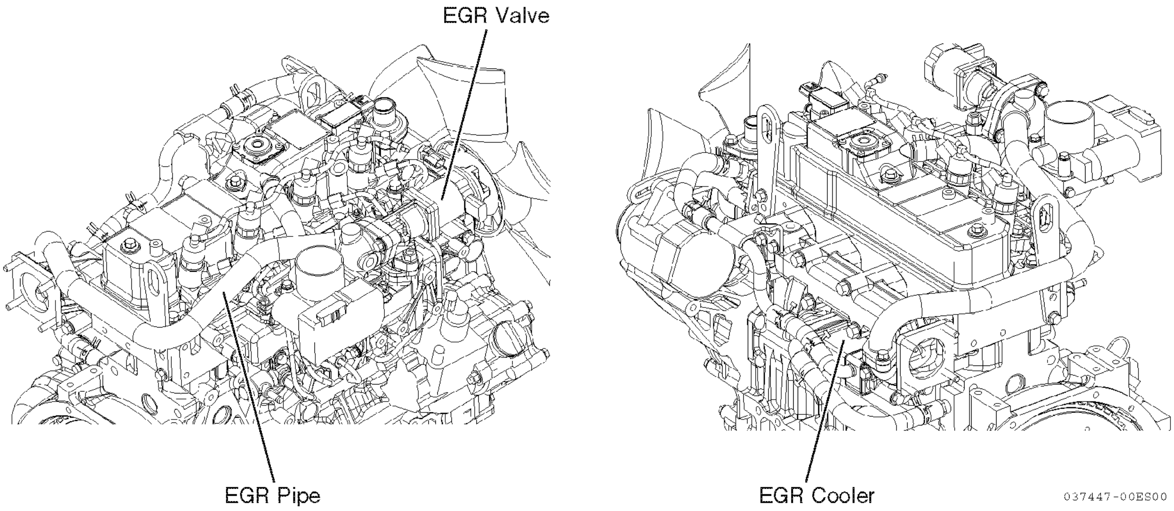
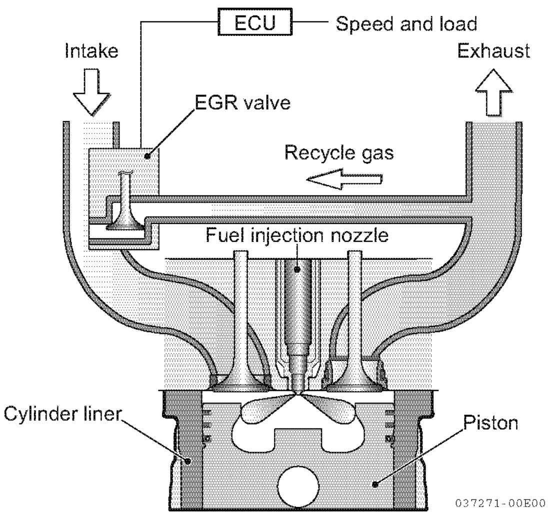


Figure 8-1

Structure of Each Device

EGR valve



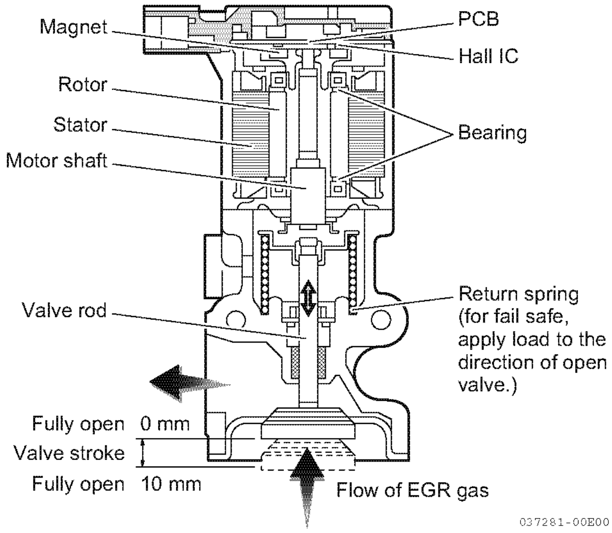


Figure 8-2

EGR operation principle

Employ the EGR valve of DC brushless motor type. The roter (magnet) rotates or holds the same position by energizing the coil with electric current to excite the stator core. The rotating motion is converted to the reciprocating motion by a shaft which is coupled with the rotor, and the shaft presses a rod to open or close the valve.

Definition of EGR rate

The EGR rate which represents the percentage of the EGR gas in the total gas introduced into the cylinder can be defined by the formula below:

$$\text{EGR rate} = \frac{CO_2 \text{ concentration in mixture gas at cylinder inlet} - CO_2 \text{ concentration in atmosphere}}{CO_2 \text{ concentration in exhaust gas} - CO_2 \text{ concentration in atmosphere}}$$

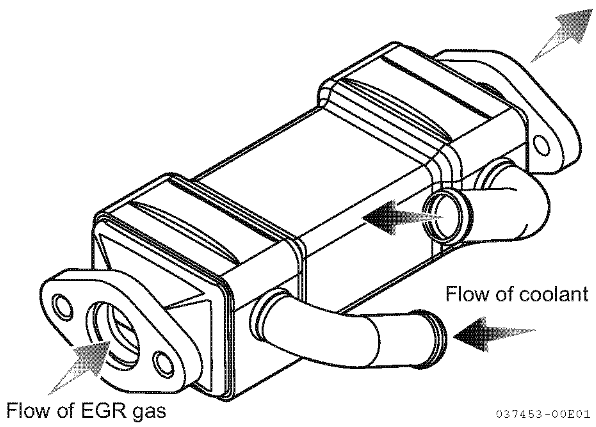


Figure 8-3

EGR cooler

The EGR cooler is a technology to lower the combustion temperature and greatly reduce NOx. By using the EGR cooler, the EGR gas is cooled with cooling water before going to the intake side and the cooled EGR gas is mixed with the intake air to lower the intake air temperature leading to even lower combustion temperature, and the NOx is greatly reduced. The heat load of the lead valve located in the downstream can also be reduced to lower the EGR gas temperature and the durability of the EGR valve can be maintained.

When installing the EGR cooler, be careful not to trap air in the EGR cooler and cooling water pipes.

Lead valve

With turbocharged engines, the charging pressure can be higher than the exhaust pressure in the middle speed range, and it may cause the EGR gas to flow back into the exhaust side without flowing into the intake side although the EGR valve is open. Because It will become difficult to reduce NOx in such cases, the lead valve is installed in the downstream of the EGR valve to improve reduction of NOx. The lead valve functions as check valve and the EGR gas can be introduced into the cylinder with the air flow pulsation even in the area where the intake/exhaust pressure reverses.As a result, the NOx can be reduced.

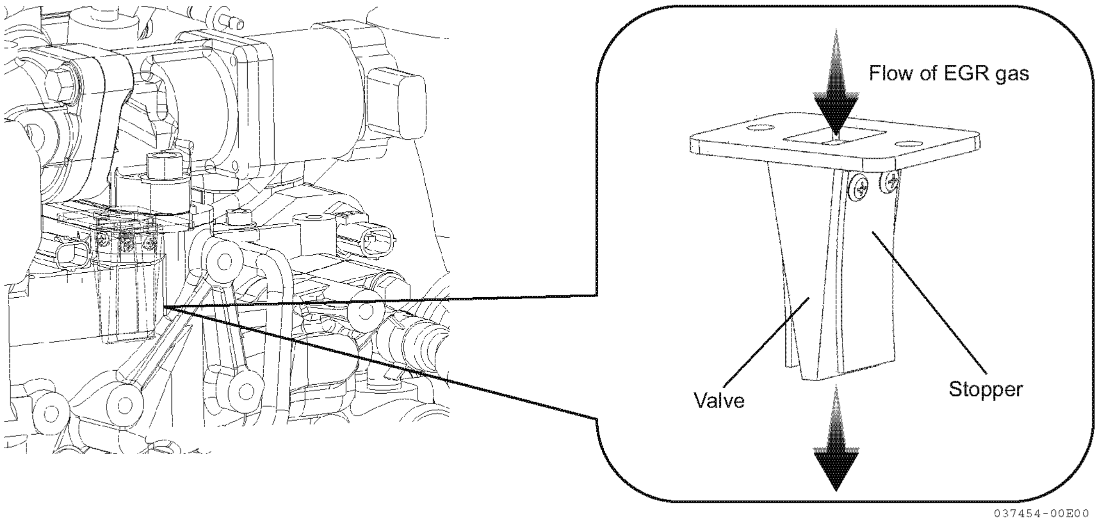


Figure 8-4

As you can see, the EGR is an effective system to reduce NOx. However, if you fail to follow the correct usage as well as the proper maintenance, the adequate engine performance cannot be obtained and the exhaust gas emission will also be worsened.

Turbocharger

Engines achieve the most efficient combustion at a certain air-fuel ratio. Although the amount of fuel injection can be increased, the amount of air that can be introduced into the cylinder is limited.

The turbocharger improves the output performance of the engine by compressing the intake air with a compressor. Exhaust gas from the engine is used to drive a gas turbine which in turn drives the compressor. Turbocharged engines are developed by matching the following criteria: the desired output performance, thermal load and durability.

The turbocharger is a precision unit that is operated in high temperature gas, rotating at a rate as high as approximately 150,000 min^{-1}. Continuous use of the unit for a long time with excellent performance requires proper handling.

Structure of turbocharger

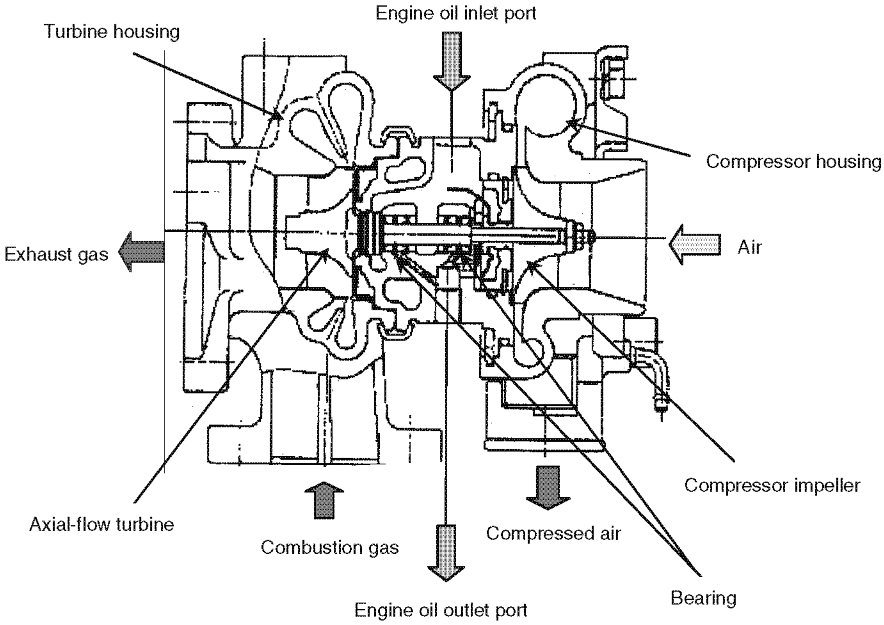


Figure 8-5

Handling the turbocharger

- Like naturally aspirated engines, turbocharged engines require idling operation for five minutes or more, especially when starting in cold weather (0 °C) or below).
  When an engine is loaded immediately after cold starting, engine oil viscosity is still high which may damage the bearing due to insufficient turbocharger lubrication.
  The engine should also run at idle for a sufficient period of time before stopping the engine. Stopping the engine immediately after loaded operation can lead to damage to the bearing because the lubricant supply stops, causing the component temperature to rise abnormally.
- Engine oil is used as the turbocharger lubricant. For the grade of the lubricant to be used, refer to *Selection of Engine Oil on page 11-5*.
- Replace engine oil every 250 hours.
- When discharging exhaust gas from the turbocharger directly to the outside, a waste gate valve, located inside the exhaust outlet flange, protrudes from the flange surface during each stroke as shown **(Figure 8-6)**. Provide enough space around the waste gate valve to prevent interference.

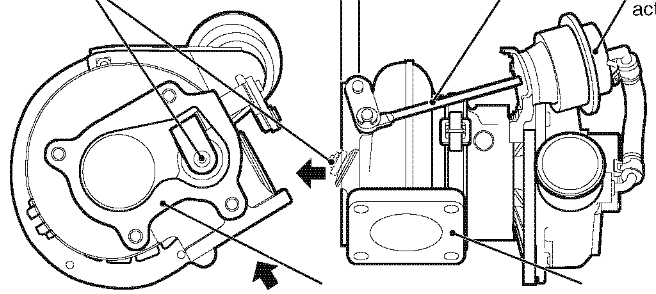
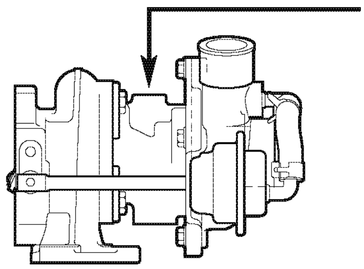


Figure 8-6

Applicable model	Protrusion (A)	Required space
3TNV86CT	4.5 mm	8.0 mm
4TNV86CT 4TNV98CT	8.5 mm	12.0 mm

- Do not support the weight of the exhaust system components with the outlet flange. The turbine housing may break or become deformed and cause internal damage.
- When you connect the air hose to the turbocharger, do not apply too much torque to the connection. Excess torque may damage the compressor housing, resulting in internal damage.
- Select an air hose with the proper rigidity and length so that will not become deformed at a negative pressure of 300 kPa (at 80 °C). A deformed hose can cause the turbocharger to overload and damage internal turbocharger components.
- Allowable vibration of turbocharger



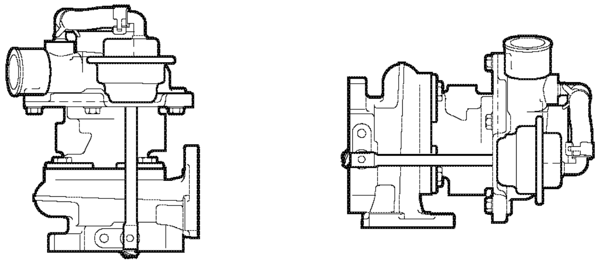
Engine oil inlet : Allowable acceleration...5.0 G

Note: Check when evaluating the installation. If the allowable vibration limit is exceeded, it is necessary to change the flexible engine mount.

Figure 8-7

- Running the turbocharger at high speed can cause high frequency rotation noise and fluid noise. The noise occurs out of phase with the engine noise especially during acceleration or deceleration. Consider sound insulation when designing the driven machine application.

- Remove the turbocharger from the engine to perform maintenance. Be sure to keep the unit horizontal when you remove it from the engine **(Figure 8-8)**.
  Holding the unit vertically can cause engine oil to leak into the compressor housing or turbine housing, leading to abnormal operation after reassembly.



Do not place unit like this. Place unit like this.

Figure 8-8

- Be sure to follow the procedures in the *TNV Service Manual* when you remove the turbocharger from the engine.

Exhaust Back Pressure

Factors contributing to the increase or decrease of exhaust back pressure (exhaust resistance) include the following:

- Exhaust gas quantity
- Capacity and specifications of the DPF
- Capacity and specifications of the DPF silencer
- Length and diameter of exhaust pipe
- Number of bends of exhaust pipe and the angles at which they are bent

Using the above items as factors, the back pressure can be calculated at the design stage of the driven machine. Refer to *Exhaust Gas Volume and Exhaust Back Pressure on page 8-16* for the calculation method. The calculation formula is for general application and discrete engine characteristics are not considered. The back pressure should be confirmed during the driven machine prototyping phase using the test equipment described in this section. This section describes how to measure the back pressure of the driven machine exhaust system and provides references to the allowable exhaust back pressure value. If the calculation or actual test results exceed the allowable value, the above items must be reconsidered.

Allowable exhaust back pressure

If the measured exhaust back pressure exceeds the allowable exhaust back pressure, review the exhaust system before putting the driven machine into production. Refer to *Allowable Air Intake Restriction and Exhaust Back Pressures on page 1-14* for the value of allowable exhaust back pressure.

The allowable exhaust back pressure value consists of an initial upper limit value and a upper limit value. The initial upper limit value should be used during the design stage of the driven machine. The upper limit value should be used during periodic maintenance procedures.

DPF System

Role of the DPF System

The diesel particulate filter (DPF) system is implemented in automobile diesel engines. It uses a soot filter (SF) to collect particulate matter (PM) from the exhaust gas and safely processes it. Application of the DPF system complies with the Tier 4 emission standards set by United States Environmental Protection Agency and the emission standards set by other countries.

Structure of All Devices

DPF

Structure of the DPF

The DPF consists of the diesel oxidation catalyst (DOC), the soot filter (SF), and the DPF case. The DPF case includes the DOC and SF and leads the exhaust gas into them.

DOC	Ceramic carrier with catalyst coating
SF	Ceramic The exhaust gas is passed through the ceramic wall by alternately closing the channels. The PM is collected while passing through the wall.
DPF case	Stainless steel The DOC is divided into the DOC case and the silencer room. (Some specifications have an outlet flange only.) Each part is bolt-tightened to the body flanges. Do not use the DPF case after you drop it. The ceramic DOC and SF are fragile and can break.
Mat	Ceramic fiber The mat holds the ceramic DOC and SF in the metal case.

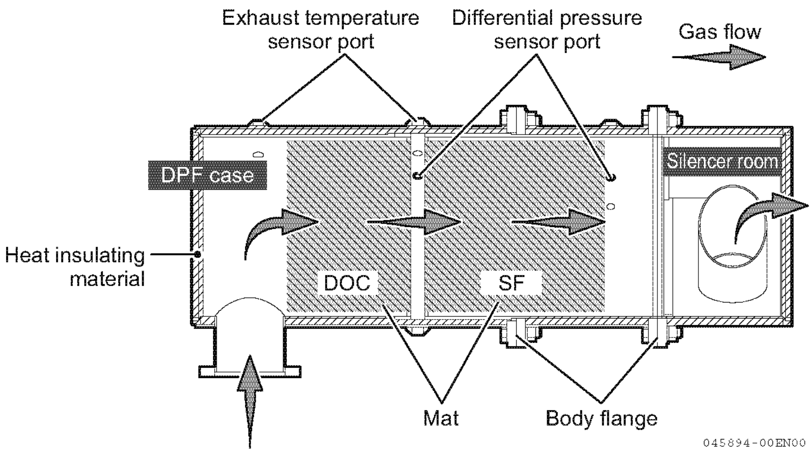


Figure 8-9 DPF cross section

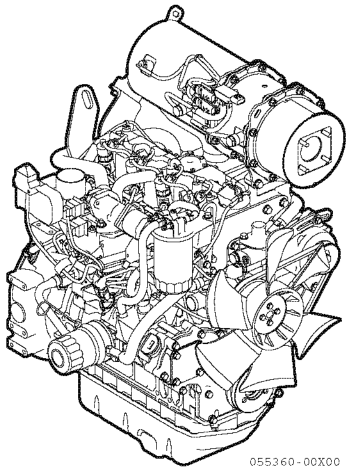
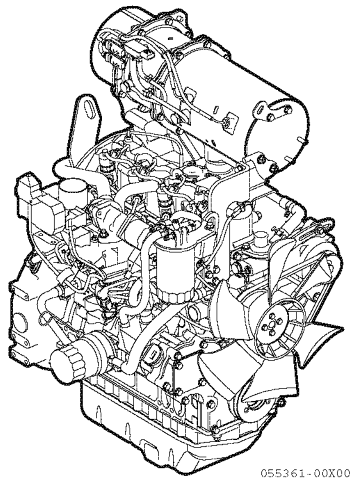
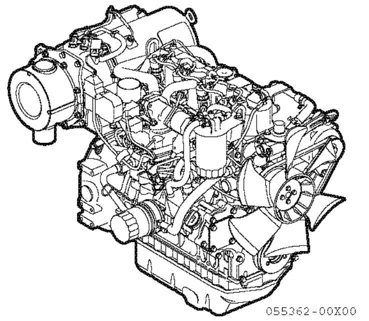
Function of the DPF

The function of the DPF is to break down harmful substances in the DOC and to collect particulate matter in the SF, thus preventing the release of contaminants into the atmosphere. Particulate matter that accumulates in the SF of the DPF causes it to clog, reducing engine performance. Therefore it is necessary to burn off the accumulated PM. There are 3 incineration methods: continuous regeneration, intermittent regeneration and additive regeneration. YANMAR engines use a continuous regeneration method, which allows the collection and at the same time incineration of particulate matter inside the DPF while continuing engine operation.

Standard DPF installation location

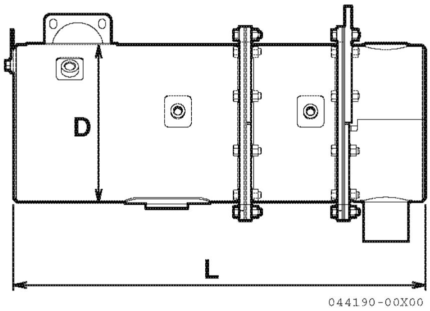
We recommend the YANMAR standard engine installation for the DPF installation location. But if the installation of the implement demands that the DPF is installed on the vehicle side or a non-standard location, consult a YANMAR representative.

Standard DPF installation layout setting

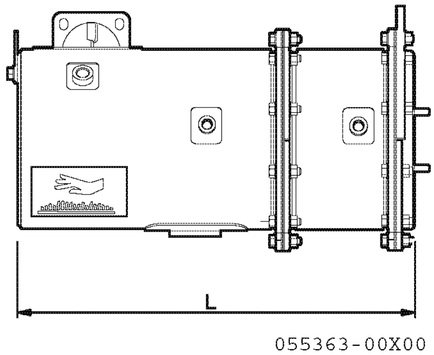
Installation location	Exhaust manifold top outlet fan side	Exhaust manifold top outlet flywheel side	Flywheel top installation
			
3TNV88C	✔	✔	✔
4TNV88C	✔	✔	✔
4TNV98C	✔	No setting	✔
3TNV86CT	✔	No setting	✔
4TNV86CT	✔	No setting	✔
4TNV98CT	✔	No setting	✔

DPF size

Check the below table for the standard DPF size of all engine models.



With silencer



Without silencer

Figure 8-10

Table 8-1 DPF size list

<table>
<tr><th rowspan="2">Engine</th><th rowspan="2">DPF installation location</th><th colspan="11">Engine speed (min^{-1})</th></tr>
<tr><th>2000</th><th>2100</th><th>2200</th><th>2300</th><th>2400</th><th>2500</th><th>2600</th><th>2700</th><th>2800</th><th>2900</th><th>3000</th></tr>
<tr><td rowspan="2">3TNV88C</td><td>Top of exhaust manifold</td><td colspan="4" rowspan="2">–</td><td colspan="7">ø170 × L474 mm with silencer</td></tr>
<tr><td>Top of flywheel</td><td colspan="7">ø170 × L467 mm with silencer</td></tr>
<tr><td rowspan="2">3TNV86CT</td><td>Top of exhaust manifold</td><td colspan="5" rowspan="2">–</td><td colspan="6">ø170 × L426 mm without silencer</td></tr>
<tr><td>Top of flywheel</td><td colspan="6">ø170 × L426 mm without silencer</td></tr>
<tr><td rowspan="2">4TNV88C</td><td>Top of exhaust manifold</td><td colspan="6">ø170 × L474 mm with silencer</td><td colspan="5">ø170 × L510 mm with silencer</td></tr>
<tr><td>Top of flywheel</td><td colspan="6">ø170 × L467 mm with silencer</td><td colspan="5">ø170 × L510 mm with silencer</td></tr>
<tr><td rowspan="2">4TNV86CT</td><td>Top of exhaust manifold</td><td colspan="4" rowspan="2">–</td><td colspan="7">ø200 × L439 mm without silencer</td></tr>
<tr><td>Top of flywheel</td><td colspan="7">ø200 × L439 mm without silencer</td></tr>
<tr><td rowspan="2">4TNV98C</td><td>Top of exhaust manifold</td><td colspan="6">ø200 × L520 mm with silencer</td><td colspan="5" rowspan="2">–</td></tr>
<tr><td>Top of flywheel</td><td colspan="6">ø200 × L523 mm with silencer</td></tr>
<tr><td rowspan="2">4TNV98CT</td><td>Top of exhaust manifold</td><td colspan="6">ø200 × L511 mm without silencer</td><td colspan="5" rowspan="2">–</td></tr>
<tr><td>Top of flywheel</td><td colspan="6">ø200 × L439 mm without silencer</td></tr>
</table>

Sensor

DPF exhaust temperature sensor

For the sensor's shape, refer to *Diesel Particulate Filter (DPF) Inside/Inlet and Exhaust Temperature Sensors on page 14-127.*

The DPF exhaust temperature sensors are directly fastened to the sensor ports (one in the front and one in the back of the DOC) installed in the DPF periphery.

DPF differential pressure sensor

For the sensor's shape, refer to *Diesel Particulate Filter (DPF) Differential Pressure Sensor on page 14-128*.

The DPF differential pressure sensor is installed through the stay in the DPF flange and connected with the steel pipe attached to the DPF and the rubber tube.

Precautions when Considering Installation on the Implement

Exhaust temperature decreasing rate	If the exhaust temperature is low, the PM cannot be burnt efficiently and PM clogging becomes a problem. Therefore, we recommend the installation of the DPF at a location near the engine (standard layout). If the DPF is installed at a location different from the standard location, a separate exhaust temperature evaluation must be performed. Please consult the YANMAR representative.
DPF installation environment	If the DPF is exposed to wind when traveling, attach a wind screen. Also, when you turn the key to OFF, the cooling system stops and the ambient temperature increases. If thermal insulation is required, consider an installation that does not leave the heat trapped. In addition, the DPF should not be exposed to rain water.
Be careful about exhaust temperature	The DPF outlet exhaust gas temperature may reach 600 °C. The exhaust temperature from the tail pipe can become higher than the engine itself. Be careful.
Surface temperature	The surface temperature of some parts of the DPF becomes high, so check it during the installation evaluation. If necessary, take measures to prevent burn injuries and fires.
Ash accumulation	The ash contained in the PM composition (mostly from metallic components in the additives to the lubricating oil) is collected in the SF but cannot be incinerated. Therefore, while the amount of exhaust is very small, it can adversely affect engine performance in the long term. For that reason, it is required to periodically remove the SF from the DPF and remove the ash. When considering the vehicle installation, also consider the removal of the SF case from the DPF body for periodical maintenance and ash removal. For the SF case draft, refer to the table below.

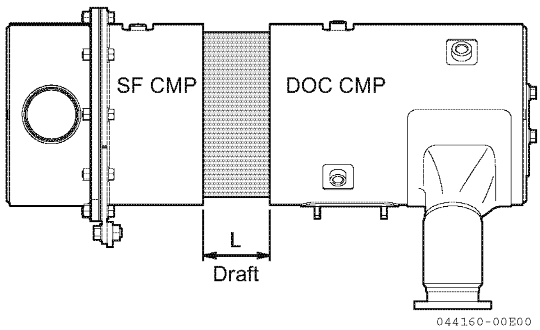


Figure 8-11

Engine	3TNV88C	4TNV88C (≤ 2500 min^{-1})	3TNV86CT	4TNV88C (≥ 2600 min^{-1})	4TNV98C	4TNV86CT	4TNV98CT
SF draft (mm)	L = 66		L = 77			L = 77 (Mounted on top of the flywheel) L = 57 (Mounted on top of the exhaust manifold)	

Precautions for Use (Precautions for Users)

- Fuel: Use light oil with a sulfur content (mass) of 15 ppm or less (ultra-low sulfur) for DPF engines. If you use other than the specified fuel, the sulfur will rapidly deteriorate the catalyst performance inside the DOC. When the regeneration performance of the DPF is inhibited and more particulate matter accumulates, the drop of engine output and the frequent switches to regeneration mode increase fuel costs and worsen the engine condition.
- Lubricating oil: Use a low-ash oil as lubricating oil. If you use a different lubricating oil than specified, a large amount of ash is vented through the exhaust, and the DPF will clog quickly. This will not only cause the engine output to decrease and fuel costs to increase, but will also make frequent maintenance of the SF necessary.
- Precautions when performing the stationary regeneration
  Ventilate well. If avoidable, do not perform the stationary regeneration in a closed place such as a storage shed.
  Regeneration causes the temperature around the tail pipe to increase. Make sure that there are no flammable materials or people nearby.
- If your engine is equipped with DPF cleaning alarm, clean the DPF when the alarm lamp comes on.
  If your engine is not equipped with DPF cleaning alarm, clean the DPF every 3000 hrs of operation.
- As the DPF is subject to emission regulations, disassembly by the user is prohibited. If a repair is required, consult a specialized service shop.
- Refer to the service manual for maintenance methods and intervals regarding ash removal.
- The smell of the exhaust gas from the DPF is different from that of a conventional engine. This is not a defect.
- White smoke may come out of the tail pipe during starting. This is water vapor and not problematic.

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Exhaust Muffler

If you attach a silencer after DPF, do a matching so that the exhaust back pressure is within limits.

The purpose of the exhaust muffler is to reduce noise from the exhaust.

The structure and appearance of exhaust mufflers may vary, but in general they fall into three types: expansion, resonance and absorption. The following is a description of how each type of muffler attenuates exhaust system noise:

Expansion type

Guides the exhaust gas to the muffler to be expanded and diffused, thus attenuating the noise energy.

Resonance type

Divides the silencing chamber into several cells with the shielding plates and attenuates the sound by resonance with the combination of cells.

Absorption type

Absorbs the sound with material such as glass wool on the outside of the exhaust tube with multiple holes. This is also called a non-resistance type.

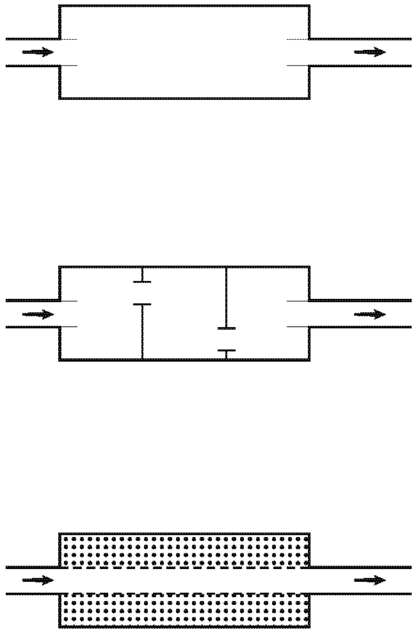

Figure 8-12

Mufflers with structures based on the principle of sound attenuation are frequently used on fixed engine installations, such as generators. Industrial engine applications generally use a complex structure that effectively combines all three muffler types.

Fitting Precautions for Exhaust System

Fitting the exhaust system requires a careful examination from a performance viewpoint and safety aspect. Also consider expansion of the system components due to heat. Carefully check the installation for the following points to prevent fire and personal injury.

Use a flexible connection pipe.

Install the exhaust muffler out of reach of people.

Routing of exhaust system components

Safety is very important when designing the routing of exhaust system components. Route the exhaust system so parts and components of the fuel system, lubrication system and electrical system are not in direct contact with, or near the exhaust system. Make sure your design includes shield plates or heat insulating material to protect against personal injury from contact with hot areas. Also consider the expansion of components due to heat.

Provide a small hole (or drain plug) at the lowest position of the exhaust pipes to provide a place to drain rainwater and condensation.

Consider the position and direction of the exhaust gas discharge from the tail pipe to prevent the heated exhaust gases from mixing with the cool air flowing through radiator or combustion air intake. This will cause the engine to overheat and allow carbon particles to be deposited on the radiator core or air filter element, leading to rapid clogging. If the engine compartment temperature rises excessively, insulate the exhaust system with the appropriate heat absorbing material. Refer to *Installation Test Procedures on page 12-1* to decide if this is necessary.

Exhaust Gas Volume and Exhaust Back Pressure

It is necessary to calculate the back pressure when you design the exhaust pipe system. Consider the length, diameter and bends of the exhaust pipe to maintain initial exhaust back pressure at the target level or less.

Exhaust Gas Volume

Combustion gas volume

First obtain the volume of combustion gas when diesel fuel reacts with the oxygen in the air to become a gaseous body of 1 atm at 273 K (0 °C).

- **Naturally aspirated engine**

$$V_d = 21.53 \times b \times P_e \times 10^{-3}/3600 \qquad m^3/sec$$

- **Normal turbocharged engine**

$$V_d = 23.76 \times b \times P_e \times 10^{-3}/3600 \qquad m^3/sec$$

Where,

V_d	: Combustion gas volume	m^3/sec (273 K (0 °C), 1 atm)
b	: Specific fuel consumption	g/kWh
P_e	: Engine output	kW

Exhaust gas volume

Heat is generated with chemical change, so the gas expanded by the exhaust temperature is the exhaust gas volume.

$$V = V_d \times \frac{T_{ex}}{273} = V_d \times \frac{273 + t}{273}\ m^3/(sec)$$

Where,

V	:	Exhaust gas volume	m^3/sec
V_d	:	Combustion gas volume	m^3/sec (273 K (0 °C), 1 atm)
T_{ex}	:	Exhaust gas temperature (K = 273 + t)	K
t	:	Exhaust gas temperature	°C

Note:

- *Exhaust gas volume V, which is the biggest factor in the calculation of exhaust back pressure, is an expanded volume of the combustion gas volume V_d under the exhaust gas temperature t °C. Since V_d in the equation of item (1) above is calculated larger than the actual volume, the exhaust gas volume V becomes greater than the actual volume.*
- *To obtain the exhaust gas volume V in the back pressure calculation of general-purpose machines, use Q_1 ($V_d = Q_1$) as described in Calculation of the Air Capacity on page 7-3 for a more realistic result.*

Exhaust back pressure

- **Specific weight of exhaust gas**

$$\gamma = \gamma_0 \times \frac{273}{K} \times \frac{P_1}{P_0}$$

Where,

γ	:	Specific weight of exhaust gas	kg/m^2
γ_0	:	Specific weight of exhaust gas (273 K (0 °C), 1 atm)	1.29 kg/m^2
K	:	Exhaust gas temperature (K = 273 + t)	K
t	:	Exhaust gas temperature	°C
P_0	:	Standard atmospheric pressure	
P_1	:	Atmospheric pressure at the service location	
P_1/P_0	1 ≈ 1		

- **Exhaust gas speed**

$$V = \frac{V}{a} = \frac{4 \times V}{\pi \times d^2}$$

Where,

v	:	Exhaust gas speed	m/sec
V	:	Exhaust gas volume	m^3/sec
a	:	Section area of exhaust pipe (refer to *Materials for Calculating Exhaust Back Pressure on page 8-19*)	m^2
d	:	Inside diameter of exhaust pipe (refer to *Materials for Calculating Exhaust Back Pressure on page 8-19*)	m

Pipe line resistance

Pipe line resistance is calculated by adding the straight pipe resistance, pipe joint resistance, muffler resistance and pipe-end discharge resistance.

Refer to *Materials for Calculating Exhaust Back Pressure on page 8-19* for a summary of the coefficients and data to be used for calculation.

- **Straight pipe resistance: ΔP_1**

$$\Delta P_1 = 2\mu \times \frac{\gamma \times v^2}{d} \times L \times 10^{-3} \quad kPa$$

- **Pipe joint resistance: ΔP_2**

$$\Delta P_2 = 2\mu \times \frac{\gamma \times v^2}{d} \times (d \times A \times n) \times 10^{-3} \quad kPa$$

Where,

m	:	Pipe friction coefficient (refer to *Materials for Calculating Exhaust Back Pressure on page 8-19*)	
g	:	Specific weight of exhaust gas	kg/m^3
v	:	Exhaust gas speed	m/sec
d	:	Inside diameter of exhaust pipe (refer to *Materials for Calculating Exhaust Back Pressure on page 8-19*)	m
L	:	Total length of straight portion of exhaust pipe	m
A	:	Resistance-equivalent length of joint (refer to *Materials for Calculating Exhaust Back Pressure on page 8-19*)	m
n	:	Number of joints	

- **Muffler resistance: ΔP_3**

(Examples)

Expansion type silencer : 0.588 kPa

Non-resistance type silencer : 0.196 kPa

- **Pipe-end discharge resistance: ΔP_4**

0.392 kPa

Total Back Pressure of Exhaust System: *P*

$$P = \Delta P_1 + \Delta P_2 + \Delta P_3 + \Delta P_4 \qquad kPa$$

If the total back pressure of the exhaust system exceeds the initial allowable exhaust back pressure described in *Allowable Air Intake Restriction and Exhaust Back Pressures on page 1-14,* re-examine the length of exhaust pipe, the number of joints, and the inside diameter of the exhaust pipe and calculate the total back pressure again.

Materials for Calculating Exhaust Back Pressure

Relationship between pipe friction coefficient μ of exhaust gas and inside diameter *d* of the exhaust pipe

Nominal size	*d* (m)	*a* (m^2)	μ	Nominal Size	*d* (m)	*a* (m^2)	μ
SGP 25A	27.6×10^{-3}	0.598×10^{-3}	0.01242	SGP 80A	80.7×10^{-3}	5.115×10^{-3}	0.00594
SGP 40A	41.6×10^{-3}	1.359×10^{-3}	0.00999	SGP 100A	105.3×10^{-3}	8.709×10^{-3}	0.00513
SGP 50A	52.9×10^{-3}	2.198×10^{-3}	0.00756	SGP 125A	130.8×10^{-3}	13.44×10^{-3}	0.00464
SGP 65A	67.9×10^{-3}	3.621×10^{-3}	0.00675	SGP 150A	155.2×10^{-3}	18.92×10^{-3}	0.00432

Note: SGP: Carbon steel pipe for ordinary piping

Resistance-equivalent length of joints *A*

Joints	SGP nominal size	*A* (m)	Joints	SGP nominal size	*A* (m)
90° elbow	10A to 65A	30	90° bend	R/d=3 to 5	10 to 20
90° elbow	80A to 150A	40	Long elbow	25A to 80A	15 to 20
90° elbow	175A to 200A	50	45° elbow	25A to 80A	15 to 20

Note: R: Radius of bending

Consult the person in charge about the DPF exhaust back pressure.

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Section 9

COOLING SYSTEM

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Cooling Fan 9-25

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Out of the heat generated by combustion of the diesel fuel, 30 to 40 % can be taken out as power. Some 25 to 30 % is carried away by the engine coolant and 30 to 35 % is released as loss into the open air by exhaust or heat radiation. The comparison of the generated heat and the breakdown of the diesel fuel consumption is called the heat balance. It varies with the presence or absence of a turbocharger and the combustion system. The figure below shows an example of heat balance for a naturally aspirated engine.

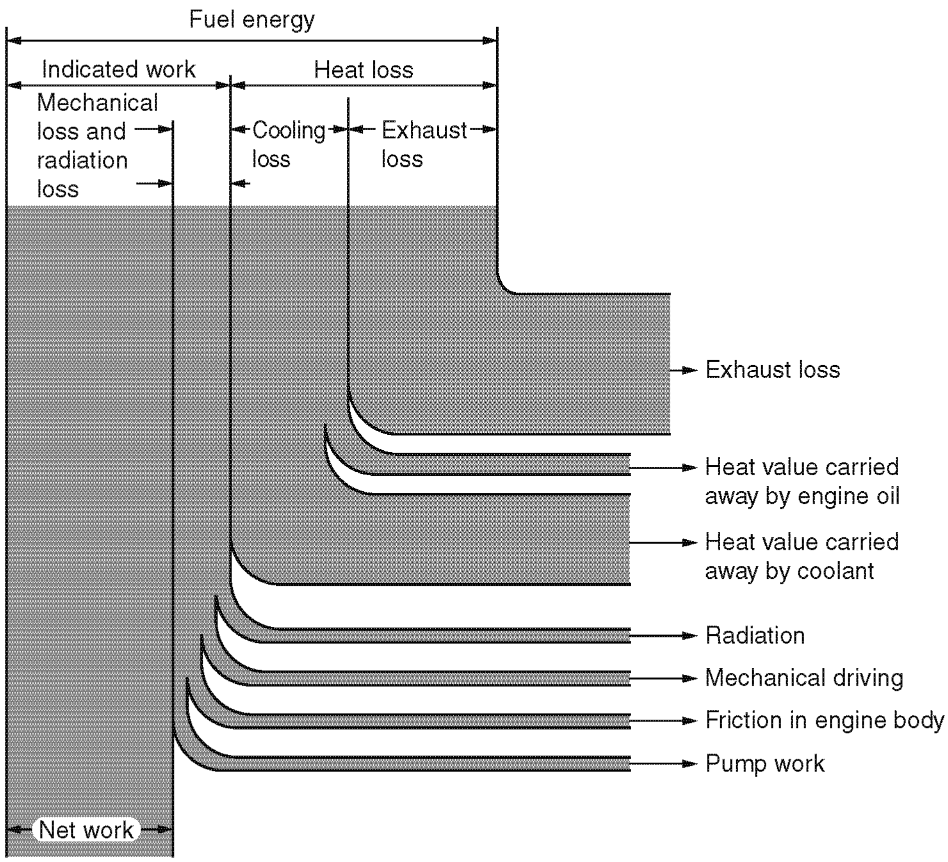

Figure 9-1

In a turbocharged engine, part of the heat that would be released exhaust gas, is recovered by the gas turbine that drives the compressor.

As seen from the figure above, cooling and exhaust account for a great portion of the loss. Reduction of these losses is important in improving the thermal efficiency.

Cooling System Diagram

Figure 9-2 shows the diagram of a DI engine.

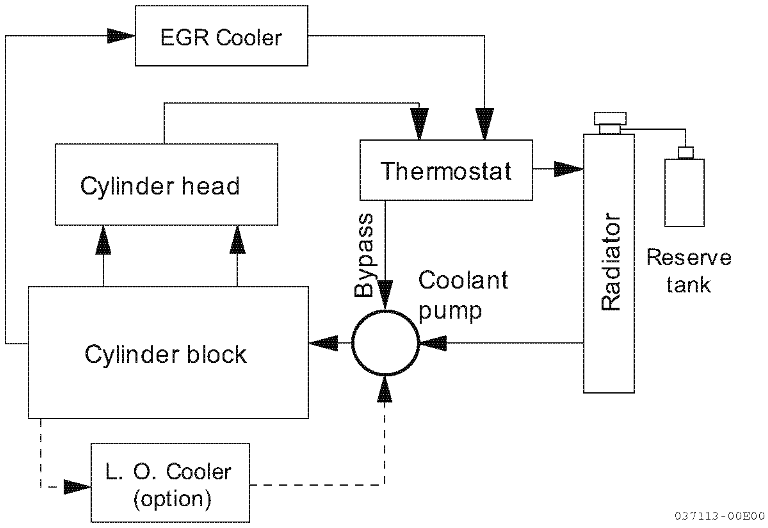

Figure 9-2

Figure 9-2 shows the cooling system diagram for the TNV series engines. The engine coolant goes through the radiator and is fed by the engine coolant pump into the engine coolant jacket to cool the inside of the engine, the cylinder outer walls and cylinder head. It then returns to the radiator via the thermostat. When the hot engine coolant goes through the radiator its heat is dissipated with the help of the cool air that the cooling fan draws or pushes through the radiator.

Engine Coolant

The heat generated by combustion process radiates to neighboring engine components. If the cooling system is inadequate, the cylinder head, combustion chamber, pistons and exhaust valves overheat and their materials lose strength, leading to component failures and shorter engine service life.
Inadequate cooling also causes the engine oil to degrade prematurely which reduces its lubrication efficiency. This may result in abnormal component wear and seizure.
If the engine coolant temperature is too low, the engine's thermal efficiency is lowered, causing poor combustion. This may also cause cylinder bores to rust or corrode. Corrosion results from reaction between carbon monoxide and sulfur dioxide generated in the combustion process and the water which condenses out of the exhaust gases.

Characteristics of water

NOTICE

The following discussion does not imply that plain water can be used as an engine coolant. It is for illustrative purposes only. Always use an engine coolant that is specified by YANMAR.

Without any measures to increase its boiling point or reduce its freezing point, water boils at 100 °C (212 °F) and freezes at 0 °C (32 °F). To expand its temperature range, the following measures are taken:

- To increase boiling point of water, the cooling system is pressurized. A radiator cap helps to maintain the cooling system pressure. For example, if the cooling system pressure is 0.9 kg/cm^2, the boiling point can be raised to approximately 118 °C (244 °F).

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- To lower the freezing point, anti-freeze, also called Long Life Coolant "LLC", is used. The specific freezing point depends on the concentration of anti-freeze used.
- Note: Plain water is not suitable as an engine coolant. Pure water leaves deposits and rust that have very low thermal conductivity. This results in the lack of cooling performance and causes damage to internal engine components.

A YANMAR standard engine coolant switch is activated at 110 ± 3 °C (230 ± 3 °F) as an overheat alarm. Therefore the engine coolant needs to be within the specified limits under all working conditions.

Water quality needed to prepare engine coolant

Table 9-1 Recommended water quality standards and major troubles from poor water quality

No.	Item	Recommended value	Description	Major trouble	
				Corrosion	Scale
1	pH 25 °C (77 °F)	6.3 ~ 8.5	Expresses hydrogen ion concentration in an aqueous solution. Used as the measure of neutrality (pH = 7), acidity (pH < 7) or alkalinity (pH > 7). Acidity increases corrosion and alkalinity increases scale generation. Generally, pH of natural water is between 6 and 8.	✔	✔
2	Electrical conductivity 25 °C (77 °F)	< 0.04 S/m	Indicates micro-mho per cm. High electrical conductivity means a high content of electrolytic ions and solids in the water, which increase corrosion and scale generation.	✔	✔
3	Total hardness ($CaCO_3$)*	< 100 ppm	Indicates the quantity of Ca ions and Mg ions in the water by the corresponding calcium carbonate in ppm. High total hardness increases scale generation.	–	✔
4	M alkalinity ($MaCO_3$)	< 150 ppm	Indicates whole alkaline content in the form of hydroxides, carbonates and bicarbonates by the corresponding calcium carbonate in ppm. High M alkalinity means dissolution of alkaline content, which increases scale generation.	–	✔
5	Chlorine ion content (Cl^-)	< 100 ppm	Indicates chlorine ion content. High chlorine ion content increases corrosiveness. The water supply of Japan contains approximately 10 to 40 ppm of chlorine ions.	✔	–
6	Sulfate ion content (SO_4^{2-})	< 100 ppm	Indicates the sulfate ion content in water. High sulfate ion content causes copper corrosion. If Ca ion content is also high, $CaSO_4$ is generated by the reaction with Ca^{2+}, which increases scale generation.	✔	✔
7	Total iron (Fe)	< 1.0 ppm	Indicates the iron content. When 0.3 ppm is exceeded, coloring by precipitation occurs. High iron content causes scale generation.	✔	✔
8	Silica (SiO_2)	< 50 ppm	Indicates Silicon Dioxide content. Hard scale is generated by combination with Ca and M2. This is not a serious problem if the water hardness is low.	–	✔
9	Evaporation residue	< 400 ppm	Quantity of non-soluble substances obtained by evaporation. Large amounts of suspended solids increase electrical conductivity, which increases corrosion.	–	✔
10	Nitrate ion	< 5 ppm		✔	
11	Ammonium ion	< 0.05 ppm		✔	
12	Sulfur ion (S^{2-})	< 1 ppm		✔	

*Note: *Use soft water instead of hard water. Water softness or hardness is determined by the amount of Ca (calcium) ion and Mg (magnesium) ion in the water.*

Required engine coolant characteristics

A mixture of LLC and water is commonly used as an engine coolant. The most commonly used LLC is made of Ethylene Glycol.

Engine coolant concentrate must provide adequate corrosion protection, lower the freezing point, and raise the boiling temperature of the engine coolant.

Table 9-2 Boiling point and freezing point (example)

vol % Anti-freeze	Freezing point	Boiling point
	°C (°F)	°C (°F)
40	-24 (-11)	106 (223)
50	-37 (-35)	108 (226)
60	-52 (-62)	111 (232)

Note: Boiling point can be raised if the cooling system is pressurized. A radiator pressure cap helps to maintain system pressure. Commercially available premixed LLC and water is recommended to ensure good water quality.

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Typical properties of LLC (YANMAR standard)

1	Density 20 °C (68 °F), g/cm^3 (undiluted):		1.136
2	Boiling point, °C (°F), (undiluted):		171 (340)
3	Flash point, °C (°F), (undiluted):		–
4	Foaming characteristics, ml, (30 %, solution):		0
5	Water, wt%, (undiluted):		–
6	Freezing point, °C (°F)	(50 vol %, solution):	-37.1 (-34.8)
		(30 vol %, solution):	–
7	Reserve Alkalinity (undiluted):		8.2
8	pH (30 vol %, solution):		7.8
9	Corrosion, mg/cm^2 (20 vol % solution, 88 °C (190 °F) × 336 hrs)		
	Aluminum:		-0.02
	Iron:		-0.10
	Steel:		0.00
	Brass:		-0.03
	Solder:		-0.05
	Copper:		0.00

If YANMAR standard LLC is not available, YANMAR recommends using a LLC that conforms to the following specifications.

- JIS K-2234 (Japanese Industrial Standard)
- SAE J814 (Engine Coolants)
- SAE J1034 (Automotive and Light Truck Engine Coolant Concentrate)
- ASTM D3306 (Specification for Ethylene Glycol Base Engine Coolant)

NOTICE

- Always add LLC to soft water. It is important to use LLC in cold weather.
  Without LLC,
  Cooling performance will decrease due to scale and rust in the engine coolant system.
  Engine coolant may freeze and expand approximately 9% in volume. This may cause serious damage in the cooling system or engine.
- Be sure to use the proper amount of coolant concentrate specified by the LLC manufacturer depending on the ambient temperature. LLC concentration should be 30 % as a minimum and 60 % as a maximum (by volume).
- Never mix different brands of LLC, otherwise harmful sludge may form.
- Replace the coolant once a year.

Radiator

A diesel engine needs to be cooled to appropriate temperature levels to avoid damage to the cylinders, cylinder head, pistons and engine oil. The radiator helps to dissipate heat created by the combustion process.

Example of the Structure of a Radiator Made from Aluminum

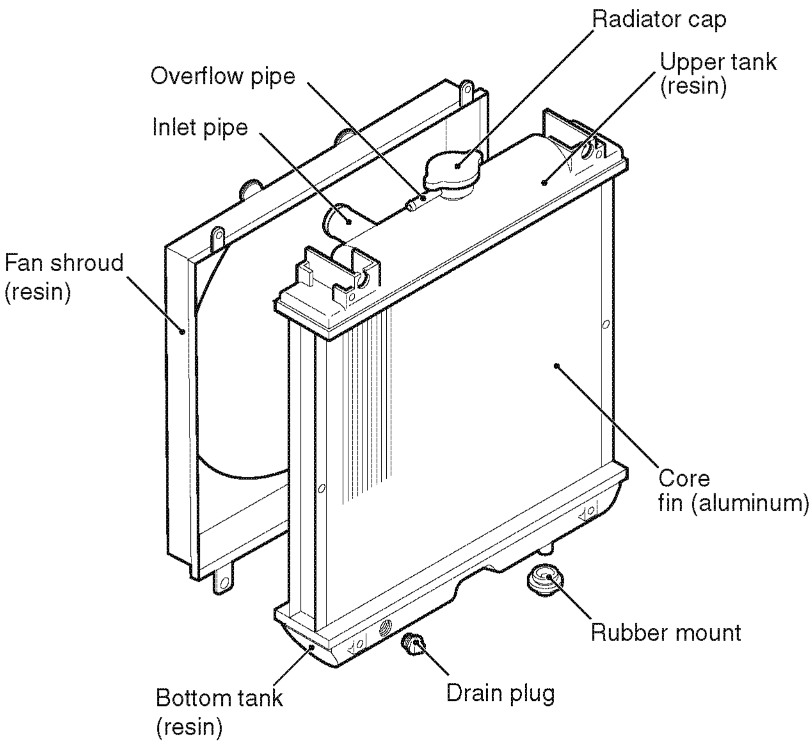


Figure 9-3

Radiator Selection

The following flow chart shows the procedure for radiator selection. This is a basic flow. For details, consult the radiator manufacturer.

Flow-chart for radiator selection

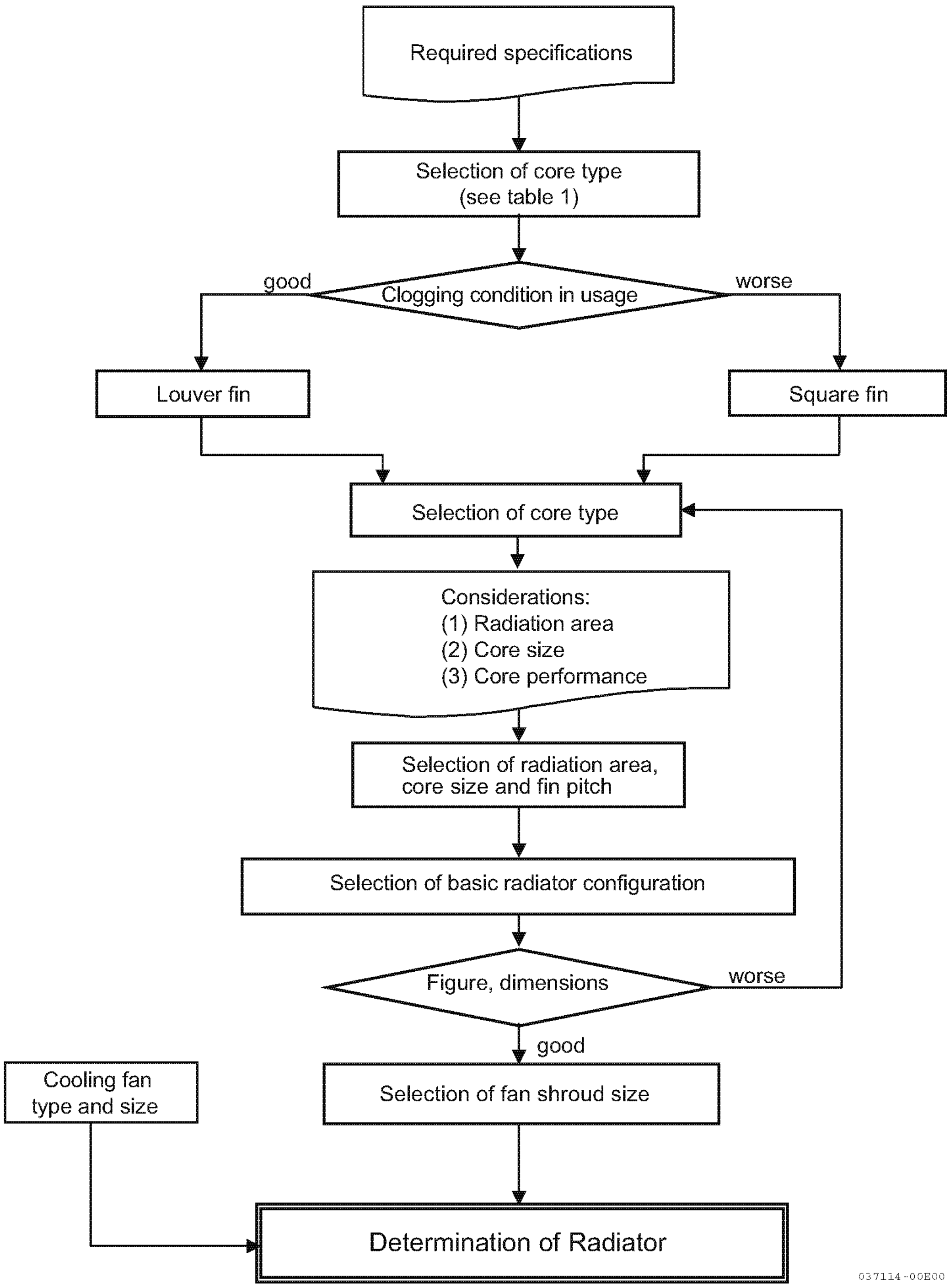
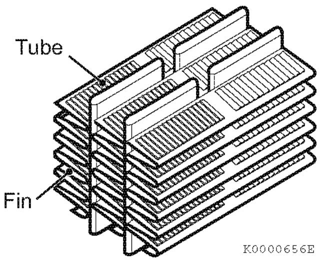
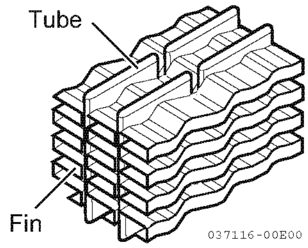


Figure 9-4

	Louver fin	Square fin
Corrugated fin figure		

Radiator Position

The relative position of the radiator and fan greatly influences its cooling efficiency. If the radiator is too close to the fan, the area near the fan shaft is not cooled sufficiently. If the radiator is too far from the fan, the air does not reach the radiator core. The air flow of the pusher fan and suction fan is different. If the radiator has a fan shroud, there must be at least 25 mm between the core surface and fan.

Refer to **(Figure 9-5)** for the relative position of the fan and shroud. The figure shown here is a general example. To obtain the best heat balance, determine the final position of the radiator and fan with the engine mounted on the driven machine.

Pusher fan

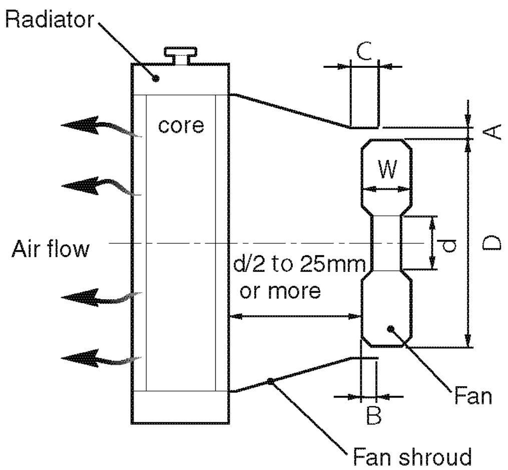


Figure 9-5

Symbol	Meaning	Description
*A	Clearance at end of fan blade	Aperture (between end of fan blade and shroud: 10 to 15 mm
B	Fan lap width	Lap at 1/3 or more of projected fan blade width (W)
C	Shroud ring width	Approx. 1/2 of projected fan blade width (W)
W	Projected width of fan blade	
D	Fan diameter	
d	Fan boss dia.	

* *Approximately 10 mm for stationary equipment and 15 mm for mobile equipment*

Puller fan

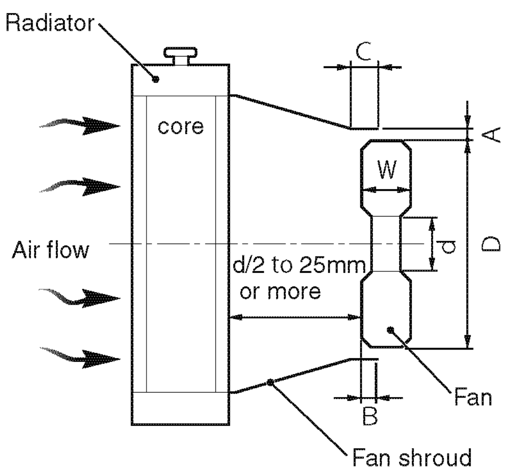


Figure 9-6

Symbol	Meaning	Description
*A	Clearance at end of fan blade	Aperture (between end of fan blade and shroud: 10 to 15 mm
B	Fan lap width	Lap at 2/3 or more of projected fan blade width (W)
C	Shroud ring width	Approx. 1/2 of projected fan blade width (W)
W	Projected width of fan blade	
D	Fan diameter	
d	Fan boss dia.	

* *Approximately 10 mm for stationary equipment and 15 mm for mobile equipment*

Radiator Standard Capacity

The hourly heat release rate (kcal/h or kW) is used to measure the radiator capacity for YANMAR engines. However, this is not the absolute value but the rate under specified test conditions. When a particular radiator is mounted on an engine, fan shape, fan speed, coolant flow rate and/or ambient temperature may be different from test conditions so the heat release may deviate from that specified on the drawing. The radiator heat release shown here indicates the relative radiator capacity.

The table below shows the capacity of standard radiators YANMAR uses with TNV engine applications. The optimum radiator should be selected by referring to the instructions in *Installation Test Procedures on page 12-1* since the radiator selected using this table is not always appropriate.

Note: The specified test conditions for the values in the following table are 8 m/sec air flow, 40 ℓ/min water flow, 50 °C (12 2°F) temperature difference between water and air.

Table 9-3 Nominal heat rejection rate unit: kW

<table>
<tr><th rowspan="2">Model</th><th>Specification</th><th colspan="2">CL</th><th colspan="10">VM</th></tr>
<tr><th>min^{-1}</th><th>1500</th><th>1800</th><th>2000</th><th>2100</th><th>2200</th><th>2300</th><th>2400</th><th>2500</th><th>2600</th><th>2700</th><th>2800</th><th>3000</th></tr>
<tr><td colspan="2">3TNV88C</td><td colspan="4"></td><td colspan="8">28.6</td></tr>
<tr><td colspan="2">3TNV86CT</td><td colspan="7"></td><td colspan="5">35.7</td></tr>
<tr><td colspan="2">4TNV88C</td><td colspan="2"></td><td colspan="10">43.6</td></tr>
<tr><td colspan="2">4TNV86CT</td><td colspan="6"></td><td colspan="6">60.3</td></tr>
<tr><td colspan="2">4TNV98C</td><td></td><td colspan="8">60.3</td><td colspan="3"></td></tr>
<tr><td colspan="2">4TNV98CT</td><td></td><td colspan="7">60.3</td><td colspan="4"></td></tr>
</table>

Precautions for Installation

To avoid possible failure of the radiator core, it is important to protect the radiator from excessive vibration and/or shock loading. If the radiator is directly installed on an engine mount, the vibration of the engine is transmitted to the radiator. It is necessary to provide vibration dampening for the radiator mount. Vibration acceleration must be 59 m/s^2 (6 G) or less.

Installation example of an aluminum radiator with resin tank

To take advantage of the resin tank, the right and left brackets that secure it are eliminated. Instead, the tank is designed to be installed directly on the engine frame using a rubber mount. The lower rubber mount accommodates various assembling methods and absorbs the thermal expansion of the component.

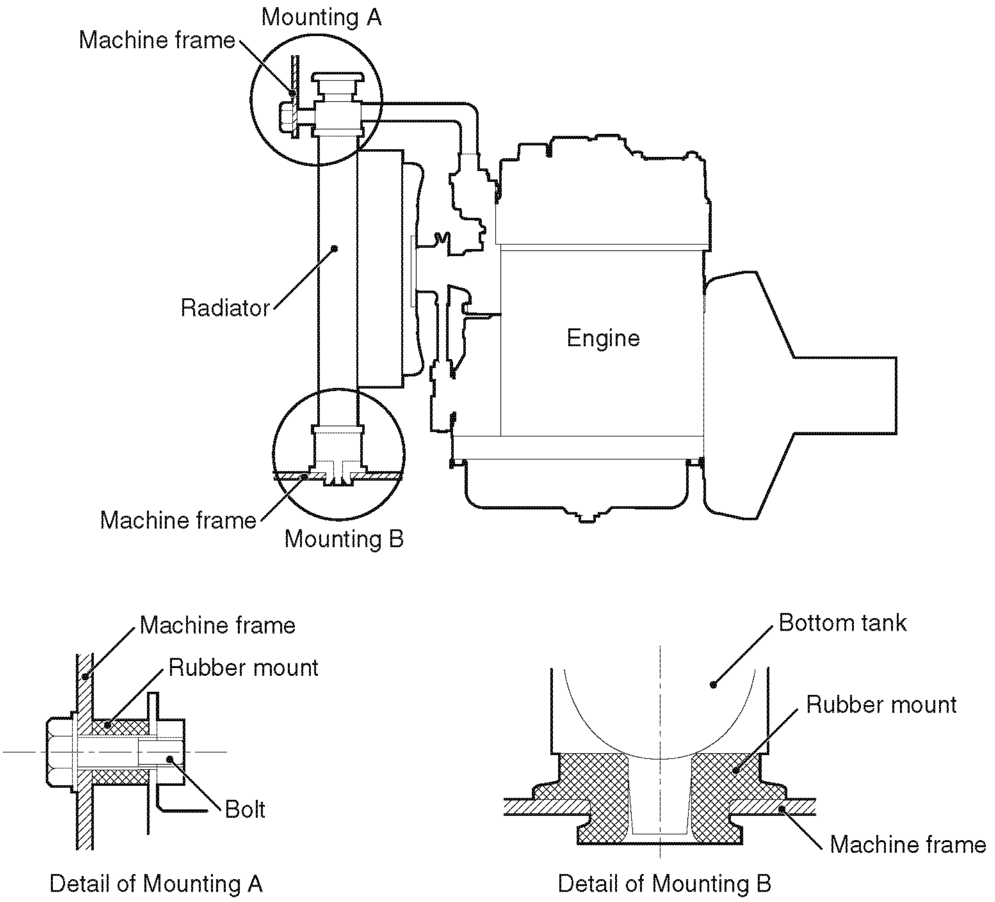


Figure 9-7

Notes on installation:

- Upper rubber mount: Be sure that the upper rubber mount does not resonate with vibration in the up-down direction (bouncing) and vibration in the rolling direction.
- It is recommended that the radiator support member be made of a highly rigid material. The radiator is not a strong member and is easily affected by body deformity. The periphery of the radiator should be rigid to protect the component.

Prevent hot air from mixing with cool air in driven machine applications that have an engine compartment by providing a duct or baffle plate for the radiator. Examples are shown **(Figure 9-8)**.

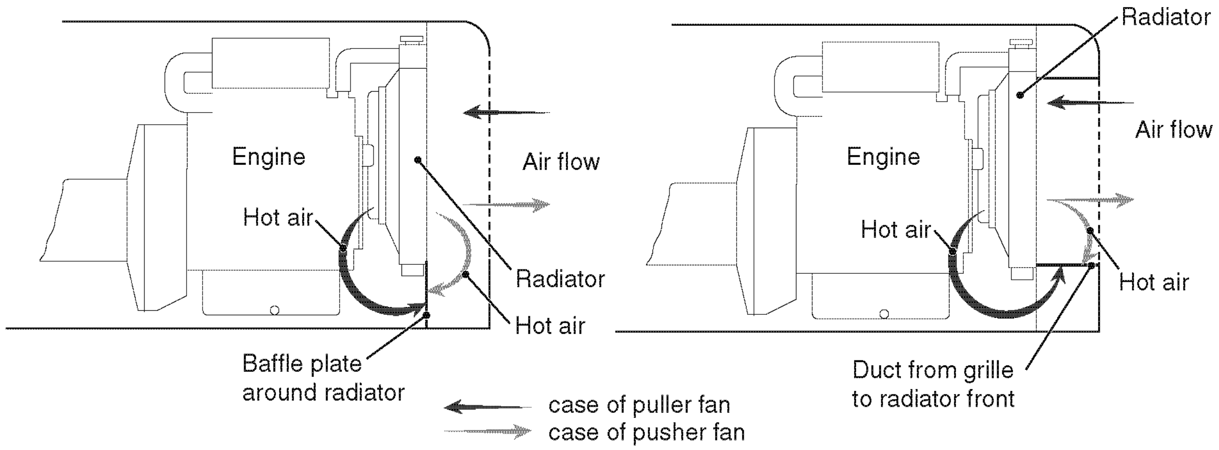


Figure 9-8

Other precautions:

- Make sure the square area of the “cool air inlet” in the engine compartment that provides cool air flow for the radiator is at least 20 % larger than the surface area of the front of the radiator.
- Install an engine coolant recovery tank for the radiator. As the engine coolant temperature rises, increased pressure in the radiator forces engine coolant through the overflow hose into the engine coolant recovery tank. When the engine coolant temperature drops, the radiator pressure decreases and the coolant moves from the recovery tank back into the radiator. This provides a reserve supply of engine coolant and makes the process of checking the engine coolant level simpler. For calculation of the engine coolant recovery tank capacity. Refer to *Cooling System Recovery Tank on page 9-21*.
- Never paint the radiator core.
- Design the cooling system so the fan belt can be tensioned and replaced easily.
- Prevent wear of the engine coolant hoses by making sure they do not contact other engine components.

Cooling System Hoses

Rubber Hose Conditions

The rubber hose used in the cooling system must comply with heat resistance and pressure resistance conditions specified by YANMAR. The hose should be double layered with an internal support or spring to avoid being deformed from vacuum pressure. An improper type of rubber hose may burst under the cooling system pressure or be deformed by the vacuum created when the engine coolant temperature changes from hot to cold. These situations can obstruct the flow of engine coolant.

Table 9-4 Rubber hose material conditions recommended by YANMAR

Type	Double layer with internal support or spring
Thickness	5 mm (The minimum allowable hose thickness is 3.5 mm.)
Pressure resistance	196 kPa or more
Heat resistance	393 K (120 °C) or more
Tensile strength	8820 kPa or more
Elongation	30 % or more
Hardness	Hs70 ± 5
Material	EPDM (ethylene propylene diene rubber)

Precautions for Cooling System Hoses

The cooling system hoses (including drain hose) should not protrude from the driven machine. They should be protected to prevent damage from external obstacles. Prevent the coolant system hoses from coming in contact with other engine components.

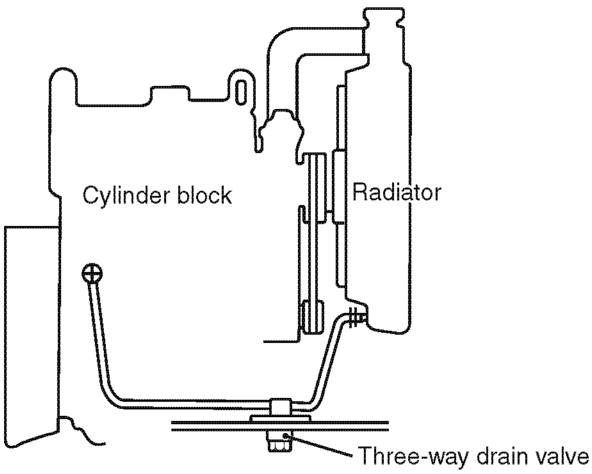


Figure 9-9

Provide a means to drain engine coolant from the radiator and engine. The example shown **(Figure 9-9)** uses a three-way drain valve to drain both the radiator and engine at the same time. If the engine is mounted on a vehicle, provide a shield to protect the drain hose from being damaged by external objects.

When a cooling system hose is used to connect the engine coolant outlet to the radiator, arrange the hose so it doesn't have any convex bends. A convex bend will trap air in the hose and restrict the flow of engine coolant. This results in poor cooling system performance and causes the engine to overheat.

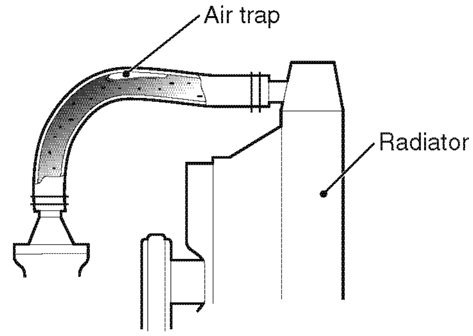


Figure 9-10

Always install an engine coolant temperature indicator. Refer to *Engine Coolant Temperature Sensor on page 9-20.*

Hose Clamps

Make sure the hose clamps have no sharp edges that will damage cooling system hoses and cause loss of engine coolant.

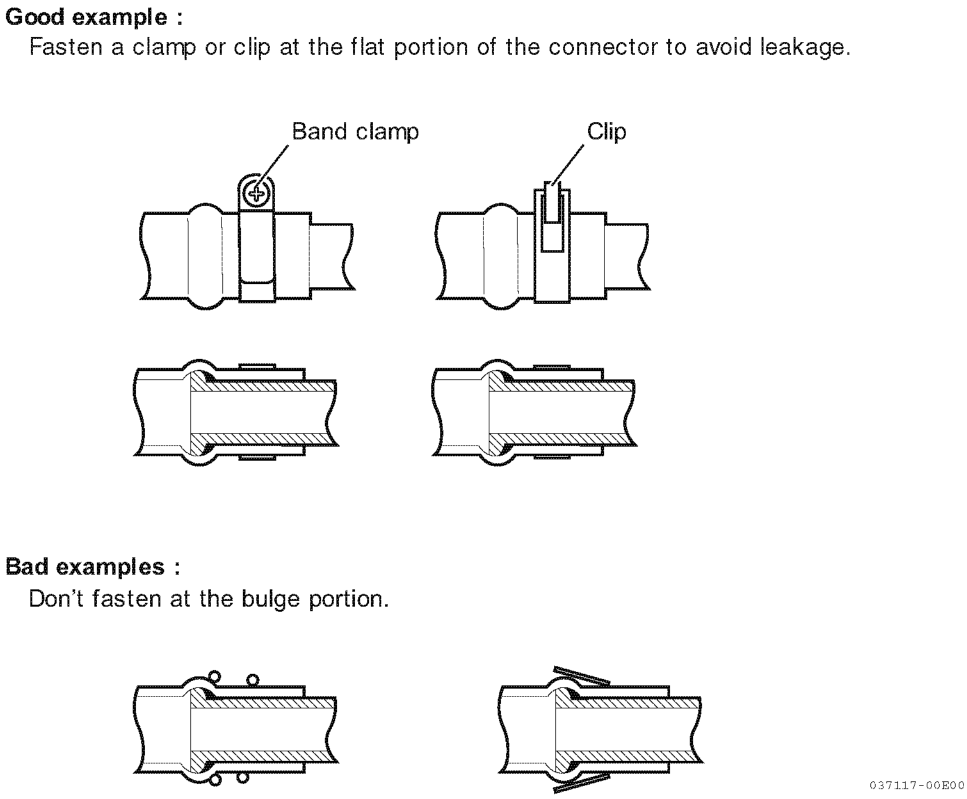


Figure 9-11

Supplying Engine Coolant

Engine coolant has to completely fill the engine block and all cooling system components or the engine will overheat.

Engine coolant supplying recommendations:

- After engine coolant is poured into the radiator, run the engine for a short period of time to remove air from the cooling system.
- The engine coolant level should be just below the engine coolant filler port on the radiator. If necessary, fill it again. Run engine long enough to open thermostat. Check that the radiator top is hot.
- Repeat these processes until the engine coolant level stays just below the engine coolant filler port.

Note: The amount of engine coolant added to the cooling system during production of the driven machine should be based on data obtained during design and prototype testing.

Thermostat

The thermostat provides automatic control of the engine coolant temperature and is generally installed in the cooling system line between the cylinder head and upper radiator tank. The purpose of the thermostat is to prevent engine coolant from circulating into the radiator until the engine coolant temperature reaches a preset temperature. This allows the engine to warm-up more quickly. When the engine reaches operating temperature, the thermostat valve starts to open to let the engine coolant to flow into the radiator. The TNV series engine uses a wax pellet type of thermostat. The performance of this thermostat is shown in the table below. When engine coolant is used to supply heat to warm the interior of the driven machine, use a thermostat that opens at a higher temperature. The shape is identical for each type.

	Standard		**(For heater) option**	
	3TNV86CT 3TNV88C 4TNV86CT 4TNV88C	**4TNV98C (T)**	**3TNV86CT 3TNV88C 4TNV86CT 4TNV88C**	**4TNV98C (T)**
Part code	129155-49800	121850-49810	129574-49800	121850-49800
Thermostat type	Wax pellet type			
Valve opening temperature	71 °C ± 1.5 °C (160 °F ± 1.5 °F)		82 °C ± 1.5 °C (180 °F ± 1.5 °F)	
Full opening temperature	85 °C (185 °F)		95 °C (203 °F)	
Maximum lift	8 mm or more			
Flange diameter D	ϕ 44 mm	ϕ 54 mm	ϕ 44 mm	ϕ 54 mm
ID color	Blue		Brown	None
Type	B		B	

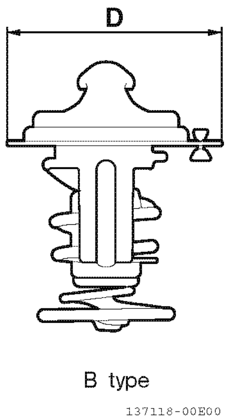
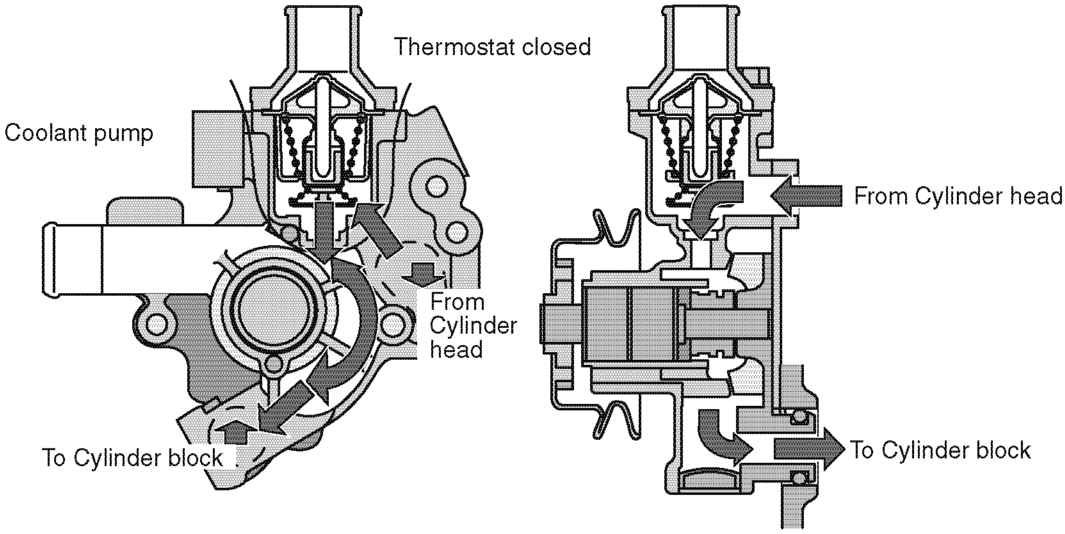


Figure 9-12

Operation of Thermostat and Flow of Coolant

Under cold conditions



Engine coolant does not go into the radiator when the thermostat is closed.

Figure 9-13

Under warm conditions

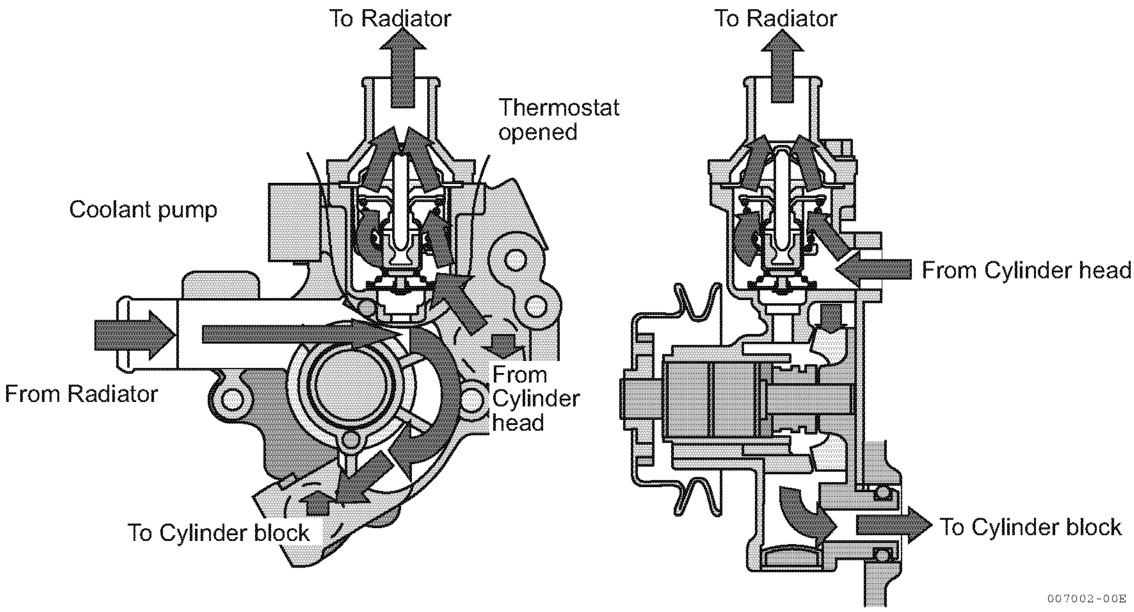


Figure 9-14

Engine Coolant Temperature Sensor

An engine coolant temperature sensor is installed as standard equipment to be used for engine control. Refer to *Roles of a water temperature sensor on page 14-12* for details.

Engine Coolant Temperature Switch

An abnormal increase in engine coolant temperature may cause serious engine damage. An engine coolant temperature switch is installed as optional setting to sense abnormal coolant temperature and ensure safe operation of the engine. Alert the operator or shut down the engine when the coolant temperature rises over the specified temperature. Contact YANMAR representative for more details.

Table 9-5 Coolant temperature switch specified for radiator installed in TNV series engine

		All models of TNV series
YANMAR code No.		121250-44901
Operating temperature of coolant	ON	110 ± 3 (230 ± 3)
temperature switch °C (°F)	OFF	100 (212) or below
Contact point capacity		12 V DC – 3.4 W or below
ID color		Gray

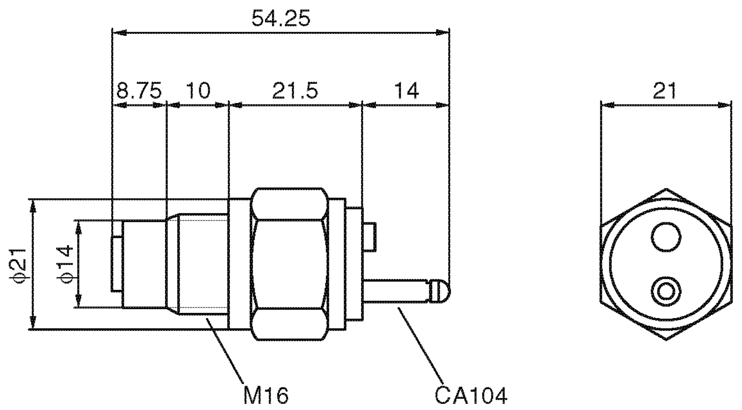


Figure 9-15

Example of wiring diagram

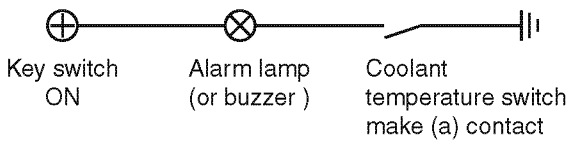


Figure 9-16

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NOTICE

The engine coolant temperature switch should be located below the upper tank of the radiator because the switch does not operate reliably unless immersed in coolant.

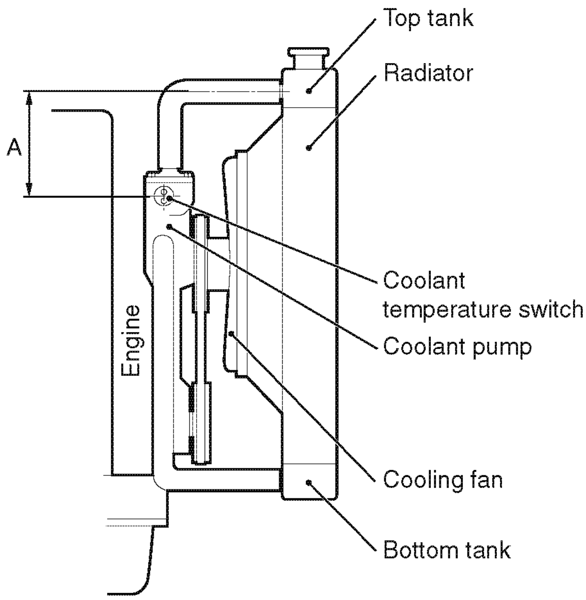


Figure 9-17

Cooling System Recovery Tank

The cooling system is a closed circuit, but small amounts of engine coolant are lost through the radiator cap while the engine is operated.

It is necessary to check and replenish engine coolant periodically. The cooling system recovery tank is designed to extend the interval between engine coolant level checks.

Radiator cap structure

Besides serving as the lid for the engine coolant filler port, the radiator cap has a pressure valve to maintain high cooling system pressure and a vacuum relief valve to prevent the cooling system from becoming damaged from a negative pressure.

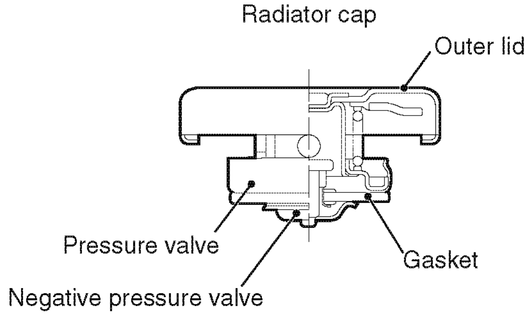


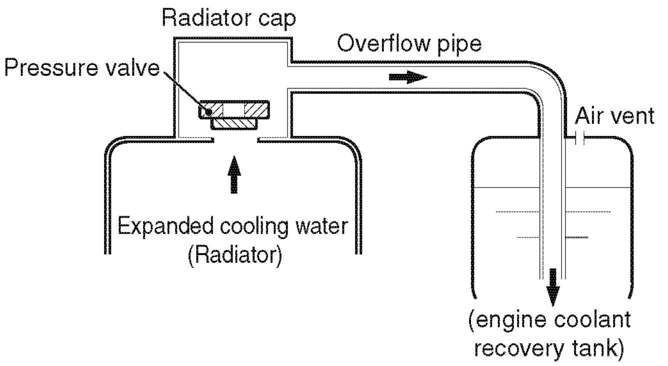
Figure 9-18

The pressure valve opens outward when the pressure in the radiator exceeds 88 kPa (0.9 kg/cm^2). It keeps the coolant under high pressure to prevent it from boiling and protects the radiator from being damaged by too much pressure.

The negative pressure valve opens inward and protects the cooling system from being crushed when engine coolant cools down and the pressure inside the radiator becomes negative at 4.9 kPa (0.05 kg/cm^2) or less.

Function of cooling system recovery tank

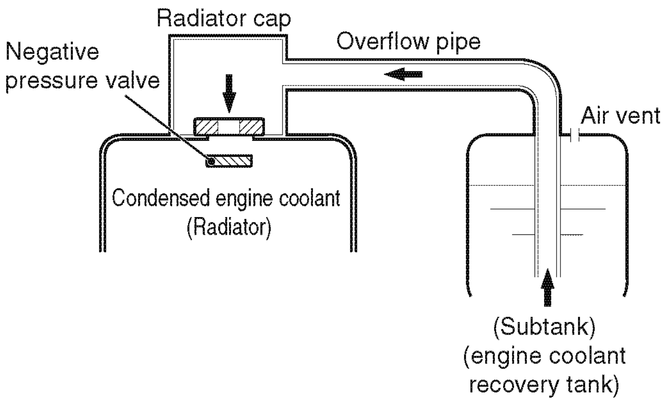
When engine coolant temperature increases it expands which causes the cooling system pressure to increase. When the cooling system pressure reaches 88 kPa (0.9 kg/cm^2) or more the pressure valve in the radiator cap opens and engine coolant flows through the overflow hose and into the engine coolant recovery tank. If the engine is operated frequently, the engine coolant in the radiator gradually decreases and must be replenished. Engine coolant stored in the engine coolant recovery tank is used to replenish the engine coolant in the radiator.



Warmed up state (in operation)

When the engine is running, the expanding coolant gradually opens the pressure valve in the radiator cap and flows into the engine coolant recovery tank through the overflow hose.

The flow of engine coolant stops when the temperature of the engine coolant stops rising.



Cold state (standstill)

When the engine is shut off, the engine coolant temperature rises temporarily then gradually drops. As the engine coolant temperature drops it contracts inside of the radiator which causes the cooling system pressure to drop. The pressure inside of the radiator ultimately goes negative relative to the ambient pressure.

When this negative pressure exceeds 4.9 kPa (0.05 kg/cm^2), the negative pressure valve in the radiator cap opens to allow the engine coolant in the engine coolant recovery tank to be sucked back into the radiator.

Figure 9-19

It is not possible to prevent engine coolant from evaporating through the air vent hole. Sooner or later the engine coolant decreases and needs to be replenished. Engines with engine coolant recovery tanks should be replenished from the engine coolant recovery tank. However, the initial fill of engine coolant should be supplied to both the radiator and the engine coolant recovery tank.

Selection of engine coolant recovery tank capacity

4.5 % of the total coolant quantity Vo flows into the engine coolant recovery tank and then is sucked back into the radiator.

To determine the engine coolant recovery tank capacity, select an engine coolant recovery tank that meets the following conditions: the effective quantity obtained by subtracting the LOW line on the engine coolant recovery tank scale from the FULL line is greater than the inflow quantity q_S to the engine coolant recovery tank, and that the excess quantity (allowance) obtained by subtracting the quantity of the FULL line from the total quantity in the engine coolant recovery tank is also greater than the inflow quantity q_S to the engine coolant recovery tank.

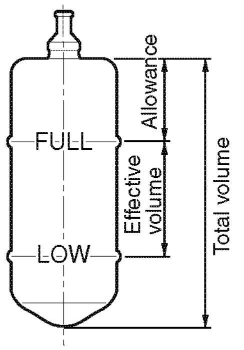


Figure 9-20

In practice, if the effective quantity is greater than the inflow quantity q_S to the engine coolant recovery tank, no problem should occur. If the excess quantity (allowance) is small, part of the coolant may overflow from the engine coolant recovery tank in the early stage of operation. This may require cleaning of contamination.

Installation of engine coolant recovery tank

The engine coolant recovery tank should be installed near the radiator. The bottom of the reserve tank should not be below the bottom of the radiator tank. The top of the reserve tank should be not be above the top of the radiator tank.

Adjust the overflow hose length or location of the engine coolant recovery tank so that the end of the overflow hose is at the bottom of the engine coolant recovery tank.

Install the engine coolant recovery tank where the engine coolant level can easily be checked and refilled.

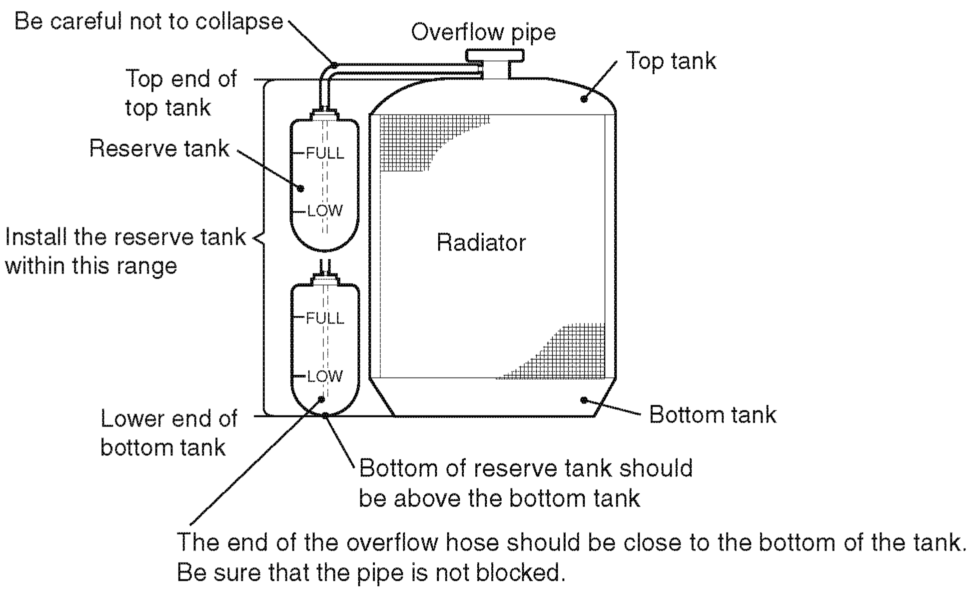


Figure 9-21

Heat Rejection to Engine Coolant

Calculation of Heat Rejection to Engine Coolant

Calculate the diesel fuel combustion heat carried away by the cooling system as follows:

$$q = f \times b \times P_0 \times H_u \times 10^{-3}$$

Where,

q	:	Heat rejection to engine coolant	kJ/h
f	:	Heat rejection ratio to engine coolant	
b	:	Specific fuel consumption	g/kW·h
P_0	:	Engine output	kW
H_u	:	Lower heat value of diesel fuel 4.3116×10^4	kJ/kg

Discharge Engine Coolant Flow from Engine Coolant Pump

Select the radiator according to the engine coolant pump discharge flow table below and the heat release to the engine coolant above.

Coolant pump capacity

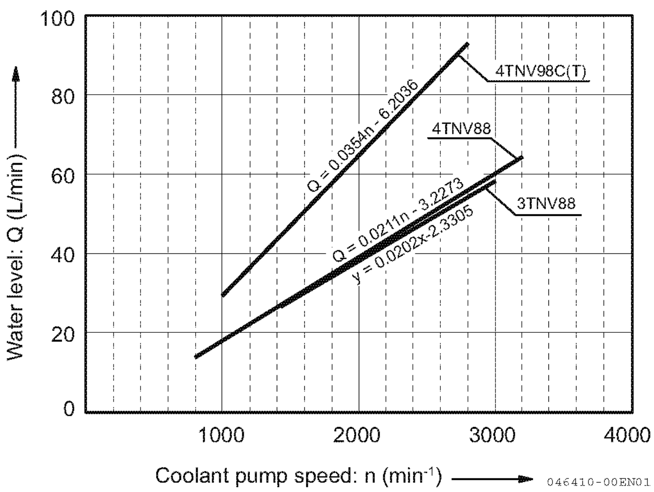
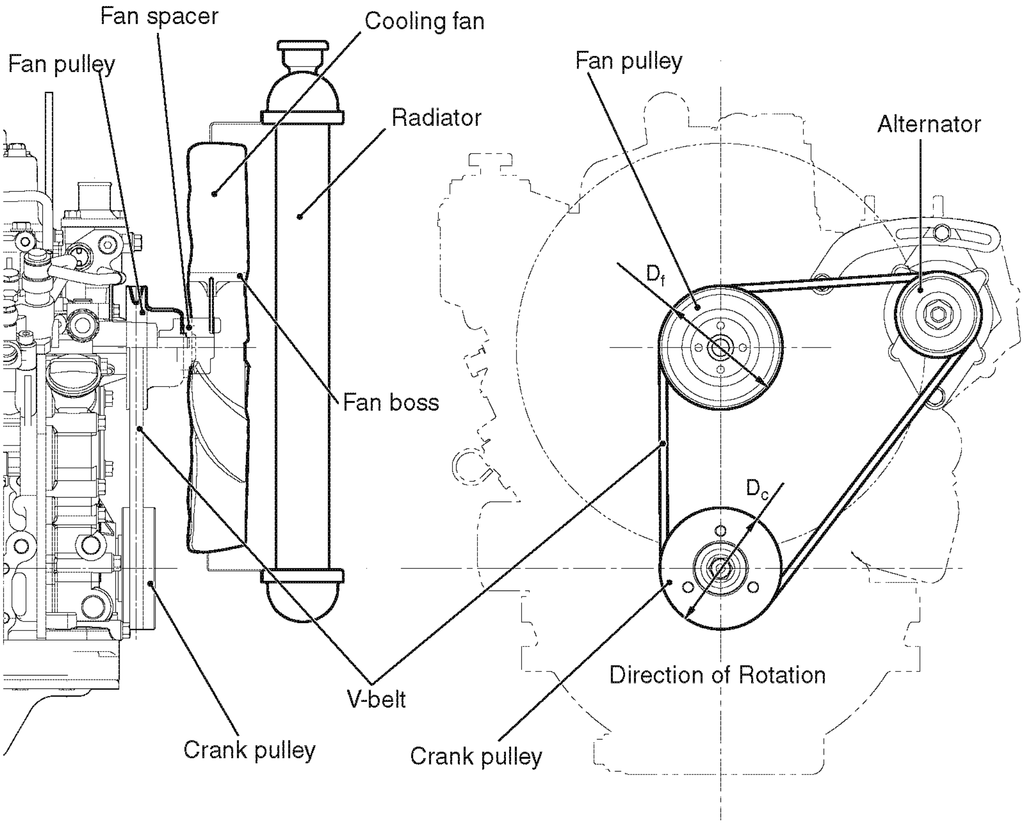


Figure 9-22

Cooling Fan and Its Drive System

The cooling fan and its drive system are mounted as shown **(Figure 9-23)**.



D_f: Nominal fan pulley dia.
D_c: Nominal crank pulley dia.
V-pulley ratio = D_c/D_f

Figure 9-23

Cooling Fan

The cooling fan provides cool air flow around the engine in addition to cooling the radiator:

- Eliminates hot spots in the exhaust system
- Protects electrical components from heat
- Reduces voltage drop in the wiring harness
- Reduces fuel temperature rise
- Cools radiation heat on the surface of the engine
- Cools oil pan surface (engine oil cooling)
- Cools cylinder jacket surface
- Cools hydraulic equipment of the driven machine and generator

Selection of cooling fan

Types of cooling fans are listed in the *YANMAR TNV Option Menu, D-e*. They are all plastic fans, which are characterized by a large volume of air flow and low noise emission.

Required flow volume, fan revolution speed, and fan shroud resistance should be considered when selecting a cooling fan.

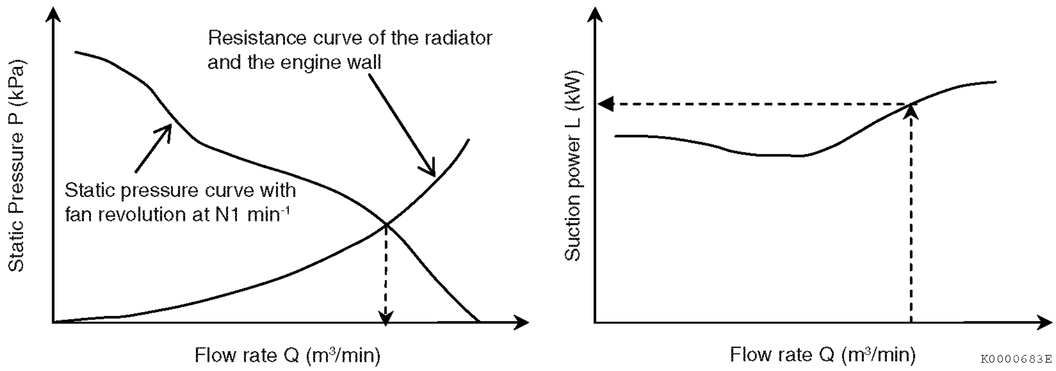


Figure 9-24

Fan performance curves as shown above can be supplied on request.

It is difficult to determine the air flow rate required beforehand since the heat exchange rate of the radiator and the scavenging volume of engine compartment should be considered. That is why it is often determined empirically.

You can use the standard YANMAR cooling fan specification for your application. You need to consider the evaluated heat balance, fan speed, and fan size. If you need a different fan speed, change the V-pulley ratio **(Figure 9-23)**.

NOTICE

If the V-pulley ratio or the fan type is changed, the net engine output will be affected.

Pusher fan/puller fan

Advantages and disadvantages of pusher fans and puller fans, respectively, are listed in the table below.

YANMAR recommends a pusher fan, considering various engine-related issues, such as the ambient temperature of the electrical components and harnesses, and diesel fuel temperature rise.

	Pusher type	Puller type
Advantages	• Lower temperature in the engine compartment • Lower ambient temperature of electrical components and harnesses • Greater cooling efficiency of hydraulic components	• Greater cooling efficiency of hydraulic oil cooler and radiator
Disadvantages	• Radiator heat exchange deteriorates because cool air heats up around the engine and hydraulic oil cooler. (The engine coolant temperature is high) (Greater radiator size) • Hydraulic oil cooler is located between the fan and the radiator making maintenance and repair difficult. • Dust is sucked into the engine compartment.	• Higher ambient temperature in the engine compartment. • Higher ambient temperature of the electrical components and harnesses may result in reduced performance. • Temperature of the engine oil is higher. • Power output may be lower due to temperature rise of diesel fuel and intake air.

Material and deformation of the cooling fan

Cooling fans are made of polypropylene and subject to becoming deformed due to heat or air pressure.

In dusty areas, the material should be changed to PP (polypropylene) + glass-fiber-reinforced plastics.

To prevent heat deformity or degraded strength, keep the ambient temperature of the fan at or under 80 °C (176 °F). Keep the periphery speed at or under 70 m/s to prevent deformation from air pressure and reduce damage to the fan boss (it loses strength at higher temperatures).

Pusher fans may be deformed to the engine side and puller fans may be deformed to the radiator side. Provide a gap of 10 mm or more on the periphery of the fan.

Fan spacer

(See the *Option Menu* for spacer.)

The fan spacer reduces cooling air flow resistance caused by the engine block by having a distance between the fan and cylinder block.

However, if the spacer becomes longer, the service life of the bearing for coolant pump is shortened, resulting in a cause of failure. If you wish to have the spacer length not listed in the option menu, consult YANMAR.

V-pulley

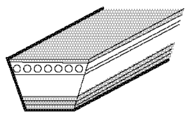
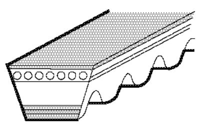
The cooling fan is driven by the crankshaft V-pulley, fan belt and a fan V-pulley. Cooling fan speed is controlled by the ratio between the crankshaft V-pulley and fan V-pulley. The ratio is D_c/D_f, with the crankshaft V-pulley outer diameter being D_c and the fan V-pulley outer diameter being D_f. (Both pulleys are shown in **Figure 9-23**).

High engine coolant temperature can be improved by raising the fan pulley ratio to increase fan speed. This will increase the fan noise.

Refer to *YANMAR TNV Option Menu D-f and D-g* when selecting a V-pulley.

V-belt

V-belts may be a plain or cog type, each of which has the following characteristics.

V-belt type	Form	Characteristics
Low edge plain		Standard
Low edge cog		• Shows better resistance against ambient temperature due to bigger belt surface area. • More flexible and can be used for smaller V-pulleys. • Ice or snow may stick to the belt and break it. • High cost

A plain belt is supplied as standard unless otherwise requested.
If the ambient temperature of the fan belt may be higher than 70 °C (158 °F), the cog type V-belt should be used.

V-belt life

The life of the belt depends greatly on the ambient temperature as shown **(Figure 9-25)**. Make sure the driven machine is operated in an environment that is within the ambient temperature range as specified in *Application Standard on page 1-1*.

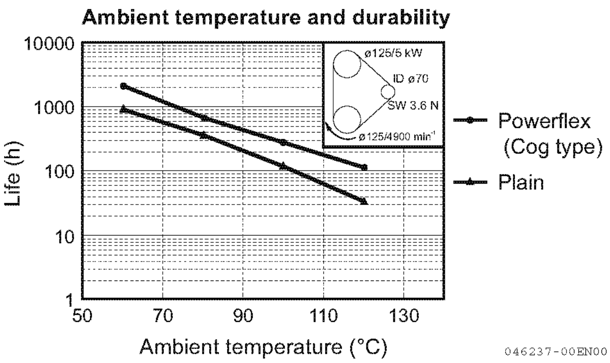


Figure 9-25

NOTICE

The data shown **(Figure 9-25)** is experimental data obtained from continuous operation under certain conditions and should not be treated as data obtained from actual driven machine operation.

Lower belt tension can cause the belt to slip which causes it to heat up and result in premature belt wear or breakage. It is important to check belt tension in accordance with the Periodic Maintenance Section of the TNV Operation Manual.

Section 10

DIESEL FUEL SYSTEM

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The diesel fuel injection pump is the heart of the diesel fuel system. The diesel fuel injection system injects a mist of diesel fuel under high pressure into the hot pressurized air in the combustion chamber. The output of the engine is determined by the amount of diesel fuel that is burned. Accurate control of the diesel fuel injected into the combustion chamber is necessary to achieve the engine rated output as specified in *Application Standard on page 1-1*.

Careful installation of the fuel tank and lines, use of good quality diesel fuel, and maintenance of the diesel fuel filter are necessary for the proper operation of the diesel fuel system.

Fuel inlet label

It is a requirement to attach a fuel inlet label near the fuel inlet of the driven machine.

Refer to Fuel inlet label of Emission Control Regulations for Non-road Diesel Engine (Requirements for the Driven Machine Manufacturers) on page 1-18 for details.

Fuel Injection System

Overview

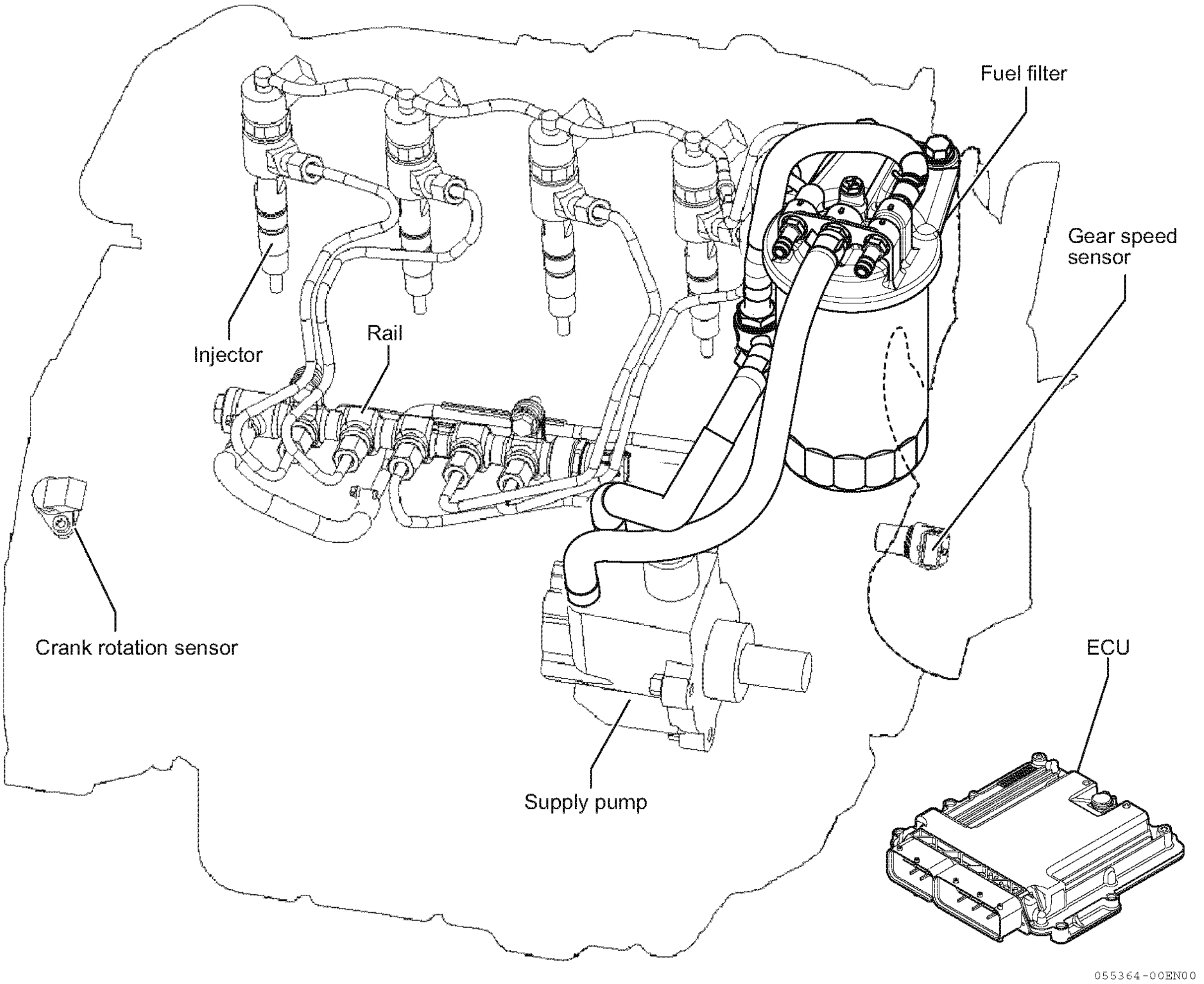


Figure 10-1

The common rail system detects the operating condition of the engine (engine speed, accelerator opening, etc.) with sensors and accordingly controls the fuel injection volume, fuel injection timing, and fuel injection pressure with the ECU (controller) in a comprehensive manner to operate the engine at optimum condition. This results in highly reliable running performance, low fuel consumption, and cleaner exhaust gas. Furthermore, the ECU runs a self-diagnosis of the major components, notifies the operator in case of an abnormality and controls the safe running conditions.

Characteristics

- The pressure of fuel inside the accumulator called “rail” reaches up to 160 MPa. This improves the atomization of fuel spray over the conventional mechanical injection system, resulting in cleaner exhaust gas.
- The mechanism injects fuel by operating the solenoid valve injector highly accurately with the ECU, and it can set fuel injection timing freely, resulting in cleaner exhaust gas.
- The mechanism can perform multiple injections in one injection process, resulting in less noise and improvement of PDF regeneration performance.

System Structure

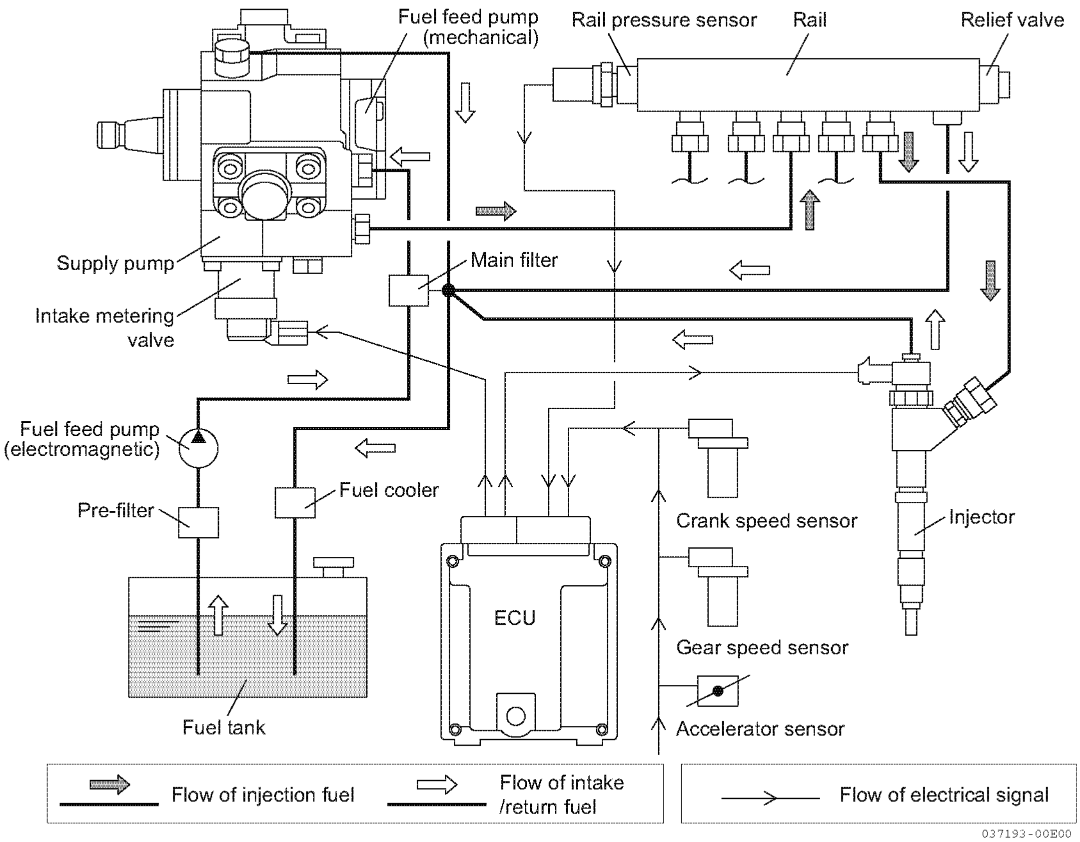


Figure 10-2

Supply pump

The fuel passes the pre-filter and is pressure-fed by a fuel feed pump to the main filter, then it arrives at the supply pump. The ECU controls the opening of the intake metering valve and adjusts the fuel intake volume so that the rail pressure is at the target value. The fuel pressurized in the supply pump is fed to the rail.

Rail

A pressure of up to 160 MPa is accumulated in the rail. The rail is equipped with a rail pressure sensor and it sends information to the ECU. In the case of an abnormal increase in the rail pressure, the mechanical relief valve opens to prevent the pressure increase.

Injector

The ECU controls the injector to maintain optimum injection volume and injection timing and injects the high pressure fuel accumulated in the rail into the cylinder.

To improve the precision of the injection volume, each injector has the correction data, which is printed in the upper part of the injector.

As the correction data is written in the ECU and the injection volume is corrected based on that data, it is required to rewrite the correction data when replacing the injector or the ECU.

For details, see Service Manual. A high-voltage current flows in the injector. Do not touch the electric cable while you turn on the key.

Crank speed sensor and gear speed sensor

The crank speed sensor is equipped on the flywheel side and the gear speed sensor is equipped on the gear side. Based on these 2 sensor outputs, the ECU recognizes the engine speed and each piston position.

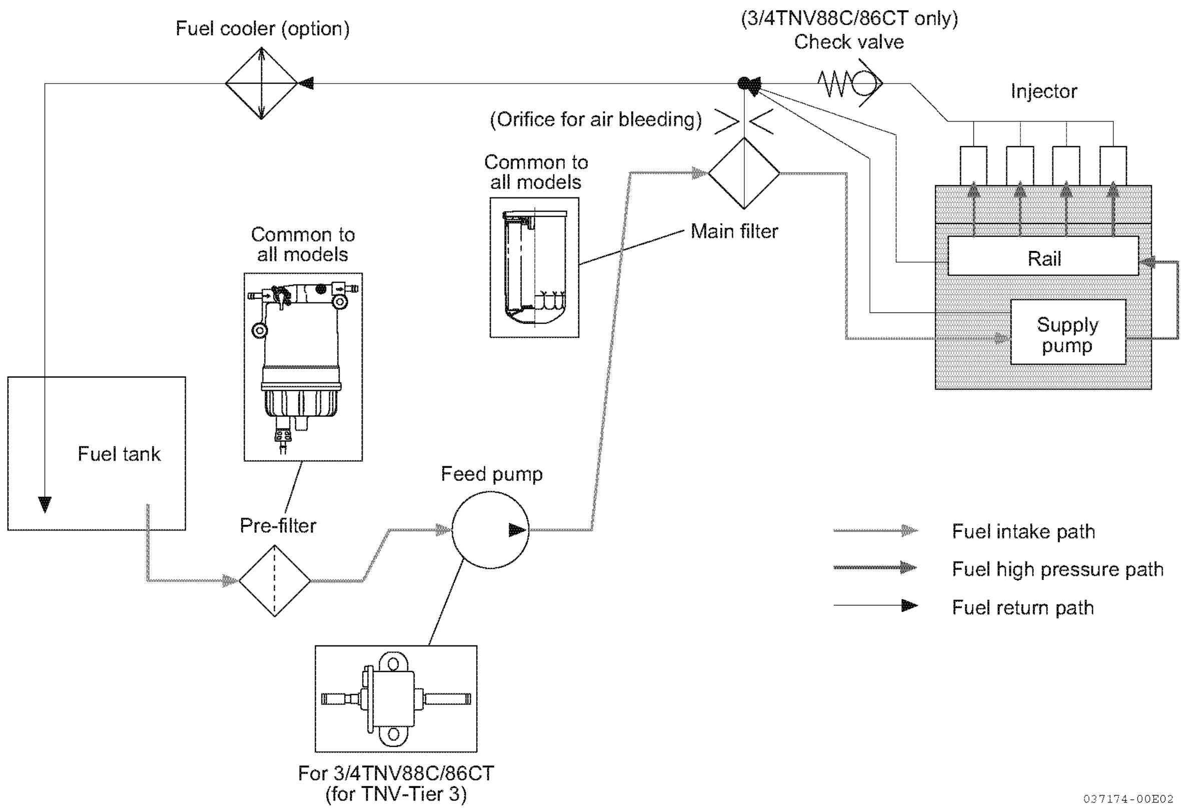
ECU

Based on the information from each sensor, ECU determines optimum injection volume, injection timing and rail pressure, and controls the intake metering valve of the supply pump and injector. It also monitors the occurrence of system abnormality at all times. If an abnormality is detected, it notifies the operator and controls the safe running condition of the system.

Diesel Fuel System Diagram

The following diagrams show standard diesel fuel system configurations.

Fuel System (DI Engine/Equipped with Electric Fuel Feed Pump)



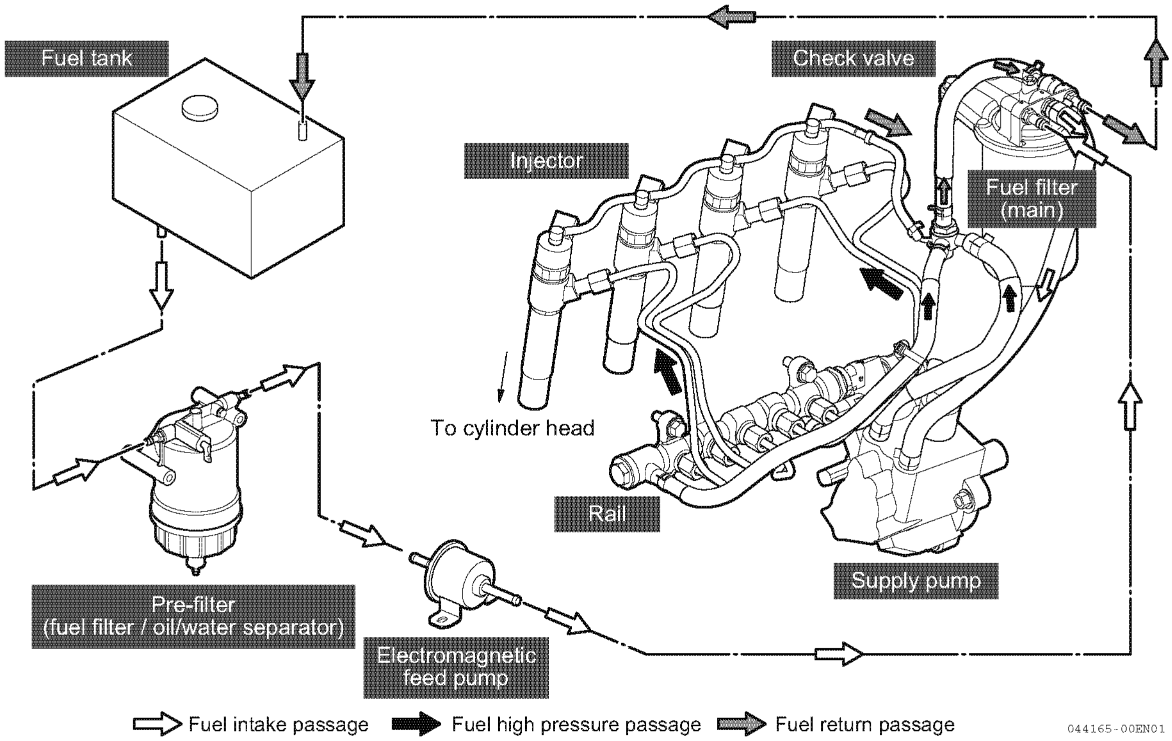


Figure 10-3

Standard Diesel Fuel Line Layout

The below diagram shows the standard fuel line layout for TNV-CR engines.

Layout for DI-CR Engines

Fuel line layout for DI-CR engines

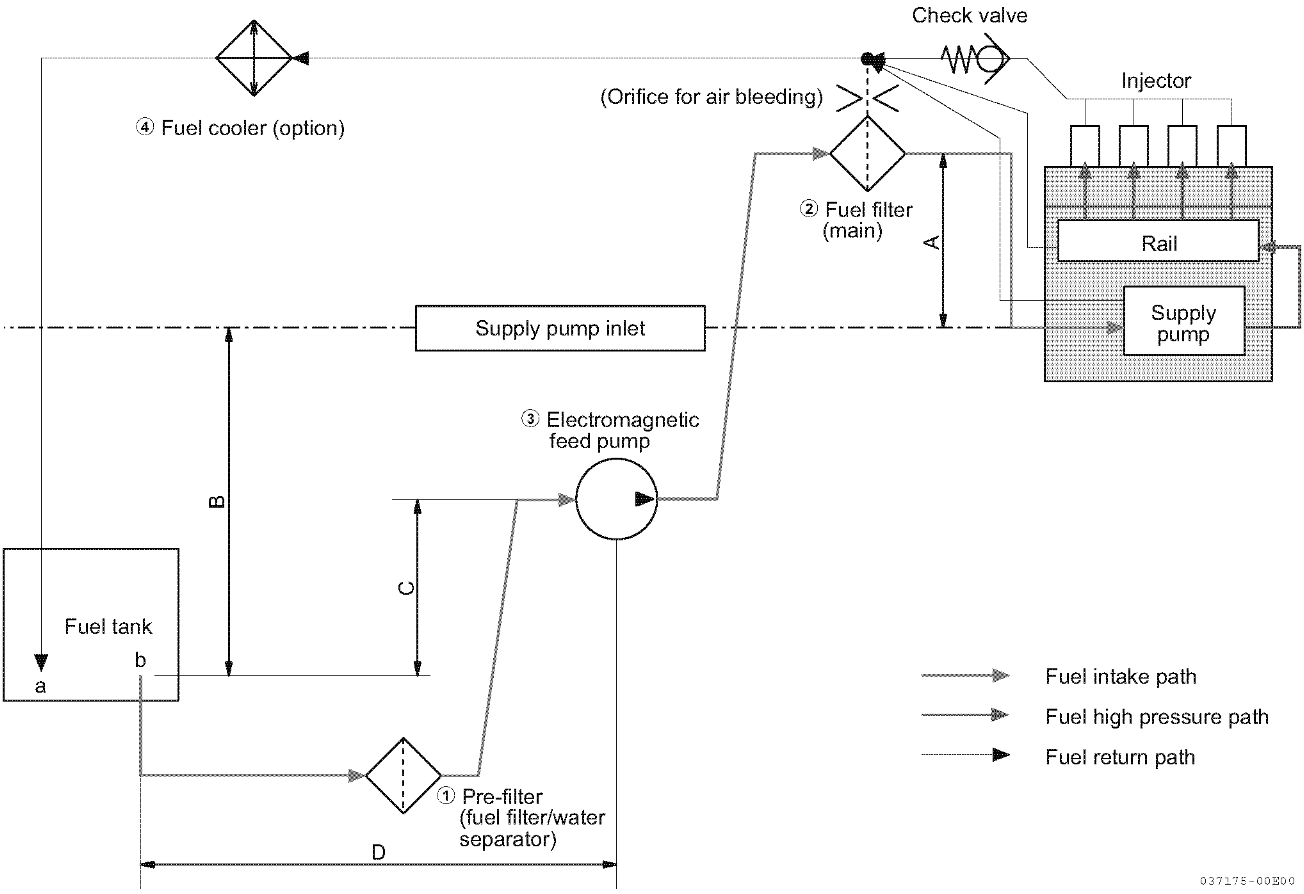


Figure 10-4

NOTICE

Keep return line (a) away from diesel fuel outlet (b) to prevent the diesel fuel line from drawing in air and/or hot diesel fuel. Never connect return line (a) to the inlet line.

Diesel fuel system part names and functions for DI-CR engines

No.	Part name	Function
1	Pre-filter (diesel fuel filter/water separator)	The pre-filter (diesel fuel filter/water separator) is an essential part of the TNV Tier 4 engine. By separating moisture from the fuel oil through the element, it prevents damage to engine parts caused by water entering the supply pump. The common rail system uses an element that is sensitive to contamination and achieves an efficiency of filtration of 90 % and more (dust grain diameter: 5 μ m). When you replace or clean the pre-filter element, close the fuel cock of the pre-filter and stop the fuel supply.
2	Diesel fuel filter (main)	Has a mesh paper element with a filtration efficiency of more than 99 % (dust grain diameter: 5 μ m). inside. Capacity to resist pressure is 7 MPa.
3	Electric feed pump	Sends fuel to the supply pump from fuel tank. Mounted off the engine. Consult YANMAR before using a non-YANMAR fuel pump. An additional check valve is not necessary on the YANMAR electric fuel pump since it has one built in. *Note: On a bench test, diesel fuel injection pump performance was not influenced by a minimum voltage of 10 V.*
4	Diesel fuel cooler (option)	Cools the heated diesel fuel. If the fuel becomes heated, the output decreases. Because it also leads to damage of the fuel piping and fuel injection system, use the fuel cooler if the temperature at the supply pump inlet increases over 80 ÅãC under the worst operating conditions.

Note: Mechanical feed pump is not available for DI-CR engines.

Fuel line layout (DI-CR engines)

Position	Standard value	Content
A	50 - 350 mm	From fuel filter outlet to supply pump inlet. For air bleeding, the fuel filter outlet position should be higher than the supply pump inlet position.
B	≤ 1000 mm	Total head of supply pump (from diesel fuel tank outlet to supply pump inlet)
C	≤ 400 mm	Suction head in dry conditions (from diesel fuel tank outlet to diesel fuel pump inlet)
D	≤ 2000 mm	Suppression of the suction side resistance at of the fuel feed pump (From diesel fuel tank outlet to diesel fuel feed pump inlet)

Parts specification for DI-CR engine

Engine model	3TNV88C - 4TNV98CT	
Diesel fuel pump	Electric type:	3TNV88C ~ 4TNV98CT: 119225-52102 (standard) 129612-52100 (with water proof coupler)
Pre-filter (Diesel fuel filter/water separator)	Standard: With sensor Filtration efficiency: Filtration size: Water reservoir:	129A00-55700 (fuel inlet and outlet horizontal) 129C01-55700 (fuel inlet and outlet horizontal) 90 % and more (dust grain diameter: 5 μm and more) 4000 cm^3 160 cc
Diesel fuel filter	Bracket: Filter: Filtration efficiency: Filtration size:	129A00-55610 (with automatic air bleeding hole ϕ 0.5) 129A00-55800 99 % or more (dust grain diameter: 5 μ m or more) 2000 cm^3
Fuel cooler (option)	Heat release	129973-55900 2.77 kW (@ frontal wind speed 8 m/s, oil flow 10 ℓ/min, inlet temperature gradient 100 °C)

Diesel Fuel

Quality and composition of diesel fuel is very important. Poor fuel reduces engine performance and durability. Be sure to use the fuel with the below-listed specifications.

Fuel Specifications Required by Common Rail Engine

Diesel fuel should comply with the following specifications.

1. Compliance is required with EN590, ASTM D975 or JIS K2204.
2. The following requirements also need to be fulfilled.
    - Cetane number should equal 45 or higher.
    - Sulfur content of the diesel fuel should be less than 15 ppm.
    - Lubricity wear should be less than 460 μ m (HFRR testing wear scar value 1.4).
    - Water and sediment in the diesel fuel should not exceed 200 mg/kg.
    - Ash should not exceed 0.01 % by mass. Aluminum, silicon and magnesium should be below 1 mass ppm.
    - Free the zinc anode and sodium.
    - 10 % carbon residue content of the fuel; it should not exceed 0.35 % by volume and preferably be below 0.1 %.
    - Total contamination should not exceed 24 mg/kg.
    - Oxidation stability should be 20 hours or more in the Rancimat value.
    - Aromatics (total) content of the fuel should not exceed 35 % by volume and preferably be below 30 %. Aromatics (PAH*) content of the fuel should preferably be below 10 %.
      (PAH*: Polycyclic aromatic hydrocarbons)

Prohibition:

- Never use kerosene.
- Never mix kerosene with diesel fuel.
- Never use residual fuels that cause diesel fuel filter clogging and carbon deposits on the injectors.
- Never use fuels stored for a long time in a drum can or similar container.
- Never use fuels purchased from unauthorized dealer.

Fuels for Diesel Engines

Classifications of mineral oil

Diesel fuel is part of the mineral oil family. In general the family is classified as follows:

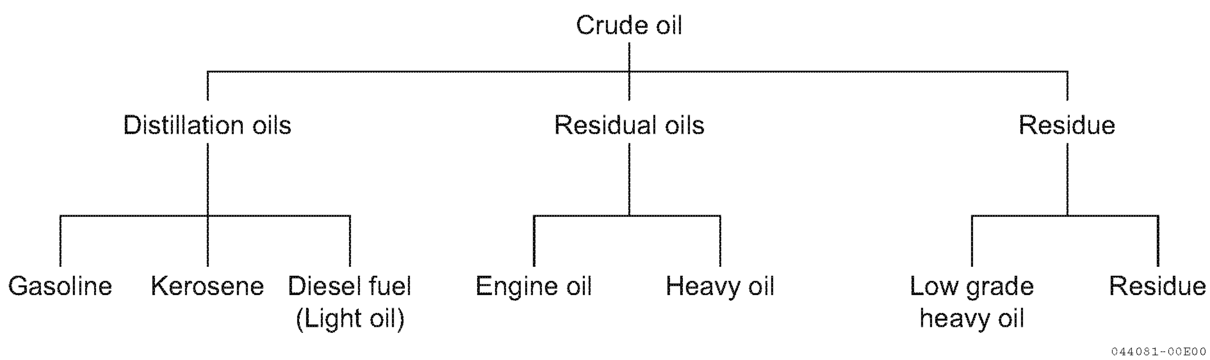


Figure 10-5

Fundamental requirements for diesel fuel

Requirements for diesel fuel are appropriate combustibility, viscosity, purity, and a large calorific value. Combustibility should be sufficient to maintain the diesel cycle, with controlled combustion and keeping maximum pressure under a normal level. Viscosity is important when mixing diesel fuel with air in the combustion chamber to obtain complete combustion, in the process of fuel atomization, dispersion and distribution. In general, the lower the viscosity of the diesel fuel, the higher the quality (with better combustibility and purity).

Properties of diesel fuel

Diesel fuel has many standardized properties around the world. The major properties among them are as follows.

Specific gravity

Specific gravity has no direct connection with combustion. High speed engines commonly use a specific gravity lower than 0.88. A specific gravity of 0.83 to 0.85 is recommended for industrial and construction engines. Specific gravity is indicated at the standard temperature 15 °C. Specific gravity falls by about 0.0007 for every 1 °C rise. High diesel fuel temperature lowers the specific gravity, decreasing engine output. Winter fuel has a lower specific gravity than summer fuel.

Flash point

In general, the higher the specific gravity, the higher is the flash point. The flash point has no direct effect on combustion performance. Special fire precautions should be used with diesel fuel with a low flash point. Diesel fuels normally have a flash point of 50 to 60 °C or more.

Viscosity

Viscosity in general increases with specific gravity. This has a large influence on the accuracy of injection atomization, which is necessary for ignition and combustion. Diesel fuels with high viscosity are capable of penetrating the compressed air wall, but ignition is slow due to insufficient fuel atomization and combustion performance is inferior. Diesel fuels with low viscosity have poor fuel distribution, which results in delayed combustion. In the terms of combustion, it would be ideal to use diesel fuel with a relatively low viscosity injected at high pressure to raise both the penetration and atomization.

Lower grades of diesel fuel have higher viscosity and more impurities. It is necessary to remove the impurities completely with filters and purifiers before using such diesel fuels. If this is not done, both diesel fuel system life and the engine life will be shortened.

Diesel fuel viscosity has a large influence on the injection system and combustibility. Low viscosity diesel fuel accelerates the wear of parts due to insufficient lubrication. This can result in diesel fuel leakage. The high pressure of high viscosity diesel fuel places an excessive load on the injection mechanism and can cause problems.

Residual carbon

Residual carbon is deposited on the combustion chamber wall and accelerates wear of the cylinder, piston and piston rings. Less carbon is better for the engine.

Residual carbon increases when diesel fuel quality degrades or is contaminated. Residual carbon of below 0.1 % is recommended.

Asphalt

Asphalt is a byproduct of petroleum distillation. Most asphalt content turns into sticky residual carbon during the combustion process. This causes the piston rings to stick. The lower the asphalt content, the better.

Ash content

Ash content is directly related to cylinder wear. Ash content is peculiar to specific diesel oils but impurities can enter the diesel fuel during transportation and storage and turn to ash content. Higher sulfur content results in higher particulate emission.It is important to remove as much of the ash content as possible with filters and purifiers. Content of below 0.01 % (by mass) is required.

Sulfur content

Sulfur content turns to sulfur dioxide and sulfur trioxide after combustion. Sulfur trioxide combines with water produced by combustion and turns into sulfuric acid, which corrodes the cylinder wall, piston, exhaust valve, exhaust pipe, and Diesel Particulate Filter. The lower the sulfur content, the better. Sulfur content of below 15 ppm (by mass) is required.

Cetane number

The cetane number is important for exhaust emission compliance regulations and engine performance. Diesel fuel with good ignitability allows easy starting and smooth running with minimal smoke and noise. Ignitability is indicated by the cetane number and it should be more than 45. A higher cetane number ensures a smaller firing lag and better starting performance.

Polycyclic aromatic hydrocarbon content

Reduce polycyclic aromatic hydrocarbons for reduction of particulate matter emission that consists of more than two benzene rings of hydrocarbon composition for environmental improvement.

Water and microorganisms

When purchased, there is a small amount of water in diesel fuel from the manufacturing process. This amount of water increases with long term storage. Microorganisms in the water will start to grow if the diesel fuel is allowed to be stored for a long period of time. Microorganisms are harmful to the supply pump and the injectors. Periodically drain and check the diesel fuel tank.

Lubricity/lubricity assessment

Wear mark of WS 1.4 (Calculated Wear Scar Diameter at 1.4 kPa) diameter should be Maximum 460 μm at HFRR (High Frequency Reciprocating Rig) test. But immediately after you replace the supply pump or the injector, we recommend using fuel up to 400 μm.

Engine Trouble Caused by Improper Diesel Fuel

Deposits on the exhaust valve

Causes compression failure, incomplete combustion and excessive diesel fuel consumption. Uncombusted fuel can also blow out in the exhaust gas and corrode the exhaust valve.

Deposits on the piston ring grooves

Causes piston rings to stick, blow-by gas to form, faulty lubrication, incomplete combustion, excessive fuel consumption, engine oil contamination and accelerated wear of the cylinder liners and pistons due to formation of blow-by gas.

Clogging or corrosion of the injection hole of the fuel injection valve

Causes incomplete combustion and wear of the pistons and liners and accelerates wear and corrosion of the fuel injection system. It also accelerates wear and corrosion of the injection hole.
In environments where metals, especially Zn and Pb are separated in the fuel, the injection hole clogs and causes a decrease in output.

Sediments inside the crankcase

Besides sometimes attributed to the engine oil quality, use of inferior diesel fuel can also cause sediments to accumulate inside the crankcase.

Diesel Fuel Properties and Engine Performance

Diesel fuel properties related to engine performance are as follows:

Diesel fuel properties and engine performance

FO properties	Starting performance	Operational smoothness	Smoke production	Exhaust smell	Output	Diesel fuel consumption	Combustion chamber deposits
Combustibility; cetane number	Direct relation; the larger the cetane number, the better the starting performance	Direct relation; the larger the cetane number, the better the operation smoothness	Close relation; the lower the cetane number, the more the smoke	Direct relation; decreases as cetane number increases	No relation	Related.	Related; decreases as cetane number increases
Volatility	No definite relation known	Related; worse with lower volatility	Direct relation; the lower the volatility, the more smoke	No direct relation	No relation	No relation	Related; the lower the volatility, the more deposits
Viscosity	No definite relation	Some relation; as viscosity increases combustion performance degrades	Related; the higher the viscosity, the more the smoke	No independent relation	No relation	No relation	Related; increases as viscosity increases.
Specific gravity	No relation	No relation	Related.Viscosity becomes higher as specific gravity increases, causing more smoke	No independent relation	Direct relation in terms of calorific value	Direct relation in terms of calorific value	Related depending on engine characteristics
10 % residual carbon	No relation	No relation	Related.Smoke decreases as residual carbon content reduces.	No independent relation	No relation	No relation	Related; deposits decrease with carbon reduction
Sulfur				No independent relation			
Flash point				No independent relation			

Alternative Fuels

Contact YANMAR before using any alternative fuels.

Bio fuel

General description of biodiesel

- Bio-diesel is a fuel made from agricultural and renewable resources such as soybeans or rapeseeds. Biodiesel is a fuel comprised of methyl or ethyl ester-based oxygenates of long chain fatty acids derived from the transesterification of vegetable oils, animal fats, and cooking oils. It contains no petroleum-based diesel fuel but can be blended at any level with petroleum-based diesel fuel. In case it is not blended with petroleum-based diesel fuel such biodiesel is referred to as “B 100”, which means that it consists of 100 % (pure) biodiesel. However, most common biodiesel is blended with conventional (petroleum-based) diesel fuel. The percentage of the blend can be identified by its name. The most common blends are “B 5” (consisting of 5 % bio- diesel and 95 % conventional petroleum-based diesel fuel) and “B 20” (a blend of 20 % biodiesel and 80 % conventional diesel). Raw pressed vegetable oils are not considered to be biodiesel.

- Advantages of biodiesel:
  - Biodiesel produces less visible smoke and a lower amount of particulate matter.
  - Biodiesel is biodegradable and nontoxic.
  - Biodiesel is safer than conventional diesel fuel because of its higher flash point.

  Following the increased interest in the reduction of emissions and the reduction of the use of petroleum distillate based fuels; many governments and regulating bodies encourage the use of biodiesel.

- Disadvantages of biodiesel:

  Concentrations that are higher than 7 % of biodiesel (higher than B 7) can have an adverse affect on the engine’s performance, its integrity and/or durability. The risk of problems occurring in the engine increases as the level of biodiesel blend increases. The following negative affects are exemplary and typical for the usage of high concentrated biodiesel blends:

  - Biodiesel can accelerate the oxidation of Aluminum, Brass, Bronze, Copper and Zinc.
  - Biodiesel damages, and finally seeps through certain seals, gaskets, hoses, glues and plastics.
  - Certain natural rubbers, nitride and butyl rubbers will become harder and more brittle as degradation proceeds when used with biodiesel.
  - Biodiesel typically creates deposits in the engines.
  - Biodiesel fuel easily oxidizes if you store it for an extended period. Operating the engine with such deteriorated fuel causes damage to the injection system.

Approved engines

All of the following engine series of YANMAR can be operated with biodiesel with concentrations up to B 7. In case of using biodiesel fuel up to B 7 concentrations, no special preparations etc. have to be made and the original operating conditions and service intervals as stated in the operating manuals apply.

Approved fuel

In case of using biodiesel (only concentrations up to B 7) such fuel should comply with the below recommended standards. However, raw pressed vegetable oils are not considered to be biodiesel and are not acceptable for use as fuel in any concentration in YANMAR engines.

- EN14215 and EN590 (Oxidation stability) (European standard) or ASTM D-6751 and ASTM D-7467 (Oxidation stability) (American standard), and JIS K 2390 (Japanese standard).
  (Refer to *Fuel Specifications Required by Common Rail Engine on page 10-10* for blended diesel oils.)
- Bio-diesel fuel must be used within 3 months from its production.

JP-8/JP-5 fuel, military applications

Refining crude petroleum makes JP-8 (NATO F34). The primary ingredient in JP-8 is kerosene that is about 99.8 % by weight. JP-8 contains very small amounts of other substances, such as benzene, and additives to inhibit icing, prevent static charge buildup, avoid oxidation, and decrease corrosion.
The lubricity of JP8 is low and irregular wear and burns can occur on the injection system. The viscosity is also low, and high leak fuel results in higher fuel temperature, deterioration of fuel results in increased deposits and bad injection amounts of the supply pump. Its use is not permitted.
JP-4 fuel is not allowed.

Engine Oil Filter System

Sliding parts such as diesel fuel injection pump plungers, pistons of the injector and diesel fuel injection valve needles can wear when impurities are mixed in with the diesel fuel. Water in the diesel fuel adversely affects the diesel fuel injection system. A diesel fuel filter/water separator is installed on the inlet side of the fuel injection pump as a pre-filter between the diesel fuel tank and the diesel fuel pump.

Fuel Filter

The diesel fuel filter, a standard part of the diesel fuel system, is the main filter in all TNV series engines. A standard diesel fuel filter uses a cartridge type with a metal body.

Cautions for installation

- YANMAR genuine parts should be used.
- Install diesel fuel filters where the ambient temperature is 80 °C or below.
- Install diesel fuel filters where the vibration acceleration is within 55 m/sec^2 [RMS] (low pass filter is set for 1 kHz).
- Install the diesel fuel filter in a direction and position that does not allow air to remain in the filter and diesel fuel line.
- Position the diesel fuel filter so it is not exposed to dust, mud, or water.
- Make sure to clean the base of the filter when you replace the diesel fuel filter.

How to check or replace diesel fuel filter

Maintenance on the diesel fuel filter should be done after the drain valve of the pre-filter is CLOSED.
Make sure the drain valve is OPEN before you start the engine.

Maintenance

Replacement interval: 500 hours

Pre-filter (Diesel Fuel Filter/Water Separator)

A pre-filter is a fuel filter with a water-separation function and it is mandatory for TNV engine series. Finely dispersed water in the diesel fuel tends to coagulate when the flow speed sharply drops. Coagulated water separates by gravity because of the difference in the specific gravity of the water and diesel fuel.
By adopting a water repellent element, a pre-filter efficiently removes water from the diesel fuel system.

The pre-filter is generally installed between the diesel fuel tank and the diesel fuel pump. When engines are used in an industrial application, water, dust and mud are very likely to enter the diesel fuel tank. These impurities may be collected by a pre-filter with a water-separation function. Installation of pre-filter protects the diesel fuel pump, extends the service life of the diesel fuel injection system by preventing rust, and prevents engine starting failures caused by cold weather/freezing conditions.

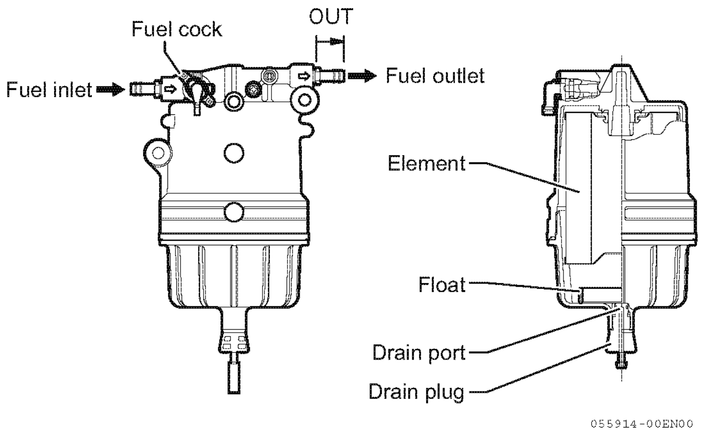


Figure 10-6

Cautions for installation

- To ensure correct performance with the main fuel filter, use only genuine YANMAR parts.
- Install in a location where the ambient temperature is 80 °C or below.
- Install diesel fuel filters where the vibration acceleration is within 55 m/sec^2 [RMS] (low pass filter is set for 1 kHz).
- Install the pre-filter between the diesel fuel tank and diesel fuel pump. If it is installed near the diesel fuel pump, separating diesel fuel and water becomes difficult.
- The pre-filter must be installed near the lower level of the fuel tank where maintenance (water-bleeding, air-bleeding) can be performed easily. If you consider installing the pre-filter to a place with low visibility or indication to the meter panel, there is an optional pre-filter with water level sensor.
- Place the pre-filter at the lowest position in the diesel fuel line. (Installation on intake manifold is disapprove)

Maintenance

- Check and drain water : 50 hours
- Replacing : 500 hours

Diesel Fuel Tank

The diesel fuel tank is generally made of steel plate or synthetic resin. Install a diesel fuel level gauge, outlet line, return line, filler port strainer and drain valve on the diesel fuel tank, and provide an air bleeder on the diesel fuel tank lid. A large air vent hole should be at the diesel fuel filler port to prevent the diesel fuel from overflowing from the strainer during filling.

Material of diesel fuel tank

Blow-formed plastic is not recommended for diesel fuel tanks because glass fiber dust and/or plastics are harmful to diesel fuel injection equipment. Glass fibers damage the diaphragm of the diesel fuel pump and approximately 60 μm diameter particles will be stuck in the plunger barrel. (Select the material so that no contamination occurs during use and clean and remove contamination before use.)
Do not use materials such as the metals Pb and Cu that separate easily and clog the injection hole. Also do not use Zn coating inside the fuel tank.

Structure of diesel fuel tank

Avoiding air bubbles in the diesel fuel line that leads into the supply pump and the return line back to the fuel tank are two of the primary fuel system design considerations.

- When the fuel tank is mounted at the same level or higher than the supply pump, the return line should be routed to the top of the fuel tank and as far away as possible from the supply line to the engine to avoid formation of air bubbles.

Case1: When the suction port is at the bottom of the tank Case2: When the suction port is at the top of the tank

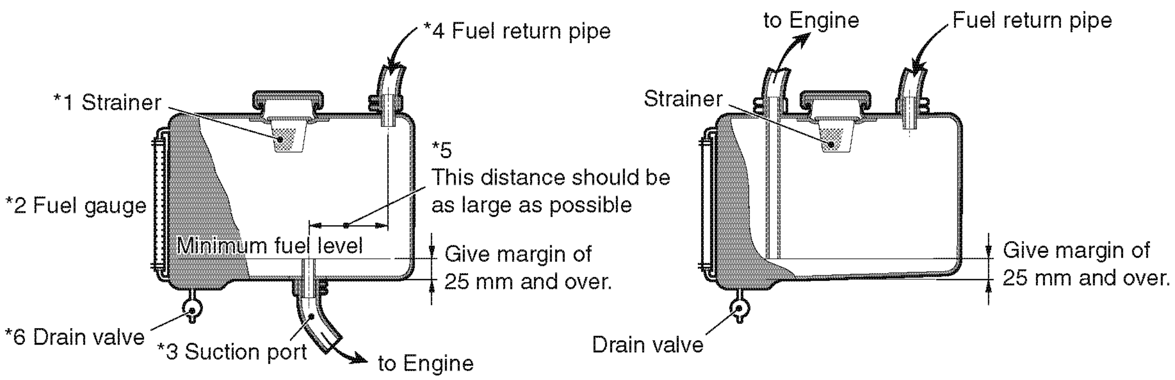


Figure 10-7

- When the fuel tank is mounted lower than the supply pump, the fuel return line should be routed deep into the fuel tank as far from the supply line as possible for a closed loop fuel line, to avoid getting air into the diesel fuel line.

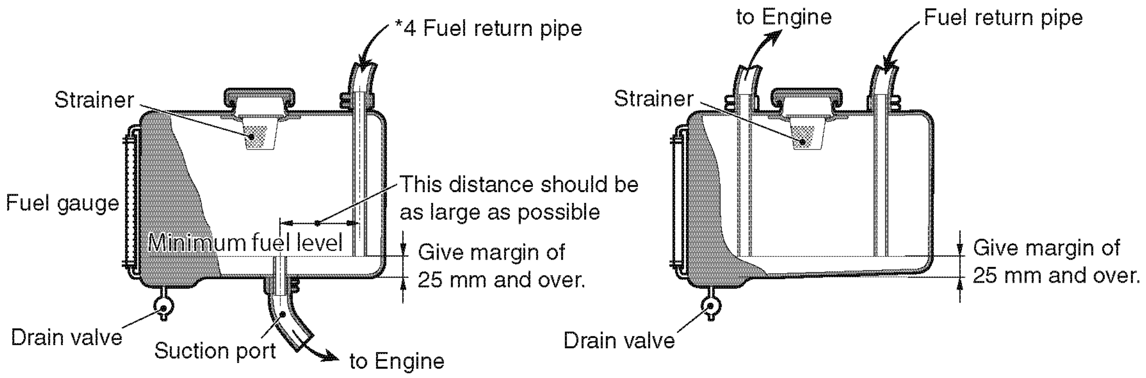


Figure 10-8

- Strainer: Use an approximately 40 mesh element which can be removed and replaced.
- Diesel fuel level gauge: The minimum diesel fuel level line on the gauge must be higher than the position of the diesel fuel suction port (to prevent air suction).
- Suction port: Should be installed at the center of the tank to prevent air suction during inclined operation. Avoid installing it just under the diesel fuel filler port.
  The **Figure 10-9** illustrates why the suction port should be located at the center of the tank:

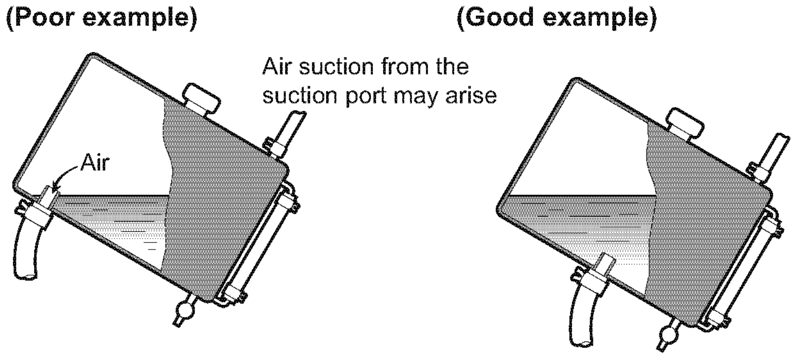


Figure 10-9

- The end of the diesel fuel return line should be as close to the minimum fuel level as possible.
- The end of diesel fuel return line should be as far from fuel outlet of the fuel tank as possible.
- Drain valve and diesel fuel tank bottom shape

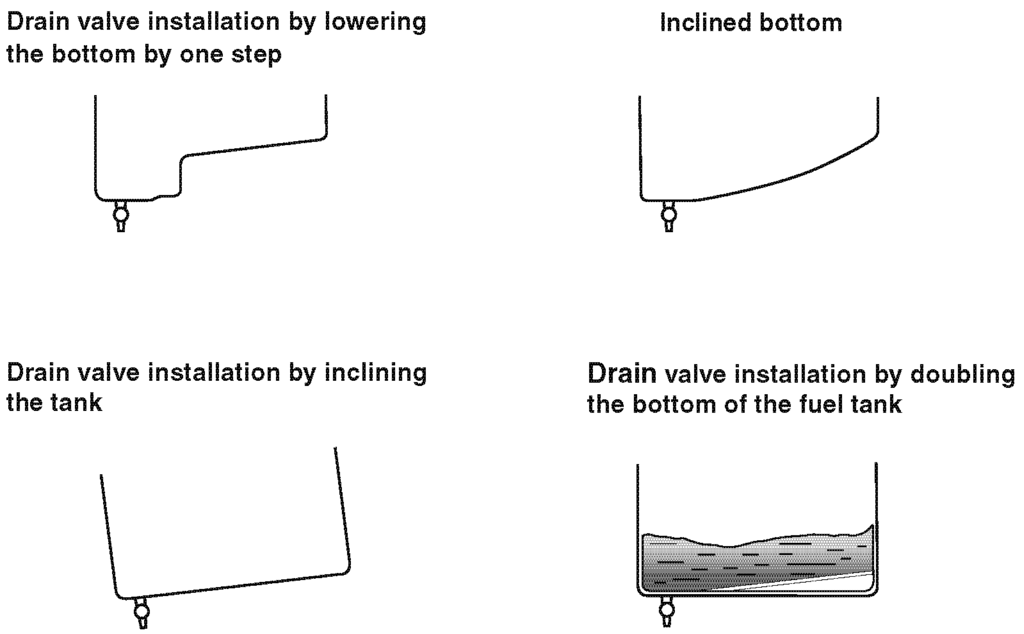


Figure 10-10

Fuel tank capacity

Refer to *Fuel Tank on page 19-4*.

Diesel Fuel Pump

The diesel fuel pump force-feeds diesel fuel from the diesel fuel tank to the supply pump.
DI engines use an electrical diesel fuel pump.

Precautions for installation

Electric diesel fuel pump (solenoid type)

- Install the electric diesel fuel pump in a dry place. The electric diesel fuel pump is not waterproof. Use a genuine YANMAR pump.
- Install the electric diesel fuel pump horizontally or vertically (outlet is on the top side) in a place with a low level of vibration, not on the engine.

Other cautions

- On a stationary machine, if the minimum diesel fuel level of the fuel tank is higher than the fuel inlet of the injection pump, a diesel fuel pump is not necessary, as long as the standard value of the fuel pump inlet pressure (3TNV88C - 4TNV98CT: -50 to +10 kPa) is satisfied.
- Install a YANMAR genuine pre-filter with an oil-water separation function.

Layout of Diesel Fuel Line

Precaution

To avoid fire, the distance between a diesel fuel line and exhaust pipe should be as follows.

Recommended distance:

- Diesel fuel line - Exhaust pipe (minimum 100 mm)
- Diesel fuel filter - Exhaust pipe (minimum 50 mm)

Diesel Fuel Injection Lines

Diesel fuel injection lines should not be in contact with other parts. Contact could result in a serious accident. Electric wires especially should not be attached to the diesel fuel injection lines and/or fuel hoses.

Do not reuse the diesel fuel injection lines at reassembly after engine disassembly. It will result in diesel fuel leakage.

There are 2 types of the diesel fuel injection lines for the CR engines: Supply pump to rail, and rail to injector.

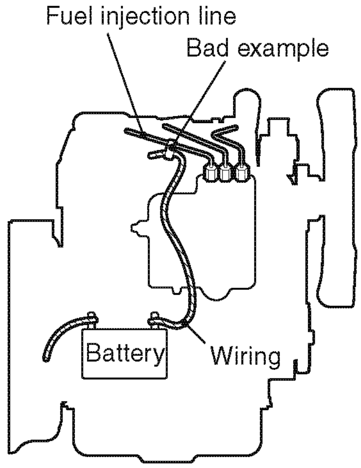


Figure 10-11

Hose clamping is needed in some cases

When the diesel fuel hoses are bundled with a clamp, they should be protected by corrugated tube. Fuel hoses in contact with engine and/or chassis should also be protected.

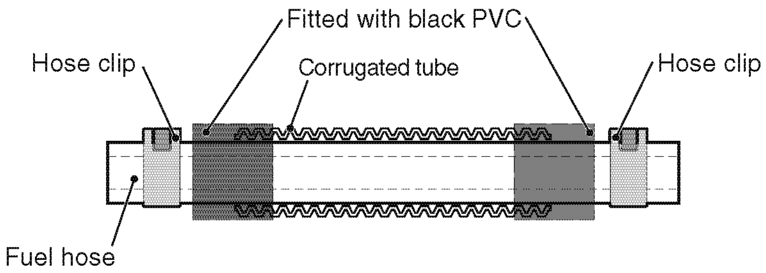


Figure 10-12

Fuel hose material (SAE J30R7)

	Inside	Outside
Material recommendations	Fluoro rubber (FKM)	Acrylic rubber (ACM)
Pressure-resistance	200 kPa or more	
Temperature-resistance	-30 °C to -150 °C	
Climate-resistance	Necessary (Ozone, moisture, engine oil, ultraviolet rays)	

Note:
- *Vinyl hose is not used as a fuel hose because heat causes significant deformity.*
- *Check the materials whether metals like Pb and Zn separated from the fuel pipes into the fuel. (This may also be caused by mould release agents used during manufacturing.)*
- *Brush the fuel pipes to remove contamination. Then assemble them. Contamination can cause wear on the injector.*

Shape of fuel line

Try to avoid high points in the fuel line where air will collect.

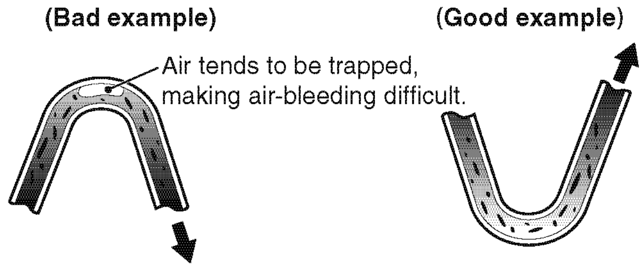


Figure 10-13

Fuel line layout

Refer to *Standard Diesel Fuel Line Layout on page 10-8.*

Fuel Line Maintenance

Maintenance and Replacement

	Maintenance (hr) check and drain	Replacement (hr)
Fuel filter	–	500
Diesel fuel filter/water separator	50	500

Air-bleeding after Replacement of the Filter and/or Fuel Hoses

The engine may not start or the engine speed may fluctuate if air is trapped in the diesel fuel system.

Engine with electric diesel fuel pump (solenoid type)

1. Open the fuel cock of the diesel fuel filter/water separator.
2. Turn the key switch to the ON position. The electric diesel fuel pump runs to automatically bleed air from the diesel fuel line.
3. It takes 10 to 60 seconds to bleed air from the diesel fuel line. The time varies depending on the air volume inside the diesel fuel line.

NOTICE

Never bleed air by using the starter motor.

Section 11

LUBRICATING SYSTEM

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The lubricating system force-feeds engine oil to the crankshaft main bearings, connecting rod large end bearings, camshaft bearings, valve train, and moving portions of other components, such as the turbocharger. The engine oil lubricates and cools these components.

Engine oil is supplied to pistons, cylinders and gears by splash lubrication or through piston cooling nozzles. If any of these functions are lost, the engine oil will be consumed and degraded during engine operation and engine damage will result. To maintain lubricating system performance, use the recommended engine oil, check the level and change according to recommended schedule.

Lubricating System Diagram

The TNV-Tier 4 series engines uses a wet sump lubrication system. In this system, the engine oil pump pumps engine oil from the oil pan through a suction pipe and to the crankcase and the other lubricating circuit components.

The TNV-Tier 4 series engine lubricating system is shown in **Figure 11-1**:

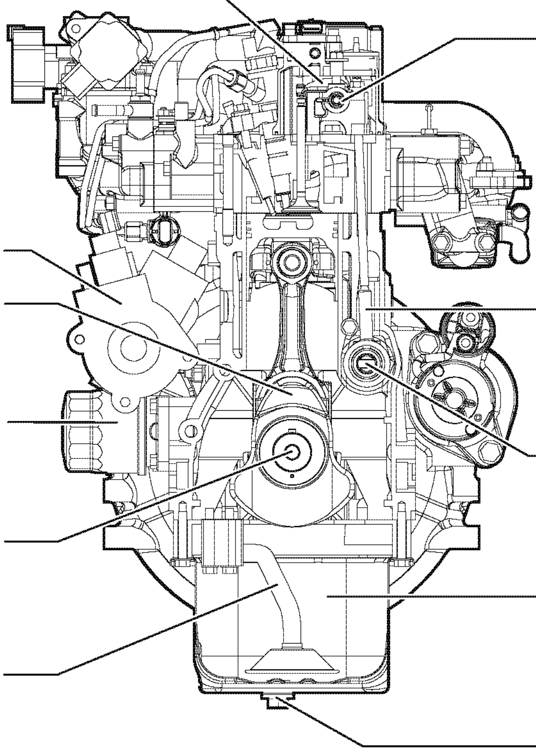

Figure 11-1

DI (Direct Injection) Engine

3TNV88C, 3TNV86CT, 4TNV88C, 4TNV86CT, 4TNV98C, 4TNV98CT

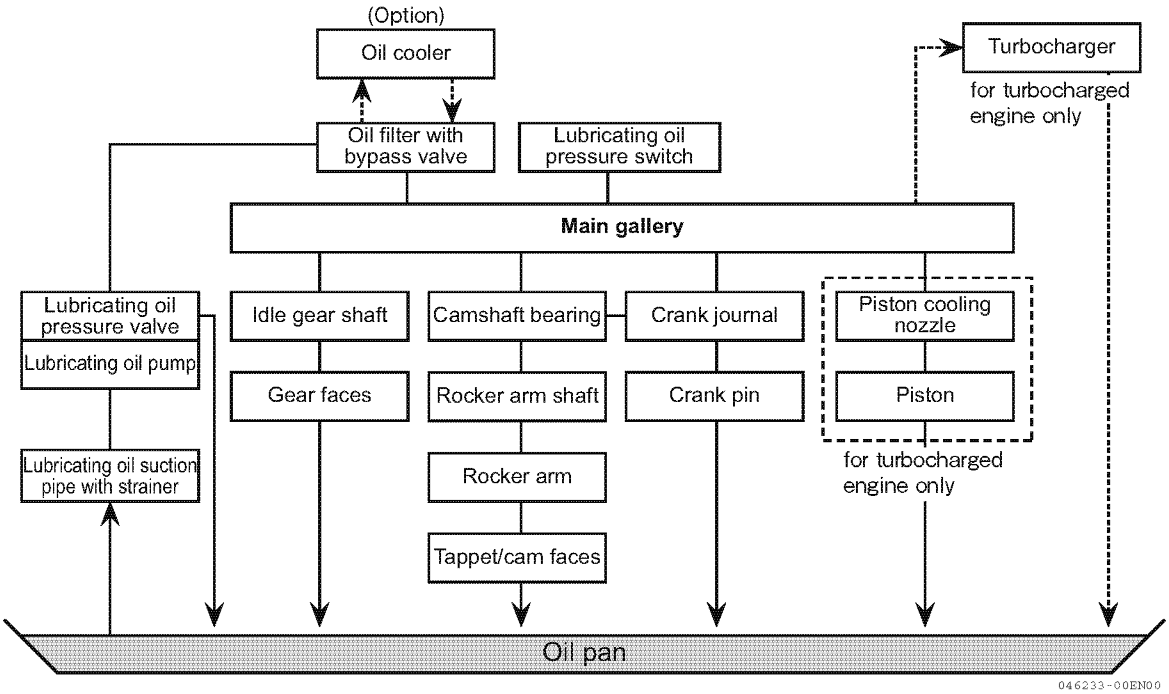

Figure 11-2

Engine Oil

Engine oil used for industrial engines varies with engine application and environmental temperature. Engine oil properties are classified according to the required functions. Engine manufacturers typically recommend the appropriate engine oil according to the API (American Petroleum Institute) service classification and SAE (Society of Automotive Engineers) service grades. The engine oil class varies with the operating conditions, environment and the type of fuel to be used. If the fuel has a high sulfur content, it is important to use high-grade engine oil, as the corrosive products generated by combustion must be neutralized by the engine oil.

Selection of Engine Oil

Use a low ash oil that complies with the following specifications as engine lubricating oil. If you use another lubricating oil, a great amount of ash content is discharged, causing early clogging of the Diesel Particulate Filter, reduced engine output, higher fuel consumption, and the need for SF maintenance in the short term.

Classification

		API classification CJ-4	ACEA classification E6	JASO classification DH-2
Sulfated ash	mass%	≤ 1.0	≤ 1.0	1.0 ± 0.1
Sulfur	mass%	≤ 0.4	≤ 0.3	≤ 0.5
Phosphorus	mass%	≤ 0.12	≤ 0.08	≤ 0.12
Chlorine	mass ppm	–	–	≤ 150
TBN	mg KOH/g	–	≥ 7	≥ 5.5

Definitions

API Classification [American Petroleum Institute]. ACEA Classification [Association des Constructeurs Européens d’Automobiles]. JASO [Japanese Automobile Standards Organization].

Additional guidelines

- The engine oil must be changed when the Total Base Number (TBN) has been reduced to 1.0.
- TBN (mgKOH/g) test method; JIS K-2501-5.2-2 (HCl), ASTM D4739 (HCl).
- Standard engine oil service interval is 250 hours or every 12 months.
- Never add any additives to the engine oil.
- Never mix the different types (brands) of engine oil.

Never use the following engine oils

Do not use the engine oils except CJ-4, E6, and DH-2. If the other engine oils except these are used, the clogging of DPF and the reduction of engine performance due to increase in the exhaust back pressure may result. Also, more frequent maintenance for DPF may be required.

Classification by engine oil viscosity (SAE viscosity classification)

There are eleven viscosity levels of SAE (Society of Automotive Engineering) classification, i.e., 0 W, 5 W, 10 W, 15 W, 20 W, 25 W, 20, 30, 40, 50 and 60. This classification system is very popular and has been used all over the world for many years.

Table 11-1 SAE viscosity grades for engine oils[*1] - SAE J300 Dec 99 (document 2)

Low-temperature viscosities			High-temperature viscosities		
SAE viscosity grade	Cranking[*2] mPa • s (cP) max at temperature °C	Pumping[*3] mPa • s (cP) max with no yield stress at temperature °C	Low shear rate kinematic[*4] mm^2/s (cSt), (100 °C)		High shear[*5] rate mPa • s (cP), (150 °C Min)
			Min	Max	
0 W	6200 at -35	60,000 at -40	3.8	–	–
5 W	6600 at -30	60,000 at -35	3.8	–	–
10 W	7000 at -25	60,000 at -30	4.1	–	–
15 W	7000 at -20	60,000 at -25	5.6	–	–
20 W	9500 at -5	60,000 at -20	5.6	–	–
25 W	13,000 at -10	60,000 at -15	9.3	–	–
20	–	–	5.6	< 9.3	2.6
30	–	–	9.3	< 12.5	2.9
40	–	–	12.5	< 16.3	2.9 (0W-40, 5W-40, 10W-40 grades)
40	–	–	12.5	< 16.3	3.7 (15W-40, 20W-40, 25W-40, 40 grades)
50	–	–	16.3	< 21.9	3.7
60	–	–	21.9	< 26.3	3.7

*1: *All values are critical specifications as defined by ASTM D 3244 (refer to text, Section 3).*
*2: *ASTM D 5293*
*3: *ASTM D 4684 (refer to also Appendix B and text Section 4.1): The presence of any yield stress detected by this method constitutes a failure regardless of viscosity.*
*4: *ASTM D 445*
*5: *ASTM D 4683, ASTM D 4741, CEC-L-36-A90*

Selection of SAE service grade oil according to temperature

Use multi grade oil in TNV-Tier 4 engines.

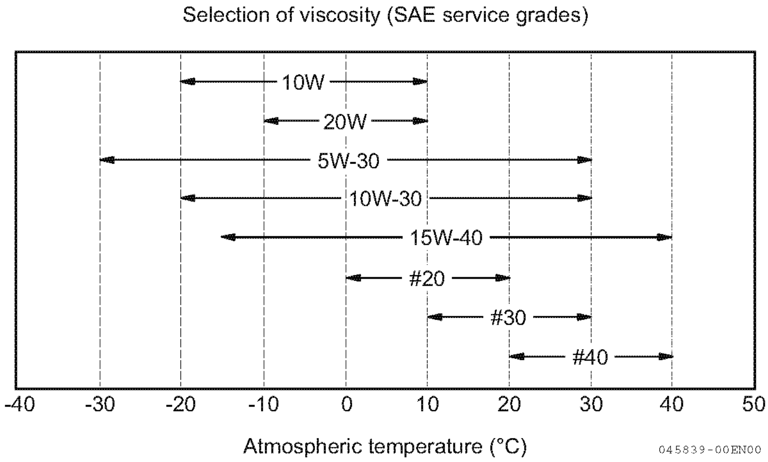

Figure 11-3

Heavy duty oil

Heavy-duty oils (HD oils) are oils with added antioxidant and detergent-dispersant agent. HD oil is appropriate for use as diesel engine oil. The HD oil is long lasting due to the antioxidant effect. The detergent- dispersant keeps the pistons clean and prevents piston ring sticking and contamination of the oil passages. A detergent-dispersant with a total base number also neutralizes the sulfuric acid produced by the combustion of the sulfur content in diesel oils, preventing liner and ring wear. The detergent-dispersant neutralizes strong acid entering the crankcase and prevents corrosion of engine parts.

Multi-grade oil

Multi-grade oil is an engine oil designed to meet both low temperature and high temperature viscosity characteristics represented with "W", as "10W", represented as "10W-30". This type of oil provides good starting at low temperature, good fuel economy, and proper viscosity at high temperature.

As an example, **Figure 11-4** shows the viscosity-temperature characteristics of genuine YANMAR engine lubricating oil. This chart uses kinematic viscosity at 40 °C and 100 °C shown in the property table. Although the lower temperature characteristics of oil are generally shown with cranking viscosity, it is shown here using kinematic viscosity as a standard. On this graph with semi-logarithmic scale, the temperature and viscosity are related linearly. However, for single grade oil, the rate of increase of the viscosity increases a little at the lower temperature range. For the multi-grade oil, the viscosity changes with temperature mostly as shown in the graph.

Viscosity-temperature characteristics of engine oil

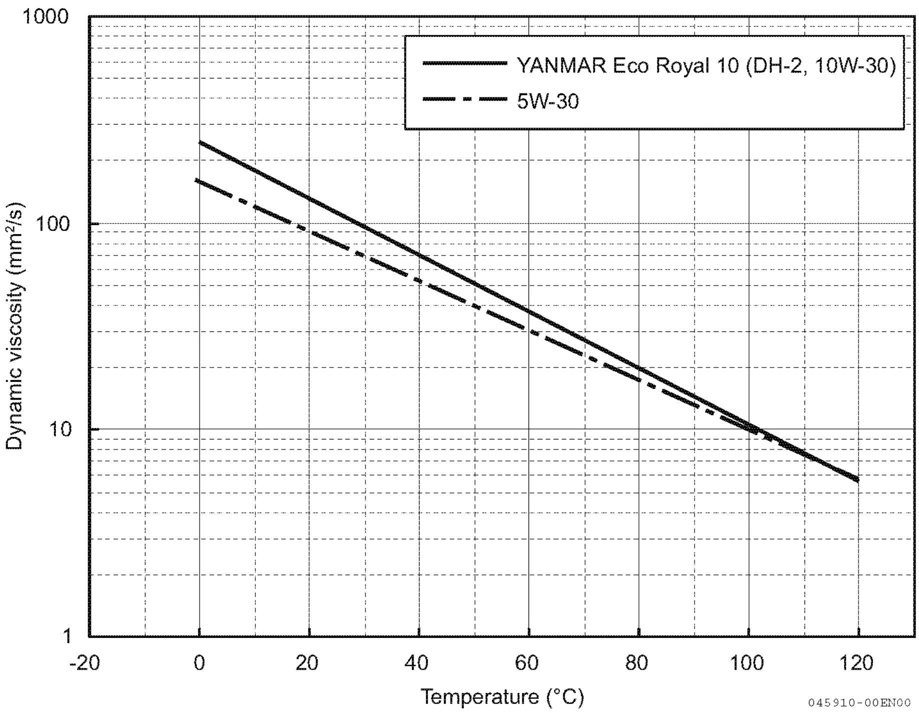

Figure 11-4

Preventing Wear

Prevention engine wear is of utmost concern to all engine operators. The following can be said about this problem:

Oil film breakdown at high temperatures

Oil viscosity decreases as the engine temperature rises. This can cause the oil film to rupture and metals to rub against each other.

To prevent this, use an engine oil with a high viscosity index raising agent or change the SAE viscosity number according to the season. It is best to use SAE20 oil in winter, SAE30 or SAE40 oil in summer and SAE30 in spring or fall.

Poor circulation of oil when the engine is started

The shaft and bearing come in direct contact when the engine stops. When the engine oil viscosity is too high, engine oil circulation while the engine is starting can be poor, causing metals to rub directly against each other. Special care must be taken in this situation since starting wear can be extreme.

To prevent this, use an engine oil with a high viscosity index raising agent or change the SAE number according to the season, (No. 20 oil in winter and No. 40 oil in summer). Fully priming the engine oil system before starting the engine is also recommended.

Poor oil circulation due to deposits

When oil degenerates due to oxidation, varnish-like accumulations and other deposits are produced. These deposits stick to engine parts which hinders engine oil circulation and causes the oil film to break, resulting in metal wear.

The solution to this is to use engine oil which does not oxidize and degenerate easily and is good at dispersing sludge and varnish in the oil, (engine oil which has superior anti-rust, anti-oxidation and detergent characteristics). Using engine oil mixed with anti-oxidation, detergent and carbon dispersion additives or checking and replacing the engine oil on a periodic basis is recommended. The viscosity of oxidized oil becomes very high at low temperatures, making the engine difficult to start.

Materials scratched by deposits

Deposits can scratch materials when they stick to the moving parts of the engine.

Use an engine oil supplemented with an anti-oxidation agent that has superior anti-oxidation and detergent characteristics. Checking and replacing the engine oil periodically is recommended. It is also necessary to keep the engine compartment clean.

Corrosion of materials

Use an engine oil with superior anti-oxidation characteristics or replace the oil at shorter intervals.

Corrosion derives from not only the engine oil but also from sulfur in fuel. Sulfur produces sulfur dioxide gas during combustion and some of that gas turns to sulfur trioxide. This mixes with condensed water in the cylinder and becomes sulfuric acid, which corrodes engine parts.

It is necessary to neutralize these strong acids with alkali to remove the corrosiveness and prevent harmful sulfuric corrosion. Use engine oil with acid neutralizing performance, (Total base number, 4 - 15 mg KOH/g).

Replacing Engine Oil

Necessity of replacement

Engine oil is exposed to high temperatures and air during engine operation and so gradually oxidizes and degenerates. As engine oil is contaminated and diluted with water, impurities and diesel fuel, it gradually loses its characteristics. When water and impurities mix with the engine oil, emulsified substances and sludge are produced, increasing the engine oil's viscosity. Continuous use of degenerated oil causes wear and corrosion of moving and rotational parts and eventually abnormal wear and seizure of bearings and liners.

Important

Replace engine oil according to the specified interval. Expected engine oil problems due to degeneration and the entry of impurities are as follows:

Contamination of engine oil by diesel fuel

When diesel fuel mixes with engine oil, viscosity is diluted. It is dangerous to continually use engine oil that is diluted by more than 25 %.

Be careful of fuel dilution. This engine has a higher tendency to mix fuel into the lubricating oil at the time of DPF regeneration than conventional engines without DPF. Be sure to change the lubricating oil if fuel dilution of 5 % or more occurs.

Oil circulation is hindered and lubrication and cooling effects are lowered when emulsified substances and sludge are produced by water and impurities entering the engine oil. The engine oil must be replaced.

Excessive increase of acidity

Engine oil acidity increases when exposed to water, air and heat. Acidity increases rapidly in regular class oils without anti-oxidation agents and oils with inferior anti-oxidation stability. This acidity produces organic acids that rust and corrode the bearing face, cylinder liner and piston. The process also produces sludge and eventually causes the oil to decompose and degenerate. Lubrication performance will be lost. Engine oil with an acid value of over 1.0 must be replaced.

Increase of insoluble matter in the oil

Metal powder, dust and products of incomplete diesel fuel combustion cause an increase of insoluble matter (sludge and solid impurities) in the oil. This worsens lubrication performance, oil circulation and cooling effect. Solid impurities can damage the bearings and the inside of the cylinder liners. The engine oil must be replaced when these impurities are present.

Water in the oil that can't be removed

Water that leaks into the crankcase turns to carbonic acid gas and steam by the fuel combustion. The steam turns back to water when it cools and can also enter the crankcase. The entry of water into engine oil produces an emulsified substance that hinders lubrication and causes bearing and piston wear. The sulfuric compound in the fuel turns into sulfur trioxide after combustion. This combines with water and produces sulfuric acid that corrodes the bearings, piston, intake and exhaust valves and exhaust pipe.
If the lubricating oil filter is not able to remove water in the lubricating oil, replace the lubricating oil as soon as possible.

Excessive drop of flash point

A drop in flash point indicates that the engine oil is contaminated with diesel fuel. When the flash point drops to 35 °C in gasoline engines and to 25 °C in diesel engines, oil film and oiliness are lost and thermal-resistance and lubrication performance are degraded. This has an adverse effect on the engine and can even lead to explosion. Replace the engine oil as soon as possible.

Degeneration of oil as a result of a spot test

The usual way to test engine oil is to send a sample to the laboratory for analysis. This takes a considerable amount of time and the engine may be damaged in the meantime by the use of unsuitable engine oil.

A spot test is a quick way to gauge engine oil degeneration. The spot test provides a rough idea of detergent-dispersant performance, degree of contamination and alkali or acid status of the engine oil by spreading it on a test paper and analyzing its color.

The extent of dilution by diesel fuel, entry of water or oil filter negligence can be determined by this method. This is a convenient and effective way to maintain the engine.

Replacement interval (engine oil service interval)

Service interval varies depending on engine type, engine oil, diesel fuel quality and operation conditions. Determine service intervals by analyzing the engine oil properties under working conditions. After analyzing the results of the test, determine the service interval.

Engine oil degeneration speed varies depending on the engine oil quality, engine and operation conditions and maintenance of oil filters and air cleaner filters.

YANMAR has researched various applications and determined standard service intervals, which are specified in the *TNV Operation Manual*.

Check the engine oil condition frequently and replace it early irrespective of the fixed interval if the engine oil has degenerated.

P/N: 0DTN4-G00400 Rev.01 2013. September

Table 11-2 Criteria to replace the engine oil

Properties		Criteria
1. Increase/decrease of viscosity at 40 °C		25 % or more increase/decrease from new engine oil
2. Total base value mg KOH/g		1.0 or below (HCl method); 4.0 or below ($HClO_4$ method)
3.	Increase of insoluble substance	–
	Pentane insoluble content (mass)%	2.0 or above
	Insoluble resin (mass) %	2.0 or above
4. Water content (volume) %		0.2 or above
5. Flash point		Below 200 °C
6. Fuel dilution (vol. %)		5.0 or above

Cautions for replacing engine oil

In used engines, you do not know what type of engine oil is previously used. So, change it to a new engine oil.

If different types of engine oil are used together, the engine oil may emulsify and produce sediments. It is important not to mix different types of engine oil.

When refilling or changing the engine oil, make sure that no other oil, dust or dirt is deposited on the container, hose, pump and funnel. Take care that no water, impurities or waste enters when refilling or replacing engine oil.

Engine oil consumption

The major cause of excessive engine oil consumption is oil blowing by the cylinder wall because of the pumping effect of the piston rings. The amount of engine oil directly leaked from the crankcase and the valve train system is insignificant and presents no problem in normal operation. The best way to control the engine oil consumption is to reduce the engine oil blow-by by supplying the minimum necessary amount of engine oil for cylinder lubrication.

Oil viscosity and engine revolution speed are factors for engine oil consumption. Studies show that the engine oil consumption increases as oil viscosity decreases and revolution speed increases. To reduce engine oil consumption, use the proper engine oil, maintain a sufficient amount of engine oil, replace it at the specified intervals, and operate the engine under the specified conditions.

Oil temperature

As the oil temperature rises, the oil film becomes thinner and hydrodynamic lubrication changes into boundary lubrication, increasing the friction loss and leading to seizure. As engine oil temperature influences engine service life, always test the temperature of the engine oil after the engine is installed in the driven machine. If the temperature of engine oil exceeds the specified limit, check the installation configuration or oil cooler equipment.

Table 11-3 Oil Temperature and engine oil replacement interval

Service classification	Allowable lubricating oil temperature	Engine oil replacement interval
CJ-4, E6, DH-2	120 °C or below	Every 250 hours

In a closed engine compartment, provide air circulation near the oil pan (2 m/sec) to limit the engine oil temperature rise. The maximum engine oil temperature limit is the maximum ambient temperature. Do not operate the engine beyond the specified maximum ambient temperature.

Oil refilling

Engine operation manuals for working machines recommend checking the engine oil level by using the dipstick. Engine oil should be refilled to the upper limit mark of the dipstick. The oil should be checked every day and refilled as needed. Do not overfill.

Engine Oil Filter System

The purpose of the engine oil filtering system is to supply clean engine oil to the moving portions of the engine while trapping impurities.

Engine Oil Suction Pipe

An engine lubricating oil suction pipe with inlet is installed between the oil pan and engine lubricating oil pump. A metallic inlet is attached to the end of the suction pipe to trap larger-sized foreign matter.

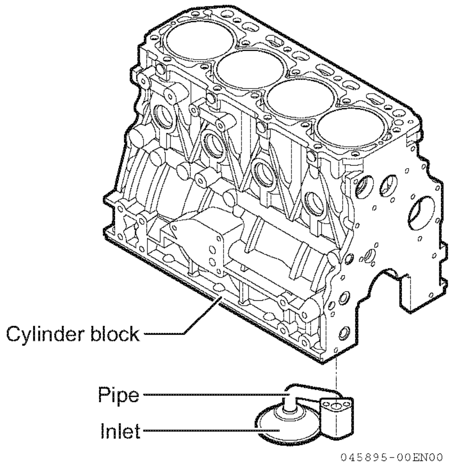

Figure 11-5

Oil Filter

The purpose of an oil filter is to prevent wear or seizure of moving engine components and to extend the engine oil replacement interval by cleaning it and preventing deterioration. Engine oil contains soot generated by combustion of fuel and engine oil, oxides, and worn metal particles. If these impurities are not removed, moving engine components will prematurely wear, moving components can become sticky, and the cooling effect of the oil is degraded. All of these accelerate bearing corrosion, rusting of metal surfaces and degradation of the engine oil. The oil filter is intended to remove these impurities. The oil filter installed on the TNV-Tier 4 series engine uses a cartridge type paper element. If the oil pressure difference between the inlet and outlet of this filter reaches 78.5 to 118 kPa (0.8 to 1.2 kg/cm^2) due to element clogging, the relief valve is activated to bypass the engine oil directly to the oil gallery to prevent engine seizure. Continuous flow of unfiltered engine oil in the engine is not good for engine life. Be sure to replace the oil and oil filter at regular intervals, based on the maintenance schedule.

Table 11-4 Oil filter installed on TNV-Tier 4 series engines

Engine model	DI	
Type	STD	Large capacity
Filtration area (cm^2)	1160	1630
YANMAR code	129150-35153	119005-35151

“STD (standard)” and “large capacity” types are available for TNV-Tier 4 series engines. A large capacity type is applied to specifications that require long-term maintenance, e.g. driven machines in very dusty environments or refrigerator specifications.

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Oil Pan

Shallow and deep oil pans are available. The deep oil pan is recommended because it can deliver good performance in an inclined position. The shallow pan is recommended when lower overall height is preferred.

Two types of drain plug mounting positions are available; a downward draining plug and sideways draining plug. The downward draining plug is recommended. The sideways plug should be used when the oil cannot be drained downward because of engine position.

Since engines are installed in various positions on the driven machine, choose an oil pan that best fits the purpose, function and structure of the machine.

For the standard specifications of the oil pan of TNV-Tier 4 engines, refer to *the YANMAR TNV Option Menu*.

Oil Pump Structure

The TNV-Tier 4 series engines use a trochoid engine oil pump. The oil pump is located in the gear case, which is driven by either the crank gear or idle gear. For more details about the structure, refer to *the TNV-Tier 4 series engine service manual*.

Inclined Performance

The TNV-Tier 4 series engine uses a wet sump lubrication system oil pan. If the engine is operated at an inclination angle that exceeds the maximum inclination angle, air gets into the engine oil suction pipe preventing engine oil circulation. Air reservoirs are generated in the engine oil system and the temperature of engine components rise, causing bearing failure.

To prevent this failure, check the engine oil level by using the dipstick when the engine is level. The maximum inclination angle refers to an angle when the oil level is at the minimum oil level mark of the dipstick.

The maximum inclination angle for the TNV-Tier 4 series engine with deep oil pan (standard) is as follows:

Engine type	DI
Continuous operation	30° for all directions
Instantaneous operation (within 3 min.)	35° for all directions

Note: The above values have been confirmed in tests using a single engine.
For the driven machine with significant movement, identify the inclination characteristics associated with the operating conditions.

Consult YANMAR if the engine must be used at an angle exceeding the maximum inclination angle.

Inclination angle during continuous operation

NOTICE

Keep the engine flat while supplying engine oil or coolant.

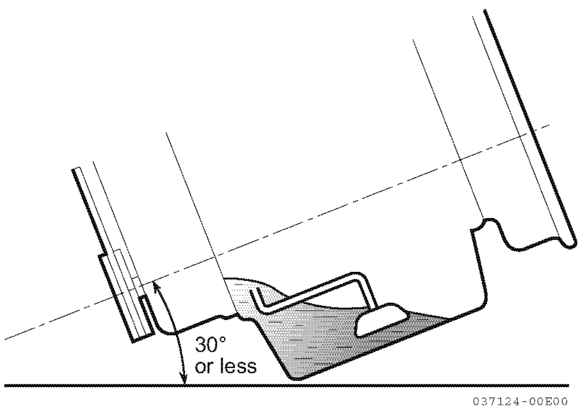

Figure 11-6

Crankcase Breather System

A fluctuation of pressure is generated in the crankcase by the reciprocating motion of the pistons. Blow-by gas escapes through the clearance between the cylinder and the piston ring and flows into the crankcase. The purpose of the breather system is to maintain normal pressure inside the crankcase. The breather system is either an intake circulation system or release system. The release system releases upward pressure fluctuation and blow-by gases into the open air through a pipe installed in the valve cover. However, emission of the blow-by gases (emissions from the crankcase) into the open air is prohibited by recent EPA and EU emission regulations. In the intake circulation system, the valve cover and intake manifold are connected by a pipe or other means to release pressure fluctuation. The breather gas in the crankcase is sucked back into the intake manifold for re-combustion.

All of the TNV-Tier 4 series engines use intake circulating systems. In a turbocharged engine, however, blow-by gas cannot be sucked into the intake manifold (after turbocharged) because the air pressure is very high. Therefore, turbocharged engines have a structure between the air cleaner and turbocharger inlet to suck back the blow-by gas. Care is required if the routing of hoses between the air cleaner and turbocharger is performed by an OEM company. Refer to *Precautions for breather system hoses on page 11-16.*

Structure of Breather System (the Intake Circulation System)

The blow-by gas enters the diaphragm assembly through a baffle plate located in the valve cover. It goes through the breather pipe to the intake manifold and then returns to the combustion chamber. The mist of engine oil mixed in the blow-by gas is removed by the action of the baffle plate chamber. Pressure inside the crankcase is regulated by the function of the diaphragm assembly and a suitable amount of blow-by gas is returned to the intake air system.

Breather system components (naturally aspirated engine)

3TNV88C, 4TNV88C, 4TNV98C engines

A system that returns the blow-by gas from the breather to the intake manifold through a pipe.

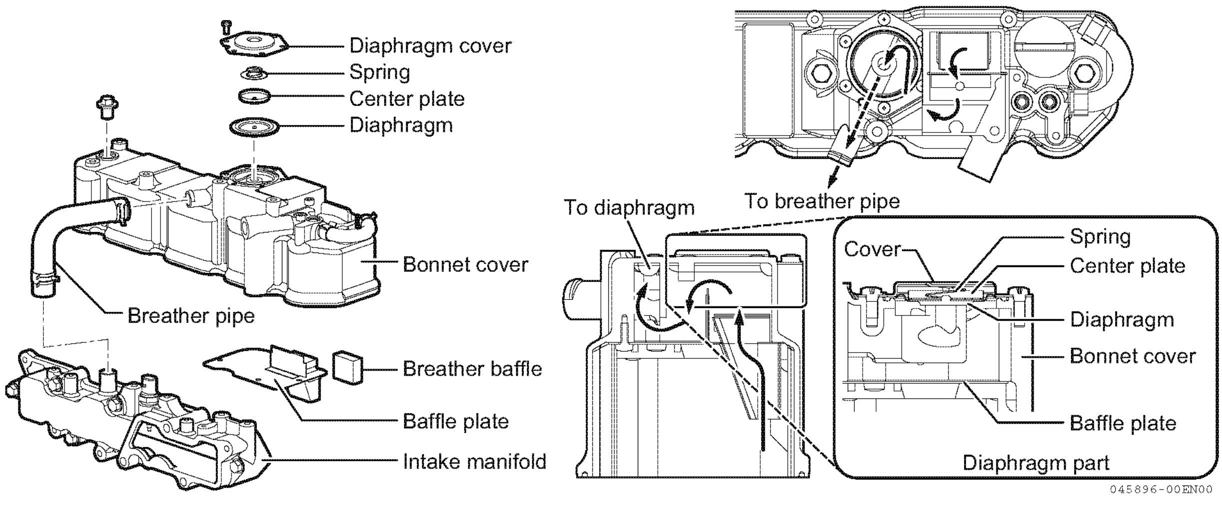

Figure 11-7

Breather system components (turbocharged engines)

3TNV86CT, 4TNV86CT, 4TNV98CT engines

A system that returns the blow-by gas from the breather before the turbocharger through a pipe. For turbocharged engines, blow-by gas must be returned before the turbocharger because the air pressure of the intake manifold side (after turbocharged) becomes very high. Please note that you need to perform the routing of the breather system hoses if you have the intake system components (including intake air hose, air cleaner) prepared by yourself. The hoses must be routed according to the following precautions:

Precautions for breather system hoses

The breather pipe and intake hoses must be made of oil resistant material

- **Recommended location of the breather system hoses**

  Route the hose from 40 mm to 300 mm immediately before the turbocharger inlet.
  It is necessary to install a new air temperature sensor to the intake hose. The sensor is required for engine control. To measure the correct intake air temperature, arrange this sensor in the same position as the breather hose or further upstream.

- **About the height difference between the bonnet and blow-by return position**

  To return oil to the bonnet, place the blow-by return position higher than the joint part of the bonnet. Any pitting of the hose will trap oil and the passage is narrowed. Fuel dilution may cause the negative pressure to increase, and lubricating oil may suddenly be sucked into the turbocharger side. Make sure that the piping is not dented.

- **About the specifications of piping components (return joint, intake air hose)**

  Provide ø18 mm outer diameter for the return joint part and an aperture inside. Do not use a return joint inside a curved pipe because the return joint will increase the negative pressure. Use intake air hoses made of materials with oil resistance.
  The following optional components are available:
  These joints have seats to install the new air temperature sensor that measures the intake air temperature.

Part name	Code No.	Aperture d	Joint diameter D	Note
Joint (breather	129A01-03050	ø3.0	ø36	For 3TNV86CT
Joint (breather	129E01-03050	ø5.5	ø46	For 4TNV98CT
Joint (breather	129978-03050	ø3.5	ø46	For 4TNV86CT

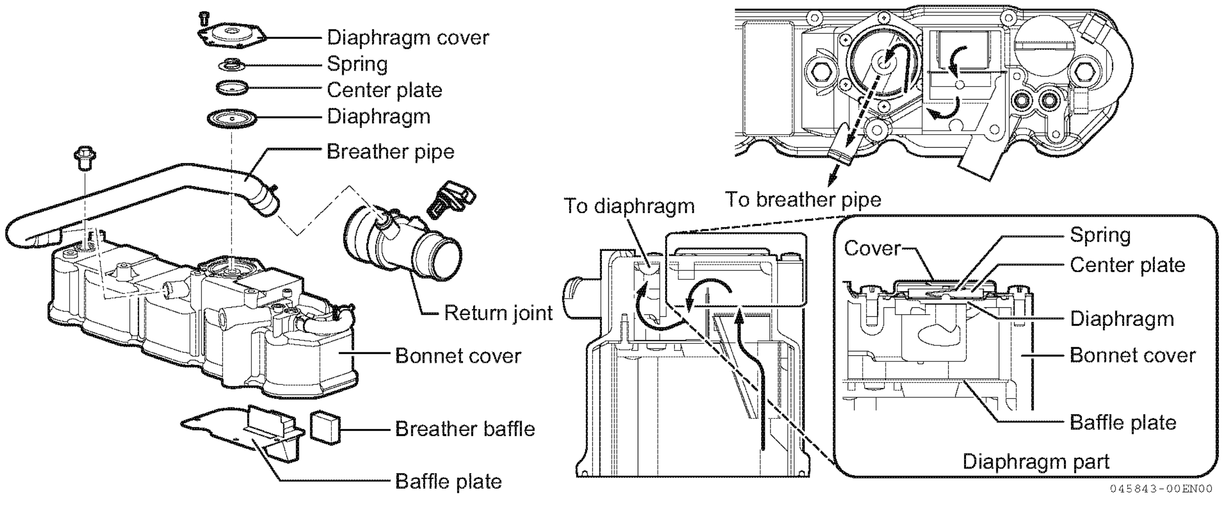

Figure 11-8

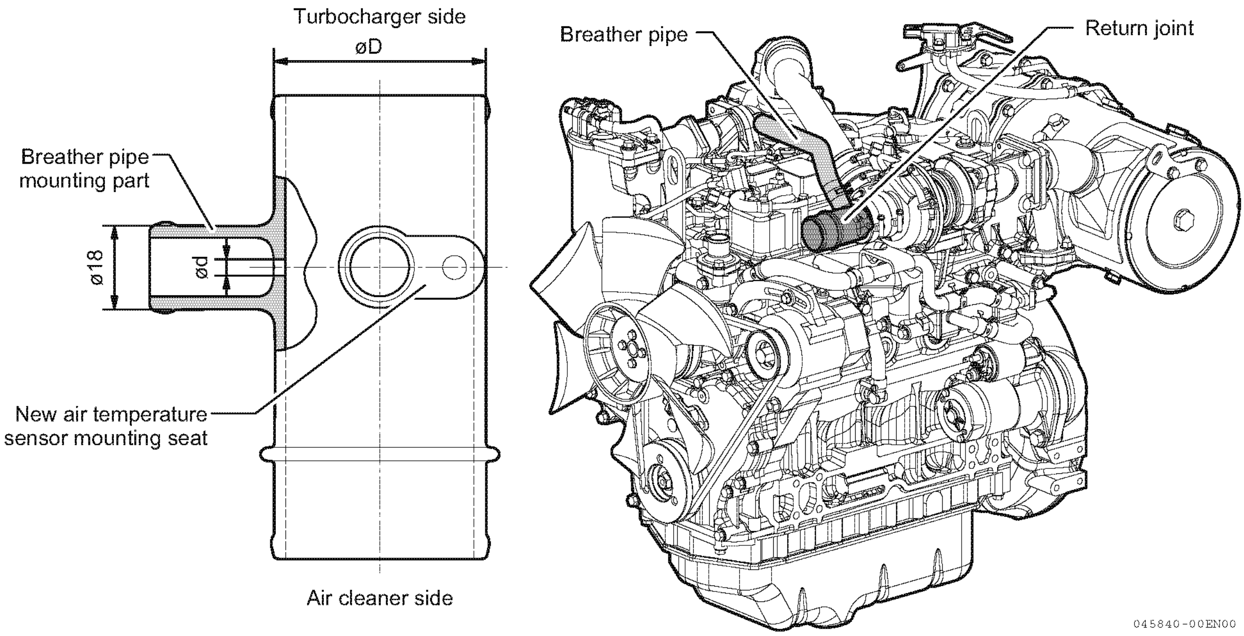

Figure 11-9

Engine Oil Pressure Switch

Decreased engine oil pressure may cause engine failure. An engine oil pressure switch is installed and used in combination with an indicator, buzzer or shutdown system to alert or prevent problems. Refer to *Application Functions on page 14-43* for details of the engine malfunction detection with the use of engine oil pressure switch.

Table 11-5 Engine oil pressure switch mounted on the TNV-Tier4 series engine

Terminal shape	Giboshi	Flat plate	M4 thread
YANMAR code No.	114250-39450	119761-39450	121252-39450
Actuation pressure of engine oil pressure switch	49.0 ± 9.8 kPa		
Contact capacity	12 V DC/0.4 A, 24 V DC/0.2 A		

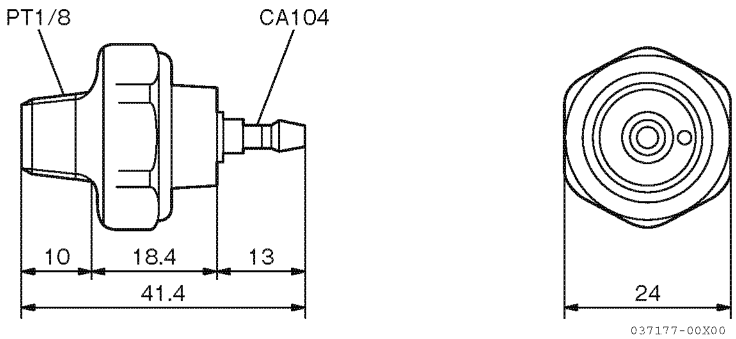

Figure 11-10

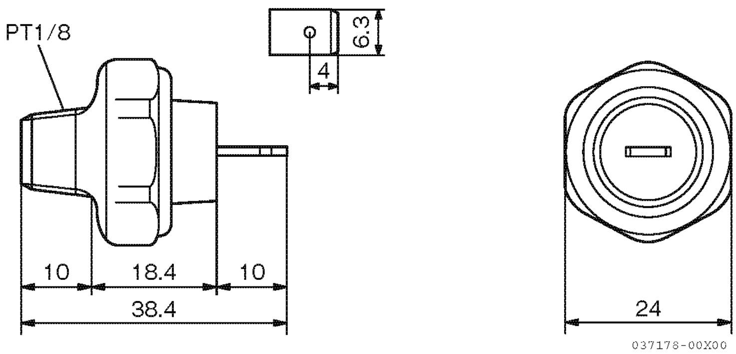

Figure 11-11

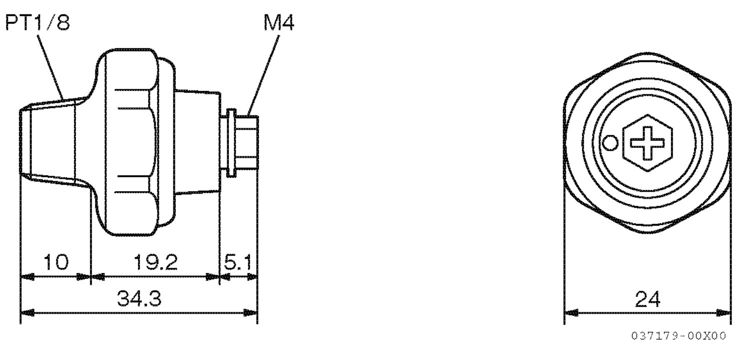

Figure 11-12

The contacts of the engine oil pressure switch are closed when no pressure is present in the engine oil system. If the key switch is turned to the ON position before engine operation, the oil indicator will light. When the oil pressure is at a high level during engine operation and the pressure switch contact is open, the indicator turns OFF.

The oil pressure switch is used to detect reduced oil pressure due to wear or inclination. The dipstick or another level control system must still be used to check the oil volume.

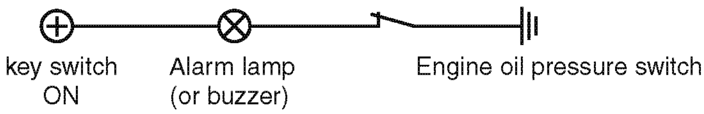

Figure 11-13 An example of wiring diagram

Engine Oil Cooler

The engine oil cooler is used on the following engines:

Naturally aspirated engines	3TNV88C (2800, 3000 min^{-1} specification), 4TNV88C (2800, 3000 min^{-1} specification), 4TNV98C (2200 - 2500 min^{-1} specification)
Turbocharged engines	3TNV86CT, 4TNV86CT, 4TNV98CT

Depending on the installation of the driven machine, the engine oil cooler can be used for engines other than the above if engine oil temperature are above the limits shown in *Application Standard on page 1-3*.

Specifications of Engine Oil Cooler

For the TNV-Tier 4 series engines, the specifications of the engine oil cooler and their applicable engine models are as shown below.

Code No.		**129508-33010**	**129908-33010**	**Remarks**
Cooler type	–	Cylinder type	Cylinder type	
Core size	mm	ø83 × 7 steps	ø93 × 11 steps	
Applicable engine models		3TNV88C (2800, 3000 min^{-1} specification), 4TNV88C (2800, 3000 min^{-1} specification), 3TNV86CT	4TNV98C (2200 - 2500 min^{-1} specification), 4TNV86CT, 4TNV98CT	All models are optional except for those shown on the left.

Structure of Engine Oil Cooler

The structure of engine oil cooler is largely divided to 2 types.

Cylindrical type

Applicable engine: 3TNV88C, 4TNV88C, 3TNV86CT, 4TNV86CT, 4TNV98C, 4TNV98CT

The cylindrical type engine oil cooler is installed between the cylinder block engine oil outlet and the engine oil filter so that the engine oil is cooled before it passes into the filter.
Engine coolant comes out of the engine block coolant jacket and goes through the coolant inlet hose that connects to the engine oil cooler. After it leaves the engine oil cooler, the engine coolant goes back to the coolant pump via the coolant discharge hose.

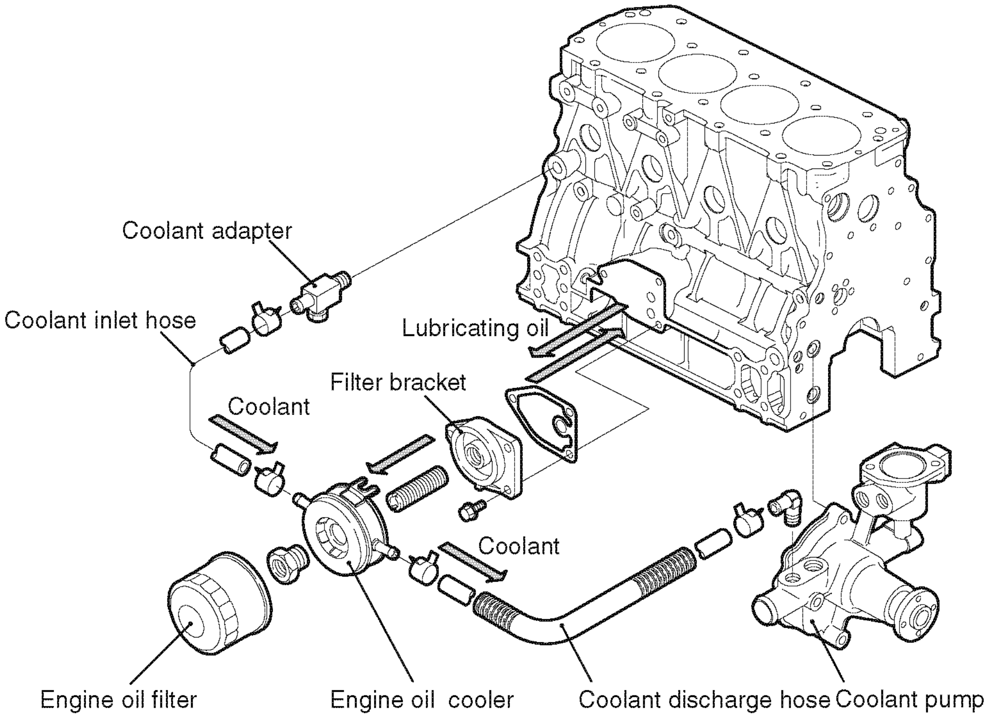

Figure 11-14

Notes on Installation of Engine Oil Cooler

When adding an engine oil cooler to an engine that does not come with one as standard equipment, check the specifications of the cooling system because the engine coolant temperature may be higher in these configurations.

Section 12

INSTALLATION TEST PROCEDURES

Page

Purpose of the Installation Test..12-3
Test Items and Evaluation Purpose 12-4
Tools Required for Tests..12-5
Engine Parts Required for Tests 12-6
Preparations before the Test...12-8
Test and Measurement Procedures...12-9

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Purpose of the Installation Test

All engine performance specifications are developed under standard atmospheric conditions. It is indispensable to confirm in advance whether an engine and its driven machine can function without problems in a given operating environment. This confirmation is achieved through the onboard-installation test. The series of tests predicts how data collected under standard atmospheric conditions changes under the operating environment of the driven machine and determines if the result would adversely influence the performance of the driven machine. This method includes suggestions for improvements to meet the functional requirements.

The installation test should be performed on the engine and the driven machine, with the cooperation of the driven machine manufacturer. Verification of reliability and durability should be conducted by the driven machine manufacturer.

The main contents of the installation test are as shown on the next page. Additional test items may depend on the specification required by OEM or installation design because these contents on next page are standard items.

Operation with the machine loaded varies by the type of the driven machine. Therefore, the following conditions are required for the installation test:

- Do the test under a load actually applied by the user.
- During the test, follow the work pattern designated by the driven machine manufacturer.
- Do the test under the maximum load capacity of the driven machine.

It is important to establish and agree on the appropriate maximum load and duty cycle. These test conditions must be submitted together with the measurement result in document as part of the engine evaluation data.

Test Items and Evaluation Purpose

Test items	Evaluation purpose
DPF regeneration test	The YANMAR Diesel Particulate Filter (DPF) is equipped with a stationary regeneration function that utilizes the parasitic load of the driven machine as a means of regeneration when the SF is clogged. This function is checked by the DPF regeneration test. If the regeneration conditions are not satisfied, it is required to attach a dummy load or other measures. For details, consult YANMAR separately.
Intake restriction and exhaust back pressure test	To make sure that an engine is mounted on the driven machine that complies with the emission standards, check the intake restriction and exhaust back pressure.
Output matching test	Check that the engine power complies with the driven machine load of the customer. Depending on the type of work load, a speed reduction due to temporary overload may occur in the test. It is necessary for the manufacturer of the driven machine and YANMAR to agree whether the workability was not influenced by that speed reduction.
Heat balance test	Check that the engine cooling capability and the heat resistance of each engine part are satisfactory. A temperature evaluation must be performed in an environment under the upper temperature limit for usage. If the result of the checking shows that the standard is not satisfied, improve the radiator capacity and handling of the cooling wind in order to meet the required coolability and heat resistance at the upper temperature limit for usage.
Fuel temperature test	Check that the heat resistance of the fuel system is satisfactory. If the standard is not met, it is required to install the fuel cooler.
Vibration test	Check that the mechanical strength is kept under the usage conditions of the driven machine. If the standard is not met, improvement is required.
Low temperature startability test	Check that the starting capability is maintained in an environment of the lower temperature limit of usage. To improve the startability, measures such as the modification of the electric capacity and selection of the appropriate fuel are required.
Installation state check	Check the installation state of each engine part and electronic control part and check that there are no performance, durability and maintenance problems. Also, it is required to check that all lamps and switches related to the DPF regeneration control are correctly functioning and the end users can easily see and operate them.
The function of electric control application	Confirm the match between electrical control application menu and operator IO designed by OEM. In case of mismatch, need to modify application menu or operator IO designed by OEM.
Additional test	Yanmar may offer additional test plan to understand the engine function properly. Yanmar may add any requirements based on regulations.

For criteria of the above test results and installation state check sheet, check the separate installation evaluation sheets.

Tools Required for Tests

	Measuring instrument	Main usage and tool selection summary
1	Dry- and wet-bulb thermometer	This thermometer measures the outside temperature and relative humidity as the environmental condition when tests including output matching, heat balance, and DPF regeneration are performed. Take the measurement in a shaded, well-ventilated area that is not influenced by the temperature of the tested driven machine.
2	Speed sensor	• When performing an evaluation and analysis based on speed such as the vibration test (resonance search). • When measuring the speed in the low speed range such as low temperature startability. Install the speed sensor and record the speed. YANMAR engines can be equipped with a magnetic pulse tachometer on the fuel filler port of the gear case to measure the speed (gear pulse). 60 pulses or more per revolution is the standard for the low temperature startability test. Speed measurement from the alternator P terminal cannot be used for the purpose of analysis. When performing other operation tests, the speed can be measured by the SA-D and CAN logger from the ECU.
3	Thermocouple	This is used in the heat balance test. Generally, the K-type thermocouple is used. The T-type thermocouple is used to improve the measurement accuracy of the cooling water temperature. The cooling water temperature, fuel temperature (in the supply pump), and intake temperature (new air temperature sensor) can be measured from the ECU.
4	Vibration acceleration sensor	This sensor is used in the vibration test. It is a small-sized, three-axis sensor. Use adhesive to install the sensor. When the vibration meter is used to measure the engine feet, be sure to use a tool that complies with ISO 2954 “Mechanical vibration of rotating and reciprocating machinery” or JIS B0907 “Mechanical vibration of rotating and reciprocating machinery”.
5	Manometer	This measures the intake restriction and exhaust back pressure. The chamber is recommended to reduce the pulsation of air or gas if electrical sensor is used.
6	Data logger	Prepare the data logger for the analog sensor, and the SA-D and CAN data logger for ECU data. During the vibration test and low temperature startability test (for the analog sensor), high-speed sampling of data is required. Use a CAN logger that can switch the verification function for the Acknowledge Slot normal reception on and off. (For details, contact the CAN logger manufacturer.)
7	Digital camera	This camera is used to record images of the engine installation condition. Provide the following images: • Images of the whole engine from the front, sides and diagonally. • Images from the driven machine to confirm maintenance. • Images of the parts connecting the driven machine including the fuel, intake/ exhaust, and lubricating oil drain. Also, provide as many images of the driven machine as possible.
8	Milli-ohm tester	This equipment is used to measure the resistance between E-ECU and battery.

Engine Parts Required for Tests

Fully-opened thermostat

This is used in the heat balance test.
Using this part is mandatory when the engine coolant outlet port temperature is predicted to be under 85 °C (185 °F).
There is no need to use a fully-opened thermostat if the driven machine is tested at an environment at the upper temperature limit for usage in a high constant temperature chamber.

Gasket for thermostat

This is used for repairs after replacement of the fully-opened thermostat that is used in the heat balance test.
Prepare two sets (for measurement and replacement) to repair possible breakage during the test.

Part	Engine model	3TNV88C 3TNV86CT	4TNV88C 4TNV86CT	4TNV98C 4TNV98CT
Fully-opened thermostat		129155-92100		529938-49830
Gasket				
Cooling water pump (Low position)	For thermostat cover	129795-49551		121850-49540
	For thermostat body	129150-49811		121850-49550
Cooling water pump (High position)	For thermostat cover	129795-49551		129900-49560
	For thermostat body	129150-49811		121850-49550

Speed sensor installation part

This installation jig is used when the speed sensor (magnetic pulse type: M12 × 1 mm pitch) is used on the fuel filler port of the gear case.
The central axis of the fuel filler port of the gear case is slightly misaligned from the center of the supply pump gear.
When adjusting the sensor gear to the appropriate clearance, comply with the handling instructions of the sensor manufacturer.

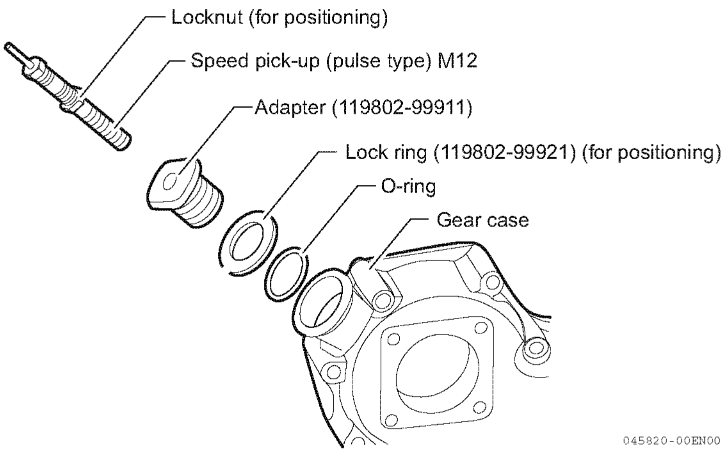

Figure 12-1 Speed measurement with the use of supply pump gear

The speed ratio between the supply pump gear teeth numbers and the crankshaft is shown below.

	3TNV88C 3TNV86CT	4TNV88C 4TNV86CT	4TNV98C 4TNV98CT
Supply pump gear teeth	28	28	32
Speed ratio Crankshaft: pump gear	1 : 1	1 : 1	1 : 1

Check Harness (129A00-91080)

This is the harness to measure the resistance between E-ECU and battery, is available to confirm the IO of E-ECU. The harness can be inserted between a pair of E-ECU connectors.

Chamber

The chamber is recommended to reduce the pulsation of air or gas if electrical sensor is used.

The measurement configuration is as below.

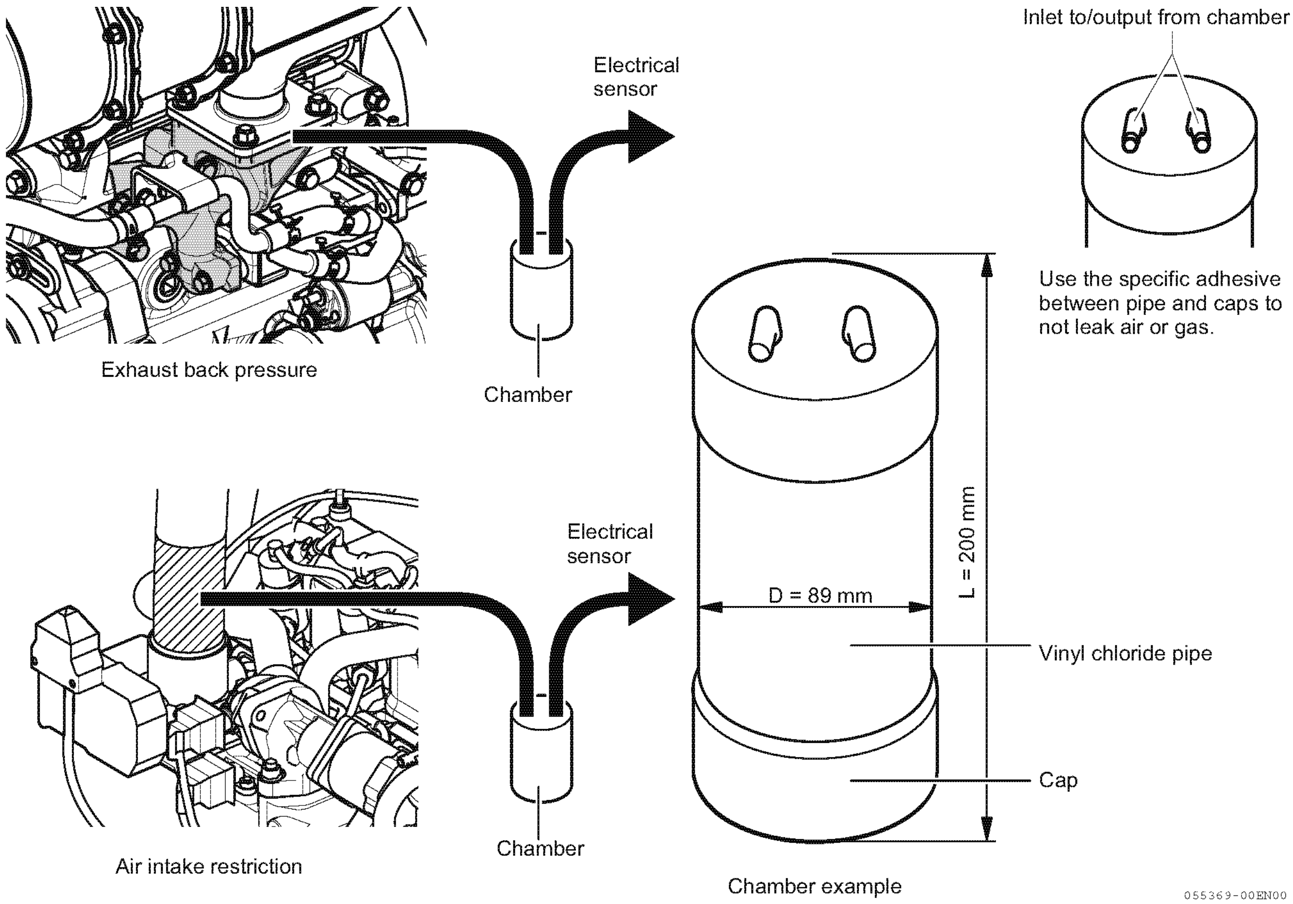

Figure 12-2 Piping configuration for air intake restriction and exhaust back pressure

Preparations before the Test

This section describes in the following the preparations common for all tests. Care must be taken for the following points before starting the engine:

1. Inspect the engine oil level.
2. Check the engine cooling water level.
3. Check that the test equipment is not in contact with any rotating part.
4. The exhaust parts become hot. Make sure that safety in regard of high temperatures is assured.
5. The fuel tank must be installed on the driven machine. When a fuel tank is used that is installed on the top of the testing room, the head pressure may become high and fuel leaks may occur. Take decompression measures to prevent the head pressure from increasing.
6. To connect the measuring instrument to the fuel system, take care to prevent the intrusion of foreign matter. Also, do not apply cleaning fluids inside the fuel hose. Use diesel fuel for testing.
7. Warm up the engine before starting the test. Perform the warm-up operation with an engine cooling water temperature of 60 °C or more. While the machine is warming up, check for oil, water, or fuel leaks from the thermocouple mounting or other areas of the engine.
8. Check that the speed can be set to the specified high idle and low idle during the engine operation.
9. It is required to prevent the automatic transition from the normal operation to the reset regeneration (every 100 hours or less) during the heat balance test. Before reaching 100 hours of operation, perform the stationary regeneration to prevent the automatic transition during the test. Here, the stationary regeneration is conducted every 50 hours or more.

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Test and Measurement Procedures

DPF regeneration test

Test method outline

- Stationary test
- Manual operation by using regeneration require SW

Preparation

- 50 hours pass after prior reset or stationary regeneration mode
- Coolant ≥ 60 °C

Measurement items

For evaluation

- Engine speed (SA-D)
- DPF inside temp. (SA-D)
- In case of remote DPF, add DPF inlet temp. and exhaust manifold outlet temp.

For confirmation of test condition

- Load rate (SA-D)
- In case of remote DPF, add mid. point temp. between DPF and exhaust manifold, surface temp. of exhaust pipe

Engine operating requirement

- Set low idle speed
- Set stationary regeneration mode manually
- Confirm visibility of regeneration lamp
- Confirm to both complete by time-limit function 30 min and interrupt by using regeneration require SW again

Measurement procedure image

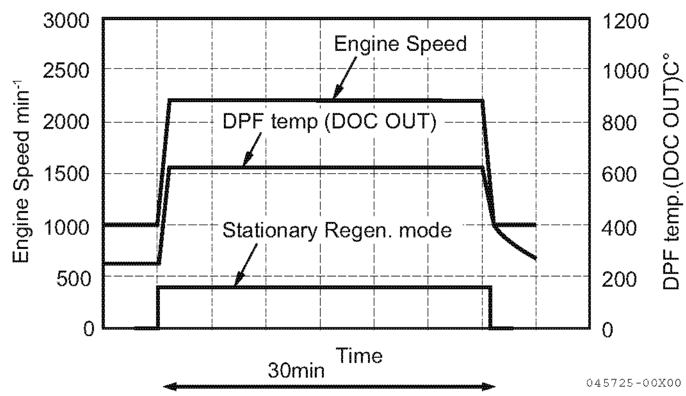

Figure 12-3 Stationary regeneration test procedures

Air intake restriction, exhaust back pressure test

Test outline

- Install production configuration
- Confirmation of air intake restriction, exhaust back pressure, difference pressure between them

Preparation

- Confirm that maximum load rate works are available on the vehicle
- Coolant temp. ≥ 60 °C to warm-up

Measurement items

For evaluation

- Air intake restriction
- Exhaust back pressure
- Engine speed (SA-D)
- Load rate (SA-D)
- Actual EGR valve position (SA-D)

For confirmation of test condition

- Coolant temp. (SA-D)

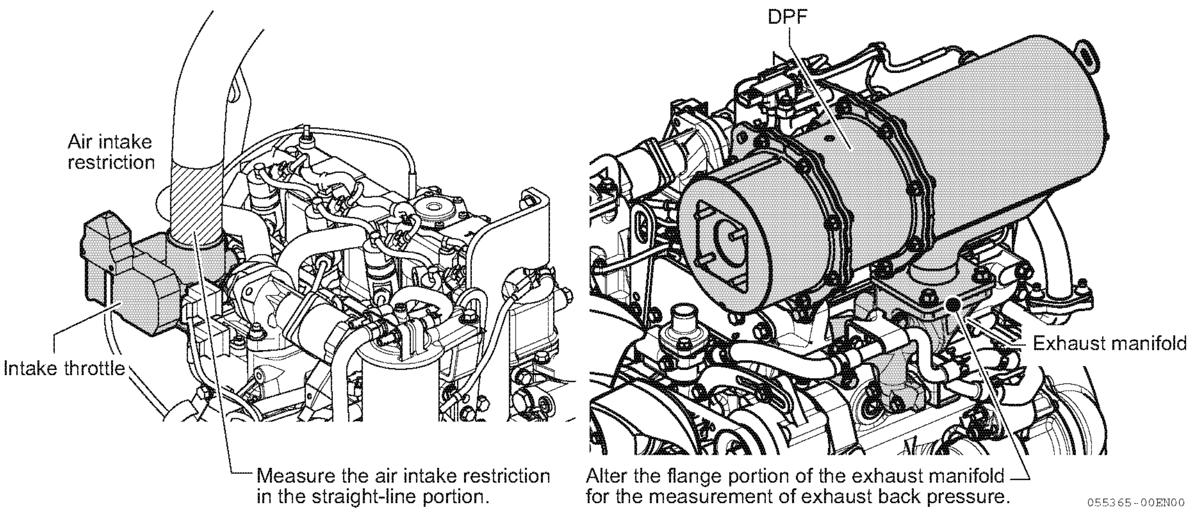

Figure 12-4 Measurement points for intake/exhaust pressure (without the turbocharger)

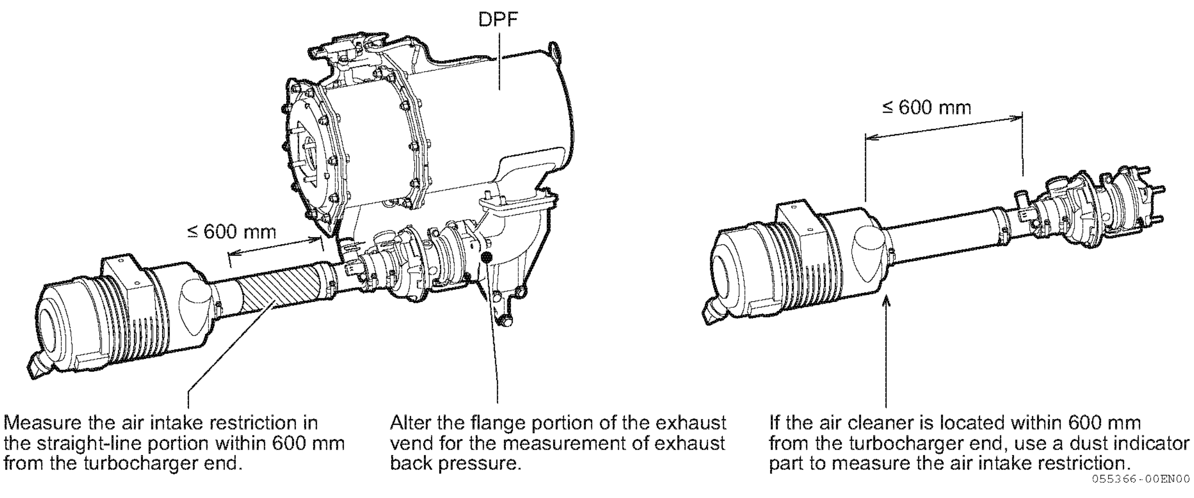

Figure 12-5 Measurement points for intake/exhaust pressure (with the turbocharger)

Recording requirement

- Raise coolant temp. ≥ 60 °C
- Set rated power or maximum load from hi-idle
- Close EGR valve position (by SA-D)
- Evaluate averaged data
- If engine speed changed drastically by work pattern, average data around rated speed
- If rated power does not load, please send data of pressure, load rate, engine speed to YANMAR for convert

Output performance test

Test outline

- Maximum output or maximum load rate work
- Confirm load rate in all engine speed range by changing the engine speed request
- Apply all PTO devices and maximum load at the test
- Install air clearer and exhaust tail pipe for production type
- Confirm engine output against work load
- In case of uncontrollable high load works, confirm acceptable engine speed down or not (e.g digging, mowing, ...)

Preparation

- Confirm that maximum load rate works are available on the vehicle
- Coolant temp. ≥ 60 °C to warm-up

Measurement items

For evaluation

- Engine speed (SA-D)
- Load rate (SA-D)

For confirmation of test condition

- Coolant temp. (SA-D)
- Fresh air temp. (SA-D)
- Fuel temp. (SA-D)
- Ambient temp.
- Barometric pressure (SA-D)

Recording requirement

- Record data during loading after setting high-idle engine speed
- Evaluate averaged load rate at maximum load

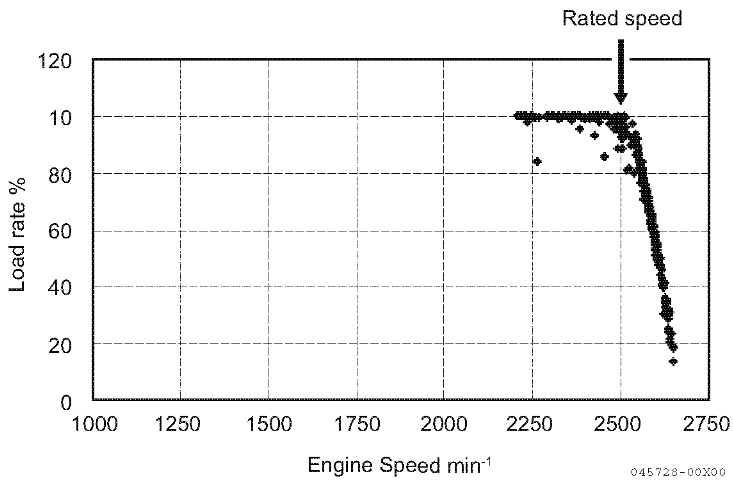

Figure 12-6 Output matching test measurement example

Evaluation of output performance

In case of engine working between high idle engine speed and rated speed as usual:

If ambient temperature is over expected highest ambient, engine works under overload condition and engine speed will down below rated speed.

If engine works under overload condition as usual, it is necessary to reduce the load.

If engine works under overload condition transiently, it is necessary to agree between OEM and YANMAR that engine speed down is not problem for work pattern.

In case of engine working below rated engine speed as usual:

Please confirm to be allowable engine speed down or not for working if the engine works over expected highest ambient.

It is necessary to agree between OEM and YANMAR that engine speed down is not problem for work pattern.

If maximum load was NOT applied:

Confirm that engine output performance is satisfied by design estimation (e.g. HVAC Compressor).

Cooling performance and heat resistance evaluation

Test outline

- Maximum output or maximum load rate work
- Evaluate at expected highest ambient, or 40 °C (correct data when tested at lower ambient)
- Conduct both normal and reset regeneration mode
- After temp. are saturated, heat soak test is needed
- If engine oil cooler effect need to be evaluated, conduct test both w/ and w/o the cooler
- If fuel cooler effect need to be evaluated, conduct test both w/ and w/o the cooler
- If special worst case test (ex. blocking radiator w/dust) can be planned, conduct it as well

Preparation

- Radiator open pressure 88 kPa
- If coolant temp. at engine outlet is below 85 °C, full open thermostat is needed
  If the tests are performed at upper limited usable temperature, standard thermostat is available

Measurement items

For evaluation

- Ambient temp.
- Coolant temp.
- Engine oil temp.
- Alternator
- Starter
- ECU
- See other sheet for temp. measurement points for electrical devices

For confirmation of test condition

- Engine speed (SA-D)
- Load rate (SA-D)

Engine operating requirement

- Single and continuous maximum output or load rate work

Recording requirement

- Record continuously until all temp. are saturated. (for 30 - 50 minutes)
- Saturation means below 1 °C/10 min of temp. variation
- Sampling rate ≤ 1 s.
- Please see the figure that engine works under normal mode, reset mode and heat soak continuously

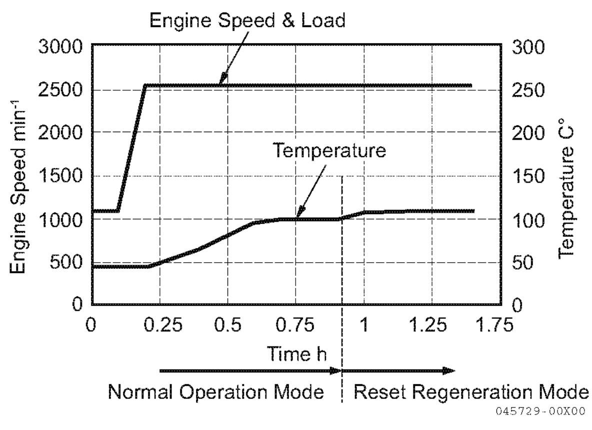

Figure 12-7 Heat balance test method (including the reset regeneration operation)

Conversion method from the atmospheric temperature during the test

Example of cooling water temperature

- The temperature obtained in the test is as follows:

T_a	:	Atmospheric temperature	19 °C
T_w	:	Coolant engine outlet port temperature	87 °C
T_{mw}	:	Allowable maximum temperature of coolant	105 °C (usage of 88 kPa radiator cap)
T_{cw}	:	Coolant use limit atmospheric temperature	

- Coolant use limit atmospheric temperature estimation T_{cw}

$$T_{cw} = (T_{mw} - T_w) + T_a = (105 - 87) + 19 = 37\ °C$$

- Estimation in an environment under the upper temperature limit of usage (if the upper temperature limit of usage is 40 °C)

$$T_w \text{ (reduced temperature: 40 °C)} = (40 - 19) + 87 = 108\ °C$$

Hence, it exceeds the standard value by 3 °C.

To do this, improve the air flow by changing the shape of the engine compartment, the fan speed, radiator capacity, and conduct the heat balance test again.

Example of lubricating oil temperature

- The temperature obtained in the test is as follows:

T_a	:	Atmospheric temperature	19 °C
T_o	:	Engine lubricating oil temperature	111 °C
T_{mo}	:	Allowable maximum engine lubricating oil temperature	120 °C
T_{co}	:	Engine lubricating oil use limit atmospheric temperature	

- Engine lubricating oil use limit atmospheric temperature estimation T_{co}

$$T_{co} = (T_{mo} - T_o) / 0.8 + T_a = (120 - 111) / 0.8 + 19 = 30.3\ °C$$

- Estimation in an environment under the upper temperature limit of usage (if the upper temperature limit of usage is 40 °C)

$$T_w \text{ (reduced temperature: 40 °C)} = (40 - 19) \times 0.8 + 111 = 127.8\ °C$$

Hence, it exceeds the standard value by 7.8 °C.

To do this, improve the air flow around the oil pan by changing the shape of the engine compartment or install an engine lubricating oil cooler. Evaluation and measurement of this should be done at the same time as the coolant temperature evaluation.

Fuel temp. test

Test outline

- Install fuel tank at the position of production type
- Lower fuel level of tank
- Conduct measurement in the cooling performance test
- Evaluate at expected highest ambient, or 40 °C (correct data when tested at lower ambient)

Preparation

- Avoid the air in the fuel line
- Avoid the dust, in the fuel tank

Measurement items

For evaluation

- Fuel temp. (at 100 mm in front of fuel pump)
- Ambient temp.

Evaluate after correcting temp data to them at expected highest ambient, or 40 °C.

For confirmation of test condition

- Fuel temp. (SA-D)
- Engine speed (SA-D)
- Load rate (SA-D)
- Check the fuel level in the tank

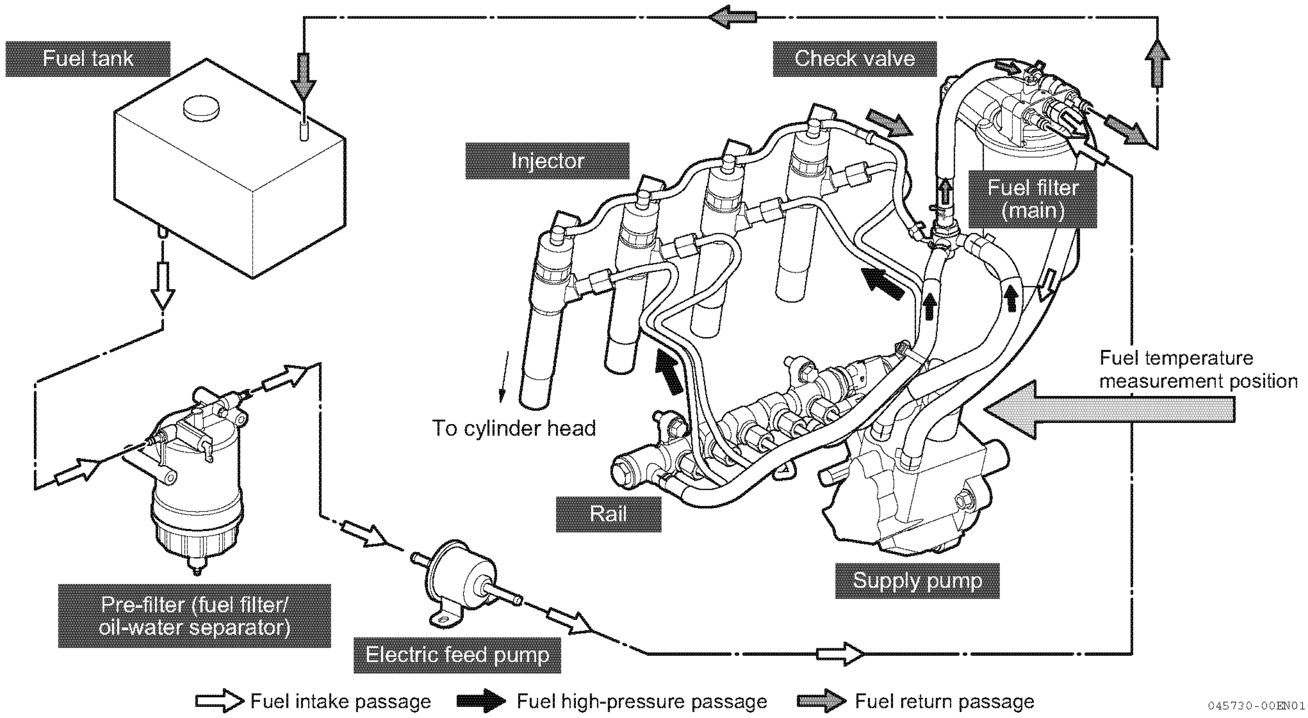

Figure 12-8 Fuel temperature measurement position

Recording requirement

- Sampling rate ≤ 1 s.
- Evaluate under expected maximum ambient same as coolant

Structure strength test

Test outline

- Sweep test of engine speed (from engine start to stop) w/o load
- Confirm resonance speed from LI to HI at all of the points by stationary test
- Load test at resonance engine speed and rated speed w/maximum output by stationary test

Preparation

- Before test, avoid the unexpectable contact the parts or harshness by vibration
- Use shock-proof material around the recording device under the structure severity test

Measurement items

- Engine speed data (output FV converter)

Note: If raw gear teeth data are record to logger, see recording requirement for sampling rate.

Measure acceleration at following points by tri-axis accelerometer.

- Engine foot
- DPF (exhaust inlet side)
- DPF (exhaust outlet side)
- DPF differential pressure sensor (in case of installing on the vehicle)

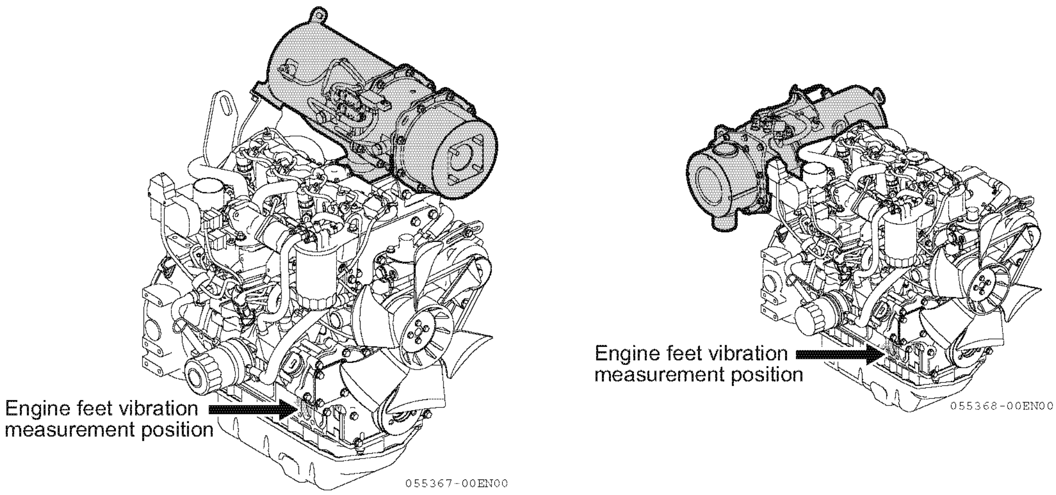

Figure 12-9 Vibration measurement points

Engine operating requirement

Recording requirement

- The strain data should be recorded with vibration data simultaneously
- Sampling rate ≥ 2 kHz and set the half of frequency the cut-off low pass filter as aliasing filter

If raw gear teeth data are record to logger, set sampling rate ≥ 5 kHz

Sweep test of engine speed

- Record data from before engine start to after engine stop
- Sweep time target is approx. 2 minutes/2000 min^{-1}
  Need to vary speed smoothly
- If recording memory is insufficient, divide sweep range

Stationary test w/maximum load or w/load at resonance speed

- Select resonance speed according to sweep test
  If multiple resonance speeds appear, select multiple speeds
- Recording time is approx. 30 sec. w/stable condition

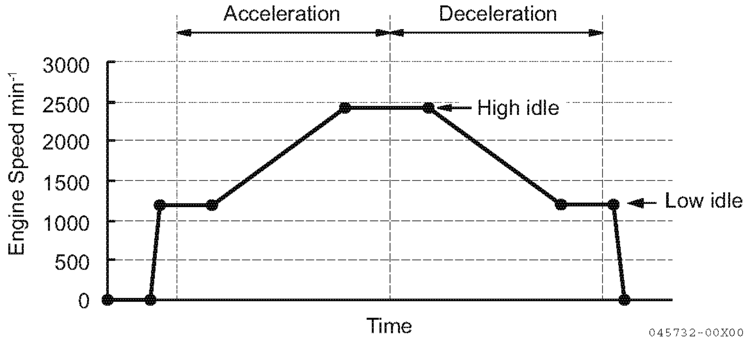

Figure 12-10 Operation method at the vibration test (rotation sweep test)

Analysis method

- The evaluation of DPF vibration needs frequency analysis. Please contact YANMAR for detail.
- Additional structure strength evaluation depend on the specifications required by OEM, the configuration of parts, the mount by using open thread, PTO configuration, etc..
- YANMAR and OEM need to make the plan for these evaluations in early stage.

ECU vibration test

Test outline

- Running test w/o no load is requested to evaluate power spectrum density of ECU vibration
- Vehicle speed should be varied smoothly up to maximum speed
- Running test is requested on a smooth track with typical tire configuration
- Stationary engine speed sweep test can be substitute running test, if engine mounted rigidly on vehicle

Preparation

- Before test, avoid the unexpectable contact the parts or harshness by vibration
- Use shock-proof material around the recording device under the structure severity test

Measurement items

For evaluation

- ECU

For confirmation of test condition

- Chassis mounted ECU
- Engine foot

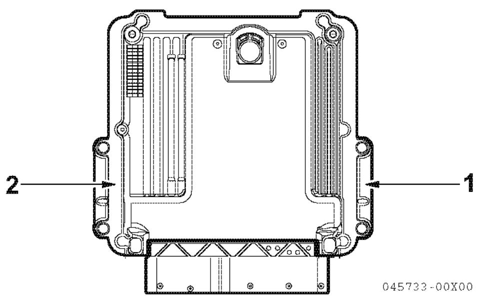

Figure 12-11 ECU vibration measurement points

Recording requirement

- Sampling rate should be selected one of 4096 Hz, 4800 Hz, 5000 Hz
- Recording time is approx. 10 sec.
- If vehicle speed is controlled by transmission, engine speed set high idle
- Or if vehicle speed is corresponded with engine speed, engine speed should be varied
- Vehicle speed should be varied smoothly from stop condition up to maximum speed and then varied to zero speed
- Acceleration and deceleration time are depend on running mode of each machinery

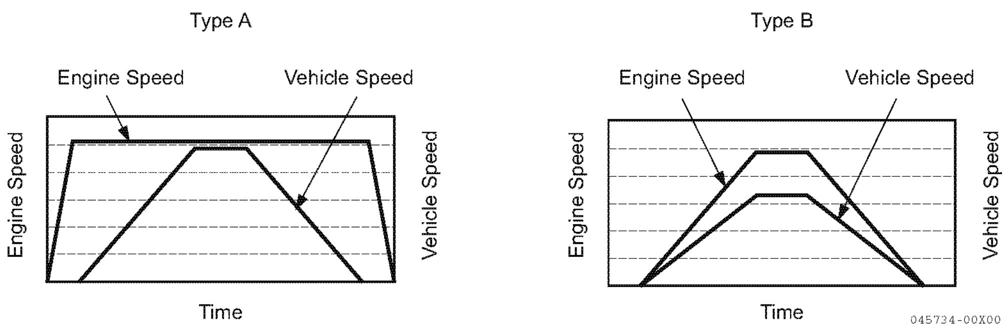

Figure 12-12 Travel pattern when measuring the ECU vibration

Analysis method

- For analysis method of PSD, please contact YANMAR
- The evaluation of ECU vibration needs PSD analysis. Please contact YANMAR for detail.

Cold ambient characteristic test

Test outline

- Evaluate at expected lowest ambient
- Evaluate at battery charging ratio OEM specify
- Use fuel suited at low temperature (recommend)

Preparation

- Confirmation battery charge rate
- Confirmation of nothing to loose condition for ground cable and connecter
- Confirmation of that over 100 min^{-1} of engine speed is measurable

Measurement items

For evaluation

- Engine speed (gear teeth needs for low speed)
- ECU voltage

For confirmation of test condition

- Battery voltage
- Glow voltage
- Starter voltage
- Starter current
- LO line pressure

Recording requirement

- Starter ON after pre-heat 15 sec.
- Use gear tooth to measure engine speed
- Sampling rate 0.2 ms - 0.5 ms to confirm ECU voltage drop

The function of electric control application

Test outline

- Confirm the matching between electrical control application menu and operator I/O designed by OEM

Preparation

- Perform the test with key SW ON but NOT starting engine
- Perform the test by using Harness and Interface as same as mass production type

Measurement items

- Input data to ECU by using SA-D
- Harness resistance between E-ECU and battery (by using Yanmar checker harness and milli-ohm tester)

Recording requirement

- Connect SA-D to E-ECU
- Confirm the input data to ECU operating the IO for E-ECU individually

The evaluation items depend on Engine control function by OEM's requirement.
Please ask YANMAR the detail of check procedure.

Section 13

ELECTRICAL SYSTEM

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The battery and alternator supply power to the engine starting/stopping system and other electrical components such as the control panel indicators. Twelve (12) V is the nominal voltage for TNV series engine electrical components.

Consult YANMAR before deviating from the wiring diagrams provided.

Precautions for Using Electrical Components

When designing a driven machine application, consider the following precautions for use of electrical components. The driven machine user should also be aware of these precautions.

Starter Motor

(Refer to *Starter Motor on page 13-6.*)

Use a battery with appropriate capacity for the starter motor

Engine starting performance is affected by battery capacity. Battery capacity varies with ambient temperature and driven machine application. To determine battery capacity, the driven machine manufacturer should identify these applications, consult with YANMAR, and test the machine. (Refer to *Battery on page 13-22.*)

Use battery cables with appropriate capacity for the load

Overall battery cable resistance between the starter motor and battery should be equal to or less than the value specified in the wiring diagram. If the overall wiring resistance exceeds the specified value, the starter motor may malfunction. (Refer to *Battery Cable Selection on page 13-28.*)

Use starter motor cables with appropriate capacity for the load

The overall wiring resistance between the starter motor, key switch and power relay should be equal to or less than the value specified in the wiring diagram. The engine may be difficult to start if the overall wiring resistance exceeds the specified value. This may also melt the contact point of the starter solenoid and burn the armature coil. (Refer to *Starter Solenoid Cable Selection on page 13-30.*)

Use fuse with appropriate capacity for the load

If you use a fuse with inappropriate capacity, it may frequently cause the fuse to blow or the wiring harness to disconnect. Refer to the *standard wiring diagram* for the fuse circuit design.

Safety relay

In engines that have a CR installed, connecting the E-ECU with the starter relay acts as a safety relay. For that reason, a safety relay is not required. (Refer to *Starter Motor Restraint Control on page 14-70.*)

Never use the starter motor to air-bleed the fuel system

Using the starter motor for air-bleeding the fuel system may burn the magnetic switch coil. Perform air-bleeding with an electric fuel pump in accordance with the *TNV Operation Manual.*

NOTICE

Instruct the driven machine user to perform fuel system air-bleeding in accordance with the *TNV Operation Manual.*

Protect the starter motor from water

The starter motor is protected from general rainfall and water splashes (level R2 conforming to JIS D 0203). Never submerge the unit in water and avoid direct high pressure cleaning.

NOTICE

Instruct the driven machine user not to submerge the unit in water and to avoid direct high pressure cleaning.

Be careful of operation in high temperature

The starter motor is resistant to a maximum ambient temperature of 80 °C or maximum surface temperature if 100 °C. If the starter motor is placed near hot components, such the exhaust system, an insulator (shield) should be placed between them.

Be careful of corrosive gas

Be sure to make a vent opening on the clutch case of a driven machine that uses a dry clutch. The ammonia gas produced by the friction of the clutch may cause corrosion of the magnetic switch contacts.

Charging System

(Refer to *Charging System on page 13-19.*)

In engines that have a CR installed, use an alternator with built-in regulator.

Consult YANMAR before using the L-line

Consult the YANMAR development division before connecting an electrical load or electrical signal from the L-terminal of the alternator to the built-in regulator. Manufacturers of the alternator with a built-in regulator do not control the rising output characteristic from the L-terminal, so we cannot guarantee stability and accuracy. YANMAR does not warrant failure of electrical components when the output from the L-terminal is used.

Be careful with battery indicator operation

The battery indicator does not verify that the battery is charging but verifies normal function of the alternator with a built-in regulator. The charging system still functions normally even if the battery indicator is not used.

When an LED is used as the battery indicator, it may be light faintly during normal operation. This is the effect of the battery indicator controlling circuit and is not abnormal. (Refer to *Control of Battery Indicator on page 13-21*)

NOTICE

Instruct the driven machine user not to be confused by the operation of the battery indicator.

Be sure to use the specified V-belt

Using a V-belt other than the one specified may cause defective charging and shorten the service life of the component.

NOTICE

Instruct the driven machine user to use the specified V-belt.

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Protect the alternator with a built-in regulator from water

Place the alternator with a built-in regulator in a dry place. Never submerge it in water or clean it by using high pressure water, which can cause water to enter the brush area and lead to defective charging.

NOTICE

Instruct the driven machine user not to submerge the alternator with a built-in regulator and to avoid direct high pressure cleaning.

Never expose the alternator directly to chemicals

Chemicals such as fertilizer, salt, pesticides, and herbicides (especially those with sulfur content) attach to the IC regulator and may corrode the board, possibly leading to overcharging (boiling of electrolyte) or defective charging.

P-terminal

An alternator with a P-terminal is an available option for detecting engine speed. The P-terminal can be used only for pulse signals and the current load cannot be taken from the terminal.

Be careful when operating at high temperatures

The alternator with a built-in regulator is resistant to a maximum ambient temperature of 80 °C. If the alternator with a built-in regulator is placed near hot components such as the exhaust system, an insulator (shield) should be placed between them.

Never disconnect the battery cable during engine operation

Disconnecting the battery cable or removing the battery during engine operation may cause the alternator with built-in regulator to malfunction, creating high voltage. This can destroy the alternator with a built-in regulator and other electrical components.

NOTICE

Instruct the driven machine user not to disconnect the battery cable or remove the battery while the engine is running.

Never reverse the battery cable connections

Reverse connection of the positive and negative leads of the battery cable will destroy the SCR diode of the alternator with a built-in regulator. To prevent this, design the driven machine by determining the lengths of cables or using a structure that makes it impossible to reverse the connections of the battery cables.

NOTICE

Instruct the driven machine user not to reverse the battery cable connections.

Starter Motor

Although the starter motor is used only to start the engine, its operating environment and installation must be considered to make the most of its performance.

Outline and Precautions

Starter motor types

Various mechanisms are used to smoothly engage and disengage the starter motor pinion from the flywheel ring gear. A conventional magnetic engaging starter motor is used on the TNV series engines. With this type of starter motor the pinion is pushed by the solenoid force via the drive lever for engagement with the flywheel ring gear.

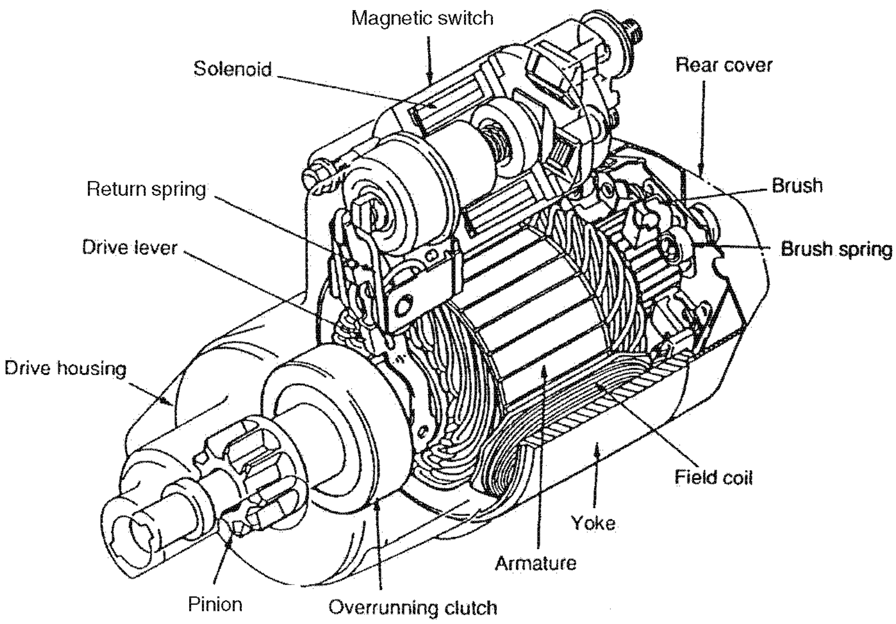

Figure 13-1 Structure of conventional type starting motor

The conventional starter motor **(Figure 13-1)** has a pinion and armature shaft that is coaxial. A reduction starter motor has a pinion and armature shaft that is not coaxial. Both of these are available. The reduction starter motor has a small high-speed motor that rotates the pinion by reducing the armature revolving speed to 1/3 to 1/4. This is smaller in size than the standard starter motor with the same output. An example is shown in the next illustration.

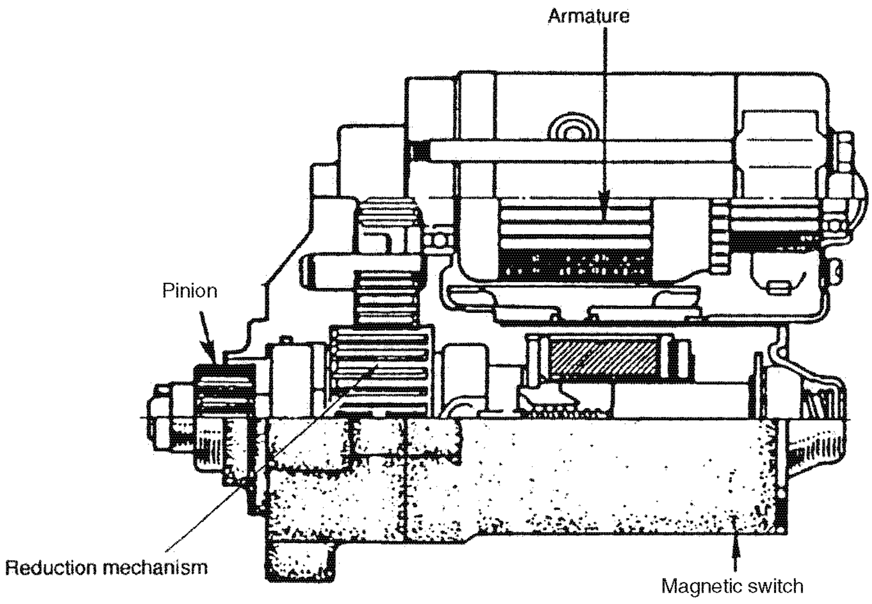

Figure 13-2 Structure of gear reduction starter motor

Starter motor selection

The objective of the starter motor is to crank the engine. Starter motor capacity varies with engine size and the required starting torque for the driven machine. As the required starting torque varies greatly with the temperature, the starter motor capacity must be selected to satisfy all conditions. The standard starter motor and engine combinations are as shown in *Low-temperature Startability on page 1-7* but it is necessary to check the connected load state when determining which starter motor to use.

Precautions for use

Wiring

Starter motor output depends not only on battery capacity but also on wiring resistance. When the wiring resistance between the key switch and magnetic switch is great, defective pinion engagement may occur. The starter motor cable must have a resistance no greater than 0.05 Ω. Since the starter motor requires a large amount of current, sufficient starter motor performance cannot be obtained if the battery cable wiring resistance is high, so the appropriate battery cable diameter must be considered. Refer to *Wiring on page 13-27* for the method of selecting the cable diameter.

Temperature

When the ambient temperature rises, wear of the metal bearing in the starter motor tends to increase. This temperature rise also causes the magnetic switch operating voltage to rise, lowering starter motor performance due to decreased pull-in force and pinion malfunction. To prevent this, keep the ambient temperature below 80 °C (176 °F) during engine operation. In cold areas, the grease used to lubricate the pinion and other drive components may freeze or increase in viscosity, causing pinion malfunction. To prevent this, use low temperature grease when the unit will be used at low temperatures.

Oil

Generally, abnormal wear or defective conductivity of the brushes and contacts occurs if oil enters the starter motor armature commutator or magnetic switch contact. Be careful not to splash oil on the starter motor.

Dust

Dust deposits on the armature shaft or the pinion and drive components increases their friction and causes defective pinion engagement. Carefully perform inspection and maintenance.

Vibration

Try to dampen engine vibration to prevent resonance when installed in the driven machine.

Water

If water enters the pinion drive components, commutator or magnetic switch contacts, the starter motor may fail to operate due to corrosion. Never allow the starter motor to be splashed with water. Since the water-proof performance of the starter motor is in the R2 level of JIS D 0203, Never subject it to steam or pressurized washing. The R2 level refers to the water spray test for examining the performance of a part indirectly exposed to rainwater or splash.

Salt damage

In cold areas where salt is used on the road to prevent freezing or the driven machine is used near the seashore, salt damage as mentioned below can be expected. The hood and cover of the driven machine should be constructed to prevent direct salt damage to the engine.

- Rusting of the threaded portion, malfunction of sliding section
- Short circuit or burning of terminals by galvanic corrosion
- Defective contact of insert type terminals

Operation

To protect the starter motor from overheating, Never hold the key in the START position for longer than 15 seconds or the starter motor will overheat.

Safety

By connecting the E-ECU and starter relay, the starter motor is prevented from overrunning (over speed and/or excessive duration of energization). (Refer to *Starter Motor Restraint Control on page 14-70.*) When the starter reaches the specified speed and the engine starts, the starter motor circuit automatically cuts off the starter motor. This function prevents pinion gear engagement due to operator error during engine operation.

Principle of Operation

The two major causes of starter motor problems are starter motor coil burning and overrunning clutch damage. In many cases, they are caused by defective wiring or incorrect operation.

To prevent malfunction due to these causes, it is important, to understand the operation of the starter motor. For overall structure of the starter motor, Refer to *Outline and Precautions on page 13-6*.

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Starter solenoid

Figure 13-3 illustrates the magnetic starter solenoid. The magnetic switch has the following major functions:

- Pulls in the plunger to push out the pinion and engage it with the ring gear of the engine
- Closes the moving contact to allow battery current to flow through the armature.

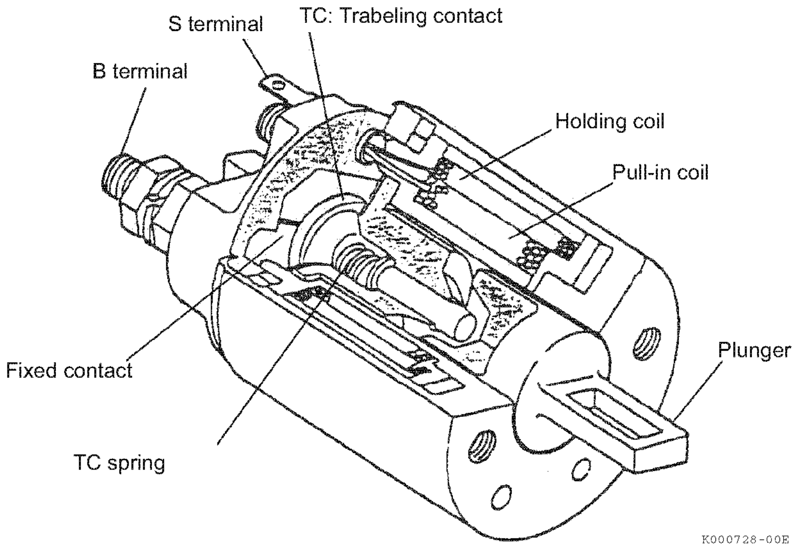

Figure 13-3

Movement of pinion

Figure 13-4 shows the starter motor electric circuit to illustrate the movement of the pinion and the moving contact point, and the flow of current.

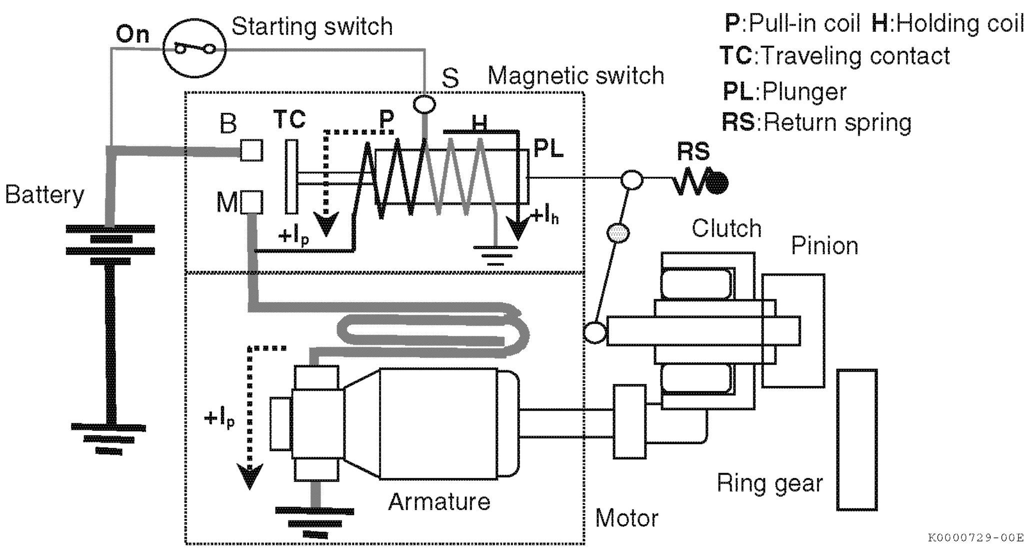

Figure 13-4

Turning the key switch to the START position applies battery voltage V_b to the S terminal. As a result, current flows through the pull-in coil P ($+I_p$) and holding coil H ($+I_h$), and both coils attract plunger PL. As a result, the pinion flies out to engage the ring gear. At the same time, moving contact TC makes contact with contact points B and M.

Rotation of the pinion

When contact points B and M are closed, battery current I_b flows from the battery to the armature. The pinion vigorously rotates to drive the ring gear of the engine. This process is illustrated in **Figure 13-5**.

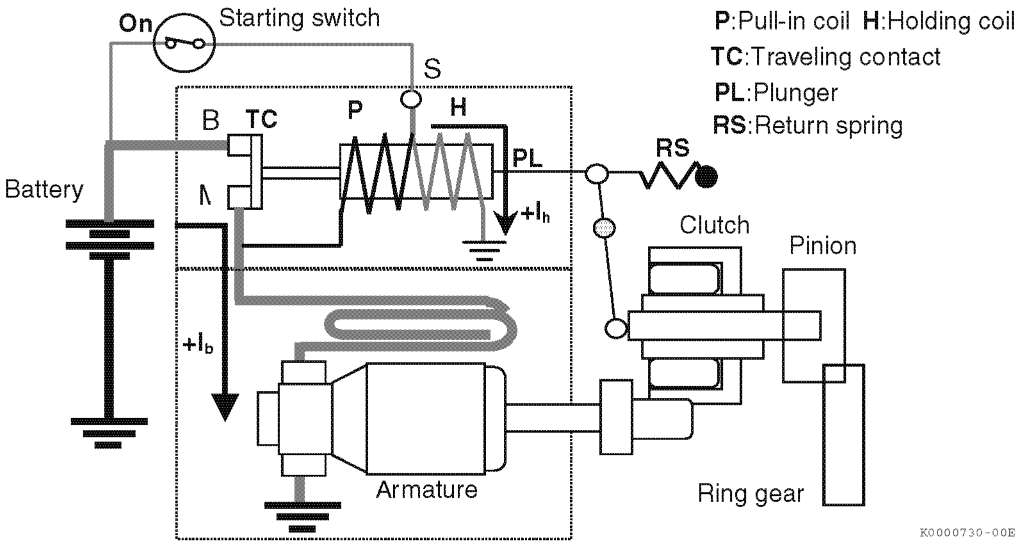

Figure 13-5

At the same time, battery voltage V_b is applied to the M terminal side and S terminal side of pull-in coil P. As a result, the terminals of pull-in coil P are at the same voltage and the current I_p disappears. However, since current I_h still flows through the holding coil, plunger PL is kept pulled-in. As a result, the starter motor continues to crank the engine.

When the starter motor is cranking, no current flows through pull-in coil P. The current I_h that flows through holding coil H is called the holding current. The current that flows through the pull-in coil and holding coil when the key switch is turned to the START position is called instantaneous current. The actual magnitude of the instantaneous current varies among the starter motors. Refer to *Determination of cable size and length on page 13-29*.

When the engine has started

When the engine has started, the key switch automatically returns to the ON position. **Figure 13-6** shows the flow of current at this moment.

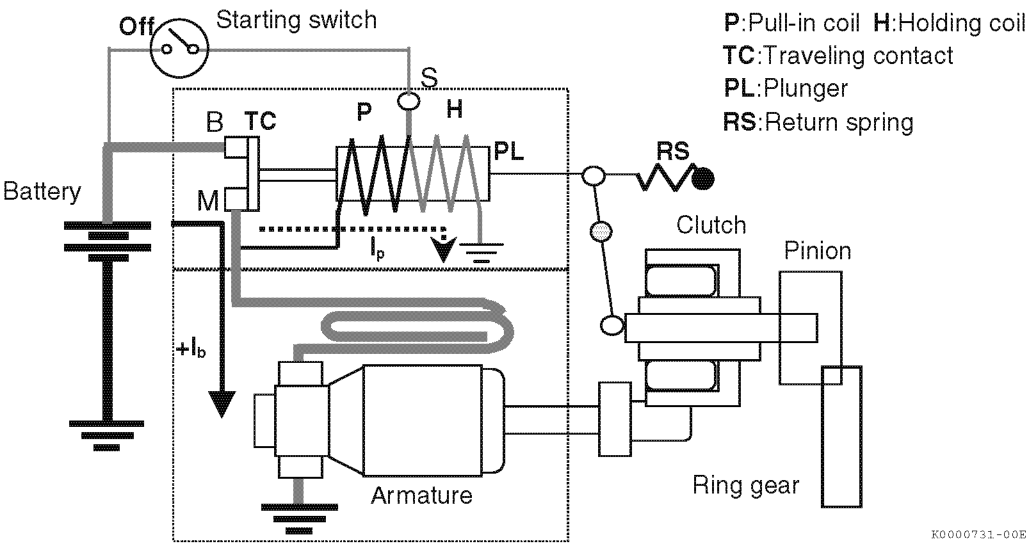

Figure 13-6

At this moment, battery voltage V_b at S terminal disappears. On the other hand, battery voltage V_b is applied to contact point M. As a result, the current flows from contact point M to holding coil H through pull-in coil P, and finally to ground.

In the state shown in **(Figure 13-6)**, both coils are in series connection. Therefore, the magnitude of the current that flows through the coils is the same. However, the direction of the current in the pull-in coil is negative, and the one in the holding coil is positive.

Physical characteristics of coils and their structures

To understand how the solenoid operates, it is necessary to know the physical characteristics of the coils and their structures. This knowledge is very important for analyzing starter motor failure.

Physical coil characteristics

The physical coil characteristics are provided by the following formula.

$$M_f \propto A \times T$$

M_f : Magnetic force

A : Amperage

T : Number of turns of coil

This formula implies that the magnitude of the magnetic force of the pull-in coil and holding coil is the same if the magnitude of the current that flows through the coils is the same and the number of turns of the coils is the same.

Structure of coil

Figure 13-4 shows that pull-in coil P is on the left side of the plunger and holding coil H on the right side. Actually, both coils are in a two-tiered structure as shown in **(Figure 13-3)**. Therefore, though **(Figure 13-4)** describes the flow of current to the left and right separately, it actually flows in the same direction in both coils. That is, the lines of magnetic force of both coils are in the same direction.

If the direction of current flow I_p for the pull-in coil changes, the lines of magnetic force also change their direction. As a result, the lines of magnetic force of both coils cancel each other and result in eliminating the magnetic force that pulls in the plunger. This theory is further explained in *Key switch turned to ON position on page 13-12*.

Another important point in the coil structure is that the number of turns of the pull-in and holding coil are the same. That is, the formula of the magnetic force in *Physical characteristics of coils and their structures on page 13-11* implies that the magnitude of the magnetic force of both coils is the same if the magnitude of the current that flows through both coils is the same and the number of turns of both coils is the same.

The pull-in coil uses thicker wire. Therefore, though the number of turns of both coils is the same, the resistance of the pull-in coil is lower than that of the holding coil. If a current of equal magnitude flows through these coils, more heat is produced by the holding coil than the pull-in coil. This is why the holding coil has more problems with burning.

Key switch turned to ON position

In the following description, the theory described in *Physical characteristics of coils and their structures on page 13-11* is applied to the action when the key switch is turned to the ON position (described in *When the engine has started on page 13-11*).

- The magnitude of current (I_p) that flows through both coils is the same. The number of turns (T) of both coils is also the same. Therefore, the magnitude of the magnetic force (M_f) produced by both coils ($M_f = I_p \times T$) is the same.
- The direction of the current that flows through pull-in coil P when the starter motor is cranking is left (positive) as shown in **(Figure 13-4)**. The direction of the current that flows through pull-in coil P when the key switch returns to the ON position is right (negative) as shown in **(Figure 13-6)**. On the other hand, the direction of the current that flows through the holding coil when the starter motor is cranking and when the key switch returns to the ON position is the same (positive).
- That is, the direction of the lines of magnetic force of pull-in coil P when the key switch returns to the ON position is reversed (negative). Therefore, the magnetic force is given by the following formula.

  M_f of holding coil $= +I_p \times T$

  M_f of pull-in coil $= -I_p \times T$

  As a result, pull-in coil P and holding coil H negate each other's magnetic force.

When key switch returns to ON position

At the moment the key switch returns to the ON position, plunger PL is returned to the initial position by return spring RS because pull-in coil P and holding coil H negate each other's magnetic force.

As a result, the pinion is disengaged from the ring gear. Moving contact point TC is also released from contact points B and M. Since battery current I_b that flows through the armature is turned Off, the starter motor stops.

This is the normal operation of the starter motor.

Causes of Starter Motor Failure

There are two types of starter motor failure.

- Burning of the holding coil H due to flow of current through the S terminal for more than the specified period. In most cases overcranking or overrunning will cause burning of holding coil H.
- Failures due to excessive resistance of the wire harness. The wire harness may have high resistance because of a small cross-sectional area of the cable or due to degradation. The increase of the resistance can lead to melting or roughening of the magnetic switch contacts.

Burning of the holding coil or melting of the contacts can lead to burning of the armature and damage to the pinion and clutch.

The following describes typical starter motor failures. Even if the actual problem is complex, the basic causes of failure can be analyzed based on these cases.

Failure

Turning the key switch to the START position causes pinion to repeatedly fly in and out.

Analysis

This failure occurs when the wire of holding coil H is broken. The broken H coil wire causes the starter motor to repeat the operation as described below.

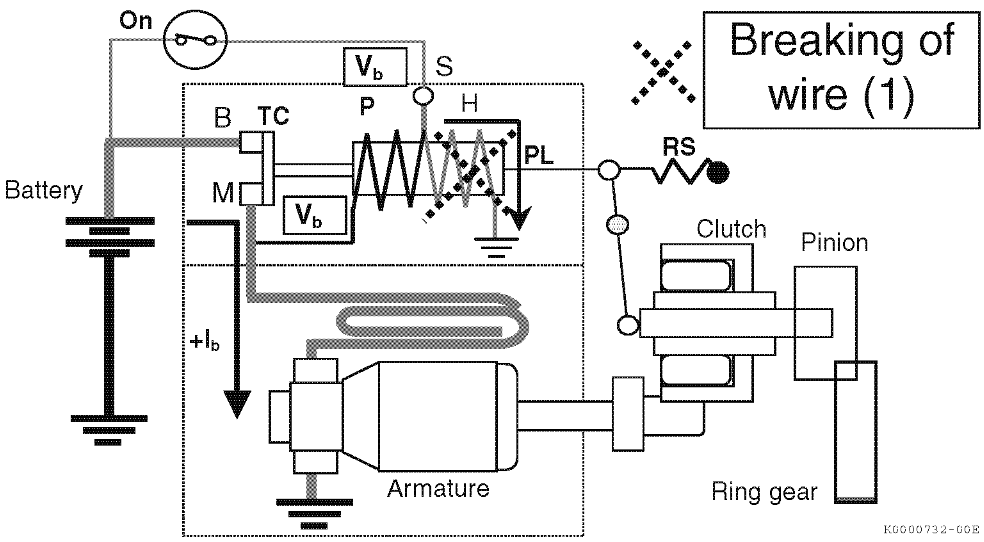

Figure 13-7

Turning the key switch to the START position causes pull-in coil P to momentarily attract plunger PL. The pinion then flies out once and moving contact point TC closes. When moving contact point TC closes, battery voltage V_b is applied to the S terminal side and M terminal side of the pull-in coil at the same time. Since both terminals of the pull-in coil become equipotential, no current flows through the coil and pull-in coil P loses magnetic force. Since the wire of holding coil H is broken, plunger PL is returned to its initial position by return spring RS.

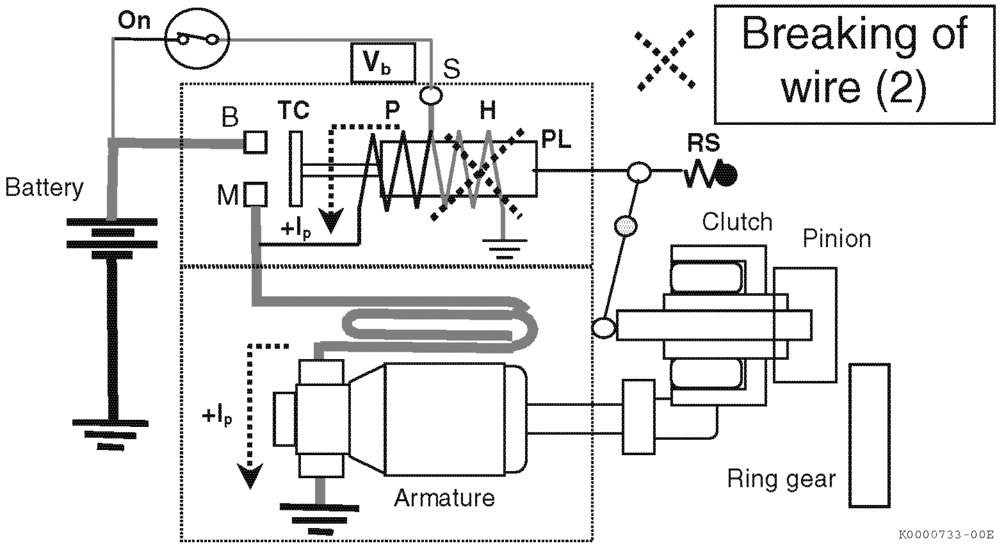

Figure 13-8

When contact points B and M are opened, then, battery voltage V_b is applied only to the S terminal side of pull-in coil P. Since pull-in coil P attracts the plunger again, the pinion flies out. In this way, the pinion keeps flying out and retracting. Moving contact point TC may finally become molten.

Cause of failure

The breaking of the holding coil H wire may be due to the coil burning.

While cranking, the current flows through the holding coil and the armature, as shown in **(Figure 13-5)**. If current flow exceeds the specified period, holding coil H produces excess heat and may eventually burn, although in many cases the heat will only cause discoloration of the armature.

Prevention of failure

The recommended limit of continuous energizing is 15 seconds and the starter motor must never be energized for more than 30 seconds. If the starter motor has been energized for 20 to 30 seconds, it should be turned off for over one minute. This can protect the battery from over-discharging. Exceeding recommended period of continuous energizing or a shorter shut-down period can cause abnormal heating of the starter motor.

Using the motor to air-bleed the fuel system is a common cause of energizing the starter motor for longer than the specified time. Even if the period of continuous energization of the motor is 20 seconds or less, the holding coil can burn if the de-energization period is too short. Air-bleeding should be done in accordance with the *TNV Operation Manual*. It is very important to instruct the users not to use the starter motor for air-bleeding.

A defective key switch may also cause the holding coil to burn. If the key switch does not return to its initial position, the holding coil may burn due to the flow of current through the coil for a long period. This may lead to damage to the pinion or clutch.

Holding coil burning is caused by incorrect operation or other external causes. Therefore, overheating of the starter motor holding coil is not covered by warranty.

Failure

Turning the key switch to the ON position will not stop the starter motor.

Analysis

When the key switch returns to the ON position, the starter motor does not stop. In this case, disconnecting the S terminal does not stop the starter motor. Since the pinion and clutch receive starting torque from the engine, they may be discolored by the heat and the clutch may be damaged.

This failure may be misunderstood as the melting of moving contact point TC. The failure occurs, however, when holding coil H has generated a layer short.

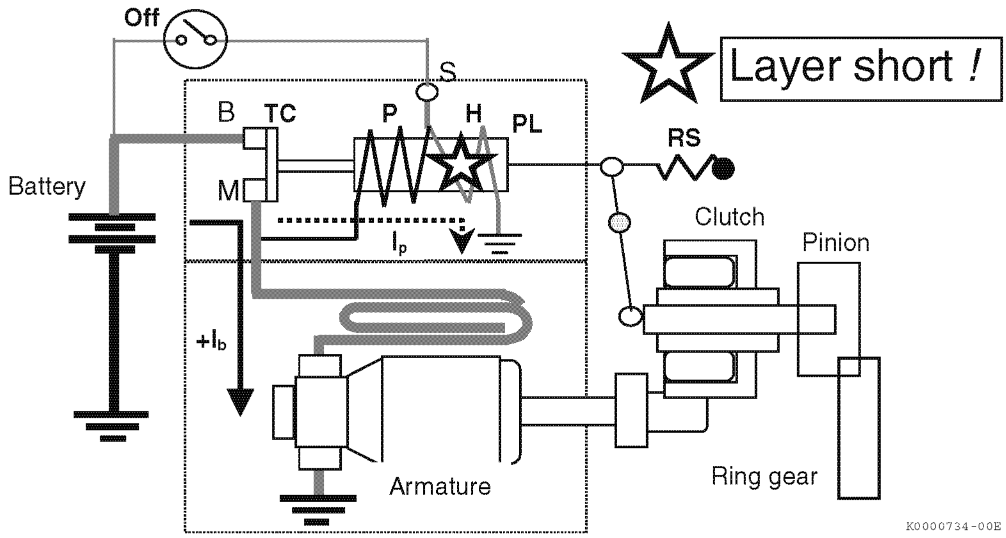

Figure 13-9

According to **(Figure 13-6)**, the pull-in and holding coils negate their magnetic force at the moment the key switch returns to the ON position. For details, read *When the engine has started on page 13-11* and *Physical characteristics of coils and their structures on page 13-11*.

When holding coil H is in the layer short state, the number of turns of holding coil H that function as a magnet is reduced. The magnetic force of the holding coil is then lowered in proportion to the number of turns reduced. As a result, the magnetic force of both coils does not negate each other perfectly, making the magnetic force of pull-in coil P effective, which keeps attracting plunger PL. Thus, the starter motor keeps cranking even after the key switch returns to the ON position.

When the level of layer short is low, return spring RS may return the plunger PL to its initial position.

Cause of failure

A layer short will also cause the holding coil to burn. The cause of the holding coil layer short of is also the same as *Causes of Starter Motor Failure on page 13-13*. That is, the holding coil layer short is caused by incorrect operation or other external factors.

Prevention of failure

Measures for the prevention of failure are also the same as *Causes of Starter Motor Failure on page 13-13*. Therefore, a starter motor holding coil layer short is not covered by the warranty.

Failure

The key switch returns to the ON position and the pinion retracts but the pinion keeps rotating.

Analysis

The situation in which returning the key switch to the “ON” position retracts the pinion but the pinion keeps rotating will occur when the moving contact point TC is welded.

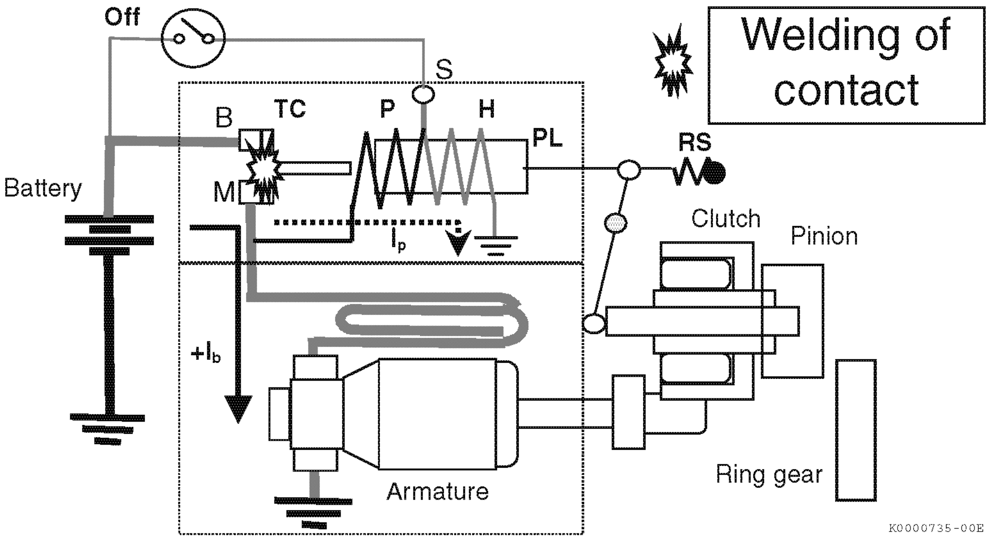

Figure 13-10

At the moment the key switch returns to the ON position, pull-in coil P and holding coil H negate their magnetic force. Plunger PL is returned by return spring RS. The pinion is disengaged from the engine. But when moving contact point TC is welded so contacts B and M remain in contact with TC, current I_b keeps flowing through the armature and the pinion keeps turning even though it retracts from the ring gear.

Since the current keeps flowing through both coils, they produce excessive heat and lead to burning. Since the wire diameter of the holding coil is smaller than that of the pull-in coil, the damage to the holding coil occurs sooner than the pull-in coil and the damage is more serious.

Cause of failure: mechanism of melting of contact point

The contact point melts when the resistance of the starter circuit (battery - key switch - S terminal) is high.

When the starter circuit resistance is high, the contact point melts in accordance with the mechanism described in **(Figure 13-11)**.

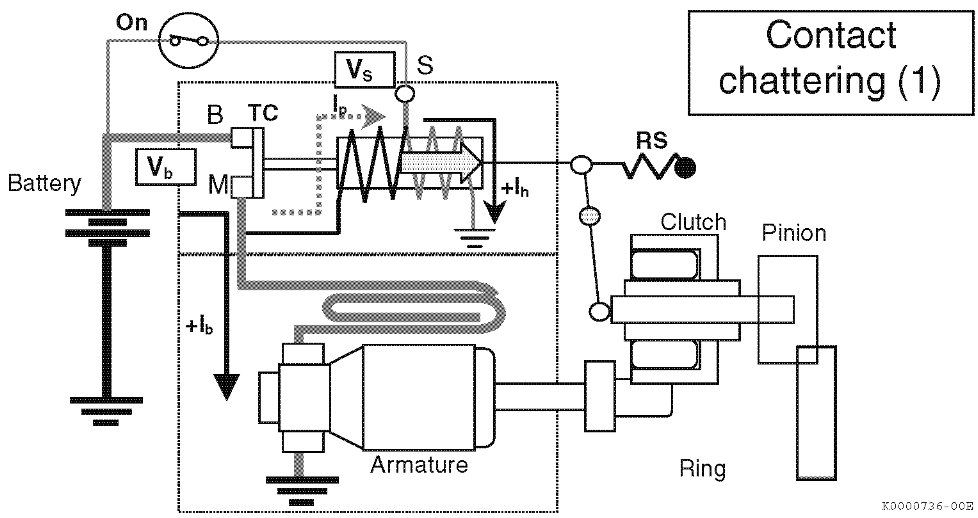

Figure 13-11

When resistance R of the starter circuit is high, voltage V_s of S terminal is lower than voltage V_b of M terminal. As a result, current ($-I_p$) flows in pull-in coil P from M terminal to S terminal. Since - I_p acts to negate the magnetic force that is produced with holding coil current ($+I_h$), the plunger holding force is reduced. When the force of return spring RS is larger than the plunger holding force, the plunger is returned to its initial position and moving contact point TC is turned off.

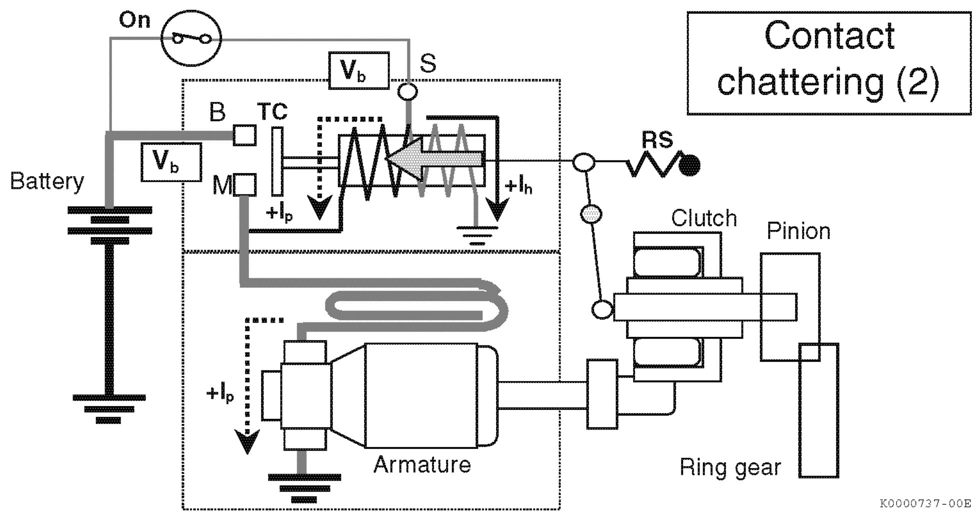

Figure 13-12

When moving contact point TC is turned off, voltage V_b of M terminal disappears. At the same time, current ($+I_p$) flows from S terminal to pull-in coil P. Since the magnetic force produced by $+I_p$ is added to the one produced by $+I_h$, plunger PL is pulled in again. Moving contact point TC is turned on again, returning to the state shown in **(Figure 13-11)**.

In this way, plunger PL repeats the operation as shown in **(Figure 13-11)** and **(Figure 13-12)** very rapidly. The contact point produces an excessively large arc to make the contact point melt. This is the mechanism that melts the contact point.

Prevention of failure

Contact point melting is caused by high resistance in the starter circuit. The allowable resistance of the starter circuit varies among the starter motors. For the allowable resistance of each starter motor, Refer to *Starter Solenoid Cable Selection on page 13-30*.

The resistance of the starter circuit increases gradually, even though the initial resistance is lower than the allowable resistance, due to degradation caused by corroded terminals. Instruct the users to check the wiring harness periodically and remove any corrosion.

Actions to be Taken when Starter Motor does not Function

Many starter motors are returned because they will not start the engine, but check out normally in the shop. This indicates that the problem is elsewhere in the electrical system, such as the wiring harness or key switch.

If a new starter motor starts the engine and the old starter motor checks-out normally, examine the starter motor wiring and battery terminals for corroded contacts or other causes of high resistance.

Starter motors that fit the criteria described in *Causes of Starter Motor Failure on page 13-13* and *Actions to be Taken when Starter Motor does not Function on page 13-18* are not covered by warranty.

Starter Motor Failures that are not Prevented by the Starter Motor Check

For starter motor check/control, refer to *Starter Motor Restraint Control on page 14-70*.

Overcranking

To do a starter motor check, the engine has to run at the specified speed at least once. The speed that an engine has to exceed to do a starter motor check varies among engine types and engine specifications.

If an engine will not start, it may be necessary to make the starter motor crank the engine for a long time (one or two minutes) or to turn the starter motor on and off frequently. This is called overcranking and can cause the starter motor to generate heat that may cause the coils to burn.

The starter motor check cannot prevent burning of the starter motor caused by overcranking. Engine operators sometimes overcrank their engines when attempting to air-bleed the fuel system by cranking the starter motor.

To prevent the burning of the starter motor due to overcranking, it is important to thoroughly instruct users to bleed air with the electric fuel pump (solenoid pump) in accordance with the air-bleeding procedure described in the *TNV Series Operation Manual*. Never use the starter motor to air-bleed the fuel system.

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Charging System

In general, alternators with built-in regulators are belt driven, deriving their motive force from the engine. They supply electric power to charge the battery and to the electric load. They generate AC power and convert it to DC. This section describes the attributes of alternators with built-in regulators.

Features of an Alternator with a Built-in Regulator

In place of the permanent magnet used in the dynamo, the alternator uses an exciting field coil.

The alternating current output by the alternator is rectified into direct current by an IC regulator.

The regulator is part of the alternator.

Alternator structure

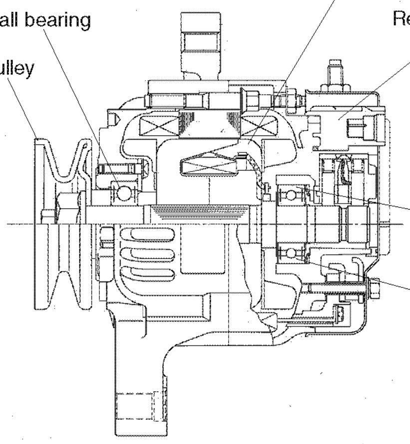

Figure 13-13

Charging system capacity

The charging system must be able to supply the necessary power to the electrical system during engine operation and to charge the battery. The types of charging systems used in TNV engines are as shown in the table below. When you select the type of charging system for your application, consider the engine speed range and electrical system load. For details, Refer to the separate *YANMAR TNV Option Menu*.

Nominal output	Alternator
12 V - 40 A	O
12 V - 55 A	O
12 V - 80 A	O

Output Characteristics

Alternator output characteristics

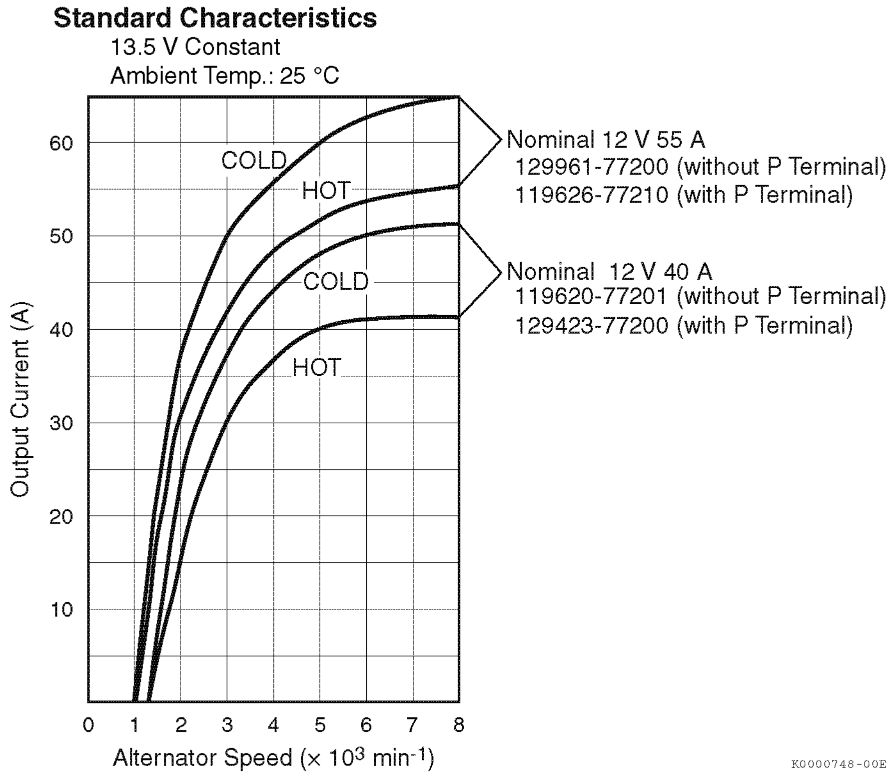

Figure 13-14

Regulator

The electric output from the alternator with a built-in regulator is alternating current. The electronic circuit that rectifies it to direct current is generally called a regulator.

The AC to DC conversion is performed in various ways. The alternator has a built-in IC regulator in the body. YANMAR calls this type of regulator an “alternator with built-in IC regulator”.

Control of Battery Indicator

A major feature of the IC regulator system is the control of the battery indicator. Turning the power On applies voltage to the battery indicator to light it.

When the engine is running and a specified engine speed (specified charging voltage) is attained, the voltage at the grounding side of the indicator rises and the voltage across the indicator becomes almost equal. If the indicator is a lamp and not an LED, it should go Off because the potential difference across it is very small. When an LED is used, however, it may light “faintly” even in normal operation because of a small potential difference (approx. 0.2 V). A “faint” glow of the battery indicator is normal.

When the engine speed exceeds the speed specified, but generator speed is so low that the power produced by the generator is less than the amount of current required by the load, the battery makes up the shortfall. Since the battery is not charged in this situation, it will be completely discharged if the situation continues for too long. Since the generator is operating normally, the indicator does not light.

The battery indicator is only used for checking whether the generator generates electricity, and not for checking whether the battery is being charged.

Since the alternator with a built-in regulator uses electronic parts, avoid connecting the battery cables with the wrong polarity or disconnecting the battery cable while the engine is running as it may cause damage to the charging system or other electronic components.

Battery

The battery supplies power to the starter motor while the engine is cranking. It also supplies power to other electrical components and the exciting current to the generator or alternator when the engine is cranking.

How to Check the Battery

Battery types

Batteries are roughly classified into alkaline storage and lead acid storage categories. Alkaline storage batteries are mostly used in large capacity engines for emergency use. Lead acid storage batteries are mostly used for industrial engines.

Battery capacity

The battery capacity is represented in Ah (ampere-hour). It represents the total quantity of electricity (Ah) that will be discharged at a constant current. In other words, it is the product of the discharge current (A) and the number of hours (h) until the final discharge voltage is reached. The total quantity of electricity that is discharged decreases as the discharge current increases.

- It is possible to continue battery discharge until the terminal voltage reaches 0 V in principle, but such a discharge makes it impossible to restore the battery to its original state. Discharge, therefore, must be terminated at the proper voltage level. This voltage level is called the final discharge voltage.

> Ah = Discharge current (A) × Discharge time (h) until final discharge voltage.
>
> For example, if the final discharge voltage is reached upon discharging at 10 A for 5 hours, the capacity of this battery is said to be 50 Ah (10 A × 5 h) at the 5-hour rate.

- For the reserve capacity and cold cranking current, Refer to *Battery types on page 13-22*.
- As already described, a symbol “Ah (ampere-hour)” is used to represent the battery capacity. However, the symbol should be used with care because the meaning of “capacity” is different between the US, Europe and Japan. JIS (Japanese Industrial Standard) defines “Ah” based on the 5-hour rate and in the US and European countries it is based on the 20-hour rate.

  Use the following conversion to determine the approximate equivalence.

  “Ah” based on the 20-hour rate × 0.8 = “Ah” based on the 5-hour rate

  For example, 70 Ah (20-hour rate) in the US or European standard is equivalent to 56 Ah (5-hour rate) in the Japanese standard because 70 Ah × 0.8 = 56 Ah, which corresponds to 65D31R of JIS. This conversion is accurate enough for use in normal conditions. When driven machines have a large parasitic torque, or when batteries are used in an extremely cold region, it is necessary to compare the CCA (cold cranking current) instead of Ah.

Battery related terms

Term	Meaning
Nominal voltage	Standard voltage (V) used for indication of battery voltage.
Capacity (5-hour rate)	Product of 5-hour rate current and time (hours) until final discharge voltage. Also, the quantity of electricity (Ah) discharged at 5-hour rate until the final discharge voltage is reached.
5-hour rate current	Indicates the battery charging/discharge current (A) obtained by dividing the (5-hour rate) capacity by 5.
High rate discharge characteristics	Discharge characteristics at a current near the automobile engine starting current.
Final discharge voltage	Battery terminal voltage (V) where discharge must be stopped.
Charge acceptability	Characteristic showing whether a discharged battery will accept a charge at a constant voltage.
Reserve capacity	Measure of a fully charged automotive battery capacity in duration (minutes) with a continuous discharge current of 25 A until a final discharge voltage of 10.5 V is reached. Battery is maintained at 25 ± 2 °C.
Cold cranking current (CCA)	Measure of engine starting performance in terms of discharge current (A) of an automobile battery at 18 °C that causes the voltage to drop to 7.2 V within 30 seconds.
Heavy-load life	Number of repeated discharge/charge cycles in the heavy-load range with one discharge depth at 20 % or more in the life test method.
Light-load life	Number of repeated discharge/charge cycles in the light-load range with one discharge depth at 10 % or less in the life test method.

Battery types

The table below shows the types of batteries specified in JIS D 5301-2006.

Type	External dimensions (mm)				Capacity		Startability					Life			
								High Rate Discharge Characteristic at 258K (-15°C)							
	Overall height (maximum)	Box height	Width	Length	Rated reserve (RC)	5-hour rate (5HR)	Rated cold cranking current (CCA)	Discharge current	Duration	Voltage after 5 sec.	Voltage after 30 sec.	Light-load life	Heavy-load life	Charge acceptability	(Reference) Mass (including liquid)
					(min)	(Ah)	(A)	(A)	(min)	(V)	(V)	(cycle)	(cycle)	(A)	kg (approx.)
26B17	227	203	127	167	29	21	185	150	1.8	8.4	–	800	–	2.6	7.5
28B17					32	24	195		2.3	9.0		900		3.0	8.0
34B17					38	27	240		3.0	9.2		1000		3.3	8.5
34B19				187								1100			9.5
38B19					43	28	265		3.0	9.5		1200		3.3	10.0
38B20			129	197					3.5	9.5		1300		3.5	10.5
44B20					51	34	300		4.0			1400		4.0	11.5
46B24				238	56	36	295		4.2			1500		4.5	12.5
55B24					64		370	300	2.0	8.6		1800			13.5
50D20	225	204	173	202	63	40	310	150	4.0	9.6		2200		5.0	13.0
55D23				232	74	48	320	300	1.9	8.0		3100	315	6.0	15.5
65D23					90	52	370		2.5	8.5	8.4	3400	320	6.5	16.5
75D23					95		465		2.9	8.9	-	3800			17.0
75D26				260	98		450				8.8		330		18.0
80D26					103	55	490		3.5	9.2	9.1				19.0
95D31				306	125	64	565		4.3	–	9.3	4700	375	8.0	21.5
105D31					132		655		4.4		9.4	5000			22.5
115E41	234	213	176	410	170	88	610	500	2.6		8.3	–	485	11.0	29.0
130E41					195	92	680		3.0		8.8				30.0
115F51	257		182	55	180	96	575		2.6		8.2			12.0	32.0
145F51					225	112	735		3.4		8.8		600	14.0	36.0
145G51			222	508	240	120	685		3.6		8.6			15.0	40.0
165G51					300	136	710		4.8		9.0		785	17.0	45.0
195G51					320	140	930		5.4		9.5		700		47.0
190H52	270	220	278	521	370	160	765		5.6		9.0		785	20.0	58.0
210H52					380		910		6.0		9.3		790	21.0	62.0
245H52					405	176	1170		7.8		9.9		800	22.0	70.0

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Type code designation method

28 B 19 R

- R — Terminal position (R, L or no code)
- 19 — Battery length (cm)
- B — Battery width   box height class (eight classes A to H)
- 28 — Performance rank at electrolyte specific gravity of 1.280 at 20 °C (relative performance indication and not absolute value indication)

Battery Charging

If an engine is frequently operated, the battery should maintain its charge. But if it is stored for an extended period of time, the battery may lose its charge. Guidelines for long-term storage and charging time is as follows:

Guideline for self-discharge and charging cycle

Batteries self-discharge (natural discharge) without being used. Self-discharge per day is 0.5 to 1.0 % of the battery capacity.

To start an engine, residual battery capacity of 40 to 50 % will be enough at “ordinary” temperature. By considering charging efficiency and battery life, it is desirable to charge batteries before the residual battery capacity reaches 60 to 70 %.

In other words, if a 100 % capacity battery that self-discharges at the rate of 1 % a day is shelved, it will lose 30 % of its capacity after 30 days. Thus the residual battery capacity is 70 %. Therefore, batteries should be charged at least once per month.

Starter motor battery discharge and charging

How long do you need to run the engine to restore the original charge capacity after starting the engine with the starter motor?

Theoretically, this can be calculated if the amount of cranking current that flows through the starter motor, length of time starter motor is energized and the output of the generator/alternator are known. An example of this calculation is shown below:

Battery discharge

$$q = S_a \times \frac{t}{3600}$$

q	: Battery discharge	Ah
S_a	: Mean cranking current	A
t	: Energized duration of starting motor	sec

Operating time for restoring discharged potential

$$H_c = \frac{q}{A_c \times \beta}$$

H_c	: Charge time (operating time)	h
q	: Battery discharge	Ah
A_c	: Generator output	A
β	: Charging efficiency	0.8

Descriptions

Since mean cranking current varies depending on the output level of the starter motor, size of the torque of driven machine and whether the ambient temperature is “ordinary” or “low,” it is not possible to provide a definite numerical value.

To estimate the mean cranking current use the following chart.

Starter motor output ≤ (kW)	Mean cranking current (A)
1.0	170
1.2	215
1.4	260
2.0	290

It normally takes several seconds to start the engine, but when making the calculation, the target duration of 20 sec for the cold starting test will be sufficient.

Calculation example

What is the battery discharge that occurs when a 3TNV88C series engine is started one time, and how many hours does it take to restore the charge? Charging should be made while operating at 2400 min^{-1}.

The starter motor output of this engine is 1.2 kW. Therefore, you set an approximate mean cranking current at 215 A. By energizing the starter motor for 20 sec with allowance, the battery discharge will be calculated as follows:

q	: Battery discharge	Ah
S_a	: Mean cranking current	215 A
t	: Energized duration of starting motor	20 sec

$$q = S_a \times \frac{t}{3600}$$

$$= 215 \times \frac{20}{3600}$$

$$= 1.19\ Ah$$

To restore this discharge while operating the engine at 2400 min^{-1}, first look at the *YANMAR TNV Option Menu* for the output of the generator/alternator. We will use 37.8 A. The operating time necessary for restoring the battery to 100 % is:

H_c	: Charge time (operating time)	h
q	: Battery discharge	1.19 Ah
A_c	: Generator output	37.8 A
β	: Charging efficiency	0.8

$$H_c = \frac{q}{A_c \times \beta}$$

$$= \frac{1.19}{37.8 \times 0.8}$$

$$= 0.04\ h$$

That is, if the engine is started one time using the starter motor it should be operated for 0.04 hour or 2.4 minutes to return the battery to 100 %.

Wiring

Wiring is an important electrical component that affects all industrial engine functions. If the wiring is not correct, the wiring resistance may be excessive causing malfunctioning of electrical parts or overheating/ burning. When determining which cable to use, make sure that the voltage drop is within the allowable range. Recheck the total load placed on the circuit to ensure that the wiring is adequate.

For the engine electrical components, negative (-) grounding is standard. Consult YANMAR before beginning the design, if positive (+) grounding is to be used.

Wiring Precautions

Electrical wiring is an essential element to make the engines perform safely and efficiently. Keep these precautions in mind. For precautions on the wiring control device, refer to *Harness on page 14-28*.

- Use wires with the most suitable size and length to ensure required current and voltage is available.
- Wires should be as short as possible, without sharp bends, and with sufficient strength.
- Insulate the wires completely.
- Use connectors or screws to secure the wire to the terminal. Connections should be made firmly to avoid looseness and short-circuiting.
- Avoid placing wiring in contact with oil, hot components, or rotating components. Use protectors, such as covers or shields, if necessary.
- When running wiring through an opening, protect the wire with a grommet or equivalent device.
- Secure the wires so that they are not damaged by mechanical vibration. Special care should be taken to prevent resonance with engine vibration.
  - Use wire clamps that are made of plastic. Metal clamps must be coated with plastic or rubber.
  - The area of the wire that is secured by wire clamps should be protected with corrugated tubes or equivalent
  - Never use the following components for securing the wires: Fuel tank, fuel hose, and radiator hose.
- Consider using waterproof connectors if the operating environment warrants it.
- Electrical ground connections:
  - Prepare the areas where the grounding wire will be attached (such as removing paint) **(Figure 13-15)**.
  - The grounding wires should not be attached to other components, such as an engine mount.
  - Ground the battery to the engine block as close as possible to the starter motor.

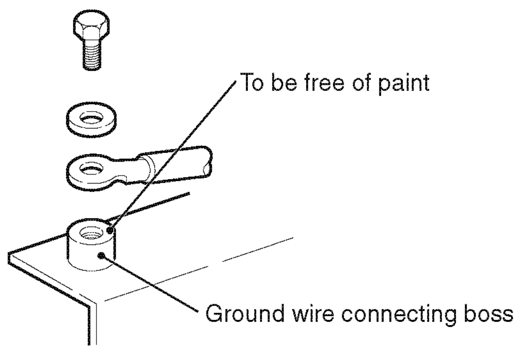


Figure 13-15

- To prevent connecting the battery cables to the wrong terminals, determine their "length" and "battery location" properly.
- As selection of battery cables affects the ECU start-up, selection of wire cables and earth cables should be appropriately done.
- The electrical components that are not installed directly on the engine (such as key switch, timer, relay, diodes and current limiter) should be installed in the places where they are not exposed to the rain, and are subjected to good ventilation and vibration acceleration of no more than 39.2 m/sec^2 (4 G).
- Check that surge voltage and surge current do not occur during normal operation and abnormal conditions. To prevent surges, use diodes to protect inductive or capacitive load components.

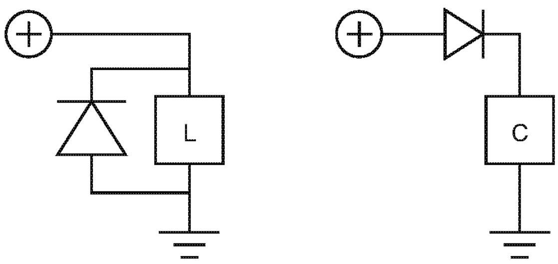


Figure 13-16

Battery Cable Selection

Selection of battery cables is an essential element for full performance of the starter motor. Using the wrong cable size or length can affect the starting performance and also cause damage to the starter motor.

Use the following information to select proper battery cables.

Definitions of battery cable size and length

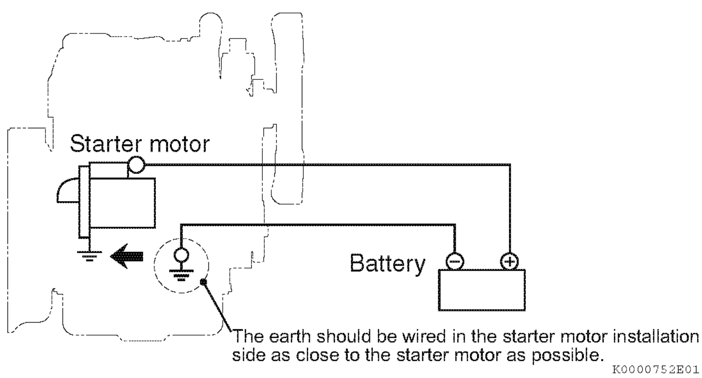
Battery cable size

The cable size is defined as nominal cross-sectional area of the conductor of the cable to be used.

Battery cable length

The cable length is defined as the total length of positive and negative cables between the starter motor and the battery.

Schematic diagram of connection circuit (assuming body grounding)

Schematic diagram	Overall length of cable (L)
	$L = L_1 + L_2$

Determination of cable size and length

The most suitable size and length of cable can be obtained by determining the allowable resistance (Ω) of the battery cables (depends upon the rated output of the starter motor) and specific conductor resistance (Ω/m) for each size of cable. The resistance of the battery cables must be matched so that the resistance does not fall below the ECU minimum voltage at engine start.

Allowable resistance of the battery cables

The allowable resistance of the battery cables varies according to the capacity of the starter motor. Connect the cables to the terminal using a bolt. The resistance of the connection at the terminal is assumed to be 0 Ω.

Rated voltage	12 V	
Rated output of starting motor	Less than 2 kW	2 kW or over
Total allowable resistance ($L = L_1 + L_2$) of battery cables R (Ω)	0.0020 or less	0.0012 or less

Note: R should include the resistance (Ω) of the battery switch if it is used in the battery circuit. The resistance should be confirmed by obtaining the information from the manufacturer.

Specific conductor resistance of the battery cables

Nominal cross-sectional area of conductor (mm^2)	Specific conductor resistance (r) of automobile low voltage wire (AV wire) (Ω/m) [at 20 °C]
15	0.001380
20	0.000887
30	0.000520
40	0.000428
50	0.000337
60	0.000287
85	0.000215
100	0.000168

Relationship between battery cable length and size

$$L = (R - \alpha)/r$$

Where;

L	: Allowable length of battery cable	m
R	: Allowable resistance of battery cable	Ω
α	: Resistance of battery switch	Ω (Assume 0.0002 Ω if the resistance is unknown)
r	: Specific conductor resistance of the battery cables	Ω/m

Calculation example:

What is the allowable length of the battery cable when a cable with nominal cross-sectional area of 20 mm^2 is used for a 1.8 kW starter motor?

L	:	Allowable length of battery cable	m
R	:	Allowable resistance of battery cable	0.002 Ω
α	:	Resistance of battery switch	Ω (because the battery switch is not used)
r	:	Specific conductor resistance of the battery cables	0.000887 Ω/m

Substituting the above values for their corresponding terms in the formula, the allowable length of the battery cable is obtained as follows.

$$L = (R - \alpha)/r$$

$$= (0.002 - 0)/0.000887$$

$$= 2.3\ m$$

The allowable length of the battery cable in this example is 2.3 m.

Starter Solenoid Cable Selection

When the starter motor does not crank properly, the magnetic switch produces a “clicking” noise when the key switch is turned to the START position. If this noise continues, the magnetic switch contact will produce heat, which can cause it to melt. If the contact melts, turning the key switch to the ON position will not stop the motor, causing the motor to burn and to be destroyed.

This trouble occurs when the starter motor circuit resistance is large. Even though the starter motor cable resistance is small when it is new, the starter motor circuit resistance increases with time due to contamination and corrosion. When designing a starter motor circuit, it is necessary to select the cables with sufficient size and length and allow for eventual cable deterioration.

Allowable resistance of starter circuit

Keep the total resistance of the starter circuit equal to or less than the allowable resistance for proper operation of the starter solenoid. The allowable resistance varies according to the starter motor output range, nominal rated voltage and the manufacturer. Determine the type of the starter motor that will be used and find the allowable resistance from the following tables.

Note that the allowable resistance of the starter motor circuit is the overall value that includes the resistance of the cables and cable terminal connections.

Table 13-1 Starting motor circuit allowable resistance R_S

Voltage	Starting motor output	Manufacturer	Starting motor circuit allowable resistance at 20°C
12 V	1.7 to 3.0 kW	Hitachi	≤ 0.050 Ω
	1.2 to 2.0 kW	Denso	≤ 0.050 Ω
	2.5 kW (R2.5)	Denso	≤ 0.035 Ω

Note: No matter what starter motor you use, be sure to use a starter relay.

Size and length of the starter motor cable

Definition of cable size

The cable size is defined as the nominal cross-sectional area of the starter motor cable conductor.

Definition of cable length

The cable length is defined as the total cable length, including supply and return paths as described below.

Current supply to the key switch should be taken from either the battery or magnetic switch terminal *B*, whichever result in shortest in overall length.

Starting motor circuit that uses a starting motor relay

Starter motor cable length $L = L1 + L2$

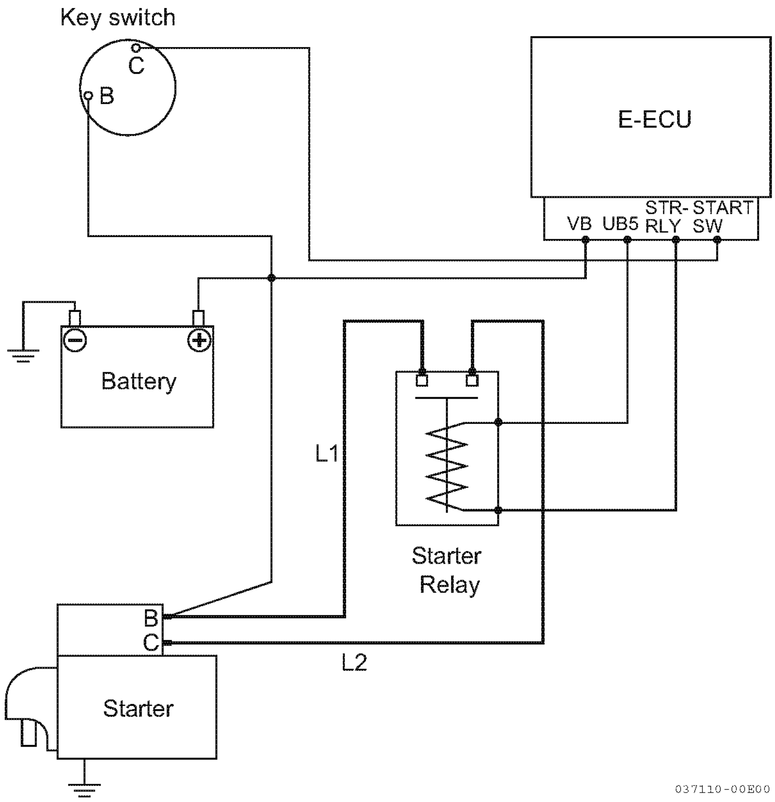


Figure 13-17

Selection of cables for the starter motor circuit

The size and length of the starter motor cable depends on the specific resistance of the cable (*Specific resistance of low voltage wire for automobiles (AV wires) on page 13-32*), the resistance of the terminals (*How to estimate the cable connection terminal resistance on page 13-32)* and the ambient temperature (*Ambient temperature and allowable current for determination of cable size on page 13-33)*.

Specific resistance of low voltage wire for automobiles (AV wires)

The specific resistance of each cable is shown in the following table.

Name (AV wire)	Nominal cross-sectional area (mm^2)	Specific resistance of cable (Ω/m) at 20 °C
AV1.25	1.25	0.0143
AV2	2.0	0.00881
AV3	3.0	0.00559
AV5	5.0	0.00352
AV8	8.0	0.00232

How to estimate the cable connection terminal resistance

The allowable resistance of the cable that is shown in the above table does not include the terminal resistance of the connections. For the actual circuit, resistance of the cable connections at the starter motor and key switch has to be taken into consideration. The calculation to obtain the allowable length (L) of the cable is described by the following formula.

$$L = (R_s - R_t)/r$$

L	: Allowable length of starting motor cable	m
R_s	: Allowable resistance of starting motor circuit	Ω
R_t	: Overall resistance of coupler connection terminals	Coupler connection terminal resistance: 0.010 Ω/connection Screw connection terminal resistance: 0 Ω
r	: Specific resistance of cable	Ω/m

Calculation example

When an AV2 cable is used for a Hitachi 1.7 kW starter motor, the allowable length of the starter cable is:

L	: Allowable length of starting motor cable	m
R_s	: Allowable resistance of starting motor circuit	0.050 Ω
R_t	: Overall resistance of coupler connection terminals	0.010 Ω
r	: Specific resistance of cable	0.00881 Ω/m

$$L = (R_s - R_t)/r$$

$$= (0.050 - 0.010)/0.00881$$

$$= 4.5\ m$$

This means that the total length of the supply and return wires of Hitachi's 1.7 kW starter motor circuit is approximately 4 meters when a cable size AV2 cable is used, including some margin.

Ambient temperature and allowable current for determination of cable size

The amount of current that is allowable for cables of the same size (nominal cross-sectional area) varies depending on the ambient temperature.

For the determination of the cable size, the standard ambient temperature of 70 °C (158 °F) is used. When selecting the size of the automotive low voltage wire (AV and AVS wires), determine the nominal cross-sectional area of the cable to be used. Make sure the maximum starter motor magnetic switch holding current is at or below the allowable current shown in the following table.

Table 13-2 Allowable current of AV and AVS wires (maximum allowable temperature of conductor: 80 °C [176 °F]) and their voltage drop (derived from JASOD609, attached table 2)

Nominal cross-sectional area of cable (mm^2)	Ambient temperature					
	30 °C (86 °F)		50 °C (122 °F)		70 °C (158 °F)	
	Allowable current	Voltage drop	Allowable current	Voltage drop	Allowable current	Voltage drop
	A	mV/m	A	mV/m	A	mV/m
1.25	23	400	18	313	10	174
2.0	31	332	24	257	14	150
3.0	42	285	33	224	19	129
5.0	57	243	44	188	25	107
8.0	75	211	58	163	33	93

For the holding current of the starter solenoid, Refer to *Charging System on page 13-19*.

Holding current of the starter solenoid

The holding current of the starter solenoid varies depending on the type of the starter motor. Consult with YANMAR when using a starter motor other than specified in the following table.
When you select a starter relay, use instantaneous current as a guideline.

Hitachi starter motor

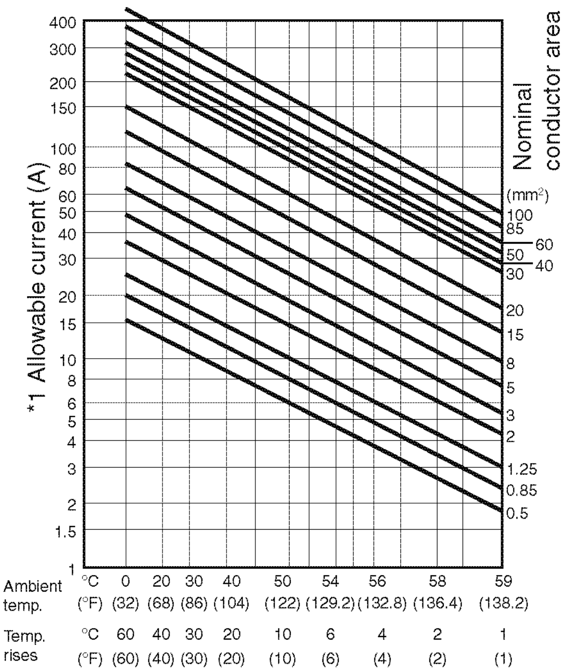
No.	Part code	Type of switch	Output (V-kW)	Instantaneous current/ holding current (A)
1	129608-77010	Coaxial, (reduction)	12 - 1.4	52/19
2	129242-77010	The same as above	12 - 1.7	52/19
3	129900-77012	The same as above	12 - 2.3	66/27
4	129940-77011	The same as above	12 - 3.0	52/19
5	129900-77030	The same as above	24 - 3.5	-/19

Denso starting motor

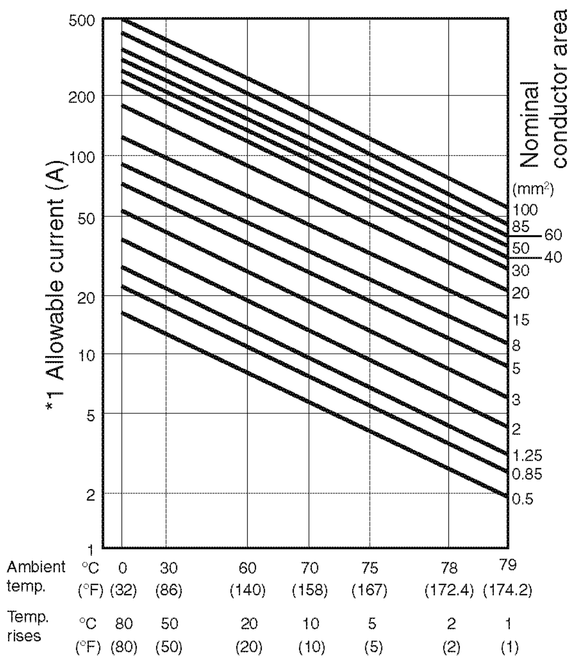
No.	Part code	Type of switch	Output (V-kW)	Instantaneous holding current (A)
1	129129-77010	RA1.2	12 - 1.2	51/14
2	129407-77010	RA1.4	12 - 1.4	51/14
3	129429-77011	RA2.0	12 - 2.0	51/14

Cable Temperature Rise and Allowable Current

When a cable conducts electrical current its temperature rises and the quality of its insulation decreases. Check the cable capacity and use a cable of an appropriate size. The figures below show the relationship between the allowable current at 60 °C and 80 °C, nominal conductor cross-sectional area and temperature rise of the AV cable (low-voltage cables for automotive use). Be careful as the cable types vary from country to country.



Allowable current for AV cables rated for a maximum ambient temperature of 60 °C



Allowable current for AV cables rated for a maximum ambient temperature of 80 °C

Figure 13-18

Allowable current

The maximum current is determined for a cable by considering the mechanical strength and insulation degradation caused by temperature rise. This is called the allowable current.

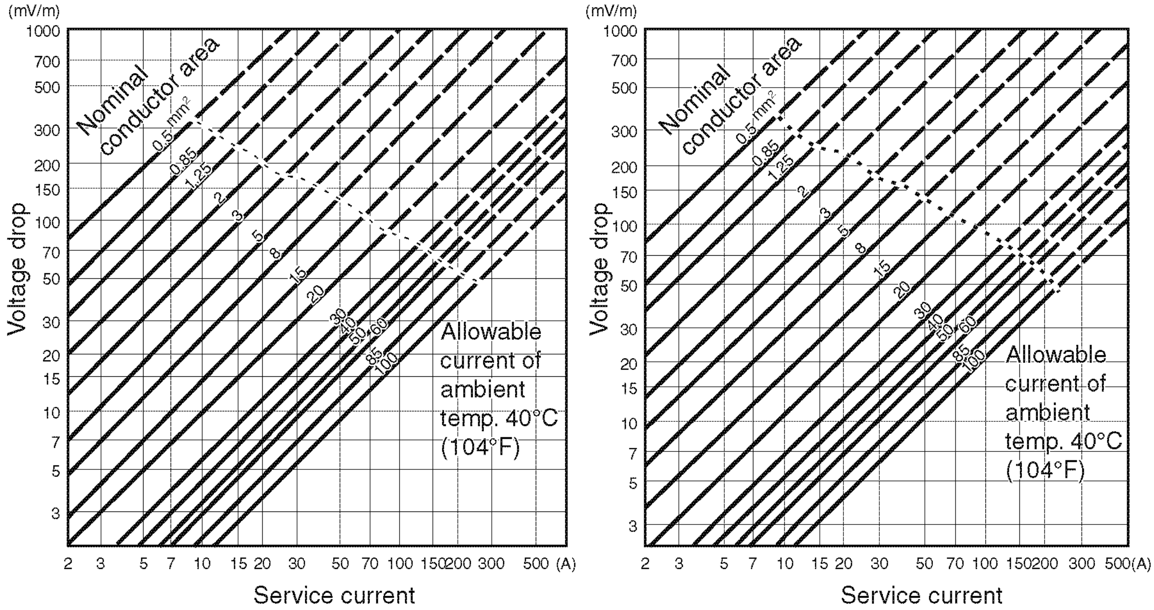
Read the tables **(Figure 13-18)** as follows:

When the maximum ambient temperature rating for an AV cable is 60 °C and the nominal cross-sectional area is 0.5 mm^2 and the ambient temperature is 50 °C, the value of the allowable current is 6 A. This allowable current will raise the cable temperature by 10 °C.

These tables show an example where a single cable is used. When a multi-conductor harness is used, the allowable current varies due to the radiation from each cable. When the multi-conductor harness is used, multiply the allowable current shown in **(Figure 13-18)** by the coefficient in the table below to obtain the multi-cable harness allowable current.

Number of bound conductors	1	2	3	4	5	6, 7
Coefficient	1.00	0.80	0.70	0.60	0.55	0.50

Allowable Current and Voltage Drop



Allowable current and voltage drop for AV cables rated for a maximum ambient temperature of 60 °C

Allowable current and voltage drop for AV cables rated for a maximum ambient temperature of 80 °C

Figure 13-19

How to read the figure above: When the allowable maximum temperature for an AV cable is 60 °C **(Figure 13-19)**, the voltage drops by 100 mV (0.1 V) per 1 m when a current of 10 A flows through a cable whose nominal conductor sectional area is 2 mm^2.

Cable Heat Resistance Comparison

Typically AV cables are used for applications where an engine drives an industrial machine. Typically IV or HIV cables are used for equipment engines and their control circuits. The following table provides information on heat resistance for these cables.

		AV cable	**IV cable**	**HIC cable**
JIS	No.	C3406	C3307	C3317
	Name	Low-voltage cables for automobiles	600 V Polyvinyl chloride insulated wires	600 V Grade heat-resistant polyvinyl chloride insulated wires
Heat resistance temperature		120 °C/120 hours	100 °C/48 hours	120 °C/120 hours
Flame resistance		Must go out spontaneously within 15 sec.	Must go out spontaneously within 60 sec.	Must go out spontaneously within 60 sec.

Notes for Manufacturing Wire Harness

For precautions on the control device-related wire harness production, refer to *Harness on page 14-28*.

Notes for main cables

- Starter motor wiring must observe the following precautions to avoid starter motor damage.
  - Total electric resistance of battery cable (①+②) should be calculated according to *on page 13-28*.

    Reference: AV15 : ≤ 1.4 m, AV20 : ≤ 2.2 m
    AV30 : ≤ 3.8 m, AV40 : ≤ 4.6 m

  - Total electric resistance of wiring for starter motor should be calculated according to *Starter Solenoid Cable Selection on page 13-30*.

    Reference for terminal resistance:
    15/1000 Ω per coupler
    0 Ω per screw setting

  - Ensure a good battery ground (①) connection by cleaning all paint off the surface the cable will be connected to.
- Handle the battery as follows. Failure to comply may cause electric equipment or components to burn. Alternator (diodes) burning caused by a reversed battery cable connection is not warranted.
  - Battery should be firmly secured and immovable using a mounting bracket.
  - Battery cable length should be adjusted properly and clamped. Never reverse battery cable connections.
  - Never loosen a battery cable terminal, or turn the battery switch Off while the engine is running.
- Only connect specified loads to the “L” and “P” alternator terminals. Never connect a load that is unspecified without YANMAR approval.
- Check for any surge current or voltage under normal operations and expected abnormal conditions, and make sure no surge occurs in the circuit. Provide a diode for “C-load component” and a diode for “L-load component”.

Table 13-3 Symbol for wire color

Symbol	Color
B	Black
W	White
R	Red
L	Blue
G	Green
Y	Yellow
Br	Brown
Lg	Light green
Sb	Sky blue
O	Orange
P	Pink
Gr	Gray
R/W	Red/White

Machine wiring caution

Safety precautions during design, assembling and durability testing are the responsibility of the driven machine manufacturer. Observe these precautions.

- A single conductor cable of 0.5 mm^2 or less should since it might not have enough mechanical strength. Make sure the cables meet the allowable current specifications discussed previously.
- Always use an insulator between a cable clamp and the cable. Never tighten a metal cable clamp directly to a cable without using an insulator.
- Prevent damage from vibration. Standard interval between wire clamps is 250 mm.
- Prevent fires:
  - The wire harness should not be attached to the fuel system, lubrication system or exhaust system.
  - Never run the wire harness through areas that could be exposed to spilled fuel from refueling or air bleeding.
- Prevent damage from contact with other components. The wire harness should be installed away from rotating or vibrating parts.
- Prevent incorrect wire connection. Use a different color for each terminal in a multi-terminal connector.

Section 14

ELECTRONIC CONTROL SYSTEM

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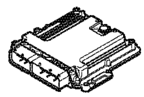
* *In this material "DPF" means a filter designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine.*

YANMAR has turned its own proprietary electronic control governor engine into a commercial product in 1989. The product meets the Tier 3 Standards set by the U.S. Environmental Protection Agency (EPA), pioneering the use of electronic controls over 37 kW. The electronic control application of the YANMAR-developed engine controller (hereinafter E-ECU) became available as an optional part and is made to match different customer requests.

Building upon the above achievements and experience, YANMAR provides further evolved products, support, and service that meet EPA Tier 4 Standards.

The figure below shows the electronic control systems that meet the Tier 4 Standards. In the engine categories of 19 to 56 kW, YANMAR implements the most suitable electronic control systems, employing the common rail fuel injection system (CR), exhaust gas recycle system (EGR) and Diesel Particulate Filter (DPF) for their electronic control devices in order to lower emissions.

Table 14-1 Electronic control devices for Tier 4 standards

Output range	EPA	Electronic controlled devices	E-ECU
19 - 56 kW	T4	CR + EGR + DPF	EDC17CV54 (RB)  037396-00X00

RB: Bosch

The following sections describe the system and application functions. Options of the E-ECU require to be configured by YANMAR beforehand. Please contact YANMAR for further details.

Among the harnesses to be connected to the E-ECU and engine, those connected to the sensors and actuators used for engine control are provided being connected to the engine, and those connected to other electrical equipment such as the E-ECU, and starter are prepared by users. (Refer to *Harness on page 14-28*, for details.)

Third party's industrial property

Depending on the combination with a driven machine, the application functions may conflict with a third party's industrial property. Please note that YANMAR does not warrant the product for any violation of a third party's industrial property that was caused when the customer used YANMAR supplied engine application functions in combination with their own driven machine.

Precautions for Using Electrical Component in the Control System

Electrical Components in General

Common rail engines contain a number of electrical components. Be careful of the following when handling the components. Otherwise, a failure will be caused.

- The Engine controller (hereinafter referred to as “E-ECU”) must be used in combination with the engine which has the type and the serial number specified by YANMAR. The engine performance cannot be guaranteed if the E-ECU was used in an incorrect combination.
- Never perform any applications that are not specified by YANMAR, such as replacing the E-ECU, rewriting or altering the E-ECU data, leaving failure conditions, or replacing a sensor or actuator, since they can be considered to be an act violating the law regarding exhaust gas regulations. YANMAR does not warrant the product for any misapplications.
- Do not use steam or high pressure cleaning for the engine. Otherwise, a failure will be caused.
- Avoid touching the connector pins of the electrical components directly. Otherwise, a failure will be caused.
- Use caution to avoid entry of water into couplers when connecting or disconnecting connectors. Otherwise, a failure will be caused.
- When you attach or detach connectors of the E-ECU or other electrical equipment, make sure that you turn the key switch to OFF. If the key switch is turned to ON and you touch the connector terminal, you can receive an electric shock. Also, if the key switch is turned to ON and you attach or detach the E-ECU or other electric equipment, the E-ECU or electric equipment can be damaged.

Safety Mechanisms

If the driving force necessary to run is provided by the engine, make sure that you install a stop mechanism that can cut-off the driving force and stop the vehicle (ex. a neutral gear of hydraulic transmission, a clutch). Also make sure that the stop mechanism is easy to operate by a lever or pedal.

If the E-ECU detects engine abnormalities through its engine abnormality detection or control abnormality detection functions, it will counteract by limiting the rotation speed and output or stop the engine. But you still need to establish the above safety mechanisms in order to avoid defects that cannot be prevented by the control system.

Controller and Wiring Harness

When you design an electrical system including the engine controller (E-ECU) or other electrical components, you must read *Control System on page 14-9* thoroughly and comply with the operating requirements and precautions of each device.

When you design the wiring harness, comply with the precautions in *Harness on page 14-28*.

Please complete the installation evaluation (YANMAR specification) of the E-ECU and electrical equipment after installation and make necessary improvements so that the operation conditions of each device are met.

The engine type and the engine serial number (YANMAR specified) must be used in the same combination as E-ECU and the engine. The engine performance cannot be guaranteed if the E-ECU was used in an incorrect combination.

Do not continue to use the E-ECU under an abnormal condition (when the fault indicator lamp is lit). If you continue to use the E-ECU under an abnormal condition, not only the engine performance cannot be guaranteed, but also a more serious failure can occur. Never continue to operate the engine when the fault indicator lamp is lit.

Make sure that the fault indicator lamp or other failure indicators are installed at a location where the operator can find easily.

Be sure to contact YANMAR if you want to replace the E-ECU. The injection amount adjustment data of the injector needs to be re-entered into the new E-ECU from the old one. Engine performance cannot be guaranteed if the E-ECU operates without correct injection amount adjustment data of the injector.

YANMAR genuine service tool (hereinafter referred to as SA-D: SMARTASSIST-DIRECT) should be used to perform maintenance of the injection amount adjustment data of the injector that is recorded on the E-ECU. For the maintenance procedures, refer to *the SA-D Manual*.

Never perform any applications that are not specified by YANMAR since they can result in accidents and be considered as an act violating the law regarding exhaust gas regulations. YANMAR does not warrant the product for any misapplications. (Replacing the ECU, rewriting or altering the E-ECU data, leaving failure conditions, or removing a sensor or actuator, etc.)

Do not use steam cleaning or high pressure water cleaning on the E-ECU.

Make sure that the E-ECU housing is grounded.

Connect each terminal of the E-ECU as specified in the wiring diagram. YANMAR does not warrant the product for any miswiring of EUC.

Power Wiring of the Controller

Make sure that the power wiring of the E-ECU connects directly to the positive (+) pole of the battery (this is the correct wiring shown in the diagram below). If you connect the B-terminal of the starter to the power wiring of the E-ECU (this is the wrong wiring shown in the diagram below), the voltage of the E-ECU decreases due to the resistance of the starter wiring even when the battery is charged. As a result, the E-ECU does not operate and you cannot start the engine.

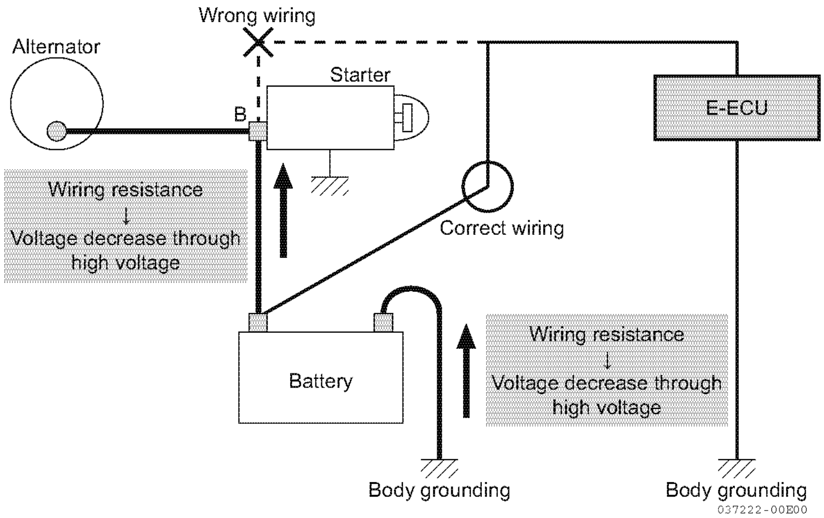


Figure 14-1 Power wiring of the E-ECU

Use a thick and short wire to connect the negative (-) pole of the battery to the body of the driven machine (body grounding). (For details, refer to *on page 13-28*) Wiring resistance can cause the E-ECU to not operate correctly. Also, make sure that the body grounding is connected to an appropriate location on the frame of the driven machine where it is not affected by the conductor resistance of the body.

Do not connect battery positive (+) and negative (-) terminals with reversed polarity. YANMAR does not warrant any reversed battery cable connection.

Common Rail System

It is necessary to collect data about the fuel injection volume control from each of the injectors individually. When you replace an injector, make sure that you update the data that is recorded inside the E-ECU with the fuel injection volume control data that is attached to the injector. For details, contact YANMAR.

Diesel Particulate Filter (DPF) System

The YANMAR DPF system continuously burns particulate matter (PM) that collects in the soot filter (SF). This process is called DPF regeneration. (For details, refer to *DPF System on page 8-10*) Also, electrical equipment (DPF differential pressure sensor, temperature sensor and suction throttle) is installed to the DPF. If the DPF cannot continuously regenerate due to low load operation, the E-ECU uses these electrical devices to prevent excessive deposits and automatically assist DPF regeneration. This is called DPF regeneration control. (For details, refer to *Diesel Particulate Filter (DPF) System Control Overview (Under Development) on page 14-107*)

At this point, because of the characteristics of the DPF system, the below conditions can occur, but are not defects.

- It may happen that the engine sound changes when the engine operates in no-load idle.
  This is caused by the (automatic) DPF regeneration control.
- It may happen that the exhaust smoke turns white immediately after a cold start or when accelerating. This is because water vapor is released. When the exhaust temperature increases, the white smoke disappears.
- It may happen that the exhaust gas smells differently from other diesel engines.
  This is because exhaust gas, that passes through the catalyst inside the DPF and is purified, smells differently.

Precautions for control of DPF regeneration

When the E-ECU controls the DPF regeneration, the EGT lamp illuminates and after the specified time passes, the suction throttle and common rail start to control the multi-stepped injection.
Accordingly, install the EGT lamp at a location that is easy to notice for the operator. When it illuminates, obey the following:

- It may happen that CO and HC are created by the multi-stepped injection of the common rail. Make sure that closed rooms are ventilated well.
- Make sure that no flammables or people are near. There is danger of fire and injury.

Lamps/switches required for stationary regeneration and precautions for operation

Even when the E-ECU controls the DPF regeneration, it may happen that particulate matter cannot burn (i.e. DPF regeneration is not possible) because the operating conditions (e.g. no-load idle or low-speed low-load operation) can change frequently. In that case, the DPF regeneration request lamp illuminates when the E-ECU judges that implementing stationary regeneration is required. When the lamp illuminates, press the interlock switch and DPF regeneration request switch because it is necessary that the E-ECU automatically controls the rotation speed and burns the particulate matter (stationary regeneration). (For details, refer to *Diesel Particulate Filter (DPF) System Control Overview (Under Development) on page 14-107*) When at this point stationary regeneration starts, as standard procedure, press the interlock switch (e.g. parking break) and operate the interlock function. But note that the interlock function is currently under development.

If you continue to operate the engine while the DPF regeneration lamp illuminates, a lot of particulate collects and burns, which may cause damage or fire. Accordingly, make sure that you install the DPF Regen Req lamp, interlock switch, and the DPF regeneration request switch at a location that is easy to access for the operator. Also obey the following instructions when you do a stationary regeneration.

- Do not do this in a badly-ventilated area. There is the danger of carbon monoxide poisoning.
- To avoid fires, make sure that there are no flammables near the exhaust outlet.
- To avoid injury, make sure that there are no people near the exhaust outlet. Also, do not touch the exhaust pipes during stationary regeneration.

Acceleration Sensor

You must connect the acceleration sensor in accordance with the wiring shown in the recommended electrical wiring diagram. In particular, you must make the power supply of the acceleration sensor to have common reference potential (GND potential) with the E-ECU, as shown in **Figure 14-2** [A].

If the E-ECU is wired with other control devices (for example, a driven machine controller) as shown in **Figure 14-2** [B] and [C], the reference potential are different between the engine controller and the driven machine controller to be used as an acceleration sensor ($V_1 \neq V_2$). This could cause excessive voltage to be applied to the engine controller's APS input or cause excessive voltage to flow through GND-A, which could cause a malfunction or failure.

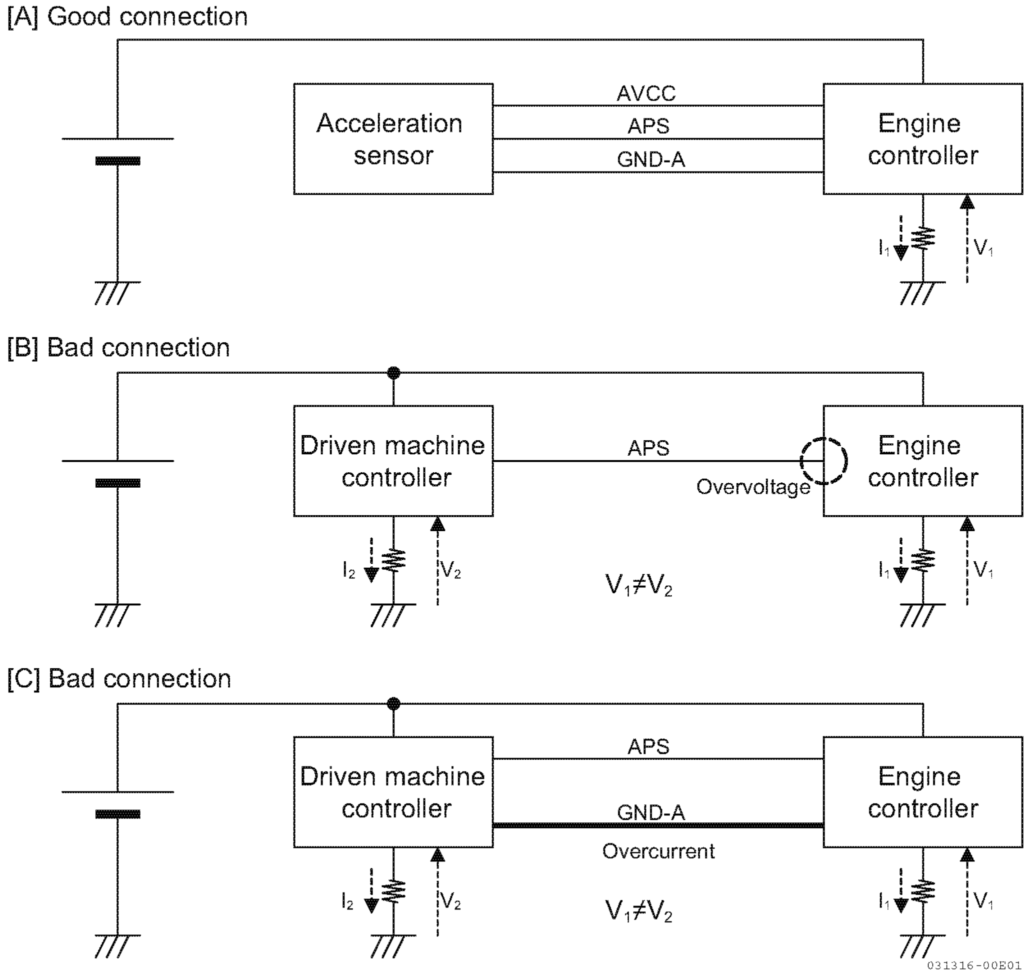


Figure 14-2 Examples of improper acceleration sensor wiring

When you use a YANMAR genuine acceleration sensor, you must read *Acceleration Sensor on page 14-135* thoroughly and comply with its operating requirements and precautions.

You must perform installation evaluations (specified by YANMAR) of the acceleration sensor and evaluate/ improve the installed driven machine to satisfy its operating requirements.

Relays

You must perform installation evaluations (specified by YANMAR) of the relays and evaluate/improve the installed driven machine to satisfy their operating requirements.

SA-D (SMARTASSIST-DIRECT)

To connect the SA-D, YANMAR genuine service tool, you must install the connector shown in **Figure 14-3** to a location that is easy to access on this device. In addition, for waterproof of the connector, engage and place the mating connector.

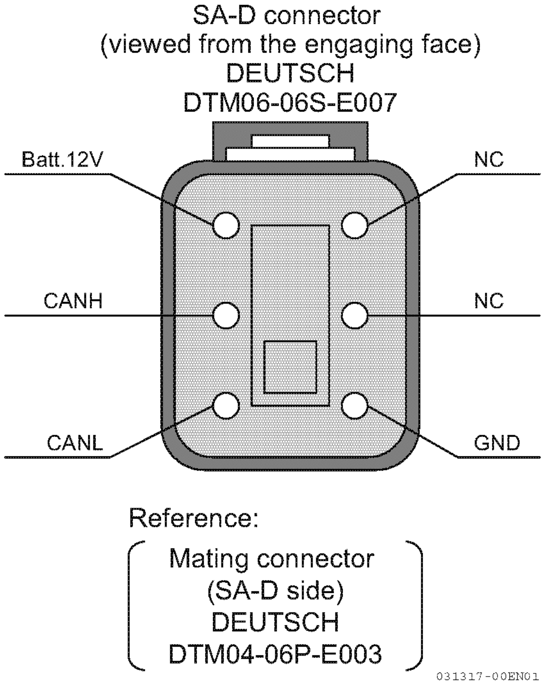


Figure 14-3 SA-D connector

Control System

System Overview

The standard electrical wiring diagram of the 3TNV88C, 3TNV86CT, 4TNV88C, 4TNV86CT, 4TNV98C, 4TNV98CT is shown in **Figure 14-4**.

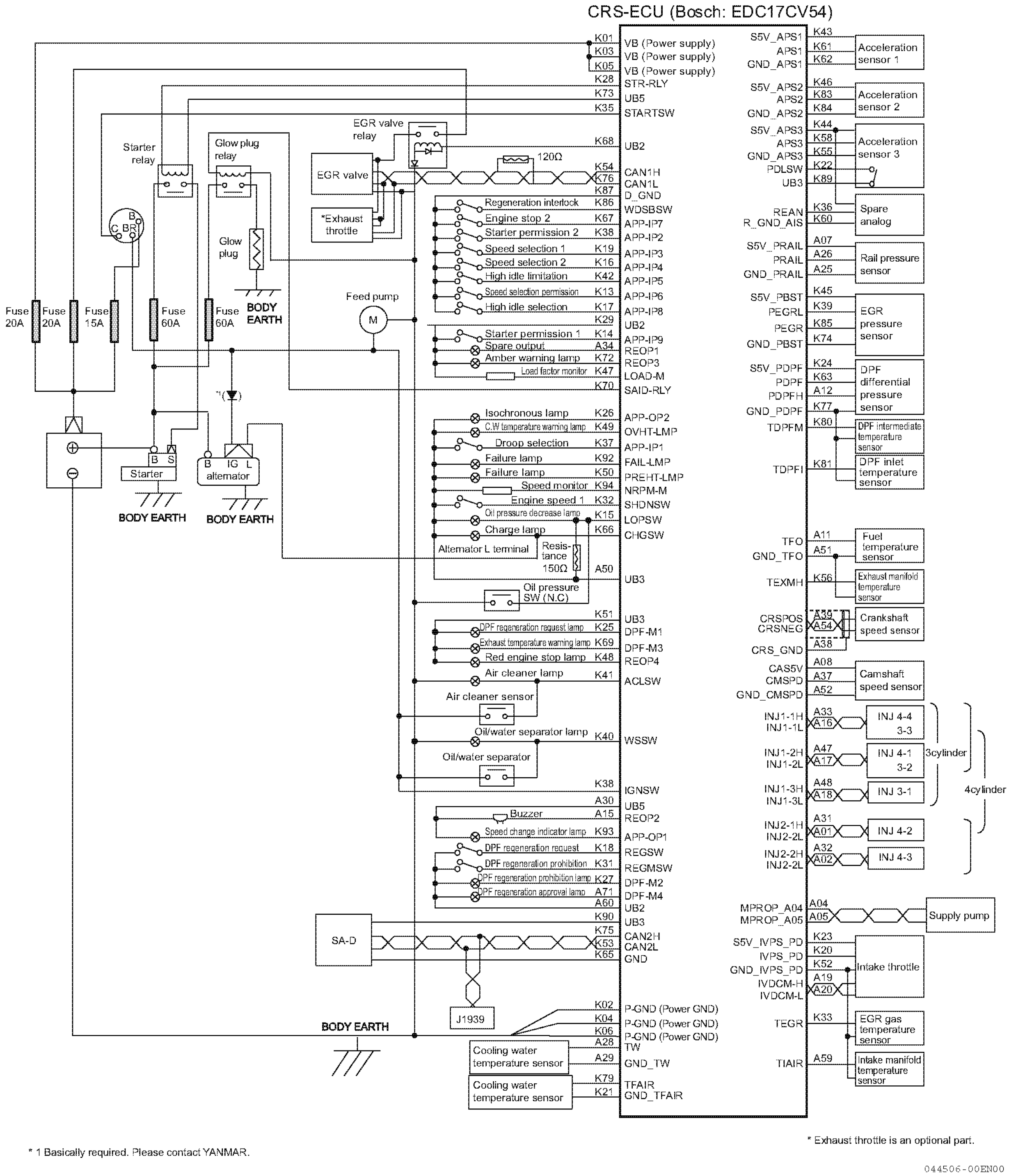


Figure 14-4 Standard electrical wiring diagram (3TNV88C, 3TNV86CT, 4TNV88C, 4TNV86CT, 4TNV98C, and 4TNV98CT)

Configurations of the temperature sensors and pressure sensors in the N/A engine and T/C engine are respectively shown in **Figure 14-5**. Those temperature sensors and pressure sensors are installed to the engine.

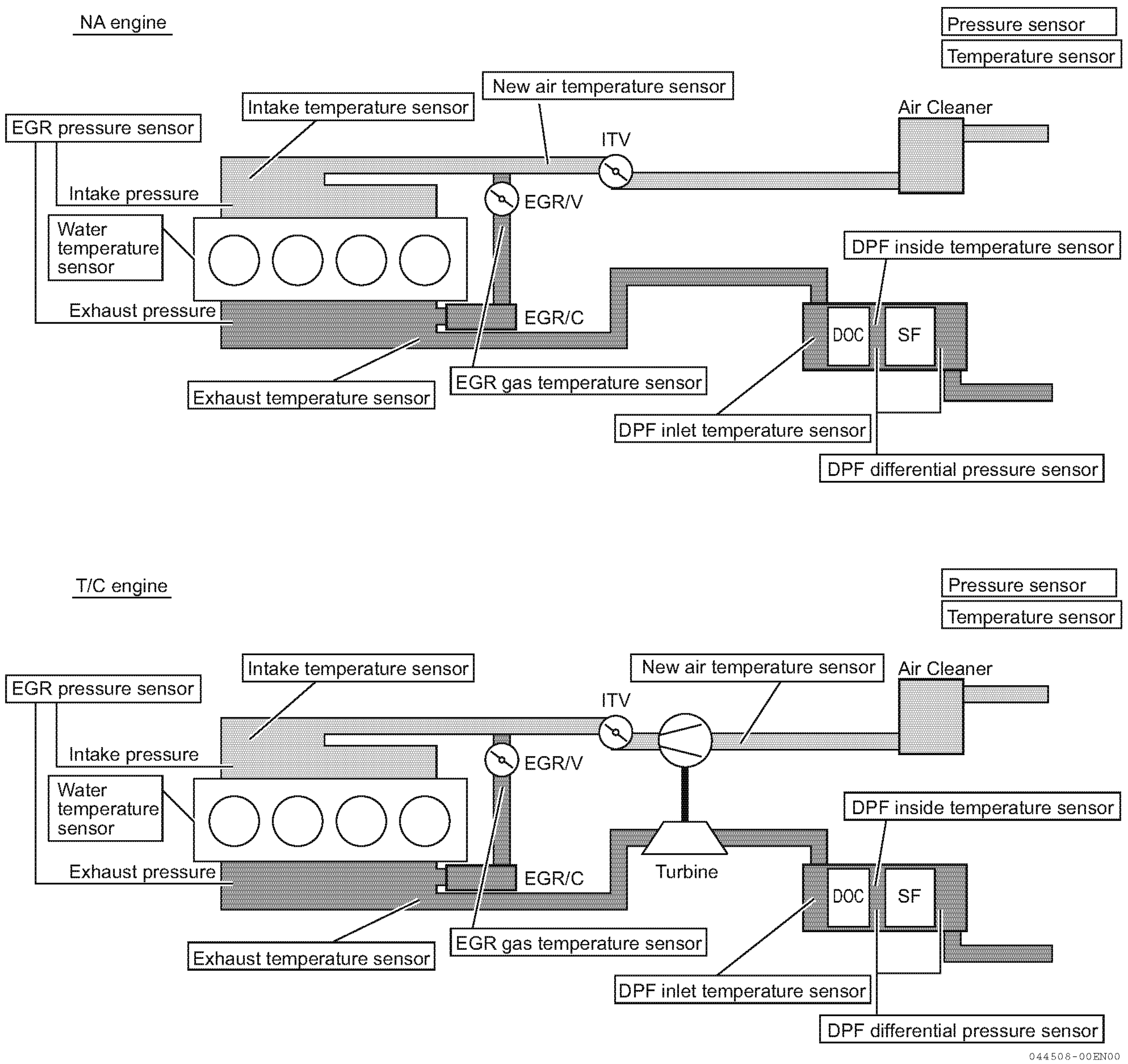


Figure 14-5 Configurations of temperature sensors and pressure sensors

The following section describes the necessity of each component shown in **Figure 14-4**.

Roles of a glow plug relay

- Reducing the circuit length
  By not wiring via the key switch, a starting aid relay prevents the circuit length between the battery and the starting aid device becoming too long. In addition, no large amount of current will flow the key switch, which allows you to use a key switch with smaller capacity.
- Starting aid control
  It controls the starting aid device including the on-glow, after-heat, and simultaneous energizing controls.

Roles of a starter relay

- Starter motor restraint
  It performs restraint of the starter motor action to prevent the engine from being started during a rack self diagnosis when turning the key ON.
- Starter motor protection
  As with a safety relay, it prevents a failure due to overrunning of the starter motor.
- Cranking control
  An option setting allows you to prevent a failure due to overcranking of the starter motor, limiting the continuous energizing duration of the starter motor.
- Synchronizing the restraint
  An option setting allows you to synchronize the starter motor restraint with the clutch pedal switch, etc.

Role of a EGR valve relay

- Turning the Key switch to OFF closes the EGR valve. It is necessary to maintain the power supply in the meantime.

Role of a fault indicator lamp

- It is used for an initial diagnosis to notify the energization state to the E-ECU or defects occurring in the common rail system to the operator.

Roles of SA-D

(The SA-D for Tier 4 engines is currently under development.)

- Confirming the control/history information
  SA-D can be used to confirm the control and history information on the E-ECU. This information is used when troubleshooting based on the service manual.
- Replacement of the injector and E-ECU
  SA-D is used to perform maintenance of the program, map, and adjustment values in the E-ECU. This is required when replacing a injector or E-ECU on the market.

Roles of an acceleration sensor

- Target speed setting
  The target speed is determined by voltage from the acceleration sensor.
- Generator specifications
  If only the rated speed is required as for a generator specification engine, the speed can be switched using a panel switch. In this case, no acceleration sensor is required.
- CAN communication
  The CAN communication can be used to instruct the target speed from the ECU on the driven machine. In this case, no acceleration sensor is required as well.

Roles of a water temperature sensor

- EGR control
  It is used for the EGR control to reduce exhaust gas. A YANMAR genuine component cannot be used in conjunction with other devices.
- Water temperature rise alarms
  A water temperature sensor can be used to generate cooling water temperature rise alarms. Upon generation of a cooling water temperature rise alarm, you can make the alarm lamp illuminate or limit engine operation actions.
- Environmental compensation
  It is used for optimization of the fuel injection pattern and governing of the engine speed depending on the operating environment.

Roles of ambient temperature sensor

- It is used for the control to optimize the fuel injection pattern depending on the operating environment.

Roles of EGR pressure sensor/intake temperature sensor/EGR temperature sensor/exhaust temperature sensor

- It is used for the EGR control to reduce exhaust gas.

Roles of DPF differential pressure sensor, intake air throttle, and DPF inlet/inside temperature sensors

- It is used to remove the particulate matter accumulated in the DPF.

Role of a panel switch and lamp

- They are used to activate an option function equipped with the E-ECU. No connection is required if you do not need to activate an option function.

Notes for the necessity to insert a diode before the alternator IG terminal

- Protection against current backflow
  Backflow of the current generated by the alternator from the alternator's IG terminal to the harness circuit side may prevent you from stopping the engine.
  In order to avoid the trouble, it is recommended that to separate the circuit of the alternator IG terminal from the rack actuator relay exciting circuit or to insert a diode to prevent current backflow from the alternator IG terminal.
- When a genuine component is used
  No diode needs to be inserted when you use a YANMAR genuine alternator (19620-77201, 129423-77200, 129961-77200, 119626-77210, or 129612-77290).

Notes for preheating

If a key switch with a glow position is used in the standard wiring diagram, the pre-heat lamp is illuminated in both the glow position and the ON position (accessory). However, please note that if preheating is not performed in the glow position, it is not necessary to perform preheating in the ON position again.

Timing of the E-ECU (Under Confirmation)

E-ECU (EDC17: Bosch)

External dimensions

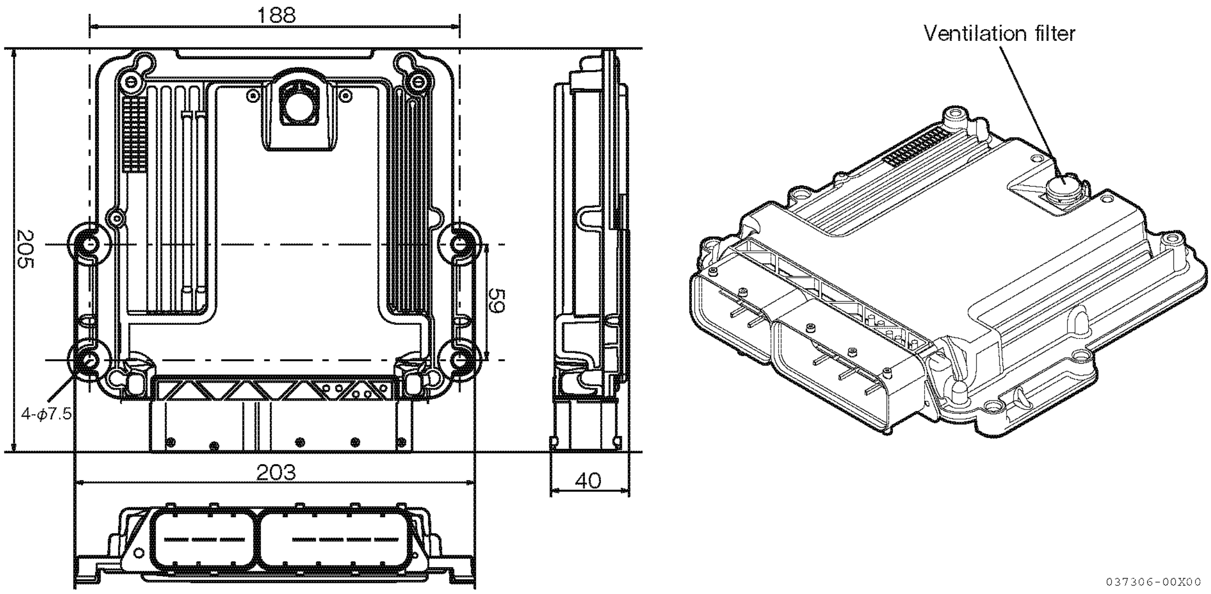
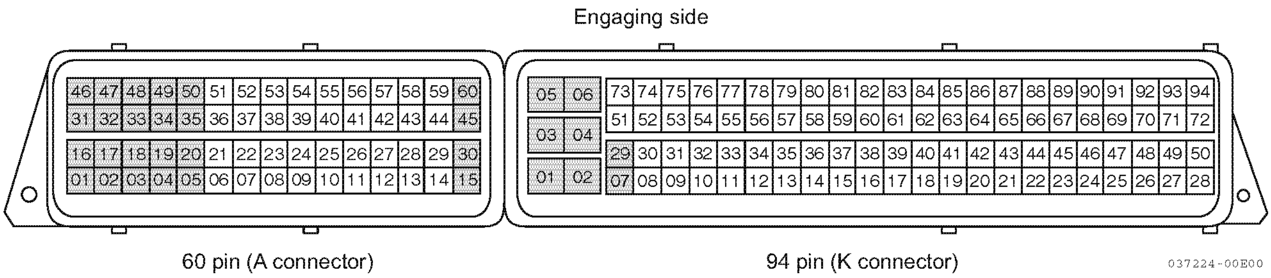


Figure 14-6 E-ECU external dimensions (EDC17: Bosch)

Notes for the circuit symbols

The pin numbers of the E-ECU are shown in **Figure 14-7**. In the standard electrical wiring diagram shown in **Figure 14-4**, a circuit symbol is indicated as by those pin numbers with an additional letter “A” or “K”.



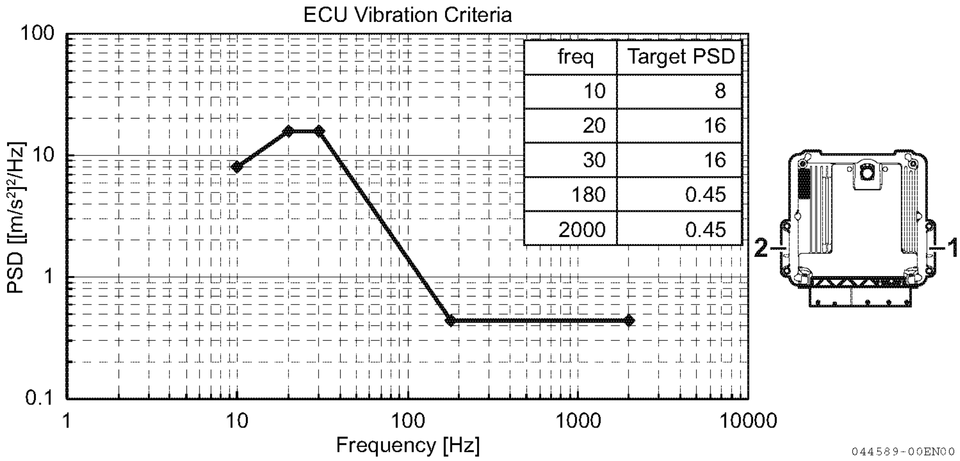
Circuit symbols are indicated as by those pin numbers with an additional letter “A” or “K”.

Figure 14-7 Pin numbers of the E-ECU connector (EDC17: Bosch)

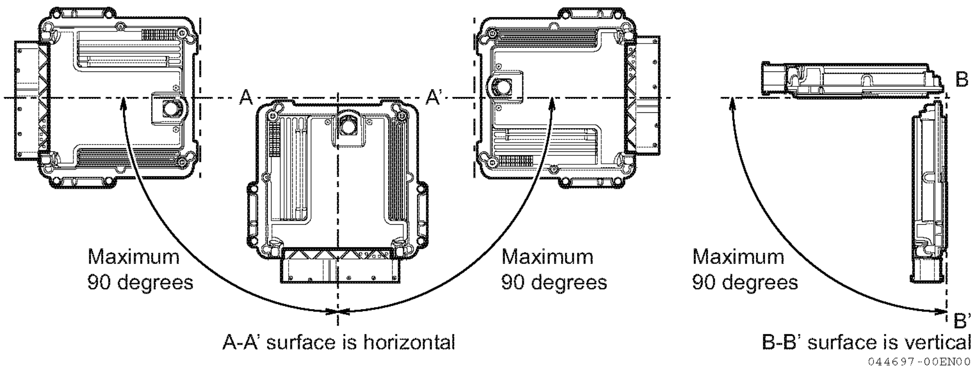
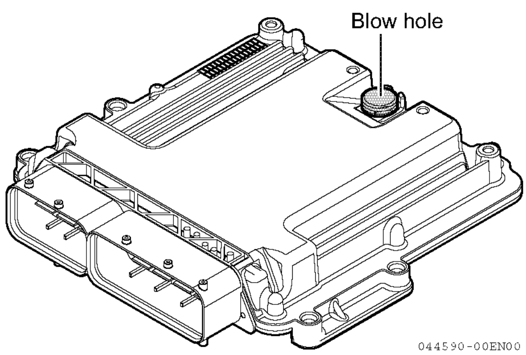
Operating requirements

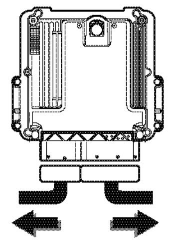
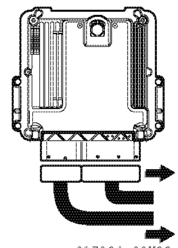
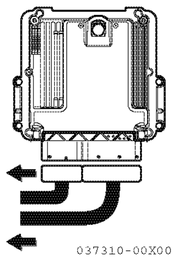
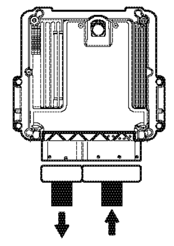
The operating requirements of the E-ECU are shown in **Table 14-2**.

Table 14-2 E-ECU specifications (EDC17: Bosch) (provisional value)

Item		Operating requirements
Rating	Rated voltage	12 V DC
	Operating ambient temperature range	-40 °C - 79 °C
	Storage ambient temperature range	-40 °C - 105 °C
Basic performance	Available voltage range	9.0 V - 32.0 V DC
	Minimum operating voltage	6.0 V DC or greater
Vibration		 The ECU vibration (an average value of (1) and (2)) shall satisfy the above PSD (Power Spectrum Density). (Please contact us separately for the measurement method.)
Water resistance	Water resistance (on connector)	• IP protection equivalent to IEC529: IP56 (JIS D0203 S2) or lower should be provided. • The connector part should not be installed upward from the horizontal plane.
Noise	Noise resistance	ISO13766: 2006 compliant (ISO7637-2: 2004)
E-ECU weight		870 g ± 5 %
Consumption current	CR system	Average: about 5 A (at 12 V)

Other precautions

Item	Description
Handling	• Do not use the E-ECU after dropping it. • Avoid touching the connector pins of the E-ECU directly. Do not disassemble them. Electrical circuits inside the E-ECU create high voltage. Be careful of electrical shocks.
Mounting parts	• Install the E-ECU to a part with good thermal conductivity and heat dissipation when exposed to circulation of the air. • Do not install it directly to the engine.
Water tightness of the ECU unit	• The water tightness of the E-ECU unit cannot be guaranteed.
Water resistance	• To avoid water intrusion if the vehicle is submerged in water, install the E-ECU as high as possible. The E-ECU has a water-proof design, but its function cannot be guaranteed when submerged in water. • Do not install the E-ECU at a place where its regularly exposed to water. • Install the E-ECU in a location that will not be exposed directly to steam or high pressure cleaning. (Water protection higher than the IP6K9K standard cannot be guaranteed.)
Installation angle	• Install the E-ECU connectors facing downward from the horizontal plane of the driven machine. Water can be trapped in the connector part and cause corrosion of the connector pins.  • We recommend the rotation and inclination shown in the figure above. Reason: This set-up prevents water drops from running down the cables and collecting inside the connector.
Protection from mud splashes	• Install a mud shield or similar in a place where the E-ECU is regularly exposed to mud splashes or similar. • Do not install the E-ECU at a place where it might be exposed to oil or fuel.
Weather resistance	• The E-ECU must be installed in a well-ventilated location where it is not exposed to direct sunlight.
Grounding of the E-ECU housing	• Do not paint the ECU installation surface on the vehicle side.
Masking	• Do not paint the E-ECU. As shown in the figure on the right, the E-ECU has a breathing hole. If this hole is blocked, the water tightness performance is deteriorated. As the E-ECU integrates the atmospheric pressure sensor, if the breathing hole is blocked, the atmospheric pressure is not detected normally. 

<table>
<tr><th>Item</th><th>Description</th></tr>
<tr><td>Removing the harness</td><td>• Remove the wire harness downwards and make sure that you pull it in the correct direction depending on the connector (refer to the figure below).
<table>
<tr><td colspan="2">Direction to remove the harness</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">E-ECU connector to other appliances</td><td>Bosch</td><td>○</td><td>○</td><td>○</td><td></td></tr>
<tr><td>Tyco</td><td>○</td><td>○</td><td></td><td>○</td></tr>
</table></td></tr>
<tr><td>Harness clamp</td><td>• Clamp the wire harness that connects the ECU close (about. 20 to 30 cm) to the ECU. Make sure that the clamp makes enough allowance.
• Correctly place the wire so that no drops run down the wire and collect in the connector.</td></tr>
<tr><td>About the required specifications by the connector manufacturer</td><td>• Follow the specifications by the connector maker about the wire harness design and the connector handling. Especially the coating affects the water proofing.</td></tr>
<tr><td>Removing the connector</td><td>• Do not remove the E-ECU connectors for about 30 seconds after turning the power supply ON or OFF.</td></tr>
<tr><td>Static electricity</td><td>• Avoid touching the connector pins of the E-ECU directly. Otherwise, corrosion or static electricity of the connector pins can damage the electrical circuits inside the E-ECU.</td></tr>
<tr><td>Corrosion</td><td>• Use caution to avoid entry of water into couplers when connecting or disconnecting connectors. Otherwise, a malfunction may be caused by corrosion of the connector pins.</td></tr>
<tr><td>Defective contact</td><td>• Do not force a measurement probe of a tester, etc. into the female coupler of the connector. Otherwise, a malfunction may be caused by defective contact of the connector pins. Do not connect (or disconnect) the connector more than 10 times. Otherwise, a malfunction may be caused by defective contact of the connector pins.</td></tr>
<tr><td>Salt water resistance</td><td>• If the driven machine is used in cold areas where salt is used on the road to prevent freezing or is used in areas near the seashore, it is assumed that the aluminum case part of the E-ECU will corrode and that a failure may occur. You must take precautions such as covering the E-ECU to prevent damage caused by salt.</td></tr>
</table>

Current consumption (under confirmation)

Notes about the alternator capacity

The average current consumption for devices that control the engine is 5 A (at 12 V).

Minimum detection speed (under confirmation)

Minimum operating voltage

Notes about the battery voltage

The minimum operating voltage of the E-ECU is 6.0 V DC. If the E-ECU power supply voltage reaches below 6.0 V, the E-ECU stops its operation. Once the power supply voltage is regained, the E-ECU is restarted from the initial condition.

For example, in case of humping and injector energization in the compression process in cranking during low temperature starting, engine start is disabled if the power voltage of E-ECU becomes 6.0 V or below even for a moment. Be sure to check the battery voltage and E-ECU power voltage.

The conditions of the E-ECU power supply voltage at engine start are shown in **Figure 14-8**.

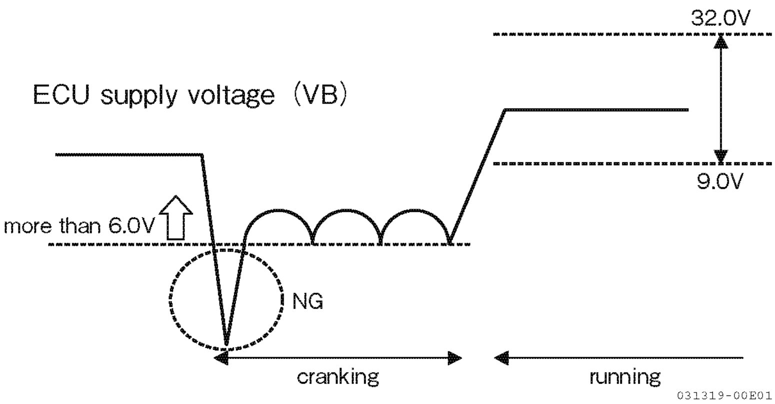


Figure 14-8 E-ECU power supply voltage conditions at engine start

Input/output specifications

Table 14-3 E-ECU terminal specifications (Bosch: EDC17C)

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I/O	Type	Pin function/name	Wiring symbol	ECU Pin No.	Description
Power supply	Input	VB	VB	K01, K03, K05	
	Output	External 12 V	UB2	K68 K29 A60	
			UB3	K89 K90 A50 K51	
			UB5	K73 A30	
		Sensor 5 V	5VS	K43 K44	Group1 5 V max150 mA
				K23 K45 K46 A08	Group2 5 V max150 mA
				K24 A07	Group3 5 V max70 mA
GND	GND	ECU GND	GND	K02, K04, K06	
	GND-P	Power GND	–	–	
	GND-C	Case GND	–	–	

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I/O	Type	Pin function/name	Wiring symbol	ECU Pin No.	Description
GND	GND-A	Analog GND	A-GND	K21 K77 K74 K52 K62 K84 K55 K60 A29 A51 A25 A52 A38	K79 A12, K63, A27, K80, K81 K39, K85 K20, A59, K33 K61 K83 K58 K36 A28 A11, K56 A26 A37 A39, A54 (Shield)
			D-GND	K65 K87	for SA-D for DigitalInput
Digital input	Low-side output	Key switch on	IGNSW	K88	Lo-side output PD = 7.6 kohm sink current = 1.6 mA @12 V
		Key switch start	STARTSW	K35	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		Engine stop 1	SHUDNSW	K32	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		DPF regeneration request	REGSW	K18	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		DPF regeneration inhibit	REGMSW	K31	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		Droop	APP-IP1	K37	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		Starter permission 1	APP-IP9	K14	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		Accel. Pedal	PDLSW	K22	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		Air cleaner sensor	ACLSW	K41	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		Water separator sensor	WSSW	K40	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V
		CAN time out	CANTO	K12	Lo-side output PD = 10 kohm sink current = 1.2 mA @12 V

I/O	Type	Pin function/name	Wiring symbol	ECU Pin No.	Description
Digital input	HI-side output	Regeneration interlock	WDSBSW	K86	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		Starter permission 2	APP-IP2	K38	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		Speed 1	APP-IP3	K19	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		Speed 2	APP-IP4	K16	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		Hi-idle limit enable	APP-IP5	K42	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		Speed selection enable	APP-IP6	K13	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		Engine stop 2	APP-IP7	K67	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		Hi-idle speed select	APP-IP8	K17	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		YMR exclusive 1	–	–	
		YMR exclusive 2	–	–	
		Alternator L terminal	CHGSW	K66	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
		LO pressure switch	LOPSW	K15	Hi-side output PU = 10 kohm (UB1) source current = 1.2 mA @12 V
Analog input	Analog input	Rail pressure	PRAIL	A26	PU VCC: 5V/V (A07) GND: GND (A25)
		Accel. Sensor 1	APS1	K61	PD = 215 kohm
		Accel. Sensor 2	APS2	K83	PD = 215 kohm
		Accel. Sensor 3	APS3	K58	PD = 100 kohm
		Reserve analog	REAN	K36	PD = 5.62 kohm
		Intake valve sensor	IVPS	K20	PD = 31.6 kohm
		DPF differential pressure sensor	PDPF	K63	PD = 215 kohm
		DPF Hi-side pressure sensor	PDPFH	A12	PU = 215 kohm
		EGR Hi-side pressure sensor	PEGR	K85	PD = 215 kohm
		EGR Low-side pressure sensor	PEGRL	K39	PD = 215 kohm
	Thermistor	CW temperature sensor	TW	A28	PU = 1277 ohm ± 1 %
		FO temperature sensor	TFO	A11	PU = 1277 ohm ± 1 %
		Fresh air temperature sensor	TFAIR	K79	PU = 1405 ohm ± 1 %
		Intake air temperature sensor	TIAIR	A59	PU = 2750 ohm ± 1 %
		EGR gas temperature sensor	TEGR	K33	PU = 2750 ohm ± 1 %
		Exhaust gas temperature sensor	TEXMN	K56	PU = 1470 ohm ± 1 %
		DPF inside temperature sensor	TDPFM	K80	PU = 1470 ohm ± 1 %
		DPF inlet temperature sensor	TDPFI	K81	PU = 1470 ohm ± 1 %
Pulse input	Pulse	Crank speed	CKSPD	A39, A54	pos: A39 neg: A54 shield: GND/G_R_CRS (A38)
		Cam speed	CMSPD	A37	VCC: 5V/V_V_5VSS2D (A08) GND: I_F_CASNEG (A52)
		Vehicle speed	VS	K34	External circuit: Lo-side PU = 3.73 kohm

I/O	Type	Pin function/name	Wiring symbol	ECU Pin No.	Description
Digital output	Relay	Main relay	–	–	Internal
		Starter relay	STR-RLY	K28	Lo-side output sink current: max 3.0 A Inductive energy proof: 18 mJ Over current protection: 3 - 6 A On resistance: 50 - 550 mohm Leak current: max 1.0 mA With fly back diode (to UB5)
		Starting aid relay	SAID-RLY	K70	Hi-side output source current: max 1.3 A Inductive energy proof: 128 mJ Over current protection: 4 - 9 A On resistance: 380 mohm Leak current: 5 uA Without fly back diode (PU UB1)
	Lamp	Failure lamp	FAIL-LMP	K92	Lo-side output sink current: max 0.6 A Inductive energy proof: 6.5 mJ Over current protection: 0.6 - 2.4 A On resistance: 0.3 - 2.4 ohm Leak current: 1.0 mA Diag. Current on/off Without fly back diode
		Pre-heat lamp	PREHT-LMP	K50	Lo-side output sink current: max 2.2 A Inductive energy proof: 4 mJ Over current protection: 2.2 - 4.0 A On resistance: 80 - 800 mohm Leak current: max 1.0 mA Without fly back diode
		CWT warning lamp	OVHT-LMP	K49	Lo-side output sink current: max 0.05 A Inductive energy proof: 0.1 mJ Over current protection: 60 - 240 mA On resistance: 1 - 12 ohm Leak current: 0.5 mA Diag. Current on/off Without fly back diode
		Speed selection lamp	APP-OP1	K93	Lo-side output sink current: max 2.2 A Inductive energy proof: 4 mJ Over current protection: 2.2 - 4.0 A On resistance: 80 - 800 mohm Leak current: max 1.0 mA Without fly back diode
		Iso-chronous lamp	APP-OP2	K26	Lo-side output sink current: max 2.2 A Inductive energy proof: 4 mJ Over current protection: 2.2 - 4.0 A On resistance: 80 - 800 mohm Leak current: max 1.0 mA Without fly back diode
		DPF regeneration request	DPF-M1	K25	Lo-side output sink current: max 2.2 A Inductive energy proof: 9 mJ Over current protection: 2.2 - 4.0 A On resistance: 80 - 800 mohm Leak current: 1.0 mA Diag. Current on/off Without fly back diode

I/O	Type	Pin function/name	Wiring symbol	ECU Pin No.	Description
Digital output	Lamp	DPF regeneration inhibit lamp	DPF-M2	K27	Lo-side output sink current: max 2.2 A Inductive energy proof: 9 mJ Over current protection: 2.2 - 4.0 A On resistance: 80 - 800 mohm Leak current: 1.0 mA Diag. Current on/off Without fly back diode
		EGT lamp	DPF-M3	K69	Lo-side output sink current: max 0.05 A Inductive energy proof: 0.1 mJ Over current protection: 60 - 240 mA On resistance: 1 - 12 ohm Leak current: 0.5 mA Diag. Current on/off Without fly back diode
		DPF regeneration acknowledge lamp	DPF-M4	K71	Lo-side output sink current: max 2.2 A Inductive energy proof: 9 mJ Over current protection: 2.2-4.0 A On resistance: 80 - 800 mohm Leak current: 1.0 mA Diag. Current on/off Without fly back diode
		Reserve	REOP1	A34	Lo-side output sink current: max 2.2 A Inductive energy proof: 18 mJ Over current protection: 2.2 - 4.0 A On resistance: 80 - 800 mohm Leak current: max 1.0 mA Without fly back diode
		Buzzer	REOP2	A15	Lo-side output sink current: max 3.0 A Inductive energy proof: 18 mJ Over current protection: 5.5 - 10 A On resistance: 50 - 550 mphm Leak current: max 1.0 mA With fly back diode (to UB5)
		Amber warning lamp	REOP3	K72	Lo-side output sink current: max 2.2 A Inductive energy proof: 9 mJ Over current protection: 2.2 - 4.0 A On resistance: 80 - 800 mohm Leak current: 1.0 mA Diag. Current on/off Without fly back diode
		Red engine stop lamp	REOP4	K48	Lo-side output sink current: max 0.6 A Inductive energy proof: 6.5 mJ Over current protection: 0.6 - 2.4 A On resistance: 0.3 - 2.4 ohm Leak current: 1.0 mA Diag. Current on/off Without fly back diode

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<table>
<tr><th>I/O</th><th>Type</th><th>Pin function/name</th><th>Wiring symbol</th><th>ECU Pin No.</th><th>Description</th></tr>
<tr><td rowspan="3">Plus output</td><td rowspan="2">Monitor</td><td>Speed monitor</td><td>NRPM-M</td><td>K94</td><td>Lo-side output
sink current: max 2.2 A
inductive energy proof: 18 mJ
Over current protection: 2.2 - 4.0 A
On resistance: 80 - 800 mohm
Leak current: max 1.0 mA
With fly back diode (to UB3)</td></tr>
<tr><td>Load ratio monitor</td><td>LOAD-M</td><td>K47</td><td>Lo-side output
sink current: max 2.2 A
Inductive energy proof: 4 mJ
Over current protection: 2.2 - 4.0 A
On resistance: 80 - 800 mohm
Leak current: max 1.0 mA
With fly back diode (to UB2)</td></tr>
<tr><td>DC motor</td><td>Intake valve motor</td><td>IVDCM-H, L</td><td>A19, A20</td><td>H-Bridge circuit
Output current: max 4.0 A</td></tr>
<tr><td rowspan="5">CRS</td><td rowspan="5">Solenoid</td><td>Injector H</td><td>INJH1 - 4</td><td>A33, A47,
A31, A32,
A33, A47,
A48</td><td>4 cylinder
3 cylinder</td></tr>
<tr><td>Injector L</td><td>INJL1 - 4</td><td>A16, A17,
A01, A02,
A16, A17,
A18</td><td>4 cylinder
3 cylinder</td></tr>
<tr><td>SCV H</td><td>MPROP-H</td><td>A04</td><td>source</td></tr>
<tr><td>SCV L</td><td>HPPSOL</td><td>A05</td><td>sink</td></tr>
<tr><td>Reserve</td><td>DUMLD</td><td>A35</td><td>Lo-side output
sink current: max 3.0 A
Inductive energy proof: 18 mJ
Over current protection: 3.6 - 6.0 A
On resistance: 50 - 550 mohm
Leak current: max 1.0 mA
With fly back diode (to UB2)
PU to A45</td></tr>
<tr><td rowspan="4">Communication</td><td rowspan="2">CAN1</td><td>CAN-H1</td><td>CAN1H</td><td>K54</td><td rowspan="2">Terminator: 120 ohm
Bus rate: 500 kbps</td></tr>
<tr><td>CAN-L1</td><td>CAN1L</td><td>K76</td></tr>
<tr><td rowspan="2">CAN2</td><td>CAN-H2</td><td>CAN2H</td><td>K75</td><td rowspan="2">Terminator: 120 ohm
Bus rate: 250/500 kbps</td></tr>
<tr><td>CAN-L2</td><td>CAN2L</td><td>K53</td></tr>
</table>

Note: Each terminal acts according to its function(s) specified in the control specifications described later. It is not allowed to use them for any other action purposes.

Electrical Components

Table 14-4 Electrical component list of the YANMAR electrical control system (YANMAR genuine component*2)

Component	Function	Setting*1	EDC17 E-ECU
Supply pump (129A00-51000)	Fuel injection control	◉	○
Fuel temperature sensor (129A00-51000)	Fuel injection control	◉	○
Rail pressure sensor (3 cylinder engine: 129A00-57000) (4 cylinder engine: 129C00-57000)	Fuel injection control	◉	○
Crank rotation sensor (129A00-21710)	Engine control	◉	○
Cam speed sensor (129A00-14710)	Engine control	◉	○
Cooling water temperature sensor (129927-44900)	Engine control (Use only for engine control)	◉	○
New air temperature sensor (129A00-12710)	Engine control	◉	○
Intake temperature sensor (129A00-12720)	Engine control	◉	○
EGR temperature sensor (129A00-13750)	Engine control	◉	○
Exhaust temperature sensor (129A00-13760 (representative))	Engine control	◉	○
DPF intermediate temperature sensor (529A00-13980)	DPF regeneration control	◉	○
DPF inlet temperature sensor (529A00-13990)	DPF regeneration control	◉	○
DPF differential pressure sensor (129A00-17700)	DPF regeneration control	◉	○
EGR pressure sensor (129A00-12700)	EGR control	◉	○
EGR valve (3TNV88C: 3TNV86CT: 129A00-13900) (4TNV88C: 4TNV86CT: 129C00-13900) (4TNV98C: 4TNV98CT: 129E00-13900)	EGR control	◉	○
Intake throttle (129A00-12900)	DPF regeneration control	◉	○
Exhaust throttle (529C00-13510)	DPF regeneration control	○*3	
Glow plug (e.g., 119803-77830)	Cold start	◉	○
Oil pressure SW (119761-39450)	• Oil pressure alarm/indication (acts under abnormal conditions) • Lamp should be installed together even when E-ECU is connected (lamp equiv. load is also acceptable)	◉	○
Diesel fuel pump (119225-52102)	• Fuel supply • Automatic air bleeding	◉	○

Table 14-5 Electrical component list of the YANMAR electrical control system (general-purpose component*2)

Component	Function	Setting*1	EDC17 E-ECU
Alternator (e.g., 129423-77200)	• Battery charge • Charge alarm/indication (ECU connection is option)	◉	○
Starter (e.g., 129900-77010)	Engine startup	◉	○
Acceleration sensor (129938-77800)	• Target engine speed instructions • Optional for generator specification	○*5	○
Starter motor relay (129927-77920)*4	• Starter motor restraint • Connector: Yazaki 7223-6146-30 (recommended) Bracket for the above connector: 129927-77910	◉	○
Glow plug relay (e.g., 129927-77920)*4	• On-glow control, etc. • Connector: Yazaki 7223-6146-30 (recommended) Bracket for the above connector: 129927-77910	◉	○
EGR valve relay (198461-52950)	Power supply self-hold	◉	○
Failure lamp (124732-77720)	• E-ECU action indication • E-ECU abnormality indication	◉*6	○
Oil pressure lamp (No setting)	Oil pressure drop indication	△	○
Charge lamp (No setting)		△	○
Air cleaner lamp (No setting)	Air cleaner clogging alarm/indication (acts under abnormal conditions)	△	○
Water separator lamp (No setting)	Water separator alarm/indication (acts under abnormal conditions)	△	○
Isochronous lamp (No setting)	Isochronous control indication	△	○
CWT lamp (No setting)	Water temperature abnormality indication	◉	○
DPF Regen Req lamp (No setting)	DPF regeneration request indication	◉	○
DPF Regen Ack lamp	DPF regeneration acknowledgement indication	◉	○
DPF Regen inhibit lamp (No setting)	DPF regeneration inhibit indication	△	○
EGT lamp (No setting)	Exhaust temperature abnormality indication	◉	○
Speed selection lamp (No setting)	Speed change indication	◉	○
Buzzer (No setting)	Alarm for DPF regeneration control (under development)	△	○
Amber warning lamp (No setting)	Indications for stationary regeneration standby and ash cleaning request	△	○
Red engine stop lamp (No setting)	Indication in backup mode	△	○
Preheat lamp (No setting)	On-glow and preheat indications	△	○
DPF regeneration request SW (No setting)	• Stationary regeneration start request Refer to *Diesel Particulate Filter (DPF) System Control Overview (Under Development)* for details	◉	○
DPF regeneration inhibit SW (No setting)	• For reset/stationary regeneration inhibit operations Refer to *Diesel Particulate Filter (DPF) System Control Overview (Under Development)* for details	△	○
Regeneration interlock SW (No setting)	• For actuating interlock function (upon stationary regeneration start request) Refer to *Diesel Particulate Filter (DPF) System Control Overview (Under Development)* for details	◉	○
Air cleaner (w/sensor) (e.g., 129601-12610)	• Air cleaner clogging alarm/indication (acts under abnormal conditions) • Lamp should be installed together	△ Customer selectable if sensor equipped	○
Harness (e.g., 529A00-91111. Refer to Harness.)	• Electrical component connection • SA-D connection (German DTM connector)	◉	○
Key switch (194215-52110)	• For glow position control • On-glow use is option	○	○

*1: *The electrical components of the YANMAR electrical control system are configured as follows:*
◉: Standard component
O: Recommended option component
△: Option component

*2: *The engine performance cannot be guaranteed for any components other than YANMAR genuine component. General-purpose components can be used, provided that the component specifications provided by YANMAR should be satisfied.*

*3: *Standard part depending on the specification.*

*4: *YANMAR genuine glow plug relays and starter motor relays do not have mounting brackets. Brackets (129927-77910) for ISO relay connectors (Yazaki: 7223-6146-30) are configured.*

*5: *No acceleration sensors are configured in the standard setting of the standard generator specification. In this case, speed can be switched by the switches attached to the APP-IP3 and APP-IP4 terminals of the E-ECU.*

*6: *Install the defect lamps and DPF regeneration request lamps at a place that is easy to check for the operator.*

*7: *Parts of the harness are YANMAR genuine parts. For details, refer to Harness on page 14-28.*

Notes for the electrical specifications required for general-purpose components

If CR system components are configured by the customer (i.e., if YANMAR genuine components are not used), those components must meet the requirements in **Table 14-6**, at the very least. If these requirements are not satisfied, engine performance may be affected or a failure of the E-ECU may occur.

Table 14-6 Electrical specifications required for general-purpose components

Component	Required electrical specifications
Acceleration sensor input	• Sensor output voltage: 0 - 5 V (standard setting: 0.7 V (min. speed) to 3.0 V (max. speed)) • Sensor's recommended available range is from 10 % to 80 % (input voltage: 0.5 - 4.0 V). *The E-ECU detects sensor abnormalities when sensor input voltage is ≤ 0.2 V or ≥ 4.6 V. • For resistor type potentiometers: ≥ 2.0 kΩ (5.0 kΩ is recommended) • For Hall type position sensors: current consumption ≥ 10 mA (5 V)
Starter motor relay	Contact: Normally open (“a” contact) Rated voltage: 12 V DC Rated load current: 12 V DC/40 A or above - 30s Instantaneous load current: 12 V DC/100 A or above Coil current: 12 V DC/300 mA or lower Coil inductance: 200 mH or lower Action delay time: 20 ms or lower Electrical open/close lifetime: 100,000 times or more Other performance should meet the installation environment requirements.
Glow plug relay	Contact: Normally open (“a” contact) Rated voltage: 12 V DC Rated load current: 400 W: 12 V DC/40 A or above - 30 min (at 30 °C) 500 W: 12 V DC/50 A or above - 4 min (at 30 °C) 800 W: 12 V DC/80 A or above - 4 min (at 30 °C) 1000 W: 12 V DC/90 A or above - 4 min (at 30 °C) Coil current: 12 V DC/1.0 A or lower Coil inductance: 200 mH or lower Electrical open/close lifetime: 100,000 times or more Other performance should meet the installation environment requirements.
Lamp (e.g. defect lamp)	Lamp load: 12 V - 3.4 W or lower Inrush current: 12 V/3 A-10 ms or lower
Harness	Requirements of the separately provided standard wiring diagram should be satisfied. (Parts of the harness are YANMAR genuine parts. For details, refer to *Harness on page 14-28.*)
Air cleaner (sensor SW)	The following requirements for the switch should be satisfied. • Contact type: Normally open (“a” contact) • The maximum allowable current for the contact shall be 20 mA or higher. • The minimum available current should be 10 mA or lower. (A gold plated contact is recommend-ed.)
Key switch	No circuit instantaneous interruption to the ON terminal power supply should occur when the key is turned from ON to START.

Note: The above requirements are the required electrical specifications for connection to the E-ECU, which does not offer YANMAR's quality assurance for customer-configured components.

Table 14-7 Requirements for customer-configured electrical components

Component	ECU connection terminal No.	Requirements
Load factor monitor	LOAD-M	Resistance load: Pulled up to 12 V power supply Maximum current: 12 V DC/200 mA or above ON voltage: 1.5 V or lower OFF voltage: Power supply voltage
Speed monitor	NRPM-M	
Shutdown switch 1	SHUDNSW	The following requirements for the switch should be satisfied. • Contact type: Normally open (“a” contact) for standard; Normally close (“b” contact) for option • The maximum allowable current for the contact shall be 20 mA or higher. • The minimum available current should be 10 mA or lower. (A gold plated contact is recommended.)
Shutdown switch 2	APP-IP7	
Droop selection SW	APP-IP1	
Starter motor permission SW 1	APP-IP9	
Starter motor permission SW 2	APP-IP2	
Speed selection SW 1	APP-IP3	
Speed selection SW 2	APP-IP4	
High idle selection SW	APP-IP5	
Speed selection permission SW	APP-IP6	
High idle selection SW	APP-IP8	
DPF regeneration request SW	REGSW	
DPF regeneration prohibition SW	REGMSW	
Regeneration interlock SW	WDSBSW	

Harness

For the standard wiring and standard harness diagrams, refer to the table below.
The standard harness has 3 cables combined in one set. For a design chart, refer to the diagram below.
For details, refer to the below tables Standard Circuit and Standard Harness.

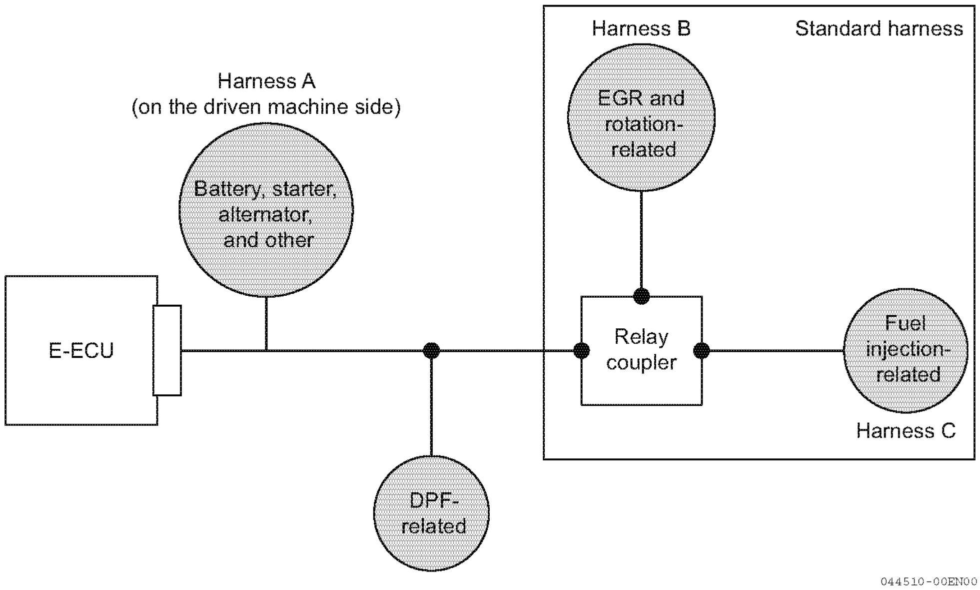


Figure 14-9 Standard harness design chart

YANMAR can supply the harnesses B and C that are shown in the below diagram, but we do not supply harnesses customized for each customer. YANMAR can supply the harnesses A (on the driven machine side) as genuine YANMAR parts, but we do not supply harnesses customized for each customer.

The engine performance has been confirmed by YANMAR using this standard harness. Therefore, if the harnesses A (on the driven machine side) are prepared by the customer, the harness design must be performed according to the standard wiring and standard harness diagrams.

Table 14-8 Standard circuit and standard harness

Engine model	Harness diagram	Connection diagram
3TNV88C	A: 529A00-91111 B: 529A00-91221 C: 529A00-91231	JAP: E5-29A00-0111 ENG: E5-29A00-0121
3TNV86CT		
4TNV88CT	A: 529C00-91111 B: 129C00-91220 C: 129C00-91230	JAP: E5-29C00-0111 ENG: E5-29C00-0121
4TNV86CT		
4TNV98C	A: 529C00-91111 B: 529E00-91221 C: 529E00-91231	
4TNV98CT		

Relay Coupler

The relay coupler that mounts harness B, harness C and harness A shall be clamped. There are two clamping methods.

- Standard type
  Clamp the relay coupler to the brackets on the engine.
  For the position of the clamp for the relay coupler, refer to **Figure 14-10**.
  Clamp the harness A (on the driven machine side) about 100 to 200 mm to the engine as shown in **Figure 14-10**.
- Long type
  The relay couplers are located at a remote place.
  When using harnesses B and C of long type, clamp the relay couplers on the driven machine side. (Refer to **Figure 14-11**.)

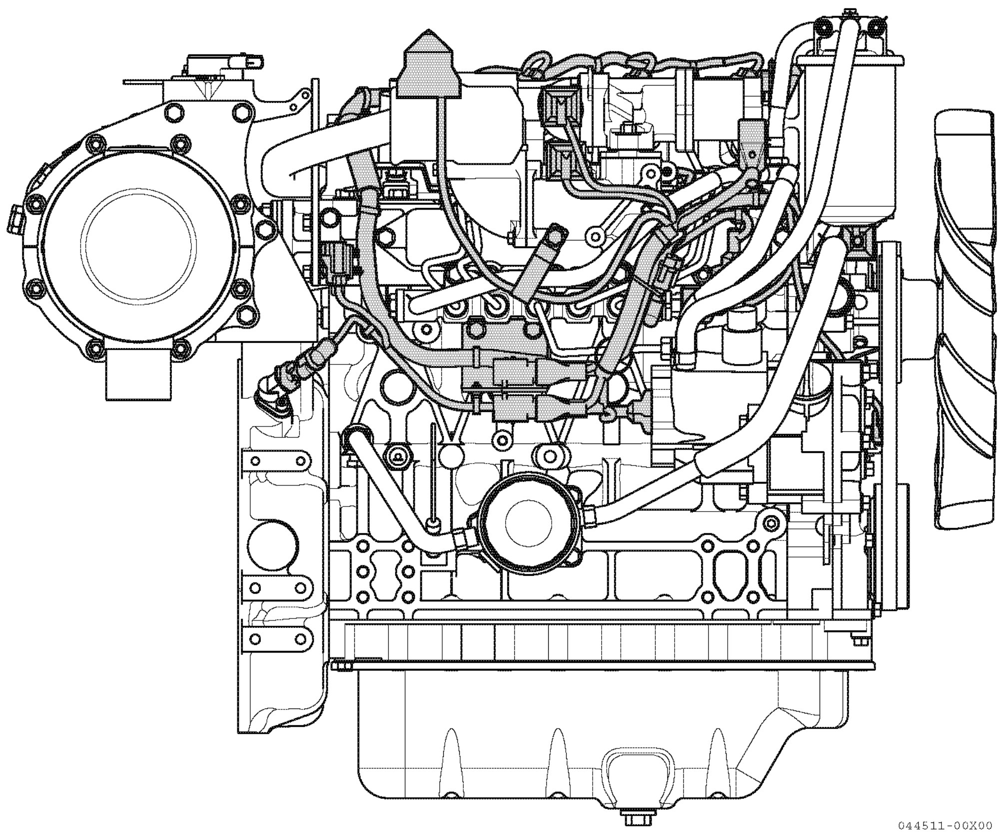


Figure 14-10 Relay coupler clamp positing (standard type)

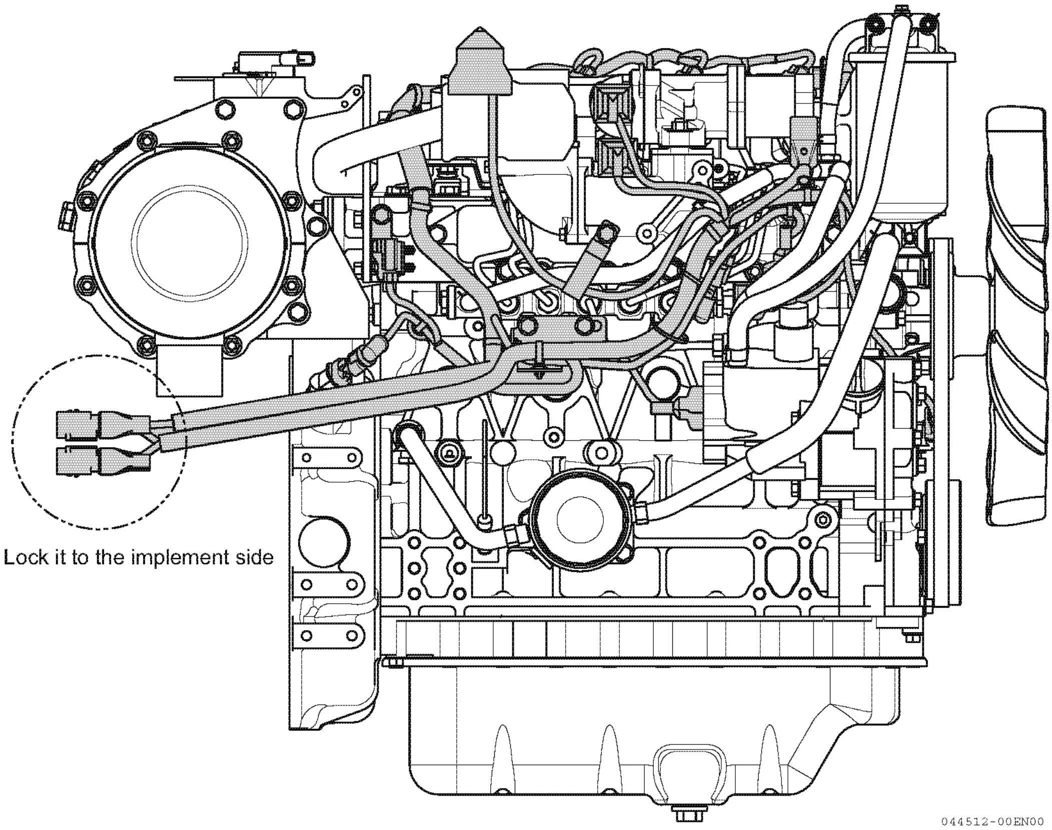


Figure 14-11 Relay coupler clamp positing (long type)

Harness Design Conditions

Be sure to comply with the following notes: Otherwise, the engine performance may be affected and a malfunction or failure may be caused.

ECU wiring

Power supply wires

- Battery cable
  For the selection of the battery cable, refer to *on page 13-28*.
  Adjust the battery cable length to prevent reverse connection.
  Prevent the battery cable from getting loose and the battery from switching off while the engine is running.
- Single point grounding for GND
  The GND terminal should be grounded to a single point and connected directly to the battery (-) terminal cable or battery (-) terminal cable.
- Potential difference
  Make sure that the potential difference between the E-ECU GND terminal and the battery GND, and between the E-ECU power supply and the battery is less than 1 V.
- Starter cable
  For the selection of the starter cable, refer to *Starter Solenoid Cable Selection on page 13-30*.
- Alternator
  Do not attach load to the alternator L and P terminals that is not specified. It is forbidden to attach other loads than those specified by YANMAR without consent by YANMAR.
  Separate the alternator IG terminal (K88A) from the ECU terminal (K88B) or connect a diode to it.

- Alternator B terminal
  Do not remove the battery terminal and the B terminal during alternator operation.
  Make sure that the electrical resistance of the B terminal cable is less than 5/100 Ω.

Other wires

- CAN communication wires
  Use a twisted pair wire for the CAN communication. The wire must be within a maximum of 40 m long. Otherwise a malfunction due to noise is likely to occur. The pitch of the twisted pair wire must be a maximum of 25 mm.
- Injector wire
  Use a twisted pair wire for the injector. Make sure that the total resistance of the injector wire is less than 15/100 Ω.
  The total resistance is a sum of that on the injector wire from the ECU coupler to the relay coupler on positive (+) and negative (-) sides respectively. The pitch of the twisted pair wire must be a maximum of 25 mm.
- Supply pump
  Use a twisted pair wire for the supply pump.
  The pitch of the twisted pair wire must be a maximum of 25 mm.
- Crank rotation sensor
  Use a shielded twisted pair wire for the crank rotation sensor.
- ECU terminal
  Obey the standard connection diagram for all ECU terminals, except those that connect to optional parts.

Load

- Key switch power supply
  No load other than the one shown in **Figure 14-4** *Standard Electrical Wiring Diagram* should be connected to the E-ECU IGNSW terminal.
  Current leakage may prevent the engine from cutting off the E-ECU power supply.
- Lamp load
  The maximum lamp load that can be connected to the E-ECU is 12 V/3.4 W.
- Contact current
  For the minimum contact current that is connected to the E-ECU, refer to **Figure 14-4**.
- Lamp attachment position
  Make sure that the fault indicator lamp is attached to a position that can easily be seen by the operator.
- Water temperature sensor
  No other load should be connected to the water temperature sensor of the E-ECU. Otherwise, the EGR control may not function properly, which can affect the cold startability and engine durability.
- Oil pressure switch
  If the oil pressure switch (119761-39450) is connected directly to the E-ECU for avoidance control in the event of a oil pressure trouble, either connect a dummy load so that 0.1 A or more contact current flows or use a pressure switch with a low contact current specification (for example, 124298-39450).
- Load connection precaution
  Do not connect any load, that is not specified in the standard harness diagram or that is outside the range of the specifications in this manual, to the E-ECU terminals.

Glow plug wiring

- Electrical resistance of the glow plug wire
  The total electrical resistance of the glow plug wire must be less than 5/1000 Ω.

Key switch

- Instantaneous power interruption
  Be sure to select a key switch that does not allow the E-ECU power supply circuit (the circuit between the B and BR terminals) to open anywhere between the ON position and START position. Instantaneous power interruption of the E-ECU power supply, for equal to or longer than 10 ms, may cause a defect such as an engine speed fluctuation or engine stall.
  Take care since the key switch is likely to produce the above defects at cold start.

General

- Wires and fuses
  Be sure to comply with the wire type, conductor cross-sectional area, and fuse capacity as specified in the standard wiring diagram.
- Heat resistance
  You must use wires with heat resistance that fits the ambient temperature of the environment in which the engine will be used.
- Mating precaution
  When mating connectors, use caution to avoid entry of water into the couplers.
- Clamping precaution
  You must clamp the harness at appropriate positions so that it will not be shaken by vibration.
- Clamping precaution
  You must clamp the harness making enough allowance to prevent any tension.
- Joint parts
  It is recommended to make the joint parts waterproof using joint couplers, butyl tape, etc.
- Surges on a misuse
  Make sure that no surge current or voltage is caused under a normal operation or expected misuse.
- Instantaneous interruption on a misuse
  Make sure that no instantaneous interruption of the power supply voltage (equal to or less than 6.0, for equal to or longer than 1 ms) is caused under a normal operation or expected misuse.
- Measurement probes
  Do not force a measurement probe, such as those of a tester, into a female coupler.

CAN Bus Termination

The E-ECU has a built-in 120 Ω CAN terminator.

Control Functions

Structure of the Control Functions

The system overview of the electronic control system for Tier 4 is shown in **Figure 14-12**.

The engine controller (E-ECU) software can be roughly divided into functions as shown below.

1. Driver : The portion that connects the hardware with the software
2. Diagnosis function : The failure diagnosis portion for the engine or other control devices
3. Communication function : The communication portion with a checker or other ECUs
4. Engine control function : The fuel injection control and EGR control by the common rail system (CRS)
5. Application function : The driven machine application functions such as the engine speed instruction (acceleration), starter control, starting aid function (glow plug), and interface portion with the device (CAN communication, switches, and lamps)
6. DPF system control function : The PM detection and DPF regeneration control (intake air throttle control, multi-stage injection) portions

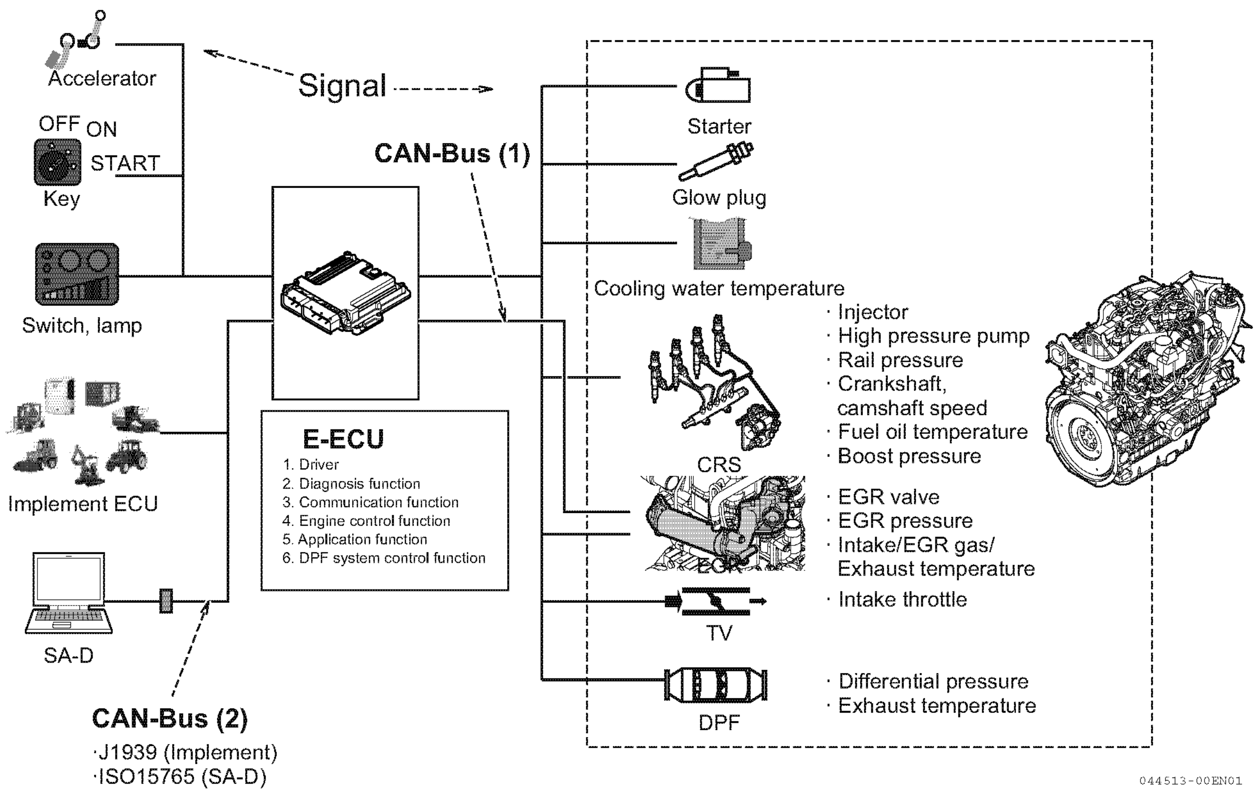


Figure 14-12 System overview of electronic control system for Tier 4

General Control

Water temperature sensor inputs

Input voltages ranging from 0 to 5 V are converted to AD values ranging from 0 to 1023.

The accuracy of the cooling water temperature sensor (129927-44900) is ± 3 °C (at 0 °C), ± 2 °C (at 20 °C), and ± 2 °C (at 110 °C). The water temperature rise warning function with the water temperature sensor is configured as standard and traditional water temperature switches (for example, 121250-44901) are no longer configured.

NOTICE

Use only the YANMAR genuine water temperature sensor for the TW terminal of the E-ECU.
*The E-ECU converts input voltages to temperatures with a map. Connecting a thermistor with different characteristics or connecting another load to the thermistor circuit will disturb the relationship between input voltages and temperatures, making it impossible to detect a correct temperature.

Contact Input

Contact input of the E-ECU include high-side input and low-side input as shown in **Figure 14-13**. For the sink current and the source current of the contact input, refer to *E-ECU terminal specifications on page 14-17*. The power supply of high-side input must be taken from the specified UB terminal. For the details of the harness connections, refer to *Standard Circuit and Standard Harness in* **Table 14-8**.

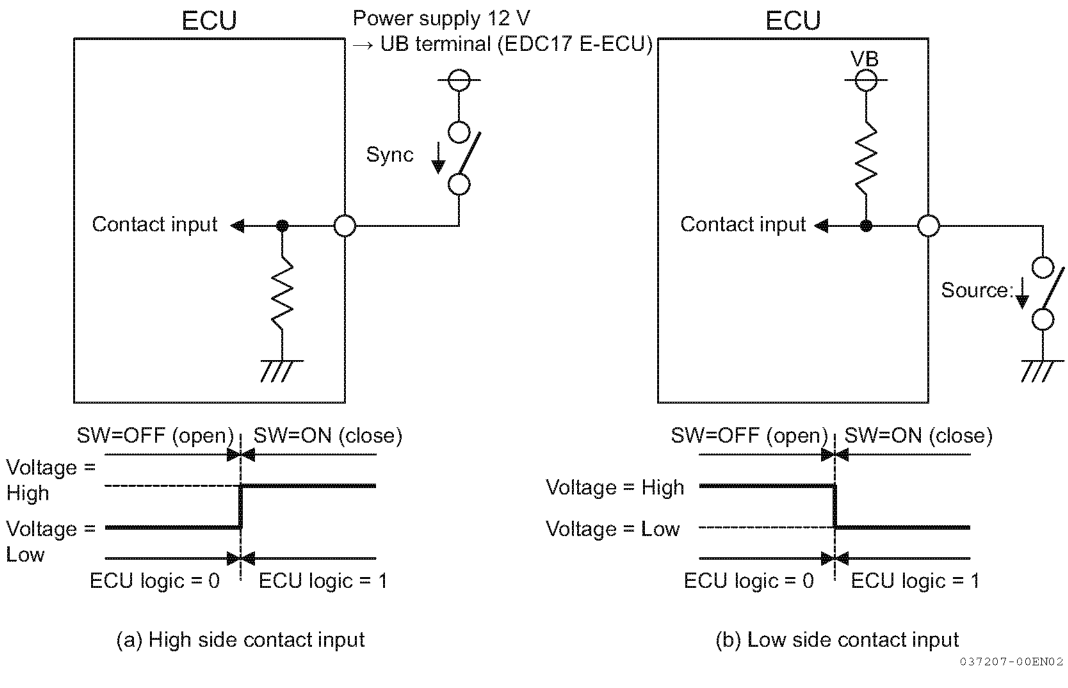


Figure 14-13 Contact input circuits and input logic

- Types of contact input
  Switches (hereinafter called “SW”) connected to contact input include the Normally Open type (hereinafter called “NO”) and the Normally Close type (hereinafter called “NC”).
- High-side contact input
  Figure 14-14 shows the difference of the input terminal voltage level by the SW types of a high-side contact input.
  For NO: SW ON (Close) → High level (the input terminal voltage)
  For NC: SW ON (Close) → Low level (the input terminal voltage)

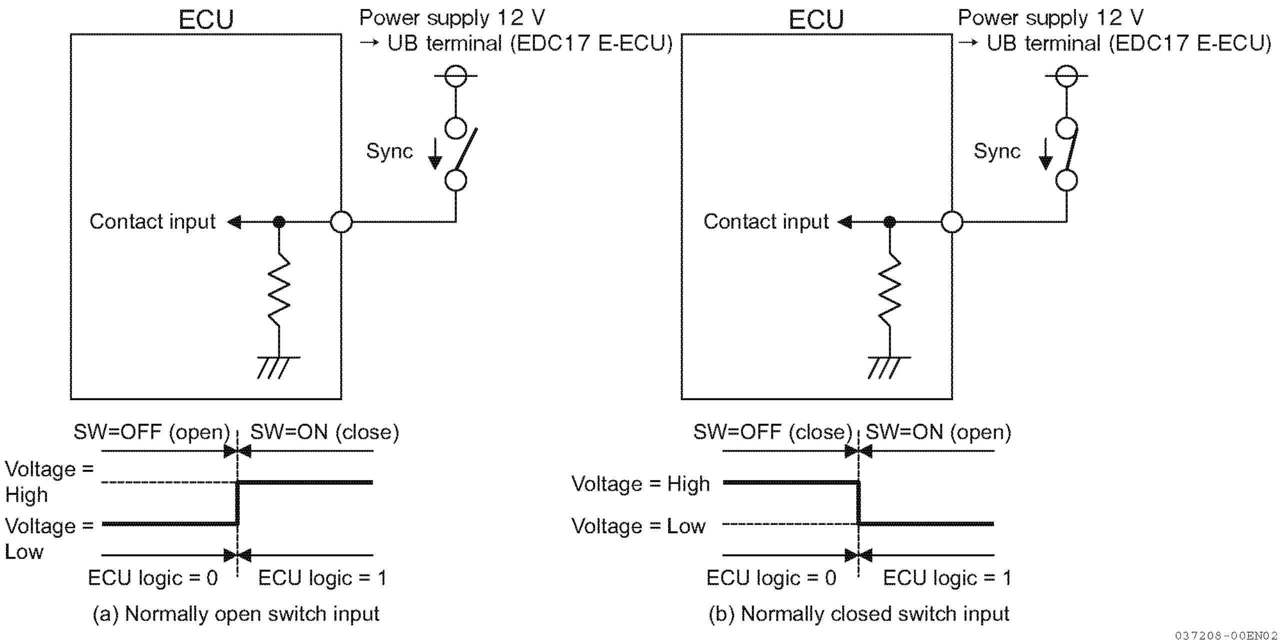


Figure 14-14 High-side contact input (switch type)

- Low-side contact input
  Figure 14-15 shows the difference of the input terminal voltage level by the SW types of a low-side contact input.
  For NO: SW ON (Close) → Low level (input terminal voltage)
  For NC: SW ON (Close) → High level (input terminal voltage)

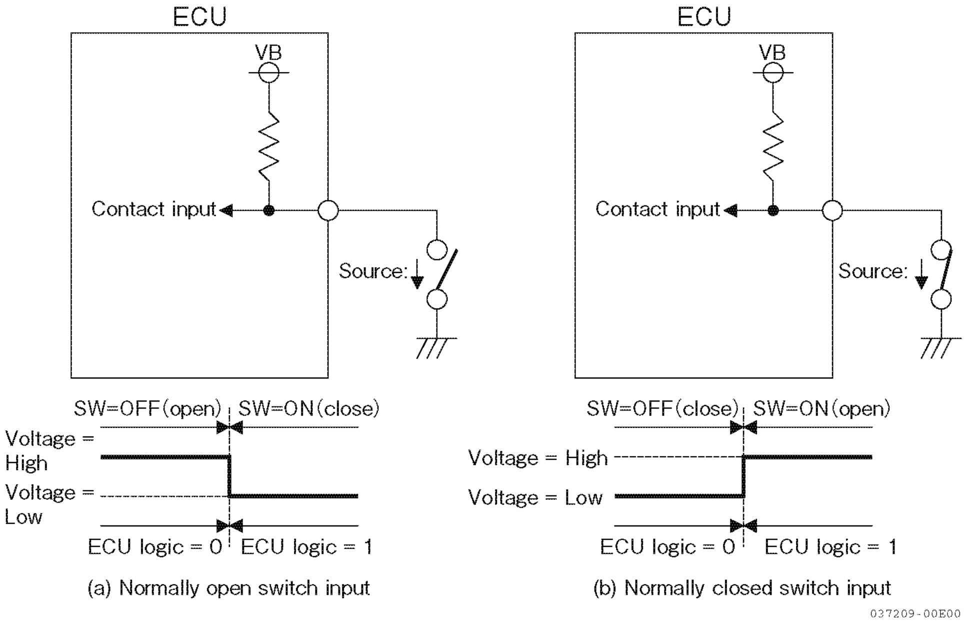


Figure 14-15 Switch types for a low-side contact input

Note: The following descriptions assume that a connection with a Normally Open type switch is used. In addition, conditions in which the switch is pressed (SW close) are considered to be the ON conditions and they indicate that the corresponding functions/actions are enabled (unless otherwise documented in this application manual).

- List of the contact input terminals
  You can choose the input logic of the contact input terminal for the E-ECU with map flag settings.
  For details, refer to *ECU Application Menu on page 14-141*.

Contact output

Contact output of the E-ECU include high-side output and low-side output as shown in **Figure 14-16**.

For more information about the E-ECU contact output including the sink/source current or allowable current values, refer to *E-ECU terminal specifications on page 14-17*.

The power supply of high-side input must be taken from the specified UB terminal. For the details of the harness connections, refer to *Standard Circuit and Standard Harness in* **Table 14-8**.

Note: The descriptions in this manual assume that the ON condition of the output transistor (Tr) corresponds to "logic: 1" and that the OFF condition of the output transistor (Tr) corresponds to "logic: 0".

High-side outputs: Transistor OFF → High level (the E-ECU output terminal condition)
Low-side outputs: Transistor OFF → Low level (the E-ECU output terminal condition)

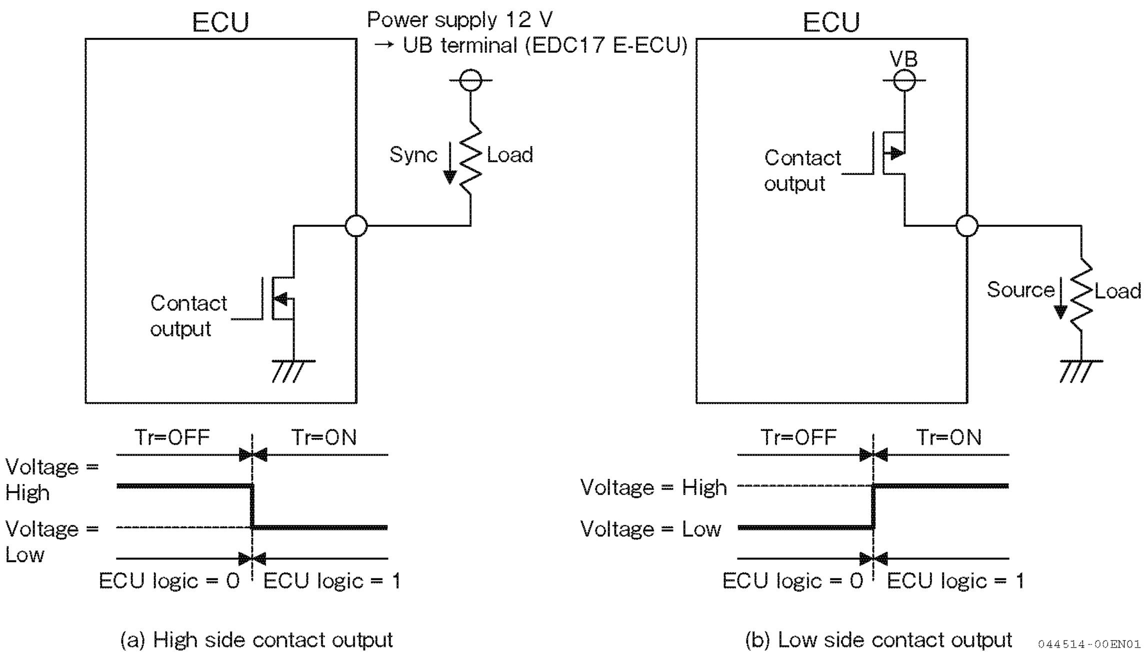


Figure 14-16 Contact output circuits and output logic

Engine Control Overview

Self-hold function of the E-ECU power supply

- Recording the history data
  The E-ECU records the history of engine operations such as the failure history or operating hours on the internal EEPROM. In order to avoid losing these history data, the E-ECU holds the power supply by itself until the recording to the EEPROM is complete even when the key switch is turned OFF accidentally.
- EGR valve closing operation
  The E-ECU moves the EGR valve to the fully closed condition when the engine is stopped so that the starting sequence begins with the valve fully closed. Therefore, the E-ECU holds the power supply by itself until the stop action of the EGR valve is complete when the key switch is turned OFF.
- Power supply self-hold using CAN communication input (under development)
  The power supply self-hold function can be performed using a CAN communication input.
  For more information, refer to the CAN communication specification.

Starting control

The basic startup sequence of an engine is shown in the figure on the right.

1. E-ECU initial operation
   The E-ECU conducts the initial operation just after the key switch input is turned to ON. The E-ECU initial operation includes the learning process of the EGR pressure sensor and DPF differential pressure sensor and the readout of the history data recorded in the EEPROM inside the E-ECU without startup of the engine. It is necessary to restrain the starter operation by the starter motor relay and inhibit startup of the engine during the E-ECU initial operation.
2. On-glow control
   If the on-glow control is configured (standard), the energizing time to the glow plug relay is controlled according to the cooling water temperature. This will illuminate the preheat lamp. When the on-glow control is finished, the engine will wait until the key switch is turned to the START position.
3. Starting control
   If the key switch is turned to the START position (the starter input terminal is ON), cranking starts and the engine speed is detected, the starting rack position control is initiated.
4. Speed control
   If the engine speed reaches equal to or greater than 600 min^{-1} (which varies depending on the engine model), the controller transitions from the start control to the speed control. The injection volume is controlled through the speed control so that the engine speed is kept at the speed instructed by the accelerator. The engine stops when the engine speed reaches 0 min-1, or the key switch is turned to OFF.

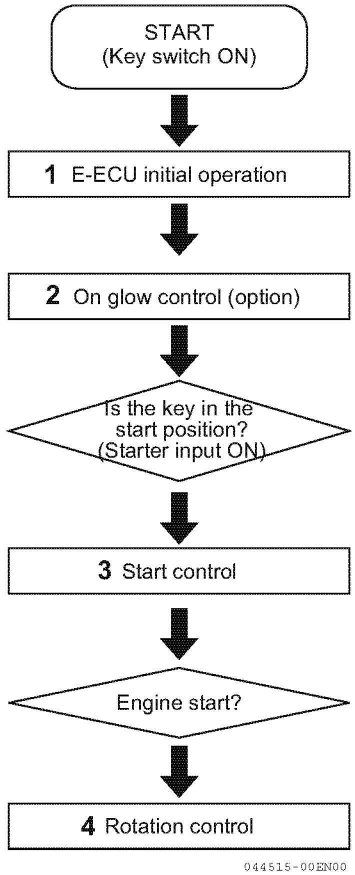


Figure 14-17
Basic start-up sequence

Regulation

There is a short delay before the engine speed is stabilized by the specified regulation in a certain situation, such as when the engine load or speed has changed instantly.
The following engine regulation settings are available:

1. Iso-chronous
   The speed is constant (regulation = 0 %) regardless of the load.
2. Virtual droop (the torque curve of the base engine)
   Regulation with approximately 120 min^{-1} (which varies depending on the engine model) is performed regardless of the speed.
   The speed is maintained to reach a load factor of around 30 % so that the idle (no-load) speed does not change even if the horsepower loss is somewhat changed after installation to a driven machine.
   Iso-chronous control at low idle speed - The engine can be configured so that the engine speed will reach the low idle speed or lower even while the virtual droop is active (option).

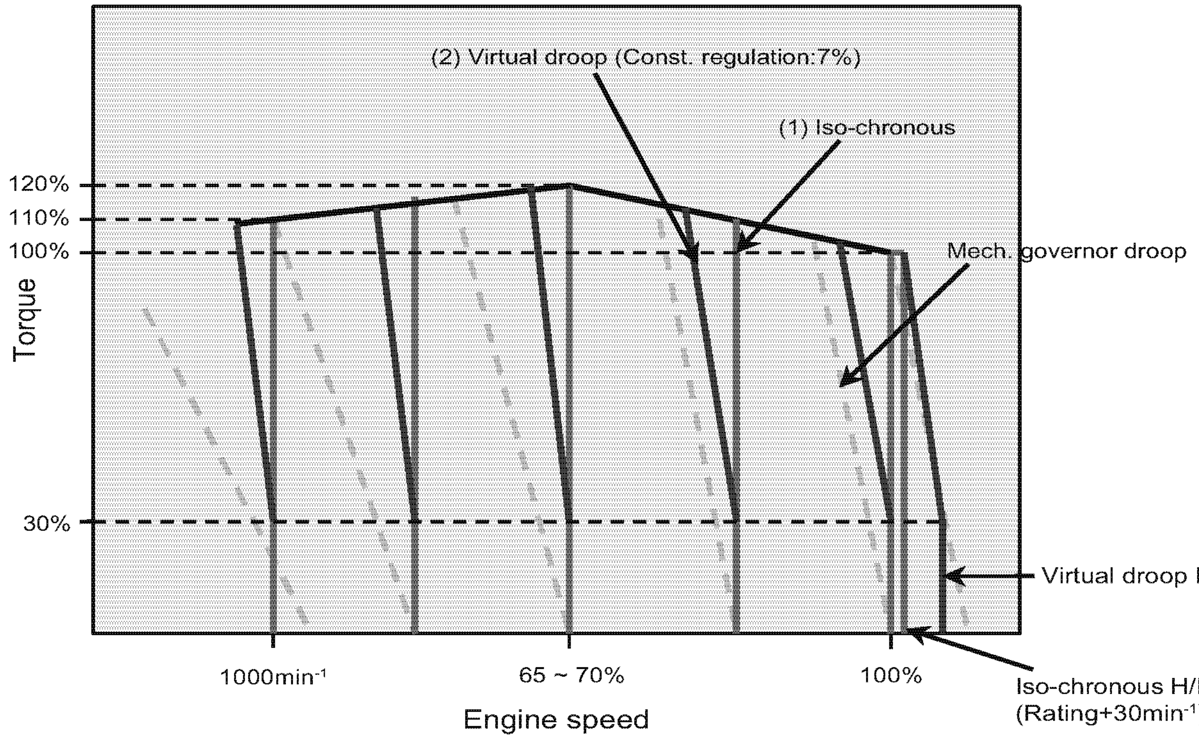


Figure 14-18 (Example) Conceptual figure of the standard torque curve

- Switching the regulation
  The Iso-chronous and virtual droop settings can be switched using an external switch or CAN communication. In addition, the Iso-chronous and virtual droop settings can be switched even while the engine is running. However, the engine speed changes if you change the setting during engine operation.
- Configuring as the standard condition
  Upon a customer's request, either the iso-chronous or virtual droop setting can be configured as the standard condition.
  For details, refer to *Application Functions on page 14-43*.

Speed control

The target engine speed is determined by the input from the acceleration sensor or CAN communication. Summaries for each item and descriptions of the option setting items are documented later.

1. Acceleration sensor selection
   Depending on the acceleration sensor setting and conditions of each acceleration sensor, the controller selects which input it enables from either one of the acceleration sensors (refer to *Configuring the analog input terminal voltages on page 14-47* for details).
2. Speed selection function (option)
   The target speed from the acceleration sensors are changed depending on the condition of the external switches; APP-IP3, APP-IP4, and APP-IP6 (refer to *Speed Selection Function on page 14-73* for details).
3. Automatic control of engine speed by DPF regeneration control
   When the stationary regeneration starts, the E-ECU automatically controls the target speed gradually to high-idle speed or low-idle speed (refer to *Diesel Particulate Filter (DPF) System Diesel Particulate Filter (DPF) System Control Overview (Under Development) on page 14-107* for details).
4. Idle up function (option)
   The engine's low idle speed is increased depending on the cooling water temperature (refer to *Idle Up Function on page 14-87* for details).
5. Blue/white smoke suppression control (option)
   The engine's high idle speed is decreased depending on the cooling water temperature (refer to *Low-temperature High Idle Limit Function on page 14-88* for details).
6. Governing control
   The target speed of the virtual droop settings is calculated (refer to *Regulation on page 14-39* for details).
7. Accelerator filter
   The change amount of the target speeds are suppressed in order to reduce overshoots or undershoots of the engine speed (refer to *Acceleration filter on page 14-41* for details).
8. Low/high idle speed limits
   The target speeds determined as described above are checked if they are within the ranges of the low idle and high idle speeds for correction.

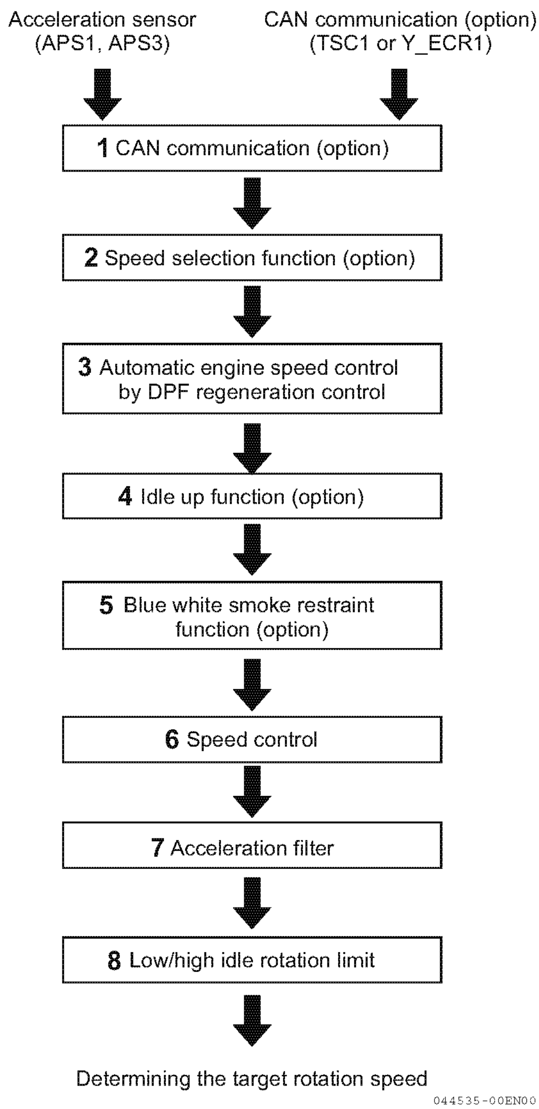


Figure 14-19

Setup flow of target engine speed

Acceleration filter

The accelerator filter controls the tradeoff between the acceleration/deceleration times and the occurrences of overshooting/undershooting. When the results of evaluation testing on driven machines indicate the necessity of adjusting the behavior of the accelerator filter to improve the engine speed stability and response, YANMAR will make such adjustments by changing the model-specific control map settings.

The accelerator filter is optimized prior to shipment. You do not have to change its settings under normal circumstances.

Figure 14-20 shows the behavior and effect of the accelerator filter.

- When the change of the target engine speed is delayed:
  → O: Overshooting/undershooting of the engine speed can be controlled.
  → X: The response during acceleration/deceleration is sacrificed.
- When the change of the target engine speed is advanced:
  → O: Overshooting/undershooting of the engine speed may occur.
  → X: The response during acceleration/deceleration is improved.

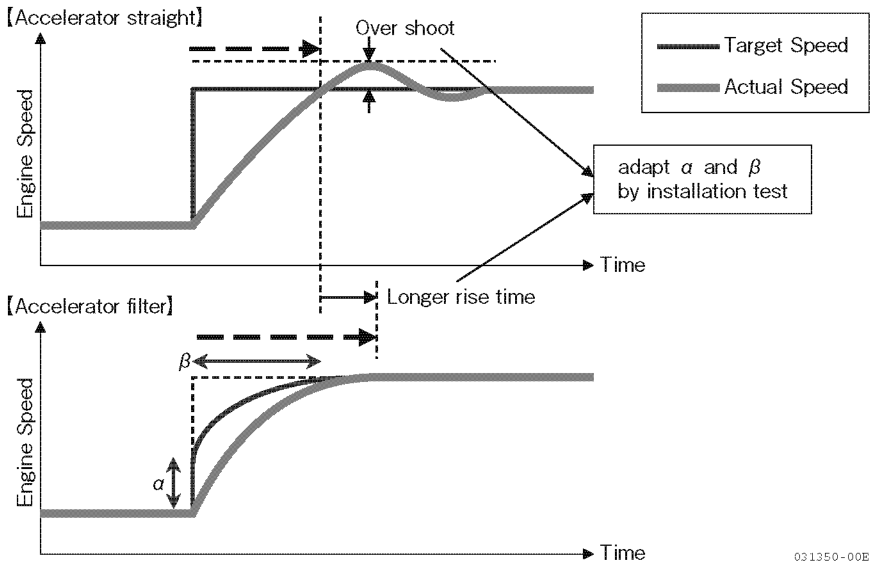


Figure 14-20 Behavior of the accelerator filter

EGR control

The common rail engine provides NOx reduction by installing an electronic control EGR valve.

The E-ECU calculates the EGR valve opening based on the engine speed, engine load factor, intake air temperature/EGR temperature/exhaust gas temperature, and EGR downstream/upstream pressures (intake air pressure/exhaust air pressure) and adjusts the exhaust gas recirculation volume by controlling the EGR valve.

The EGR valve is active under normal warm conditions, however, it is designed not to open when the cooling water temperature is 60 °C or lower in order to prevent sulfuric acid corrosion of the engine under cold conditions due to concentration of exhaust gas components.

Load factor monitoring (load factor output)

As shown in **Figure 14-21**, the engine load is calculated as a percent load factor based on the target fuel injection volume (Q_T) in relation to the no-load (idle) fuel injection volume (Q_{idl}), maximum fuel injection volume (Q_{max}), and minimum (injection-cutting) fuel injection volume (= 0) (Q_{min}).

The calculated load factor of the engine is output from the CAN communication.

A negative load factor is output at transition such as a rapid decrease in engine speed or load rejection.

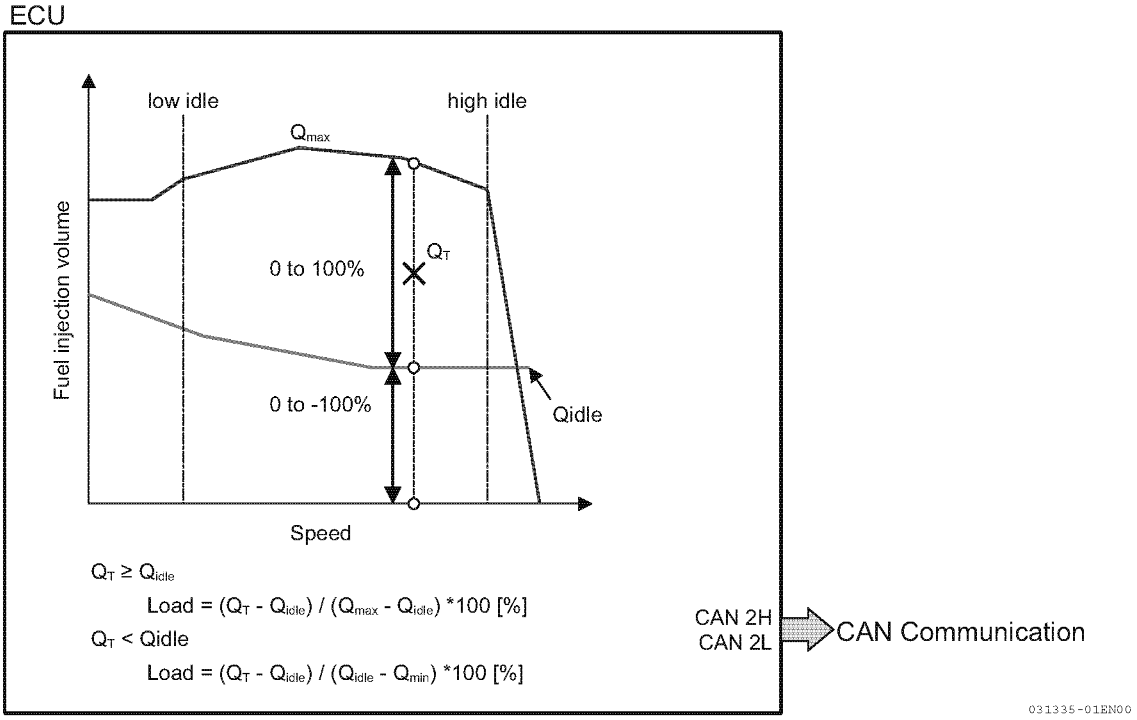


Figure 14-21 Detection method of the load factor

Speed monitoring (speed output)

The engine speed is output from the NRPM-M terminal of the E-ECU as pulse signals, while it is also output from the CAN communication. For details, please ask YANMAR.

Instantaneous fuel consumption (under development)

Total fuel consumption (under development)

Application Functions

Outline

Table 14-9 Application functions

Item		Outline (refer to below for details)
Droop selection function		Switch droop/Switch the isochronous
Iso-chronous control at low idle speed		Even when droop is selected, Iso-chronous control performed at low idle speed only
Electric acceleration		Max. analog entry 3 system and CAN adjustable
TSC1 torque limit control		Engine torque limited on CAN (TSC1)
Starting aid control		On-glow control (preheat), simultaneous power supply control
Starter restraint & protection		Starting prohibited, starter overturning protection, power supply time limit
Speed selection function	One-touch deceleration* (Constant speed, deceleration control)	Change rotation with switch (regular rotation, reduction)
	Automatic deceleration*	Lower rotation with hydraulic switch when not operating
High-idle limit		Limit the high-idle rotation with the switch
Engine stop		Stop the engine with the switch (entry 2 system)
Idle up function		Low-idle speed increased at lowered cooling water temperature
High-idle decrease function at low temperature		High-idle speed limited at engine startup at low temperature
Engine fault detection		Oil pressure switch, water separator, air cleaner
Control fault detection function		Fault diagnosis by E-ECU
CAN communication function		J1939: rotation speed, load factor, DTC information
DPF operator interface		Selection and indicator lamps of DPF regeneration request/regeneration inhibit/ regeneration interlock input
SA-D function		Defect analysis, data locking, history, settings

Applications marked with an "" cannot be set at the same time (because the same entry board is used).*

Droop Selection Function (Droop/Iso-chronous Control Switching)

Function

This function allows you to switch between Iso-chronous and droop controls using an external switch or CAN communication.

Application menu

- Droop selection input
  → 0: from APP-IP1 (toggle type) (standard)
  → 1: from APP-IP1 (momentary type, default: Droop)
  → 2: from APP-IP1 (momentary type, default: Iso-chronous)
  → 3: from CAN (Y_EC)
- Logic setup of APP-IP1 terminal (droop selection)
  → 0: SW close → Droop, or 1: SW close → Iso-chronous (standard)

Description

By standard, the system is configured to use droop control when an external switch is not connected (i.e., when the ECU terminal APP-IP1 is open). You can optionally change the logical configuration of the APP-IP1 terminal to configure the system to use iso-chronous control when an external switch is not connected. For wiring connections, refer to **Figure 14-22**. Refer to **Table 14-35** for the logic settings of the APP-IP1 terminal.

As an option, the APP-OP2 terminal can be connected to the iso-chronous lamp. The E-ECU illuminates the iso-chronous lamp when the iso-chronous operates. The iso-chronous lamp also shines when the engine is stopped.
If a momentary switch is set in the logic settings of the APP-IP1, find out whether the droop control or the iso-chronous control operates and connect the iso-chronous lamp.

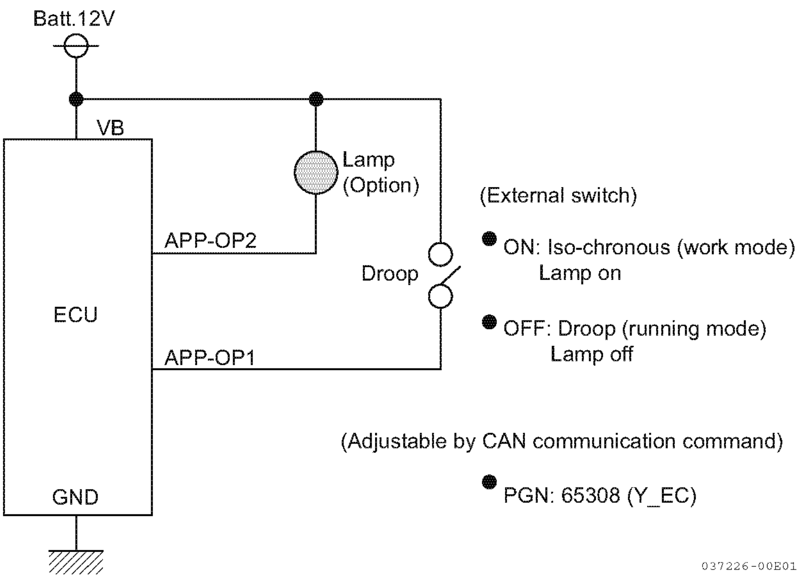


Figure 14-22 Iso-chronous/droop switching connections

Iso-chronous Control at Low Idle Speed

Function

You can optionally configure the system to prevent the engine speed (target engine speed) from falling below the low idle speed, as shown in **Figure 14-23**.

Application menu

- Iso-chronous control at low idle speed → 0: disabled (standard), → 1: enabled.

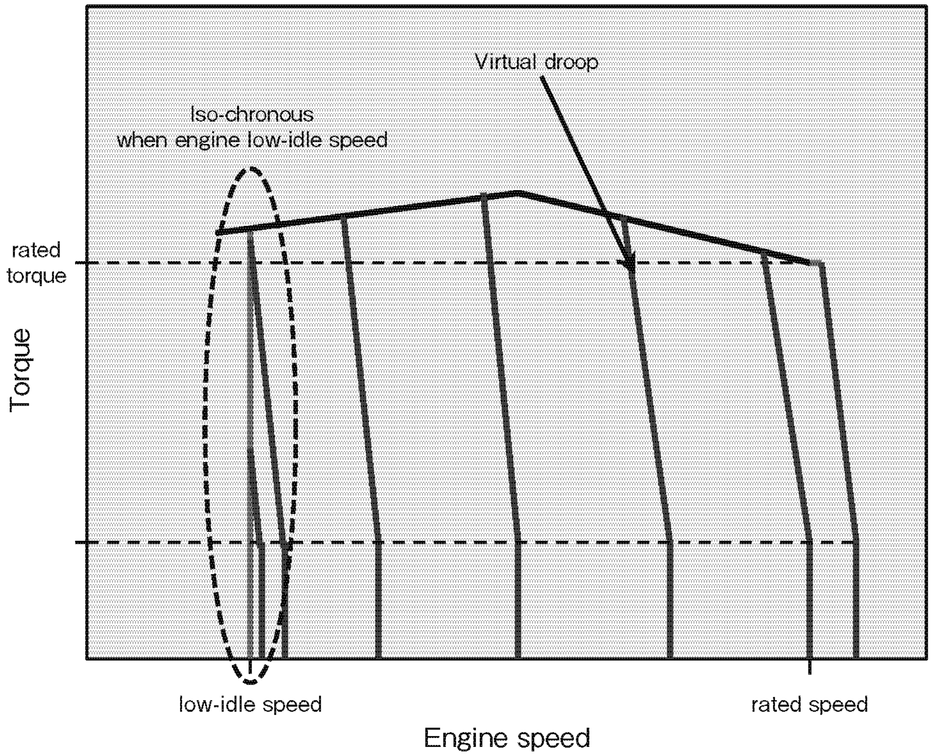


Figure 14-23 Iso-chronous control at low idle speed

Electric Acceleration

Acceleration input

E-ECU calculates the target engine speed based on the input voltage from the acceleration sensor or the input value from the CAN communication. (Because the actual engine speed is determined by the relationship between the engine maximum torque and the load torque, it does not necessarily match the target engine speed.)

As shown in **Figure 14-24**, the acceleration inputs include the analog acceleration sensor (single output analog), dual output acceleration sensor (dual output analog), SAE foot pedal (single output analog with contact) and CAN communication (TSC1 or TSC1 + Y_ECR1). Refer to the detailed descriptions of the dual output acceleration sensor, SAE foot pedal and CAN communication that are provided later.

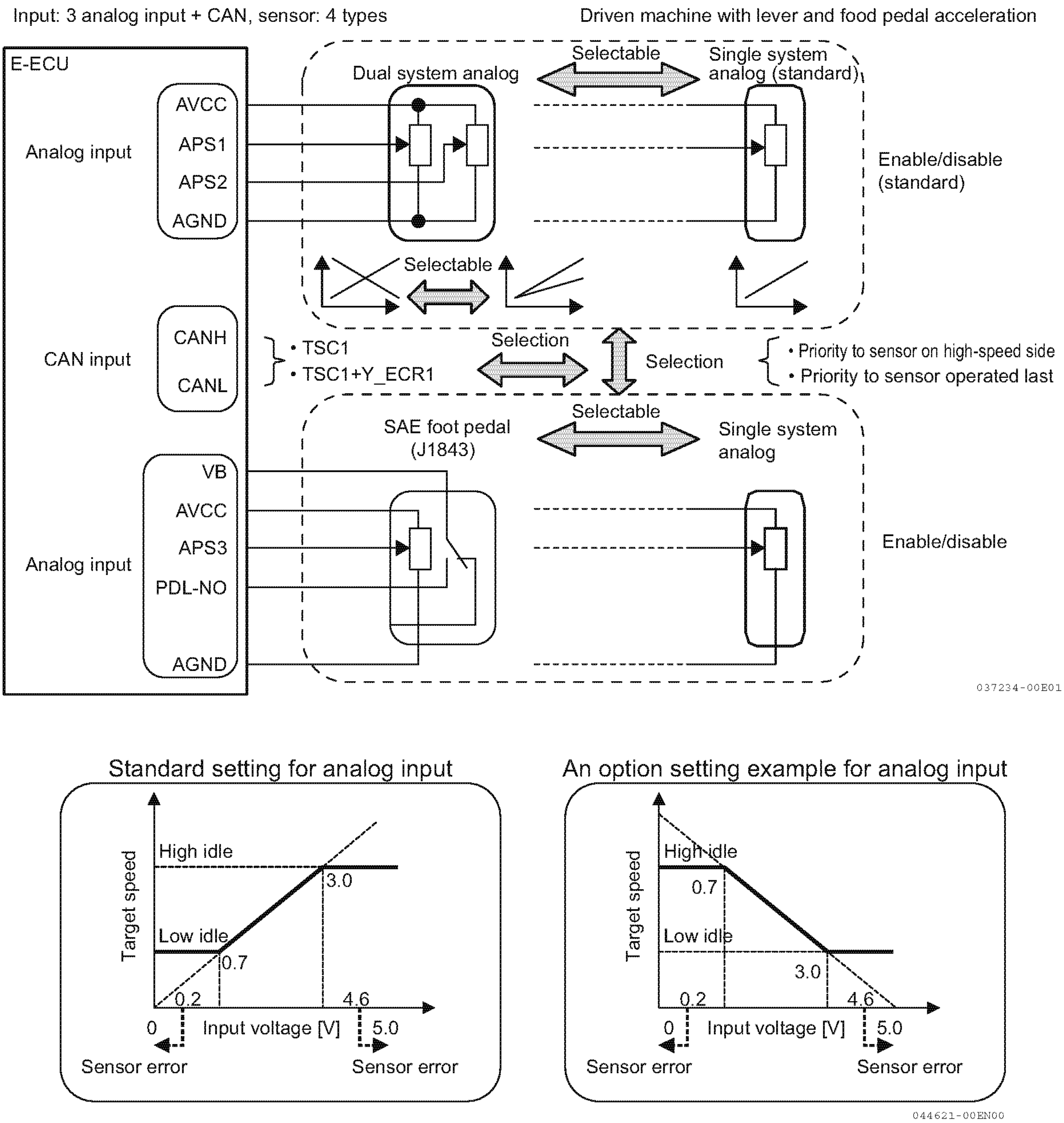


Figure 14-24 Acceleration input

Configuring the analog input terminal voltages

Function

You can configure each of the APS1 terminal, APS2 terminal, and APS3 terminal that are used as the acceleration input terminals with the input voltages equivalent of the low idle and high idle speeds, respectively.

The input voltage from the acceleration sensor is converted to an engine speed from the low idle speed to the high idle speed as shown in **Figure 14-24**. The standard setting assumes that an input voltage of 0.7 V leads to the low idle speed and 3.0 V leads to the high idle speed. The input voltages corresponding to the low idle speed and high idle speed can be changed respectively within a range where no acceleration sensor error as described later is detected. You can also reverse the gradient of the input voltage curve corresponding to a range from the low idle speed to the high idle speed.

Note: *E-ECU has a detection error in terms of the electric circuit and a hysteresis characteristic in terms of the software for the input voltage from the acceleration sensor. The sum of these amounts to ±0.125 V. Therefore, if the acceleration sensor voltage is used with the standard setting (0.7 to 3.0 V), the voltage must at least fall in a range shown in* ***Figure 14-25****. E-ECU detects an acceleration sensor error if the input voltage from the acceleration sensor is 0.2 V or less or 4.6 V or more.*

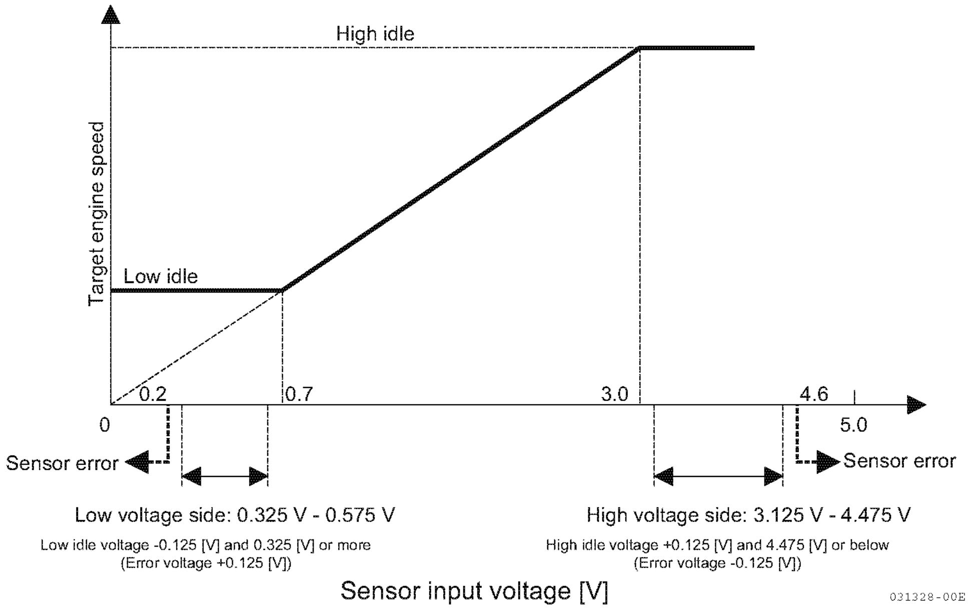


Figure 14-25 Required accuracy by acceleration sensor

Application menu

Table 14-10

Terminal	Description	Standard value [V]
APS1	voltage for low idle rotation speed	0.7
	voltage for high idle rotation speed	3.0
APS2	voltage for low idle rotation speed	According to dual output analog specification
	voltage for high idle rotation speed	According to dual output analog specification
APS3	voltage for low idle rotation speed	0.7
	voltage for high idle rotation speed	3.0

Note: *The E-ECU has an error of ± 0.125 V in voltage settings. When you use the standard setting indicated above, therefore, you have to change the input voltage across the range from the low idle voltage = 0.575 V (0.7 - 0.125 V) to the high idle voltage = 3.125 V (3.0 + 0.125 V).*

Selecting acceleration function

Application menu

As shown in **Figure 14-24**, you can select the acceleration functions indicated below by combining the analog acceleration sensor (single output analog), dual output acceleration sensor (dual output analog), SAE foot pedal (single output analog with contact) and acceleration input via CAN communication. For details on the operation under abnormal condition of these acceleration functions, refer to *Fault handling of each acceleration function on page 14-57*.

Table 14-11 Selection flags for acceleration functions

Selecting acceleration function		Functional overview
Set value	**Item**	
0	No acceleration sensor	The engine speed is changed over only by the contact input.
1	Single output acceleration	• A single acceleration input is used to indicate the engine speed. • If the acceleration input is abnormal, the system follows the all acceleration fault handling actions.*1
2	Dual output acceleration (Higher speed input or normal input is prioritized.)	• The system uses two acceleration inputs and operates with the higher engine speed of the two signals. • If either acceleration input is abnormal, the system operates with the target engine speed of the normal one.*2 • If all acceleration inputs are abnormal, the system follows the all acceleration signal fault handling.*1
3	Dual output acceleration (Last operated one or normal input is prioritized.)	• The system uses two acceleration inputs and operates with the target engine speed of the last operated one. • If either acceleration input is abnormal, the system operates with the target engine speed of the normal one.*2 • If all acceleration inputs are abnormal, the system follows the all acceleration signal fault handling.*1
4	Backup acceleration	• The system uses two acceleration inputs differently, one for the main input and the other for backup. In normal state, the system operates with the engine speed indicated by the main acceleration input. • If the main acceleration input is abnormal, the system operates with the engine speed indicated by the backup acceleration input.*2 • If all acceleration inputs are abnormal, the system follows the all acceleration signal fault handling action.*1
5	CAN communication/ analog changeover	• The system uses the CAN communication signal and one acceleration input (analog) and operates with the engine speed indicated by the CAN communication signal in normal state. • If the CAN communication signal is abnormal or invalid, the system operates with the engine speed indicated by the analog acceleration input.*2 • If the CAN communication signal is abnormal or invalid AND the acceleration input is abnormal, the system follows the all acceleration signal fault handling.*1
6	Service acceleration device (under development)	• The system uses one acceleration input as the main input and the single output analog as the service acceleration input. In normal state, the service acceleration device is not connected and the system operates with the target engine speed indicated by the main acceleration input. No abnormal condition detection takes place for the service acceleration input. • If a service acceleration device is connected, the system operates with the engine speed indicated by the service acceleration input.*2 • If no service acceleration device is connected AND the acceleration input is abnormal, the system follows the all acceleration fault handling actions.*1

**1: Changeover and return to/from all acceleration signal fault handling: Once all acceleration inputs are found abnormal, the system changes the target engine speed according to a specified change rate (4 min-1/40 ms).*

**2: "Dual output acceleration", "Backup acceleration", and "CAN communication/analog changeover" described above: For the main-to-backup changeover and return operations, you can select various patterns using the setting flags as described later.*

Table 14-12 Selecting acceleration changeover operations

Selecting acceleration changeover operation		Overview
Set value	**Content**	
0	Without "gradual change"	As soon as an acceleration changeover occurs, the target engine speed is changed.
1	With "gradual change"	After an acceleration changeover occurs, the target engine speed is changed gradually according to a specified change rate (4 min-1/40 ms)
2	Without "gradual change" + Without acceleration transfer only	When an acceleration changeover occurs: • If Target engine speed before changeover Target engine speed after changeover (accelerating), the system retains the target engine speed before changeover. After the changeover, the retention is cancelled when Current target engine speed Target engine speed before changeover. • Target speed before switching > the target speed is immediately changed after switching in case of the target speed after switching (in the deceleration direction).
3	With "gradual change" + Without acceleration transfer only	When an acceleration changeover occurs: • If Target engine speed before changeover Target engine speed after changeover (accelerating), the system retains the target engine speed before changeover. After the changeover, the retention is cancelled when Current target engine speed Target engine speed before changeover. • If Target engine speed before changeover > Target engine speed after changeover (decelerating), the system gradually changes the target engine speed according to a specified change rate (4 min-1/40 ms) after the changeover.
4	Last value retention until crossing	When an acceleration changeover occurs: • If Target engine speed before changeover < Target engine speed after changeover, the system retains the target engine speed before changeover. After the changeover, the retention is cancelled when Current target engine speed < Target engine speed before changeover and the system operates with the current target engine speed. • If Target engine speed before changeover > Target engine speed after changeover, the system retains the target engine speed before changeover. After the changeover, the retention is cancelled when Current target engine speed > Target engine speed before changeover and the system operates with the current target engine speed. • If Target engine speed before changeover = Target engine speed after changeover, the system operates according to the target engine speed after changeover (no last value retention).

In addition, you can select the configuration of each acceleration function by the setting flags shown in **Table 14-13**.

Table 14-13 Configuration flag list for each acceleration function

Item	Set value and configuration
Single output acceleration configuration	0: Single output analog (APS1) 1: Dual output analog (APS1 + APS2) 2: SAE foot pedal (APS3 + PDLSW) 3: CAN communication (TSC1 or TSC1 + Y_ECR1)
Dual output acceleration configuration	0: Single output analog × 2 (APS1, APS3) 1: Single output analog (APS3) + Dual output analog (APS1 + APS2) 2: Single output analog (APS1) + SAE foot pedal (APS3 + PDLSW) 3: Dual output analog (APS1 + APS2) + SAE foot pedal (APS3 + PDLSW)
Backup acceleration configuration	0: CAN communication (TSC1 or TSC1 + Y_ECR1) → Single output analog (APS1) 1: Single output analog (APS1) → CAN communication (TSC1 or TSC1 + Y_ECR1) 2: Dual output analog (APS1 + APS2) → CAN communication (TSC1 or TSC1 + Y_ECR1) 3: SAE foot pedal (APS3 + PDLSW) → CAN communication (TSC1 or TSC1 + Y_ECR1)
CAN communication/ analog changeover configuration	0: CAN communication (TSC1 or TSC1 + Y_ECR1) <=> Single output analog (APS1) 1: CAN communication (TSC1 or TSC1 + Y_ECR1) <=> Dual output analog (APS1 + APS2) 2: CAN communication (TSC1 or TSC1 + Y_ECR1) <=> SAE foot pedal (APS3 + PDLSW)
Service acceleration configuration (under development)	0: Service acceleration <=> No acceleration 1: Service acceleration <=> Single output analog (APS1) 2: Service acceleration <=> Dual output analog (APS1 + APS2) 3: Service acceleration <=> SAE foot pedal (APS3 + PDLSW) 4: Service acceleration <=> CAN communication (TSC1 or TSC1 + Y_ECR1)

Acceleration based on CAN communication

Function

To achieve the acceleration by CAN communication, the methods shown in Table 14-16 are available. For details on the CAN communication and data format, refer to *ON-Vehicle Communication CAN Specification on page 15-1*.

If the specified CAN ID cannot be received, a CAN communication error is detected. The operation with an error detected is in accordance with the configuration of acceleration functions. For further details, refer to *Fault handling of each acceleration function on page 14-57*. Note that a CAN communication error is not cancelled until the E-ECU power is turned OFF. (No automatic reset takes place even when the normal state is restored.)

Table 14-14 Acceleration methods by CAN communication

	Acceleration by CAN communication	CAN ID to be used	Overview
(a)	Method of specifying with target engine speed (min^{-1})	TSC1 (PGN = 0)	When TSC1 “Override control mode” is “1: Rotation control mode”, E-ECU controls the engine speed based on the “Requested engine speed (min^{-1})” value of TSC1.
(b)	Method of specifying with accelerator position (%)	TSC1 (PGN = 0) Y_ECR1 (PGN = 65282)	When TSC1 “Override control mode” is “0: Override disabled”, E-ECU controls the engine speed based on the “Acceleration pedal position (%)” value of Y_ECR1. Note: Both TSC1 and Y_ECR1 must be transmitted to E-ECU.

Application menu

When any of the following values is set with the following setting flags, the acceleration by CAN communication is enabled.

- Configuration of single output acceleration → 3: CAN communication (TSC1 or TSC1 + Y_ECR1)
- Configuration of backup acceleration
  → 0: CAN communication (TSC1 or TSC1 + Y_ECR1) → Single output analog (APS1)
  → 1: Single output analog (APS1) → CAN communication (TSC1 or TSC1 + Y_ECR1)
  → 2: Dual output analog (APS1 + APS2) → CAN communication (TSC1 or TSC1 + Y_ECR1)
  → 3: SAE foot pedal (APS3 + PDLSW) → CAN communication (TSC1 or TSC1 + Y_ECR1)
- CAN communication <=> Analog changeover
  → 0: CAN communication (TSC1 or TSC1 + Y_ECR1) <=> Single output analog (APS1)
  → 1: CAN communication (TSC1 or TSC1 + Y_ECR1) <=> Dual output analog (APS1 + APS2)
  → 2: CAN communication (TSC1 or TSC1 + Y_ECR1) <=> SAE foot pedal (APS3 + PDLSW)
- Configuration of service acceleration
  → 4: Service acceleration <=> CAN communication (TSC1 or TSC1 + Y_ECR1)

Description

(a) Example of setting transmission CAN data in method specifying target engine speed

Configure TSC1 (PGN = 0) as shown in **Table 14-15** and send it to the E-ECU.

TSC1 (PGN = 0, ID = 0x0C0000)**

Table 14-15

Data byte	Description		SPN	Recommended	Remarks
1	LSB	Override control mode	695	01B	“Requested speed” is available
		Requested speed control condition	696	11B	Not available
		Override control mode priority	897	00B	Not available
	MSB	Not defined	–	00B	
2	LSB of “Requested speed”		898	80h (example)	When 2000 min^{-1} is requested. 2000/0.125 = 16000 = 3E80h
3	MSB of “Requested speed”			3Eh (example)	
4	Requested torque		518	00h	Not available
5	Not defined		–	00h	
6	Not defined		–	00h	
7	Not defined		–	00h	
8	Not defined		–	00h	

1) Continuous 10 ms period
2) The E-ECU does not judge the SA.

(b) Specifying the accelerator pedal position

Configure TSC1 (PGN = 0) and Y_ECR1 (PGN = 65282) as shown in **Table 14-16** and **Table 14-17**, and send them to E-ECU.

TSC1 (PGN = 0, ID = 0x0C0000)**

Table 14-16

Data byte	Description		SPN	Recommended	Remarks
1	LSB	Override control mode	695	00B	"Accelerator pedal position" is available
		Requested speed control condition	696	11B	Not available
		Override control mode priority	897	00B	Not available
	MSB	Not defined	–	00B	
2	LSB of "Requested speed"		898	00h	Not use
3	MSB of "Requested speed"			00h	
4	Requested torque		518	00h	Not available
5	Not defined		–	00h	
6	Not defined		–	00h	
7	Not defined		–	00h	
8	Not defined		–	00h	

1) Continuous 10 ms period
2) The E-ECU does not judge the SA.

Y_ECR1 (PGN = 65282, ID = 0x0CFF02)**

Table 14-17

Data byte	Description		SPN	Recommended	Remarks
1	Not defined		–	00B	
2	LSB	Not defined	–	00B	
		Shutdown requests	–	00B	Depends on other functions
		Not defined	–	00B	
	MSB	Power supply/Key position	–	00B	Depends on other functions
3	Not defined		–	00h	
4	Accelerator pedal position		–	FAh	When 100 % (H/I speed) is requested. 100/0.4 = 250 = FAh
5	(Reserved)		–	00h	
6	Not defined		–	00h	
7	Not defined		–	00h	
8	Not defined		–	00h	

1) Continuous 10 ms period
2) The E-ECU does not judge the SA.

SAE foot pedal

Function

The SAEJ1843 foot pedal changes the input voltage and pedal switch state depending on the foot pedal angle as indicated by the operation example in **Figure 14-26**. E-ECU monitors the input voltage and pedal switch state to detect any abnormal condition of the foot pedal.

To E-ECU, a pedal switch of high-side contact input type can be connected. Besides, although the connection of a normally open (NO) type pedal switch (ON when SW is closed) is assumed as standard, you can select either the normally open (NO) input logic or the normally close (NC) input logic (OFF when SW is closed) by an option setting according to the type of the pedal switch.

However, the control system does not support a foot pedal with a sensor characteristic that decreases the input voltage as the foot pedal angle increases, requiring the following setting: “Low idle speed voltage” > “High idle speed voltage”.

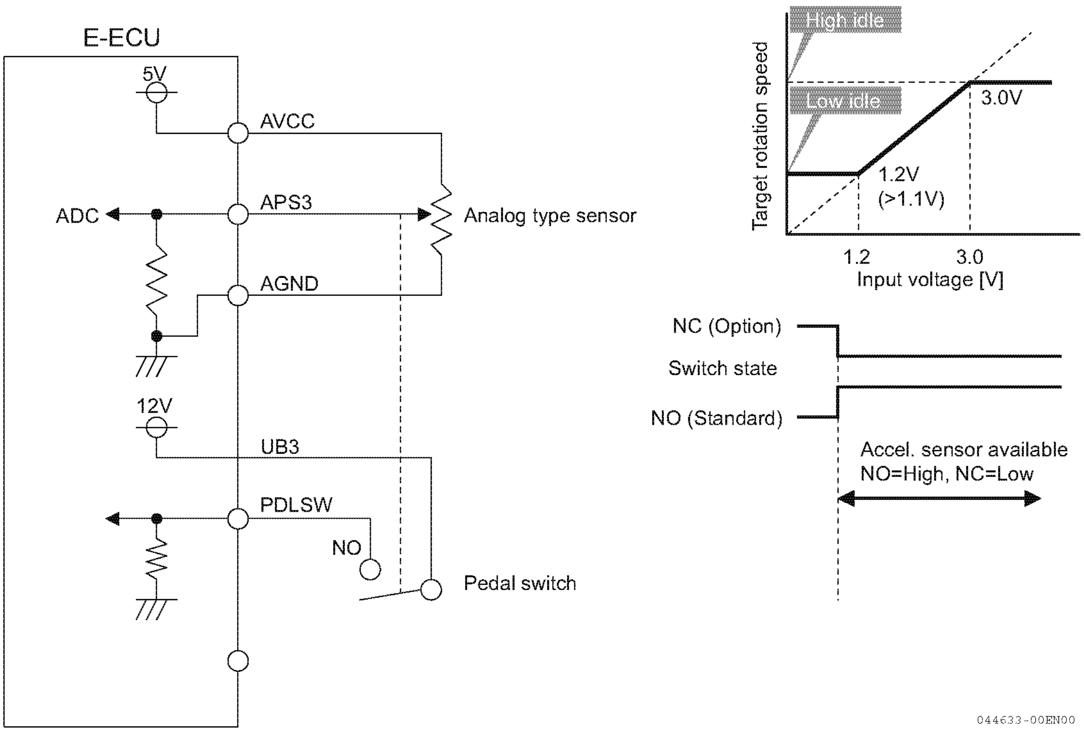


Figure 14-26 Operation example of foot pedal

Application menu

When any of the following values is set with the following setting flags, the SAE foot pedal is enabled.

- Configuration of single output acceleration → 2: SAE foot pedal (APS3 + PDLSW)
- Configuration of dual output acceleration
  → 2: Single output analog (APS1) + SAE foot pedal (APS3 + PDLSW)
  → 3: Dual output analog (APS1 + APS2) + SAE foot pedal (APS3 + PDLSW)
- Configuration of backup acceleration
  → 3: SAE foot pedal (APS3 + PDLSW) → CAN communication (TSC1 or TSC1 + Y_ECR1)
- CAN communication <=> Analog changeover
  → 2: CAN communication (TSC1 or TSC1 + Y_ECR1) <=> SAE foot pedal (APS3 + PDLSW)
- Configuration of service acceleration
  → 3: Service acceleration (APS1) + SAE foot pedal (APS3 + PDLSW)

When the foot pedal is selected, we recommend setting the low idle and high idle speed voltages as follows.

Table 14-18 APS3 terminal input voltage settings

Terminal	Content	Standard value (V)
APS3	Voltage at low idle speed	1.2 (>1.1)
	Voltage at high idle speed	Option

Description

Figure 14-27 shows the abnormal condition detection method for the foot pedal in the above operation example. If the judgment conditions below are satisfied, a foot pedal error (opened position) or foot pedal error (closed position) is detected. The operation during error detection is in accordance with the configuration of acceleration functions. For further details, refer to *Fault handling of each acceleration function on page 14-57*. Note that a foot pedal error is not cancelled until the E-ECU power is turned OFF. (No automatic reset takes place even when the normal state is restored.)

- As with a normal acceleration sensor, a sensor error is detected when the input voltage is 0.2 V or less or 4.6 V or more. However, if any of the above sensor errors is detected, the error judgment by PDLSW terminal as shown below does not take place.
- When input voltage is 1.1 V or more:
  (In case of NO setting) A foot pedal error (opened position) is detected when PDLSW terminal is Low (standard setting).
  (In case of NC setting) A foot pedal error (opened position) is detected when PDLSW terminal is High.
- When input voltage is 0.65 V or less:
  (In case of NO setting) A foot pedal error (closed position) is detected when PDLSW terminal is High (standard setting).
  (In case of NC setting) A foot pedal error (closed position) is detected when PDLSW terminal is Low.

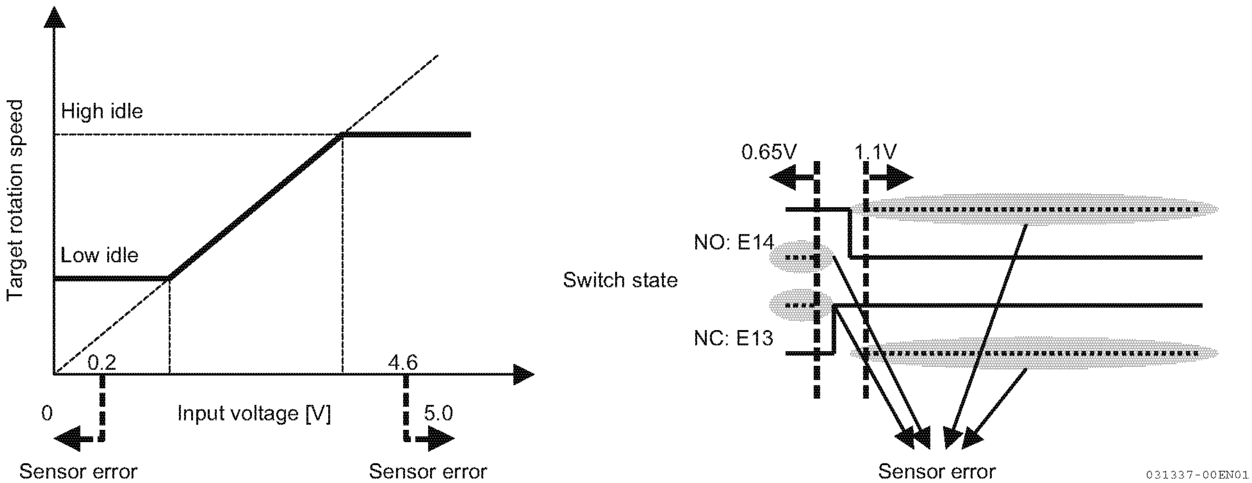


Figure 14-27 Fault detection on foot pedal

Note: E-ECU has an error of 0.125 V for the detected voltage above. Accordingly, the pedal switch needs to change over in a range from 0.775 V (0.650 + 0.125) to 0.975 V (1.1 - 0.125).

Dual output acceleration sensor (dual output analog)

Function

As shown in **Figure 14-28**, the dual output acceleration sensor (dual output analog) has two analog sensors and offers three types of characteristics for the sensor voltage that changes according to the accelerator pedal position. E-ECU uses one of the two input voltage signals from this sensor (APS1 terminal) to calculate the target engine speed and performs an error judgment for the accelerator pedal position by referring to the other input voltage (APS2 terminal).

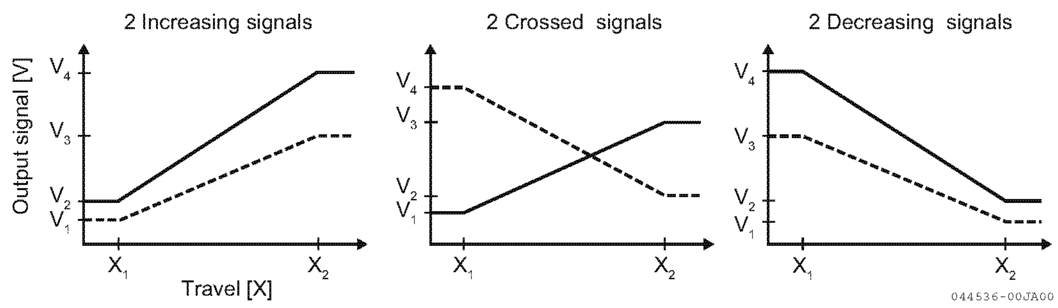


Figure 14-28

Application menu

When any of the following values is set with the following setting flags, the dual output acceleration sensor (dual output analog) is enabled.

- Configuration of single output acceleration → 1: Dual output analog (APS1 + APS2)
- Configuration of dual output acceleration → 1: Single output analog (APS3) + dual output analog (APS1 + APS2)
- Configuration of backup acceleration
  → 2: Dual output analog (APS1 + APS2) → CAN communication (TSC1 or TSC1 + Y_ECR1)
- CAN communication <=> analog changeover
  → 1: CAN communication (TSC1 or TSC1 + Y_ECR1) <=> Dual output analog (APS1 + APS2)
- Configuration of service acceleration
  → 2: Service acceleration (APS3) + Dual output analog (APS1 + APS2)

When the dual output analog is selected, configure the voltage characteristics as shown in **Figure 14-28** using the voltage values set in the following menu. These voltage values are also used for error judgment.

Table 14-19 APS3 terminal input voltage settings

Terminal	Content	Standard value (V)
APS1	Voltage at low idle speed	0.7
	Voltage at high idle speed	3.0
APS2	Voltage at low idle speed	According to the dual output analog specification
	Voltage at high idle speed	According to the dual output analog specification

Description

When the dual output acceleration sensor (dual output analog) is selected, E-ECU calculates the target engine speed from the input voltage value of APS1 terminal. In addition, E-ECU calculates the input voltage value (estimate) of APS2 terminal from the APS1 terminal input voltage value (actual value). If the difference between the calculation result and the APS2 terminal input voltage (actual value) is larger than the error judgment threshold, it detects an acceleration sensor error (opened position) or acceleration sensor error (closed position). The details of the error judgment logic are shown below. Also when the dual output analog is enabled, the error judgment for the APS1 terminal and APS2 terminal input voltage values takes place respectively.

- Judgment logic for acceleration sensor error (opened position/closed position)

$$\text{APS2 terminal input voltage value (estimate)} = \frac{D - C}{B - A} \times (\text{APS1 terminal input voltage value (actual value)} - A) + C$$

The APS2 terminal input voltage value (estimate) is calculated by the following calculation formula.

- A = APS1 terminal voltage at low idle speed
- B = APS1 terminal voltage at high idle speed
- C = APS2 terminal voltage at low idle speed
- D = APS2 terminal voltage at high idle speed

An acceleration sensor error (opened position/closed position) is judged according to the following judgment conditions. The judgment threshold E is determined by the sensor characteristic. To confirm the threshold, contact YANMAR by offering the sensor characteristic.
(E = Acceleration sensor error (opened position/closed position) judgment threshold)

- If APS2 terminal input voltage value (estimate) - APS2 terminal input voltage value (actual value) > E, “Acceleration sensor error (opened position)” is detected.
- If APS2 terminal input voltage value (estimate) - APS2 terminal input voltage value (actual value) < - E, “Acceleration sensor error (closed position)” is detected.

The acceleration sensor errors (opened position/closed position) and the errors of each analog input are not cancelled until the E-ECU power is turned OFF. (No automatic reset takes place even when the normal state is restored.)

Fault handling of each acceleration function

Figure 14-19 to **Figure 14-24** show the details of the operation under abnormal input condition of each acceleration function.

For any item with “Fault” indicated at the acceleration input column in these tables, the relevant error indication (e.g., error code, failure lamp) is output.

The automatic error reset for the APS1 terminal, APS2 terminal, and APS3 terminal input voltages as well as CAN communication can be set separately. On the other hand, the errors for PDLSW terminal and dual output analog are cancelled when the E-ECU power is turned OFF.

Table 14-20 Single output acceleration fault handling actions

Single output acceleration configuration		Acceleration input						Target speed
Set value	**Item**	**APS1**	**APS2**	**APS3**	**CAN**	**PDLSW**	**Dual**	
0	Single output analog (APS1)	Normal	–	–	–	–	–	Calculated from input voltage at APS1 terminal
		Fault	–	–	–	–	–	According to all acceleration fault handling actions
1	Dual output analog (APS1 + APS2)	Normal	Normal	–	–	–	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	–	–	–	Fault	According to all acceleration fault handling actions
		Fault	Normal	–	–	–	Fault	According to all acceleration fault handling actions
		Normal	Fault	–	–	–	Fault	According to all acceleration fault handling actions
		Fault	Fault	–	–	–	Fault	According to all acceleration fault handling actions
2	SAE foot pedal (APS3 + PDLSW)	–	–	Normal	–	Normal	–	Calculated from input voltage at APS3 terminal
		–	–	Fault	–	Normal	–	According to all acceleration fault handling actions
		–	–	Normal	–	Fault	–	According to all acceleration fault handling actions
		–	–	Fault	–	Fault	–	According to all acceleration fault handling actions
3	CAN communication (TSC1 or TSC1 + Y_ECR1)	–	–	–	Normal	–	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		–	–	–	Fault	–	–	According to all acceleration fault handling actions

Table 14-21 Dual output acceleration fault handling actions (priority is given to high-speed or normal side)

Dual output acceleration configuration		Acceleration input						Target speed
Set value	Item	APS1	APS2	APS3	CAN	PDLSW	Dual	
0	Single output analog x 2 (APS1, APS3)	Normal	–	Normal	–	–	–	According to APS1 or APS3 terminal input voltage whichever higher
		Fault	–	Normal	–	–	–	Calculated from input voltage at APS3 terminal
		Normal	–	Fault	–	–	–	Calculated from input voltage at APS1 terminal
		Fault	–	Fault	–	–	–	According to all acceleration fault handling actions
1	Single output analog (APS3) + dual output analog (APS1 + APS2)	Normal	Normal	Normal	–	–	Normal	According to APS1 or APS3 terminal input voltage whichever higher
		Normal	Normal	Fault	–	–	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	Normal	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Normal	Normal	–	–	Fault	Calculated from input voltage at APS3 terminal
		Normal	Fault	Normal	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Fault	Normal	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Fault	Fault	–	–	Fault	According to all acceleration fault handling actions
2	Single output analog (APS1) + SAE foot pedal (APS3 + PDLSW)	Normal	–	Normal	–	Normal	–	According to APS1 or APS3 terminal input voltage whichever higher
		Fault	–	Normal	–	Normal	–	Calculated from input voltage at APS3 terminal
		Normal	–	Fault	–	Normal	–	Calculated from input voltage at APS1 terminal
		Normal	–	Normal	–	Fault	–	Calculated from input voltage at APS1 terminal
		Normal	–	Fault	–	Fault	–	Calculated from input voltage at APS1 terminal
		Fault	–	Fault	–	Fault	–	According to all acceleration fault handling actions

Dual output acceleration configuration		Acceleration input						Target speed
Set value	Item	APS1	APS2	APS3	CAN	PDLSW	Dual	
3	Dual output analog (APS1 + APS2) + SAE foot pedal (APS3 + PDLSW)	Normal	Normal	Normal	–	Normal	Normal	According to APS1 or APS3 terminal input voltage whichever higher
		Normal	Normal	Normal	–	Normal	Fault	Calculated from input voltage at APS3 terminal
		Fault	Normal	Normal	–	Normal	Fault	Calculated from input voltage at APS3 terminal
		Normal	Fault	Normal	–	Normal	Fault	Calculated from input voltage at APS3 terminal
		Fault	Fault	Normal	–	Normal	Fault	Calculated from input voltage at APS3 terminal
		Normal	Normal	Fault	–	Normal	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	Normal	–	Fault	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	Fault	–	Fault	Normal	Calculated from input voltage at APS1 terminal
		Fault	Fault	Fault	–	Fault	Fault	According to all acceleration fault handling actions

Table 14-22 Dual output acceleration fault handling actions (priority is given to post operation or normal side)

Dual output acceleration configuration		Acceleration input						Target speed
Set value	Item	APS1	APS2	APS3	CAN	PDLSW	Dual	
0	Single output analog x 2 (APS1, APS3)	Normal	–	Normal	–	–	–	According to APS1 or APS3 terminal input voltage whichever operated later
		Fault	–	Normal	–	–	–	Calculated from input voltage at APS3 terminal
		Normal	–	Fault	–	–	–	Calculated from input voltage at APS1 terminal
		Fault	–	Fault	–	–	–	According to all acceleration fault handling actions
1	Single output analog (APS3) + dual output analog (APS1 + APS2)	Normal	Normal	Normal	–	–	Normal	According to APS1 or APS3 terminal input voltage whichever operated later
		Normal	Normal	Fault	–	–	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	Normal	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Normal	Normal	–	–	Fault	Calculated from input voltage at APS3 terminal
		Normal	Fault	Normal	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Fault	Normal	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Fault	Fault	–	–	Fault	According to all acceleration fault handling actions
2	Single output analog (APS1) + SAE foot pedal (APS3 + PDLSW)	Normal	–	Normal	–	Normal	–	According to APS1 or APS3 terminal input voltage whichever operated later
		Fault	–	Normal	–	Normal	–	Calculated from input voltage at APS3 terminal
		Normal	–	Fault	–	Normal	–	Calculated from input voltage at APS1 terminal
		Normal	–	Normal	–	Fault	–	Calculated from input voltage at APS1 terminal
		Normal	–	Fault	–	Fault	–	Calculated from input voltage at APS1 terminal
		Fault	–	Fault	–	Fault	–	According to all acceleration fault handling actions

Dual output acceleration configuration		Acceleration input						Target speed
Set value	**Item**	**APS1**	**APS2**	**APS3**	**CAN**	**PDLSW**	**Dual**	
3	Dual output analog (APS1 + APS2) + SAE foot pedal (APS3 + PDLSW)	Normal	Normal	Normal	–	Normal	Normal	According to APS1 or APS3 terminal input voltage whichever operated later
		Normal	Normal	Normal	–	Normal	Fault	Calculated from input voltage at APS3 terminal
		Fault	Normal	Normal	–	Normal	Fault	Calculated from input voltage at APS3 terminal
		Normal	Fault	Normal	–	Normal	Fault	Calculated from input voltage at APS3 terminal
		Fault	Fault	Normal	–	Normal	Fault	Calculated from input voltage at APS3 terminal
		Normal	Normal	Fault	–	Normal	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	Normal	–	Fault	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	Fault	–	Fault	Normal	Calculated from input voltage at APS1 terminal
		Fault	Fault	Fault	–	Fault	Fault	According to all acceleration fault handling actions

Table 14-23 Backup acceleration fault handling actions

Backup acceleration configuration		Acceleration input						Target speed
Set value	Item	APS1	APS2	APS3	CAN	PDLSW	Dual	
0	CAN communication (TSC1 or TSC1 + Y_ECR1) → Single output analog (APS1)	Normal	–	–	Normal	–	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Fault	–	–	Normal	–	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Normal	–	–	Fault	–	–	Calculated from input voltage at APS1 terminal
		Fault	–	–	Fault	–	–	According to all acceleration fault handling actions
1	Single output analog (APS1) → CAN communication (TSC1 or TSC1 + Y_ECR1)	Normal	–	–	Normal	–	–	Calculated from input voltage at APS1 terminal
		Normal	–	–	Fault	–	–	Calculated from input voltage at APS1 terminal
		Fault	–	–	Normal	–	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Fault	–	–	Fault	–	–	According to all acceleration fault handling actions
2	Dual output analog (APS1 + APS2) → CAN communication (TSC1 or TSC1 + Y_ECR1)	Normal	Normal	–	Normal	–	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	–	Fault	–	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	–	Normal	–	Fault	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Fault	Normal	–	Normal	–	Fault	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Normal	Fault	–	Normal	–	Fault	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Fault	Fault	–	Normal	–	Fault	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Fault	Fault	–	Fault	–	Fault	According to all acceleration fault handling actions

Backup acceleration configuration		Acceleration input						Target speed
Set value	**Item**	**APS1**	**APS2**	**APS3**	**CAN**	**PDLSW**	**Dual**	
3	SAE foot pedal (APS3 + PDLSW) → CAN communication (TSC1 or TSC1 + Y_ECR1)	–	–	Normal	Normal	Normal	–	Calculated from input voltage at APS3 terminal
		–	–	Normal	Fault	Normal	–	Calculated from input voltage at APS3 terminal
		–	–	Fault	Normal	Normal	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		–	–	Normal	Normal	Fault	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		–	–	Fault	Normal	Fault	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		–	–	Fault	Fault	Fault	–	According to all acceleration fault handling actions

Table 14-24 CAN communication/analog input changeover fault handling actions

Changeover between CAN communication and analog input		Acceleration input						Target speed
Set value	Item	APS1	APS2	APS3	CAN	PDLSW	Dual	
0	CAN communication (TSC1 or TSC1 + Y_ECR1) <=> Single output analog (APS1)	Normal	–	–	Normal	–	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Fault	–	–	Normal	–	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Normal	–	–	Fault/ disabled	–	–	Calculated from input voltage at APS1 terminal
		Fault	–	–	Fault/ disabled	–	–	According to all acceleration fault handling actions
1	CAN communication (TSC1 or TSC1 + Y_ECR1) <=> Dual output analog (APS1 + APS2)	Normal	Normal	–	Normal	–	Normal	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Normal	Normal	–	Normal	–	Fault	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Fault	Normal	–	Normal	–	Fault	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Normal	Fault	–	Normal	–	Fault	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Fault	Fault	–	Normal	–	Fault	According to a value specified by TSC1 or TSC1 + Y_ECR1
		Normal	Normal	–	Fault/ disabled	–	Normal	Calculated from input voltage at APS1 terminal
		Fault	Fault	–	Fault/ disabled	–	Fault	According to all acceleration fault handling actions
2	CAN communication (TSC1 or TSC1 + Y_ECR1) <=> SAE foot pedal (APS3 + PDLSW)	–	–	Normal	Normal	Normal	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		–	–	Fault	Normal	Normal	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		–	–	Normal	Normal	Fault	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		–	–	Fault	Normal	Fault	–	According to a value specified by TSC1 or TSC1 + Y_ECR1
		–	–	Normal	Fault/ disabled	Normal	–	Calculated from input voltage at APS3 terminal
		–	–	Fault	Fault	Fault	–	According to all acceleration fault handling actions

Table 14-25 Service acceleration function fault handling actions (under development)

Service acceleration configuration		Acceleration input						Target speed
Set value	Item	APS1	APS2	APS3	CAN	PDLSW	Dual	
0	Service acceleration (APS1) <=> No acceleration	Not connected*1	–	–	–	–	–	Changeover between constant speed and contact input
		Connected	–	–	–	–	–	Calculated from input voltage at APS1 terminal
1	Service acceleration (APS3) <=> Single output analog (APS1)	Normal	–	Not connected*1	–	–	–	Calculated from input voltage at APS1 terminal
		Normal	–	Connected	–	–	–	Calculated from input voltage at APS3 terminal
		Fault	–	Connected	–	–	–	Calculated from input voltage at APS3 terminal
		Fault	–	Not connected*1	–	–	–	According to all acceleration fault handling actions
2	Service acceleration (APS3) <=> Dual output analog (APS1 + APS2)	Normal	Normal	Not connected*1	–	–	Normal	Calculated from input voltage at APS1 terminal
		Normal	Normal	Connected	–	–	Normal	Calculated from input voltage at APS3 terminal
		Normal	Normal	Connected	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Normal	Connected	–	–	Fault	Calculated from input voltage at APS3 terminal
		Normal	Fault	Connected	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Fault	Connected	–	–	Fault	Calculated from input voltage at APS3 terminal
		Fault	Fault	Not connected*1	–	–	Fault	According to all acceleration fault handling actions
3	Service acceleration (APS1) <=> SAE foot pedal (APS3 + PDLSW)	Not connected*1	–	Normal	–	Normal	–	Calculated from input voltage at APS3 terminal
		Connected	–	Normal	–	Normal	–	Calculated from input voltage at APS1 terminal
		Connected	–	Fault	–	Normal	–	Calculated from input voltage at APS1 terminal
		Connected	–	Normal	–	Fault	–	Calculated from input voltage at APS1 terminal
		Connected	–	Fault	–	Fault	–	Calculated from input voltage at APS1 terminal
		Not connected*1	–	Fault	–	Fault	–	According to all acceleration fault handling actions

Service acceleration configuration		Acceleration input						Target speed
Set value	Item	APS1	APS2	APS3	CAN	PDLSW	Dual	
4	Service accelera-tion (APS1) <=> CAN communi-cation (TSC1 or TSC1 + Y_ECR1)	Not conne–cted*1	–	–	Normal	–	–	According to a value speci-fied by TSC1 or TSC1 + Y_ECR1
		Conne–cted	–	–	Normal	–	–	Calculated from input volt-age at APS1 terminal
		Conne–cted	–	–	Fault	–	–	Calculated from input volt-age at APS1 terminal
		Not conne–cted*1	–	–	Fault	–	–	According to all accelera-tion fault handling actions

**1: If the service acceleration is not connected, the service acceleration fault will not be detected.*

Configuring the all acceleration fault handling actions

Function

If no normal signal can be received from any of the set acceleration inputs, an all acceleration fault is detected. For the method to configure the fault handling actions, refer to *Configuring the fault handling actions on page 14-102*.

Application menu (provisional monitor specification)

- All acceleration fault handling process

Table 14-26 Setting for all acceleration fault handling process

Set value	Content	
0	Follow fault handling actions	For the target engine speed, one of the limit level values for speed limit in “All acceleration fault handling actions” in the table below is set.
1	Last value kept	“Last value kept” means that the engine runs at the same speed as immediately before the occurrence of the fault (until the fault is automatically reset or E-ECU power is turned OFF). If a fault is detected during key ON, one of the limit level values for speed limit in “All acceleration fault handling actions” in the table below is set.

- All acceleration fault handling actions

Table 14-27 Setting for all acceleration fault handling actions

Operation at fault	Setting content		
	Set value	Limit level	Standard setup
Speed limit Note: Unlike speed limit at other faults, the limit level of the speed limit is set to the engine target speed.	0	Disabled (low idle)	2
	1	Level 1 (1800 min^{-1} (reference))	
	2	Level 2 (1500 min^{-1} (reference))	
	3	Level 3 (option)	
	4	Level 4 (low idle speed (option))	
Maximum injection amount limit	0	Disabled	0
	1	Level 1 (75 % (reference))	
	2	Level 2 (50 % (reference))	
Engine stop	0	Disabled	0
	1	Stop without delay	
	2	Stop after delay time of 7200 s	
	3	Stop after delay time of 900 s	
	4	Stop after delay time of A (option)	
	5	Stop after delay time of B (option)	

NOTICE

If a fault occurs while the engine is accelerating or decelerating, the engine speed may be maintained as follows:
If a fault occurs during acceleration, the target speed is maintained at the high idle speed.
If a fault occurs during deceleration, the target speed is maintained at the low idle speed.
Carefully note that the engine accelerates to the preset speed if an acceleration sensor fault occurs while the engine is running at a speed lower than the preset speed.

Starting Aid Control

You can control the starting aid devices (glow plug) by configuring the following control functions based on the glow plug relay.

Disconnection detection (standard)

Function

You can configure the E-ECU to detect a disconnection or short circuit in the glow plug relay. (standard)

Application menu

- Starting aid relay fault detection function → 1: enabled (standard), 0; disabled

On-glow control (preheat) (standard)

Function

When the key switch is set to the ON position, the system automatically energizes the glow plug relay and keeps it energized for a particular amount of time depending on the cooling water temperature. You can also configure the system to turn ON the preheat lamp while the relay is being energized. (This function is equivalent to that provided by the QHS controller 129457-77900. The temperature control function of the QGS controller 119650-77900 performs 2 step switching.)

The preheat control status (preheat underway/stopping) is output via CAN communication (Y_ECACK1).

Note: The preheat time for on-glow control is configured as shown in ***Figure 14-29****. In addition, the remaining time of preheat is output via CAN communication (Y_ECACK1). (Under development)*

Application menu

- Starting aid control function: On glow → 1: enabled (standard), 0; disabled.

Simultaneous energizing control (standard)

Function

The glow plug relay is energized even when the starter motor is operated with the key switch set to the START position. (This function is equivalent to that provided by the QHS controller 129457-77900 or QGS controller 119650-77900.)

The completion criteria for the simultaneous energization control is “the completion with the engine start recognition signal” (the glow plug relay is not energized when the key switch is turned to the position except for START).

If the E-ECU power supply terminal voltage falls to 5.5 V or lower during simultaneous energizing, the system cuts off the power to the glow plug relay in order to prevent the E-ECU from being reset due to low power supply voltage. (Note that the E-ECU is designed to be reset when the power supply voltage falls to 6.0 V or lower.)

Starting aid control by CAN communication (option)

Function

The starting aid control can be stopped by CAN communication (Y_ECR1).

Application menu

- Starting aid control function by CAN communication → 0: disabled (standard), 1: enabled

Glow plug protection function (standard)

Function

To protect the glow plug and glow plug relay, when the glow plug relay is turned ON OFF ON by the start aid control, the glow plug relay, once deenergized, is kept deenergized for a specified reenergization inhibition time (480 ms: under evaluation) before it is reenergized. However, the lamp is subject to ON/OFF control even in the deenergized state during the above reenergization inhibition time. The control status of glow plug (glow plug OFF/ON/reenergization inhibition) is output via the CAN communication (Y_ECACR1).

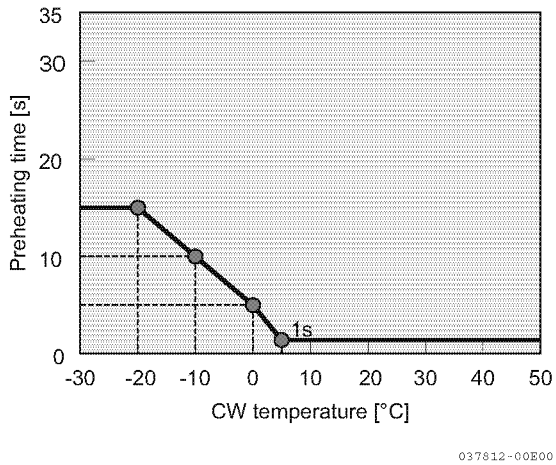


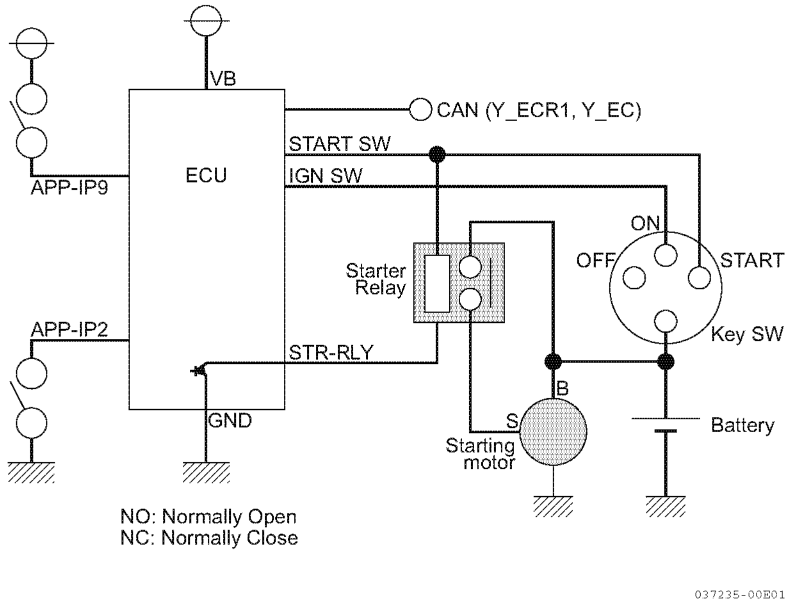
Figure 14-29 On-glow control preheat time (under confirmation)

NOTICE

When you use a key switch with a glow position in accordance with the standard wiring diagram, setting the key switch to the glow position causes the preheat lamp to automatically turn on for a specific amount of time depending on the cooling water temperature while energizing the starting aids.
When you turn the key switch from the OFF position to the ON position again to start up the engine upon completion of preheating, the preheat lamp turns ON again but you do not have to preheat the engine over again. Take care to avoid excessive preheating, or the engine may possibly fail to start up due to low battery terminal voltage.

Starter Motor Restraint Control

On the YANMAR electronic control system for Tier 4, the learning process for the EGR pressure sensor and the DPF differential pressure sensor and readout of the history data recorded in the EEPROM inside the E-ECU are performed as the E-ECU initial operation after the key switch is turned to ON. Therefore, the starter motor restraint control is performed by connecting the starter relay to the E-ECU as shown in **Figure 14-30** in order to prevent the engine from being started during the E-ECU initial operation. ("Starter motor restraint" means restraining the starter motor from rotating.) You can identify the reason for starter motor restraint by connecting a SA-D and checking the restraint reason flag. (under development)



Permission 1 SW	Logic setup	
	NO (standard)	NC (Option)
OFF (Open)	Restraint	Permission
ON (Close)	Permission	Restraint

Permission 2 SW	Logic setup	
	NO (standard)	NC (Option)
OFF (Open)	Restraint	Permission
ON (Close)	Permission	Restraint

Figure 14-30 Permission operation for starter external switch

The E-ECU has the following additional functions other than the starter restraint function during the E-ECU initial operation:

Starter input signal setting (standard)

Function

You can set the starter input signal based on whether the contact input (STARTSW terminal) or the CAN communication (Y_ECR1 (Bosch system only)). In the existing monitor provisional specification, the contact input (STARTSW terminal) is set.

Application menu

- Starter input signal setting
  → 0: based on STARTSW (standard)
  → 1: based on CAN (Y_ECR1: Crank Request)

Safety relay function (standard)

When the engine speed rises to or above 675 min^{-1} (or the speed specific to the model), the system turns OFF the starter motor and disables it until the engine speed falls to 0 min^{-1}.
(This functions is equivalent to that provided by 119802-77200 assuming that the safety relay to pulley ratio is 2.0.)

Starter motor energization time control function (option)

Function

To protect the starter motor, the system turns OFF the starter motor after it has been energized for 30 seconds or longer. The starter motor then remains unenergized for 30 seconds before it is restarted.

Application menu

- Starter motor energization time control function → 0: disabled (standard), 1: enabled.

External switch control function (option)

Function

You can disable the starter motor until an external switch input turns ON. This function is useful for implementing a safety system that prevents the starter motor from operating unless the driven machine's pedal is pressed.
The external switch you use may be either source type (APP-IP2) or sync type (APP-IP9) as shown in **Figure 14-30**. Alternatively, you can perform starter motor restraint control via the CAN communication, instead of a contact input.

Application menu

- Starter permit 1 switch (APP-IP9) → 0: disabled (standard), 1: enabled.
- Starter permit 2 switch (APP-IP2) → 0: disabled (standard), 1: enabled.
- CAN communication restraint setup
  → 0: disabled (standard)
  → 1: restraint by Y_EC (PGN65308)
  → 2: restraint by Y_ECR1 (PGN65282)
- Logic setup for APP-IP9 terminal (starter permission 1)
  → 0: SW close starter permission (standard), 1: SW close starter restraint
- Logic setup for APP-IP2 terminal (starter permission 2)
  → 0: SW close starter permission (standard), 1: SW close starter restraint

- Application example to remote (automatic) start/stop system

You can also use functions (1) and (2) described above to implement a remote (automatic) start/stop system. Details shown in **Figure 14-31**. This example uses the Engine Start Recognition: STARTSW signal from an external control device instead of the key switch.

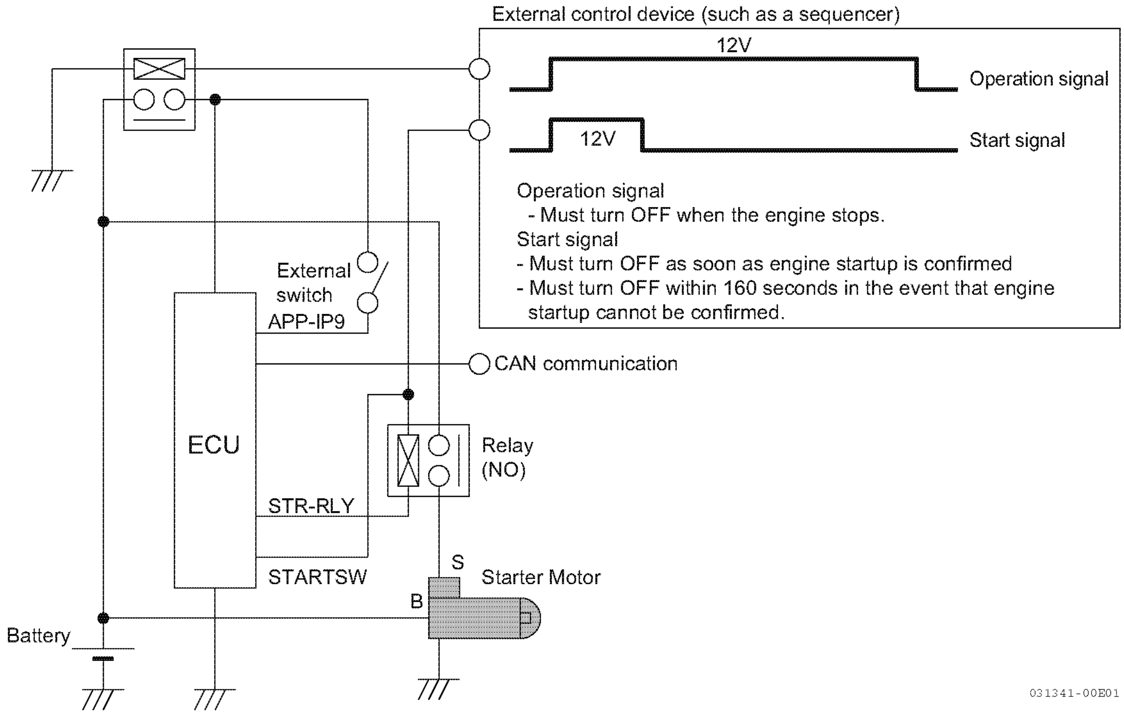


Figure 14-31 Wiring diagram of a remote (automatic) start/stop system

The run signal turns ON when the engine starts and turns OFF when the engine stops.

NOTICE

The start signal should be turned OFF in a maximum of 160 seconds as a rule. Otherwise, the starter motor will repeatedly operate at intervals of 30 seconds when the engine fails to start up for some reason.

Speed Selection Function

You can use an external switch input to change the engine speed.

The speed selection functions described below.

Note: These speed selection functions are mutually exclusive, and you can only use one of them at a time.

(1) Constant speed control : Controls the engine to run at a fixed speed.
(2) Deceleration control : Decelerates the engine speed at a constant rate from the speed determined by the acceleration sensor signal.
(3) Auto deceleration control : Controls the engine to run at a fixed speed after a specific amount of time.
(4) Auto deceleration control (with high idle speed limit function):
In addition to 3, decelerates the high idle speed momentarily depending on the external switch input.

Table 14-28 shows the relationships between the external switch status and engine speed for each of constant speed control, deceleration control, auto deceleration control, and auto deceleration control (with high idle speed limit function). The respective control functions will be described in detail later on. These external switches can also be turned ON/OFF using the CAN communication.

Table 14-28 Control functions for changing the engine speed using an external switch

Speed selection function	External switch			Engine speed
	Speed selection permission SW (APP-IP6)	Speed selection 1 SW (APP-IP3)	Speed selection 2 SW (APP-IP4)	
0: disabled (standard)	–	–	–	According to YMR standard acceleration setting.
(1) Constant speed control 1: toggle type 2: momentary type	Prohibited (OFF)	–	–	Acceleration sensor signal
	Permitted (ON)	OFF	OFF	Constant speed 2: 1500 min^{-1} [*1]
		OFF	ON	Low idle
		ON	OFF	Constant speed 1: 1800 min^{-1} [*2]
		ON	ON	High idle
(2) Deceleration control 3: toggle type 4: momentary type	Prohibited (OFF)	–	–	Acceleration sensor signal
	Permitted (ON)	OFF	OFF	Deceleration rate 2: 70% deceleration[*3]
		OFF	ON	Acceleration sensor signal
		ON	OFF	Deceleration rate 1: 85% deceleration[*4]
		ON	ON	Acceleration sensor signal
5: (reserved)	–	–	–	–
(3) Auto deceleration control 6	Prohibited (OFF)	–	–	Acceleration sensor signal
	Permitted (ON)	OFF	OFF (delay: 4 seconds[*5])	Low idle
		OFF	ON	Acceleration sensor signal
		ON	OFF (delay: 4 seconds[*5])	Constant speed 1: 1800 min^{-1} [*2]
		ON	ON	Acceleration sensor signal
(4) Auto deceleration control (with high idle speed limit function) 7	Prohibited (OFF)	–	–	Acceleration sensor signal
	Permitted (ON)	OFF	OFF (delay: 4 seconds[*5])	Low idle
		OFF	ON	Acceleration sensor signal
		ON	OFF	Acceleration sensor signal (with high idle limit depending on constant speed 1: 1800 min^{-1} [*2])
		ON	ON	

**1 - *5: These values can be changed through map settings. (option)*
**2: These values are used for maps as well.*

These external switches can also be turned ON/OFF using the CAN communication (Y_RSS).

Constant speed control

Function

While constant speed control is in effect, the target engine speed is constant regardless of the accelerator position.

You can set the fixed speed used in constant speed control to constant speed 1 (standard: 1800 min^{-1}), constant speed 2 (standard: 1500 min^{-1}), low idle speed, or high idle speed by turning ON/OFF the speed selection 1 switch (APP-IP3) and speed selection 2 switch (APP-IP4). (Refer to **Table 14-28**.)

The values of constant speeds 1 and 2 can be changed (option).

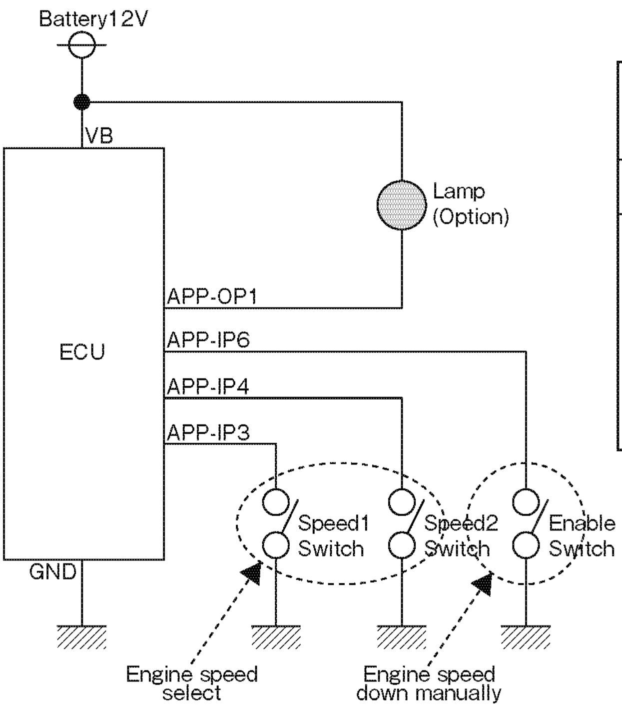
Application menu

- Speed selection function setup
  → 1: Constant speed control (toggle type)
  → 2: Constant speed control (momentary type)
- Speed selection permission input → 0: based on APP-IP6 (standard), or 1: based on CAN (Y_RSS)
- Speed selection 1 input → 0: based on APP-IP3 (standard), or 1: based on CAN (Y_RSS)
- Speed selection 2 input → 0: based on APP-IP4 (standard), or 1: based on CAN (Y_RSS)
- Constant speed 1 [min^{-1}] → Can be changed to any value (standard value is 1800).
- Constant speed 2 [min^{-1}] → Can be changed to any value (standard value is 1500).
- APP-IP6 terminal function logic setup → 0: SW close   ON (standard), or 1: SW close   OFF
- APP-IP3 terminal function logic setup → 0: SW close   ON (standard), or 1: SW close   OFF
- APP-IP4 terminal function logic setup → 0: SW close   ON (standard), or 1: SW close   OFF

Description

Figure 14-32 show how to make wiring connections for constant speed control.

Note: You can optionally connect the indicator lamp to the APP-OP1 terminal.



Switch operation

Enable Switch	Lamp	Speed 1 Switch	Speed 2 Switch	Const. Speed
off	off	–	–	Normal
on	on	off	off	1500min^{-1} (variable)
			on	Low idle
		off	off	1800min^{-1} (variable)
			on	High idle

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Figure 14-32 Wiring diagram for constant speed control

Figure 14-33 provides an operation timing chart for the constant speed control mode. For the speed selection permission switch (APP-IP6), you can choose either toggle or momentary type.

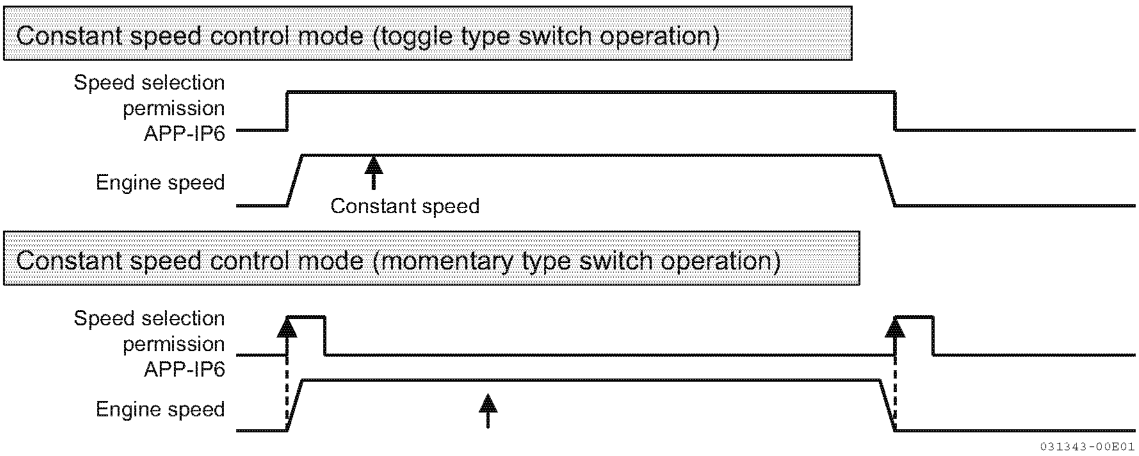


Figure 14-33 Operation timing chart for the constant speed control mode

Note: The toggle type is recommended as the standard setting since the momentary type may possibly cause the speed to fluctuate should the E-ECU be reset.

Behavior of deceleration control

Function

You can set the deceleration rate for deceleration control to 1. deceleration rate 1 (85 % by standard) or 2. deceleration rate 2 (70 % by standard) using the speed selection 1 switch (APP-IP3). (Speed selection 2 switch (APP-IP4) must be turned off. Refer to **Table 14-28**.)

You can optionally change the deceleration rate and deceleration start speed (standard: 1500 min^{-1}) for each of deceleration rates 1 and 2.

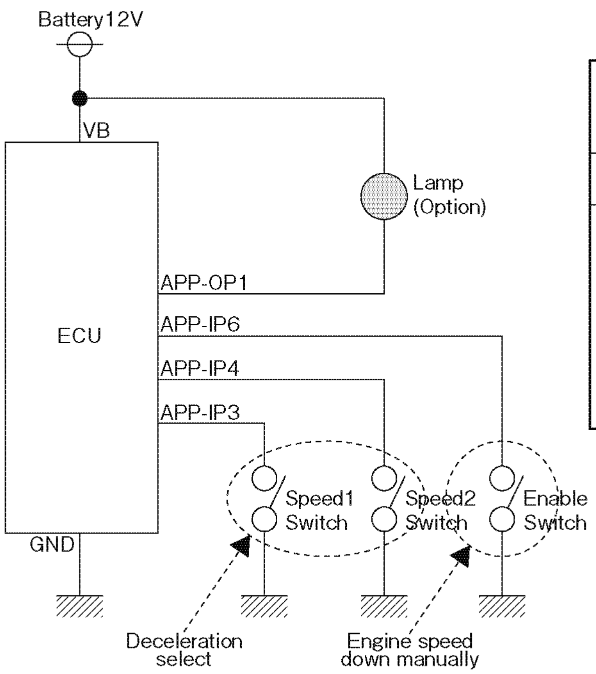
Application menu

- Speed selection function setup
  → 1: Deceleration control (toggle type)
  → 2: Deceleration control (momentary type)
- Speed selection permission input → 0: based on APP-IP6 (standard), or 1: based on CAN (Y_RSS)
- Speed selection 1 input → 0: based on APP-IP3 (standard), or 1: based on CAN (Y_RSS)
- Speed selection 2 input → 0: based on APP-IP4 (standard), or 1: based on CAN (Y_RSS)
- Deceleration start speed (min^{-1}) → Can be changed to any value (standard value is 1500).
- Deceleration rate 1 (%) → Can be changed to any value (standard value is 85).
- Deceleration rate 2 (%) → Can be changed to any value (standard value is 70).
- APP-IP6 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF
- APP-IP3 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF
- APP-IP4 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF

Description

Figure 14-34 shows how to make wiring connections for deceleration control.

Similarly to constant speed control, you can optionally connect the indicator lamp to the APP-OP1 terminal.



Switch operation

Enable Switch	Lamp	Speed 1 Switch	Speed 2 Switch	Const. Speed
off	off	–	–	Normal
on	on	off	off	70% (variable)
			on	Low idle
		off	off	85% (variable)
			on	High idle

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Figure 14-34 Wiring diagram for deceleration control

Figure 14-35 provides an operation timing chart for the deceleration control mode. For the speed selection permission switch (APP-IP6), you can choose either toggle or momentary type.

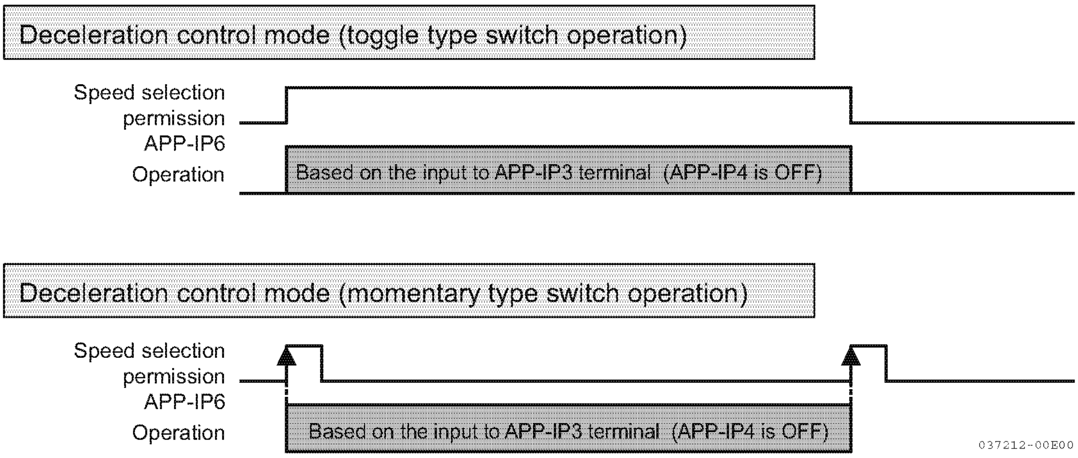


Figure 14-35 Operation timing chart for the deceleration control mode

Note: The toggle type is recommended as the standard setting since the momentary type may possibly cause the speed to fluctuate should the E-ECU be reset.

As shown in **Figure 14-36**, the target engine speed applied while deceleration control is in effect is such that the rated speed is reduced by the amount determined by the specific deceleration rate (Refer to **Table 14-28**) with respect to the accelerator position.

Indicator lamp - When the target speed is equal to or lower than the deceleration start speed, the indicator lamp described above (APP-OP1) does not turn ON even when deceleration control is in effect.

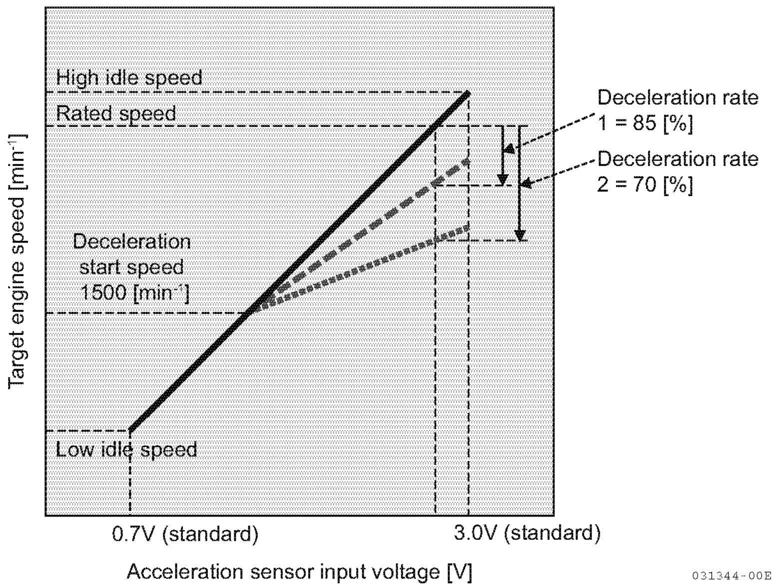


Figure 14-36 Behavior of deceleration control

Auto deceleration control

Function

To minimize fuel consumption, the system reduces the engine speed to a specific low speed.

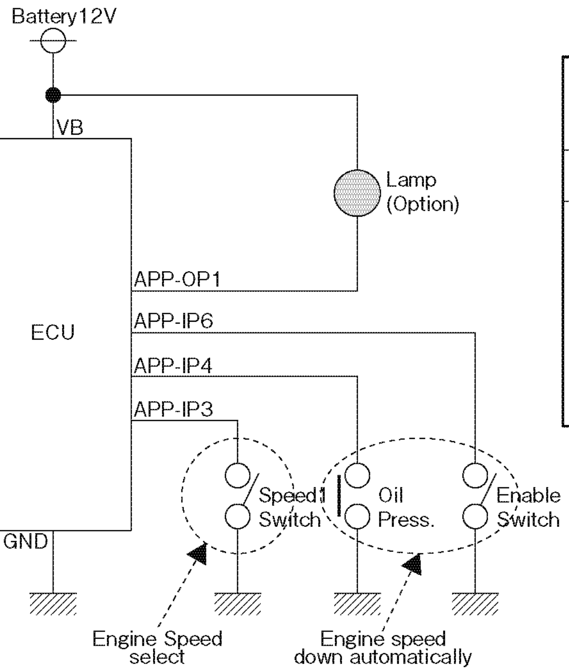
Application menu

- Speed selection function setup → 6: Auto deceleration control
- Speed selection permission input → based on APP-IP6 (standard), or 1: based on CAN (Y_RSS)
- Speed selection 1 input → based on APP-IP3 (standard), or 1: based on CAN (Y_RSS)
- Speed selection 2 input → based on APP-IP4 (standard), or 1: based on CAN (Y_RSS)
- Auto deceleration wait time (s) → Can be changed to any value (standard value is 4).
- Auto deceleration accelerator disconnection → 0: disabled (standard) or → 1: enabled.
- Constant speed 1 (min^{-1}) → Can be changed to any value (standard value is 1800).
- APP-IP6 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF
- APP-IP3 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF
- APP-IP4 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF

Description

Figure 14-37 shows how to make wiring connections for auto deceleration control.

The indicator lamp can be wired so that it turns ON when auto deceleration is permitted. Omitting this step will not affect the control behavior.



Switch operation

Enable Switch	Lamp	Speed 1 Switch	Oil Press. Switch	Const. Speed
off	off	–	–	Normal
on	on	off	off	Low idle
			on	Normal
		on	off	1800min^{-1} (variable)
			on	Normal

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Figure 14-37 Wiring diagram for auto deceleration

Figure 14-38 provides an operation timing chart for the auto deceleration control mode.

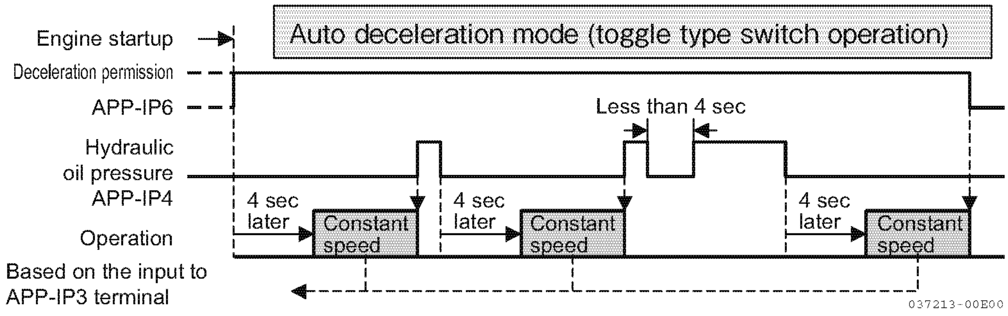


Figure 14-38 Operation timing chart for the auto deceleration control mode

When 4 seconds (the time before deceleration is permitted) or longer have elapsed with the deceleration permission switch (APP-IP6) ON and the hydraulic oil pressure switch (APP-IP4) OFF (in the non-operating status), auto deceleration control works to make constant the target engine speed regardless of the accelerator position.

You can set the deceleration rate for deceleration control to 1. deceleration rate 1 (1800 min^{-1} standard) or 2. low idle speed using the speed selection 1 switch (APP-IP3). (Refer to **Table 14-28**.)

- Changing the settings
  You can change the "constant speed 1" setting, which is shared with constant speed control. You can also change the OFF duration of the hydraulic oil pressure switch (standard: 4 seconds). (option)
- Cancellation by accelerator operation
  As shown in **Figure 14-39**, you can configure the system to temporarily cancel the constant speed operation under auto deceleration control when the accelerator is operated, regardless of whether the hydraulic oil pressure switch (APP-IP4) is ON or OFF. The system follows the target speed determined by operating the accelerator while auto deceleration is cancelled. (option)

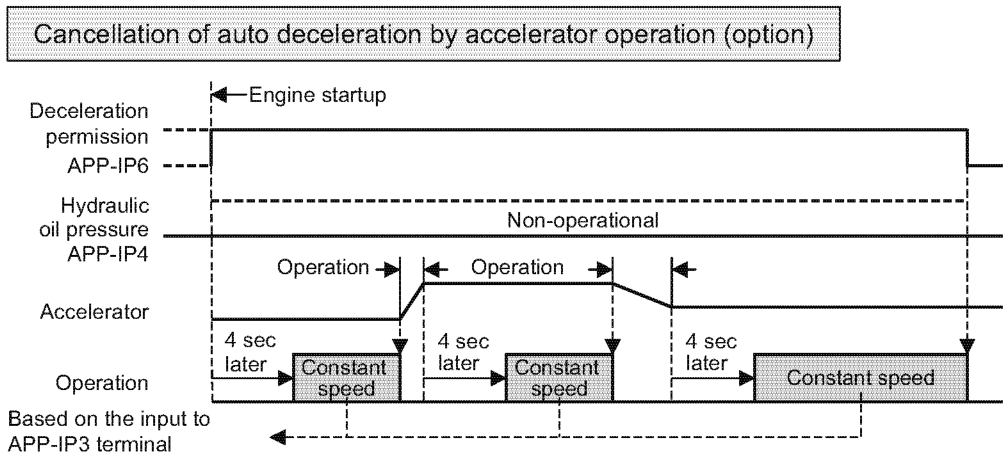


Figure 14-39 Cancellation of auto deceleration by accelerator operation

Auto deceleration control (with high idle speed limit function)

Function

This function mode allows you to select the previously mentioned auto deceleration control.

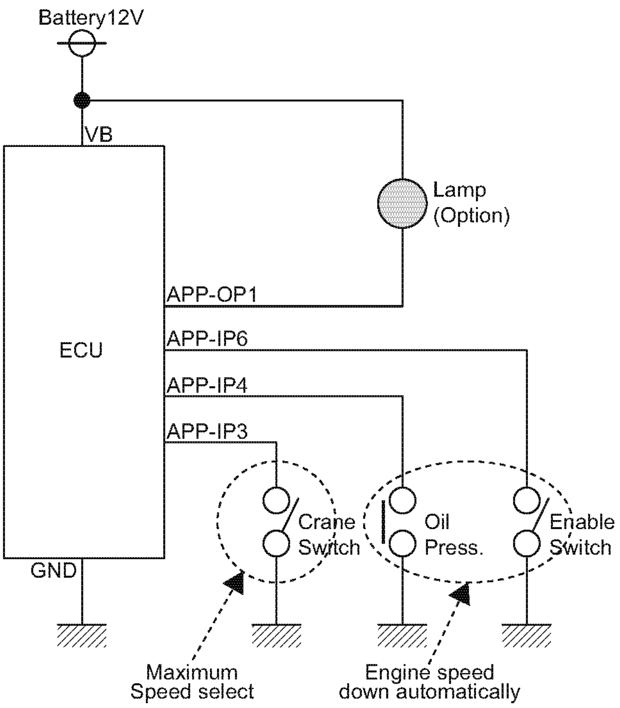
When the external switch input (APP-IP3) is ON, the engine target speed is set to the acceleration indication speed regardless of the contact condition of the speed selection permission switch input (APP-IP6), limiting the high idle speed to the constant speed 1 (standard: 1800 min^{-1}). While no operation is performed, the system reduces the engine speed to the low idle speed.

Application menu

- Speed selection function setup → 7: Auto deceleration control (with high idle speed limit function)
- Speed selection permission input → based on APP-IP6 (standard), or 1: based on CAN (Y_RSS)
- Speed selection 1 input → based on APP-IP3 (standard), or 1: based on CAN (Y_RSS)
- Speed selection 2 input → based on APP-IP4 (standard), or 1: based on CAN (Y_RSS)
- Auto deceleration wait time (s) → Can be changed to any value (standard value is 4).
- Auto deceleration accelerator disconnection → 0: disabled (standard) or → 1: enabled.
- Constant speed 1 (min^{-1}) → Can be changed to any value (standard value is 1800).
- APP-IP6 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF
- APP-IP3 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF
- APP-IP4 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF

Description

Figure 14-37 shows how to make wiring connections for auto deceleration control (with high idle speed limit function). The indicator lamp can be wired so that it turns ON when auto deceleration is permitted. Omitting this step will not affect the control behavior.



Switch operation

Enable SW	Lamp	Crane SW	Oil Press. SW	Speed control
off	off	off	–	Normal
		on		Normal (Max.1800min^{-1} (variable))
on	on	–	off(4s)	Low idle
	off	off	on	Normal
		on		Normal (Max.1800min^{-1} (variable))

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Figure 14-40 Wiring diagram for auto deceleration (with high idle speed limit function)

Figure 14-41 provides an operation timing chart for the auto deceleration control (with high idle speed limit function).

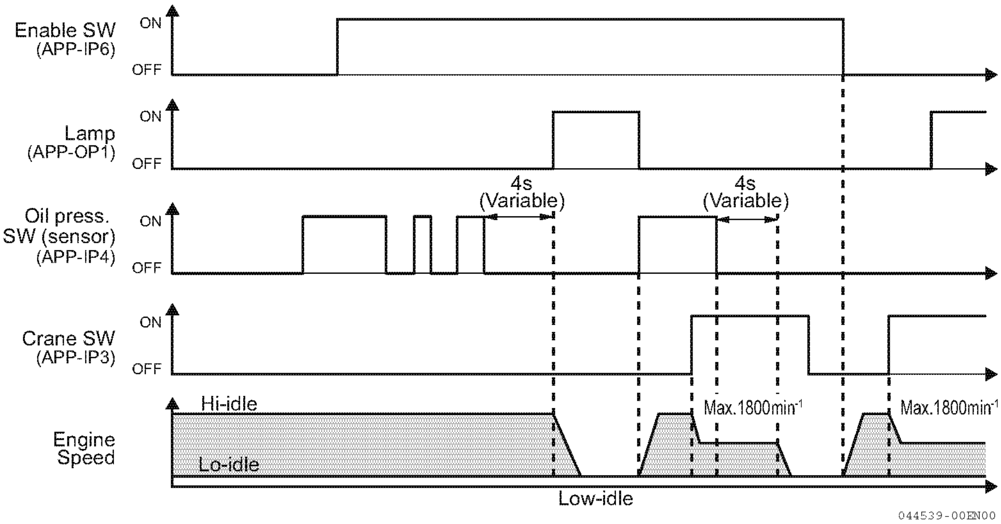


Figure 14-41 Operation timing chart for the auto deceleration control (with high idle speed limit function

When the external switch input (APP-IP3) is OFF and the deceleration permission switch (APP-IP6) is ON and the hydraulic oil pressure switch (APP-IP4) is OFF (in the non-operating status) for more than 4 seconds (adjustable), the auto deceleration control changes the engine target speed to the low idle speed regardless of the accelerator. When the external switch input (APP-IP3) is ON, the engine target speed switches to the acceleration indication speed. The high idle speed is limited to the constant speed 1 (standard: 1800 min^{-1}). (Refer to **Table 14-28**.)

- Changing the settings
  You can change the “constant speed 1” setting, which is shared with constant speed control. You can also change the OFF duration of the hydraulic oil pressure switch (standard: 4 seconds). (option)
- Cancellation by accelerator operation
  As shown in **Figure 14-39**, you can configure the system to temporarily cancel the constant speed operation under auto deceleration control when the accelerator is operated, even if the hydraulic oil pressure switch (APP-IP4) is OFF. The system follows the target speed determined by operating the accelerator while auto deceleration is cancelled. (option)

High Idle Speed Limit Function

Function

You can temporarily lower the high idle speed using an external switch input or CAN communication (Y_EC). By connecting the high idle limit switch to the APP-IP5 terminal, you can limit the maximum target speed determined by acceleration sensor operations. Also, by connecting the high idle selection switch to the APP-IP8 terminal, you can switch the speed limit between limit 1 and limit 2.
Furthermore, you can configure speed limits separately for droop and iso-chronous modes; thus 4 different speed limits are available in all.

Table 14-29

High idle limit switch APP-IP5	High idle selection switch APP-IP8	Speed limit (standard setting)	
		Droop [min^{-1}]	Iso-chronous [min^{-1}]
OFF	–	Rated speed +150	Rated speed +30
ON	OFF: limit 1	2020 (Variable)	1900 (Variable)
	ON: limit 2	1820 (Variable)	1700 (Variable)

Application menu

- High idle limit 1
  → 0: disabled
  → 1: enabled for both droop and iso-chronous modes
  → 2: enabled for droop mode only
  → 3: enabled for iso-chronous mode only
- Droop limit 1 (min^{-1}) → Can be changed to any value (standard value is 2020).
- Iso-chronous limit 1 (min^{-1}) → Can be changed to any value (standard value is 1900).
- High idle limit 2
  → 0: disabled
  → 1: enabled for both droop and iso-chronous modes
  → 2: enabled for droop mode only
  → 3: enabled for iso-chronous mode only
- Droop limit 2 (min^{-1}) → Can be changed to any value (standard value is 1820).
- Iso-chronous limit 2 (min^{-1}) → Can be changed to any value (standard value is 1700).
- High idle limit input → 0: based on APP-IP5 (standard), or 1: based on CAN (Y_EC)
- High idle selection input → 0:based on APP-IP8 (standard), or 1: based on CAN (Y_EC)
- APP-IP5 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF
- APP-IP8 terminal function logic setup → 0: SW close → ON (standard), or 1: SW close → OFF

Description

Figure 14-42 shows how to make wiring connections for high idle speed limit control. The switches you connect to APP-IP5 and APP-IP8 may be either NO (Normally Open) or NC (Normally Closed). **Table 14-29** assumes that NO (Normally Open) switches are used as the standard configuration. This function controls the target speed under no load. The actual engine speed varies depending on the load size.

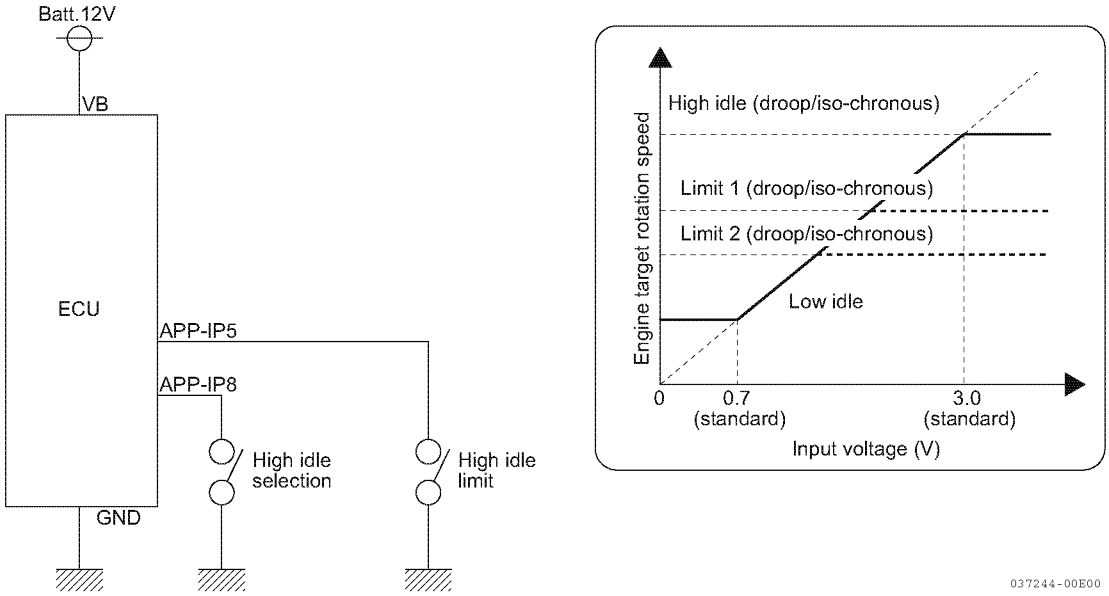


Figure 14-42 High idle speed limit function

Engine Stop Function

Beside an overload and lack of fuel, the causal factors of engine stop (hereinafter referred to as “engine stop factor”) include the following.

(1) Method by key switch

(2) Method by external switch (SHUDNSW terminal, APP-IP7 terminal, CAN communication)

(3) Control fault detection

In addition, the engine stop factors can be confirmed by SA-D. (Under development)

(1) Method by key switch

When the key switch is turned to OFF, E-ECU performs engine stop control to stop the engine. A shutdown command equivalent to key switch OFF can be executed by CAN communication (Y_ECR1).

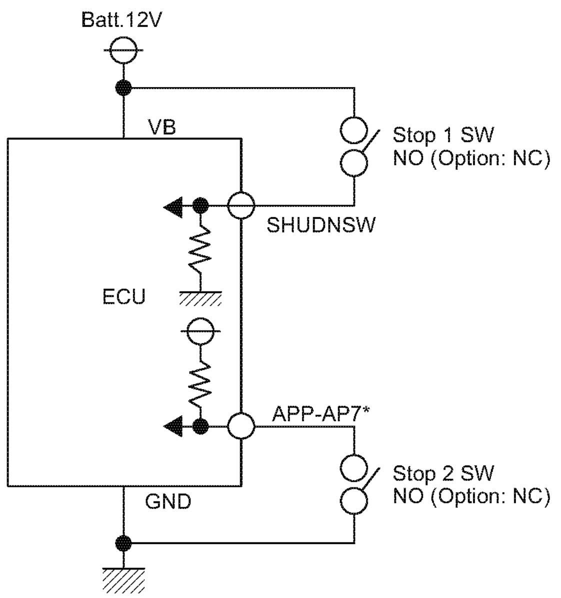
Application menu (option) (under development)

- ECU shutdown CAN command → 0: disabled, 1: enabled (Y_ECR1)

(2) Method by external switch (SHUDNSW terminal, APP-IP7 terminal, CAN communication)

Connect an engine stop 1 switch (hereinafter referred to as “stop 1 SW”) to the SHUDNSW terminal and turn ON the stop 1 SW. The engine stops. Similarly, connect an engine stop 2 switch (hereinafter referred to as “stop 2 SW”) to the APP-IP7 terminal and turn ON the stop 2 SW. The engine stops. The signals can be input also from CAN communication (Y_STP, Y_ECR1).

For the method to connect the stop 1 SW and stop 2 SW, refer to **Figure 14-43**.



Stop 1 SW	Logic setup	
	NO (standard)	NC (Option)
OFF (Open)	Operation permission	Stop
ON (Close)	Stop	Operation permission

Stop 2 SW	Logic setup	
	NO (standard)	NC (Option)
OFF (Open)	Operation permission	Stop
ON (Close)	Stop	Operation permission

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Figure 14-43 An example of stopping the engine using an external switch

The stop 1 SW and stop 2 SW have the following additional functions.

Delay time function

Function

This function does not stop the engine immediately after the stop 1 SW or stop 2 SW is turned ON, but stops the engine when either switch has remained ON continuously for 2 s (standard) or more. The function operates while the engine is starting or operating.

Application menu

- Setting of engine stop 1 (SHUDNSW terminal) → 0: No delay (standard), or 1: With delay
- Delay time setting for engine stop 1 (SHUDNSW terminal) → Can be changed to any value (2000 ms as standard)
- Setting of engine stop 2 (APP-IP7 terminal) → 0: No delay (standard), or 1: With delay
- Delay time setting for engine stop 2 (APP-IP7 terminal) → Can be changed to any value (2000 ms as standard)

Selection of engine stop factor retention operation

Function

With the standard settings, once the stop 1 SW or stop 2 SW is turned ON, the engine stop factor is retained. To restart the engine, turn OFF the key switch. While an engine stop factor is retained, the starter operation is also unavailable. However, the method to cancel the engine stop factor retention can be selected by an option setting

Application menu

- Selection of engine stop 1 factor retention operation
  → 0: Retention is cancelled when key switch is turned to OFF/ON (standard).
  → 1: Retention is cancelled when key switch is turned to OFF/ON or engine speed is 0.
  → 2: Retention is cancelled upon SHUDNSW OFF (under development).
- Selection of engine stop 2 factor retention operation
  → 0: Retention is cancelled when key switch is turned to OFF/ON (standard).
  → 1: Retention is cancelled when key switch is turned to OFF/ON or engine speed is 0.
  → 2: Retention is cancelled when APP-IP7 is OFF and CAN (STP) is OFF (under development).

Setting of ECU terminal function

Function

Because both the stop 1 SW and stop 2 SW are set to Normally Open with the standard settings, the engine can be operated without connecting a switch. For the stop 1 SW and stop 2 SW, Normally Close can be selected as well.

Application menu

- Logic setting for SHUDNSW terminal (engine stop 1)
  → 0: SW close engine stop (standard), or 1: SW close engine operating
- Logic setting for APP-IP7 terminal (engine stop 2)
  → 0: SW close engine stop (standard), or 1: SW close engine operating

Setting of engine stop 2 (CAN)

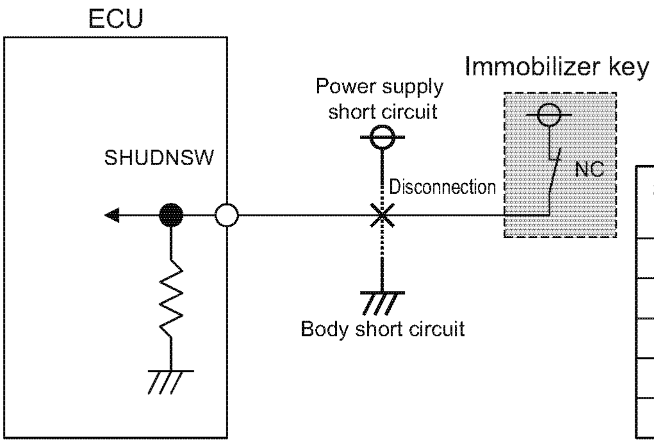
Function

The CAN communication packet used for stop 2 SW can be selected.

Application menu

- Setting of engine stop 2 (CAN)
  → 0: Disabled (standard)
  → 1: By CAN (Y_STP (On Request))
  → 2: By CAN (Y_ECR1: Engine Stop Request (Regular transmission))

- Advantages of engine stop 1 switch (SHUDNSW terminal)
  When the stop 1 SW is configured as normally closed, the engine is stopped and protected if an open or short occurs in a harness as illustrated in **Figure 14-44**. Therefore, it is suitable for utilization as a connection port for the immobilizer key.



SHUDNSW terminal logic setting = NC (option)

Status of engine stop switch (NC)	Engine operation
OFF (closed)	Permitted
ON (open)	Prohibited
Disconnection (open)	Prohibited
Body short circuit	Prohibited
Power supply short circuit	Permitted

037215-00E00

Figure 14-44 An Example of Connecting an Immobilizer

NOTICE

Precautions to take before using the normally closed configuration

Carefully note that, once you have configured the stop 1 SW as normally closed, the engine cannot run when the switch circuit is not connected.

- Advantages of engine stop 2 switch (APP-IP7 terminal)
  This function can be utilized for a safety function that stops the engine, for example, when the driven machine's cover is opened.

(3) Fault detected by the E-ECU]

The engine may stop due to a fault detected by the E-ECU. For more information, refer to *Fault Detection Function of the E-ECU on page 14-90.*

Idle Up Function

Function

This function facilitates warming up the engine at low temperature by increasing the low idle speed when the cooling water temperature is low (refer to **Figure 14-45**).

Note: Recommended only for models that use a low idle speed of 1000 min^{-1} or lower.

Application menu

- Idle up speed: Individual setting

Description

For an engine that normally uses a low idle speed of 800 min^{-1}, set the minimum speed to 1000 min^{-1} or higher in order to make more stable the engine speed at cooling water temperatures of 10 °C or lower (refer to **Figure 14-46**).

Idle up speed = low idle speed + idle up speed increase

Example: When the cooling water temperature is 10 °C and the low idle speed is 800 min^{-1}, the target speed will be 1000 min^{-1} (800 + 200).

Precautions regarding the use of the idle up function

You do not have to use the idle up function for an engine that normally uses a low idle speed of 1000 min^{-1}. As described above, when the cooling water temperature is 10 °C or lower, using the idle up function causes the engine speed to rise by 200 min^{-1} (tentative).

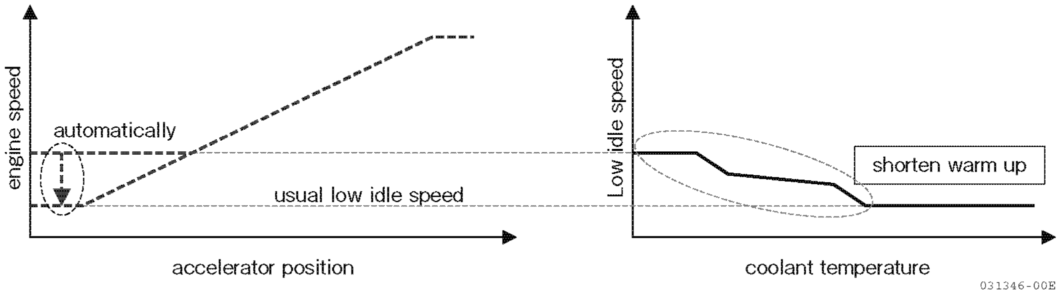


Figure 14-45 Low idle speed control at low temperatures

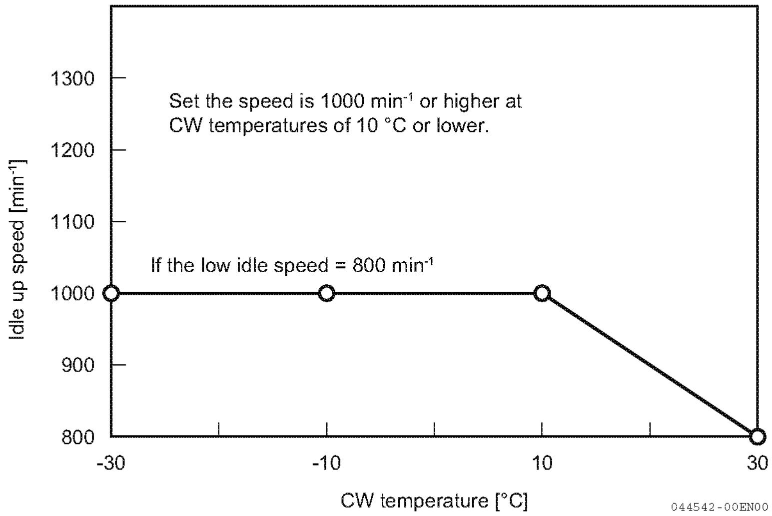


Figure 14-46 Standard settings for the idle up function (low idle speed = 800min^{-1})

Low-temperature High Idle Limit Function

Function

You can shorten the time required for the blue/white smoke goes out after the engine has started up at low temperatures by limiting the high idle speed. (Refer to **Figure 14-47**)

Application menu

- Low-temperature high idle limit function → 1: enabled or 0: disabled (standard)

Description

When setting this function to an engine with a rated speed of 2300 min^{-1} or higher, you can shorten the time required for blue/white smoke going out by reducing the high idle speed by approximately 150 min^{-1} at cooling water temperatures of 30 °C or lower.

Note: For the standard setting, the low-temperature high idle limit function is not set.

- Cancellation conditions
  This control is cancelled when, at cooling water temperatures of 30 °C or higher, the engine speed is reduced to or lower than the low-temperature high idle limit speed by operating the accelerator. If the control is cancelled at a speed higher than the low-temperature high idle limit speed, the engine speed will not automatically increase.

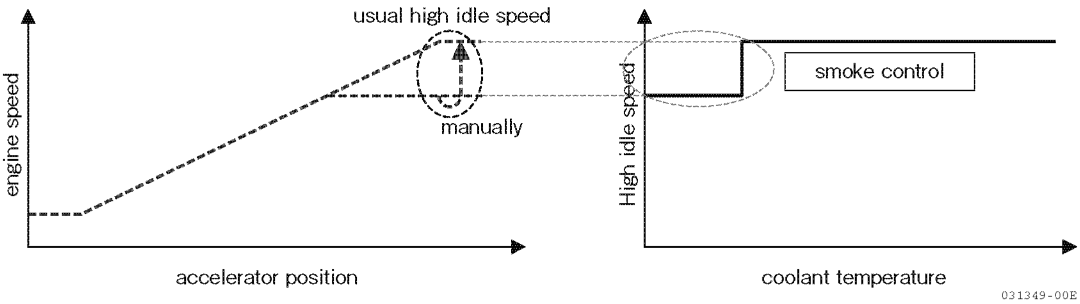


Figure 14-47 High idle speed control at low temperatures

Engine Fault Detection (Oil Pressure, Air Cleaner, etc.)

Function

You can connect the E-ECU with various engine fault detection sensors as shown in **Figure 14-48**, in addition to electronic control sensors. You can (optionally) configure fault handling actions performed depending on the status of each sensor and also (optionally) output the status of each sensor through the CAN communication. For the setting method for fault handling actions, refer to *Configuring the fault handling actions on page 14-102*. In addition, as shown in **Figure 14-48**, you can install a lamp in each engine fault detection sensor.

Take the oil pressure switch/lamp power from a specified UB terminal. In addition, take the power for the charge, air cleaner, and water separator switches/lamps from the key switch. For details on harness connections, refer to Standard Circuit and Standard Harness in **Table 14-8**.

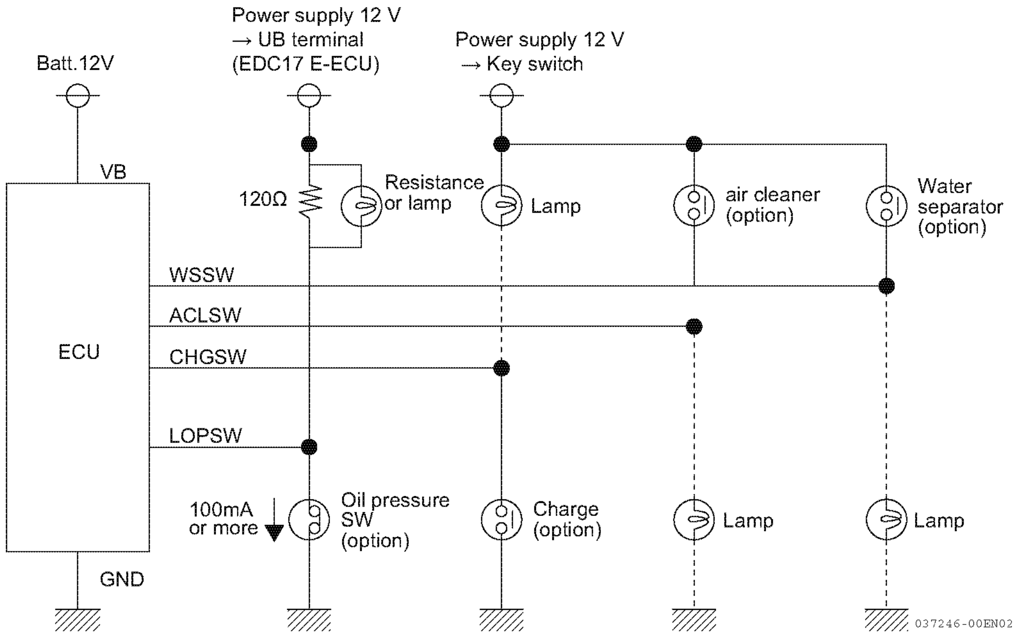


Figure 14-48 Connecting engine fault detection sensors

NOTICE

Preventing oil pressure switches from contact failures

In order to prevent oil switches (119761-39450 and so on) from contact failures due to impurities contained in the lubricating oil, connect a lamp or load resistor (120 Ω) to them so that the contact current is 100 mA or higher.

Fault Detection Function of the E-ECU

Table 14-30 provides a list of various error items covered by self diagnosis performed by E-ECU.

Table 14-30 Fault detection list (monitor provisional specification)

Item 1	Item 2	Fault	Application model: Under 56 kW	Failure decision: Prerequisite condition (Under 56 kW)	Failure decision: Detection condition (Under 56 kW)	Fail safe action: Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Recovery timing (Under 56 kW)	Fault code: DTC	Lamp information: MIL	RSL	AWL
Sensor	Crank	Abnormal signal	●	–	ECU detects abnormal signal of 15 times			●	●												ECU keeps engine operation by only cam sensor.	ECU Power OFF	P0336	●		●
		No signal	●	–	ECU does not detect crank pulse signal while cam make 10 rotations			●	●												ECU keeps engine operation by only crank sensor.	ECU Power OFF	P0337	●		●
	Cam	Abnormal signal	●	–	ECU detects abnormal cam signal pattern while crank make 2 rotations.		●		●												ECU keeps engine operation by only crank sensor.	ECU Power OFF	P0341	●		●
		No signal	●	–	ECU does not detect cam pulse signal while crank make 2.2 rotations		●		●												ECU keeps engine operation by only crank sensor.	ECU Power OFF	P0342	●		●
		Angle offset fault	●	–	The phase difference with crank is more than 30 degrees. or ECU detects the condition that the phase difference is less than -20 degrees of 2 times.		●		●													ECU Power OFF	P1341	●		●
	Acceleration sensor 1	Voltage high	●	–	Voltage of sensor signal is more than 4.6 V			(Selectable)													Fail safe action is applied to application menu.	ECU Power OFF	P0123	●		●
		Voltage low	●	–	Voltage of sensor signal is less than 0.2 V			(Selectable)													Fail safe action is applied to application menu.	ECU Power OFF	P0122	●		●
	Suction air throttle opening sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V		●		●			●	●		●		●					ECU Power OFF	P02E9	●	●	
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●			●	●		●		●					ECU Power OFF	P02E8	●	●	
	EGR low-pressure side sensor (Suction air pressure)	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V		●		●			●			●			●				ECU Power OFF	P0238	●	●	
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●			●			●			●				ECU Power OFF	P0237	●	●	

Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition Under 56 kW	Detection condition Under 56 kW	Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Under 56 kW	DTC	MIL	RSL	AWL
Sensor	EGR high-pressure side sensor (exhaust gas pressure sensor)	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V		●		●			●	●		●	●		●				ECU Power OFF	P0473	●		●
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●			●	●		●	●		●				ECU Power OFF	P0472	●		●
	Water temperature sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V		●		●			●										ECU Power OFF	P0118	●		●
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●			●										ECU Power OFF	P0117	●		●
		Water temperature increase (overheat)	●	• Water temperature sensor is normal operation (No failure detection) • After 60 seconds from when engine cranking has been completed successful	Temperature is more than the threshold (threshold: 110 degC)	(Selectable)						●					(Selectable)				Fail safe action is applied to application menu.	• When recovery condition consists or • ECU Power OFF	P0217	●	(Selectable)	
	New air temperature sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.85 V		●		●													ECU Power OFF	P0113	●		●
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.15 V		●		●													ECU Power OFF	P0112	●		●
	Fuel temperature sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V				●													ECU Power OFF	P0183	●		●
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V				●													ECU Power OFF	P0182	●		●
		High temperature	●	Fuel temperature sensor is normal operation (No failure detection)	Engine is running and Fuel temperature is more than the threshold (threshold: 90 degC)	(Selectable)											(Selectable)				Fail safe action is applied to application menu.	• When recovery condition consists or • ECU Power OFF	P0168	●	(Selectable)	

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Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition Under 56 kW	Detection condition Under 56 kW	Engine stop	Rotation limit (1800 min⁻¹)	Rotation limit (1500 min⁻¹)	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Under 56 kW	DTC	MIL	RSL	AWL
Sensor	Rail pressure sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.75 V	●		●	●		●	●										ECU Power OFF	P0193	●	●	
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.24 V	●		●	●		●	●										ECU Power OFF	P0192	●	●	
	DPF differential pressure sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V		●		●			●			●	●		●				ECU Power OFF	P2455	●	●	
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●			●			●	●		●				ECU Power OFF	P2454	●	●	
	DPF high-pressure side sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V		●		●			●			●	●		●				ECU Power OFF	P1455	●	●	
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●			●			●	●		●				ECU Power OFF	P1454	●	●	
	DPF inlet temperature sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V		●		●			●	●		●			●				ECU Power OFF	P1428	●	●	
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●			●	●		●			●				ECU Power OFF	P1427	●	●	
	DPF intermediate temperature sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8 V		●		●			●	●		●			●				ECU Power OFF	P1434	●	●	
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●			●	●		●			●				ECU Power OFF	P1435	●	●	

Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition Under 56 kW	Detection condition Under 56 kW	Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Under 56 kW	DTC	MIL	RSL	AWL
Sensor	Atmospheric pressure sensor	Voltage high	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is more than 4.8		●		●													ECU Power OFF	P2229	●		●
		Voltage low	●	• ECU does not control starter • Sensor supply voltage is normal range • AD converter is normal operation	Voltage of sensor signal is less than 0.2 V		●		●													ECU Power OFF	P2228	●		●
		Abnormal atmo-spheric pressure	●	• Atmospheric pressure sensor is normal operation • EGR high-pressure side sensor is normal operation • EGR low-pressure side sensor is normal operation	• Absolute value of final offset value of intake manifold pressure >= 5 kPa and • Absolute value of final offset value of exhaust manifold pressure >= 5 kPa * "intake manifold pressure" means "EGR low-pressure side" * "Exhaust manifold pressure" means "EGR high-pressure side"		●		●			●										ECU Power OFF	P1231	●		●
	EGR gas temperature sensor	Voltage high	●	• ECU does not control starter	Voltage of sensor signal is more than 4.8 V		●		●			●										ECU Power OFF	P041D	●		●
		Voltage low	●	• ECU does not control starter	Voltage of sensor signal is less than 0.2 V		●		●			●										ECU Power OFF	P041C	●		●
	Intake air temperature sensor	Voltage high	●	• ECU does not control starter	Voltage of sensor signal is more than 4.8 V		●		●			●	●		●	●		●				ECU Power OFF	P040D	●	●	
		Voltage low	●	• ECU does not control starter	Voltage of sensor signal is less than 0.2 V		●		●			●	●		●	●		●				ECU Power OFF	P040C	●	●	
	Exhaust temperature sensor	Voltage high	●	• ECU does not control starter	Voltage of sensor signal is more than 4.8 V		●		●			●										ECU Power OFF	P0546	●		●
		Voltage low	●	• ECU does not control starter	Voltage of sensor signal is less than 0.2 V		●		●			●										ECU Power OFF	P0545	●		●
Digital Output	Main relay	Relay contact stuck	●	When ECU conducts shut-down sequence	Main relay is not opened after 150ms from when the ECU shutdown has been done			●		●												ECU Power OFF	P068B	●		●
		Power-off without self-hold	●	When ECU conducts initialization	ECU power-off without self-hold			●		●												ECU Power OFF	P068A	●		●
	Start assist relay	Disconnection	●	When ECU controls the relay OFF	Driver voltage that the ECU internal circuit detects is more than 3 V			●		●												ECU Power OFF	P0543	●		●
		GND short-circuit	●	When ECU controls the relay ON	Driver voltage that the ECU internal circuit detects is less than 2.8 V			●		●												ECU Power OFF	P0541	●		●
CRS	Injector 1 4TNV: Cyl No. 4 3TNV: Cyl No. 3 Port: 4TNV: 1-2 3TNV: 1-3	Disconnection	●	(under confirmation)	Disconnection is detected by the drive circuit.		●		●			●					●			●		ECU Power OFF	P0204 (4TNV) P0203 (3TNV)	●	●	
		Short circuit (inner coil)	●	(under confirmation)	Layer short-circuit in injector coil		●		●			●					●			●		ECU Power OFF	P0271 (4TNV) P0268 (3TNV)	●	●	
		Short circuit	●	(under confirmation)	VB short-circuit of low side is detected by the drive circuit.		●		●			●					●			●		ECU Power OFF	P1271 (4TNV) P1262 (3TNV)	●	●	
		Unclassified	●	(under confirmation)	Multiple failure related to injector		●		●			●					●			●		ECU Power OFF	P1272 (4TNV) P1263 (4TNV)	●	●	

Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition Under 56 kW	Detection condition Under 56 kW	Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Under 56 kW	DTC	MIL	RSL	AWL
CRS	Injector 2 4TNV: Cyl No. 2 3TNV: Cyl No. 2 Port: 4TNV: 2-1 3TNV: 1-2	Disconnec-tion	●	(under confirmation)	Disconnection is detected by the drive circuit.		●		●			●					●			●		ECU Power OFF	P0202	●	●	
		Short circuit (inner coil)	●	(under confirmation)	Layer short-circuit in injector coil		●		●			●					●			●		ECU Power OFF	P0265	●	●	
		Short circuit	●	(under confirmation)	VB short-circuit of low side is detected by the drive circuit.		●		●			●					●			●		ECU Power OFF	P1265	●	●	
		Unclassi-fied	●	(under confirmation)	Multiple failure related to injector		●		●			●					●			●		ECU Power OFF	P1266	●	●	
	Injector 3 4TNV: Cyl No. 1 3TNV: Cyl No. 1 Port: 4TNV: 2-2 3TNV: 1-1	Disconnec-tion	●	(under confirmation)	Disconnection is detected by the drive circuit.		●		●			●					●			●		ECU Power OFF	P0201	●	●	
		Short circuit (inner coil)	●	(under confirmation)	Layer short-circuit in injector coil		●		●			●					●			●		ECU Power OFF	P0262	●	●	
		Short circuit	●	(under confirmation)	VB short-circuit of low side is detected by the drive circuit.		●		●			●					●			●		ECU Power OFF	P1262	●	●	
		Unclassi-fied	●	(under confirmation)	Multiple failure related to injector		●		●			●					●			●		ECU Power OFF	P1263	●	●	
	Injector 4 4TNV: Cyl No. 3 Port: 4TNV: 1-1	Disconnec-tion	●	(under confirmation)	Disconnection is detected by the drive circuit.		●		●			●					●			●		ECU Power OFF	P0203	●	●	
		Short circuit (inner coil)	●	(under confirmation)	Layer short-circuit in injector coil		●		●			●					●			●		ECU Power OFF	P0268	●	●	
		Short circuit	●	(under confirmation)	VB short-circuit of low side is detected by the drive circuit.		●		●			●					●			●		ECU Power OFF	P1268	●	●	
		Unclassi-fied	●	(under confirmation)	Multiple failure related to injector		●		●			●					●			●		ECU Power OFF	P1269	●	●	
	Injector driver circuit	Injector driving IC error	●	–	Driving IC fault detected		●		●			●					●			●		ECU Power OFF	P0611	●	●	
	Injector (common)	Driving cir-cuit (Bank 1) short-circuit (4TN: No. 1, 4 and 3TN : all cylin-ders common circuit)	●	(under confirmation)	The following short-cir-cuit is detected by the drive circuit • VB short-circuit of high side port or • GND short-circuit of high side port and low side port		●		●			●					●		●			ECU Power OFF	P1146	●	●	
		Driving cir-cuit (Bank 2) short-circuit (4TN: No. 2, 3 cylinder circuit)	●	(under confirmation)	The following short-cir-cuit is detected by the drive circuit • VB short-circuit of high side port or • GND short-circuit of high side port and low side port		●		●			●					●		●			ECU Power OFF	P1149	●	●	
	SCV (MPROP)	Low side VB short-circuit	●	(under confirmation)	VB short-circuit on actu-ator low side is detected by the ECU internal IC.	●	●		●			●										ECU Power OFF	P1641	●	●	
		High side GND short-circuit	●	(under confirmation)	GND short-circuit on actuator high side is detected by the ECU internal IC.	●	●		●			●		●								ECU Power OFF	P1642	●	●	
		Disconnec-tion	●	(under confirmation)	Disconnection is detected by the ECU internal IC.	●	●		●			●		●								ECU Power OFF	P0627	●	●	

Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition Under 56 kW	Detection condition Under 56 kW	Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Under 56 kW	DTC	MIL	RSL	AWL
CRS	Rail pressure fault	Over-pressure rail error	●	Rail pressure sensor is normal operation (No failure detection)	Rail pressure is more then 170 [MPa]	●																ECU Power OFF	P0088	●	●	
		Rail pressure deviation error when actual pressure is too low	●	Rail pressure sensor is normal operation (No failure detection)	Actual rail pressure is less than target rail pressure, the difference between those pressure is more than 20 [MPa]	●																ECU Power OFF	P0094	●	●	
		Rail pressure deviation error when actual pressure is too high	●	Rail pressure sensor is normal operation (No failure detection)	Actual rail pressure is more than target rail pressure, the difference in those pressure is more than 20 [MPa]	●																ECU Power OFF	P0093	●	●	
	PLV	PLV open-valve	●	-	PLV (pressure control valve) open-valve detected	●																ECU Power OFF	P000F	●	●	
The others	Overspeed	Overrotation	●	-	When actual engine speed is more than Rated Speed + 300 min^{-1}	●																ECU Power OFF	P0219	●	●	
Actuator	Suction air throttle driven circuit	No-load of driving circuit	●	(under confirmation)	Detection of no-load (disconnection) of H bridge			●	●			●			●		●				Throttle valve is full-opened by stopping energizing to the throttle.	ECU Power OFF	P0660	●	●	
	Suction air throttle driven circuit	Power supply short-circuit of driving output 1	●	(under confirmation)	Detection of power supply short-circuit on output plug of H bridge 1			●	●			●	●		●		●					ECU Power OFF	P1658	●	●	
	Suction air throttle driven circuit	Power supply short-circuit of driving output 2	●	(under confirmation)	Detection of power supply short-circuit on output plug of H bridge 2			●	●			●	●		●		●					ECU Power OFF	P1661	●	●	
	Suction air throttle driven circuit	GND short-circuit of driving output 1	●	(under confirmation)	Detection of GND short-circuit on output plug of H bridge 1			●	●			●	●		●		●					ECU Power OFF	P1659	●	●	
	Suction air throttle driven circuit	GND short-circuit of driving output 2	●	(under confirmation)	Detection of GND short-circuit on output plug of H bridge 2			●	●			●	●		●		●					ECU Power OFF	P1662	●	●	
Communication	TSC1 (CAN message)	Reception message time out error	♦	• After 2 seconds from when key switch has been turned on • ECU does not control starter • Key switch is not turned off • ECU power supply is more than 10V	ECU does not receive the message for TSC1																Fail safe action is applied to application menu.	ECU Power OFF	U0292	●		●
	Y_ECR1 (CAN message)	Reception message time out error	♦	• After 2 seconds from when key switch has been turned on • ECU does not control starter • Key switch is not turned off • ECU power supply is more than 10V	ECU does not receive the message for Y_ECR1																Fail safe action is applied to application menu.	ECU Power OFF	U1292	●		●
	Y_EC (CAN message)	TBD																								

Item 1	Item 2	Fault	Application model: Under 56 kW	Failure decision: Prerequisite condition (Under 56 kW)	Failure decision: Detection condition (Under 56 kW)	Fail safe action: Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Recovery timing (Under 56 kW)	Fault code: DTC	Lamp information: MIL	RSL	AWL
Communication	Y_RSS (CAN message)	TBD																								
	VH (CAN message)	TBD																								
	Y_ETCP1 (CAN message)	TBD																								
	Y_DPFIF (CAN message)	TBD																								
	EGR	CAN1(for EGR): Time out error (received message)	●	After 2 seconds from when key switch has been turned on	ECU does not receive the message for EGR		●		●			●										ECU Power OFF	U010B	●		●
		CAN1(for EGR): Data Length Code error (received message)	●	After 2 seconds from when key switch has been turned on	CAN packet length is not matched from EGR valve		●		●			●										ECU Power OFF	U040C	●		●
Actuator	EGR	Disconnection in motor coil	●	ECU judges by receiving data from EGR	Disconnection in motor is detected		●		●			●										ECU Power OFF	P0403	●		●
		Short-circuit in motor coil	●	ECU judges by receiving data from EGR	Over current by short-circuit in motor coil is detected		●		●			●										ECU Power OFF	P1405	●		●
		Position sensor fault	●	ECU judges by receiving data from EGR	Position sensor signal is over-voltage or under-voltage		●		●			●										ECU Power OFF	P0488	●		●
		Feedback fault		ECU judges by receiving data from EGR	Over-duty to motor driving is detected			●		●		●										ECU Power OFF	P1409	●		●
		Valve stuck open fault		ECU judges by receiving data from EGR	The number of step from all-open to all-close is abnormal when initializing (more than 45 steps)			●		●		●										ECU Power OFF	P148A	●		●
		Initialize fault		ECU judges by receiving data from EGR	Initializing process time is longer than specified		●		●			●										ECU Power OFF	P049D	●		●
		ECM data fault		ECU judges by receiving data from EGR	Instruction packet cut-off from ECU is detected		●		●			●										ECU Power OFF	U0401	●		●
		Out of target value range		ECU judges by receiving data from EGR	Out-of-range of the target position from ECU is detected		●		●			●										ECU Power OFF	U0401	●		●
		Over-voltage fault		ECU judges by receiving data from EGR	Supply voltage to EGRV is more than 18 V for more than 5 seconds		●		●			●										ECU Power OFF	P0404	●		●
		Under-voltage fault		ECU judges by receiving data from EGR	Supply voltage to EGRV is less than 8 V for more than 13 seconds		●		●			●										ECU Power OFF	P0404	●		●
		High-temperature thermistor fault		ECU judges by receiving data from EGR	Internal high-temperature side of control unit thermistor voltage is less than 0.2 V		●		●			●										ECU Power OFF	P1410	●		●
		Low-temperature thermistor fault		ECU judges by receiving data from EGR	Internal low-temperature side of control unit thermistor voltage is less than 0.2 V		●		●			●										ECU Power OFF	P1411	●		●
ECU	EEPROM	EEPROM memory deletion error		–	(under confirmation)		●		●			●										ECU Power OFF	P0601	●	●	
		EEPROM memory read error		–	(under confirmation)		●		●			●										ECU Power OFF	P160E	●	●	
		EEPROM memory write error		–	(under confirmation)		●		●			●										ECU Power OFF	P160F	●	●	

Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition Under 56 kW	Detection condition Under 56 kW	Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Under 56 kW	DTC	MIL	RSL	AWL
ECU	ECU internal failure	WDA/ABE communi-cation error		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1607	●	●	
		CY146 SPI communi-cation error		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1613	●	●	
	ECU internal failure	CY320 SPI communi-cation error		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1615	●	●	
		R2S2 MSC communi-cation error		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1616	●	●	
		Sensor power supply 1 voltage: too high		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1608	●	●	
		Sensor power supply 1 voltage: too low		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1617	●	●	
		Sensor power supply 1 (5 V): Voltage error		(under confirmation)	(under confirmation)																	ECU Power OFF	P1609	●	●	
		Sensor power supply 2 (5 V): Voltage error		(under confirmation)	(under confirmation)																	ECU Power OFF	P1618	●	●	
		Sensor power supply 3 (5 V): Voltage error		(under confirmation)	(under confirmation)																	ECU Power OFF	P1619	●	●	
		Internal sensor power sup-ply: Voltage-low		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1624	●	●	
		Actuator driver circuit 1VB short		(under confirmation)	(under confirmation)																	ECU Power OFF	P160A	●	●	
		Actuator driver circuit 2VB short		(under confirmation)	(under confirmation)																	ECU Power OFF	P1625	●	●	
		Actuator driver circuit 1GND short		(under confirmation)	(under confirmation)																	ECU Power OFF	P1626	●	●	
		Actuator driver circuit 2GND short		(under confirmation)	(under confirmation)																	ECU Power OFF	P1633	●	●	
		ECU soft reset 1		(under confirmation)	(under confirmation)																	ECU Power OFF	P160B	●	●	
		ECU soft reset 2		(under confirmation)	(under confirmation)																	ECU Power OFF	P1636	●	●	
		ECU soft reset 3		(under confirmation)	(under confirmation)																	ECU Power OFF	P1637	●	●	
		WDA/ABE shut off (Too low voltage)		(under confirmation)	(under confirmation)	●																ECU Power OFF	P160D	●	●	
		WDA/ABE shut off (Too high voltage)		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1639	●	●	

Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition	Detection condition	Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note		DTC	MIL	RSL	AWL
				Under 56 kW	Under 56 kW																	Under 56 kW				
ECU	ECU internal failure	WDA/ABE shut off (Operation malfunction)		(under confirmation)	(under confirmation)	●																ECU Power OFF	P1640	●	●	
Digital Input	Air cleaner switch	Air cleaner blockage alarm		• Key switch is turned on • Battery voltage is more then 9 V	Air cleaner switch is turned on	(Selectable)											(Selectable)				Fail safe action is applied to application menu.	ECU Power OFF	P1101	●		(Selectable)
	Oily water separator switch	Oily water separator alarm		• Key switch is turned on • Battery voltage is more then 9 V	Oily water separator switch is turned on	(Selectable)											(Selectable)				Fail safe action is applied to application menu.	ECU Power OFF	P1151	●		(Selectable)
	Charge switch	Disconnection		• Key switch is turned on • Judgement finish condition is not satisfied *Judgement finish condition: Judgement finishes when starter relay ON or engine speed is more than 45 rpm	Charge switch is turned off	(Selectable)											(Selectable)				Fail safe action is applied to application menu.	• When recovery condition consists • ECU Power OFF	P1562	●		(Selectable)
		Charge failure		• Key switch is turned on • After engine cranking has been completed successful	Charge switch is turned on	(Selectable)											(Selectable)				Fail safe action is applied to application menu.	When recovery condition consists	P1568	●		(Selectable)
	Oil pressure switch	Disconnection		• Engine speed is not reached to 45 rpm after key switch ON. Or starter is not energized after key switch ON. • Key switch is turned on • Battery voltage is more then 9 V	Oil pressure switch is turned off	(Selectable)											(Selectable)				Fail safe action is applied to application menu.	• When recovery condition consists • ECU Power OFF	P1192	●		(Selectable)
		Oil pressure too low		• Key switch is turned on • After engine cranking has been completed successful • Battery voltage is more then 9 V • After "delay time of oil pressure failure detection start" * "delay time of oil pressure failure detection start" is calculated based on water temperature	Oil pressure switch is turned on	(Selectable)											(Selectable)				Fail safe action is applied to application menu.	ECU Power OFF	P1198	●		(Selectable)
Aftertreatment control	DPF intermediate temperature sensor	Low temperature		• Exhaust temperature sensor is normal operation • DPF inlet temperature sensor is normal operation • DPF intermediate temperature sensor is normal operation	DPF regeneration defect timer 3 >= 1200s		●		●			●			●							ECU Power OFF	P0420	●		●
	DPF	Over PM accumulation (C method)		• After engine cranking has been completed successful • PM accumulation (C method) failure correction is not operated	PM accumulation by C method is more than 12g/L, then Stationary Regeneration Request Flag is "3"																	When recovery condition consists	P2463			
		Over PM accumulation (P method)		• After engine cranking has been completed successful • PM accumulation (P method) calculation stop is not operated	PM accumulation by P method is more than 12g/L, then Stationary Regeneration Request Flag is "3"																	When recovery condition consists	P1463			

Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition (Under 56 kW)	Detection condition (Under 56 kW)	Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Under 56 kW	DTC	MIL	RSL	AWL
Aftertreatment control	DPF	Regeneration defect (Stationary regeneration failed)		–	Stationary regeneration is not completed within the regular time, then Stationary Regeneration Request Flag is "3"																	When recovery condition consists	P2458			
		Regeneration defect (Stationary regeneration not operated)		–	Stationary regeneration is not operated within the regular time though stationary regeneration is requested, then Stationary Regeneration Request Flag is "3"																	When recovery condition consists	P2459			
		Maintenance (Maintenance is not conducted during the regular time)		All of the following sensor is normal operation • DPF differential pressure sensor • DPF high-pressure side sensor • Ambient pressure sensor • Fuel temperature sensor • EGR low-pressure side sensor • EGR high-pressure side sensor • Intake air temperature sensor • Fresh air temperature sensor • EGR gas temperature sensor • Exhaust temperature sensor • Water temperature sensor • DPF intermediate temperature sensor • DPF inlet temperature sensor	All of the following condition is satisfied • After engine cranking has been completed successful • Engine speed is more then 1800 min^{-1}] • After 300 seconds from when PM reset condition consists • Before 900 seconds from when PM reset condition consists • DPF differential pressure is more than the threshold A *the threshold A is calculated by MAP		●		●			●						●				ECU Power OFF	P1437	●	●	
	DPF operator interface	Ash cleaning request 1		–	Ash accumulation is more than 50 g/L, then Ash Cleaning Request Flag is "1"																	When recovery condition consists	P242F	●		●
		Ash cleaning request 2		–	Ash accumulation is more than 60 g/L, then Ash Cleaning Request Flag is "2"		●											●				When recovery condition consists	P1420	●	●	
		Stationary regeneration standby		–	• Stationary regeneration mode is requested by except SW or CAN operation, then Stationary Regeneration Request Flag is "2" and • Stationary regeneration is not operated																	When recovery condition consists	P1421	●		●
		BackUp mode		–	• BackUp mode is operated, then Stationary Regeneration Request Flag is "3"		●			●		●						●				When recovery condition consists	P1424	●	●	
		Reset regeneration inhibit		–	• Reset regeneration is operated, then DPF Regeneration Mode Flag is "2" and • DPF regeneration inhibit switch is turned off (Disable)																	When recovery condition consists	–			

Item 1	Item 2	Fault	Application model	Failure decision		Fail safe action																Recovery timing	Fault code	Lamp information		
			Under 56 kW	Prerequisite condition (Under 56 kW)	Detection condition (Under 56 kW)	Engine stop	Rotation limit (1800 min^{-1})	Rotation limit (1500 min^{-1})	Max. injection amount limit (75 %)	Max. injection amount limit (50 %)	Rail pressure limit	EGR command full-close	Suction air throttle full-open	Rail pressure back-up control	DPF regeneration stop	Deposit amount calculation stop depending on DPF differential pressure	Engine stop 1 with delay time (2 hour)	Engine stop 2 with delay time (15 minutes)	Failure bank injection stop	Failure cylinder injection stop	Note	Under 56 kW	DTC	MIL	RSL	AWL
Aftertreatment control	DPF inlet temperature sensor	High temperature		DPF inlet temperature sensor is normal operation	DPF inlet temperature is more then 700 degC				●													ECU Power OFF	P1436	●		●
	DPF differential pressure sensor	High differential pressure		• DPF differential pressure sensor is normal operation • After engine cranking has been completed successful	DPF differential pressure is more than 50 kPa		●		●			●			●			●				ECU Power OFF	P2452	●	●	
	DPF intermediate temperature sensor	High temperature		• Regeneration (Post injection) is operated • DPF intermediate temperature sensor is normal operation	DPF intermediate temperature is more than 700 degC		●		●			●			●			●				ECU Power OFF	P1426	●	●	

- Fault indicator lamp
  Upon detecting one of the faults listed in **Table 14-30**, the E-ECU flashes the fault indicator lamp. The fault indicator lamp is lit for 2 seconds and then goes off after the power to the E-ECU has been turned ON; thus, you can check the fault indicator lamp to determine whether the E-ECU is being supplied with the power. (The fault indicator lamp is a mandatory component for E-ECU operation check and diagnosis.)
- Obtaining detailed fault information (under development)
  By connecting YANMAR genuine SA-D as shown in **Figure 14-49**, you can view further detailed fault information, fault history, freeze frame data, and status monitor and can conduct diagnosis tests. The fault history can be used to record the time when a fault occurred (timestamp). The following types of timestamps are available:

Table 14-31 List of fault occurrence timestamps

Flag Selecting failure occurrence time	Type of recorded timestamp
0 (Standard)	Total engine operating hours
1	Total ECU energized hours
2	CAN communication hours

For more information, refer to the user guide and troubleshooting guide for SA-D.

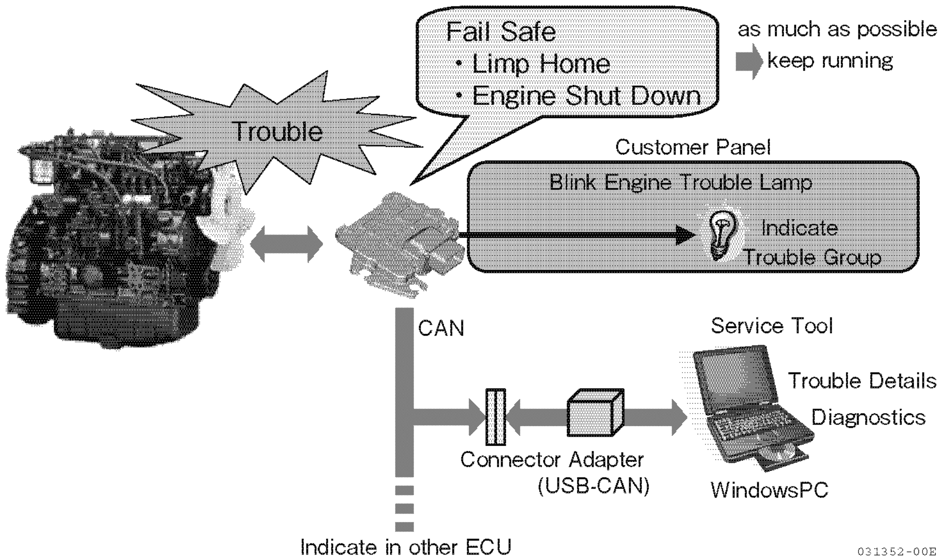

Figure 14-49 Diagnosing the TNV engine (under development)

Configuring the fault handling actions

For the alarms/faults listed in **Table 14-32**, you can set whether the alarm/fault is detected by using the specified setting flag. In addition, you can change the alarm/fault handling actions (operation methods) depending on the specifics of the driven machine on which the engine is mounted.

Table 14-32 List of flags that determine whether to detect each alarm/fault

Item	Detection flag
Cooling water temperature high alarm	Depends on the “Cooling water temperature alarm setup”.
Fuel temperature rise alarm	Depends on the “Fuel temperature rise alarm setup”.
All acceleration fault handling actions*1	Depends on the “All acceleration fault handling process”.
Oil pressure low alarm	Depends on the “Oil pressure low alarm setup”.
Charge alarm	Depends on the “Charge alarm setup”.
Air cleaner clog alarm	Depends on the “Air cleaner clog alarm setup”.
Water separator alarm	Depends on the “Water separator alarm setup”

**1: This fault is detected if the accelerators including those for backup are faulty.*

Table 14-33 provides a list of map flag settings that specify the alarm/fault handling actions.

For the map flag setting method, “rotation limit”, “max. injection amount limit”, and “engine stop” are available as the operations upon fault, for each of which you can set the limit level by the setting value. Some setting examples are indicated below.

Setting example [1]

With the configuration of “Rotation limit” = “1: Level 1 (1800 min^{-1} (reference value))”, “Max. injection amount limit” = “1: Level 1 (75 % (reference value))”, and “Engine stop” = “0: Disabled”, the engine is operated with the high idle speed limited to 1800 min-1 and the max. injection amount limited to 75 % after E-ECU detects a fault.

Setting example [2]

With the configuration of “Rotation limit” = “0: Disabled”, “Max. injection amount limit” = “0: Disabled”, and “Engine stop” = “1: Stop without delay”, the engine is stopped immediately after E-ECU detects a fault.

Setting example [3]

With the configuration of “Rotation limit” = “1: Level 1 (1800 min^{-1} (reference value))”, “Max. injection amount limit” = “1: Level 1 (75 % (reference value))”, and “Engine stop” = “2: Stop after delay time of 7200 s”, the engine is operated with the high idle speed limited to 1800 min^{-1} and the max. injection amount limited to 75 % just after a fault detection. When 7200 s have passed since the fault detection, the engine is stopped.

Table 14-33 Map settings for fault handling actions

Fault handling action	Setting content	
	Set value	Limit level
Speed limit	0	Disabled
	1	Level 1 (1800 min^{-1} (reference))
	2	Level 2 (1500 min^{-1} (reference))
	3	Level 3 (option)
	4	Level 4 (low idle speed (option))
Maximum injection volume limit	0	Disabled
	1	Level 1 (75 % (reference))
	2	Level 2 (50 % (reference))
Engine stop	0	Disabled
	1	Stop without delay
	2	Stop after delay time of 7200 s
	3	Stop after delay time of 900 s
	4	Stop after delay time of A (option)
	5	Stop after delay time of B (option)

Table 14-34 List of changeable alarm/fault handling actions and standard settings

Item	Standard setting		
	Speed limit	Max. injection volume limit	Engine stop
Action for cooling water temperature high alarm	0	1 (75 %)	0
Action for fuel temperature rise alarm	0	2 (50 %)	0
All acceleration fault handling actions*1	2 (1500 min^{-1})	0	0
Action for oil pressure low alarm	0	0	0
Action for charge alarm	0	0	0
Action for air cleaner clog alarm	0	0	0

**1: Unlike the speed limit at other faults, the speed limit level of all acceleration fault handling actions is set to the engine target speed.*

Configuring the ECU terminal functions

You can configure the contact input terminals as one of two types: Normally Closed (NC) and Normally Open (NO). You can also configure them as momentary input logic depending on the contact input terminals. The contact input switches that can be chosen are listed below.

Table 14-35 List of contact input terminals that can be configured as either NC or NO

Terminal name	Function	Standard input logic
APP-IP1	Droop selection	0: SW Close → Droop 1: SW Close → Iso-chronous (standard)
APP-IP2	Starter permission 2	0: SW Close → Starter permission (standard) 1: SW Close → Starter restraint
APP-IP3	Speed selection 1	0: SW Close → ON (standard) 1: SW Close → OFF
APP-IP4	Speed selection 2	0: SW Close → ON (standard) 1: SW Close → OFF
APP-IP5	High idle limit	0: SW Close → ON (standard) 1: SW Close → OFF
APP-IP6	Speed selection permission	0: SW Close → ON (standard) 1: SW Close → OFF
APP-IP7	Engine stop 2	0: SW Close → Engine stop (standard) 1: SW Close → Engine running
APP-IP8	High idle selection	0: SW Close → ON (standard) 1: SW Close → OFF
APP-IP9	Starter permission 1	0: SW Close → Starter permission (standard) 1: SW Close → Starter restraint
SHUDNSW	Engine stop	0: SW Close → Engine stop (standard) 1: SW Close → Engine running
PDLSW	Acceleration pedal switch	0: SW Close → ON (standard) 1: SW Close → OFF
REGMSW	Regeneration prohibit switch	0: SW close → Regeneration permission (standard) 1: SW close → Regeneration inhibit
WDSBSW	Regeneration interlock switch	0: SW close → Regeneration not permitted 1: SW close → Regeneration permission (standard)

Lamp check function

The E-ECU turns on all lamps for approximately 2 seconds to check the lamp disconnection when the power is turned on (key switch on). Check the lamp, if it does not turn on at the time of turning on the key switch. The lamp shown in the lamp output for each indication is for indication. Do not use the lamp output to determine an abnormality.

Table 14-36 Indication lamp output

Lamp name	E-ECU terminal name	Lamp name	E-ECU terminal name
Fault indicator lamp	FAIL-LMP	DPF Regen inhibit lamp	DPF-M2
Cooling water temperature alarm lamp	OVHT-LMP	Exhaust temperature lamp	DPF-M3
Speed change indicator lamp	APP-OP1	DPF Regen Ack lamp	DPF-M4
Iso-chronous lamp	APP-OP2	Amber warning lamp	REOP3
DPF Regen Req lamp	DPF-M1	Red stop engine lamp	REOP3

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CAN Communication Function

The E-ECU is complete with a single CAN communication port that can be used for either communications with SA-D or communications with another controller (inter-ECU communications). The CAN communication interface of the E-ECU implements ISO11898 Ver2.0B and uses an ID length of 29 bits. It can be configured with a communication speed of 250 kbps (standard) or 500 kbps. (Refer to **Figure 14-50**.)

Communications protocols supported by the E-ECU include ISO15765 & ISO14229 for SA-D and SAE J1939 for inter-ECU communications.

By using SA-D, you can monitor, diagnose, and configure the engine. For more information, refer to *the manual of SA-D*.

Through inter-ECU communications, the engine ECU (E-ECU) can receive various control commands such as target speed instructions from the ECU of the driven machine. In addition, the E-ECU sends control state information such as the actual engine speed as well as information commands such as fault codes to the ECU of the driven machine. For more information, refer to *the CAN communication manual*.

Application menu

- CAN setup → 0: 500 kbps, or 1: 250 kbps (standard)

Description

Information commands from the E-ECU are sent regardless of whether or not the above application function settings have been configured.

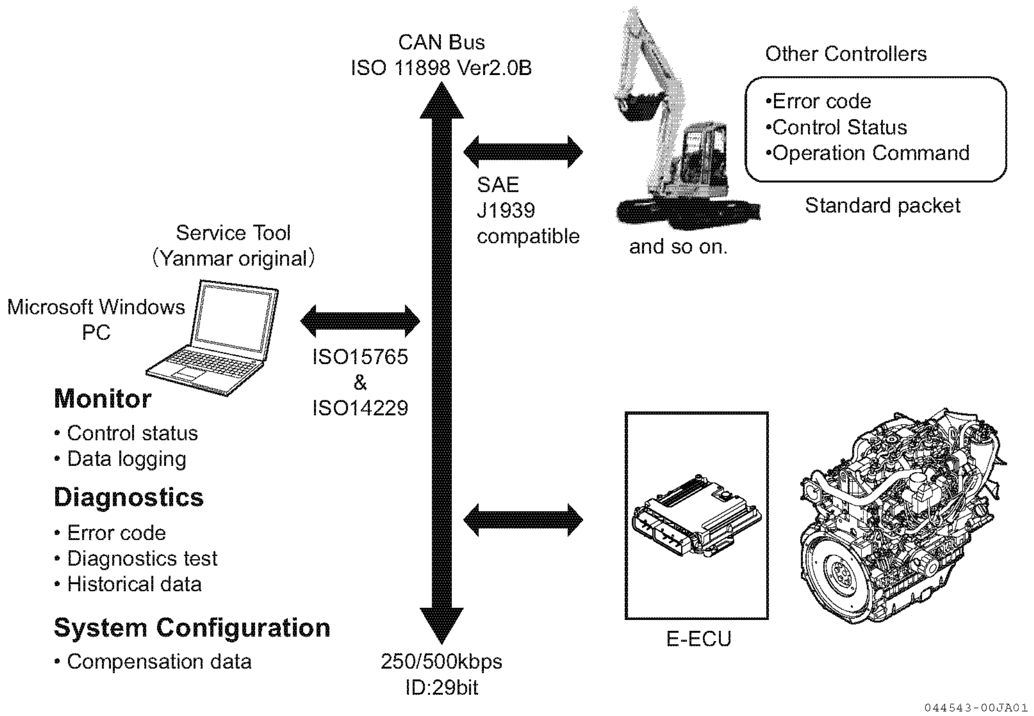


Figure 14-50 CAN communication overview

Precautions in the use of CAN communication

When using the settings described in **Table 14-37**, make sure that the J1939 PGN signals specified in this table are transmitted.

If the necessary CAN data can not be received, a CAN communication error will result.

Note: For more information, refer to *ON-Vehicle Communication CAN Specification on page 15-1*.

Table 14-37

Function	Item			Setting (model specific control map)	PGN: Transmitted data	Cycle length [ms]
Electronic acceleration	AND	Selection of acceleration function		1: Single output acceleration	[TSC1 Override when Control Mode is 1] PGN = 0 (TSC1)	10
		Single output acceleration configuration		3: CAN communication (TSC1 or TSC1 + Y_ECR1)		
	AND	Selection of acceleration function		4: Backup acceleration	[TSC1 Override when Control Mode is 0] PGN = 0 (TSC1) PGN = 65282 (Y_ECR1)	10 50
		Backup acceleration configuration		0: CAN communication → Single output analog		
Speed regulation mode switch	Droop selection input			3: Depending on CAN (Y_EC)	PGN = 65308 (Y_EC)	100
TSC1 torque limit control	Selection of Enabled for TSC1 torque limit function			1: Enabled	PGN = 0 (TSC1)	10
Starter restraint function	Starter input signal setup			1: Depending on CAN (Y_ECR1: Crank	PGN = 65282 (Y_ECR1)	50
	AND	Permit/restrain starter motor		1: Enabled - NO - relay 2: Enabled - NC - relay	If in addition you use “b) 2-22 CAN communication based restraint switching function”, configure using the following PGN:	
		CAN communication based restraint switching function		0: based on Y_EC (PGN 65308)	PGN = 65308 (Y_EC)	100
				1: based on Y_ECR1 (PGN 65282)	PGN = 65282 (Y_ECR1)	50
Engine stop function	Engine stop 2 (CAN) setup			2: Depending on CAN (Y_ECR1: Engine Stop Request (Regular transmission))	PGN = 65282 (Y_ECR1)	50
				*1: Depending on CAN (Y_STP (On Request))	Because PGN = 65309 (Y_STP) is an On Request message, no error detection is performed.	
High idle limit function	AND	High idle limit 1		1 - 3: Enabled	PGN = 65308 (Y_EC)	100
		High idle limit input		1: Depending on CAN (Y_EC)		
	AND	High idle limit 2		1 - 3: Enabled		
		High idle selection input		1: Depending on CAN (Y_EC)		
Speed selection function	AND	Speed selection function setup		1 to 4, 6, 7: Enabled (constant speed, deceleration, auto deceleration, etc.)	PGN = 65310 (Y_RSS)	10
		OR	Speed selection permission input	1: Depending on CAN (Y_RSS)		
			Speed selection 1 input	1: Depending on CAN (Y_RSS)		
			Speed selection (oil pressure switch) Input	1: Depending on CAN (Y_RSS)		
DPF operator interface	DPF Regen Req input			1: Depending on CAN (Y_DPFIF)	PGN = 65304 (Y_DPFIF)	1000
	DPF Regen inhibit input			1: Depending on CAN (Y_DPFIF)		
	Regeneration interlock input			1: Depending on CAN (Y_DPFIF)		
Control fault detection function	Error occurrence time selection			2: CAN communication receiving hours	PGN = 65255 (VH)	1000

Diesel Particulate Filter (DPF) System Control Overview (Under Development)

Overview

YANMAR's DPF system continuously burns particulate matter that accumulates on the SF (soot filter). This is called DPF regeneration. (For details, refer to *DPF System on page 8-10*)

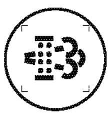
Electrical equipment such as the DPF differential pressure sensor, temperature sensor and intake air throttle are installed to the DPF. If the DPF can not continue to regenerate while operating at low load, the E-ECU automatically assist the DPF regeneration (DPF regeneration assistance) using the electrical equipment and avoiding accumulation of particulate matter.

The table below shows the outline of DPF regeneration assistance. YANMAR uses an original DPF regeneration method that combines regeneration by the regeneration assistance devices (intake air amount control by the intake air throttle and extension of the injection timing by the common rail) and regeneration by the common rail multi-step injection (post-injection by the common rail).

Table 14-38 shows the outline of the DPF regeneration control, **Figure 14-51** provides a conceptual figure of DPF regeneration control in YANMAR DPF system, and **Figure 14-52** illustrates the state transitions of DPF regeneration control with YANMAR standard specifications. For details, contact YANMAR.

The YANMAR DPF system has lamps for DPF alarm display and switches for DPF regeneration control operation. For details on these operator interfaces, refer to *DPF regeneration and operator interface on page 14-109*.

Table 14-38 Outline of DPF regeneration control

Terminology	Control content	Explanation	Remarks
Self regeneration	Regeneration without regeneration assist unit (normal)	In a high speed and high load operation, the exhaust temperature rises and PM are burnt and removed continuously.	These regenerations can be performed during operation. No operator intervention is needed.
Assisted regeneration	Regeneration with regeneration assist unit.	In a low speed and low load operation, the exhaust temperature is too low for continuous regeneration. Therefore E-ECU automatically performs the regeneration controls shown on the left to increase the exhaust temperature and burn/remove PM.	
Reset regeneration	Regeneration with assist regeneration and post injection		
Stationary regeneration	Regeneration with more effective reset regeneration and automatic control to engine speed suitable for DPF regeneration  044549-00X00 DPF Regen Req lamp  044554-00X00 Amber warning lamp	In a low speed/low load operation continuing long time, the assist regeneration/reset regeneration may not be enabled because the exhaust temperature does not rise sufficiently. If the PM deposit amount reaches a certain level in this situation, the DPF Regen Req lamp and Failure lamp illuminate and the Amber warning lamp flashes. At that time, the operator can start the stationary regeneration to burn/remove PM by operating the DPF regeneration request switch.	When the DPF Regen Req lamp illuminates, the operator should move the driven machine to a safe place without any flammable matters nearby before operating the stationary regeneration. For details, refer to *Stationary regeneration execution on page 14-119*. Do not perform any working operation because a special control dedicated for DPF regeneration takes place.

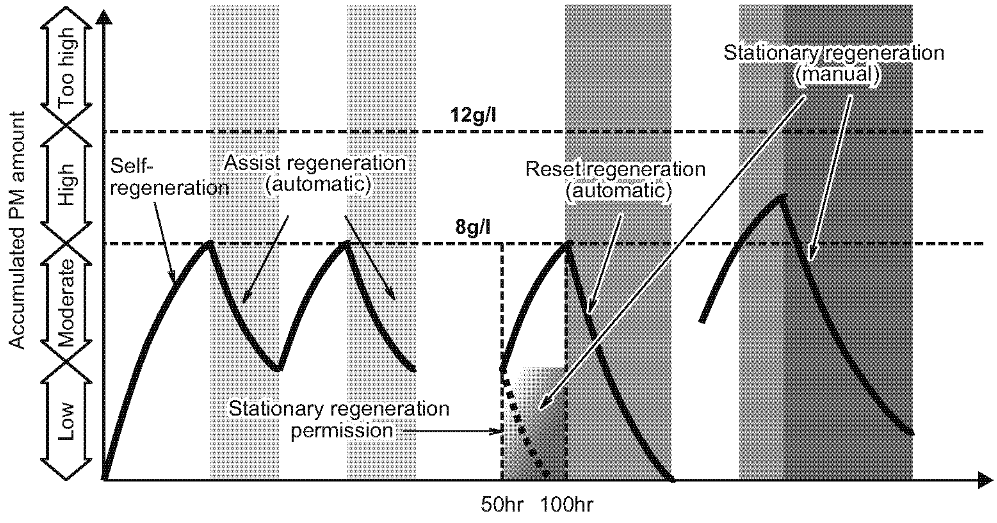


Figure 14-51 Conceptual figure of DPF regeneration control in YANMAR DPF system

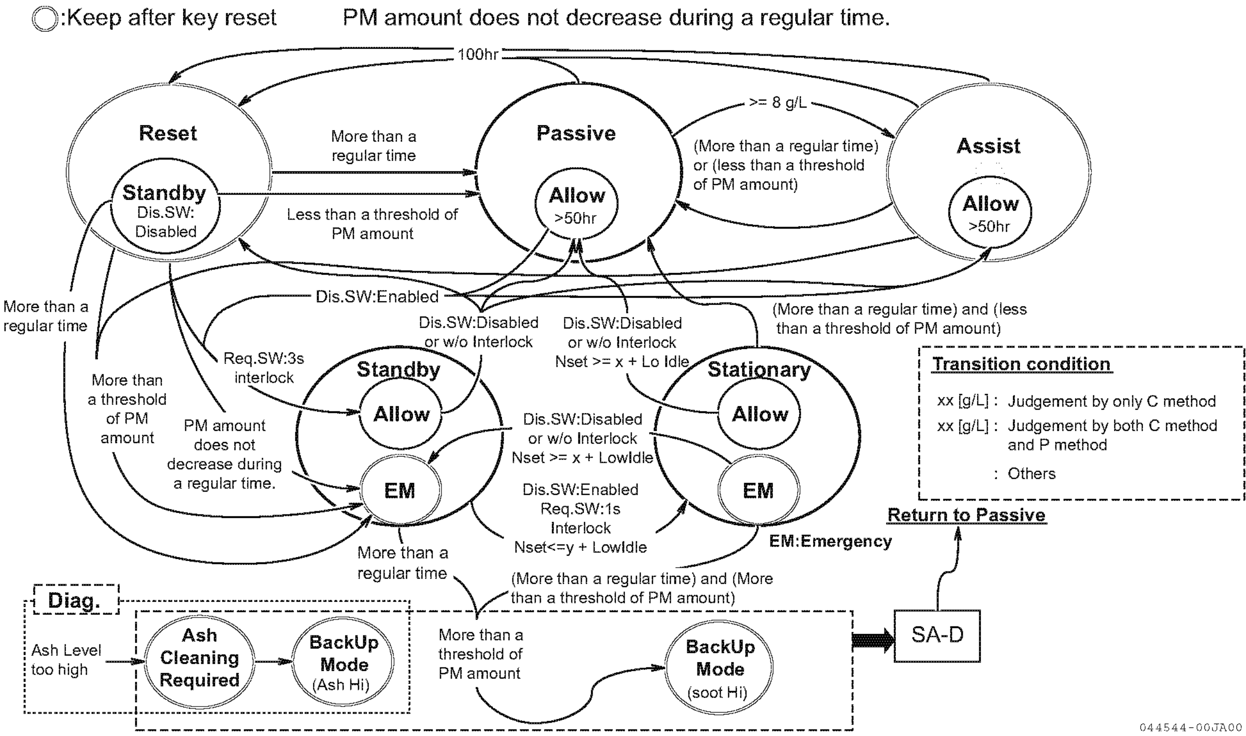


Figure 14-52 Transition of DPF regeneration control in YANMAR standard (Each judgment threshold in the drawing is provisional value)

DPF regeneration and operator interface

Function

The YANMAR DPF system offers DPF regeneration and operator interfaces including lamps for DPF alarm display and switches for DPF regeneration control operation as shown in **Figure 14-53**. Beside these contact input/output terminals, it also offers CAN communication interfaces. For details such as the CAN data formats, refer to *ON-Vehicle Communication CAN Specification on page 15-1*.

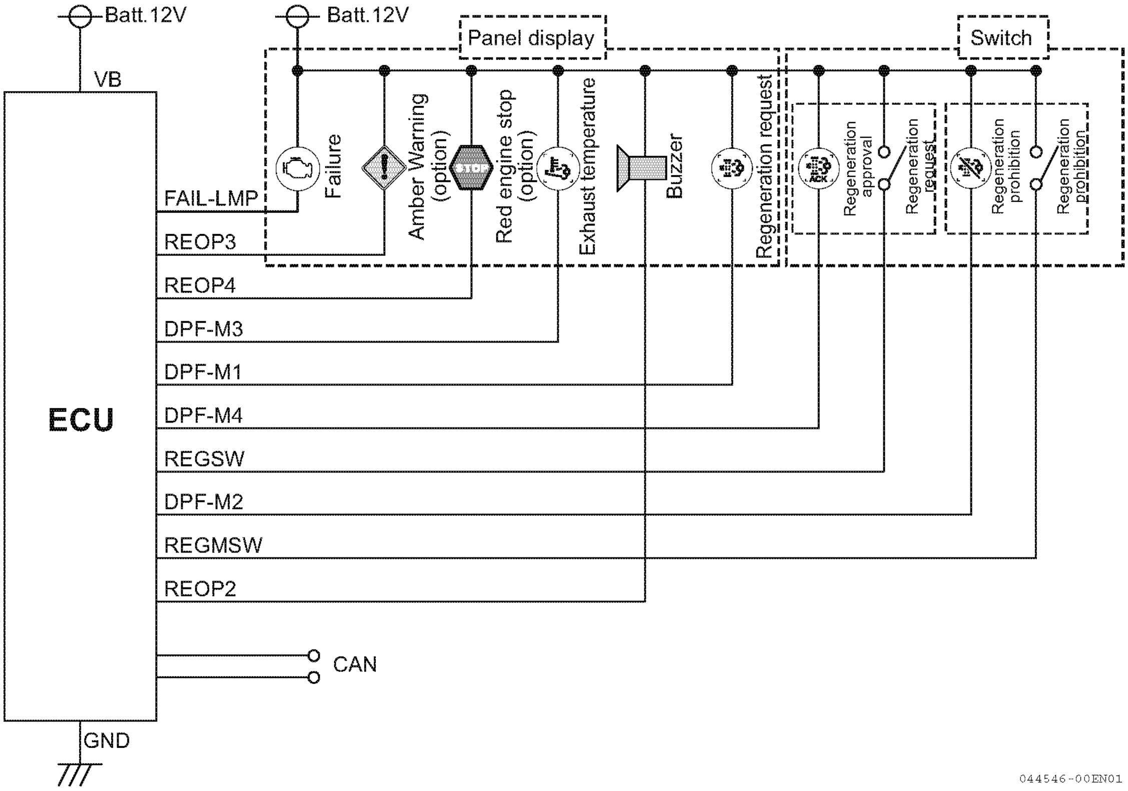


Figure 14-53 Wiring diagram of contact I/O terminals used for DPF regeneration & operator interface

Application menu

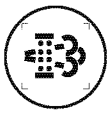
- DPF regeneration request input → 0: based on REGSW terminal (standard), or 1: based on CAN (Y_DPFIF)
- DPF regeneration inhibit input → 0: based on REGMSW terminal (standard), or 1: based on CAN (Y_DPFIF)
- Regeneration interlock input → 0: based on WDSBSW terminal (standard), or 1: based on CAN (Y_DPFIF)
- Set value when CAN (Y_DPFIF) reception error is detected:
  DPF regeneration request input → 0: No regeneration request, or 1: With regeneration request
  DPF regeneration inhibit input → 0: Regeneration permitted, or 1: Regeneration inhibited
  Regeneration interlock input → 0: Regeneration inhibited, or 1: Regeneration permitted

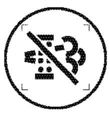
Description

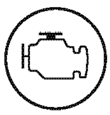
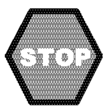
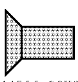
Table 14-39 indicates the specifications of each DPF regeneration and operator interface, and **Table 14-40** offers application examples of DPF operator interfaces. For details on the DPF regeneration control and operator interfaces, refer to State Transitions of DPF Regeneration Control. For details on the CAN data formats, refer to *ON-Vehicle Communication CAN Specification on page 15-1*. **Table 14-41** describes the relationships between DPF regeneration controls and operator interface displays/operations.

Table 14-39 Interface specifications

	Name	Interface		Specification	Installation
		Contact	CAN		
Input	DPF regeneration request switch	REGSW	Y_DPFIF (PGN: 65304)	Used for starting manual stationary regeneration. (Switch must be of momentary type. Switch logic is as follows: “OFF” for SW Open, “ON” for SW Close.)	Must
	DPF regeneration inhibit switch	REGMSW	Y_DPFIF (PGN: 65304)	• Used for inhibiting manual reset generation. • Used for interrupting reset/stationary regeneration. (Switch must be of toggle type. Switch logic (standard set value: 1) is as follows: “Regeneration permitted” for SW Open, “Regeneration inhibited” for SW Close.)	Option
	Regeneration interlock switch	WDSBSW	Y_DPFIF (PGN: 65304)	Because E-ECU changes the target engine speed automatically in stationary regeneration, it is necessary to inform E-ECU that the interlock mechanism such as the parking brake, neutral is enabled (drive force interrupted). This switch is used. *Regeneration interlock SW must be installed so that switch signal is linked with enabled/disabled state of the interlock mechanism. (Switch must be of toggle type. Switch logic (standard set value: 1) is as follows: “Regeneration inhibited (interlock disabled)” for SW Open, “Regeneration permitted (interlock enabled)” for SW Close.)	Must

<table>
<tr><th rowspan="2"></th><th rowspan="2">Name</th><th colspan="2">Interface</th><th rowspan="2" colspan="2">Specification</th><th rowspan="2">Installation</th></tr>
<tr><th>Contact</th><th>CAN</th></tr>
<tr><td rowspan="8">Output</td><td rowspan="3">DPF Regen Req lamp

044549-00X00</td><td rowspan="3">DPF-M1</td><td rowspan="3">DPFC1*[1]
(PGN: 64892)
or
Y_I/OS*[1]
(PGN: 65297)</td><td colspan="2">Used for notifying operators that DPF regeneration inhibit SW has been left in “Regeneration inhibited” state for the specified period, and also prompt operators to implement stationary regeneration.</td><td rowspan="3">Must</td></tr>
<tr><td>On</td><td>• While DPF regeneration inhibit SW is in “Regeneration inhibited” state, when stationary regeneration is permitted (50 h have passed since the last reset or last stationary regeneration.)
• During stationary regeneration standby or in back up mode</td></tr>
<tr><td>Flash</td><td>• During reset regeneration standby (during reset regeneration, DPF regeneration inhibit SW is in “Regeneration inhibited” state)</td></tr>
<tr><td rowspan="2">EGT lamp

044550-00X00</td><td rowspan="2">DPF-M3</td><td rowspan="2">DPFC1*[1]
(PGN: 64892)
or
Y_I/OS*[1]
(PGN: 65297)</td><td colspan="2">Used for notifying operators of high exhaust temperature caused by reset/stationary regeneration.</td><td rowspan="2">Must</td></tr>
<tr><td>On</td><td>Reset/stationary regeneration is active.</td></tr>
<tr><td rowspan="2">DPF Regen inhibit lamp

044551-00X00</td><td rowspan="2">DPF-M2</td><td rowspan="2">DPFC1*[1]
(PGN: 64892)
or
Y_I/OS*[1]
(PGN: 65297)</td><td colspan="2">Used for notifying operators that reset/stationary regeneration is in “inhibited” state.</td><td rowspan="2">Option</td></tr>
<tr><td>On</td><td>While DPF regeneration inhibit SW is in “Regeneration inhibited” state</td></tr>
</table>

	Name	Interface		Specification		Installation
		Contact	CAN			
Output	DPF Regen Ack lamp  044552-00X00	DPF-M4	Y_I/OS (PGN: 65297)	Used for notifying operators of reset/stationary regeneration standby status to prompt operators to start regeneration and also notifying operators that stationary regeneration is in process.		Must
				On	o Stationary regeneration is in process. o For 3 seconds after DPF regeneration request SW is pressed and hold	
				Flash	• During reset regeneration standby (DPF regeneration inhibit switch is in “Regeneration inhibited” state), when regeneration interlock switch is in “Regeneration permitted (interlock enabled)” status • During stationary regeneration standby or backup mode, when DPF regeneration inhibit SW is in “Re-generation permitted” status and regeneration inter-lock switch is in “Regeneration permitted (interlock enabled)” status	
	Failure lamp  044553-00X00	FAIL-LMP	Y_I/OS (PGN: 65297)	Used for notifying operators of the following status.		Option *2
				On	When stationary regeneration standby in the emergency condition, during the backup mode, and the ash cleaning is required. (The failure lamp also turns on when an error except for the DPF regeneration control related failure occurs.)	
	Amber warning lamp  044554-00X00	REOP3	Y_I/OS (PGN: 65297)	Used for notifying operators of the following status.		Option *2
				Flash	When stationary regeneration standby in the emergency condition, and the ash cleaning is required.	
	Red engine stop lamp  044555-00X00	REOP4	Y_I/OS (PGN: 65297)	Used to notify the following conditions to the operator.		Option *2
				Flash	During backup mode	
	Buzzer  044556-00X00	REOP2	Y_I/OS (PGN: 65297)	Used for prompting operator to start stationary regeneration in emergency status.		Option
				Beep	During stationary regeneration standby in emergency status, when PM deposit does not reach a certain amount	
				Continuous sound	During stationary regeneration standby in emergency status, when PM deposit reaches or exceeds a certain amount	

**1: In DPFC1 (PGN: 64892), the lamp status is shown by multiple bits.*
In Y_I/OS (PGN: 65297), a value identical to the relevant contact output (0: OFF, 1: ON) is shown by 1 bit.
Refer to the CAN PGN list for details.
**2: “Failure lamp individual” has functions equivalent to “Amber warning lamp + Red engine stop lamp”. Select whichever you like.*

The following table shows some examples of DPF operator interface application.

Table 14-40 Examples of DPF operator interface application

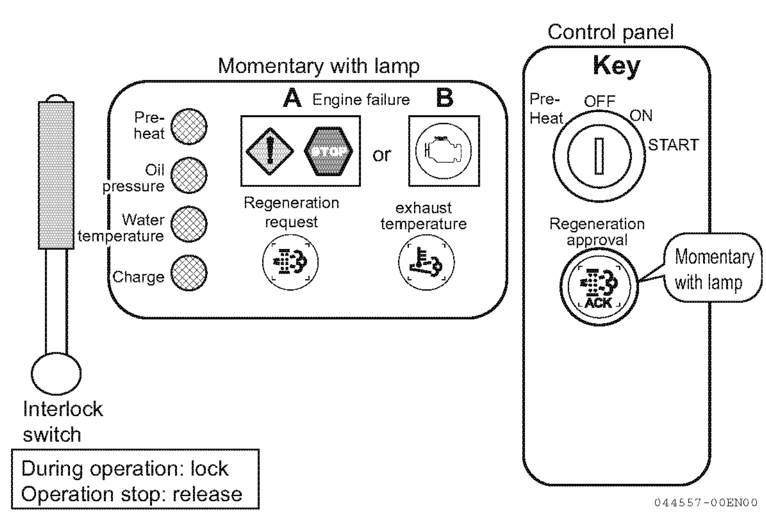
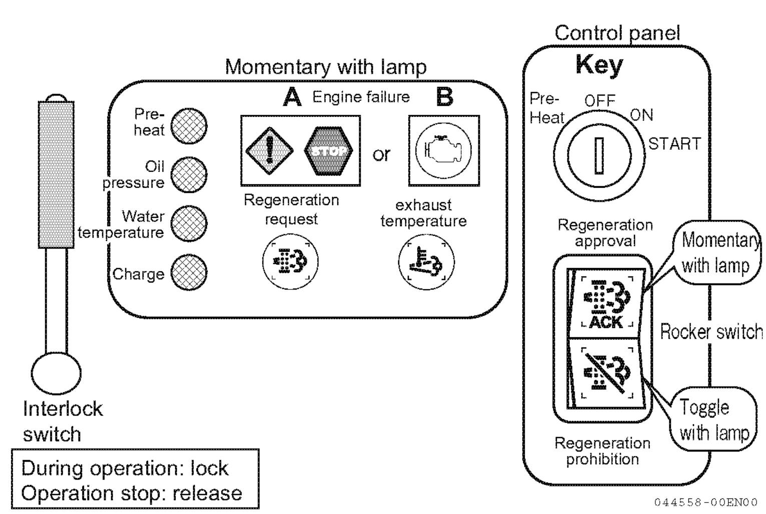
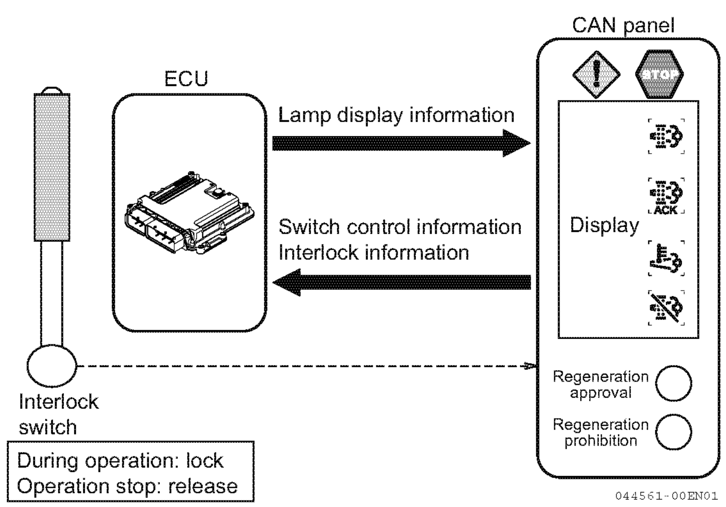
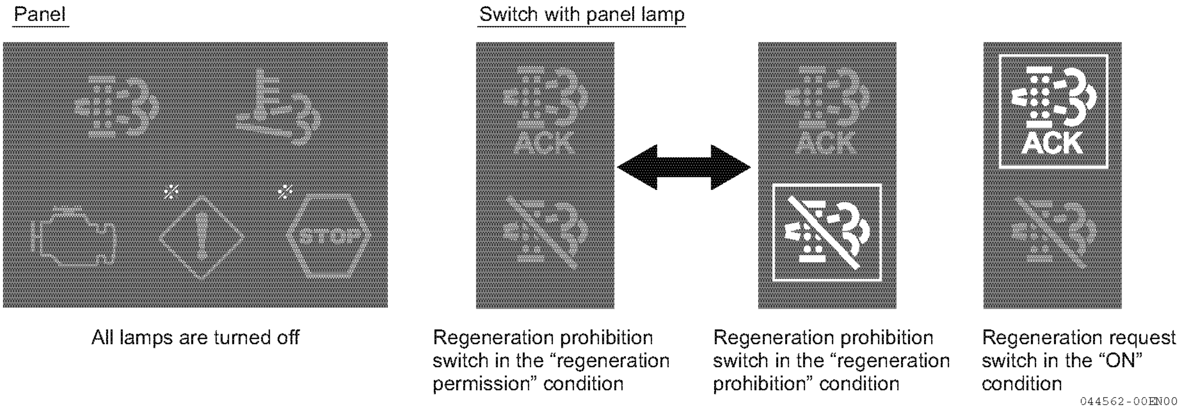
Interface	Operator intervention	Example of application
Standard specification (general-purpose switch) • Failure lamp (A or B) • DPF Regen Req lamp • EGT lamp • DPF Regen Ack lamp • DPF regeneration request SW	• Reset regeneration automatic execution • Stationary regeneration manual execution	
Standard specification (rocker switch with lamp) • Failure lamp (A or B) • DPF Regen Req lamp • EGT lamp • Rocker switch with lamp [DPF Regen Ack lamp, DPF regeneration request SW, DPF Regen inhibit lamp, DPF regeneration inhibit SW]	• Reset regeneration automatic/manual execution can be selected. • Regeneration inhibition and regeneration interruption during regeneration • Stationary regeneration manual execution	
Optional specification (CAN communication) Prepare lamp and switch functions on CAN panel.	Either of the above can be selected.	

Table 14-41 shows examples of operator interface displays/operations with the standard specifications (rocker switch with lamp) used.

Table 14-41 Relationships between DPF regeneration controls and operator interface displays/operations

[1] Self regeneration (normal operation) and assist regeneration operating

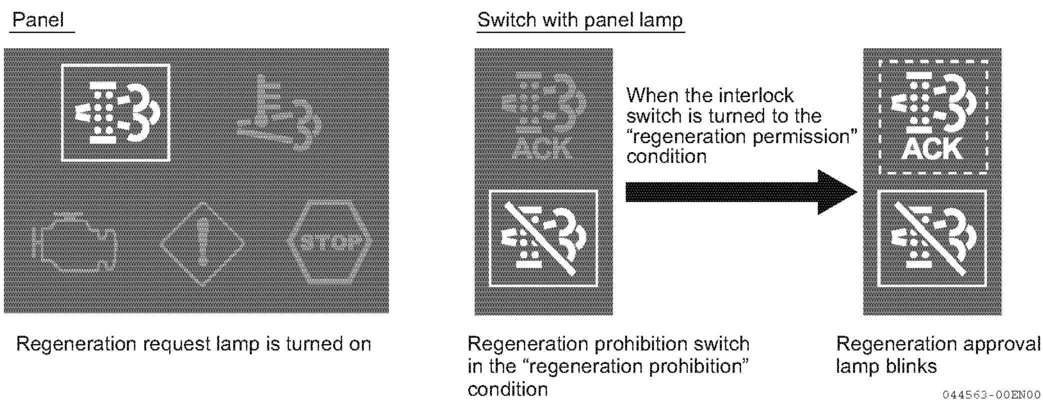


*Either can be selected as desired. (Refer to **Table 14-39**)

Description

- When the DPF regeneration inhibit SW is set to "Regeneration inhibited" state, the DPF Regen inhibit lamp illuminates.
  However, the assist regeneration will not stop even when the "Regeneration inhibited" state is established.
- When the DPF regeneration request SW is set to "ON" state, the DPF Regen Ack lamp illuminates. The DPF Regen Ack lamp remains illuminated for 3 seconds after the DPF regeneration request SW is pressed and held.
- When 50 hours have passed since the last reset/stationary regeneration, DPF transfers to the state [2] or [3] described below.

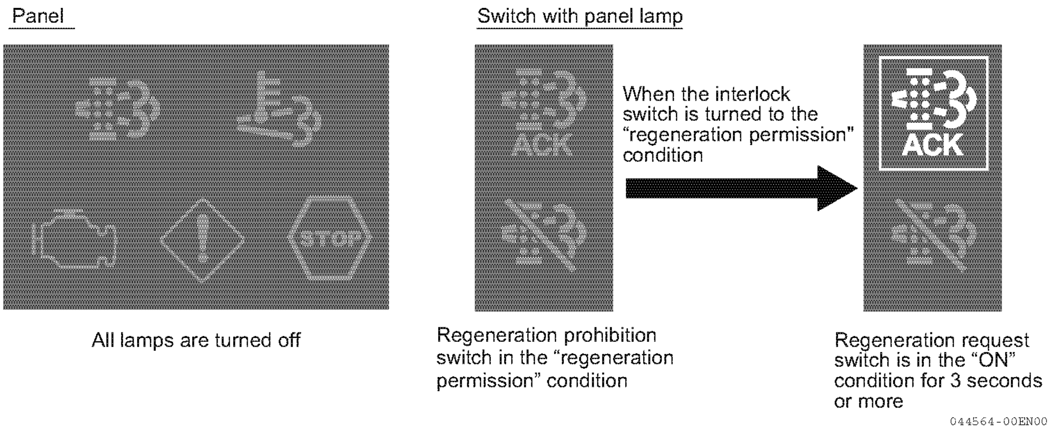
[2] Self regeneration (normal operation) and assist regeneration operating (Elapsed time since last reset: 50 hours or more, regeneration inhibited state)



Description

- When 50 hours have passed with the DPF regeneration inhibit SW set to "Regeneration inhibited" state since the last re-set/stationary regeneration, the DPF Regen Req lamp illuminates. This means that stationary regeneration execution is permitted. According to the need for stationary regeneration, set the DPF regeneration inhibit SW to "Regeneration permitted" state and perform the operation [3] described below.
- When 100 hours have passed since the last reset, DPF transfers to the reset regeneration standby state ([5] described later).

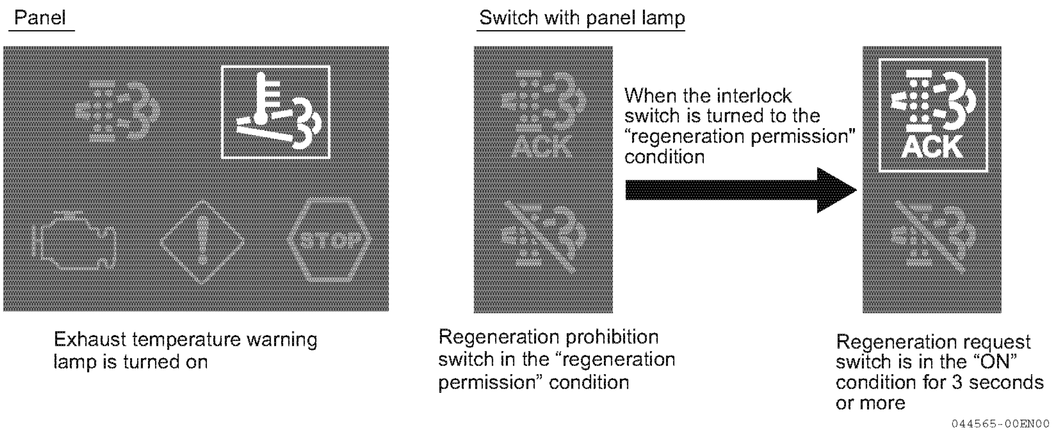
[3] Self regeneration (normal operation) and assist regeneration operating (Elapsed time since last reset: 50 hours or more, no regeneration inhibition)



Description

- When 100 hours have passed since the last reset, reset regeneration is started automatically (transfer to [4] described below).
- When 50 hours have passed since the last reset, stationary regeneration execution is permitted.
- At that time, setting the interlock switch to "Regeneration permitted" state and holding the DPF regeneration request SW to "ON" state for 3 seconds or more causes DPF to transfer to the stationary regeneration standby state ([6] described later). For the operation method after the stationary regeneration standby state, refer to [6] described later.

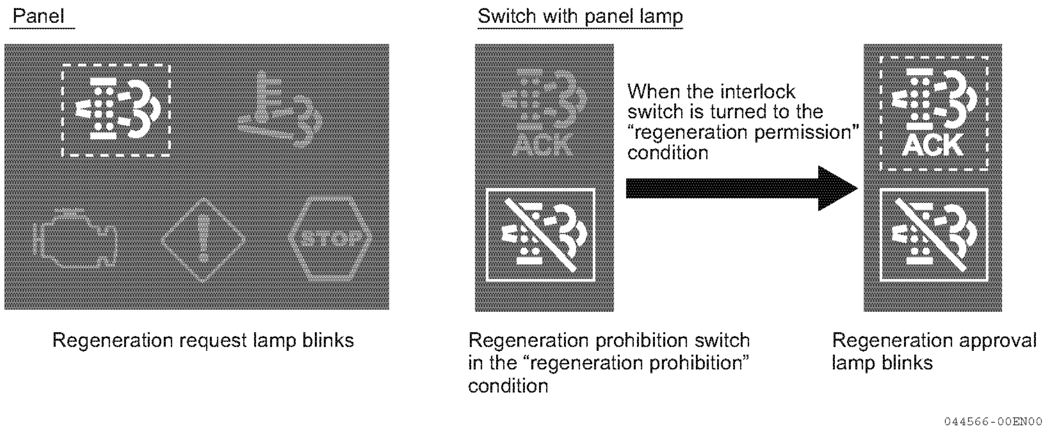
[4] Reset regeneration operating (Elapsed time since last reset: 100 hours, no regeneration inhibition)



Description

- The reset regeneration is completed in approximately 25 to 30 minutes. (After the reset regeneration completion, DPF transfers to [1] described before.)
- When the DPF regeneration inhibit SW is set to "Regeneration inhibited" state, the reset regeneration stops and DPF transfers to the reset regeneration standby state ([5] described later).
- As in [3] described before, setting the interlock switch to "Regeneration permitted" state and holding the DPF regeneration request SW to "ON" state for 3 seconds or more causes DPF to transfer to the stationary regeneration standby state ([6] de-scribed later).

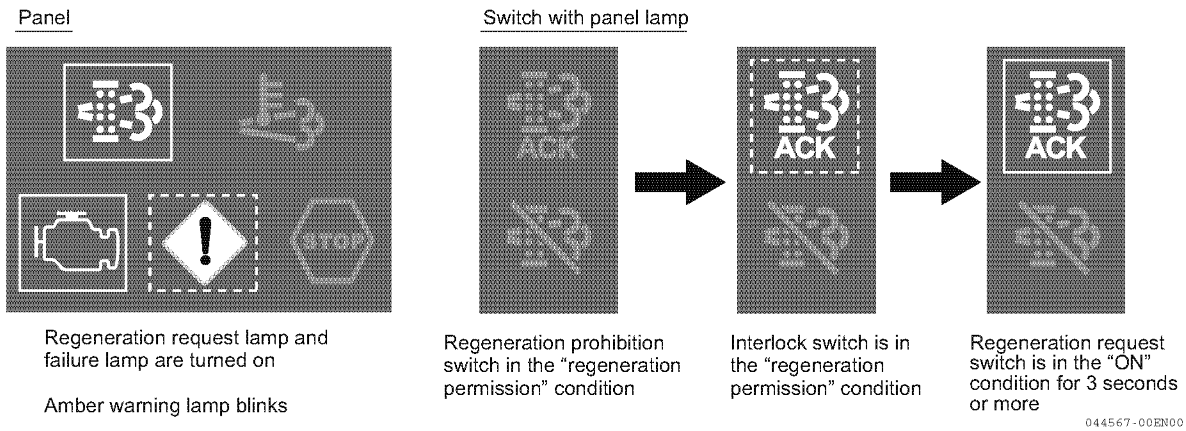
[5] Reset regeneration standby (Elapsed time since last reset: 100 hours, regeneration inhibited state)



Description

- While the DPF regeneration inhibit SW is set to "Regeneration inhibited" state, the reset regeneration is stopped.
- When 1 hour has passed in the reset regeneration standby state, DPF automatically transfers to the stationary regeneration standby state ([6] described below). For details on the stationary regeneration standby, refer to [6] described below.
- If the PM deposit amount decreases by a certain amount in the reset regeneration standby state, the reset regeneration ends automatically and transfers to the normal operation ([1] described before).

[6] Stationary regeneration standby

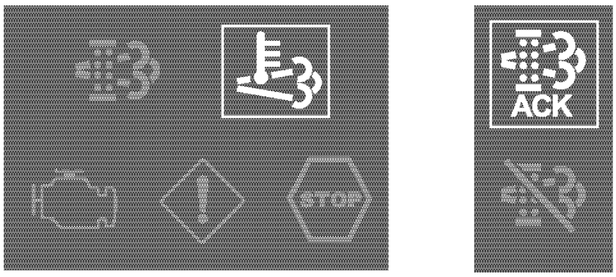


Description

- An operator intervention ([3], [4] above) (hereinafter referred to as "Allow state") or detection of certain PM deposit amount or more (hereinafter referred to as "Emergency state") causes DPF to transfer to the stationary regeneration standby.
- When the transition is made from the above "Allow" condition to the stationary regeneration standby, only the regeneration request lamp is turned on. When the transition is made from the above "Emergency" condition, the regeneration request lamp and failure lamp are turned on and the Amber warning lamp blinks, and DTC: P1421 is displayed.
- Make sure to refer to *Stationary regeneration execution on page 14-119* and confirm the operation procedures and precautions for the interlock mechanism and DPF regeneration request SW before starting stationary regeneration (transfer to [7] de-scribed later).
- If a certain length of time elapses AND the PM deposit amount reaches to or above a certain level, DPF automatically transfers to the backup mode ([8] described later).

[7] Stationary regeneration operating

Panel | Switch with panel lamp



Exhaust temperature warning lamp is turned on

Regeneration approval lamp is turned on

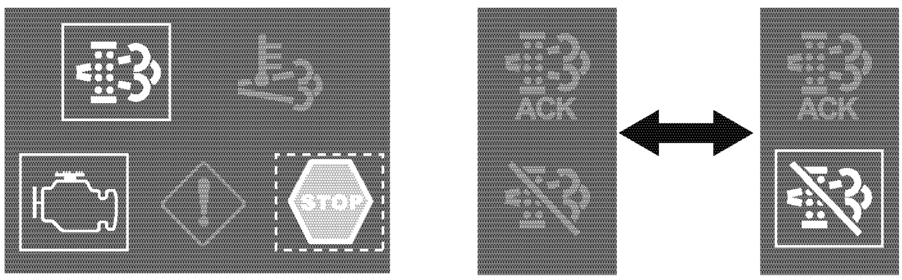
044568-00EN00

Description

- The stationary regeneration is completed in approximately 25 to 30 minutes. (After the stationary regeneration completion, DPF transfers to [1] described before.)
- If the stationary regeneration has started in the Allow state, setting the DPF regeneration inhibit SW to “Regeneration inhibited” state interrupts the stationary regeneration and DPF transfers to the state [2] described before. On the other hand, when the interlock switch is set to “Nonrenewable” state while the DPF regeneration inhibit SW is set to “Regeneration permitted” state, the stationary regeneration is interrupted and DPF transfers to the state [3] described before.
- If the stationary regeneration has started in the Emergency state, any of the following operations interrupts the stationary re-generation and DPF transfers to the stationary regeneration standby state ([6] described before).
  - Set DPF regeneration inhibit SW to “Regeneration inhibited” state
  - When the interlock switch is turned to the “regeneration prohibition” condition
  - Command an accelerator position equal to or more than the minimum position
  - Turn key switch to OFF

[8] Backup mode

Panel | Switch with panel lamp



Regeneration request lamp and failure lamp are turned on

Red engine stop lamp blinks

Regeneration prohibition switch in the “regeneration permission” condition

Regeneration prohibition switch in the “regeneration prohibition” condition

044569-00EN00

Description

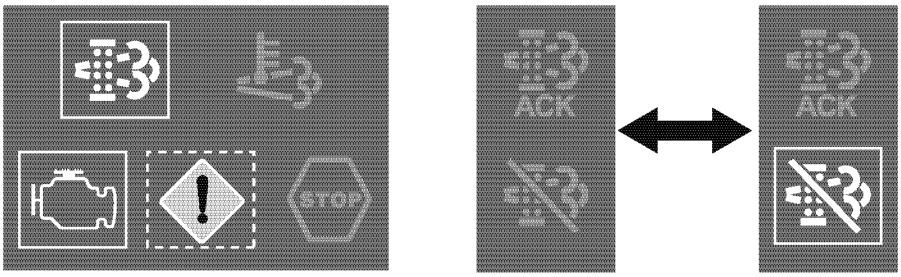
- In the backup mode, the engine is operated with speed limit and/or max. injection amount limit. (Settings are modifiable).
- In the backup mode, DTC for the relevant factor as listed below is displayed along with the specified DTC: P1424.

1. If PM deposit amount (C method) is equal to or larger than a certain amount, DTC: P2463
2. If PM deposit amount (P method) is equal to or larger than a certain amount, DTC: P1463
3. If PM deposit amount is equal to or larger than a certain amount even after stationary regeneration has been executed for a specified time, DTC: P2458
4. If a certain length of time elapses in stationary regeneration standby state, DTC: P2459

- To cancel the backup mode, you need to use the service tool (SA-D).

[9] Ash cleaning request

Panel | Switch with panel lamp



Regeneration request lamp is turned on

Failure lamp and Amber warning lamp blink

Regeneration prohibition switch in the “regeneration permission” condition

Regeneration prohibition switch in the “regeneration prohibition” condition

044570-00EN00

Description

- Details are under development.

As shown in **Table 14-42**, E-ECU outputs information related to the DPF regeneration control via CAN communication. For details on the CAN data formats, refer to *ON-Vehicle Communication CAN Specification on page 15-1*.

Table 14-42 Information related to DPF regeneration control

Name	CAN data			Contents
	PGN	Name	SPN	
State of contact input/ output terminals	65297	Y_I/OS	–	Outputs the state of each contact input/output terminals related to the DPF operator interfaces. “0: OFF” or “1: ON”
Active Regeneration state	64892	DPFC1	3700	“01: Active”: Reset/stationary regeneration operating “00: Not Active”: Except above
DPF state	64892	DPFC1	3701	“000: Regeneration not need”: DPF regeneration control not operating “001: Regeneration needed-lowest level”: Assist/reset/stationary regeneration operating (including permission and standby) “011: Regeneration needed-highest level”: Backup mode
Active Regeneration Forced State	64892	DPFC1	4175	“000: Not active”: DPF regeneration control not operating or stationary regeneration not permitted “001: Active - Forced by switch”: Stationary regeneration operating “010: Active - Forced by service tool”: (Reserved) “011:Allow upon Request”: Stationary regeneration permitted or standby
DPF regeneration control mode status	65322	Y_ATF	–	Outputs the status of DPF regeneration control mode.
DPF regeneration control process status	65322	Y_ATF	–	Outputs the status of process in each DPF regeneration control.
Emergency mode status	65322	Y_ATF	–	Outputs the respective emergency judgment results during assist/reset/stationary regeneration.
Progress of stationary regeneration	65322	Y_ATF	–	Outputs the rough progress [%] of stationary regeneration.
PM deposit amount	65327	Y_PM D	–	Outputs the PM deposit amount (P method/C method) estimated by E-ECU.

Stationary regeneration execution

Even when E-ECU performs assist regeneration or reset regeneration, PM may not be burnt (DPF may not be regenerated) if idling with no load or operation with low speed/load is repeated frequently. At that time, if E-ECU judges that stationary regeneration should be executed, it illuminates the DPF Regen Req lamp. (With an option setting, the Failure lamp or Amber warning lamp also illuminates.) When the DPF Regen Req lamp illuminates (Failure lamp or Amber warning lamp flashes), E-ECU needs to control the engine speed automatically to perform a process of burning PM (stationary regeneration). Continued operation with the DPF Regen Req lamp illuminated (Failure lamp or Amber warning lamp flashing) allows PM to accumulate excessively and may cause an abnormal burning of PM, resulting in DPF damage or fire. Therefore, perform stationary regeneration by operating the regeneration interlock SW and the DPF regeneration request switch according to the procedure below. When starting stationary regeneration in such a situation, you should basically activate the interlock function by operating an interlock mechanism (linked with regeneration interlock SW) such as the parking brake.
When performing stationary regeneration, follow the precautions listed below.

Safety precautions

- Do not do a stationary regeneration in a badly ventilated location. There is the danger of carbon monoxide poisoning.
- Make sure that there are no flammables near the exhaust pipes to avoid fires.
- Do not touch the exhaust pipes during stationary regeneration to avoid injury. Make sure that there are no people close to the exhaust pipes.
- After stationary regeneration starts, white smoke may be discharged from the exhaust pipe. This is not a fault but steam discharged when the exhaust temperature is low. As the exhaust temperature increases, the white smoke will disappear.
- Stationary regeneration may not operate while the engine is cold. Start it after the engine is warmed up.
- The exhaust gas has a different odor from that of a conventional diesel engine. This is not a fault. The different odor is generated because the exhaust gas is purified by the catalyst integrated in DPF.

Operating procedures for stationary regeneration

1. Move to a safe location that is well-ventilated.
2. Set the acceleration lever to the lowest position and run the engine at idle speed.

   Note: *If a DPF regeneration inhibit SW is installed, set the DPF regeneration inhibit SW to "Regeneration permitted" state.*

3. Activate the interlock function by operating an interlock mechanism (linked with regeneration interlock SW) such as the parking brake. (Set the interlock switch to "Regeneration permitted" state.)

   Note: *When E-ECU recognizes that the interlock system is enabled (driving force is shut off) via the regeneration interlock SW, the DPF Regen Ack lamp flashes.*

4. When the DPF regeneration request SW is pressed and held for 1 s (TBD) or more, stationary regeneration starts.

   Note:

   - *When the stationary regeneration starts, the engine speed will gradually increase to high idle speed and reset regeneration will be performed under this operation condition.*
   - *When stationary regeneration starts, the DPF Regen Req lamp turns off (Failure lamp or Amber warning lamp turns off), the DPF Regen Ack lamp changes from flashing to constant illumination, and the EGT lamp illuminates.*
   - *The stationary regeneration will be finished after approx. 25 to 30 minutes.*
   - *To abort the stationary regeneration, perform either of the following operations.*

- *Set the interlock switch to "Nonrenewable" state.*
- *Set the DPF regeneration inhibit SW to "Regeneration inhibited" state.*
- *Command an accelerator position equal to or more than the minimum position.*
- *Turn the key switch to OFF.*

5. When the above time has passed, the engine speed gradually decreases to the low idle speed and the DPF Regen Ack lamp and EGT lamp turn off. Stationary regeneration is completed.

Functional Overview of SA-D (Currently Under Development)

With the common rail system, you can use SA-D to monitor, diagnose, and configure the E-ECU. This section provides supplementary information for SA-D. For more information, refer to *the SA-D manual*.

Supply Pump

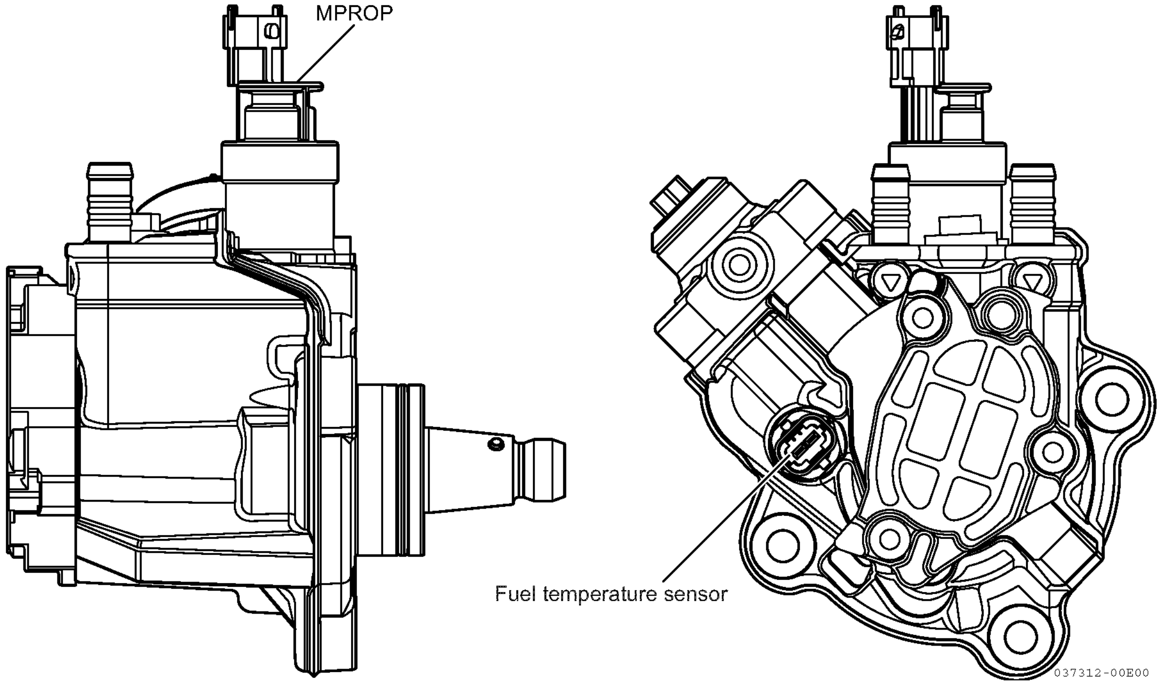


Figure 14-54 Supply pump

Item	Supply pump (MPROP)	Fuel temperature sensor
Part number	129A00-51000	129A00-51000
Water resistance	–	IPX4K equivalent
Temperature	-20 to 100 °C	-20 to 100 °C
Vibration	*Under investigation	*Under investigation

Rail Pressure Sensor

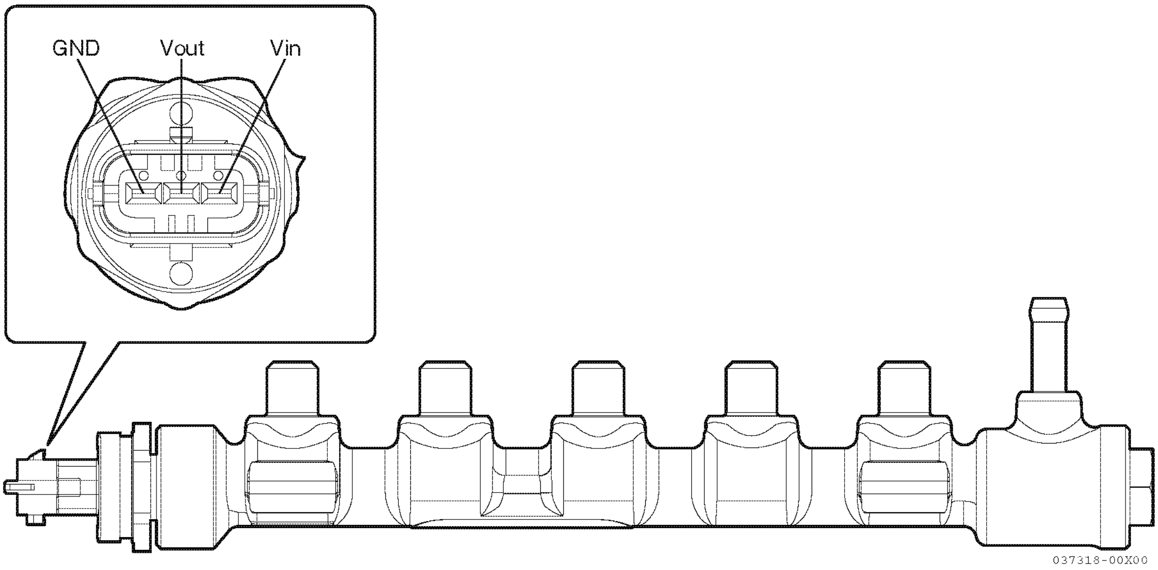


Figure 14-55 Rail pressure sensor

Item	3TNV88C, 3TNV86T	4TNV88C, 4TNV86CT 4TNV98C, 4TNV98CT
Part number	129A00-57000	129C00-57000
Water resistance	IPX6K/9K equivalent	IPX6K/9K equivalent
Temperature	-20 to 100 °C	-20 to 100 °C
Vibration	*Under investigation	*Under investigation

Crank Rotation Sensor

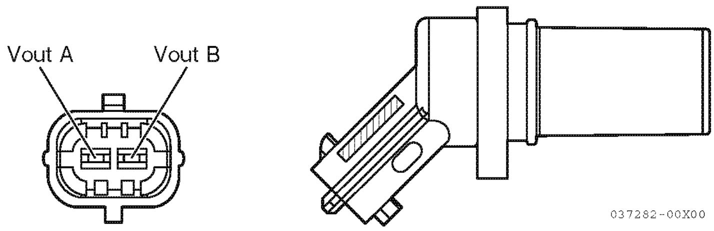


Figure 14-56 Crank rotation sensor

Item	Content
Part number	529A00-21710
Water resistance	IPX6K/9K equivalent
Sensor installation tightening torque	8 ± 2 N·m
Temperature	-20 to 100 °C
Vibration	*Under investigation
Safety precaution	• Do not use sensors that dropped.

Cam Speed Sensor

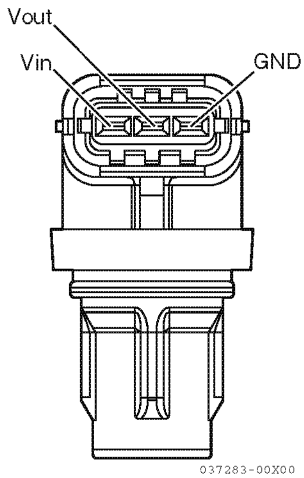


Figure 14-57 Cam speed sensor

Item	Content
Part number	529A00-14710
Water resistance	IPX9K equivalent
Sensor installation tightening torque	8 ± 0.5 N·m
Temperature	-20 to 100 °C
Vibration	*Under investigation
Safety precaution	• Do not use sensors that dropped.

Cooling Water Temperature Sensor

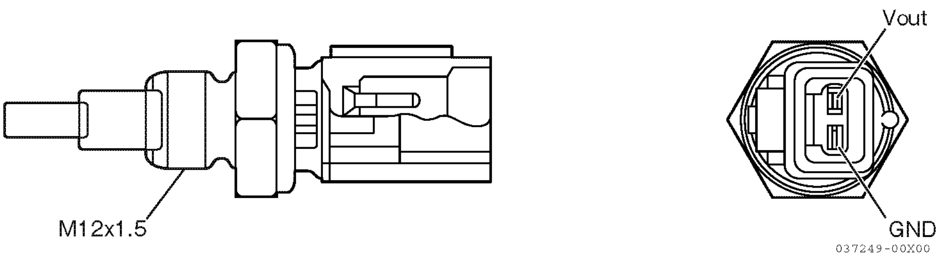


Figure 14-58 Water temperature sensor

Item	Content
Part number	129927-44900
Mating part connector	Housing: AMP 178390-2 Clamping contact: AMP 171662-5 Rubber plug: AMP 172746-2
Sensor installation tightening torque	22 ± 2 N·m
Temperature	*Under investigation
Vibration	*Under investigation
Safety precaution	• Do not use sensors that dropped.

New Air Temperature Sensor

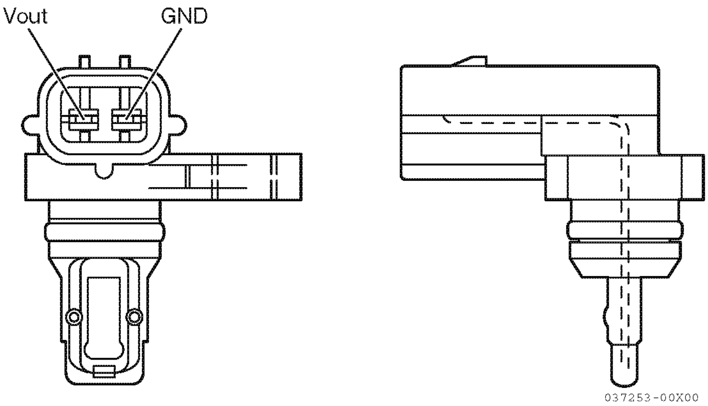


Figure 14-59 New air temperature sensor

Item	Content
Part number	129A00-12710
Mating part connector	AMP: 174352
Water resistance	JIS D0203 S2 equivalent
Sensor installation tightening torque	7 ± 1.4 N·m
Temperature	*Under investigation
Vibration	*Under investigation
Safety precaution	• Do not use sensors that dropped.

Diesel Particulate Filter (DPF) Inside/Inlet and Exhaust Temperature Sensors

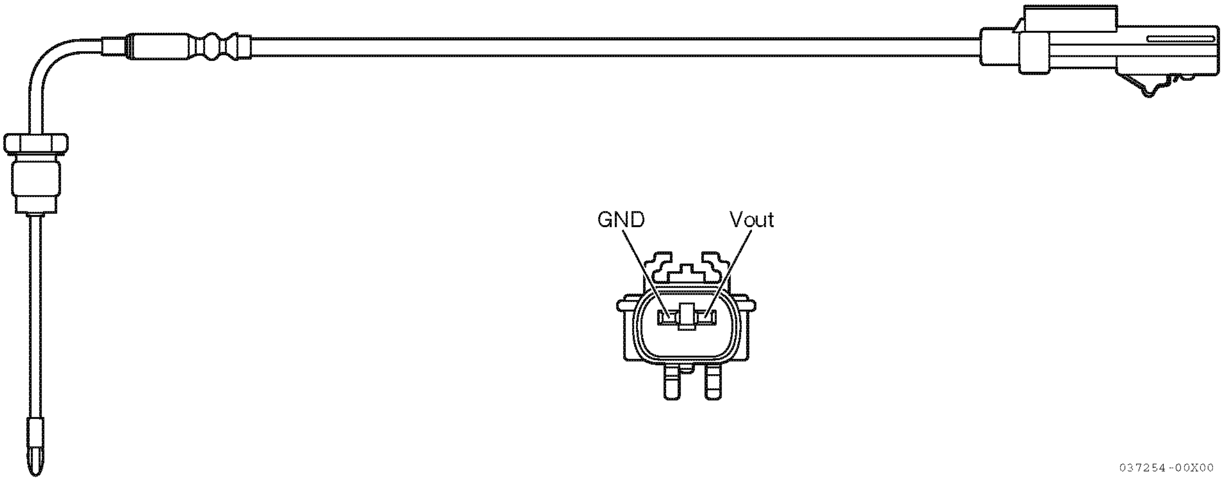


Figure 14-60 DPF inside/inlet and exhaust temperature sensors

Item	Exhaust temperature sensor	DPF intermediate temperature sensor	DPF inlet temperature sensor
Part number	129A00-13760 (Representative)	129A00-13980	129A00-13990
Mating part connector	FCI 54200 207 “B”	FCI 54200 206 “A”	FCI 54200 208 “C”
	*To avoid mistakes, the coupler keys are different		
Water resistance	JIS D0203 S2 equivalent	JIS D0203 S2 equivalent	JIS D0203 S2 equivalent
Sensor installation tightening torque	25 ± 40 N·m	25 ± 40 N·m	25 ± 40 N·m
Vibration	*Under investigation	*Under investigation	*Under investigation
Safety precaution	• Do not use sensors that dropped. • Do not lift the DPF by holding the sensor part.		

Diesel Particulate Filter (DPF) Differential Pressure Sensor

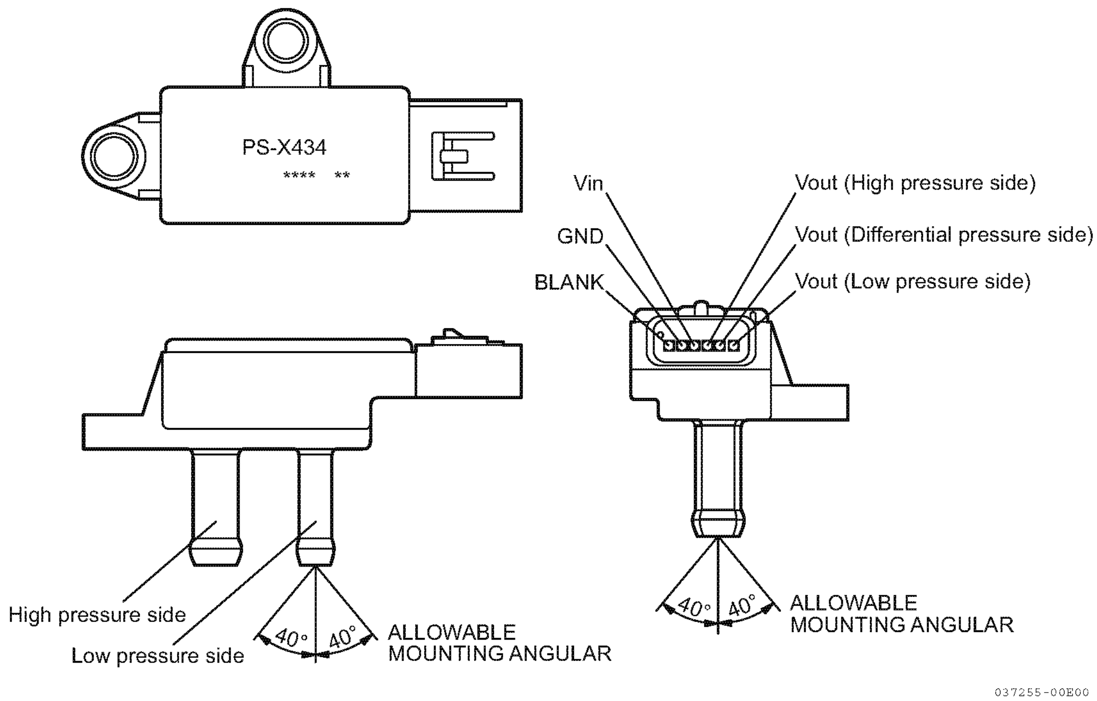
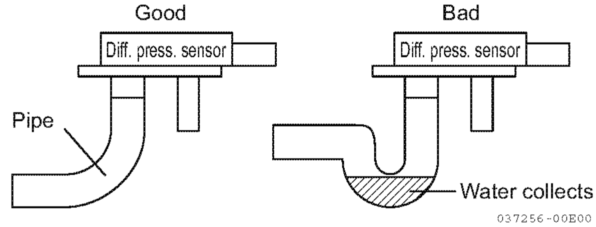


Figure 14-61 New air temperature sensor

Item	Content
Part number	129A00-17700
Mating part connector	AMP: 1438153-5
Sensor inlet gas temperature	≤ 120 °C
Water resistance	JIS D0203 S2 equivalent
Sensor installation tightening torque	7 ± 1.4 N·m
Vibration	*Under investigation
Safety precaution	• Do not use sensors that dropped. • Install the differential pressure switch so that the allowed angle shown in the above figure is met even when the vehicle is tilted. • If you install a pipe to the DPF differential pressure sensor, do not install it as shown in the below figure. If water collects, the pressure cannot be detected.  Differential pressure sensor pipe installation (example)

EGR Pressure Sensor

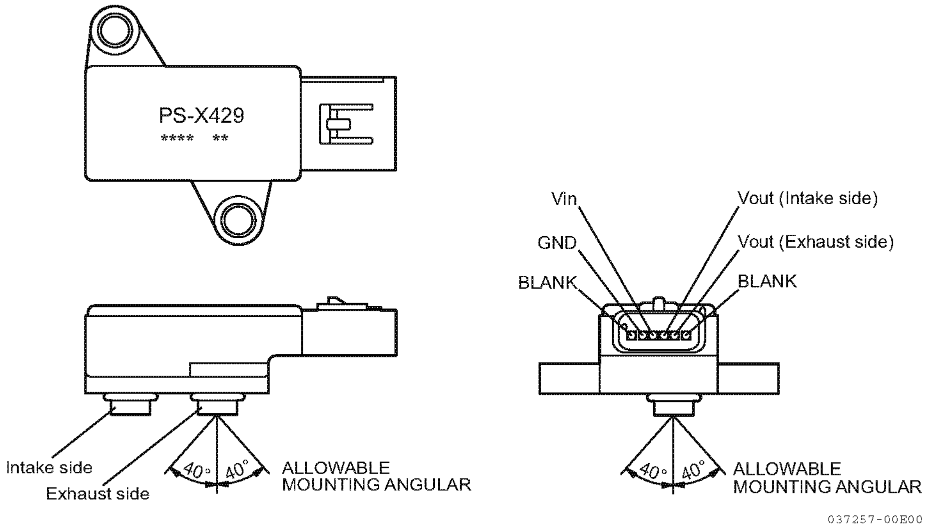


Figure 14-62 EGR pressure sensor

Item	Content
Part number	129A00-12700
Mating part connector	AMP: 1438153-5
Water resistance	JIS D0203 S2 equivalent
Sensor installation tightening torque	7 ± 1.4 N·m
Vibration	*Under investigation
Safety precaution	• Do not use sensors that dropped. • Install the differential pressure switch so that the allowed angle shown in the above figure is met even when the vehicle is tilted.

Intake Temperature Sensor

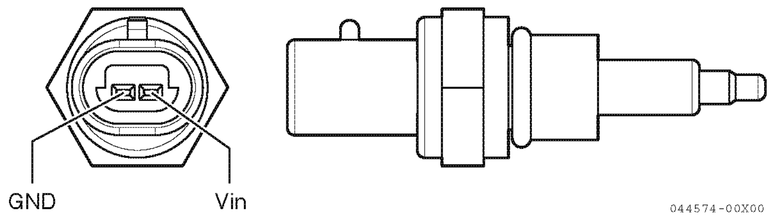


Figure 14-63 Intake temperature sensor

Item	Content
Part number	129A00-12720
Mating part connector	DELPHI: GT15335987
Water resistance	*Under investigation
Sensor installation tightening torque	14 ± 3 N·m
Vibration	*Under investigation
Safety precaution	• Do not use sensors that dropped.

EGR Temperature Sensor

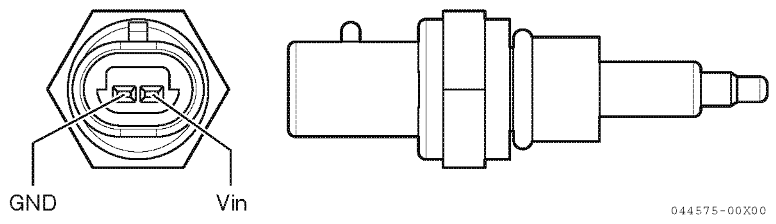


Figure 14-64 EGR temperature sensor

Item	Content
Part number	129A00-13750
Mating part connector	DELPHI: GT15336004
Water resistance	*Under investigation
Sensor installation tightening torque	14 ± 3 N·m
Vibration	*Under investigation
Safety precaution	• Do not use sensors that dropped.

EGR Valve

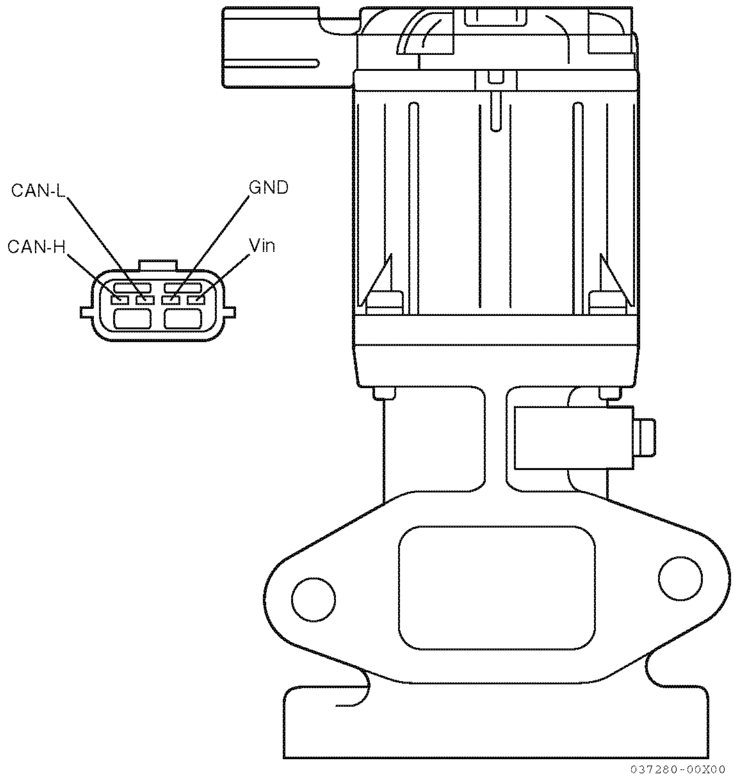


Figure 14-65 EGR Valve

Model	Part Number
3TNV88C, 3TNV86T	129A00-13900
4TNV88C, 4TNV86CT	129C00-13900
4TNV98C, 4TNV98CT	129E00-13900

Item	Content
Mating part connector	Sumitomo Wiring Systems: 6195-0030
Water resistance	JIS D0203 S1 equivalent
Vibration	*Under investigation
Safety precaution	• Do not use EGR valves that dropped. • Do not do high-pressure cleaning.

intake Air Throttles

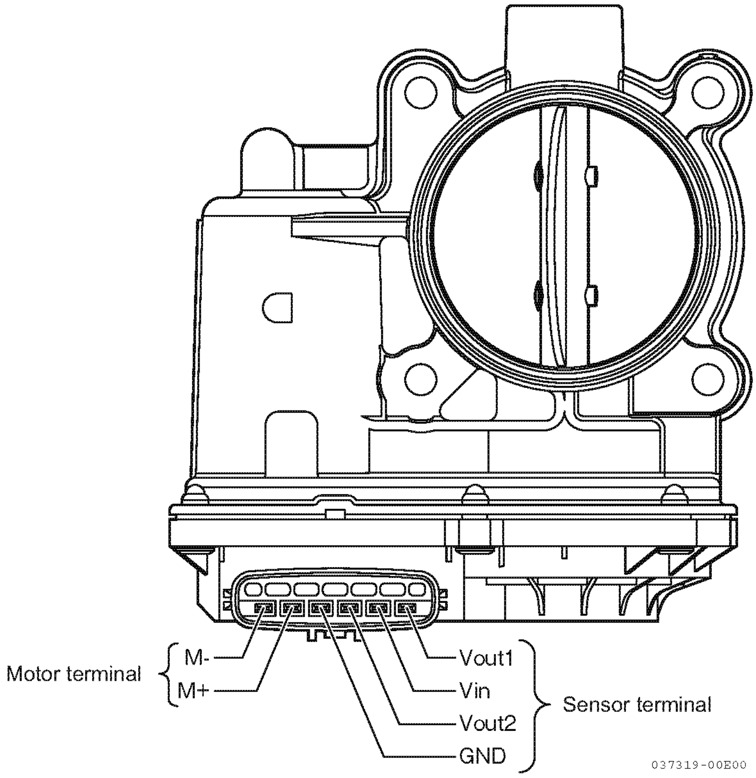


Figure 14-66 Intake air throttles

Item	Content
Part number	129A00-12900
Mating part connector	Yazaki Corporation: 7283-1968-30
Water resistance	JIS D0203 S2 equivalent
Sensor installation tightening torque	9.0 ± 1.8 N·m
Vibration	*Under investigation
Safety precaution	• Do not use intake air throttles that dropped. • Do not expose to excessive impact or load. • Do not touch moving parts. Do not forcefully retain moving parts.

Exhaust Air Throttles

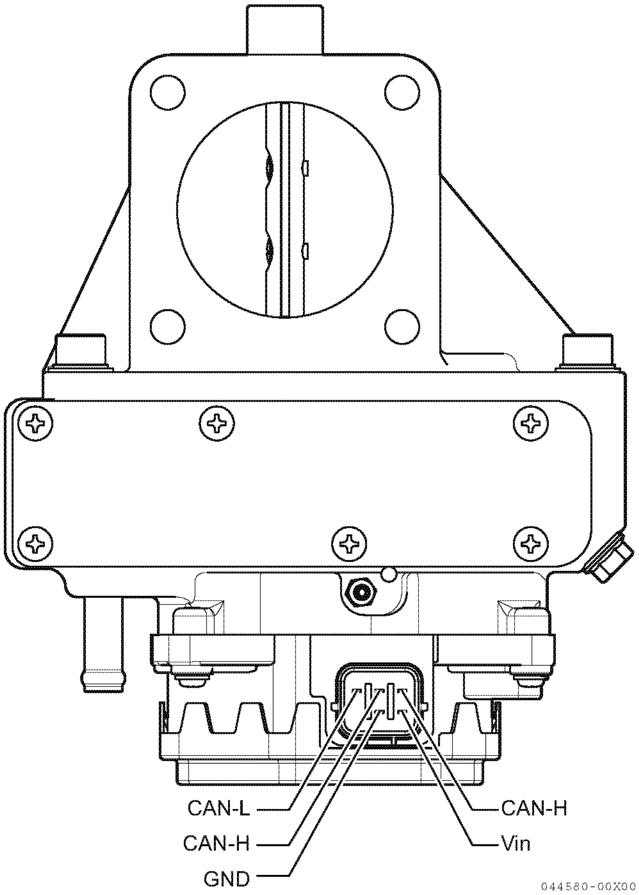


Figure 14-67 Exhaust air throttles

Item	Content
Part number	529C00-13510
Mating part connector	Yazaki Corporation: 7283-1968-30
Water resistance	JIS D0203 S2 equivalent
Vibration	*Under investigation
Safety precaution	• Do not use throttles that dropped. • Do not expose to excessive impact or load. • Do not touch moving parts. Do not forcefully retain moving parts.

Acceleration Sensor

The acceleration sensor you use may be YANMAR standard acceleration sensor shown in **Figure 14-68** or equivalent. For general requirements regarding the acceleration sensor, refer to **Figure 14-2**, **Table 14-6**, *Electric Acceleration on page 14-46*.

The acceleration sensor may be omitted for generator engines (which are provided as standard engines to be installed on driven machines for generators) and other constant speed engines; for more information, contact YANMAR.

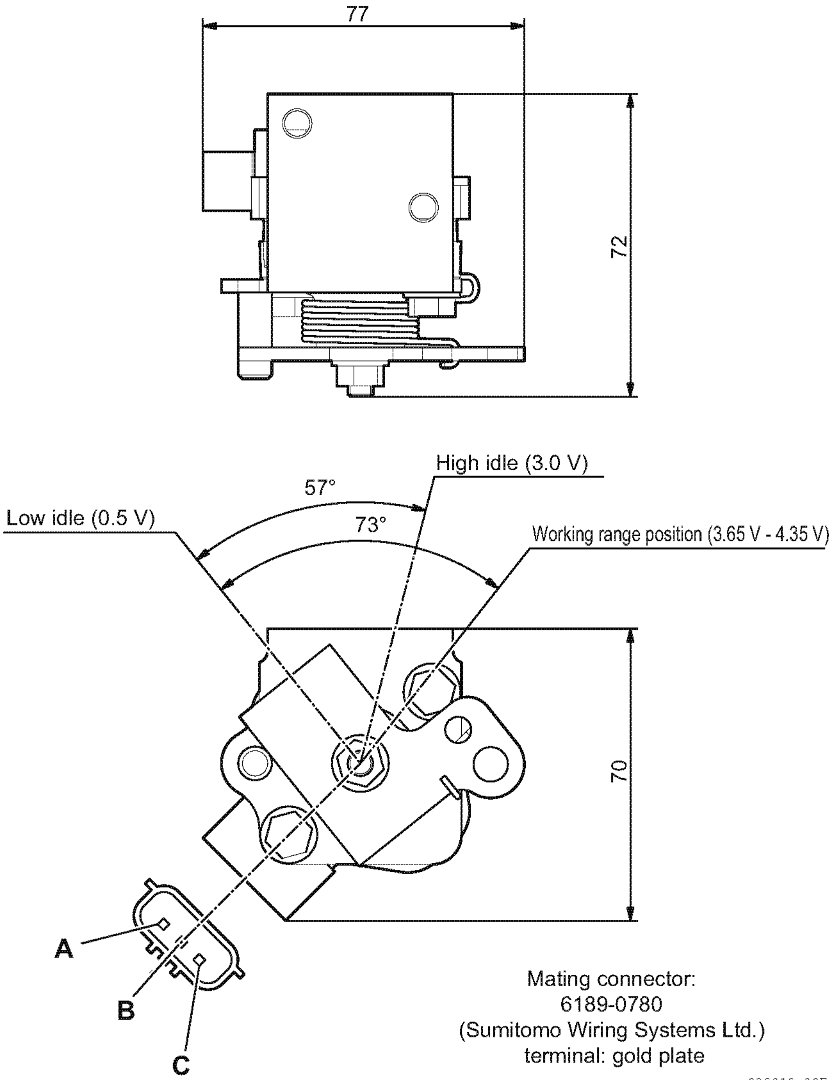


Figure 14-68 YANMAR standard acceleration sensor (129938-77800)

Terminal	Wire
A	GND GND-A
B	OUTPUT APS
C	INPUT AVCC

The operating conditions for YANMAR standard acceleration sensor (129938-77800), observe the guidelines described below:

Waterproof guidelines

Use the following guidelines to prevent water entrance and corrosion to terminals:

- Avoid installing the acceleration sensor in any location or configuration where the sensor shaft or connector may get wet with water.
- Avoid installing the acceleration sensor in any location or configuration where the sensor or connector may be directly exposed to water during steam cleaning, high pressure cleaning, etc.
- Lay the harness making enough allowance to prevent any tension. Water may enter through the waterproof seal should the harness be pulled diagonally.

Vibration guidelines

Use the following guidelines to prevent the potentiometer resistors from wear/deterioration and the harness from disconnection:

- Avoid installing the acceleration sensor in any location or configuration where it will not be exposed to vibration beyond 2.4 GRMS (in any direction, throughout the overall frequency range of 5 to 1000 Hz).
- Avoid installing the acceleration sensor in any location or configuration where it may cause resonance with other devices or objects.
- Avoid installing the acceleration sensor in any location or configuration where the sensor lever arm may be shaken by vibration transmitted through the accelerator lever or wire cable. (For example, avoid anchoring the sensor to the same member as the wire cable.)
  Avoid installing the acceleration sensor in any location or configuration where the width of the acceleration sensor output voltage fluctuation due to vibration may exceed 1.6 mVp-p.

Noise resistance guidelines

Use the following guidelines to minimize voltage fluctuations:

- The total cable length from the E-ECU to the acceleration sensor should be within 5 meters.
- Avoid laying the cable through the vicinity of any high power device that is likely to emit noise. If it is impracticable to avoid the vicinity of a noise emitting source, protect the sensor from noise by using a twisted/shieled cable or the like; otherwise, the sensor may falsely operate.
- Avoid installing the acceleration sensor in any location or configuration where the output voltage fluctuation width may exceed 50 mVp-p.

Other

- Do not use the sensor if it has dropped or it is apparently broken.

Table 14-43 Acceleration sensor specifications

Item	Content
Rated voltage	5 V DC ± 0.01 V
YANMAR code	129938-77800
Total resistance (sensor unit)	5 ± 1.5 kΩ
Working temperature range (sensor unit)	-30 °C - 110 °C
Storage temperature range (sensor unit)	-40 °C - 130 °C

Starter Motor Relay

The starter motor relay is used to control the current flowing into the S terminal of the starter motor.

For wiring connections, refer to *the electrical wiring diagram* in **Figure 14-4**.

The starter motor relay is compatible with the status of 12 V DC/2.3 kW (129900-77010, 129910-77022) or 12 V DC/3.0 kW (129940-77010). For instructions on using the starter motor for other applications, contact YANMAR.

Because the starter motor relay is an ISO relay that lacks a built in bracket, it comes with a metal bracket for use with the mating connector (Yazaki Corporation 7223-6146-30). (Refer to **Figure 14-70**.)

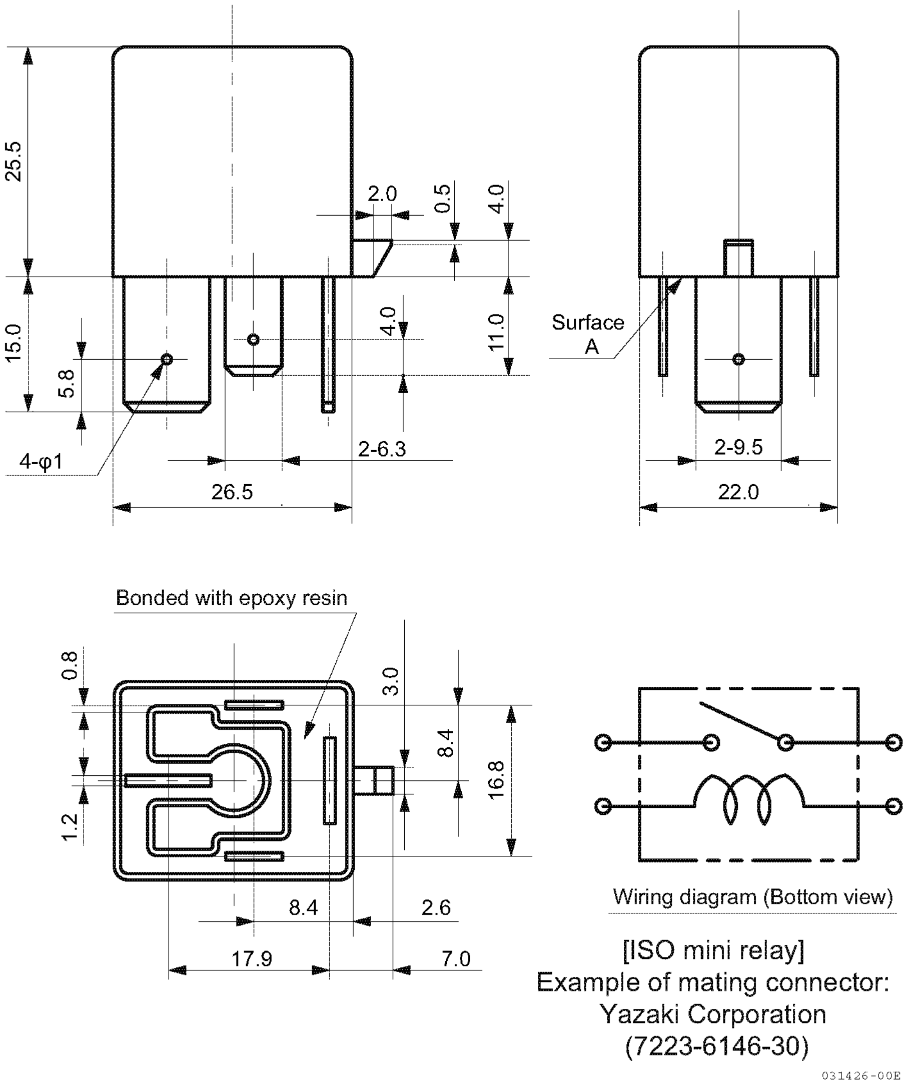


Figure 14-69 ISO relay (70A)

Table 14-44 ISO relay (70 A) specifications

Item	Content
YANMAR code	129927-77920
Rated coil voltage	12 V DC
Rated exciting current	11 7 mA
Contact specifications	a-contact
Rated contact voltage	12 V DC
Rated contact current	70 A
Operation delay time	15 ms or less
Reset delay time	15 ms or less

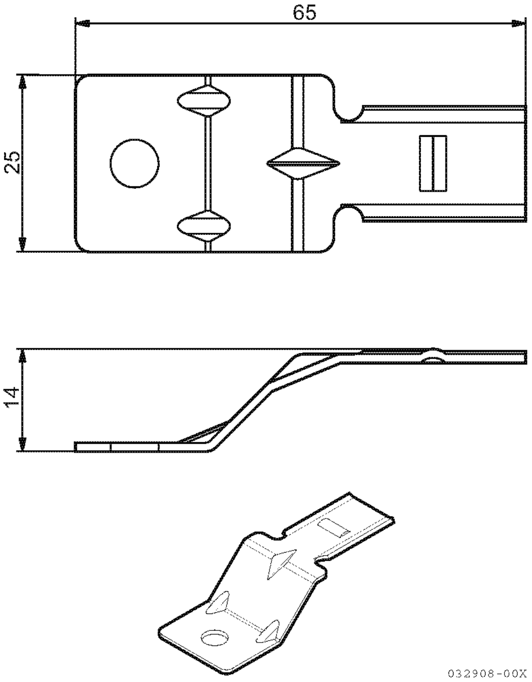


Figure 14-70 ISO relay bracket (129927-77910)

Glow Plug Relay

The glow plug relay allows the E-ECU to control the current flowing into the glow plug.

For wiring connections, refer to *the electrical wiring diagram* in **Figure 14-4**.

For the Glow Plug

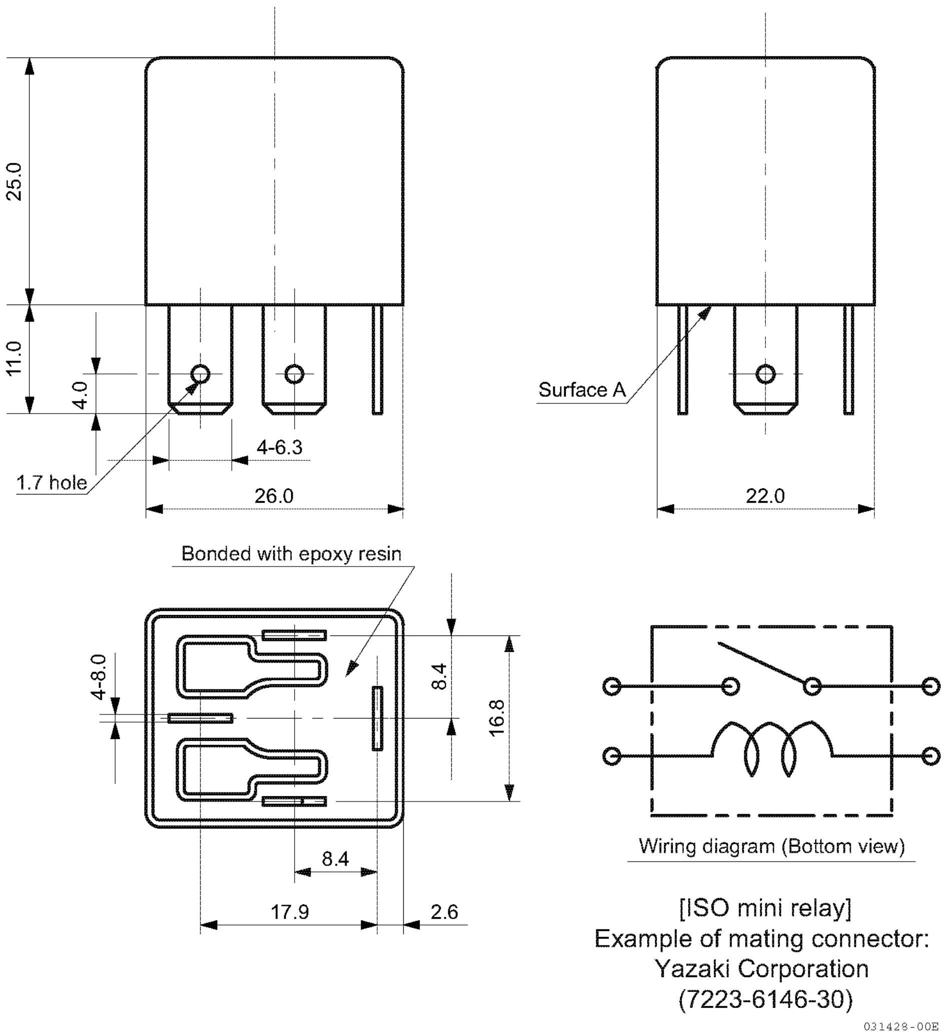


Figure 14-71 ISO relay (40 A)

Table 14-45 ISO relay (40 A) specifications

Item	Content
YANMAR code	129927-77920
Rated coil voltage	12 V DC
Rated exciting current	117 mA
Contact specifications	a-contact
Rated contact voltage	12 V DC
Rated contact current	40 A - continuous

Because the starter motor relay is an ISO relay that lacks a built in bracket, it comes with a metal bracket for use with the mating connector (Yazaki Corporation 7223-6146-30). (Refer to **Figure 14-70**.)

EGR Valve Relay

The EGR valve relay retains the power supply to the EGR valve.

For its connection, refer to *the electric wiring diagram* in **Figure 14-4**.

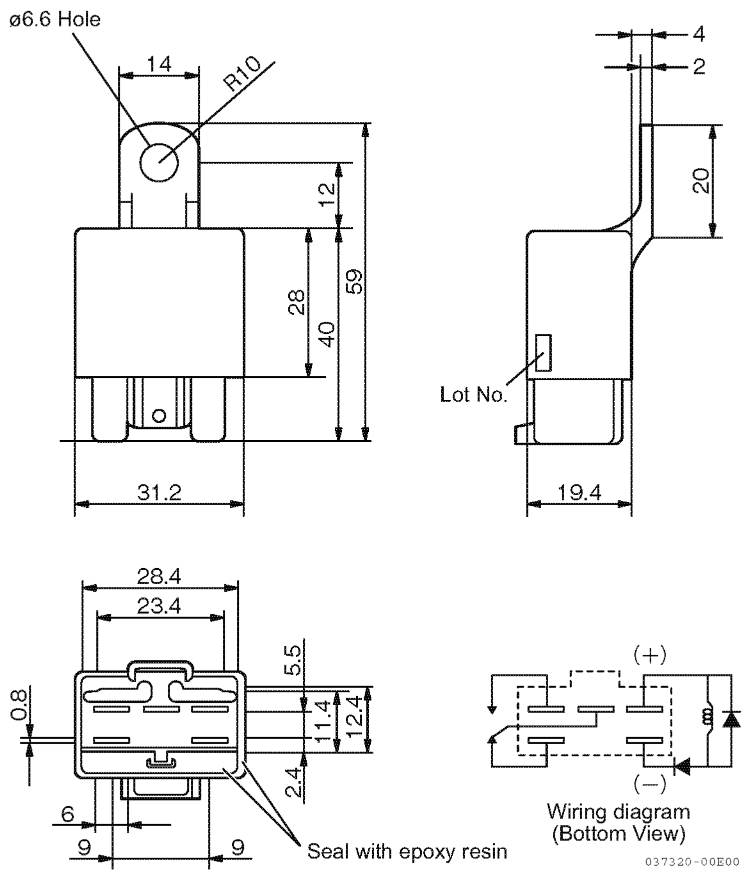


Figure 14-72 CA relay (20 A)

Table 14-46 CA relay (20 A) specifications

Item	Content
YANMAR code	198461-52950
Rated coil voltage	12 V DC
Rated exciting current	150 mA
Contact specifications	c-contact
Rated contact voltage	12 V DC
Rated contact current	20 A

ECU Application Menu

The contents of the application menu are subject to change. Contact YANMAR for the availability of the latest application menu.

2011.12.XX

No.	Sub	Item (Content)	Menu	Base initial value (Planned)	Condition during Monitoring (Corresponds to Bosch V192R55)	Customer Setting
a) Engine control setting part						
1	Engine item					
	1	Low idle rotation speed	Target speed	Individual model	OK	
2	Idle-up function					
	1	Idle-up speed coordinates	Cooling water temperature	-30, -10, 10, 30	OK	
	2	Idle-up speed	Low idle speed during idle-up	Individual model	OK	
3	Limited operation condition					
	1	Engine stop, delayed time A	Delayed time [sec]	30	OK	
	2	Engine stop, delayed time B	Delayed time [sec]	180	OK	
b) Application function setting part						
1	ECU control function setting					
		Setting for YMR standard acceleration				
	1	Selection of acceleration function	0: No acceleration sensor 1: 1 system accelerator 2: 2 system accelerator (high speed or normal side is prioritized) 3: 2 system accelerator (rear control or normal side is prioritized) 4: Backup accelerator 5: CAN communication analog interconnection switch * Under consideration 6: Service acceleration *Under consideration 10: Reserved (YN pulse accelerator (CAN communication + APP-IP3))	1	0, 1, 4 only (Others are under consideration)	
	2	Structure of 1 system accelerator	0: Single system analog (APS1) 1: Dual system analog (APS1 + APS2) 2: SAE foot pedal (APS3 + PDLSW) 3: CAN communication (TSC1 or TSC1 + Y_ECR1)	0	0, 3 only (Others are under consideration)	
	3	Structure of 2 system accelerator	0: Single system analog x 2 1: Single system analog + dual system analog 2: Single system analog + SAE foot pedal 3: Dual system analog + SAE foot pedal	0	Disabled (Under consideration)	No setting available
	4	Structure of backup accelerator	0: CAN communication → single system analog 1: Single system analog → CAN communication *Under consideration 2: Dual system analog → CAN communication *Under consideration 3: SAE foot pedal → CAN communication *Under consideration	0	0 only (Others are under consideration)	0 Fixed
	5	Structure of CAN communication <=> analog interconnection switch *Under consideration	0: CAN communication <=> single system analog 1: CAN communication <=> dual system analog 2: CAN communication <=> SAE foot pedal	0	Disabled (Under consideration)	No setting available
	6	Structure of service accelerator *Under consideration	0: Service accelerator <=> no accelerator 1: Service accelerator <=> single system analog 2: Service accelerator <=> dual system analog 3: Service accelerator <=> SAE foot pedal 4: Service accelerator <=> CAN communication	0	Disabled (Under consideration)	No setting available
	7	Selection of accelerator switch operation	0: No “gradual change” 1: With “gradual change” 2: No “gradual change” + no acceleration transition only 3: With “gradual change” + no acceleration transition only 4: The final value is kept until intersection	0	0, 4 only (Under consideration)	
	8	APS1 low idle rotation voltage	Input is [mV]	0.7	OK	
	9	APS1 high idle rotation voltage	Input is [mV]	3.0	OK	
	10	APS2 low idle rotation voltage	Input is [mV]	(The setting value conforms to the dual system accelerator specifications)	Disabled	No setting available
	11	APS2 high idle rotation voltage	Input is [mV]	(The setting value conforms to the dual system accelerator specifications)	Disabled	No setting available
	12	APS3 low idle rotation voltage	Input is [mV]	0.7	Disabled	No setting available
	13	APS3 high idle rotation voltage	Input is [mV]	3.0	Disabled	No setting available

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No.	Sub	Item (Content)	Menu	Base initial value (Planned)	Condition during Monitoring (Corresponds to Bosch V192R55)	Customer Setting
	14	Setting for analog accelerator malfunction automatic recovery	0: Disabled 1: Enabled	0	Disabled	No setting available
	15	Setting for CAN accelerator malfunction automatic recovery	0: Disabled 1: Enabled	0	Disabled	No setting available
	16	Enable selection of TSC1 torque limit function	0: Disabled 1: Enabled	0	Disabled (Under consideration)	No setting available
	17	Droop selection input	0: By APP-IP1 (toggle type) 1: By APP-IP1 (momentary type, default: droop) 2: By APP-IP1 (momentary type, default: isochronous) 3: By CAN (Y_EC)	0	OK	
	18	Isochronous control during low idle speed	0: Disabled 1: Enabled	0	OK	
	19	Selection of starter restraint control	0: Disabled 1: Enabled - NO-Relay 2: (Unavailable)	1 (Required)	1 Only	1 Fixed
	20	Setting for starter input signal	0: By STARTSW 1: By CAN (Y_ECR1: Crank Request) (Bosch only)	0	OK	
	21	Setting for starter permission 1 switch (APP-IP9)	0: Disabled 1: Enabled	0	OK	
	22	Setting for starter permission 2 switch (APP-IP2)	0: Disabled 1: Enabled	0	OK	
	23	Setting for CAN communication restraint	0: Disabled 1: Restraint by Y_EC (PGN 65308) 2: Restraint by Y_ECR1 (PGN 65282)	0	Disabled	No setting available
	24	Starter energization time control function	0: Disabled 1: Enabled	0	OK	
	25	Start auxiliary relay malfunction detection function	0: Disabled 1: Enabled	1 (Recommended)	OK	
	26	Start auxiliary control function: on-glow	0: Disabled 1: Enabled	1 (Recommended)	OK	
	27	Start auxiliary control function: simultaneous energization	0: Disabled 1: Enabled (complete at the engine start speed) 2: Enabled (complete at the engine start recognition signal)	2 (Recommended)	OK	
	28	Start auxiliary control function by CAN communication	0: Disabled 1: Enabled	0	OK	
		Setting for engine stop function				
	29	Setting for engine stop 1 (SHUDNSW terminal)	0: No delay 1: With delay	0	OK	
	30	Delay time setting for engine stop 1 (SHUDNSW terminal)	Delay time [ms]	2000	OK	
	31	Retention operation selection for engine stop 1 factor	0: When "IGNSW OFF → ON", retention of the engine stop factor is released 1: Retention of the engine stop factor is released in one of the following cases: • IGNSW OFF → ON • Engine stall (engine speed = 0) 2: Retention of the engine stop factor is released with SHUDNSW OFF	0	0 or 1 (Others are under consideration)	
	32	Setting for engine stop 2 (APP-IP7 terminal)	0: No delay 1: With delay	0	OK	
	33	Delay time setting for engine stop 2 (APP-IP7 terminal)	Delay time [ms]	2000	OK	
	34	Setting for engine stop 2 (CAN)	0: Disabled 1: By CAN (Y_STP (On Request) 2: By CAN (Y_ECR1: Engine Stop Request (Regular transmission))	0	OK	
	35	Retention operation selection for engine stop 2 factor	0: When "IGNSW OFF → ON", retention of the engine stop factor is released 1: Retention of the engine stop factor is released in one of the following cases: • IGNSW OFF → ON • Engine stall (engine speed = 0) 2: Retention of the engine stop factor is released with APP-IP7 OFF and CAN (Y_STP) OFF	0	0 or 1 (Others are under consideration)	
	36	Setting for speed selection function	0: Disabled 1: Constant speed control (APP-IP6 terminal toggle type) 2: Constant speed control (APP-IP6 terminal momentary type) 3: Deceleration control (APP-IP6 terminal toggle type) 4: Deceleration control (APP-IP6 terminal momentary type) 5: (Reserved) 6: Auto deceleration control 7: Auto deceleration control (with high idle limit function)	0	OK	
		Speed selection input				

2011.12.XX

No.	Sub	Item (Content)	Menu	Base initial value (Planned)	Condition during Monitoring (Corresponds to Bosch V192R55)	Customer Setting
	37	Speed selection permission input	0: By APP-IP6 1: By CAN (Y_RSS)	0	OK	
	38	Speed selection 1 input	0: By APP-IP3 1: By CAN (Y_RSS)	0	OK	
	39	Speed selection 2input	0: By APP-IP4 1: By CAN (Y_RSS)	0	OK	
		Constant speed control				
	40	Constant speed 1	Application is switched due to the value of setting for speed selection function Except for 7: Target speed [min-1] 7: High idle limit speed [min-1]	1800	OK	
	41	Constant speed 2	Target speed [min-1]	1500	OK	
		Deceleration control				
	42	Deceleration start speed	Target speed [min-1]	1500	OK	
	43	Deceleration rate 1	Deceleration rate of high idle [%]	85	OK	
	44	Deceleration rate 2	Deceleration rate of high idle [%]	70	OK	
	45	Auto deceleration waiting time	Waiting time [s]	4	OK	
	46	Acceleration release for auto deceleration	0: Auto deceleration is not released by operating the accelerator 1: Auto deceleration is released by operating the accelerator	0	OK	
	47	High idle limit 1	0: Disabled 1: Enabled during both droop and isochronous 2: Enabled only during droop 3: Enabled only during isochronous	0	OK	
	48	High idle limit 2	0: Disabled 1: Enabled during both droop and isochronous 2: Enabled only during droop 3: Enabled only during isochronous	0	OK	
		High idle limit input				
	49	High idle limit input	0: By APP-IP5 1: By CAN (Y_EC)	0	OK	
	50	High idle selection input	0: By APP-IP8 1: By CAN (Y_EC)	0	OK	
		High idle limit speed				
	51	Droop limit speed 1	Limit speed 1	1900	OK	
	52	Isochronous limit speed 1	Limit speed 1	1900	OK	
	53	Droop limit speed 2	Limit speed 2	1700	OK	
	54	Isochronous limit speed 2	Limit speed 2	1700	OK	
	55	Blue white smoke restraint control (high idle down function during low temperature)	0: Disabled 1: Enabled	0	Disabled	No setting available
	56	CAN immobilizer	0: Disabled 1: Enabled	0	Disabled	No setting available
	57	Immobilizer calculation method switch flag	0: For OEM (default) 1: Exclusively for YANMAR 2: (Reserved)	0	Disabled	No setting available
	58	Immobilizer manufacturer code	*YANMAR will determine. Please contact YANMAR.	Individual setting	Disabled	No setting available
		DPF operator interface				
	59	DPF regeneration request input	0: By REGSW 1: By CAN (Y_DPFIF)	0	OK	
	60	DPF regeneration prohibition input	0: By REGMSW 1: By CAN (Y_DPFIF)	0	OK	
	61	Regeneration interlock input	0: By WDSBSW 1: By CAN (Y_DPFIF)	0	OK	
		Set value during detection of CAN (Y_DPFIF) reception error				
	62	DPF regeneration request input	0: No regeneration request 1: Regeneration request	0	OK	
	63	DPF regeneration prohibition input	0: Regeneration permission 1: Regeneration prohibition	0	OK	
	64	Regeneration interlock input	0: Regeneration not available 1: Regeneration permission	0	OK	
	65	ECU shutdown CAN direction	0: Disabled 1: Enabled (Y_ECR1)	0	Disabled	No setting available
2		Setting for ECU terminal function				
	1	Logic setting for APP-IP1 terminal (droop selection)	0: SW close → droop 1: SW close → isochronous	1	OK	
	2	Logic setting for APP-IP2 terminal (starter per-mission 2)	0: SW close → starter permission 1: SW close → starter restraint	0	OK	

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No.	Sub	Item (Content)	Menu	Base initial value (Planned)	Condition during Monitoring (Corresponds to Bosch V192R55)	Customer Setting
	3	Logic setting for APP-IP3 terminal (rotation selection 1)	0: SW close → ON 1: SW close → OFF	0	OK	
	4	Logic setting for APP-IP4 terminal (rotation selection 2)	0: SW close → ON 1: SW close → OFF	0	OK	
	5	Logic setting for APP-IP5 terminal (high idle limit)	0: SW close → ON 1: SW close → OFF	0	OK	
	6	Logic setting for APP-IP4 terminal (rotation speed selection permission)	0: SW close → ON 1: SW close → OFF	0	OK	
	7	Logic setting for APP-IP7 terminal (engine stop 2)	0: SW close → Engine stop 1: SW close → Engine operation	0	OK	
	8	Logic setting for APP-IP8 terminal (high idle selection)	0: SW close → ON 1: SW close → OFF	0	OK	
	9	Logic setting for APP-IP9 terminal (starter permission 1)	0: SW close → starter permission 1: SW close → starter restraint	0	OK	
	10	Logic setting for SHUDNSW terminal (engine stop 1)	0: SW close → Engine stop 1: SW close → Engine operation	0	OK	
	11	Logic setting for PDLSW terminal (accelerator pedal switch)	0: SW close → ON 1: SW close → OFF	0	Disabled	No setting available
	12	Logic setting for REGMSW terminal (regeneration prohibition switch)	0: SW close → Regeneration permission 1: SW close → Regeneration prohibition	1	OK	
	13	Logic setting for WDSBSW terminal (regeneration interlock switch)	0: SW close → Regeneration prohibition 1: SW close → Regeneration permission	1	OK	
	14	Current setting for FAIL-LMP terminal (failure lamp) diagnosis *Corresponds only with Bosch	0: Disabled (diagnosis current OFF, disconnection judgment not available) 1: Enabled (diagnosis current ON) (*Not available for use with LED type)	0	Disabled	No setting available
	15	Current setting for OVHT-LMP terminal (cooling water warning lamp) diagnosis *Corresponds only with Bosch	0: Disabled (diagnosis current OFF, disconnection judgment not available) 1: Enabled (diagnosis current ON) (*Not available for use with LED type)	0	Disabled	No setting available
	16	Current setting for DPF-M1 terminal (DPF regeneration request lamp) diagnosis *Corresponds only with Bosch	0: Disabled (diagnosis current OFF, disconnection judgment not available) 1: Enabled (diagnosis current ON) (*Not available for use with LED type)	0	Disabled	No setting available
	17	Current setting for DPF-M2 terminal (DPF regeneration prohibition lamp) diagnosis *Corresponds only with Bosch	0: Disabled (diagnosis current OFF, disconnection judgment not available) 1: Enabled (diagnosis current ON) (*Not available for use with LED type)	0	Disabled	No setting available
	18	Current setting for DPF-M3 terminal (exhaust temperature warning lamp) diagnosis *Corresponds only with Bosch	0: Disabled (diagnosis current OFF, disconnection judgment not available) 1: Enabled (diagnosis current ON) (*Not available for use with LED type)	0	Disabled	No setting available
	19	Current setting for DPF-M4 terminal (DPF regeneration approval lamp) diagnosis *Corresponds only with Bosch	0: Disabled (diagnosis current OFF, disconnection judgment not available) 1: Enabled (diagnosis current ON) (*Not available for use with LED type)	0	Disabled	No setting available
	20	Current setting for REOP3 terminal (Amber warning lamp) diagnosis *Corresponds only with Bosch	0: Disabled (diagnosis current OFF, disconnection judgment not available) 1: Enabled (diagnosis current ON) (*Not available for use with LED type)	0	Disabled	No setting available
	21	Current setting for REOP4 terminal (Red stop warning lamp) diagnosis *Corresponds only with Bosch	0: Disabled (diagnosis current OFF, disconnection judgment not available) 1: Enabled (diagnosis current ON) (*Not available for use with LED type)	0	Disabled	No setting available
3	Operation during malfunction detection					
	1	Acceleration sensorAPS1 malfunction detection setting	0: Disabled 1: Enabled	1	OK	
	2	Acceleration sensorAPS2 malfunction detection setting	0: Disabled 1: Enabled	0	OK	
	3	Acceleration sensorAPS3 malfunction detection setting	0: Disabled 1: Enabled	0	OK	
	4	CAN (TSC1) reception error detection setting	0: Disabled 1: Enabled	0	OK	
	5	Processing during all accelerator malfunction	0: Conform to the actions during a malfunction 1: Keeping the final value	0	OK	

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No.	Sub	Item (Content)	Menu			Base initial value (Planned)	Condition during Monitoring (Corresponds to Bosch V192R55)	Customer Setting
	6	Operation during all accelerator malfunction • Malfunction including backup	Setting item	Speed limit	0: Disabled (low idle) 1: Level 1 (1800 min^{-1}) 2: Level 2 (1500 min^{-1}) 3: Level 3 (option) 4: Level 4 (low idle (option))	2	0, 1, 2 only (Others are under consideration)	
				Maximum injection volume limit	0: Disabled 1: Level 1 (75 %) 2: Level 2 (50 %)	0	Disabled	No setting available
				Engine stop	0: Disabled 1: Stop without delay 2: Stop after the elapse of delay time: 7200 s 3: Stop after the elapse of delay time: 900 s 4: Stop after the elapse of delay time A 5: Stop after the elapse of delay time B	0	Disabled	No setting available
	7	Setting for cooling water temperature high alarm	0: Disabled 1: Enabled			1	OK	
	8	Setting of the actions during a cooling water temperature high alarm	Setting item	Speed limit	0: Disabled 1: Level 1 (1800 min^{-1}) 2: Level 2 (1500 min^{-1}) 3: Level 3 (option) 4: Level 4 (low idle (option))	0	0, 1, 2 only (Others are under consideration)	
				Maximum injection volume limit	0: Disabled 1: Level 1 (75 %) 2: Level 2 (50 %)	1	OK	
				Engine stop	0: Disabled 1: Stop without delay 2: Stop after the elapse of delay time: 7200 s 3: Stop after the elapse of delay time: 900 s 4: Stop after the elapse of delay time A 5: Stop after the elapse of delay time B	0	0, 1, 2, 3 only (Others are under consideration)	
	9	Cooling water temperature alarm start temperature	Temperature [°C]			110	OK	
	10	Cooling water temperature alarm end temperature	Temperature [°C]			105	OK	
	11	Setting for fuel temperature high alarm	0: Disabled 1: Enabled			1	OK	
	12	Setting of the actions during a fuel temperature high alarm	Setting item	Speed limit	0: Disabled 1: Level 1 (1800 min^{-1}) 2: Level 2 (1500 min^{-1}) 3: Level 3 (option) 4: Level 4 (low idle (option))	0	0, 1, 2 only (Others are under consideration)	
				Maximum injection volume limit	0: Disabled 1: Level 1 (75 %) 2: Level 2 (50 %)	2	OK	
				Engine stop	0: Disabled 1: Stop without delay 2: Stop after the elapse of delay time: 7200 s 3: Stop after the elapse of delay time: 900 s 4: Stop after the elapse of delay time A 5: Stop after the elapse of delay time B	0	0, 1, 2, 3 only (Others are under consideration)	
	13	Low oil pressure fault alarm	0: Disabled 1: Enabled (oil pressure switch fault detection is also enabled)			0	OK	
	14	Setting of the actions during a low oil pressure alarm	Setting item	Speed limit	0: Disabled 1: Level 1 (1800 min^{-1}) 2: Level 2 (1500 min^{-1}) 3: Level 3 (option) 4: Level 4 (low idle (option))	0	0, 1, 2 only (Others are under consideration)	
				Maximum injection volume limit	0: Disabled 1: Level 1 (75 %) 2: Level 2 (50 %)	0	OK	
				Engine stop	0: Disabled 1: Stop without delay 2: Stop after the elapse of delay time: 7200 s 3: Stop after the elapse of delay time: 900s 4: Stop after the elapse of delay time A 5: Stop after the elapse of delay time B	0	0, 1, 2, 3 only (Others are under consideration)	
	15	Air cleaner clog alarm	0: Disabled 1: Enabled			0	OK	

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No.	Sub	Item (Content)	Menu			Base initial value (Planned)	Condition during Monitoring (Corresponds to Bosch V192R55)	Customer Setting
	16	Setting of the actions during an air cleaner clogged alarm	Setting item	Speed limit	0: Disabled 1: Level 1 (1800 min^{-1}) 2: Level 2 (1500 min^{-1}) 3: Level 3 (option) 4: Level 4 (low idle (option))	0	0, 1, 2 only (Others are under consideration)	
				Maximum injection volume limit	0: Disabled 1: Level 1 (75 %) 2: Level 2 (50 %)	0	OK	
				Engine stop	0: Disabled 1: Stop without delay 2: Stop after the elapse of delay time: 7200 s 3: Stop after the elapse of delay time: 900 s 4: Stop after the elapse of delay time A 5: Stop after the elapse of delay time B	0	0, 1, 2, 3 only (Others are under consideration)	
	17	Oil-water separator alarm	0: Disabled 1: Enabled			0	OK	
	18	Setting of the actions during an oil-water separator alarm	Setting item	Speed limit	0: Disabled 1: Level 1 (1800 min^{-1}) 2: Level 2 (1500 min^{-1}) 3: Level 3 (option) 4: Level 4 (low idle (option))	0	0, 1, 2 only (Others are under consideration)	
				Maximum injection volume limit	0: Disabled 1: Level 1 (75 %) 2: Level 2 (50 %)	0	OK	
				Engine stop	0: Disabled 1: Stop without delay 2: Stop after the elapse of delay time: 7200 s 3: Stop after the elapse of delay time: 900 s 4: Stop after the elapse of delay time A 5: Stop after the elapse of delay time B	0	0, 1, 2, 3 only (Others are under consideration)	
	19	Setting for backup mode (Recovery regeneration during the standby condition)	0: Disabled 1: Enabled			1	1	No setting available
	20	Setting of the actions during the backup mode	Setting item	Speed limit	0: Disabled 1: Level 1 (1800 min^{-1}) 2: Level 2 (1500 min^{-1}) 3: Level 3 (option) 4: Level 4 (low idle (option))	1	1	No setting available
				Maximum injection volume limit	0: Disabled 1: Level 1 (75 %) 2: Level 2 (50 %)	2	2	No setting available
				Engine stop	0: Disabled 1: Stop without delay 2: Stop after the elapse of delay time: 7200 s 3: Stop after the elapse of delay time: 900 s 4: Stop after the elapse of delay time A 5: Stop after the elapse of delay time B	3	3	No setting available
	21	Charge alarm	0: Disabled 1: Enabled (charge switch malfunction detection is also enabled)			0	OK	
	22	Selection for error occurrence time	0: Engine operation cumulative time 1: ECU energization cumulative time 2: CAN communication reception time			0	0 or 1 (Others are under consideration)	
4	Setting for CAN							
	1	Communication speed	0: 500 Kbps 1: 250 Kbps			1	OK	

Note: The items under consideration may be changed in the future.

Section 15

ON-VEHICLE COMMUNICATION CAN SPECIFICATION

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Scope

This document outlines communication protocols of Y-LINK. CAN interface components of Y-LINK system are the serial communication links SAE J1939 and ISO 15765.

Y-LINK allows the following functionality via these communication links.

- E-ECU transmits engine data and active DTCs (Diagnostic Trouble Code) information at regular intervals and previously active DTCs information on request from the monitor equipment via J1939 data link.
- Y-LINK allows sharing engine data with electronic monitor displays and vehicle management information system via J1939 data link.
- E-ECU can receive the operation messages from the vehicle control unit via J1939 data link.
- E-ECU transmits and performs diagnostic procedures from TESTER via ISO 15765 data link.
- Y-LINK allows transmitting customer requested change to the E-ECU from the external equipment via ISO 15765 data link.

This document does not include communication protocols of ISO 15765.

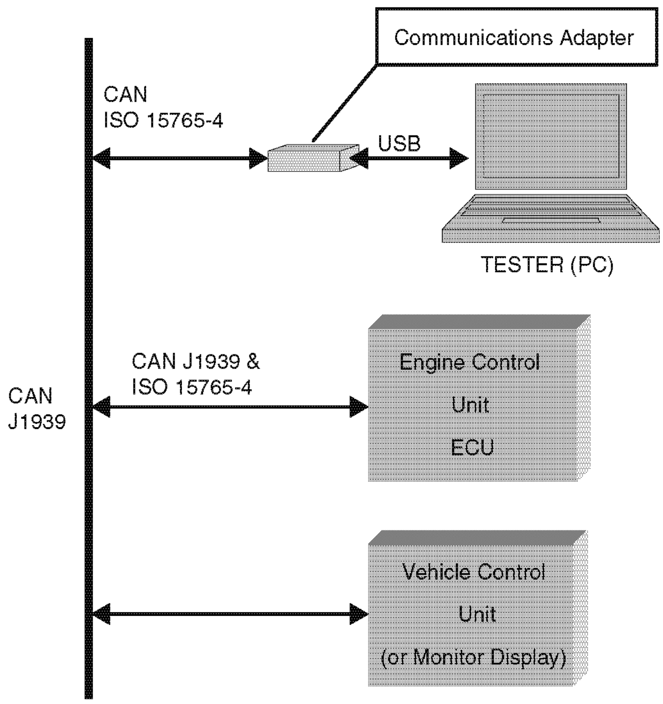

Figure 15-1 CAN-bus diagram

Communication Protocols

The following table shows a comparison between SAE J1939 and ISO15765 in OSI Basic Reference Model. The On Vehicle column (Y-LINK) indicates the communication methods between the E-ECU and the vehicle control unit.

Table 15-1 The OSI seven layer model of Y-LINK

Applicability	OSI 7 layer		Diag. on CAN	Vehicle	Y-LINK	
			ISO 15765	SAE J1939	On vehicle	Diagnostics
Seven layer according to ISO/IEC 7498 and ISO/IEC10731	Physical (layer 1)		ISO11898, ISO15765-4	J1939-13 (ISO11898)	ISO11898	ISO11898
	Data link (layer 2)		ISO11898, ISO15765-4	J1939-21	J1939-21 (2006) • Single frame • Multi-packet BAM • Multi-packet RTS/CTS • Request/acknowledge • Proprietary B	ISO11898, ISO15765-4
	Network (layer 3)		ISO15765-2, ISO15765-4	J1939-31	J1939-31 (2004)	ISO15765-2, ISO15765-4
	Transport (layer 4)		–	–	–	–
	Session (layer 5)		ISO15765-4	–	–	ISO15765-4
	Presentation (layer 6)		–	–	–	–
	Application (layer 7)	Diagnostics	ISO15031-5	J1939-73	J1939-73 (2006)*1 (DM1 - 3, 5, 11, 13)	ISO 14229
		Implement	–	–	–	ISO 15765-3
		Drivetrain	–	J1939-71	J1939-71 (2008)	–
Network management Protocol		Management	–	J1939-81	J1939-81 (2003)	–

**1: DM11 is compliant with SAE J1939-73 (2004), and active DTC is deleted.*

Data Link Layer

The data link layer is under development based on SAE J1939-21 (2006).

Message/frame format

“CAN 2.0B” Extended Frame Format

Nominal bit rate: 250 kbps (500 kbps is option)

Priority (P)

Priority bits in PDU are used to optimize message latency for transmission onto the bus only. They must be globally masked off by receiver (ignored). --- 5.2.1 J1939-21

Network Layer

Addressing

29 bit CAN normal fixed addressing

Address mapping (SA: Source Address)

E-ECU can receive the message from other ECU with a given any source address. It is necessary to prevent duplication of source addresses (ex. Only one ECU with “SA = 00H” on CAN bus). Reference SAE J1939 Appendix B, Tables B2 through B9, for source address assignments.

Table 15-2 Physical addresses of ECU and other electronic equipment

Physical CAN identifier	Description
00H	Physical CAN identifier of E-ECU
01H	Reserved
240 (F0H)	SA-D
255 (FFH)	Global (All-any node)

Communication methods

- Single frame message: data length ≤ 8 bytes
- Multi-packet broadcast message: data length > 8 bytes and DA global (FFH)
- Multi-packet RTS/CTS message: data length > 8 bytes and DA specific (ex. 00H)
- Multi-packet broadcast message is used to send DTCs (Diagnostic Trouble Code) and component ID etc.

Table 15-3 indicates which Request/Response procedure setting is required in service item. However, if an item which is not supported is requested, NACK is returned by PGN59392.

Table 15-3 Request and response requirements (provisional)

No.	Service item	Description	Data length	Request PGN 59904	Response	TP used
1	J1939-71 application layer send/receive message	Single frame message	≤ 8 bytes	None	DA global	NA
2	Active diagnostic trouble code Send message (DM1)	Single frame message	≤ 8 bytes	None/ DA specific/ DA global	DA global	NA
		Multi-packet message Global destination	> 8 bytes	None/ DA global	DA global	BAM
		On request specific, Multi-packet message Destination specific		DA specific	DA specific	RTS/CTS
3	Send message of previously active DTCs (DM2)	Single frame message	≤ 8 bytes	DA specific/ DA global	DA global	NA
		On request global, Multi-packet message Global destination	> 8 bytes	DA Global	DA global	BAM
		On request specific, Multi-packet message Destination specific		DA Specific	DA specific	RTS/CTS
4	Diagnostic data clear/reset of previously active DTCs (DM3)	On request, Acknowledgement	≤ 8 bytes	DA global	None	NA
		On request specific, Acknowledgement		DA specific	DA global (PGN 59392)	NA
5	Send message of the number of DTCs (DM5)	Single frame message	≤ 8 bytes	DA specific/ DA global	DA global	NA
6	Diagnostic data clear/reset of active DTCs (DM11)	On request, Acknowledgement	≤ 8 bytes	DA global	None	NA
		On request specific, Acknowledgement		DA specific	DA global (PGN 59392)	NA
7	Stop/restart request message of J1939 Broadcast Message (DM13)	DA specific message Reception	≤ 8 bytes	None	None	NA
		DA global message Reception		None	None	NA

Note: • *TP = Transport protocol*
• *BAM = Broadcast Announce Message*
• *RTS/CTS = Request to Send/Clear to Send (send request/send permission)*
• *DA = Destination Address*

Notes to **Table 15-3** General rules of operation for determining whether to send a PGN to a global or specific destination: --- 5.4.2 J1939-21

- If the Request is sent to a global address, then the response is sent to a global address.

  Note • E-ECU does not return a NACK as a response to a global request.

  • E-ECU does not return ACK as a response to a global DM3/DM11 request.

- If the Request is sent to a specific address, then the response is sent to a specific address.

  Note: E-ECU returns a NACK if the PGN not supported by E-ECU is requested.

  - If the data length is more than 9 bytes, the Transport Protocol RTS/CTS must be used for the response to a specific address.
  - Exceptions:
    - PDU2 format PGNs (0x00F000 - 0x00FFFF) with less than 8 bytes can only be sent to a global destination because there is no destination address field in the PDU2 Format.
    - The Address Claim PGN is sent to the global destination address even though the request message for it may have been to a specific destination address (refer to J1939-81).
    - The Acknowledgment PGN (sending ACK/NACK) uses a global destination address even though the PGN that causes Acknowledgment was sent to a specific destination address.

Physical Layer

General

The physical layer and physical signaling of the external test equipment shall be in accordance with ISO 11898-1 and ISO 11898-2, with the following restriction.

Baud rate

Nominal bit rate: 250 kbps (500 kbps is option)

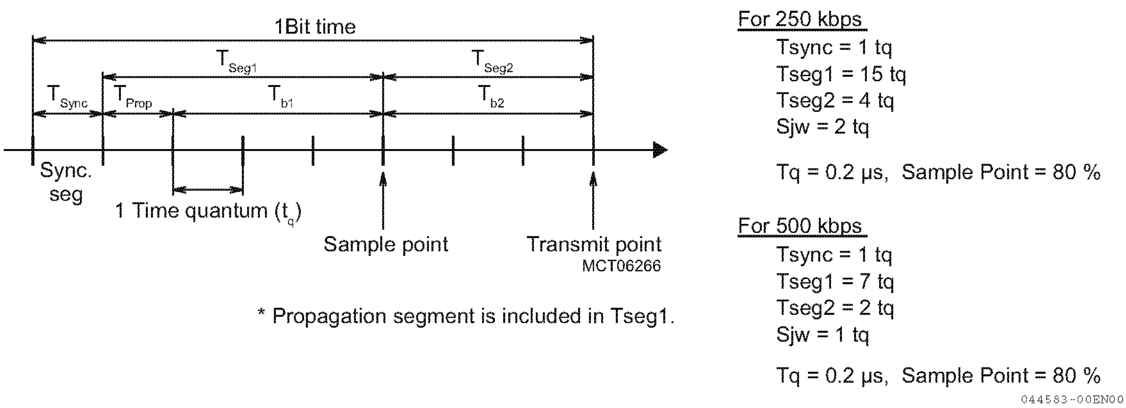

Figure 15-2

CAN bit timing (provisional value)

Receive and Send Message CAN ID Summary

(Refer to Appendix A)

Message Format

J1939-71 Application Layer

(Refer to Appendix B)

pgn0 - Torque/speed control #1 - TSC1 -

Transmission repetition rate:		when active; 10 ms to engine	
Data length:		8 bytes	
Data page:		0	
PDU format:		0	
PDU specific:		DA	
Default priority:		3	
Parameter group number:		0 (0x000000)	
Bit start position/bytes	Length	SPN description	SPN
1.1	2 bits	**Override control mode**	695
1.3	2 bits	Requested speed control conditions <N/A>	696
1.5	2 bits	Override control mode priority <N/A>	897
2 - 3	2 bytes	**Requested speed/speed limit**	898
4	1 byte	Requested torque/torque limit	518

pgn61443 - Electronic engine controller #2 - EEC2 -

Transmission repetition rate:		50 ms	
Data length:		8 bytes	
Data page:		0	
PDU format:		240	
PDU specific:		3	
Default priority:		3	
Parameter group number:		61443 (0x00F003)	
Bit start position/bytes	Length	SPN description	SPN
1.1	2 bits	Accelerator pedal low idle switch <N/A>	558
1.3	2 bits	Accelerator pedal kickdown switch <N/A>	559
1.5	2 bits	Road speed limit status <N/A>	1437
2	1 byte	**Accelerator pedal position**	91
3	1 byte	**Percent load at current speed**	92
4	1 byte	Remote accelerator <N/A>	974

pgn61444 - Electronic engine controller #1 - EEC1 -

Transmission repetition rate:		Engine speed dependent	
Data length:		8 bytes	
Data page:		0	
PDU format:		240	
PDU specific:		4	
Default priority:		3	
Parameter group number:		61444 (0x00F004)	
Bit start position/Bytes	Length	SPN description	SPN
1.1	4 bits	Engine torque mode <N/A>	899
2	1 byte	Driver's demand engine - percent torque <N/A>	512
3	1 byte	Actual engine - percent torque <N/A>	513
4 - 5	2 bytes	**Engine speed**	190
6	1 byte	Source address of controlling device for engine control <N/A>	1483
7.1	4 bits	**Engine starter mode**	1675

pgn65188 - Engine temperature #2 - ET2 -

Transmission repetition rate:		1s	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		164	
Default priority:		6	
Parameter group number:		65188 (0x00FEA4)	
Bit start position/bytes length		SPN description	SPN
1 - 2	2 bytes	Engine oil temperature 2 <N/A>	1135
3 - 4	2 bytes	**Engine ECU temperature <N/A>**	1136
5 - 6	2 bytes	Engine EGR differential pressure	411
7 - 8	2 bytes	Engine EGR temperature	412

pgn65247 - Electronic engine controller #3 - EEC3 -

Transmission repetition rate:		250 ms	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		223	
Default priority:		6	
Parameter group number:		65247 (0x00FEDF)	
Bit start position/bytes	Length	SPN description	SPN
1	1 byte	Nominal friction - percent torque <N/A>	514
2 - 3	2 bytes	**Engine’s desired operating speed**	515
4	1 byte	Engine’s desired operating speed asymmetry adjustment <N/A>	519

pgn65253 - Engine hours, revolutions - HOURS -

Transmission repetition rate:		On request	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		229	
Default priority:		6	
Parameter group number:		65253 (0x00FEE5)	
Bit start position/bytes	Length	SPN description	SPN
1 - 4	4 bytes	**Total engine hours**	247
5 - 8	4 bytes	Total engine revolutions <N/A>	249

pgn65255 - Vehicle hours - VH -

Transmission repetition rate:		1000 ms	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		231	
Default priority:		6	
Parameter group number:		65255 (0x00FEE7)	
Bit start position/bytes	Length	SPN description	SPN
1 - 4	4 bytes	**Total vehicle hours**	246
5 - 8	4 bytes	Total power takeoff hours <N/A>	248

pgn65259 - Component identification - CI -

Transmission repetition rate:		On request	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		235	
Default priority:		6	
Parameter group number:		65262 (0x00FEEB)	
Bit start position/bytes	Length	SPN description	SPN
1 - 5	5 bytes	**Make (ASCII *5)**	586
6 - 25	20 bytes	**Engine model number (ASCII *20)**	587
26	1 byte	Delimiter "*"	
27 - 46	20 bytes	**Engine serial number (ASCII *20)**	588
47	1 byte	Delimiter "*"	
48 - 61	14 bytes	**ECU model number (ASCII *14)**	233
62	1 byte	Delimiter "*"	

pgn65260 - Vehicle identification - VI -

Transmission repetition rate:		On request	
Data length:		Variable bytes	
Data page:		0	
PDU format:		254	
PDU specific:		236	
Default priority:		6	
Parameter group number:		65260 (0x00FEEC)	
Bit start position/bytes	Length	SPN description	SPN
1 - 32	32 bytes	Vehicle identification number	237
33	1 byte	Delimiter "*"	

pgn65269 - Ambient conditions - AMB -

Transmission repetition rate:		1000 ms	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		245	
Default priority:		6	
Parameter group number:		65269 (0x00FEF5)	
Bit start position/bytes	Length	SPN description	SPN
1	1 byte	**Barometric pressure**	108
2 - 3	2 bytes	Cab interior temperature <N/A>	170
4 - 5	2 bytes	Ambient air temperature	171
6	1 byte	Air inlet temperature <N/A>	172
7 - 8	2 bytes	Road surface temperature <N/A>	79

pgn65257 - Fuel consumption (liquid) - LFC -

Transmission repetition rate:	1000 ms
Data length:	8 bytes
Data page:	0
PDU format:	254
PDU specific:	233
Default priority:	6
Parameter group number:	65257 (0x00FEE9)

Bit start position/bytes	Length	SPN description	SPN
1	4 bytes	Trip fuel	182
5	4 bytes	Total fuel in use	250

pgn65266 - Fuel economy (liquid) - LFE -

Transmission repetition rate:	1000 ms
Data length:	8 bytes
Data page:	0
PDU format:	254
PDU specific:	242
Default priority:	6
Parameter group number:	65266 (0x00FEF2)

Bit start position/bytes	Length	SPN description	SPN
1 - 2	2 bytes	Fuel consumption	182
3 - 4	2 bytes	Instantaneous fuel consumption <N/A>	184
5 - 6	2 bytes	Mean fuel consumption <N/A>	185
7	1 byte	Intake throttle actual opening	51

pgn65271 - Vehicle electrical power - VEP -

Transmission repetition rate:	1000 ms
Data length:	8 bytes
Data page:	0
PDU format:	254
PDU specific:	247
Default priority:	6
Parameter group number:	65271 (0x00FEF7)

Bit start position/bytes	Length	SPN description	SPN
1	1 byte	Net battery current <N/A>	114
3 - 4	2 bytes	Alternator potential (voltage) <N/A>	167
5 - 6	2 bytes	Electrical potential (voltage) <N/A>	168
7 - 8	2 bytes	**Battery potential (voltage), switched**	158

pgn56320 - Anti-theft status - ATS - (correspondence under review)

Transmission repetition rate:		This message is transmitted in response to an Anti-Theft Request message. This message is also sent when the component abnormal power interruption. In this situation the Anti-Theft Status Report is sent without the Anti-Theft Request.	
Data length:		8 bytes	
Data page:		0	
PDU format:		220	
PDU specific:		DA	
Default priority:		7	
Parameter group number:		56320 (0x00DC00)	
Bit start position/bytes	Length	SPN description	SPN
1.1	2 bits	**Anti-theft encryption seed present indicator**	1194
1.3	2 bits	**Anti-theft password valid indicator**	1195
1.5	2 bits	**Anti-theft component status states**	1196
1.7	2 bits	**Anti-theft modify password states**	1197
2 - 8	7 bytes	**Anti-theft random number**	1198

Note: Refer to Figure PGN56320_D for examples of Anti-theft message transfers. Bit 1 is the right most bit in each byte.

pgn56576 - Anti-theft request - ATR - (correspondence under review)

Transmission repetition rate:		Transmission of this message is interrupt driven. This message is also transmitted upon power-up of the interfacing device this message.	
Data length:		8 bytes	
Data page:		0	
PDU format:		221	
PDU specific:		DA	
Default priority:		7	
Parameter group number:		56576 (0x00DD00)	
Bit start position/bytes	Length	SPN description	SPN
1.2	2 bits	**Anti-theft encryption indicator states**	1199
1.4	2 bits	Anti-theft desired exit mode states	1200
1.6	3 bits	**Anti-theft command states**	1201
2 - 8	7 bytes	**Anti-theft password representation**	1202

Note: Refer to Figure PGN56320 for examples of Anti-theft message transfers. Bit 1 is the right most bit in each byte. For further details the reader is referred to our Development Dept. <R,1,1>

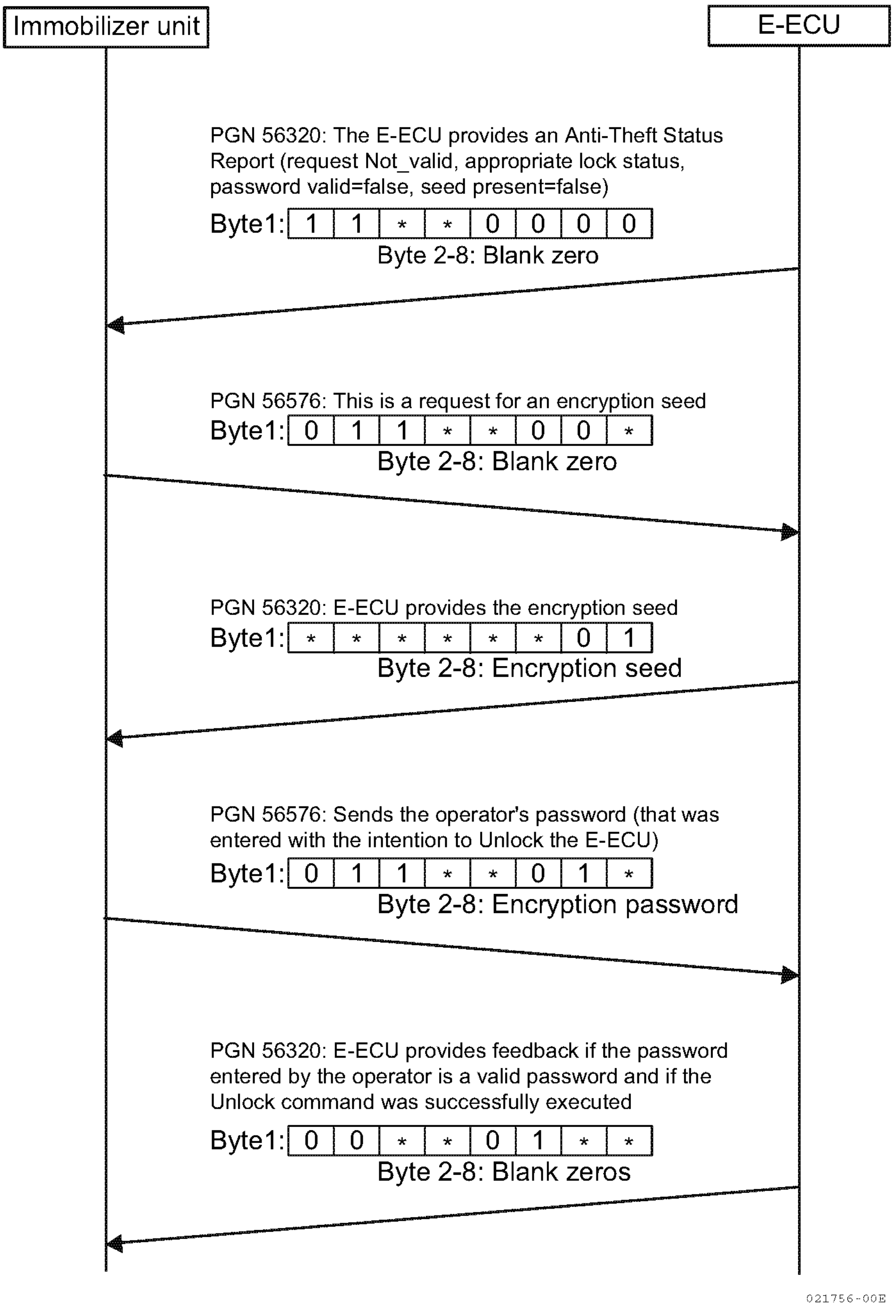

Figure 15-3 PGN56320 - Operator desires to unlock the E-ECU <R.1.1>

pgn64892 - Diesel Particulate Filter control 1 - DPFC1 -

Transmission repetition rate:		1000 ms, when changed	
Data length:		8 bytes	
Data page:		0	
PDU format:		253	
PDU specific:		124	
Default priority:		6	
Parameter group number:		64892 (0x00FD7C)	
Bit start position/bytes	Length	SPN description	SPN
1.1	3 bits	Diesel Particulate Filter lamp command	3697
2.1	2 bits	Diesel Particulate Filter passive regeneration status <N/A>	3699
2.3	2 bits	Diesel Particulate Filter active regeneration status	3700
2.5	3 bits	Diesel Particulate Filter status	3701
3.1	2 bits	Diesel Particulate Filter active regeneration inhibited status	3702
3.3	2 bits	Diesel Particulate Filter active regeneration inhibited due to inhibit switch <N/A>	3703
3.5	2 bits	Diesel Particulate Filter active regeneration inhibited due to clutch <N/A>	3704
3.7	2 bits	Diesel Particulate Filter active regeneration inhibited due to service brake <N/A>	3705
4.1	2 bits	Diesel Particulate Filter active regeneration inhibited due to PTO active <N/A>	3706
4.3	2 bits	Diesel Particulate Filter active regeneration inhibited due to accelerator pedal off idle <N/A>	3707
4.5	2 bits	Diesel Particulate Filter active regeneration inhibited due to out of neutral <N/A>	3708
4.7	2 bits	Diesel Particulate Filter active regeneration inhibited due to vehicle speed above allowed speed <N/A>	3709
5.1	2 bits	Diesel Particulate Filter active regeneration inhibited due to parking brake not set <N/A>	3710
5.3	2 bits	Diesel Particulate Filter active regeneration inhibited due to low exhaust gas temperature <N/A>	3711
5.5	2 bits	Diesel Particulate Filter active regeneration inhibited due to system fault active <N/A>	3712
5.7	2 bits	Diesel Particulate Filter active regeneration inhibited due to system timeout <N/A>	3713
6.1	2 bits	Diesel Particulate Filter active regeneration inhibited due to temporary system lockout <N/A>	3714
6.3	2 bits	Diesel Particulate Filter active regeneration inhibited due to permanent system lockout <N/A>	3715
6.5	2 bits	Diesel Particulate Filter active regeneration inhibited due to engine not warmed up <N/A>	3716
6.7	2 bits	Diesel Particulate Filter active regeneration inhibited due to vehicle speed below allowed speed <N/A>	3717
7.1	2 bits	Diesel Particulate Filter automatic active regeneration initiation configuration <N/A>	3718
7.3	3 bits	Exhaust system high temperature lamp command	3698
7.6	3 bits	Diesel Particulate Filter active regeneration forced status	4175

pgn64891 - After treatment 1 service - AT1S -

Transmission repetition rate:	On request
Data length:	8 bytes
Data page:	0
PDU format:	253
PDU specific:	123
Default priority:	6
Parameter group number:	64891 (0x18FD7C00)

Bit start position/bytes	Length	SPN description	SPN
1	1 bits	Diesel Particulate Filter 1soot load percent	3719
2	1 bits	**Diesel Particulate Filter 1 ash load percent**	3720
3 - 6	4 bytes	Diesel Particulate Filter 1 time since last active regeneration	3721
7 - 8	2 bytes	Not defined	

pgn61441 - Electronic brake controller1 - EBC1 -

Transmission repetition rate:	100 ms
Data length:	8 bytes
Data page:	0
PDU format:	240
PDU specific:	1
Default priority:	6
Parameter group number:	61441 (0x18F001**)

Bit start position/bytes	Length	SPN description	SPN
1.1	2 bits	ASR engine control active <N/A>	561
1.3	2 bits	**ASR brake control active <N/A>**	562
1.5	2 bits	**Anti-lock braking (ABS) active <N/A>**	563
1.7	2 bits	**EBS brake switch <N/A>**	1121
2	1 bits	**Brake pedal position <N/A>**	521
3.1	2 bits	**ABS off-road switch <N/A>**	575
3.3	2 bits	**ABS on-road switch <N/A>**	576
3.5	2 bits	**ABS “Hill holder” switch <N/A>**	577
3.7	2 bits	**Traction control override switch <N/A>**	1238
4.1	2 bits	**Accelerator interlock switch**	972
4.3	2 bits	Engine delete switch <N/A>	971
4.5	2 bits	Engine auxiliary shutdown switch <N/A>	970
4.7	2 bits	Remote accelerator enable switch <N/A>	969
5	1 bytes	Engine retarder selection <N/A>	973
6.1	2 bits	ABS fully operational <N/A>	1243
6.3	2 bits	EBS red warning signal <N/A>	1439
6.5	2 bits	ABS/EBS amber warning signal (powered vehicle) <N/A>	1438
6.7	2 bits	ATC/ASR information signal <N/A>	1793
7	1 bytes	Source address of controlling device for brake control <N/A>	1481
8.3	2 bits	Halt brake switch <N/A>	2911
8.5	2 bits	Trailer ABS status <N/A>	1836
8.7	2 bits	Tractor-mounted trailer ABS warning signal <N/A>	1792

pgn61466 - Engine throttle/fuel actuator control command - TFAC -

Transmission repetition rate: 50 ms
Data length: 8 bytes
Data page: 0
PDU format: 240
PDU specific: 26
Default priority: 4
Parameter group number: 61466 (0x00F01A)

Bit start position/bytes	Length	SPN description	SPN
1 - 2	2 bytes	**Intake throttle target opening**	3464
3 - 4	2 bytes	Intake throttle target opening 2 <N/A>	3465
5 - 6	2 bytes	Engine fuel actuator 1 control command <N/A>	633
7 - 8	2 bytes	Engine fuel actuator 2 control command <N/A>	1244

pgn64914 - Engine operating information - EOI -

Transmission repetition rate: 250 ms
Data length: 8 bytes
Data page: 0
PDU format: 253
PDU specific: 146
Default priority: 3
Parameter group number: 64914 (0x00FD92)

Bit start position/bytes	Length	SPN description	SPN
1.1	4 bits	**Engine operating status**	3543
1.5	2 bits	**Fuel pump primer control <N/A>**	4082
2 - 3	2 bits	**Time remaining in engine operating state <N/A>**	3544
4.1	2 bits	**Engine fuel shutoff vent control <N/A>**	3608
4.3	2 bits	**Engine fuel shutoff 1 control <N/A>**	632
4.5	2 bits	**Engine fuel shutoff 2 control <N/A>**	2807
4.7	2 bits	**Engine fuel shutoff valve leak test control <N/A>**	3601
5.1	2 bits	**Engine oil priming pump control <N/A>**	3589
5.3	2 bits	**Engine oil pre-heater control <N/A>**	3602
5.5	2 bits	**Engine electrical system power conservation control <N/A>**	3603
5.7	2 bits	**Engine block/coolant pre-heater control <N/A>**	3604
6.1	2 bits	**Engine coolant circulating pump control <N/A>**	3605
6.3	2 bits	Engine controlled shutdown request <N/A>	3606
6.5	2 bits	Engine emergency (immediate) shutdown indication <N/A>	3607
8	1 bytes	Engine derate request <N/A>	3644

pgn64946 - Aftertreatment 1 intermediate gas - AT1IMG -

Transmission repetition rate: 500 ms
Data length: 8 bytes
Data page: 0
PDU format: 253
PDU specific: 178
Default priority: 6
Parameter group number: 64946 (0x00FDB2)

Bit start position/bytes	Length	SPN description	SPN
1 - 2	2 bytes	Aftertreatment 1 Exhaust gas temperature 2 <N/A>	3249
3 - 4	2 bytes	**Aftertreatment 1 Diesel Particulate Filter (DPF) intermediate temperature**	3250
5 - 6	2 bytes	**Aftertreatment 1 DPF differential pressure**	3251
7.1	5 bits	Aftertreatment 1 Exhaust gas temperature 2 preliminary FMI <N/A>	3252
7.6	5 bits	Aftertreatment 1 DPF intermediate temperature preliminary FMI <N/A>	3253
8.3	5 bits	Aftertreatment 1 DPF differential pressure preliminary FMI <N/A>	3254

pgn64947 - Aftertreatment 1 outlet gas 2 - AT1OG2 -

Transmission repetition rate:		500 ms	
Data length:		8 bytes	
Data page:		0	
PDU format:		253	
PDU specific:		179	
Default priority:		6	
Parameter group number:		64947 (0x00FDB3)	
Bit start position/bytes	Length	SPN description	SPN
1 - 2	2 bytes	Aftertreatment 1 Exhaust gas temperature 3 <N/A>	3245
3 - 4	2 bytes	**Aftertreatment 1 DPF outlet temperature**	3246
5 - 6	2 bytes	Aftertreatment 1 Exhaust gas temperature 3 preliminary FMI <N/A>	3247
7 - 8	2 bytes	Aftertreatment 1 DPF outlet temperature preliminary FMI <N/A>	3248

pgn64948 - Aftertreatment 1 intake gas 2 - AT1IG2 -

Transmission repetition rate:		500 ms	
Data length:		8 bytes	
Data page:		0	
PDU format:		253	
PDU specific:		180	
Default priority:		6	
Parameter group number:		64948 (0x00FDB4)	
Bit start position/bytes	Length	SPN description	SPN
1 - 2	2 bytes	Aftertreatment 1 Exhaust gas temperature 1	3241
3 - 4	2 bytes	**Aftertreatment 1 DPF inlet temperature**	3242
5 - 6	2 bytes	Aftertreatment 1 Exhaust gas temperature 1 preliminary FMI <N/A>	3243
7 - 8	2 bytes	Aftertreatment 1 DPF inlet temperature preliminary FMI <N/A>	3244

pgn65243 - Engine fluid level/pressure 2 - EFL/P2 -

Transmission repetition rate:		500 ms	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		219	
Default priority:		6	
Parameter group number:		65243 (0x00FEDB)	
Bit start position/bytes	Length	SPN description	SPN
1 - 2	2 bytes	Target injection pressure <N/A>	164
3 - 4	2 bytes	**Common rail pressure 1**	157
5 - 6	2 bytes	Injector timing rail pressure 1 <N/A>	156
7 - 8	2 bytes	Common rail pressure 2 <N/A>	1349

pgn65252 - Shutdown - SHUTDN -

Transmission repetition rate:		1 s	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		228	
Default priority:		6	
Parameter group number:		65252 (0x00FEE4)	
Bit start position/bytes	Length	SPN description	SPN
1.1	2 bits	**Engine idle shutdown has shutdown engine <N/A>**	593
1.3	2 bits	**Engine idle shutdown driver alert mode <N/A>**	594
1.5	2 bits	**Engine idle shutdown timer override <N/A>**	592
1.7	2 bits	**Engine idle shutdown timer state <N/A>**	590
2.7	2 bits	**Engine idle shutdown timer function <N/A>**	591
3.1	2 bits	**A/C high pressure fan switch <N/A>**	985
3.3	2 bits	**Refrigerant low pressure switch <N/A>**	875
3.5	2 bits	**Refrigerant high pressure switch <N/A>**	605
4.1	2 bits	**Engine wait to start lamp**	1081
5.1	2 bits	**Engine protection system has shutdown engine <N/A>**	1110
5.3	2 bits	**Engine protection system approaching shutdown <N/A>**	1109
5.5	2 bits	**Engine protection system timer override <N/A>**	1108
5.7	2 bits	Engine protection system timer state <N/A>	1107
6.7	2 bits	Engine protection system configuration <N/A>	1111
7.1	2 bits	Engine alarm acknowledge <N/A>	2815
7.3	2 bits	Engine alarm output command status <N/A>	2814
7.5	2 bits	Engine air shutoff command status <N/A>	2813
7.7	2 bits	Engine overspeed test <N/A>	2812
8	2 bits	Engine air shutoff status <N/A>	3667

pgn65270 - Intake/exhaust conditions 1 - IC1 -

Transmission repetition rate:		500 ms	
Data length:		8 bytes	
Data page:		0	
PDU format:		254	
PDU specific:		246	
Default priority:		6	
Parameter group number:		65270 (0x00FEF6)	
Bit start position/bytes	Length	SPN description	SPN
1	1 byte	**DPF inlet pressure (EGR high pressure side pressure)**	81
2	1 byte	Intake manifold pressure <N/A>	102
3	1 byte	**Intake temperature 1**	105
4	1 byte	**Actual intake manifold pressure**	106
5	1 byte	Air filter differential pressure 1 <N/A>	107
6 - 7	2 bytes	Exhaust gas temperature <N/A>	173
8	1 byte	Cooling water filter differential pressure <N/A>	112

J1939-21 Data Link Layer

(Refer to Appendix B)

Acknowledgment

Definition: The acknowledgment PG is used to provide a handshake mechanism between transmitting and receiving devices.

Transmission repetition rate:		Upon reception of a parameter group number that requires this form of acknowledgment.
Data length:		8 bytes
Data page:		0
PDU format:		232
PDU specific:		Destination address[1] = Global (255)
Default priority:		6
Parameter group number:		59392 (0x00E800)

Data ranges for parameters used by this message type:

Control byte:	0 - 3	Refer to definitions below
	4 - 255	Reserved for assignment by SAE
Group function value	0 - 250	Definition is specific to the individual PGN, when applicable. Most often it is located as the first byte in the data field of the applicable group function PG.
	251 - 255	Follows conventions defined in J1939-71

Positive acknowledgment: Control byte = 0

Byte:	1	Control byte = 0, Positive acknowledgment (ACK)
	2	Group function value (if applicable) <N/A> 0xFF
	3 - 4	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	5	SA of requestor ECU
	6	Parameter group number of requested information (8 LSB of parameter group number, bit 8 most significant)
	7	Parameter group number of requested information (2nd byte of parameter group number, bit 8 most significant)
	8	Parameter group number of requested information (8 MSBs of parameter group number, bit 8 most significant)

Negative acknowledgment: Control byte = 1

Byte:	1	Control byte = 1, Negative acknowledgment (NACK)
	2	Group function value (if applicable) <N/A> 0xFF
	3 - 4	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	5	SA of requestor ECU
	6 - 8	Parameter group number of requested information (refer to above)

Access denied: Control byte = 2

Byte:	1	Control byte = 2, Access denied (PGN supported but security denied access)
	2	Group function value (if applicable) <N/A> 0xFF
	3 - 4	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	5	SA of requestor ECU
	6 - 8	Parameter group number of requested information (refer to above)

Cannot respond: Control byte = 3

Byte:	1	Control byte = 3, Cannot respond (PGN supported but ECU is busy and cannot respond now. Re-request the data at a later time.)
	2	Group function value (if applicable) <N/A> 0xFF
	3 - 4	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	5	SA of requestor ECU
	6 - 8	Parameter group number of requested information (refer to above)

Request

Definition:		Used to request a parameter group from a network device or devices.
Transmission repetition rate:		Per user requirements, generally recommended that requests occur no more than 2 or 3 times per second.
Data length:		3 bytes (The CAN frame for this PG shall set the DLC to 3.)
Data page:		0
PDU format:		234
PDU specific field:		Destination address (global or specific)
Default priority:		6
Parameter group number:		59904 (0x00EA00)
Byte:	1, 2, 3	Parameter group number being requested

Transport protocol.data transfer (TP.DT)

Definition:		Used for the transfer of data associated with parameter groups that have more than 8 bytes of data
Transmission repetition rate:		Per the parameter group to be transferred
Data length:		8 bytes
Data page:		0
PDU format:		235
PDU specified field:		Destination address (Global (DA = 255) for TP.CM.BAM data transfers) (Global not allowed for RTS/CTS data transfers)
Default priority:		7
Parameter group number:		60160 (0x00EB00)
Data ranges for parameters used by this group function:		
Sequence number:		1 - 255 (1 byte)
Byte:	1	Sequence number
	2 - 8	Packetized data (7 bytes). Note the last packet of a multi-packet parameter group may require less than 8 data bytes. The extra bytes should be filled with 0xFF

Transport protocol. connection management (TP. CM)

Definition:	Used for the transfer of parameter groups that have 9 bytes or more of data.
Transmission repetition rate:	Per the parameter group number to be transferred
Data length:	8 bytes
Data page:	0
PDU format:	236
PDU specific:	Destination address
Default priority:	7
Parameter group number:	60416 (0x00EC00)
Data ranges for parameters used by this group function:	
Control byte:	0 - 15, 18, 20 - 31, 33 - 254 are reserved for SAE assignment
Total message size, number of bytes:	9 - 1785 (2 bytes), 0 - 8 and 1786 - 65535 not allowed
Total number of packets:	2 - 255 (1 byte), 0 - 1 are not allowed
Maximum number of packets:	2 - 255 (1 byte), 0 - 1 are not allowed
Number of packets that can be sent:	0 - 255 (1 byte)
Next packet number to be sent:	1 - 255 (1 byte), 0 not allowed
Sequence number:	1 - 255 (1 byte), 0 not allowed

Connection mode request to send (TP.CM_RTS): destination specific

Byte:	1	Control byte = 16, Destination specific Request_to_send (RTS)
	2, 3	Total message size, number of bytes
	4	Total number of packets
	5	Maximum number of packets that can be sent in response to one CTS. 0xFF indicates that no limit exists for the originator.
	6 - 8	Parameter group number of the packeted message Byte 6 parameter group number of requested information (8 LSB of parameter group number, bit 8 most significant) (R) Byte 7 parameter group number of requested information (2nd byte of parameter group number, bit 8 most significant) (R) Byte 8 parameter group number of requested information (8 MSBs of parameter group number, bit 8 most significant) (R)

Connection mode clear to send (TP.CM_CTS): destination specific

Byte:	1	Control byte = 17, Destination specific Clear_to_send (CTS)
	2	Number of packets that can be sent. This value shall be no larger than the value in byte 5 of the RTS message.
	3	Next packet number to be sent
	4 - 5	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	6 - 8	Parameter group number of the packeted message

End of message acknowledgment (TP.CM_EndOfMsgACK): destination specific

Byte:	1	Control byte = 19, End_of_message acknowledge
	2, 3	Total message size, number of bytes
	4	Total number of packets
	5	Reserved for assignment by SAE, this byte should be filled with 0xFF
	6 - 8	Parameter group number of the packeted message

Connection abort (TP.Conn_Abort): destination specific

Byte:	1	Control byte = 255, Connection abort
	2	Connection abort reason
	3 - 5	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	6 - 8	Parameter group number of the packeted message

Broadcast announce message (TP.CM_BAM): global destination

Byte:	1	Control byte = 32, Broadcast announce message
	2, 3	Total message size, number of bytes
	4	Total number of packets
	5	Reserved for assignment by SAE, this byte should be filled with 0xFF
	6 - 8	Parameter group number of the packeted message

BAM communication (multi-packet broadcast message)

Example: DM1 (2 active DTCs in E-ECU)

1 Request message (not required in the case of periodic transmission of DM1 per 1 second)

CAN ID: 18EAFFFA, Data: CA, FE, 00

2 TP.CM_BAM (PGN: 10 bytes data of 0 x 00FECA is sent in 2 packets)

CAN ID: 1CECFF00, Data: 20, 0A, 00, 02, FF, CA, FE, 00

3 TP.DT (1st packet)

CAN ID: 1CEBFF00, Data: 01, 00, FF, B8, 04, 03, 0A, 7F

4 TP.DT (2nd packet)

CAN ID: 1CEBFF00, Data: 02, 02, 02, A, FF, FF, FF, FF

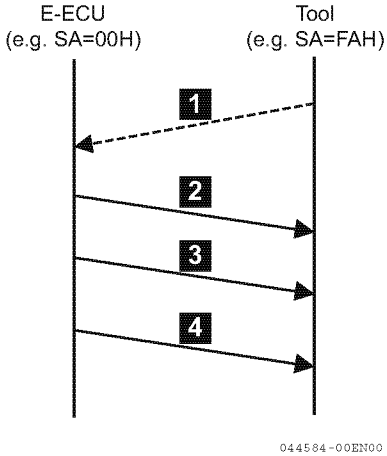

Figure 15-4

RTS/CTS communication

Example: DM2 (4 previously active DTCs in E-ECU)

1 Request message

CAN ID: 18EA00FA, Data: CB, FE, 00

2 TP.CM_RTS (PGN: 18 bytes data of 0 x 00FECB is sent in 3 packets)

CAN ID: 1CECFA00, Data: 10, 12, 00, 03, FF, CB, FE, 00

3 TP.CM_CTS (2 packets from the 1st packet are permitted for transmission)

CAN ID: 1CEC00FA, Data: 11, 02, 01, FF, FF, CB, FE, 00

4 TP.DT (1st packet)

CAN ID: 1CEBFA00, Data: 01, 51, FF, 5B, 01, 04, 01, 7F

5 TP.DT (2nd packet)

CAN ID: 1CEBFA00, Data: 02, 02, 01, 06, B3, 0C, 04, 01

6 TP.CM_CTS (1 packets from the 1st packet are permitted for transmission)

CAN ID: 1CEC00FA, Data: 11, 01, 03, FF, FF, CB, FE, 00

7 TP.DT (3rd packet)

CAN ID: 1CEBFA00, Data: 03, AA, 0C, 03, 01, FF, FF, FF

8 TP.CM_EndOfMsgACK (It indicates that all packets are received)

CAN ID: 1CEC00FA, Data: 13, 12, 00, 03, FF, CB, FE, 00

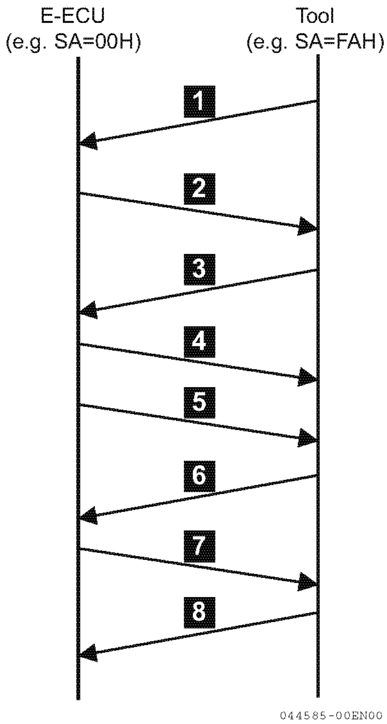

Figure 15-5

J1939-73 Diagnostic Layer

(Refer to Appendix B)

Active diagnostic trouble codes (DM1)

Transmission rate:	1. During periodic transmission of once per second. As this is lamp information, it is transmitted every second even without having an active DTC (fault). There is no change in this periodic transmission timing except in the case of No.5. 2. If a DTC status is changed to active. It is transmitted even when the other DTCs are already in active status. 3. If a DTC status is changed to non-active after being in active status that is longer than 1 second. *Supplement for (2) and (3): If a DTC status changes to active/non-active multiple times per second, it is transmitted at only the initial change during that periodic transmission timing. 4. If a Request for DM1 is received. 5. A BAM is used for the multi-packet transmission of DM1. However, 50 ms of the transmission waiting period between each packet is required for BAM, Therefore, if DM1 of the case No.2 or the other BAM is transmitting for the periodic transmission timing of DM1. the periodic transmission once per every second is not possible. In such a case, start transmitting a DM1 right after the completion of transmitting BAM at the periodic transmission timing. Also, it is recommended that the start timing become the new standard for periodic transmission.
Data length:	Variable
Data page:	0
PDU format:	254
PDU specific:	202
Default priority:	6
Parameter group number:	65226 (0x00FECA)

Bit start position/bytes	Length	
1.1	2 bits	Protect lamp (PL), 00 = Off, 01 = On
1.3	2 bits	Amber warning lamp status (AWL), 00 = Off, 01 = On
1.5	2 bits	Red stop lamp status (RSL), 00 = Off, 01 = On
1.7	2 bits	Malfunction indicator lamp status (MIL), 00 = Off, 01 = On
2.1	2 bits	PL flashing status <N/A>
2.3	2 bits	AWL flashing status <N/A>
2.5	2 bits	RSL flashing status <N/A>
2.7	2 bits	MIL flashing status <N/A>
3	1 byte	SPN, 8 least significant bits of SPN (most significant at bit 8)
4	1 byte	SPN, second byte of SPN (most significant at bit 8)
5.6	3 bits	SPN, 3 most significant bits (most significant at bit 8)
5.1	5 bits	FMI (most significant at bit 5)
6.1	7 bits	Occurrence count (maximum 126 times)
6.8	1 bit	SPN conversion method

Table 15-4 Definition of DTC

Version 4. Recommended version	DTC																															
	Byte 3 8 least significant bits of SPN (bit 8 most significant)								Byte 4 second byte of SPN (bit 8 most significant)								Byte 5 3 most significant bits of SPN and the FMI (bit 8 SPN msb and bit 5 FMI msb)								Byte 6							
	SPN																			FMI					CM	OC						
J1939 Frame format	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1
	1	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0

The transmission rate in DM1 is shown in the figure below. Nos.1 - 5 in the figure are the corresponding messages for the transmission rate (1) - (5) of DM1 in the above table.

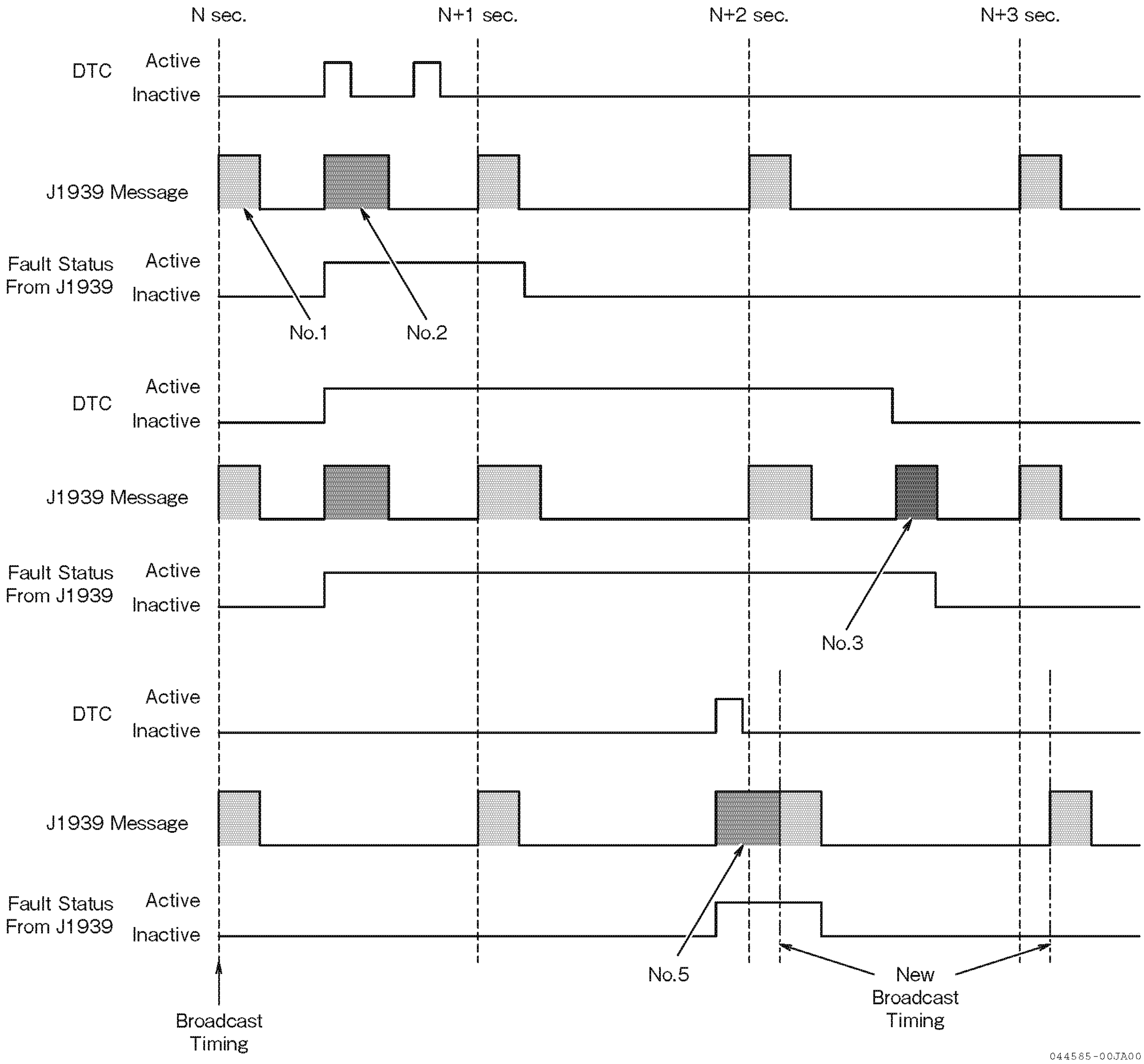

Figure 15-6

Example 1: The following illustrates the message format for when there is more than one diagnostic trouble code.

Given:

a = lamp status (LS)
b = SPN
c = FMI
d = CM and OC (Version.4 CM = 0)

Message form will be as follows: a,b,c,d,b,c,d,b,c,d,b,c,d....etc. In this example, the transport protocol of SAE J1939-21 will have to be used to send the information because it requires more than 8 data bytes. Actually any time there is more than one fault the services of the transport protocol will have to be used.

Example 2: The following illustrates the message format for when a request of the DM1 is made and there are zero active faults.

Byte 1 = 0
Bytes 3 through 6 are all zeros.

Given:

Byte 1	bits 1 - 2	= 00
	bits 3 - 4	= 00
	bits 5 - 6	= 00
	bits 7 - 8	= 00
Byte 2	bits 1 - 2	= 11
	bits 3 - 4	= 11
	bits 5 - 6	= 11
	bits 7 - 8	= 11
Byte 3-6	SPN	= 0
	FMI	= 0
	OC	= 0
	CM	= 0
Byte 7		= 255
Byte 8		= 255

Previously active DTCS (DM2)

Transmission rate:		On request using PGN 59904 See SAE J1939-21 A NACK is required if PG is not supported (Refer to SAE J1939-21 PGN 59392)
Data length:		Variable
Data page:		0
PDU format:		254
PDU specific:		203
Default priority:		6
Parameter group number:		65227 (0x00FECB)
1.1	2 bits	Protect lamp (PL), 00 = Off, 01 = On
1.3	2 bits	Amber warning lamp status (AWL), 00 = Off, 01 = On
1.5	2 bits	Red stop lamp status (RSL), 00 = Off, 01 = On
1.7	2 bits	Malfunction indicator lamp status (MIL), 00 = Off, 01 = On
2.1	2 bits	PL flashing status <N/A>
2.3	2 bits	AWL flashing status <N/A>
2.5	2 bits	RSL flashing status <N/A>
2.7	2 bits	MIL flashing status <N/A>
3	1 byte	SPN, 8 least significant bits of SPN (most significant at bit 8)
4	1 byte	SPN, second byte of SPN (most significant at bit 8)
5.6	3 bits	SPN, 3 most significant bits (most significant at bit 8)
5.1	5 bits	FMI (most significant at bit 5)
6.1	7 bits	Occurrence count (maximum 126 times)
6.8	1 bit	SPN conversion method

Example 1: The following illustrates the message format for when there is more than one diagnostic trouble code.

Given:

a = lamp status (LS) is the same as active DTC.

b = SPN

c = FMI

d = CM and OC

Message form will be as follows: a,b,c,d,b,c,d,b,c,d,b,c,d....etc. In this example, the transport protocol of SAE J1939-21 will have to be used to send the information because it requires more than 8 data bytes. Actually any time there is more than one fault the services of the transport protocol will have to be used.

Example 2: The following illustrates the message format for when a request of the DM2 is made and there are zero previously active faults. The currently defined lamps (Malfunction Indicator Lamp, Red Stop Lamp, Amber Warning Lamp, and Protect Lamp) should reflect the present state of the transmitting electronic component. In this example, the amber lamp is identified as being on. Bytes 3 through 6 are all zeros.

Given:

Byte 1	bits 1 - 2	= 00
	bits 3 - 4	= 01
	bits 5 - 6	= 00
	bits 7 - 8	= 00
Byte 2	bits 1 - 2	= 11
	bits 3 - 4	= 11
	bits 5 - 6	= 11
	bits 7 - 8	= 11
Byte 3-6	SPN	= 0
	FMI	= 0
	OC	= 0
	CM	= 0
Byte 7		= 255
Byte 8		= 255

Diagnostic data clear/reset of previously active DTCS (DM3)*2

Transmission rate:	Performed on request using PGN 59904 See SAE J1939-21 A NACK is required if PGN is not supported and conditions are not satisfied*1. Both ACK/NACK do not respond if a request is global. (Refer to SAE J1939-21 PGN 59392)
Data length:	0
Data page:	0
PDU format:	254
PDU specific:	204
Default priority:	6
Parameter group number:	65228 (0x00FECC)

**1: Previously active DTCs (SPN, FMI, OC) are cleared.*
**2: DM3 can be performed only when the ignition (power supply) is ON and the engine is stopped.*

Send message of the number of DTCs (DM5)

Transmission rate:		On request using PGN 59904 See SAE J1939-21 A NACK is required if PGN is not supported. (Refer to SAE J1939-21 PGN 59392)
Data length:		8
Data page:		0
PDU format:		254
PDU specific:		206
Default priority:		6
Parameter group number:		66230 (00FECEh)
1	1 byte	The number of active DTCs
2	1 byte	The number of previously active DTCs
3	1 byte	OBD consistency = 5 (OBD II requirement is not satisfied.)
4	1 byte	Continuous monitoring system support/conditions = 0 <N/A> *1
5	2 byte	Discontinuous monitoring system support = 0 <N/A> *1
7	2 byte	Discontinuous monitoring system conditions = 0 <N/A> *1

**1: Not Support = 0, different from normal J1939*

Diagnostic data clear/reset of active DTCS (DM11) *2

Transmission rate:	On request using PGN 59904 See SAE J1939-21 A NACK is required if PGN is not supported and conditions are not satisfied*1. Both ACK/NACK do not respond if a request is global. (Refer to SAE J1939-21 PGN 59392)
Data length:	0
Data page:	0
PDU format:	254
PDU specific:	211
Default priority:	6
Parameter group number:	65235 (0x00FED3)

**1: Active DTCs (SPN, FMI, OC) are cleared.*
**2: DM11 can be performed only when the ignition (power supply) is ON and the engine is stopped.*
**3: If diagnostic data of active DTC is deleted by receiving this message, fault decision is made as is done before receiving. (If the cause of the fault is solved, the fault is not sent as an active fault after DM11 is performed. If not, it is sent as an active fault.)*

Stop/restart request message of J1939 broadcast message (DM13)

Transmission rate:	When a tool and the like require the broadcast to be stopped or restarted, a set up message is sent. (E-ECU only receives messages.) After the change of the broadcast state of the network, a hold message is sent every 5 min to maintain the state. If E-ECU does not receive the hold message for 6 min after changing the broadcast state, the broadcast state is returned to the previous state.
Data length:	8
Data page:	0
PDU format:	223
PDU specific:	Destination address
Default priority:	6
Parameter group number:	57088 (00DF00h)

1.1	2 bits	J1939 Network #1 <N/A>
1.3	2 bits	J1922 <N/A>
1.5	2 bits	J1587 <N/A>
1.7	2 bits	Broadcast state indication of the network which has received DM13 = 00b (stop request)
2.1	2 bits	Other, manufacture specified port <N/A>
2.3	2 bits	J1850 <N/A>
2.5	2 bits	ISO 9141 <N/A>
2.7	2 bits	J1939 Network #2 <N/A>
3.1	2 bits	SAE reserved <N/A>
3.7	2 bits	SAE J1939 Network #3 <N/A>
4.1	4 bits	Suspend signal <N/A>
4.5	4 bits	Hold signal <N/A>
5	2 byte	Suspend duration <N/A>
7	2 byte	SAE reserved <N/A>

When the broadcast state maintenance is requested: bit 1.7 - 1.8 = 11b, bit 4.5 - 4.8 = 0000b or 0001b. (Hold message. Destination address is limited to global (FFH))

1.1	2 bits	J1939 Network #1 <N/A>
1.3	2 bits	J1922 <N/A>
1.5	2 bits	J1587 <N/A>
1.7	2 bits	Broadcast state indication of network which has received DM13 <N/A>
2.1	2 bits	Other, manufacture specified Port <N/A>
2.3	2 bits	J1850 <N/A>
2.5	2 bits	ISO 9141 <N/A>
2.7	2 bits	J1939 Network #2 <N/A>
3.1	2 bits	SAE reserved <N/A>
3.7	2 bits	SAE J1939 Network #3 <N/A>
4.1	4 bits	Suspend signal <N/A>
4.5	4 bits	Hold signal = 0000b (when the destination address of the broadcast stop request is global) or 0001 b (when the destination address of the broadcast stop request is specific)
5	2 byte	Suspend duration <N/A>
7	2 byte	SAE reserved <N/A>

When the broadcast restart is requested: bit 1.7 - 1.8 = 01b, bit 4.5 - 4.8 = 1111b (set up message)

1.1	2 bits	J1939 Network #1 <N/A>
1.3	2 bits	J1922 <N/A>
1.5	2 bits	J1587 <N/A>
1.7	2 bits	Broadcast state indication of the network which has received DM13 = 01b (restart request)

2.1	2 bits	Other, manufacture specified port <N/A>
2.3	2 bits	J1850 <N/A>
2.5	2 bits	ISO 9141 <N/A>
2.7	2 bits	J1939 Network #2 <N/A>
3.1	6 bits	SAE reserved <N/A>
3.7	2 bits	SAE J1939 Network #3 <N/A>
4.1	4 bits	Suspend signal <N/A>
4.5	4 bits	Hold signal <N/A>
5	2 byte	Suspend duration <N/A>
7	2 byte	SAE reserved <N/A>

J1939-81 Network Management Protocol

Acknowledgment

Definition: This is used to inform ECU on the address claim CAN bus of SA of YANMAR ECU. When SA overlaps other ECU and is low-priority, the function to change SA of YANMAR ECU is not used.

Transmission rate:		• When the power is turned ON (This message must be sent prior to sending other messages) • On request using PGN 59904 See SAE J1939-21 A NACK is required if PGN is not supported. (Refer to SAE J1939-21 PGN 59392)
Data length:		8 bytes
Data page:		0
PDU format:		238
PDU specific:		Destination address *1 = Global (255)
Default priority:		6
Parameter group number:		60928 (0x00EE00)
Data ranges for parameters used by this message type:		
Arbitrary address capable	0	SA is fixed.
	1	When SA overlaps other ECU and is low-priority, SA can be changed.
Industry group	0 - 7	Industrial number specified in SAE J1939 (refer to Table B1 in J1939 Appendix B)
Vehicle system instance	0 - 15	Range to identify existence of vehicle system in the network
Vehicle system	0 - 127	Function group name of the network (refer to Table B12 in J1939 Appendix B)
Function	0 - 127	Dependent on content of vehicle system (refer to Table B11 in J1939 Appendix B)
	128 - 255	General name of a certain controller (not a function name)
Function instance	0 - 31	Range to distinguish the same kind of multiple electronic control modules (Ex. When there are two engines and two transmissions, E-ECU whose function instance is “0” is connected physically to the transmission ECU whose function instance is also “0”.)
ECU instance	0 - 7	Range to distinguish the same kind of multiple devices (Ex. When one engine is controlled by two E-ECUs, ECU instance of each controller shall be “0” and “1”, respectively.)
Manufacture code	0 - 2047	Code of the manufacturer responsible for manufacturing of ECU (YANMAR: 172 (00010101100b))
Identity number	0 - 2097151	Range to make ECU specific even though other NAME range has the same values
Parameter data actually used		
Byte:	1 - 2, 3.8 - 3.6	Identity number total bit = 0b *2
	3.5 - 3.1, 4	Manufacture code = 172 (00010101100b)
	5.8 - 5.4	Function instance = 0
	5.3 - 5.1	ECU instance = 0
	6	Function = 0
	7.8 - 7.2	Vehicle system = 0
	7.1	Reserved = 0 (different from normal reserved bit of J1939)
	8.8	Arbitrary address capable = 0
	8.7 - 8.5	Industry group = 0
	8.7 - 8.5	Vehicle system instance = 0

**1: The address claim PGN is sent to the global destination address even though the request message for it may have been to a specific destination address (refer to J1939-81).*

**2: Although each ECU should have a different value using serial No., etc., the YANMAR ECU has a fixed value.*

YANMAR Proprietary PGN

(Refer to Appendix C)

CAN Communication Functionality

Shutdown

Shutdown request signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Dire-ction	E-ECU	Note
Y_ECR1	65282	NA	NA	50 ms	2	3 - 4	Shutdown requests	V ≥ E	Available	0: No shutdown request (normal state) 1: Shutdown request (E-ECU begins the shutdown processing.)
					2	7 - 8	Power supply/ Key position		Available	0,1:Auto preheat is disabled 2: Auto preheat is enabled 3: The starter is permitted.
					4	1 - 8	Accelerator pedal position		Available	0 - 100 %
					5	1 - 2	Crank request		Available	0: No cranking 1: Crank request 2: Engine stop request

Shutdown acknowledgement signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Dire-ction	E-ECU	Note
Y_ECACK1	65292	0	3	100 ms	2	4 - 5	Preheat function acknowledge (state of preheat energizing)	E ≥ V	Available	0: Not active (preheat OFF) 1: Active (preheat ON) 2: Error indicator (starting aid relay error) 3: NA ("preheat" only, not include starting aid function "energized simultaneously with the starter" at cranking)
					2	8	Shutdown acknowledge		Available	0: Power off not allowed 1: Power off allowed (Finished shutdown)
					3	1 - 8	Preheating function remaining time		Under development	
					4	1 - 2	Glow plug function acknowledge		Available	0: Not active (starting aid relay OFF) 1: Active (starting aid relay ON) 2: Glow plug re-energization prohibited

Shutdown process

- Normal process

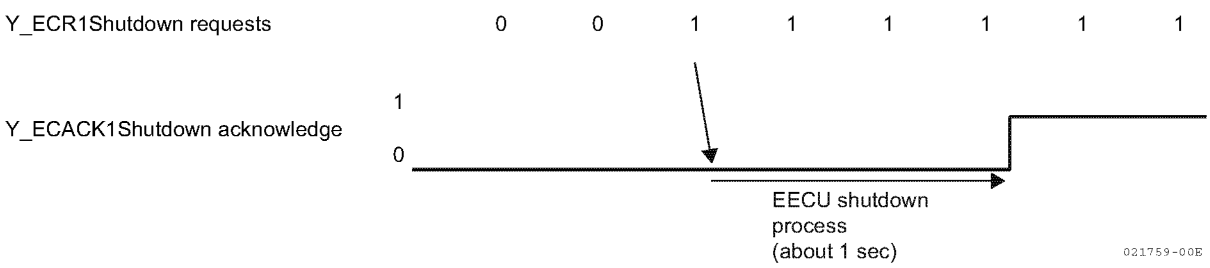

Figure 15-7

Shutdown acknowledgement turn to “1”, only when E-ECU received shutdown requests and has finished shutdown process.

- In case of cancellation of shutdown request on the shutdown process

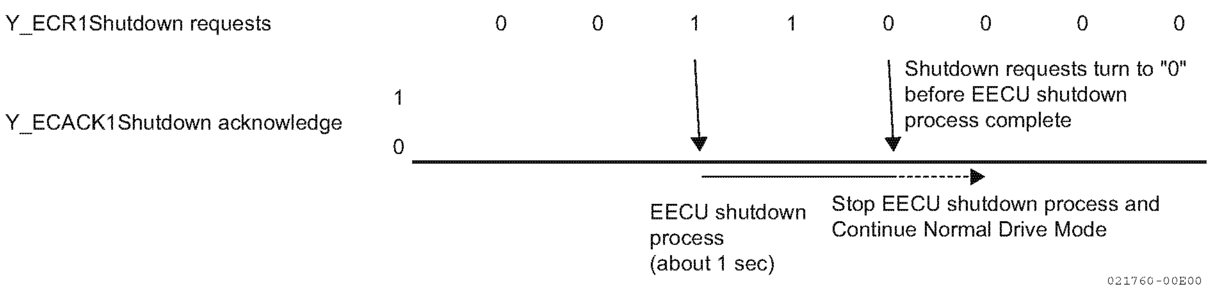

Figure 15-8

If engine is stopped by failure (ex. Over speed condition), shutdown acknowledgement not turn to “1”.

Start lock

Starter prohibition request signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direction	E-ECU	Note
Y_ECR1	65282	NA	NA	50 ms	2	3 - 4	Shutdown requests	V ≥ E	Available	0: No shutdown request (normal state) 1: Shutdown request (E-ECU begins the shutdown processing.)
					2	7 - 8	Power supply/ Key position		Available	0,1: Auto preheat is disabled 2: Auto preheat is enabled 3: The starter is permitted.
					4	1 - 8	Accelerator pedal position		Available	0 - 100 %
					5	1 - 2	Crank request		Available	0: No cranking 1: Crank request 2: Engine stop request
Y_EC	65308	NA	NA	100 ms	1	5	Starter prohibition	V ≥ E	Available	0: Permission 1: Prohibition

Cranking condition

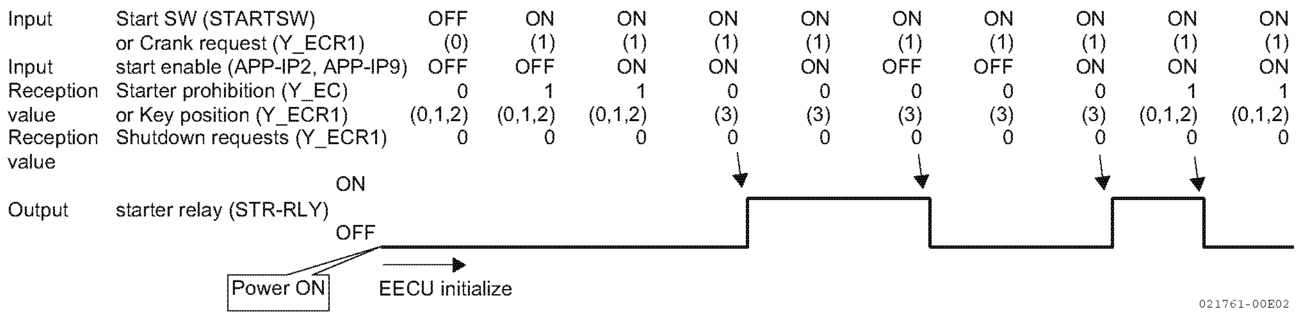

Figure 15-9

Even after cranking, if start enable becomes OFF or shutdown request comes from V-ECU, E-ECU stop engine.

Y_ECR1		STARTSW or Y_ECR1	APP-IP2 APP-IP9	(*2) Y_EC (Standard)	(*2) Y_ECR1 (Option)	STR-RLY
Shutdown requests	Engine speed	Start SW	Start enable	starter prohibition	Key position	Starter relay
0	< (*1) min^{-1}	OFF	OFF	0	3	OFF
				1	0, 1, 2	OFF
			ON	0	3	OFF
				1	0, 1, 2	OFF
		ON	OFF	0	3	OFF
				1	0, 1, 2	OFF
			ON	0	3	ON
				1	0, 1, 2	OFF
	≥ (*1) min^{-1}	–	–	–	–	OFF
1	–	–	–	–	–	OFF

**1: Starter prohibition engine speed (determined by map value: normal value 675 min^{-1})*
**2: Whether Y_ECR1 is used or Y_EC is used is set beforehand.*

Starting aid function

Preheat enable/disable signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Dire-ction	E-ECU	Note
Y_ECR1	65282	NA	NA	50 ms	2	3 - 4	Shutdown requests	V ≥ E	Available	0: No shutdown request (normal state) 1: Shutdown request (E-ECU begins the shutdown processing.)
					2	7 - 8	Power supply/ Key position		Available	0, 1: Auto preheat is disabled 2: Auto preheat is enabled 3: The starter is permitted.
					4	1 - 8	Accelerator pedal position		Available	0 - 100 %
					5	1 - 2	Crank request		Available	0: No cranking 1: Crank request 2: Engine stop request

Preheat acknowledgement signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Dire-ction	E-ECU	Note
Y_ECACK1	65292	0	3	100 ms	2	4 - 5	Preheat function acknowledge (State of preheat energizing)	E ≥ V	Available	0: Not active (preheat OFF) 1: Active (preheat ON) 2: Error indicator (starting aid relay error) 3: NA ("preheat" only, not include "air heat at cranking")
					2	8	Shutdown acknowledge		Available	0: Power off not allowed 1: Power off allowed (finished shutdown)
					3	1 - 8	Preheat function remaining time		Under development	
					4	1 - 2	Glow plug function acknowledge		Available	0: Not active (starting aid relay OFF) 1: Active (starting aid relay ON) 2: Glow plug re-energization prohibited

Starting aid function

- Enable auto preheat

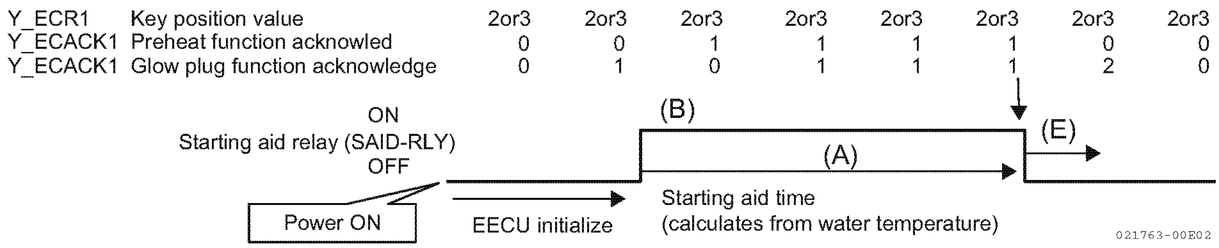

Figure 15-10

- Disable auto preheat

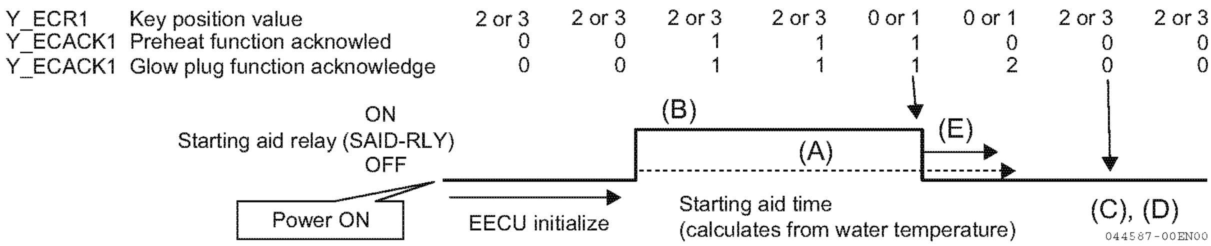

Figure 15-11

Note:

(A) E-ECU calculates starting aid time from the water temperature, and controls starting aid relay automatically.

(B) E-ECU automatically starts preheating after boot up process.

(C) Once V-ECU disables to preheat, starting aid function at cranking time (energized simultaneously with the starter) is disabled too.

(D) Once V-ECU disables to preheat, E-ECU doesn't start preheating even if V-ECU set enable bit in Y_ECR1 later. This condition is only canceled by power-on reset of E-ECU.

(E) If the starting aid function stops, ECU prohibits energization to the starting aid relay (starting aid relay OFF) for a specified time (under review) in order to protect the glow plug.

Engine speed control

Speed control signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Dire-ction	E-ECU	Note
Y_ECR1	65282	NA	NA	50 ms	2	3- 4	Shutdown requests	V ≥ E	Available	0: No shutdown request (normal state) 1: Shutdown request (E-ECU begins the shutdown processing.)
					2	7 - 8	Power supply/ Key position		Available	0,1: Auto preheat is disabled 2: Auto preheat is enabled 3: The starter is permitted.
					4	1 - 8	Accelerator pedal position		Available	0 - 100 %
					5	1 - 2	Crank request		Available	0: No cranking 1: Crank request 2: Engine stop request
TSC1	0	NA	3	10 ms	1	1 - 2	Override control mode	V ≥ E	Available	0: Override disable 1: Speed control 2: N/A 3: Rotation/torque limit
					2 - 3	1 - 16	Requested speed/speed limit	V ≥ E	Available	A value of 0xFExx is sent as “Error indica-tor” (at 0xFExx, EECU does the CAN (TSC1) error operation.)
					4	1 - 18	Requested torque limit value	V ≥ E	Available	

Engine speed information signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Dire-ction	E-ECU	Note
EEC1	61444	0	3	20 ms	4 - 5	1 - 16	Engine speed	E ≥ V	Available	A value of 0xFExx is sent as “Error indica-tor” ex.at rotation speed sensor error

Engine speed control diagram

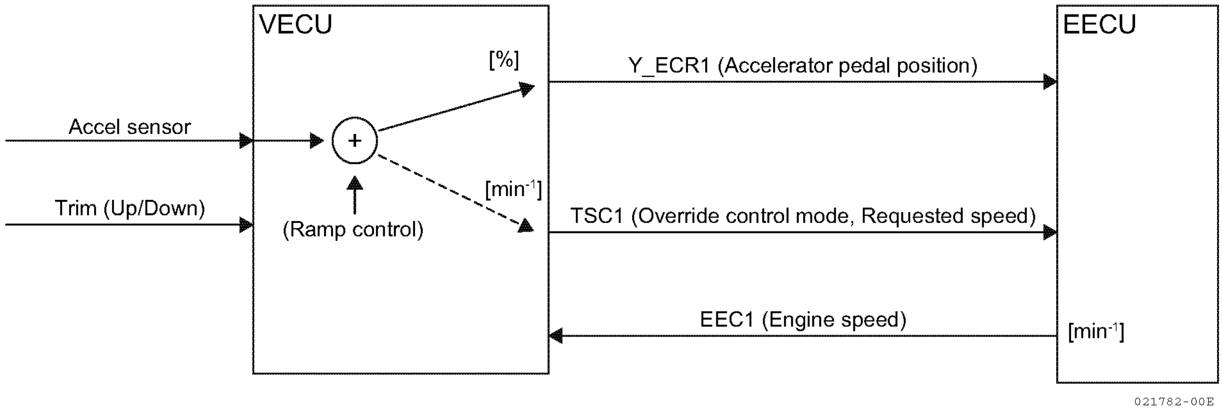

Figure 15-12

If “Override control mode” equals to “0: Override disable”, E-ECU controls the engine speed based on the value of “Accelerator pedal position” of Y_ECR1.

If “Override control mode” equals to “1: Speed control mode”, E-ECU controls the engine speed based on the value of “Requested speed” of TSC1.

Note: Exceptional conditions as below:

- *Idle speed up*
- *Max/min speed limit*
- *Engine speed transition period*
- *EGR valve failure etc.*

Torque limit control

Torque limit control

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Dire-ction	E-ECU	Note
TSC1	0	NA	3	10 ms	1	1 - 2	Override control mode	V ≥ E	Available	0: Override disabled 1: Speed control 2: N/A 3: Speed/torque limit
					2 - 3	1 - 15	Requested speed/speed limit	V ≥ E	Available	A value of 0xFExx is sent as “Error indicator” (At 0xFExx, EECU does the CAN (TSC1) error operation.)
					4	1 - 18	Requested torque limit value	V ≥ E	Available	

Engine speed information signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Dire-ction	E-ECU	Note
EEC1	61444	0	3	20 ms	4 - 5	1 - 16	Engine speed	V ≥ E	Available	A value of 0xFExx is sent as “Error indicator” ex. at rotation speed sensor error

Torque limit control diagram

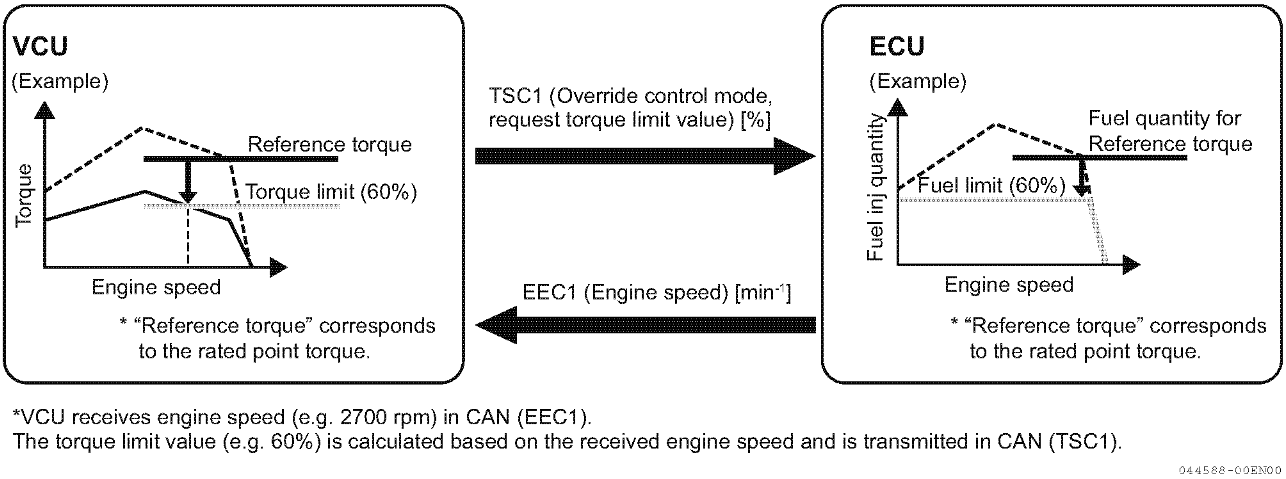

Figure 15-13

When “Override control mode” equals to “3: speed/torque limit mode”, ECU calculates fuel limit value based on the “request torque limit” value of TSC1 under the conditions that the fuel injection corresponding to the rated torque is set to 100 %, and limits the maximum amount of fuel injection with no exception. Also, when “3: Speed/torque limit mode” is being used, “1: Speed control mode” is disabled.

DPF operator interface (under development)

DPF operator interface signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direction	E-ECU	Note
Y_DPFIF	65304	NA	NA	1000 ms	1	1 - 2	Regeneration interlock switch	V ≥ E	Available	0: OFF (Regeneration not possible) 1: ON (Regeneration permitted)
						3 - 4	DPF regeneration prohibition switch		Available	0: OFF (Regeneration prohibited) 1: ON (Regeneration permitted)
						5 - 6	DPF regeneration request switch		Available	0: OFF (without regeneration request) 1: ON (with regeneration request)

DPF regeneration control information signal

Description	PGN number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direction	E-ECU	Note
Y_ATF	65322	NA	NA	100 ms	1	1 - 4	DPF regeneration control mode information	E ≥ V	Available	
						5 - 8	DPF regeneration control process information		Available	
					2	1 - 4	Emergency mode information		Available	
						5 - 8	Stationary regeneration request		Available	
					3	1 - 4	Ash cleaning request		Available	
					8	1 -16	DPF regeneration progress status		Available	0 - 100 %

CAN communication failure

It is currently under development. For details, contact your YANMAR personnel in charge.

Detect CAN communication malfunction

- At system start (Provisional)

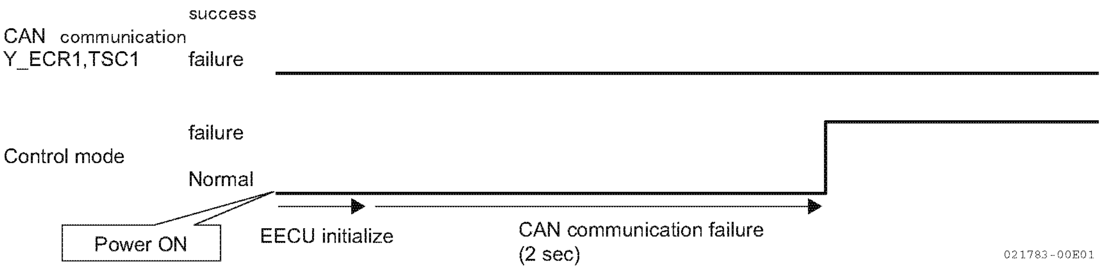

Figure 15-14

When EECU cannot receive necessary information via CAN-BUS for two seconds* after (Provisional value) power-on start, it considers that the CAN communication failure occurred.

- After system start normally (provisional)

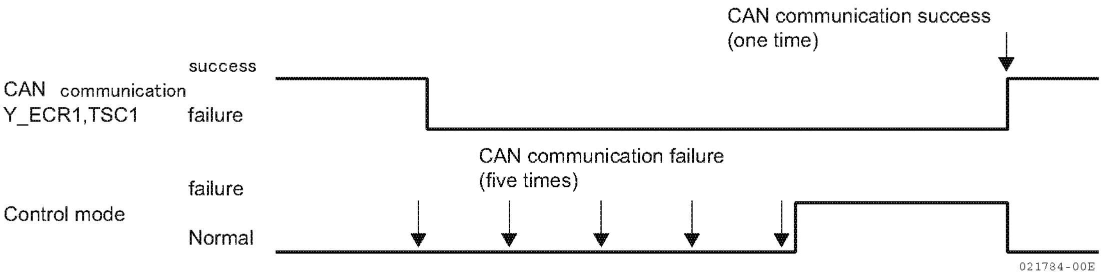

Figure 15-15

When EECU cannot receive necessary information via CAN-BUS five times (Provisional value) continuously, it is considers that the CAN communication failure occurred. (ex. period of five times: TSC1:10 × 5 ms, Y_ECR1: 50 × 5 ms)

When EECU can receive necessary information via CAN-BUS for one time, it considers that the CAN communication has done normally.

Starting control at CAN communication failure mode

When EECU cannot receive Y_ECR1 or Starter Prohibition (65308) via CAN-BUS for two seconds* after (Provisional value) power-on start, EECU will allow to start engine according to discrete input signals.

When Y_ECR1 is being used with the start switch, OFF is maintained.

Y_ECR1		**STARTSW or Y_ECR1**	**APP-IP2 APP-IP9**	**Y_EC (standard)**	**Y_ECR1 (option)**	**STR-RLY**
Shutdown requests	Engine speed	Start SW	Start enable	starter prohibition	Key position	Starter relay
–	< (*1) min^{-1}	OFF	OFF	–	–	OFF
				–	–	OFF
			ON	–	–	OFF
				–	–	OFF
		ON	OFF	–	–	OFF
				–	–	OFF
			ON	–	–	ON
				–	–	ON
	≥ (*1) min^{-1}	–	–	–	–	OFF
–	–	–	–	–	–	OFF

**1: Starter prohibition Engine speed (determined by map value: normal value 675 min^{-1})*

Engine speed control at CAN communication failure mode

If TSC1 or Y_ECR1 communication failure occurs, E-ECU will select a speed control mode as below table.

TSC1			Y_ECR1		Speed control	CAN
Communication	Override	Data	Communication	Data		
OK	Enable	OK	–	–	Requested speed	Need only TSC1
		N/A	–	–	Constant speed (ex.1800 min^{-1})	
	Disable	–	OK	OK	APS position	Need TSC1 and Y_ECR1
				N/A	Constant speed (ex.1800 min^{-1})	
			NG	–		CAN error
NG	–	–	OK	OK		CAN error
				N/A		CAN error
			NG	–		CAN error

E-ECU shutdown at CAN communication failure condition

At CAN communication failure condition E-ECU doesn't execute the shutdown process, so log-data cannot be written in EEPROM (ex. Engine run time). There is a possibility that the new log-data is broken at power OFF, when E-ECU is writing the log-data in EEPROM temporarily.

There is no influence on driving the engine even if the new log-data has been broken.

Component ID check

When E-ECU is replaced, it has no way to check the actual engine type. Therefore we recommend that VECU should check Component ID of E-ECU. IF Component ID is different from original one, VECU should turn to the derate mode.

V-ECU can get vehicle manufacture specific component ID by VI Request, if VI has already written in EEPROM.

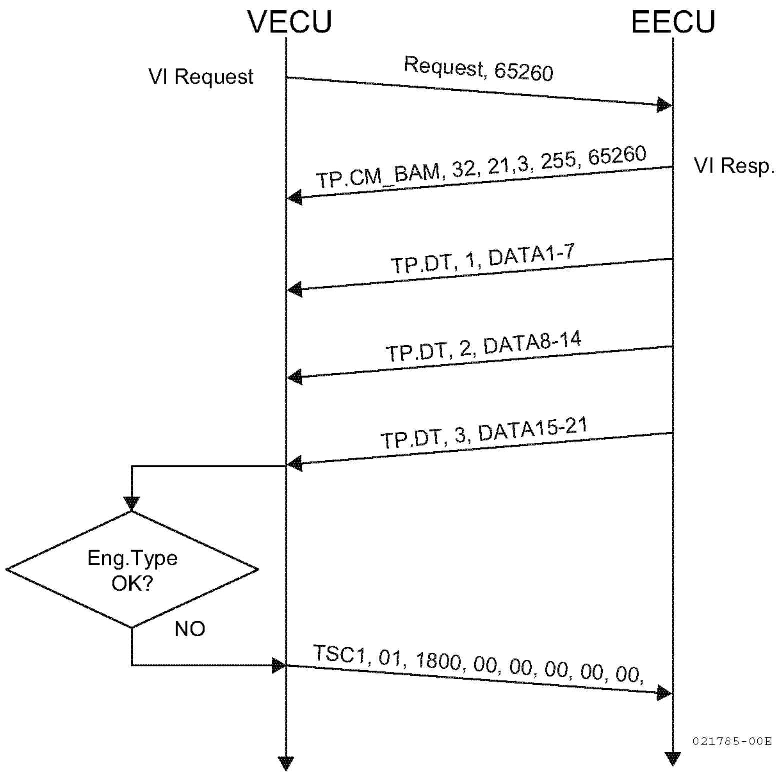

Figure 15-16

Diagnostic Trouble Codes (DTCs)

Listing of DTCs on E-ECU (Refer to Appendix D)

References

J1939/21 Data link layer

J1939/71 Vehicle application layer.

J1939/73 Application layer - diagnostics.

ISO 15765-1.3:2001 [Road vehicles - Diagnostics on CAN - Part 1: General information]

ISO 15765-2.4:2002 [Road vehicles - Diagnostics on CAN - Part 2: Network layer services]

ISO 15765-3.5:2002 [Road vehicles - Diagnostics on CAN - Part 3: implementation of diagnostic services]

ISO 15765-4.3:2001 [Road vehicles - Diagnostics on CAN - Part 4: Requirement for emission-related systems]

Appendix A : Receive and send message CAN ID summary

Appendix B : Message format (J1939-71, -73, -21)

Appendix C : Message format (YANMAR proprietary PGN)

Appendix D : DTC code list (draft)

Appendix A

	PGN	ID	Description	P (3bit)	R (1bit)	DP (1bit)	PF (8bit)	PS (GE/DA) (8bit)	SA (8bit)	With period (ms)	Data length (byte)	Acronym	R/S	Note	V191R46 Implemented
J1939-71 Application layer	0	0C0000**	Torque speed control	3	0	0	0	0	SA	10 ms	8	TSC1	R	Override control mode, Requested speed	
	56320	1CDC0000	Anti-theft status	7	0	0	220	DA	0	On request	8	ATS	S	Anti-theft status	
	56576	1CDD00**	Anti-theft request	7	0	0	221	DA	SA	As needed	8	ATR	R	Anti-theft request	
	61443	0CF00300	Electronic engine controller #2	3	0	0	240	3	0	50 ms	8	EEC2	S	Accelerator pedal position, load at current speed	x
	61444	0CF00400	Electronic engine controller #1	3	0	0	240	4	0	20 ms	8	EEC1	S	Actual engine % torque, engine speed	
	64914	18FD9200	Engine operating information	3	0	0	253	146	0	200 ms	8	EOI	S	Engine operating information	
	65188	0CFEA400	Engine temperature #2	3	0	0	254	164	0	1000 ms	8	ET2	S	EGR differential pressure, EGR gas temperature	x
	65247	0CFEDF00	Electronic engine controller #3	3	0	0	254	223	0	250 ms	8	EEC3	S	Nominal friction % torque, engine's desired speed	x
	65252	18FEE400	Shutdown	6	0	0	254	228	0	1000 ms	8	SHUT DOWN	S	Ready to crank	
	65253	18FEE500	Engine hours, revolutions	6	0	0	254	229	0	using PGN 59904	8	HOURS	S	Total engine hours, total engine revolution	x
	65255	18FEE7**	Vehicle hours	6	0	0	254	231	SA	1000 ms	8	VH	R	Total vehicle hours	x
	65259	18FEEB00	Component identification	6	0	0	254	235	0	using PGN 59904	Variable	CI	S	ECU number, engine serial number, engine type,	
	65260	18FEEC00	Vehicle identification	6	0	0	254	236	0	On request	Variable	VI	S	Vehicle identification number	
	65260	18FEEC**	Vehicle identification	6	0	0	254	236	SA	As needed	Variable	VI	R	Vehicle identification number	
	65262	18FEEE00	Engine temperature #1	6	0	0	254	238	0	1000 ms	8	ET1	S	Engine coolant temperature, fuel, oil,	x
	65269	18FEF500	Ambient conditions	6	0	0	254	245	0	1000 ms	8	AMB	S	Barometric pressure	x
	65257	18FEE900	Fuel consumption (liquid)	6	0	0	254	233	0	1000 ms	8	LFC	S	Trip fuel, total fuel used	
	65266	18FEF200	Fuel economy (liquid)	6	0	0	254	242	0	100 ms	8	LFE	S	Fuel rate, intake throttle position	x
	65271	18FEF700	Vehicle electrical power	6	0	0	254	247	0	1000 ms	8	VEP	S	Electrical potential	x
	64892	18FD7C00	Diesel Particulate Filter control 1	6	0	0	253	124	0	1000 ms	8	DPFC1	S	DPF regeneration control information	x
	64891	18FD7B00	Aftertreatment 1 service	6	0	0	253	123	0	using PGN 59904	8	AT1S	S	Soot load percent, ash load percent, time since active regeneration	
	61441	18F001**	Electronic brake controller 1	6	0	0	240	1	SA	100 ms	8	EBC1	R	Accelerator interlock switch	
	61466	10F01A00	Engine throttle/fuel actuator control command	4	0	0	240	26	0	50 ms	8	TFAC	S	Intake throttle actuator control command	x
	64946	18FDB200	Aftertreatment 1 intermediate gas	6	0	0	253	178	0	500 ms	8	AT1IMG	S	DPF temperature (mid), DPF differential pressure	x
	64947	18FDB300	Aftertreatment 1 outlet gas 2	6	0	0	253	179	0	500 ms	8	AT1OG2	S	DPF temperature (outlet)	x
	64948	18FDB400	Aftertreatment 1 intake gas 2	6	0	0	253	180	0	500 ms	8	AT1IG2	S	DPF temperature (inlet), exhaust gas temperature	x
	65243	18FEDB00	Engine fluid level/ pressure 2	6	0	0	254	219	0	500 ms	8	EFL/P2	S	Common rail pressure	x
	65270	18FEF600	Intake/exhaust conditions 1	6	0	0	254	246	0	500 ms	8	IC1	S	DPF high pressure side, EGR low pressure side, Intake manifold temperature	x

	PGN	ID	Description	P (3bit)	R (1bit)	DP (1bit)	PF (8bit)	PS (GE/DA) (8bit)	SA (8bit)	With period (ms)	Data length (byte)	Acronym	R/S	Note	V191R46 Implem ented
J1939-21 Applica-tion layer (YANMAR original)	65282	0CFF02**	Engine control request 1	3	0	0	255	2	SA	50 ms	8	Y_ECR1	R	Engine control request 1	x
	65292	0CFF0C00	Engine control acknowledge 1	3	0	0	255	12	0	100 ms	8	Y_ECACK1	S	Engine control acknowl-edge 1	x
	65297	18FF1100	State of digital in/out	6	0	0	255	17	0	100 ms	8	Y_I/OS	S	Digital ports status	x
	65303	0CFF1700	Engine load	3	0	0	255	23	0	20 ms	8	Y_LF	S	Engine percent load	x
	65308	18FF1C**	Governor functions	6	0	0	255	28	SA	100 ms	8	Y_EC	R	Droop/Isochronous, reverse droop, starter prevention	x
	65309	0CFF1D**	Engine stop command	3	0	0	255	29	SA	On request	8	Y_STP	R	Engine stop	x
	65310	18FF1E**	Speed selection functions	6	0	0	255	30	SA	50 ms	8	Y_RSS	R	Constant speed, constant deceleration	x
	65311	18FF1F00	Engine control factor	6	0	0	255	31	0	20 ms	8	Y_SRF	S	Engine stop factor, starter prevention factor	x
	65318	18FF2600	Engine speed specifications	6	0	0	255	38	0	250 ms	8	Y_SRSI	S	Lo-idle speed, hi-idle speed, available max speed	x
	65319	18FF2700	Engine control status	6	0	0	255	39	0	100 ms	8	Y_ESI	S	Engine state information	x
	65526	0CFFF6**	Electronic transmis-sion controller #1	3	0	0	255	246	SA	100 ms	8	Y_ETCP1	R	For OEM	x
	65304	18FF18**	Engine DPF regeneration control request	6	0	0	255	24	SA	1000 ms	8	Y_DPFIF	R	For OEM	x
	61184	18EF00**	Engine control mes-sage #3	6	0	0	239	0	SA	500 ms	8	Y_ECM3	R	For OEM	
	61184	(TBD)	Engine control mes-sage #3	(TBD)	(TBD)	(TBD)	(TBD)	(TBD)	0	500 ms	8	Y_ECM3	S	For OEM	
	65320	18FF2800	YMR dataloging 1	6	0	0	255	40	0	100 ms	8	Y_EGRP	S	EGR valve position (target/ actual), exhaust gas lambda, target NOx (final value)	x
	65321	18FF2900	YMR dataloging 2	6	0	0	255	41	0	100 ms	8	Y_ETVP	S	Exhaust throttle valve posi-tion (target/actual), exhaust gas mass flow, exhaust gas volume flow	x
	65322	18FF2A00	YMR dataloging 3	6	0	0	255	42	0	100 ms	8	Y_ATF	S	DPF regeneration mode status, DPF regeneration control status, emergency mode status, stationary regeneration request flag, ash cleaning request flag, DPF regeneration progress percentage	x
	65327	18FF2F00	YMR dataloging 5	6	0	0	255	47	0	1000 ms	8	Y_PMD	S	Amount of PM deposition (C method/P method/ T method/F method)	x
	65314	18FF2200	YMR dataloging 6	6	0	0	255	34	0	1000 ms	8	Y_DPFC1	S	DOC surface temperature, DPF surface temperature, DPF ash accumuration	x
	65295	18FF0F00	YMR dataloging 7	6	0	0	255	15	0	100 ms	8	Y_POI	S	Actual post injection amount, target after injec-tion amount, target post injection correction amount, total injection amount	x
	65296	18FF1000	YMR dataloging 8	6	0	0	255	16	0	1000 ms	8	Y_DPFC2	S	Target DPF temperature (OutrLop/InrLop), DPF temperature deviation amount (OutrLop/InrLop)	x
	65305	18FF1900	YMR dataloging 9	6	0	0	255	25	0	100 ms	8	Y_EST	S	Target engine speed, target injection amount, base injection timing, accelera-tion/load detection status	x
	65280	18FF0000	YMR dataloging 10	6	0	0	255	0	0	100 ms	8	Y_MPR	S	Actual exhaust/intake man-ifold pressure, target intake pressure, target intake throttle rate	x
	65281	18FF0100	YMR dataloging 11	6	0	0	255	1	0	100 ms	8	Y_POFS	S	Exhaust/intake manifold pressure offset value, smoke limit injection volume	x
	65291	18FF0B00	YMR dataloging 12	6	0	0	255	11	0	100 ms	8	Y_EOM	S	(Only Bosch-ECU) injection mode	x
	65294	18FF0E00	YMR dataloging 13	6	0	0	255	14	0	100 ms	8	Y_INJQ	S	Injection amount (main, pre, after, post)	x

	PGN	ID	Description	P (3bit)	R (1bit)	DP (1bit)	PF (8bit)	PS (GE/DA) (8bit)	SA (8bit)	With period (ms)	Data length (byte)	Acronym	R/S	Note	V191R46 Implem ented
J1939-21 Data link layer	59392	18E8FF00	Acknowledge/negative acknowledge	6	0	0	232	255	0	On request	8	Ack/Nack	S	Global response	x
	59904	18EA****	Request	6	0	0	234	DA	SA	As needed	3		R	Global request	x
	60160	1CEB****	Transport protocol-data transfer	7*	0	0	235	255	0	As required	8	TP.DT	S		x
	60416	1CEC****	Transport protocol-connection management	7*	0	0	236	255	0	As required	8	TP.CM	S	Broadcast announce message only	x
	60160	1CEB****	Transport protocol-data transfer	7*	0	0	235	255	0	As required	8	TP.DT	R		
	60416	1CEC****	Transport protocol-connection management	7*	0	0	236	255	0	As required	8	TP.CM	R	Broadcast announce message only	
J1939-73 Diagnostic layer	65226	18FECA00	Active diagnostic trouble code	6	0	0	254	202	0	1000 ms	Variable	DM1	S	Multi-packet broadcast message	x
	65227	18FECB00	Previously active diagnostic trouble code	6	0	0	254	203	0	On request	Variable	DM2	S	Multi-packet broadcast message	x
	65228	–	Diagnostic data clear/reset of previously active DTCs	–	–	–	254	204	–	On request	–	DM3	–	Positive response = ACK	x
	65230	18FECE00	Diagnostic readiness 1	6	0	0	254	206	0	On request	8	DM5	S	Diagnostic information	
	65235	–	Diagnostic data clear/reset for active DTCs	–	–	–	254	211	–	On request	–	DM11	–	Erase the active diagnostic information	
	57088	18DF****	Stop start broadcast	6	0	0	223	DA	SA	On request	8	DM13	R		
	55552	18D9****	Memory access request	6	0	0	217	DA	SA	As needed	8	DM14	R		
	55296	18D8**00	Memory access response	6	0	0	216	DA	0	As needed	8	DM15	S	Response corresponding to DM14	
	55040	18D7****	Binary data transfer	6	0	0	215	DA	SA	As needed	Variable	DM16	R		
	55040	18D7****	Binary data transfer	6	0	0	215	DA	SA	As needed	Variable	DM16	S		
J1939-81 Network management	60928	18EEFF**	Address claimed	6	0	0	238	255	SA	As required	8	AC	S	Address claim	

Appendix B

PGN	Acronym
0	TSC1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
R	1	1	2	**Override control mode**								695		x
R				Override disabled	00								"Accelerator pedal position" is enabled	x
R				Speed control	01								"Requested speed" is enabled	x
N/A				Torque control	10								Ignored (hold previous state)	x
R				Speed/torque limit	11								"Torque limit" is enabled	
N/A	1	3	2	**Requested speed control condition**								696	Not available	x
N/A				Not available	11									x
N/A	1	5	2	**Override control mode priority**								897	Not available	x
N/A				Highest	00									x
N/A				High	01									x
N/A				Medium	10									x
N/A				Low	11									x
N/A	1	7	2	**Not defined**										x
R	2	1	16	**Requested speed/speed limit**		U16	0.125	0	0	8031.875	min^{-1} (rpm)	898	The instruction engine speed from vehicle ECU. This function is enabled when "setup accel sensor flag" of the Application menu set to CAN. When receive more than "FE00h" then engine speed is according to accel sensor error operation. CAN Bus state > Initial state: According to accel sensor error operation > Error state: According to accel sensor error operation Error state is retrieved automatically.	x
R				Error indicator	FE**									x
R				Not available	FF**									x
R	4	1	8	**Requested torque/torque limit**		U8	1	-125	-125	125	%	518		
R				Error indicator	FE**									
R				Not available	FF**									
N/A	5	1	32	**Not defined**										x

PGN	Acronym	
56320	ATS	**(Currently under review)**

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
N/A	1	1	2	**Anti-theft encryption seed present indicator**								1194		
N/A				Random number is not present	00									
N/A				Random number is present	01									
N/A				Error	10									
N/A				Not availavle	11									
N/A		3	2	**Anti-theft password valid indicator**								1195		
N/A				Password is not a validated password	00									
N/A				Password is a validated password	01									
N/A				Error	10									
N/A				Not availavle	11									
N/A		5	2	**Anti-theft component status states**								1196		
S				Unlocked	00									
S				Locked	01									
N/A				Blocked	10									
N/A				Not available	11									
N/A		7	2	**Anti-theft modify password states**								1197		
N/A				OK	00									
N/A				Full of passwords	01									
N/A				Empty of passwords	10									
N/A				Not valid	11									
N/A	2	1	56	**Anti-theft random number**	ASCII				0	255		1198		

PGN	Acronym	(Currently under review)
56576	ATR	

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
	1	2	2	**Anti-theft encryption indicator states**								1199		
				Encryption seed request	00									
				Encrypted code present	01									
				Not defined	10									
				Not available	11									
		4	2	**Anti-theft desired exit mode states**								1200		
		6	3	**Anti-theft command states**								1201		
					000									
					001									
					010									
					011									
					100									
					101									
					110									
					111									
	2	1	56	**Anti-theft password representation**								1202		

PGN	Acronym
61443	EEC2

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	2	**Accelerator pedal low idle switch**								558	Not available	x
N/A				Accelerator pedal not in low idle condition	00									x
N/A				Accelerator pedal in low idle condition	01									x
N/A				Error indicator	10									x
S				Not available	11									x
S	1	3	2	**Accelerator pedal kickdown switch**								559	Not available	x
N/A				Kickdown passive	00									x
N/A				Kickdown active	01									x
N/A				Error indicator	10									x
S				Not available	11									x
S	1	5	2	**Road speed limit status**								1437	Not available	x
N/A				Active	00									x
N/A				Not active	01									x
N/A				Error indicator	10									x
S				Not available	11									x
S	1	7	2	**Accelerator pedal 2 low idle switch**								2970	Not available	x
N/A				Accelerator pedal 2 not in low idle condition	00									x
N/A				Accelerator pedal 2 in low idle condition	01									x
N/A				Error	10									x
S				Not available	11									x
S	2	1	8	**Accelerator pedal position**		U8	0.4	0	0	100	%	91	Droop mode hi-idle speed is 100 %.	x
S				Error indicator	FE									x
N/A				Not available	FF									x
S	3	1	8	**Percent load at current speed**		U8	1	0	0	100	%	92		x
S				Error indicator	FE								When the load ratio cannot be calculated.	x
N/A				Not available	FF									x
S	4	1	8	**Remote accelerator**		U8	0.4	0	0	100	%	974	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	5	1	8	**Accelerator pedal position 2**		U8	0.4	0	0	100	%	29	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	6	1	2	**Vehicle acceleration rate limit status**									Not available	x
N/A				Limit not active	00									x
N/A				Limit active	01									x
N/A				Reserved	10									x
S				Not available	11									x
S		3	6	**Not defined**										x
S	7	1	8	**Actual maximum available engine - percent torque**		U8	0.4	0	0	100	%	3357	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	8	1	8	**Not defined**										x

PGN	Acronym
61444	EEC1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	4	**Engine torque mode**								899	Not available	x
N/A				Low idle governor/no request (default mode)	0000									x
N/A				Accelerator pedal	0001									x
N/A				Cruise control	0010									x
N/A				PTO governor-N/A	0011									x
N/A				Road speed governor	0100									x
N/A				ASR control-N/A	0101									x
N/A				Transmission control	0110									x
N/A				ABS control-N/A	0111									x
N/A				Torque limiting	1000									x
N/A				High speed governor	1001									x
N/A				Braking system-N/A	1010									x
N/A				Remote accelerator	1011									x
N/A				not defined	1100									x
N/A				not defined	1101									x
N/A				Other	1110									x
S				Not available	1111									x
S	1	5	4	**Actual engine - percent torque high resolution**		U8	0.125	0.000	0.000	0.875	%	4154	Not available	x
N/A				Error indicator	1***									x
S				Not available	1***									x
S	2	1	8	**Driver's demand engine - percent torque**		U8	1	-125	-125	125	%	512	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	3	1	8	**Actual engine - percent torque**		U8	1	-125	-125	125	%	513	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	4	1	16	**Engine speed**		U16	0.125	0	0	8031.875	min^{-1} (rpm)	190		x
S				Error indicator	FE**								When crank rotation sensor failure and cam rotation sensor failure occurred.	x
N/A				Not available	FF**									x
S	6	1	8	**Source address of controlling device for engine control**		U8	1	0	0	253	–	1483	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	7	1	4	**Engine starter mode**								1675		x
S				start not requested	0000									x
S				starter active, gear not engaged	0001									x
S				starter active, gear engaged	0010									x
S				start finished; starter not active after having been actively engaged (after 50 ms mode goes to 0000)	0011									x
N/A				starter inhibited due to engine already running	0100								Not available	x
N/A				starter inhibited due to engine not ready for start (preheating)	0101								Not available	x
N/A				starter inhibited due to driveline engaged or other transmission inhibit	0110								Not available	x
N/A				starter inhibited due to active immobilizer	0111								Not available	x
N/A				starter inhibited due to starter over-temp	1000								Not available	x
N/A				Reserved	1001-1011								Not available	x
N/A				starter inhibited - reason unknown	1100								Detail is shown in PGN65311 (Y_SRF).	x
S				error (legacy implementation only, use 1110)	1101								Not available	x
N/A				error	1110								Not available	x
N/A				Not available	1111								Not available	x
S	7	5	4	**Not defined**										x
S	8	1	8	**Engine demand - percent torque**		U8	1	-125	-125	125	%	2432	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x

PGN	Acronym
65188	ET2

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Engine oil temperature 2**		U16	0.03125	-273	-273	1735	deg C	1135	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	3	1	16	**Engine ECU temperature**		U16	0.03125	-273	-273	1735	deg C	1136	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	5	1	16	**Engine EGR differential pressure**		U16	0.0078125	-250	-250	251.99	kPa	411		x
S				Error indicator	FE**								When EGR high pressure side sensor failure or EGR low pressure side sensor failure occurred.	x
N/A				Not available	FF**									x
S	7	1	16	**Engine EGR temperature**		U16	0.03125	-273	-273	1735	deg C	412		x
S				Error indicator	FE**								When EGR gas temperature sensor failure occurred.	x
N/A				Not available	FF**									x

PGN	Acronym
65247	EEC3

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Nominal friction - percent torque**		U8	1	-125	-125	125	%	514	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	2	1	16	**Engine's desired operating speed**		U16	0.125	0	0	8031.875	min^{-1} (rpm)	515		x
N/A				Error indicator	FE**									x
N/A				Not available	FF**									x
S	4	1	8	**Engine's desired operating speed asymmetry adjustment**		U8	1	0	0	250		519	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	5	1	8	**Estimated engine parasitic losses - percent torque**		U8	1	-125	-125	125	%	2978	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	6	1	16	**Aftertreatment 1 exhaust gas mass flow**		U16	0.2	0	0	12851	kg/h	3236	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	8	1	2	**Aftertreatment 1 intake dew point**									Not available	x
N/A				Not exceeded the dew point	00									x
N/A				Exceeded the dew point	01									x
N/A				Error	10									x
S				Not available	11									x
S		3	2	**Aftertreatment 1 exhaust dew point**									Not available	x
N/A				Not exceeded the dew point	00									x
N/A				Exceeded the dew point	01									x
N/A				Error	10									x
S				Not available	11									x
S		5	2	**Aftertreatment 2 intake dew point**									Not available	x
N/A				Not exceeded the dew point	00									x
N/A				Exceeded the dew point	01									x
N/A				Error	10									x
S				Not available	11									x
S		7	2	**Aftertreatment 2 exhaust dew point**									Not available	x
N/A				Not exceeded the dew point	00									x
N/A				Exceeded the dew point	01									x
N/A				Error	10									x
S				Not available	11									x

PGN	Acronym
65253	HOURS

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	32	**Total engine hours**		U32	0.05	0	0	210,554,061	hr	247	Total engine running hours	x
N/A				Error indicator	FE******									x
N/A				Not available	FF******									x
S	5	1	32	**Total engine revolutions**		U32	1,000	0	0	4,211,081,215,000	r	249	Not available	x
N/A				Error indicator	FE******									x
S				Not available	FF******									x

PGN	Acronym
65255	VH

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
R	1	1	32	**Total vehicle hours**		U32	0.05	0	0	210,554,061	hr	246	CAN bus state > Initial state : 0 > Error state : keep last state	x
R				Error indicator	FE******								Ignored	x
R				Not available	FF******								Ignored	x
N/A	5	1	32	**Total power takeoff hours**		U32	0.05	0	0	210,554,061	hr	248		x
N/A				Error indicator	FE******									x
N/A				Not available	FF******									x

PGN	Acronym
65259	CI

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	40	**Make "YDECO"**		ASCII						586		
S	6	1	8	**Delimiter "*"**		ASCII								
S	7	1	160	**Engine model number (ASCII *20)**		ASCII						587	Engine model name	
S	27	1	8	**Delimiter "*"**		ASCII								
S	28	1	160	**Engine serial number (ASCII *20)**		ASCII						588	Engine serial number	
S	48	1	8	**Delimiter "*"**		ASCII								
S	49	1	112	**ECU number (ASCII *14)**		ASCII						233	ECU ASSY part number	
S	63	1	8	**Delimiter "*"**		ASCII								

PGN	Acronym
65260	VI

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
R	1	1	256	**Vehicle identification number (ASCII)**		ASCII						237	TBD	
R	33	1	8	**Delimiter "*"**		ASCII								

PGN	Acronym
65260	VI

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	256	**Vehicle Identification number (ASCII)**		ASCII						237	TBD	
S	33	1	8	**Delimiter "*"**		ASCII								

PGN	Acronym
65262	ET1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Engine coolant temperature**		U8	1	-40	-40	210	deg C	110		x
S				Error indicator	FE								When coolant temperature sensor failure occurred.	x
N/A				Not available	FF									x
S	2	1	8	**Fuel temperature**		U8	1	-40	-40	210	deg C	174		x
S				Error indicator	FE								When fuel temperature sensor failure occurred.	x
N/A				Not available	FF									x
S	3	1	16	**Engine oil temperature**		U16	0.03125	-273	-273	1735	deg C	175	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	5	1	16	**Turbo oil temperature**		U16	0.03125	-273	-273	1735	deg C	176	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	7	1	8	**Engine intercooler temperature**		U8	1	-40	-40	210	deg C	52	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	8	1	8	**Engine intercooler thermostat opening**		U8	0.4	0	0	100	%	1134	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x

PGN	Acronym
65269	AMB

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Barometric pressure**		U8	0.5	0	0	125	kPa	108		x
S				Error indicator	FE								When barometric pressure sensor failure occurred.	x
N/A				Not available	FF									x
S	2	1	16	**Cab interior temperature**								170	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	4	1	16	**Ambient air temperature**		U16	0.03125	-273	-273	1735	deg C	171		x
S				Error indicator	FE**								When new air temperature sensor failure occurred.	x
N/A				Not available	FF**									x
S	6	1	8	**Engine air inlet temperature**		U8	1	-40	-40	210	deg C	172	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	7	1	16	**Road surface temperature**								79	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x

PGN	Acronym
65257	LFC

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	32	**Trip fuel**		32	0.5	0	0	2105540607.5	L	182		
S	5	1	32	**Total fuel used**		32	0.5	0	0	2105540607.5	L	250		

PGN	Acronym
65266	LFE

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Fuel rate**		U16	0.05	0	0	3212.75	L/h	183		
N/A				Error indicator	FE									
N/A				Not available	FF									
S	3	1	16	**Instantaneous fuel economy**		U16	1/512	0	0	125.5	km/L	184	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	5	1	16	**Average fuel economy**		U16	1/512	0	0	125.5	km/L	185	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	7	1	8	**Throttle position**		U16	0.4	0	0	100	%	51		x
S				Error indicator	FE								When Intake throttle position sensor failure occurred.	x
N/A				Not available	FF									x
S	8	1	8	**Not used (bit = 1)**										x

PGN	Acronym
65271	VEP

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Net battery current**		U8	1	-125	-125	125	A	114	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	2			Not defined										x
S	3	1	16	**Alternator potential (voltage)**		U16	0.05	0	0	3212.75	V	167	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	5	1	16	**Electrical potential (voltage)**		U16	0.05	0	0	3212.75	V	168	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	7	1	16	**Battery potential (voltage), switched**		U16	0.05	0	0	3212.75	V	158	ECU Voltage	x
N/A				Error indicator	FE**									x
N/A				Not available	FF**									x

PGN	Acronym
64892	DPFC1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	3	**Diesel Particulate Filter lamp command**								3697		x
S				OFF	000									x
S				On solid	001									x
N/A				Reserved for SAE	010								Not available	x
N/A				Reserved for SAE	011								Not available	x
S				On - fast blink (1 HZ)	100									x
N/A				Reserved for SAE	101								Not available	x
N/A				Reserved for SAE	110								Not available	x
N/A				Not available	111								Not available	x
N/A		4	5	**Not used**										x
S	2	1	2	**Diesel Particulate Filter passive regeneration status**									Not available	x
N/A				Not active	00									x
N/A				Active	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		3	2	**Diesel Particulate Filter active regen-eration status**								3700		x
S				Not active	00									x
S				Active	01									x
N/A				Reserved for SAE	10								Not available	x
N/A				Not available	11								Not available	x
S		5	3	**Diesel Particulate Filter status**								3701		x
S				Regeneration not needed	000									x
S				Regeneration needed - lowest level	001									x
N/A				Regeneration needed - moderate level	010								Not available	x
S				Regeneration needed - highest level	011									x
N/A				Reserved for SAE	100								Not available	x
N/A				Reserved for SAE	101								Not available	x
N/A				Reserved for SAE	110								Not available	x
N/A				Not available	111								Not available	x
S	3	1	2	**Diesel Particulate Filter active regen-eration inhibited status**								3702		x
S				Not inhibited	00									x
S				Inhibited	01									x
N/A				Reserved for SAE	10								Not available	x
N/A				Not available	11								Not available	x
S		3	2	**Diesel Particulate Filter active regen-eration inhibited due to inhibit switch**								3703		x
S				Not inhibited	00									x
S				Inhibited	01									x
N/A				Reserved for SAE	10								Not available	x
N/A				Not available	11								Not available	x
S		5	2	**Diesel Particulate Filter active regen-eration inhibited due to clutch disengaged**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		7	2	**Diesel Particulate Filter active regen-eration inhibited due to service brake active**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S	4	1	2	**Diesel Particulate Filter active regen-eration inhibited due to PTO active**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x

PGN	Acronym
64892	DPFC1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S		3	2	**Diesel Particulate Filter active regeneration inhibited due to accelerator pedal off idle**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		5	2	**Diesel Particulate Filter active regeneration inhibited due to out of neutral**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		7	2	**Diesel Particulate Filter active regeneration inhibited due to vehicle speed above allowed speed**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S	5	1	2	**Diesel Particulate Filter active regeneration inhibited due to parking brake not set**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		3	2	**Diesel Particulate Filter active regeneration inhibited due to low exhaust gas temperature**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		5	2	**Diesel Particulate Filter active regeneration inhibited due to system fault active**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		7	2	**Diesel Particulate Filter active regeneration inhibited due to system timeout**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S	6	1	2	**Diesel Particulate Filter active regeneration inhibited due to temporary system lockout**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		3	2	**Diesel Particulate Filter active regeneration inhibited due to permanent system lockout**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x

PGN	Acronym
64892	DPFC1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S		5	2	**Diesel Particulate Filter active regeneration inhibited due to engine not warmed up**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		7	2	**Diesel Particulate Filter active regeneration inhibited due to vehicle speed below alllowed speed**									Not available	x
N/A				Not inhibited	00									x
N/A				Inhibited	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S	7	1	2	**Diesel Particulate Filter automatic active regeneration initiation configuration**									Not available	x
N/A				Not enabled	00									x
N/A				Enabled	01									x
N/A				Reserved for SAE	10									x
S				Not available	11									x
S		3	3	**Exhaust system high temperature lamp command**								3698		x
S				OFF	000									x
S				On solid	001									x
N/A				Reserved for SAE	010 - 110								Not available	x
N/A				Not available	111								Not available	x
S		6	3	**Diesel Particulate Filter active regeneration forced status**								4175		x
S				Not active	000									x
N/A				Active forced by switch	001								Not available	x
N/A				Actve forced by service tool	010								Not available	x
S				Allow upon request	011									x
N/A				Reserved for SAE	100 - 110								Not available	x
N/A				Not available	111								Not available	x
S	8	1	8	**Not used**									Padded with "1"	x

PGN	Acronym
64891	AT1S

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Diesel Particulate Filter 1 soot load percent**		U8	1	0	0	250	%	3719		
S				Error indicator	FE									
S				Not available	FF								When the specification without DPF is applied.	
S	2	1	8	**Diesel Particulate Filter 1 ash load percent**		U8	1	0	0	250	%	3720		
S				Error indicator	FE									
S				Not available	FF								When the specification without DPF is applied.	
S	3	1	32	**Diesel Particulate Filter 1 time since last active regeneration**		32	1	0	0	4,211,081,215	s	3721		
S				Error indicator	FE**									
S				Not available	FF**								When the specification without DPF is applied.	
N/A	7	1	16	**Not defined**										

PGN	Acronym
61441	EBC1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
N/A	1	1	24	**Not used**										
R	4	1	2	**Accelerator interlock switch**								972		
R				Off	00									
R				On	01									
R				Error indicator	10									
R				Not available	11									
N/A		3	2	**Not used**										
R		5	2	**Auxiliary engine shutdown switch**			1	0	0	3		970	CAN bus state > Initial state: 01 = Off > Error state: According to calibration value	
R				Off	00								00 = Engine stop not requested	
R				On	01								01 = Engine stop	
N/A				Error indicator	10								Ignored (hold previous state)	
N/A				Not available	11								Ignored (hold previous state)	
N/A		7	2	**Not used**										
N/A	5	1	32	**Not used**										

PGN	Acronym
61466	TFAC

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Engine throttle actuator 1 control command**		U16	0.0025	0	0	160.6375	%	3464		x
N/A				Error indicator	FE**									x
N/A				Not available	FF**									x
S	3	1	16	**Engine throttle actuator 2 control command**		U16	0.0025	0	0	160.6375	%	3465	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	5	1	16	**Engine fuel actuator 1 control command**								633	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	7	1	16	**Engine fuel actuator 2 control command**								1244	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x

PGN	Acronym
64914	EOI

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	4	**Engine operating status**								3543		
S				Standby	0000									
S				Pre-crank	0001									
S				crank	0010									
S				Running	0100									
S				Running safe mode	0101									
S				Emergency stop	0110									
S		5	2	**Fuel pump primer control**								4082	Not available	
S				Not available	11									
S		7	2	**Not used**									Padded with “1”	
S	2	1	16	**Time remaining in engine operating state**								3544	Not available	
S				Not available	FFFF									
S	4	1	2	**Engine fuel shutoff vent control**								3608	Not available	
S				Not available	11									
S		3	2	**Engine fuel shutoff 1 control**								632	Not available	
S				Not available	11									
S		5	2	**Engine fuel shutoff 2 control**								2807	Not available	
S				Not available	11									
S		7	2	**Engine fuel shutoff valve leak test control**								3601	Not available	
S				Not available	11									
S	5	1	2	**Engine oil priming pump control**								3589	Not available	
S				Not available	11									
S		3	2	**Engine oil pre-heater control**								3602	Not available	
S				Not available	11									
S		5	2	**Engine electrical system power conservation**								3603	Not available	
S				Not available	11									
S		7	2	**Engine block/coolant pre-heater control**								3604	Not available	
S				Not available	11									
S	6	1	2	**Engine coolant circulating pump control**								3605	Not available	
S				Not available	11									
S		3	2	**Engine controlled shutdown request**								3606	Not available	
S				Not available	11									
S		5	2	**Engine electrical system power conservation**								3607	Not available	
S				Not available	11									
S		7	2	**Not used**									Padded with “1”	
S	7	1	8	**Not used**									Padded with “1”	
S	8	1	8	**Engine derate request**								3644	Not available	
S				Not available	FF									

PGN	Acronym
64946	AT1IMG

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Aftertreatment 1 exhaust gas temperature 2**		U16	0.03125	-273	-273	1735	deg C	3249	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	3	1	16	**Aftertreatment 1 Diesel Particulate Filter intermediate gas temperature**		U16	0.03125	-273	-273	1735	deg C	3250		x
S				Error indicator	FE**								When DPF intermediate temperature sensor failure occurred.	x
S				Not available	FF**								When the specification without DPF is applied.	
S	5	1	16	**Aftertreatment 1 Diesel Particulate Filter differential pressure**		U16	0.1	0	0	6425.5	kPa	3251		x
S				Error indicator	FE**								When DPF differential pressure sensor failure occurred.	x
S				Not available	FF**								When the specification without DPF is applied.	
S	7	1	5	**Aftertreatment 1 exhaust gas temperature 2 preliminary FMI**								3252	Not available	x
N/A				Error indicator										x
S				Not available										x
S	7	6	5	**Aftertreatment 1 Diesel Particulate Filter delta pressure preliminary FMI**								3253	Not available	x
N/A				Error indicator										x
S				Not available										x
S	8	3	5	**Aftertreatment 1 Diesel Particulate Filter intermediate gas temperature preliminary FMI**								3254	Not available	x
N/A				Error Indicator										x
S				Not available										x

PGN	Acronym
64947	AT1OG2

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Aftertreatment 1 exhaust gas temperature 3**		U16	0.03125	-273	-273	1735	deg C	3245	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	3	1	16	**Aftertreatment 1 Diesel Particulate Filter outlet gas temperature**		U16	0.03125	-273	-273	1735	deg C	3246		x
N/A				Error indicator	FE**									x
S				Not available	FF**								When the specification without DPF is applied.	
S	5	1	5	**Aftertreatment 1 exhaust gas temperature 3 preliminary FMI**								3247	Not available	x
N/A				Error indicator										x
S				Not available										x
S	5	6	3	**Not defined**										x
S	6	1	5	**Aftertreatment 1 Diesel Particulate Filter exhaust gas temperature preliminary FMI**								3248	Not available	x
N/A				Error indicator										x
S				Not available										x
S	6	6	3	**Not defined**										x
S	7	1	16	**Not defined**										x

PGN	Acronym
64948	AT1IG2

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Aftertreatment 1 exhaust gas temperature 1**		U16	0.03125	-273	-273	1735	deg C	3241		x
S				Error indicator	FE**								When exhaust gas temperature sensor failure occurred.	x
N/A				Not available	FF**									x
S	3	1	16	**Aftertreatment 1 Diesel Particulate Filter intake gas temperature**		U16	0.03125	-273	-273	1735	deg C	3242		x
S				Error indicator	FE**								When DPF inlet temperature sensor failure occurred.	x
S				Not available	FF**								When the specification without DPF is applied.	
S	5	1	5	**Aftertreatment 1 exhaust gas temperature 1 preliminary FMI**								3243	Not available	x
N/A				Error indicator										x
S				Not available										x
S	5	6	3	Not defined										x
S	6	1	5	**Aftertreatment 1 Diesel Particulate Filter intake gas temperature preliminary FMI**								3244	Not available	x
N/A				Error indicator										x
S				Not available										x
S	6	6	3	Not defined										x
S	7	1	16	Not defined										x

PGN	Acronym
65243	EFL/P2

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Engine injection control pressure**								164	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	3	1	16	**Engine injector metering rail 1 pressure**		U16	1/256	0	0	251	MPa	157		x
S				Error indicator	FE**								When rail pressure sensor failure occurred.	x
N/A				Not available	FF**									x
S	5	1	16	**Engine injector timing rail 1 pressure**								156	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	7	1	16	**Engine injector metering rail 2 pressure**								1349	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x

PGN	Acronym
65252	SHUT DOWN

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	2	**Engine idle shutdown has shutdown engine**								593	Not available	
S				Not available	11									
S		3	2	**Engine idle shutdown driver alert mode**								594	Not available	
S				Not available	11									
S		5	2	**Engine idle shutdown timer 1 override**								592	Not available	
S				Not available	11									
S		7	2	**Engine idle shutdown timer state**								590	Not available	
S				Not available	11									
S	2	1	6	**Not used**									Padded with “1”	
S		7	2	**Engine idle shutdown timer function**								591	Not available	
S				Not available	11									
S	3	1	2	**A/C high pressure fan switch**								985	Not available	
S				Not available	11									
S		3	2	**Refrigerant low pressure switch**								875	Not available	
S				Not available	11									
S		5	2	**Refrigerant high pressure switch**								605	Not available	
S				Not available	11									
S		7	2	**Not used**									Padded with “1”	
S	4	1	2	**Ready to crank [engine wait to start lamp in J1939]**								1081		
S				Ready	00									
S				No ready	01									
S				Error	10									
S				N/A	11									
S		3	6	**Not used**									Padded with “1”	
S	5	1	2	**Engine protection system has shut-down engine**								1110	Not available	
S				Not available	11									
S		3	2	**Engine protection system approach-ing shutdown**								1109	Not available	
S				Not available	11									
S		5	2	**Engine protection system timer override**								1108	Not available	
S				Not available	11									
S		7	2	**Engine protection system timer state**								1107	Not available	
S				Not available	11									
S	6	1	6	**Not used**									Padded with “1”	
S		7	2	**Engine protection system configuration**								1111	Not available	
S				Not available	11									
S	7	1	2	**Engine alarm acknowledge**								2815	Not available	
S				Not available	11									
S		3	2	**Engine alarm output command status**								2814	Not available	
S				Not available	11									
S		5	2	**Engine air shutoff command status**								2813	Not available	
S				Not available	11									
S		7	2	**Engine overspeed test**								2812	Not available	
S				Not available	11									
S	8	1	2	**Engine air shutoff status**								3667	Not available	
S				Not available	11									
S		3	6	**Not used**									Padded with “1”	

PGN	Acronym
65270	IC1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Engine Diesel Particulate Filter inlet pressure**		U8	0.5	0	0	125	kPa	81		x
S				Error indicator	FE								When DPF high pressure side sensor failure occurred.	x
S				Not available	FF								When the specification without DPF is applied.	
S	2	1	8	**Engine intake manifold #1 pressure**		U8	2	0	0	500	kPa	102	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	3	1	8	**Engine intake manifold 1 temperature**		U8	1	-40	-40	210	deg C	105		x
S				Error indicator	FE								When intake manifold tempera-ture sensor failure occurred.	x
N/A				Not available	FF									x
S	4	1	8	**Engine air inlet pressure**		U8	2	0	0	500	kPa	106		x
S				Error indicator	FE								When EGR low pressure side sensor failure occurred.	x
N/A				Not available	FF									x
S	5	1	8	**Engine air filter 1 differential pressure**		U8	0.05	0	0	12.5	kPa	107	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x
S	6	1	16	**Engine exhaust gas temperature**		U16	0.03125	-273	-273	1735	deg C	173	Not available	x
N/A				Error indicator	FE**									x
S				Not available	FF**									x
S	8	1	8	**Engine coolant filter differential pressure**		U8	0.5	0	0	125	kPa	112	Not available	x
N/A				Error indicator	FE									x
S				Not available	FF									x

Appendix C

PGN	Acronym
65282	Y_ECR1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
N/A	1	1	8	**Not defined**										x
N/A	2	1	2	**Not defined**										x
R	2	3	2	**Shutdown requests**									CAN bus state > Initial state: 00 = No shutdown requests > Error state: keep last state	
R				No shutdown request	00								normal state	
R				Shutdown request	01								Engine ECU begins the shutdown processing.	
N/A				Error indicator	10								Ignored	x
N/A				Not available	11								Ignored	x
N/A	2	5	2	**Not defined**										x
R	2	7	2	**Power supply/key position**									CAN bus state > Initial state: 00 = Ignition key in off-position > Error state: 11 = Ignition key in crank-position	x (Only starter permission)
R				Ignition key in off-position	00								Auto preheat/afterheat is disabled. / The starter is not permitted.	x (Only starter permission)
R				Ignition key in normal driving position	01								Auto preheat/afterheat is disabled. / The starter is not permitted.	x (Only starter permission)
R				Ignition key in preheat-position	10								Auto preheat/afterheat is enabled. / The starter is not permitted.	x (Only starter permission)
R				Ignition key in crank-position	11								The starter is permitted.	x (Only starter permission)
N/A	3	1	8	**Not defined**										x
R	4	1	8	**Accelerator pedal position**		U8	0.4	0	0	100	%		Percent ratio of accelerator pedal position Engine speed is increased low-idle speed to high-idle speed with pedal position. Low-idle is 0 %, and high-idle is 100 %. (Same as analog accelerator sensor.) This function is enabled when “setup accel sensor flag” of the Application menu set to CAN. This parameter is available when “Override Control Mode” of TSC1 is disabled. When receive more than “FEh” then engine control is according to accel sensor error operation. CAN Bus state > Initial state: According to accel sensor error operation > Error state: According to accel sensor error operation Error state is retrieved automatically.	x
R				Error indicator	FE									x
R				Not available	FF									x
R	5	1	2	**Crank request**										
R				No cranking	00									
R				Crank request	01									
N/A				Engine stop request	10								TBD	
N/A				N/A	11								TBD	
N/A		3	6	**Not defined**										x
R	6	1	8	**(Reserved)**										x
N/A	7	1	16	**Not defined**										x

PGN	Acronym
65292	Y_ECACK1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Not defined**										x
S	2	1	3	**Not defined**										x
S	2	4	2	**Preheat function acknowledge**									State of preheat energizing ("preheat" only, not include "afterheat" and "airheat at cranking")	x
S				Not active (preheat OFF)	00									x
S				Active (preheat ON)	01									x
S				Error indicator (glow plug relay error)	10									x
N/A				Not available	11									x
S		6	2	**Not defined**										x
S	2	8	1	**Power down enable**										0 (Fixed value)
S				Power off not allowed	0									0 (Fixed value)
S				Power off allowed (finished shutdown)	1									0 (Fixed value)
S	3	1	8	**Remaining preheat time**									TBD	
S	4	1	2	**Glow plug function acknowledge**										
S				Not active (glow plug OFF)	00									
S				Active (glow plug ON)	01									
S				Prohibit glow plug re-energizing	10									
S		3	8	**Not defined**										x
S	5	1	32	**Not defined**										x

PGN	Acronym
65297	Y_I/OS

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	3	**Digital input 1 status**									External switch OFF (open) = 0/ ON (close) = 1	x
S		1	1	STARTSW port	XX1		1	0	0	1	–			x
S		2	1	SHUDNSW port	X1X		1	0	0	1	–			x
S		3	1	IGNSW port	1XX		1	0	0	1	–			x
S		4	5	Not defined										x
S	2	1	8	**Digital input 2 status**									External switch OFF (open) = 0/ ON (close) = 1	x
S		1	1	APP-IP1	XXXXXX1		1	0	0	1	–		Droop selection SW	x
S		2	1	APP-IP2	XXXXX1X		1	0	0	1	–		Starter permission2 SW	x
S		3	1	APP-IP3	XXXX1XX		1	0	0	1	–		Speed1 SW	x
S		4	1	APP-IP4	XXX1XXX		1	0	0	1	–		Speed2 SW	x
S		5	1	APP-IP5	XX1XXXX		1	0	0	1	–		High idling limitation SW	x
S		6	1	APP-IP6	X1XXXXX		1	0	0	1	–		Speed selection enable SW	x
S		7	1	APP-IP7	1XXXXXX		1	0	0	1	–		Engine stop2 SW	x
S		8	1	Not defined										x
S	3	1	8	**Digital output 1 status**									Output port OFF = 0/ON = 1	x
S		1	1	MAIN-RLY port	XXXXXXX1		1	0	0	1	–			0 (Fixed value)
N/A		2	1	(Reserved)									YANMAR special function, 0 (Fixed value)	x
S		3	1	SAID-RLY port	XXXXX1XX		1	0	0	1	–			x
N/A		4	1	(Reserved)									YANMAR special function, 0 (Fixed value)	x
S		5	1	FAIL-LMP port	XXX1XXXX		1	0	0	1	–			x
S		6	1	PREHT-LMP port	XX1XXXXX		1	0	0	1	–			x
S		7	1	APP-OP1	X1XXXXXX		1	0	0	1	–		Speed selection indicator lamp	x
S		8	1	APP-OP2	1XXXXXXX		1	0	0	1	–		Iso-chronous lamp	x
S	4	1	8	**Digital input 3 status**									External switch OFF (open) = 0/ ON (close) = 1	x
S		1	1	CHGSW port	XXXXXXX1		1	0	0	1	–		Charge failure SW	x
S		2	1	ACLSW port	XXXXXX1X		1	0	0	1	–		Air cleaner SW	x
S		3	1	WSSW port	XXXXX1XX		1	0	0	1	–		Oily water separator SW	x
S		4	1	LOPSW port	XXXX1XXX		1	0	0	1	–		Oil pressure SW	x
S		5	1	PDLSW	XXX1XXXX		1	0	0	1	–		Accelerator pedal SW (NO)	x
S		6	1	APP-IP8	XX1XXXXX		1	0	0	1	–		High idling selection SW	x
S		7	1	APP-IP9	X1XXXXXX		1	0	0	1	–		Starter permission1 SW	x
S		8	1	Not defined										x
S	5	1	8	**Digital input 4 status**									External switch OFF (open) = 0/ ON (close) = 1	x
S		1	1	REGSW	XXXXXXX1		1	0	0	1	–		DPF regeneration request SW	x
S		2	1	REGMSW	XXXXXX1X		1	0	0	1	–		DPF regeneration inhibit SW	x
S		3	1	WDSBSW	XXXXX1XX		1	0	0	1	–		Regeneration interlock SW	x
S		4	5	Not defined										x
S	6	1	8	**Digital output 2 status**										x
S		1	1	DPF-M1 port	XXXXXXX1		1	0	0	1	–		DPF regeneration lamp	x
S		2	1	DPF-M2 port	XXXXXX1X		1	0	0	1	–		DPF regeneration inhibit lamp	x
S		3	1	DPF-M3 port	XXXXX1XX		1	0	0	1	–		Exhaust temperature lamp	x
S		4	1	DPF-M4 port	XXXX1XXX		1	0	0	1	–		DPF regeneration acknowledge lamp	x
S		5	1	REOP1	XXX1XXXX		1	0	0	1	–		Reserved	0 (Fixed value)
S		6	1	REOP2	XX1XXXXX		1	0	0	1	–		Buzzer	x
S		7	2	Not defined										x
S	7	1	8	**Digital output 3 status**										x
S		1	1	STR-RLY port	XXXXXXX1		1	0	0	1	–		Starter relay status	x
S		2	1	OVHT-LMP port	XXXXXX1X		1	0	0	1	–		Coolant temperature warning lamp	x
S		3	1	REOP3	X1XXXXXX		1	0	0	1	–		Amber warning lamp	x
S		4	1	REOP4	1XXXXXXX		1	0	0	1	–		Red engine stop lamp	x
S		5	4	Not defined										x
S	8	1	8	**Digital input 5 status**										x
S		1	1	CANTO port	XXXXXXX1		1	0	0	1	–		CAN time out	x
S	8	2	7	Not defined										x

PGN	Acronym
65303	Y_LF

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Engine gross load ratio**		U8	1	0	0	100	%			x
S				Error indicator	FE								When the load ratio cannot be calculated	x
N/A				Not available	FF									x
S	2	1	40	**(Reserved)**									YANMAR special function	x
S	7	1	8	**Engine gross load ratio (smoke limit)**		U8	1	0	0	100	%			x
S				Error indicator	FE								When the load ratio cannot be calculated	x
N/A				Not available	FF									x
S	8		8	**Not defined**										x

PGN	Acronym
65308	Y_EC

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
N/A	1	1	2	**(Reserved)**									YANMAR special function	x
R	1	3	2	**Governor mode**									CAN bus state > Initial state: 0 = OFF > Error state: keep last state	x
R		3	1	Droop mode (APP-IP1)	1								0 = OFF (isochronous)/1 = ON (droop), Depend on droop selection input setting	x
N/A		4	1	(Reserved)									YANMAR special function	x
R	1	5	1	**Starter protection**									CAN bus state > Initial state: 1 = ON > Error state: 0 = OFF	x
R		5		Starter permission	1								0 = OFF (permission)/1 = ON (protection),	x
R	1	6	2	**Hi-idle control**									YANMAR special function > Initial state: 0 = OFF CAN bus state > Error state: keep last state	x
R		6		High idling limitation (APP-IP5)	1								0 = OFF/1 = ON, depend on high idling limitation input setting	x
R		7		High idling selection (APP-IP8)	1								0 = OFF/1 = ON, depend on high idling selection input setting	x
N/A	1	8	1	**Not defined**										x
N/A	2	1	56	**Not defined**										x

PGN	Acronym
65309	Y_STP

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
R	1	1	2	**Engine stop**										x
R				Engine stop not requested	00									x
R				Engine stop	01									x
R				Error indicator	10								Ignored	x
R				Not available	11								Ignored	x
N/A		3	6	**Not defined**										x
N/A	2	1	56	**Not defined**										x

PGN	Acronym
65310	Y_RSS

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
R	1	1	5	**Speed selection function**									Constant speed, constant deceleration CAN bus state > Initial state: 0 = OFF > Error state: keep last state	x
R		1	1	Speed1 (APP-IP3)	XXXX1								0 = OFF/1 = ON, depend on speed1 input setting	x
R		2	1	Speed2 (APP-IP4)	XXX1X								0 = OFF/1 = ON, depend on speed2 input setting	x
R		3	1	(Reserved)									Only YANMAR internal	x
R		4	1	(Reserved)									Only YANMAR internal	x
R		5	1	Speed selection enable (APP-IP6)	1XXXX								0 = OFF/1 = ON, depend on speed selection enable input setting	x
N/A		6	3	Not defined										x
R	2		16	**(Reserved)**									YANMAR special function	
N/A				Error indicator	FE**									x
N/A				Not available	FF**									x
N/A	4	1	40	**Not defined**										x

PGN	Acronym
65311	Y_SRF

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Starter protection factor**										x
S		1	1	Safety relay operation	1								Protection = 1, permission = 0	x
S		2	1	Under ECU initial operation	1								Protection = 1, permission = 0	x
S		3	1	External switch	1								Protection = 1, permission = 0	x
S		4	1	Immobilizer	1								Protection = 1, permission = 0	0 (Fixed value)
S		5	1	Starter over time (more than 30 s)	1								Protection = 1, permission = 0	x
S		6	1	CAN Y_EC status	1								Protection = 1, permission = 0	x
S		7	1	Engine stop operation	1								Protection = 1, permission = 0	x
S		8	1	Key switch OFF	1								Protection = 1, permission = 0	x
S		9	1	(Reserved)	1								YANMAR special function, 0 (Fixed value)	x
S		10	1	ECU error (FLASHROM)	1								Protection = 1, permission = 0	0 (Fixed value)
S		11	1	Engine over speed error	1								Protection = 1, permission = 0	0 (Fixed value)
S		12	1	Under EEPROM initial operation, under J1939 DM13 communication	1								Protection = 1, permission = 0	0 (Fixed value)
S		13	1	ECU error (EEPROM)	1								Protection = 1, permission = 0	0 (Fixed value)
S		14	1	(Reserved)									0 (Fixed value)	x
S		15	1	(Reserved)									0 (Fixed value)	x
S		16	1	(Reserved)									0 (Fixed value)	x
S	3	1	16	**Engine stop factor**										x
S		1	1	Engine stall	1								Engine stall = 1, other = 0 When the engine speed become 240 min^{-1} or less after engine starting once.	x
S		2	1	Key switch OFF	1								Key switch OFF = 1, normal = 0 IGNSW terminal is OFF (when self power control is enabled.)	x
S		3	1	Engine stop 1 SW	1								Engine stop by SHUDNSW = 1, normal = 0 Engine stop by SHUDNSW terminal.	x
S		4	1	Engine Stop 2 SW	1								Engine stop by APP-IP7 or CAN = 1, normal = 0 Engine stop by APP-IP7 terminal or CAN.	x
S		5	1	Speed sensor error	1								Speed sensor error = 1, normal = 0 Engine stop by speed sensor error.	0 (Fixed value)
S		6	1	(Reserved)	1								YANMAR special function, 0 (Fixed value)	x
S		7	1	ECU error (FLASHROM)	1								ECU error (FlashROM) = 1, normal = 0 Engine stop by FlashROM check sum error.	0 (Fixed value)
S		8	1	Engine over speed error	1								Over speed error = 1, normal = 0 Engine stop by over speed error.	0 (Fixed value)
S		9	1	(Reserved)	1								0 (Fixed value)	x
S		10	1	Other engine stop operation	1								Engine stop operation = 1, normal = 0 Engine stop by operational limitations.	x
S		11	1	Under EEPROM initial operation	1								ECU error (EEPROM) = 1, normal = 0 Engine stop by EEPROM check sum error.	0 (Fixed value)
S		12	1	ECU error (EEPROM)	1								ECU error (EEPROM) = 1, normal = 0 Engine stop by EEPROM check sum error.	0 (Fixed value)
S		13	1	(Reserved)	1								0	x
S		14	1	(Reserved)	1								0	x
S		15	1	(Reserved)									0	x
S		16	1	(Reserved)									0	x
S	5	1	8	**Immobilizer status**										0 (Fixed value)
S		1	1	Blocked	1								Active = 1 (default)	0 (Fixed value)
S		2	1	Lock or unlock	1								Active = 1	0 (Fixed value)
S		3	1	Unlocked	1								Active = 1	0 (Fixed value)
S		4	1	Locked	1								Active = 1	0 (Fixed value)
S		5	1	N/A Immobilizer	1								Active = 1	0 (Fixed value)
S		6	3	(Reserved)										0 (Fixed value)
S	6	1	16	**Not defined**										x
S	8	1	8	**Digital input status**									External switch OFF (open) = 0/ON (close) = 1	x
S		1	1	IGNSW port	1									x
S		2	7	(Reserved)									0	x

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PGN	Acronym
65318	Y_SRSI

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Low-idle speed**		U16	0.125	0	0	8031.875	min^{-1} (rpm)	188	depend on engine specification	x
S	3	1	16	**Hi-idle speed (under droop mode)**		U16	0.125	0	0	8031.875	min^{-1} (rpm)	532	depend on engine specification	x
S	5	1	16	**Hi-idle speed (under isochro-nous mode)**		U16	0.125	0	0	8031.875	min^{-1} (rpm)		depend on engine specification	x
S	7	1	16	**Available maximum speed**		U16	0.125	0	0	8031.875	min^{-1} (rpm)		depend on control operation	x

PGN	Acronym
65319	Y_ESI

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**Engine control state**		U8							The control state of the engine is shown.	x
S				Ready	000									x
S				Engine cranking	001									x
S				Engine running	010									x
S				Engine stop by detecting engine stop factor	011								Refer to Y_SRF for the detail of engine stop factor.	x
S				Engine stop by normal operation	100									x
N/A				(Reserved)	101								YANMAR special function	x
N/A				Not available										x
S	2	1	2	**Derate mode**										x
S		1	1	Engine power derate	X1								Under derate = 1, normal = 0	x
S		2	1	Engine speed derate	1X								Under derate = 1, normal = 0	x
N/A		3	6	Not defined										x
S	3	1	3	**Optional control**										x
S		1	1	Idling speed up function	XX1								Under low-idle speed up = 1, normal = 0	x
S		2	1	White smoke control function	X1X								Under high-idle speed down = 1, normal = 0	x
S		3	1	(Reserved)									YANMAR special function	
N/A		4	5	Not defined										x
S	4	1	3	**Governor mode**										x
S		1	1	Isochronous	XX1								Isochronous mode = 1	x
S		2	1	Droop	X1X								Droop mode = 1	x
N/A		3	1	(Reserved)									YANMAR special function	x
N/A		4	5	**Not defined**										x
N/A	5	1	32	**Not defined**										x

PGN	Acronym
65526	Y_ETCP1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
N/A	1	1	16	**Not defined**										x
N/A	3	1	8	**Desired torque curve**			1	0	0	250	–			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x
N/A	4	1	16	**Rear articulation A/D value**			1	0	0	250	–			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x
R	6	1	16	**Bus throttle command**			0.00003052	0	0	100	%			x
R				Error indicator	FE									
R				Not available	FF									
N/A	8	1	8	**Governor parameter**			1	0	0	250	–			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x

PGN	Acronym
65304	Y_DPFIF

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
R	1	1	2	**Accelerator interlock switch**								972	Regeneration interlock SW (WDSBSW)	x
R				Off	00									x
R				On	01									x
N/A				Error indicator	10									x
N/A				Not available	11									
R		3	2	**CAN DslPartFltrRegInhbt swtch**								3695	DPF regeneration inhibit SW (REGMSW)	x
R				Not active	00									x
R				Active	01									x
N/A				Error indicator	10									x
N/A				Not available	11									
R		5	2	**CAN DslPartFltrRegenFrce swtch**								3696	DPF regeneration request SW (REGSW)	x
R				Not active	00									x
R				Active	01									x
N/A				Error indicator	10									x
N/A				Not available	11									
N/A		7	2	**Not used**									Ignored	x
N/A	2	1	56	**Not used**									Ignored	x

PGN	Acronym
61184	Y_ECM3

(Currently under review)

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
R	1	1	8	**(Reserved)**										
R	2	1	8	**(Reserved)**										
R	3	1	2	**Throttle calibration trigger**										
R				No request	00									
R				Trigger	01									
R				Error	10									
R				Not available	11									
R		3	2	**Throttle calibration state**										
R				Not calibrating	00									
R				Calibrating	01									
R				Error	10									
R				Not available	11									
R		5	2	**Calibration mode ready**										
R				No	00									
R				Yes	01									
R				Rsvd/stds	10									
R				Don't care/take no action	11									
R		7	2	**Calibration complete**										
R				Not complete	00									
R				Complete	01									
R				Rsvrd-Stds	10									
R				Don't care/take no action	11									
N/A	4	1	40	**(Reserved)**										

PGN	Acronym	
61184	Y_ECM3	(Currently under review)

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**(Reserved)**										
S	2	1	8	**(Reserved)**										
S	3	1	2	**Throttle calibration trigger**										
S				No request	00									
S				Trigger	01									
S				Error	10									
S				Not available	11									
S		3	2	**Throttle calibration state**										
S				Not calibrating	00									
S				Calibrating	01									
S				Error	10									
S				Not available	11									
S		5	2	**Calibration mode ready**										
S				No	00									
S				Yes	01									
S				Rsvd/stds	10									
S				Don't care/take no action	11									
S		7	2	**Calibration complete**										
S				Not complete	00									
S				Complete	01									
S				Rsvrd-Stds	10									
S				Don't care/take no action	11									
N/A	4	1	40	**(Reserved)**										

PGN	Acronym
65320	Y_EGRP

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	8	**EGR valve target position**		U8	1	0	0	106	STEP			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x
S	2	1	8	**EGR valve target position (calculated value by MAP)**		U8	1	0	0	106	STEP			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x
S	3	1	8	**Exhaust gas lambda**		U8	0.02	0	0	5	?			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x
S	4	1	8	**EGR valve actual position**		U8	1	0	0	106	STEP			x
N/A				Error indicator	FE								When EGR valve communication failure occurred.	
N/A				Not available	FF									x
S	5	1	16	**Target NOx (final value)**		U16	0.1	0	0	6425.5	ppm			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	7	1	16	**Not used**	FFFF									x

PGN	Acronym
65321	Y_ETVP

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Exhaust throttle target position**		U16	0.1	0	0	100	%			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**Exhaust throttle actual position**		U16	0.1	0	0	100	%			x
S				Error indicator	FE00								When exhaust throttle communication failure occurred.	
N/A				Not available	FFFF									x
S	3	1	16	**Exhaust gas mass flow**		U16	0.02	0	0	1285.1	kg/h			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**Exhaust gas volume flow**		U16	0.02	0	0	1285.1	kg/h			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	5	1	32	**Not used**										x

PGN	Acronym
65322	Y_ATF

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	4	**DPF regeneration mode status**		U4	1	0	0	15	–			x
S				Normal operation	0000									x
S				Assist regeneration	0001									x
S				Reset regeneration	0010									x
S				Stationary regeneration	0011									x
S				(Reserved)	0100									x
N/A				Not used	1111									x
S		5	4	**DPF regeneration control status**		U4	1	0	0	15	–			x
S				Normal operation or notification of DPF regeneration control	0000									x
S				Start of automatic speed control by ECU (gradually acceleration)	0001								Only stationary regeneration	x
S				+ After injection and retard, intake throttle operation (target position limitation)	0010									x
S				+ Intake throttle operation (no limitation of target position)	0011									x
S				+ Post injection (phase 1)	0100									x
S				+ Judgement of finishing the DPF regeneration (start of judg-ment by the DPF middle temperature)	0101									x
S				+ Post injection (phase 2)	0110									x
S				+ Judgement of finishing the DPF regeneration	0111									x
S				+ Finish of automatic speed con-trol by ECU (gradually deceleration)	1000								Only stationary regeneration	x
S				+ Accumulation value reset	1001									x
N/A				Not used	1111									x
S	2	1	4	**Emergency mode status**		U4	1	0	0	15	–		1 = Assist regen. -> Reset regen. , 2 = Reset regen. -> Stationary regen. 3 = Stationary regen. -> Backup mode	x
S				Not detected	0000									x
S				Emergency detection when operating assist regeneration	0001									x
S				Emergency detection when operating reset regeneration	0010									x
S				Emergency detection when operating stationary regeneration	0011									x
N/A				Not used	1111									x
S		5	4	**Stationary regeneration request flag**		U4	1	0	0	15	–			x
S				No stationary regeneration request	0000									x
S				Stationary regeneration request (by operator commanded)	0001									x
S				Stationary regeneration request (by emergency)	0010									x
S				(Reserved)	0011									x
N/A				Not used	1111									x
S	3	1	4	**Ash cleaning request flag**		U4	1	0	0	15	–			x
S				No ash cleaning request	0000									x
S				Ash cleaning request (low priority)	0001									x
S				Ash cleaning request (high priority)	0010									x
N/A				Not used	1111									x
S	3	5	36	**Not used**									Padded with “1”	x
S	8	1	8	**DPF regeneration progress percentage**		U8	1	0	0	100	%			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x

PGN	Acronym
65327	Y_PMD

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Amount of particulate matter (C method)**		U16	0.01	0	0	642.55	g/L			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**Amount of particulate matter (P method)**		U16	0.01	0	0	642.55	g/L			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	5	1	16	**Amount of particulate matter (T method)**		U16	0.01	0	0	642.55	g/L			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	7	1	16	**Amount of particulate matter (F method)**		U16	0.01	0	0	642.55	g/L			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x

PGN	Acronym
65314	Y_DPFC1

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**DOC surface temperature**		U16	0.03125	-273	-273	1735	deg C			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**DPF surface temperature**		U16	0.03125	-273	-273	1735	deg C			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	5	1	16	**Amount of DPF ash accumulation**		U16	0.01	0	0	642.55	g/L			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	7	1	16	**Not defined**	FFFF									x

PGN	Acronym
65295	Y_POI

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Actual post injection amount**		U16	0.1	-100	-100	6453.5	mm^3/st			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**Target after injection amount**		U16	0.1	-3212.7	-3212.7	3212.8	mm^3/st			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	5	1	16	**Target post injection correction amount**		U16	0.1	-3212.7	-3212.7	3212.8	mm^3/st			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	7	1	16	**Total injection amount**		U16	0.1	-100	-100	6453.5	mm^3/st			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x

PGN	Acronym
65296	Y_DPFC2

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Target DPF temperature (OutrLop)**		U16	0.03125	-273	-273	1735	deg C			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**DPF temperature deviation amount (OutrLop)**		U16	0.03125	-1004	-1004	1004	deg C			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	5	1	16	**Target DPF temperature (InrLop)**		U16	0.03125	-273	-273	1735	deg C			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	7	1	16	**DPF temperature deviation amount (InrLop)**		U16	0.03125	-1004	-1004	1004	deg C			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x

PGN	Acronym
65305	Y_EST

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Target engine speed**		U16	0.125	0	0	8031.875	min^{-1} (rpm)			x
N/A				Error indicator	FE**									x
N/A				Not available	FF**									x
S	3	1	16	**Target injection amount**		U16	0.1	-100	-100	6453.5	mm^3/st			x
N/A				Error indicator	FE**									x
N/A				Not available	FF**									x
S	5	1	16	**Basic injection timing**		U16	0.1	-3212.7	-3212.7	3212.8	° (CA)			x
N/A				Error indicator	FE**									x
N/A				Not available	FF**									x
S	7	1	1	**Acceleration detection status 1**		U1	1	0	0	1	–			x
S				Not detected	0									x
S				Acceleration detection	1									x
S		2	1	**Acceleration detection status 2**		U1	1	0	0	1	–			x
S				Not detected	0									x
S				Acceleration detection	1									x
S		3	1	**Load detection status 1**		U1	1	0	0	1	–			x
S				Not detected	0									x
S				Load detection	1									x
S		4	1	**Load detection status 2**		U1	1	0	0	1	–			x
S				Not detected	0									x
S				Load detection	1									x
S		5	4	**Not used**	1111									x
S	8	1	8	**Not used**	FF									x

PGN	Acronym
65280	Y_MPR

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Actual exhaust manifold pressure**		U16	0.1	0	0	6425.5	kPa			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**Actual intake manifold pressure**		U16	0.1	0	0	6425.5	kPa			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	5	1	8	**Target intake pressure**		U8	1	0	0	250	kPa			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x
S	6	1	8	**Target intake throttle rate**		U8	0.4	0	0	100	%			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x
S	7	1	16	**Not used**	FFFF									x

PGN	Acronym
65281	Y_POFS

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Exhaust manifold pressure offset value**		U16	0.1	-3000	-3000	3276.7	kPa			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**Intake manifold pressure offset value**		U16	0.1	-3000	-3000	3276.7	kPa			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	5	1	16	**Smoke limit injection volume**		U16	0.1	-100	-100	6453.5	mm^3/st			x
N/A				Error Indicator	FE00									x
N/A				Not available	FFFF									x
S	7	1	8	**Smoke limit injection volume (lambda minimum value)**		U8	0.02	0	0	5	?			x
N/A				Error indicator	FE									x
N/A				Not available	FF									x
S	8	1	8	**Not used**	FF									x

PGN	Acronym
65294	Y_INJQ

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	16	**Pre injection amount**		U16	0.1	-100	-100	6453.5	mm^3/st			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	3	1	16	**Main injection amount**		U16	0.1	-100	-100	6453.5	mm^3/st			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	5	1	16	**After injection amount**		U16	0.1	-100	-100	6453.5	mm^3/st			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x
S	7	1	16	**Post injection amount**		U16	0.1	-100	-100	6453.5	mm^3/st			x
N/A				Error indicator	FE00									x
N/A				Not available	FFFF									x

PGN	Acronym	
65291	Y_EOM	(Only Bosch-ECU)

R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note	V191R46 Impleme-nted
S	1	1	32	**Engine operation mode**										x
S		1	1	Normal mode									0 = Not active, 1= Active	x
S		2	1	Regeneration mode1									0 = Not active, 1= Active	x
S		3	1	Regeneration mode2									0 = Not active, 1= Active	x
N/A		4	1	Not used										x
N/A		5	1	Not used										x
N/A		6	1	Not used										x
N/A		7	1	Not used										x
N/A		8	1	Not used										x
N/A		9	1	Not used										x
N/A		10	1	Not used										x
S		11	1	Regeneration mode3									0 = Not active, 1= Active	x
S		12	1	Regeneration mode4									0 = Not active, 1= Active	x
S		13	1	Regeneration mode5									0 = Not active, 1= Active	x
S		14	1	Regeneration mode6									0 = Not active, 1= Active	x
S		15	1	Transient mode 1									0 = Not active, 1= Active	x
N/A		16	1	Not used										x
N/A		17	1	Not used										x
N/A		18	1	Not used										x
N/A		19	1	Not used										x
S		20	1	Stage 1									0 = Not active, 1= Active	x
N/A		21	1	Not used										x
N/A		22	1	Not used										x
N/A		23	1	Not used										x
N/A		24	1	Not used										x
N/A		25	1	Not used										x
N/A		26	1	Not used										x
N/A		27	1	Not used										x
N/A		28	1	Not used										x
N/A		29	1	Not used										x
N/A		30	1	Not used										x
N/A		31	1	Not used										x
S		32	1	Ramp end									0 = Not active, 1= Active	x
S	5	1	32	**Not used**										x

Appendix D

DTC code list (draft)

ISO 14229-1 (Tentative)		J1939 (Tentative)			Error item	
P code	Failure type	SPN (HEX)	SPN (DEC)	FMI	Area	Status
P0336	1F	7F8A0	522400	2	Crankshaft speed sensor	Error (abnormal signal)
P0337	18			5		Error (no-signal)
P0341	1F	7F8A1	522401	2	Camshaft speed sensor	Error (abnormal signal)
P0342	18			5		Error (no-signal)
P1341	71			7		Crank angle error
P0123	15	5B	91	3	Accelerator sensor 1	Error (high voltage)
P0122	14			4		Error (low voltage)
P02E9	15	33	51	3	Intake throttle position sensor	Error (high voltage)
P02E8	14			4		Error (low voltage)
P2455	15	CB3	3251	3	DPF differential pressure sensor	Error (high voltage)
P2454	14			4		Error (low voltage)
P2452	(TBD)			0		High differential pressure
P0473	15	4B9	1209	3	EGR pressure sensor (high-pressure side)	Error (high voltage)
P0472	14			4		Error (low voltage)
P0118	15	6E	110	3	Coolant temperature sensor	Error (high voltage)
P0117	14			4		Error (low voltage)
P0217	16			0	Coolant temperature	High temperature (overheat)
P0113	15	69	105	3	Fresh air temperature sensor	Error (high voltage)
P0112	14			4		Error (low voltage)
P1434	15	CB2	3250	3	DPF middle temperature sensor	Error (high voltage)
P1435	14			4		Error (low voltage)
P0420	(TBD)			1		Low temperature
P1426	(TBD)			0		High temperature
P1428	15	CAA	3242	3	DPF inlet temperature sensor	Error (high voltage)
P1427	14			4		Error (low voltage)
P1436	(TBD)			0		High temperature
P0183	15	AE	174	3	Fuel temperature sensor	Error (high voltage)
P0182	14			4		Error (low voltage)
P0168	16			0		High Temperature
P0193	15	9D	157	3	Rail pressure sensor	Error (high voltage)
P0192	14			4		Error (low voltage)
P0238	15	66	102	3	EGR low-side pressure sensor	Error (high voltage)
P0237	14			4		Error (low voltage)
P2229	15	6C	108	3	Atmospheric pressure sensor	Error (high voltage)
P2228	14			4		Error (low voltage)
P1231	(TBD)			10		Abnormal atmospheric pressure
P1455	15	E19	3609	3	DPF hi-side pressure sensor	Error (high voltage)
P1454	14			4		Error (low voltage)
P041D	(TBD)	19C	412	3	EGR gas temperature sensor	Error (high voltage)
P041C	(TBD)			4		Error (low voltage)
P040D	(TBD)	69	105	3	Intake air temperature sensor	Error (high voltage)
P040C	(TBD)			4		Error (low voltage)
P0546	(TBD)	AD	173	3	Exhaust temperature sensor	Error (high voltage)
P0545	(TBD)			4		Error (low voltage)
P068B	71	5CD	1485	7	Main relay	Stick error
P068A	1F			2		Power off without self-holding

ISO 14229-1 (Tentative)		J1939 (Tentative)			Error item	
P code	Failure type	SPN (HEX)	SPN (DEC)	FMI	Area	Status
P0541	19	7F803	522243	6	Starting aid relay	Short-circuit with GND
P0543	18			5		Disconnection
P0660	(TBD)	B86	2950	5	Intake throttle actuator	H-bridge circuit: No-load
P1658	15			3		H-bridge output 1: Short-circuit with power supply
P1659	14			4		H-bridge output 1: Short-circuit with GND
P1661	15	B87	2951	3		H-bridge output 2: Short-circuit with power supply
P1662	14			4		H-bridge output 2: Short-circuit with GND
P0204 (4TNV) P0203 (3TNV)	18	28B (4TNV) 28C (3TNV)	651 (4TNV) 652 (3TNV)	5	Injector 1 4TNV: Cyl No. 4 3TNV: Cyl No. 3 Port 4TNV: 1 - 2 3TNV: 1 - 3	Disconnection
P1272 (4TNV) P1263 (4TNV)	00			11		Failure
P1271 (4TNV) P1262 (3TNV)	15			3		Short-circuit
P0271 (4TNV) P0268 (3TNV)	19			6		Short-circuit (internal coil)
P0202	18	28D	653	5	Injector 2 4TNV: Cyl No. 2 3TNV: Cyl No. 2 Port 4TNV: 2 - 1 3TNV: 1 - 2	Disconnection
P1266	00			11		Failure
P1265	15			3		Short-circuit
P0265	19			6		Short-circuit (internal coil)
P0201	18	28E	654	5	Injector 3 4TNV: Cyl No. 1 3TNV: Cyl No. 1 Port 4TNV: 2 - 2 3TNV: 1 - 1	Disconnection
P1263	00			11		Failure
P1262	15			3		Short-circuit
P0262	19			6		Short-circuit (internal coil)
P0203	18	28C	652	5	Injector 4 4TNV: Cyl No. 3 Port 4TNV: 1 - 1	Disconnection
P1269	00			11		Failure
P1268	15			3		Short-circuit
P0268	19			6		Short-circuit (internal coil)
P1146	19	AED	2797	6	Injector (common)	Short circuit (4 Cylinder engine: Cyl No. 1, 4) (3 Cylinder engine: All Cyl)
P1149	19	AEE	2798	6		Short circuit (4 Cylinder: Cyl No. 2, 3)
P0611	92	10A1	4257	12		IC error
P0627	18	279	633	5	Supply pump (MPROP)	Disconnection
P1642	18			6		Hi-side: Short-circuit with GND
P1641	15	7F94B	522571	3		Lo-side: Short-circuit with power supply

ISO 14229-1 (Tentative)		J1939 (Tentative)			Error item	
P code	Failure type	SPN (HEX)	SPN (DEC)	FMI	Area	Status
P0094	17	9D	157	18	Rail pressure error	Rail pressure deviation error when actual pressure is too low
P0093	16			15		Rail pressure deviation error when actual pressure is too high
P0088	17			0		Fuel rail/system pressure: Too high
P000F	92			16	PLV	Fuel system over pressure relief valve activated
P0219	17	BE	190	16	Engine overspeed 1	
U040C	92	7F972	522610	19	CAN communication 1 (CAN1)	CAN1 (for EGR): Data length code error (received message)
U010B	92			9		CAN1 (for EGR): Time out error (received message)
U0292	82	7F964	522596	9	CAN communication 2 (CAN2)	CAN2 (TSC1): Time out error (received message)
U1292	82	7F967	522599	9		CAN2 (Y_ECR1): Time out error (received message)
(TBD)	(TBD)	(TBD)	(TBD)	(TBD)		CAN2 (Y_EC): Time out error (received message)
(TBD)	(TBD)	(TBD)	(TBD)	(TBD)		CAN2 (Y_RSS): Time out error (received message)
(TBD)	(TBD)	(TBD)	(TBD)	(TBD)		CAN2 (VH): Time out error (received message)
(TBD)	(TBD)	(TBD)	(TBD)	(TBD)		CAN2 (Y_ETCP1): Time out error (received message)
(TBD)	(TBD)	(TBD)	(TBD)	(TBD)		CAN2 (Y_DPFIF): Time out error (received message)
P1409	71	AE7	2791	7	EGR valve	Feedback error
P0403	92			12		Disconnection (motor coil)
P1405	92			12		Short circuit (motor coil)
P0488	92			12		Position sensor error
U0401	82			9		CAN communication error
U0401	92			12		Error (EGR valve target value)
P0404	17			0		Error (high voltage)
P0404	16			1		Error (low voltage)
P148A	71			7		Stick error
P049D	71			7		Initialize error
P1410	16			1		Thermistor error (high temperature)
P1411	16			1		Thermistor error (low temperature)
P0601	92	276	630	12	EEPROM	Deletion error
P160E						Read error
P160F						Write error

ISO 14229-1 (Tentative)		J1939 (Tentative)			Error item	
P code	Failure type	SPN (HEX)	SPN (DEC)	FMI	Area	Status
P1609	92	7FAF2	522994	12	E-ECU internal	Power supply for sensor 1 (5 V): Error
P1618	92			12		Power supply for sensor 2 (5 V): Error
P1619	92			12		Power supply for sensor 3 (5 V): Error
P1624	92			12		Power supply for sensor internal: Error (low voltage)
P1608	92			12		Power supply for IC: Error (high voltage)
P1617	92			12		Power supply for IC: Error (low voltage)
P160A	15			3		Actuator relay 1: Short-circuit with power supply
P1625	15			3		Actuator relay 2: Short-circuit with power supply
P1626	14			4		Actuator relay 1: Short-circuit with GND
P1633	14			4		Actuator relay 2: Short-circuit with GND
P1607	92			12		WDA/ABE communication error
P1613	92			12		CY146 SPI communication error
P1615	92			12		CY320 SPI communication error
P1616	92			12		R2S2 MSC communication error
P160D	92			12		WDA/ABE shut off (too low voltage)
P1639	92			12		WDA/ABE shut off (too high voltage)
P1640	92			12		WDA/ABE shut off (operation malfunction)
P160B	00			11		ECU soft reset 1
P1636	00			11		ECU soft reset 2
P1637	00			11		ECU soft reset 3
P1101	17	7F853	522323	0	Air cleaner blockage alarm	
P1151	17	7F859	522329	0	Oily water separator alarm	
P1562	(TBD)	A7	167	5	Charge switch	Disconnection
P1568	16			1		Charge failure
P1192	14	64	100	4	Oil pressure switch	Disconnection
P1198	16			1		Low pressure
P2463	(TBD)	7F94D	522573	0	DPF	Over accumulation (C method)
P1463	(TBD)	7F94E	522574	0	DPF	Over accumulation (P method)
P2458	(TBD)	7F94F	522575	7	DPF	Regeneration defect (stationary regeneration failed)
P2459	(TBD)	7F951	522577	11	DPF	Regeneration defect (stationary regeneration not operated)
P1437	(TBD)	CB3	3251	16	DPF	Maintenance (maintenance is not conducted during the regular time)
P242F	(TBD)	E88	3720	16	DPF operator interface	Ash cleaning request 1
P1420	(TBD)			0	DPF operator interface	Ash cleaning request 2
P1421	(TBD)	E87	3719	16	DPF operator interface	Stationary regeneration standby
P1424	(TBD)			0	DPF operator interface	Back up mode
–	–	–	–	–	DPF operator interface	Reset regeneration inhibit

Section 16

P.T.O. SYSTEMS

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To make the most of engine performance, it is necessary to properly design the Power Take-Off System (P.T.O.). Power Take-Off Systems can be divided into the main P.T.O., front P.T.O. and hydraulic pump drive P.T.O.

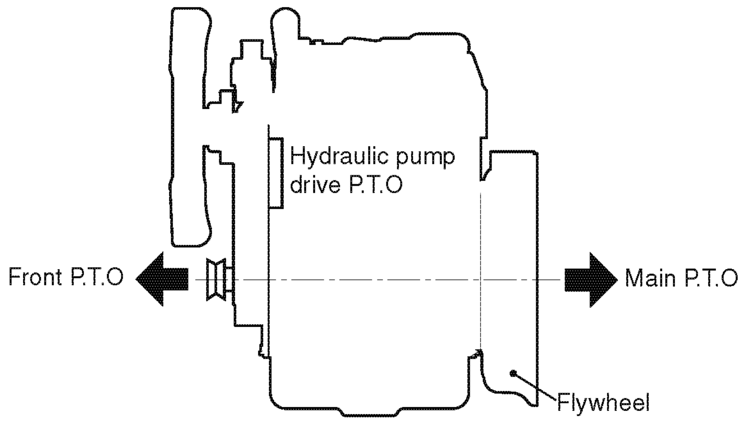


Figure 16-1

Direct Coupled P.T.O. Configurations

Allowable Torque from Front P.T.O.

When you use the main P.T.O. configuration, 100 % of the engine output may be obtained at the m flywheel side of the engine. The allowable torque take-off from the front P.T.O. side of the engine is shown in the table below, but the radiator position, etc. must be considered separately.

Allowable torque in front P.T.O. (direct coupling)

For 3TNV88C/86CT, 4TNV88C/86CT, the optional steel V-pulley can be used to increase the allowable torque.

Model	Allowable torque N·m	
	Standard pulley (made of cast iron)	Option pulley (made of steel)
3TNV88C, 3TNV86CT	43	56
4TNV88C, 4TNV86CT	57	75
4TNV98C, 4TNV98CT	(Option) 63	–

Note:These torque values are continuous torques, and not impact torques.

Allowable thrust load

The thrust load which is applied to the flywheel is supported by the thrust bearings installed in the first main bearing of the crankshaft end (flywheel side).

Allowable thrust load must be equal to or below the values shown in the table below considering the allowable contact pressure of the thrust bearings.

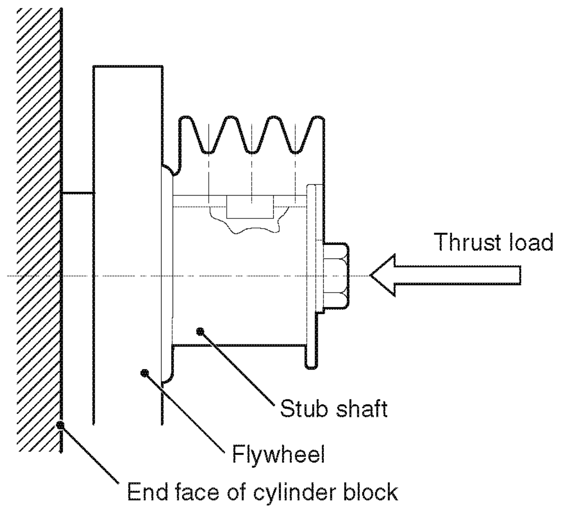


Figure 16-2

Unit: N

Engine model name	Static thrust load	Dynamic thrust load
3TNV88C, 3TNV86CT	2842	1372
4TNV88C, 4TNV86CT	2842	1372
4TNV98C, 4TNV98CT	3136	1568

Cautions for Direct Coupling to Main P.T.O.

Maximum weight and length considerations

If driven machine (such as a hydraulic pump or a generator) is directly coupled to the flywheel housing, you must consider limitations on the weight and length of the driven machine.

The driven machine can be attached to the engine when the value obtained from the following formula is less than the value shown in the Max. column in the following table. Otherwise, a means of supporting the machine must be provided.

$$M = L \times W \times g$$

M	: Bending moment at the rear face of flywheel housing	N·m
L	: Length from coupling face of flywheel housing to gravity center of equipment	m
W	: Mass weight of equipment	kg
g	: Acceleration of gravity	9.81 m/sec^2

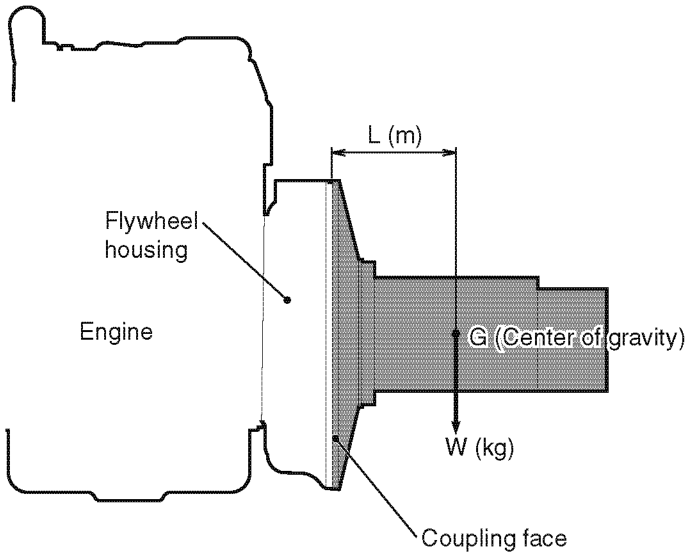


Figure 16-3

Engine model name	Max: maximum bending moment at the coupling face of flywheel housing (N·m)	Housing type
3TNV88C, 3TNV86CT, 4TNV88C, 4TNV86CT	1770	SAE #5
4TNV98C, 4TNV98CT	1960	SAE #4

Allowable runout of flywheel housing

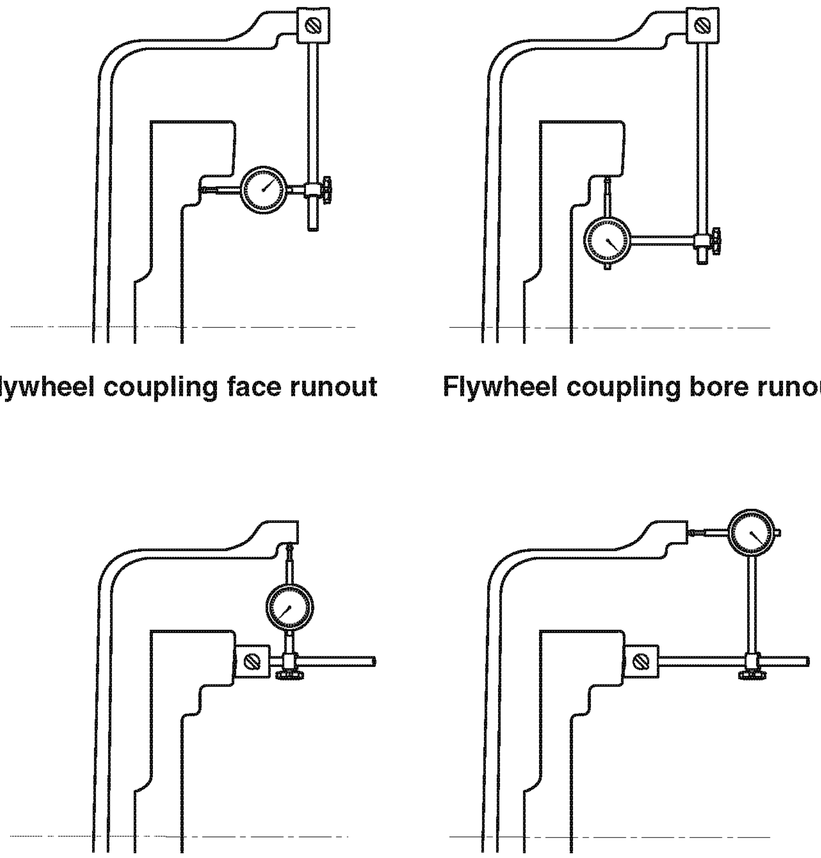
In direct coupled applications, the runout of the coupling face with respect to crankshaft direction is called face runout and the runout of the coupling axis with respect to flywheel axis is called bore runout. When these runout are large, excessive load is applied on the crankshaft and bearing which may cause abnormal abrasion of bearing or breakage of crankshaft.

Refer once to the table below for the general face and bore runout amount.

Housing size	Bore runout (*[1]TIR mm)	Face runout (*[1]TIR mm)
SAE #6	0.18	0.18
SAE #5	0.20	0.20
SAE #4	0.23	0.23
SAE #3	0.25	0.25

**1: Dial indicator reading*

To read face and bore runout with a dial gauge, install a gauge as shown **(Figure 16-4)**. Read the graduation of the dial gauge while slowly rotating the flywheel manually.



Flywheel coupling face runout **Flywheel coupling bore runout**

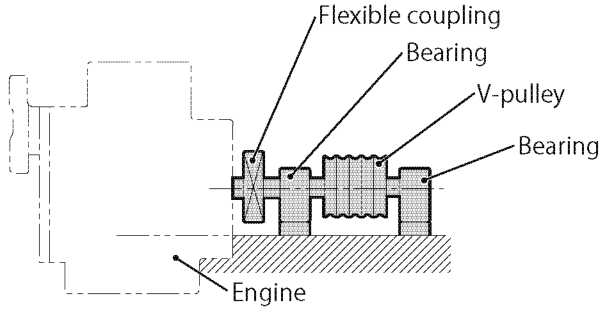
Housing bore coupling **Housing face coupling**

Figure 16-4

Caution for Side Load

- For heavy side load belt or multiple belt drives, provide external bearing housings. If external bearings are not used, the engine may be damaged due to crankshaft bending or breakage.

External bearing installation example



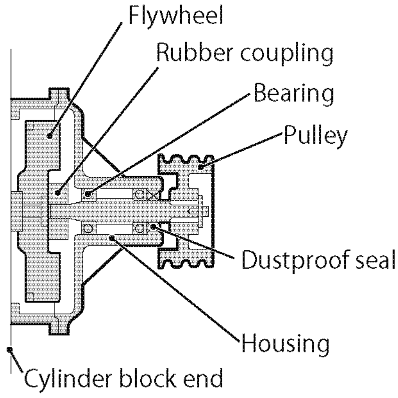


Figure 16-5

- If a side belt drive is required and an external bearing cannot be used because there is no room on the driven machine, refer to *How to Calculate the Side Load on page 16-9*, *Allowable Side Load for Main P.T.O. on page 16-27* and *Allowable Side Load for Front P.T.O. on page 16-29*. *How to Calculate the Side Load on page 16-9* describes V-belt applications. First calculate the side load for V-belt drive according to the required horsepower and speed. For a side belt drive from the main P.T.O., check that the side load is within the allowable range in *Allowable Side Load for Main P.T.O. on page 16-27*. For a belt drive from the front P.T.O., check the front load is according to the diagram in *Allowable Side Load for Front P.T.O. on page 16-29*. Belt manufacturers can be consulted for calculation assistance.
- Prepare the following data before starting the analysis:
  - Engine type
  - Required horsepower and speed for driven machine
  - Effective diameter of pulleys (on the engine side and driven machine side: D_1, D_2)
  - V-pulley overhang (L and ℓ)
    * When two or more belts are used, use the center of the V-pulley.
  - Types and numbers of belts used.
  - Relative positions of engine and driven machine (a, b)
  - Belt center-to-center distance (C)

How to calculate C

$$C = \sqrt{a^2 + b^2}$$

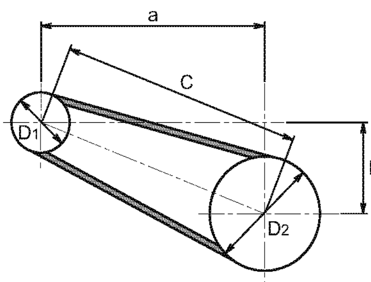
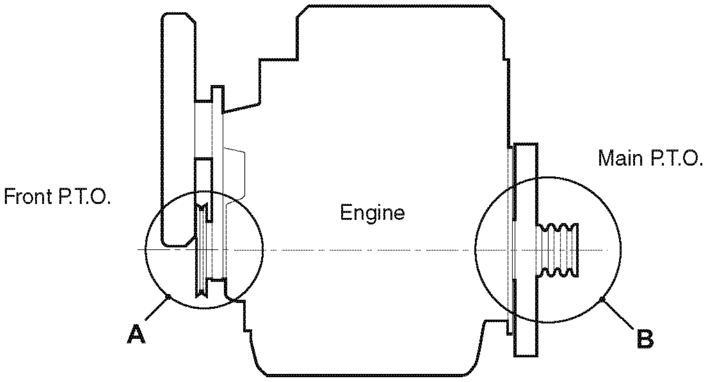
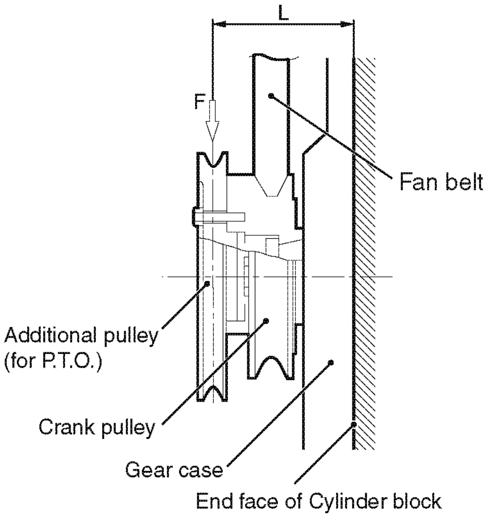


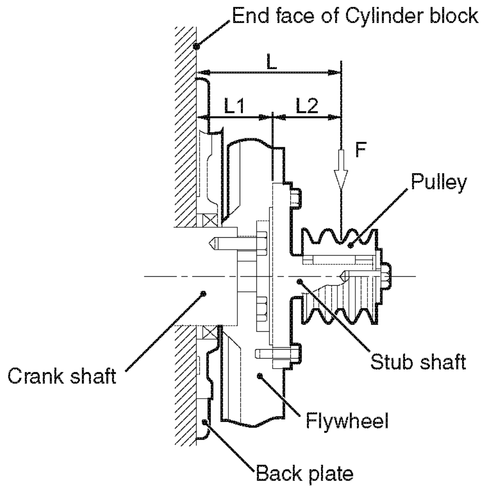
Figure 16-6



Detail of "A"

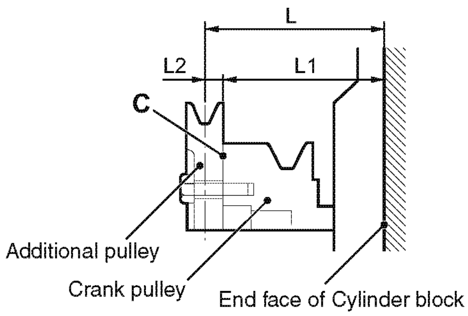


Detail of "B"



Calculation method of distance L

L is the sum of L1 and L2, whereas L2 is the distance between fixed surface C of the crank pulley and the groove center portion of the additional pulley.
L1 varies with the engine or the used crank pulley.
If you are unsure, please contact YANMAR.



Calculation method of distance L

L is the sum of L1 and L2, whereas L2 is the distance between the center of the groove that is furthest away from the stub shaft mounting surface and the center of the groove that is closest to the stub shaft mounting surface.
L1 varies with the engine or the used crank pulley.
If you are unsure, please contact YANMAR.

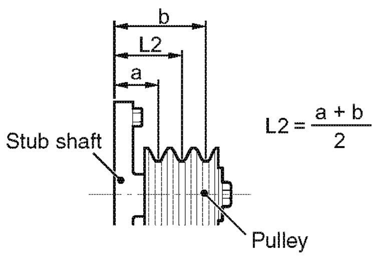


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Figure 16-7

How to Calculate the Side Load

Example

A side belt drive is connected to the front P.T.O. of a 4TNV98C engine to provide power to a 9kW/1500 min^{-1} generator. Is the side belt load within the range specified for the 4TNV98C engine?

This is the procedure needed to evaluate this situation:

1. Determine "required power" for driving this generator.
2. Examine V-belt and V-pulley requirements
   1- Determine the "design power" exerted by V-belt based on the "required power".

   2- Determine the "type" of V-belt.

   3- Calculate the length of V-belt to determine the "nominal number".

   4- Determine the "transmission capacity" of V-belt.

   5- Determine the "number" of V-belts.
3. Determine the "initial tension" of V-belt.
4. Determine the "shaft load" of side load.
5. Determine the "overhang" of V-pulley.
6. Examine whether the "shaft load" and "overhang" of V-pulley are within the allowable limits that are specified in "Allowable Side Load for Front P.T.O." of the pertinent engine.
7. If the V-pulley interferes with the radiator while the machine is running, you may need to shift the position of the radiator.

Calculating Required Power for the Generator (P_N)

Since the power generation efficiency of this generator is unknown, refer to the data shown in the table, *Generator Capacity and Engine Output on page 19-20*.

According to this table, the generator efficiency (η) at the generator capacity of around 9 kW is approx. 82%. Use the value of η provided by the manufacturer of the generator, if available.

$$\text{Required power } (P_N) = \frac{\text{Generator capacity}}{\text{Generator efficiency}} = \frac{9\ kW}{0.82} = 11\ kW$$

Examining Requirements for V-belt and V-pulley

Design power of V-belt (P_d)

$$P_d = P_N(K_0 + K_i)$$

P_d	: Design power	kW
P_N	: Required power	kW
K_0	: Service factor	(Refer to *Service factor (K_0) on page 16-21*)
K_i	: Idler correction factor	(Refer to *Idler correction factor (K_i) on page 16-22*)

If you assume that this generator is operated intermittently for 3 to 5 hours per day, the service factor (K_0) of 1.1 is used (refer to *Service factor (K_0) on page 16-21*). If the idler is not used, the idler correction factor (K_i) shown in *Idler correction factor (K_i) on page 16-22* is ignored.

$$P_d = P_N(K_0 + K_i) = 11.0(1.1 + 0)$$

$$= 12.1\ kW$$

Determining type of V-belt

Select a type of V-belt to be used from **(Figure 16-8)**.

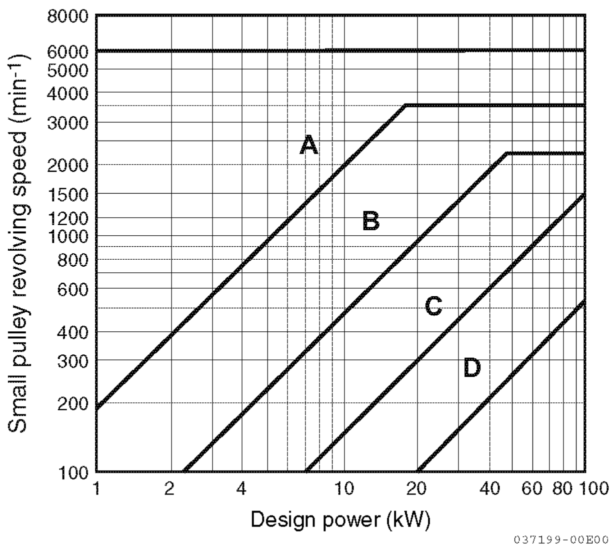

Figure 16-8

Since the speed of generator for this case is 1500 min^{-1}, if the engine is operated at N = 2250 min^{-1}, the pulley ratio is 0.667. For this case, the engine side pulley is the small pulley. (When the engine is operated at 1500 min^{-1}, the use of the pulley ratio of 1.0 causes no problem if the engine output is larger than the design power of V-belt (P_d). The use of the simple ratio makes the future calculations easier.)

According to the V-belt selection table, the use of one piece of B type belt could be suitable for the case of design power 12.1 kW of small pulley at 2250 min^{-1}. However, for reliability, we decide to use multiple A type belts.

Thus, use A type belts here.

Calculating length of V-belt to determine “Nominal number”

To obtain the length of V-belt, first use the following formula to calculate the V-belt length (L) that corresponds to the distance between engine and generator shafts (C). Then, use *V-belt length on page 16-22* to select a V-belt that is nearest to the calculated length of L to find the nominal number and record the number. The nominal number selected here is used for the following calculations.

$$L = 2C + 1.57(d_1 + d_2) + \frac{(d_2 - d_1)^2}{4C}$$

L	:	Calculated V-belt length	mm
C	:	Distance between shafts	mm
d_1	:	Pitch circle diameter of small V-pulley	mm
d_2	:	Pitch circle diameter of large V-pulley	mm

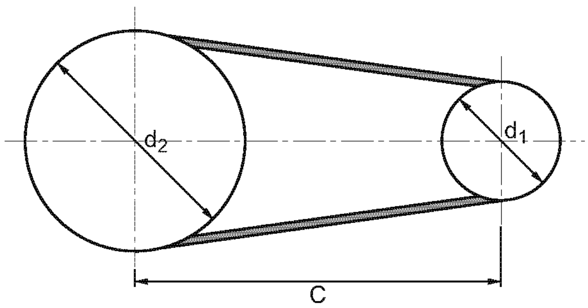

Figure 16-9

To calculate the V-belt length (L), first determine the pitch circle diameters of small and large V-pulleys (d_1 and d_2), and shaft distance (C) first.

Determining pitch circle diameter of small V-pulley (d_1)

When selecting the size (pitch circle diameter: d_1) of engine side V-pulley, the size of PTO mount for the engine crankshaft pulley should be determined carefully. For this example, the generator is driven through the front pulley of a 4TNV98C. Based on the Parts Catalog and Product Guide, the part number of the crankshaft pulley that is suited for this application is 129907-21660. The *YANMAR TNV Option Menu* size of the PTO mount for this crankshaft is pc ϕ 78, and its outer diameter is ϕ 130. Based on this data, the minimum pitch circle diameter (d_1) of the V-pulley for driving the generator is around 130 mm. In this example, the part with d_1 = 140 mm is selected (this includes “allowances”).

Determining pitch circle diameter of large V-pulley (d_2)

Since the engine speed of 2250 min^{-1}, generator speed of 1500 min^{-1}, and engine side small pulley pitch circle diameter (d_1) of 140 mm are already given, the generator side large pulley pitch circle diameter (d_2) is given by the following formula:

$$\text{Large pulley pitch circle diameter } (d_2) = \frac{\text{Engine min}^{-1}}{\text{generator min}^{-1}} \times \text{small pulley pitch circle diameter } (d_1)$$

$$= \frac{2250}{1500} \times 140$$

$$= 210 \text{ mm}$$

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Determining distance between shafts (C)

The distance between engine crankshaft and generator shaft is determined by arranging their outline drawings to determine whether there is sufficient room for engine operation and maintenance.

For this case, the distance between the shafts (C) is assumed to be 600 mm.

Determining V-belt length based on calculation (L)

The values of the parameters that have been determined above are substituted into the equation that gives the required length of V-belt (L).

$$L = 2C + 1.57(d_1 + d_2) + \frac{(d_2 - d_1)^2}{4C}$$

$$= 2 \times 600 + 1.57(140 + 210) + \frac{(210 - 140)^2}{4 \times 600}$$

$$= 1751.5 \quad mm$$

Determining "Nominal number" of V-belt

The V-belt length (L) of 1751.5 mm is a calculated value. Based on it, a commercially available product with length nearest to this value is selected from *V-belt length on page 16-22*.

As a result, the specifications of the required belt are determined as "A" type with nominal number of 69 and belt length of 1753 mm. (For actual design, the shaft distance (C) is obtained by calculating back from the length of the commercial V-belt selected.)

Determining "Transmission capacity" (P) of V-belt

The transmission capacity of each V-belt is the standard transmission capacity plus additional transmission capacity that is caused by the rotation ratio. The standard transmission capacity of a V-belt is defined as the transmission capacity of the V-belt with a standard length when the contact angle (θ) is 3.14 radians (180 degrees). In this example the standard length V-belt has a length correction factor of 1.00 (*Length correction factor (K_L) on page 16-24*). The rotation ratio is obtained by dividing pitch circle diameter of large V-pulley (d_2) by the same of small V-pulley (d_1), which is equivalent to the rotation ratio = d_2 / d_1. (Note that it is different from pulley ratio.)

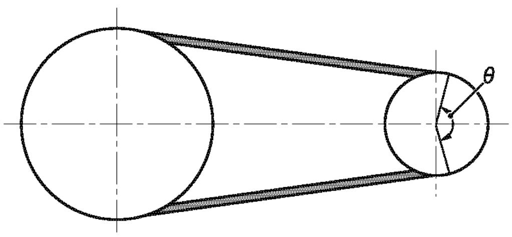


Figure 16-10

The transmission capacity of each V-belt (P) is given by the following formula.

$$P = d_1 \times n[C_1(d_1 \times n)^{-0.09} - \frac{C_2}{d_1} \times C_3(d_1 \times n)^2] + C_2 \times n\left(1 - \frac{1}{K_r}\right)$$

P	:	Transmission capacity of each V-belt	kW
d_1	:	Pitch circle diameter of small V-pulley	mm
n	:	Speed of small V-pulley	(N min^{-1}) x 10^{-3}
C_1, C_2, C_3	:	Constants	Refer to *Constants (C_1, C_2, C_3) on page 16-26*
K_r	:	Correction factor by rotation ratio	Refer to *Correction factor by rotation ratio (K_r) on page 16-26*
d_2/d_1	:	Rotation ratio	Refer to *Correction factor by rotation ratio (K_r) on page 16-26*

When the above process has been completed, calculate the transmission capacity of each V-belt (P). For this case, the parameters used for the calculation are determined as follows:

1. $d_1 = 140\ mm$
2. $n = 2250 \times 10^{-3}$
3. The values of C_1, C_2 and C_3 are selected from *Constants (C_1, C_2, C_3) on page 16-26*. Since A type belt is used, these are as follows respectively; 3.1149 × 10^{-2}, 1.0399 and 1.1108 × 10^{-8}.
4. The value of K_r is selected from *Correction factor by rotation ratio (K_r) on page 16-26*. For this case, K_r is as follows because the rotation ratio (d_2/d_1) is 210/140 = 1.5.

   $K_r = 1.1036$

$$P = 140 \times 2250 \times 10^{-3}\left[3.1149 \times 10^{-2}(140 \times 2250 \times 10^{-3})^{-0.09} - \frac{1.0399}{140} \times 1.1108\right.$$

$$\left.10^{-8}(140 \times 2250 \times 10^{-3})^2\right]1.0399 \times 2250 \times 10^{-3}\left(1 - \frac{1}{1.1036}\right)$$

$$= 315 \times [3.1149 \times 10^{-2} \times 315^{-0.09} - 8.2509 \times 10^{-11} \times 314^2] + 2.3398 \times 0.0939$$

$$= 315 \times [0.0186 - 0.000008] + 0.2197$$

$= 6.0787\ kW$ (per each A type V-belt)

Determining "the number of V-belts" (Z)

The number of V-belts for multiple belting (Z) is given by the following formula:

Corrected transmission capacity of V-belt per piece (P_c)

$$P_c = P \times K_L \times K_\theta$$

P_c	:	Corrected transmission capacity of V-belt per piece	kW
P	:	Transmission capacity of V-belt per piece	kW
K_L	:	Length correction factor	Refer to *Length correction factor (K_L) on page 16-24*
K_θ	:	Contact angle correction factor	*Contact angle correction factor (K_θ) on page 16-25*

Before using *Length correction factor (K_L) on page 16-24*, complete the following calculation.

$$\frac{(d_2 - d_1)}{C}$$

For this example case, the calculation is developed as follows.

1. The value of P, 6.0787 kW, was obtained from *Determining Transmission Capacity (P) of V-belt on page 16-12*
2. Select the value of K_L from *Length correction factor (K_L) on page 16-24.*

   From *Calculating length of V-belt to determine "Nominal number" on page 16-11*, the specifications of the required belt are determined as "A" type with nominal number of 69. Based on the nominal number, the value of K_L selected from *Length correction factor (K_L) on page 16-24* is 1.00.
3. Obtain K_θ from *Contact angle correction factor (K_θ) on page 16-25.*

   Before using the table, calculate $(d_2 - d_1)/C$.

   $$(d_2 - d_1)/C = (210 - 140)/600 = 0.12$$

   The value of K_θ that precisely corresponds to 0.12 cannot be found in the table, and thus, 0.99 is used because 0.12 is nearest to 0.10 that gives the value of 0.99.

   As a result, the corrected transmission capacity of each V-belt (P_c) is calculated as described below.

   $$P_c = P \times K_L \times K_\theta$$
   $$= 6.0787 \times 1.00 \times 0.99$$
   $$= 6.0179\ kW$$

Determining the number of V-belts (Z)

$$Z = \frac{P_d}{P_c}$$

Z	:	Number of V-belts	
P_d	:	Design power	kW
P_c	:	Corrected transmission capacity per V-belt	kW

For this example case, the calculation is developed as follows:

1. The value of P_d, 12.1 kW, was obtained in *Design Power of V-belt (P_d) on page 16-10*.
2. The value of P_c, 6.0179 kW, was obtained in *Corrected transmission capacity of V-belt per piece (P_c) on page 16-14*.

$$Z = \frac{P_d}{P_c} = \frac{12.1}{6.0179}$$

$$= 2.011$$

From the above values, the number of a type belts (Z) is determined to be 3 pieces.

Determining "Initial Tension" (F_0) of V-belt

The initial tension that is required for transmission of power through the V-belt is calculated by using the following formula:

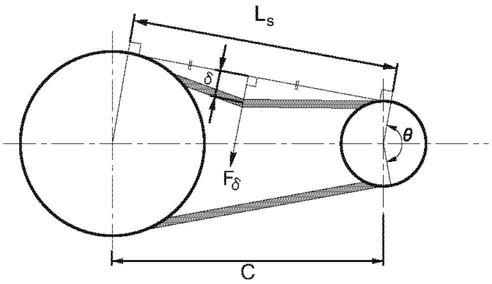


Figure 16-11

$$F_0 = 0.9\left[500\left(\frac{2.5 - K_\theta}{K_\theta}\right)\frac{P_d}{Z \times v} + m \times v^2\right]$$

F_0	: Initial tension 1 kgf = 9.80665 N	N
K_θ	: Contact angle correction factor	Refer to *Contact angle correction factor (K_θ) on page 16-25*
P_d	: Design power	kW
Z	: Number of V-belts	
v	: V-belt speed	m/s

$$v = \frac{\pi \times d_1 \times N}{1000 \times 60}$$

d_1	: Pitch circle diameter of small V-pulley	mm
N	: Speed of small V-pulley	min^{-1}
m	: V-belt mass per unit length	kg/m Refer to *Applicable V-belt length limit (allowable difference) on page 16-26*

For this example, the calculation is developed as follows.

1. The value of K_θ, 0.99 pieces, was obtained in *Determining Number of V-belts (Z) on page 16-14*.
2. The value of P_d, 12.1 kW, was obtained in *Design Power of V-belt (P_d) on page 16-10*.
3. The value of Z, 3 pieces, was obtained in *Determining the number of V-belts (Z) on page 16-15*.
4. The following parameters that are used for calculating the speed of V-belt (v) were obtained as follows.
   The value of d_1, 140, was obtained in *Determining pitch circle diameter of small V-pulley (d_1) on page 16-11*.
   The value of N, 2250, was obtained in *Determining type of V-belt on page 16-10*.

$$v = \frac{\pi \times d_1 \times N}{1000 \times 60} = \frac{3.14 \times 140 \times 2250}{1000 \times 60}$$

$$= 16.5\ m/s$$

5. The value of m is obtained from *V-belt mass per unit length and constant (Y) on page 16-26*. Since the type "A" belt is used here, the value of m is 0.12.

The above values are used to obtain the initial tension (F_0) of the belt.

$$F_0 = 0.9\left[500\left(\frac{2.5 - K_\theta}{K_\theta}\right)\frac{Pd}{Z \times v} + m \times v^2\right]$$

$$= 0.9\left[500\left(\frac{2.5 - K_\theta}{K_\theta}\right)\frac{12.1}{3 \times 16.5} + 0.12 \times 16.5^2\right]$$

$$= 0.9\left[500\left(\frac{2.5 - 0.99}{0.99}\right)\frac{12.1}{3 \times 16.5} + 0.12 \times 16.5^2\right]$$

$$= 0.9(500 \times 1.525 \times 0.244 \times 32.67)$$

$$= 0.9(186.05 + 32.67)$$

$$= 197\ N\ (20\ kgf)$$

Determining "Shaft Load"

The shaft load of the belt is calculated by using the following formulas.

Static shaft load (F_s)

The tensile force that is applied to the belt if the engine drives a generator, which is called the static shaft load (F_s), is calculated by using the following formula:

$$F_s = 1.5\left(2Z \times F_0 sin\frac{\theta}{2}\right)$$

F_s	:	Static shaft load	N
Z	:	Number of V-belts	
F_0	:	Initial tension	N
θ	:	Contact angle of small pulley	degrees Refer to *Contact angle correction factor (K_θ) on page 16-25*

For this example case, the calculation is developed as follows.

1. The value of Z, 3, was obtained in *Determining the number of V-belts (Z) on page 16-15*.
2. The value of F_0, 197, was obtained in *Determining Initial Tension (F_o) of V-belt on page 16-16*.
3. The value of θ, 174, is obtained from *Contact angle correction factor (K_θ) on page 16-25*.
   The value of K_θ, 0.99, is obtained from *Contact angle correction factor (K_θ)* on page *16-25*.

$$F_s = 1.5\left(2Z \times F_0 sin\frac{\theta}{2}\right) = 1.5\left(2 \times 3 \times 197 sin\frac{174}{\theta}\right)$$

$$= 1.5(2 \times 3 \times 197 \times 0.999)$$

$$= 1771\ N\ (181\ kgf)$$

Dynamic shaft load (F_d)

The load that is actually applied to the shaft during loaded operation is called the dynamic shaft load (F_d), which is given by the following formula:

F_d	:	Dynamic shaft load	N
K_θ	:	Contact angle correction factor	Refer to *Contact angle correction factor (K_θ) on page 16-25*
P_d	:	Design power	kW
v	:	V-belt speed	m/s
θ	:	Small V-pulley contact angle	degrees Refer to *Contact angle correction factor (K_θ) on page 16-25*

$$F_d = 9.8\left(\frac{2.5 - K_\theta}{K_\theta}\right) \times \frac{102 \times P_d}{v} \sin\frac{\theta}{2}$$

For this example case, the calculation is developed as follows:

1. The value of P_d, 12.1 kW, was obtained in *Design Power of V-belt (P_d) on page 16-10*.
2. The value of v, 16.5 m/s, was obtained in *Determining Initial Tension (F_o) of V-belt on page 16-16*.
3. The value of θ, 174 is obtained from *Contact angle correction factor (K_θ) on page 16-25*.
   The value of K_θ, 0.99, is obtained from *Contact angle correction factor (K_θ) on page 16-25*.

$$F_d = 9.8\left(\frac{2.5 - K_\theta}{K_\theta}\right) \times \frac{102 \times P_d}{v} \sin\frac{\theta}{2}$$

$$= 9.8\left(\frac{2.5 - 0.99}{0.99}\right) \times \frac{102 \times 12.1}{16.5} \sin\frac{174}{2}$$

$$= 9.8 \times 1.525 \times 74.8 \times 0.999$$

$$= 1117\ N\ (114\ kgf)$$

Generally, the dynamic shaft load (F_d) is smaller than the static shaft load (F_s). Therefore, when examining the side load that is applied to an engine, omitting the calculation of the dynamic shaft load (F_d) does not affect the result.

Determining Overhang of V-pulley

The shape of V-pulley that is required can be determined when the belt type, the number of pieces to be used and pitch circle diameter of the pulley are given. The shapes of the V-grooves which are defined by JIS are presented separately in the size table.

For this example, the shape of V-pulley is as follows because 3 each V-belt “A” type, small V-pulleys pitch circle diameter of 140 mm are used. From this shape, the overhang is determined.

Regarding the calculation of overhang, refer to ***Figure 16-7*** *on page 16-8* and ***Figure 16-17*** *on page 16-29*. In this example, L2 in ***Figure 16-7*** is 24 mm.

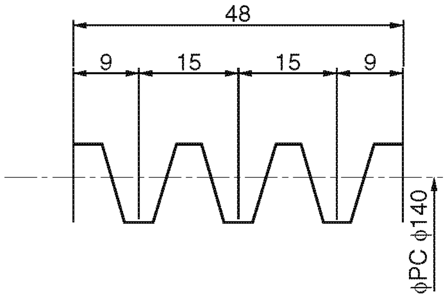


Figure 16-12

Examining Allowable Shaft Load

After the shaft load was calculated in item 4. and overhang was obtained in item 5, examine whether they are within the allowable limits for front PTO of the pertinent engine. Plot the above-mentioned data on a graph of the pertinent engine that is found in *Allowable Side Load for Front P.T.O. on page 16-30* to make sure the values are within the allowable limits. If any of the parameters are over its allowable limit, review the design plan.

For this example of the 4NTV98C engine, entering the overhang (L) of 100 + 24 = 124 mm and the shaft load of 1771 N (this value is used because the static shaft load is at maximum) into the graph shows that the side load does not cause a problem.

V-belt type [belt size]

(mm)

Type	b1	h	θ rad (°)
A	12.5	9.0	0.70 (40)
B	16.5	11.0	
C	22.0	14.0	
D	31.5	19.0	

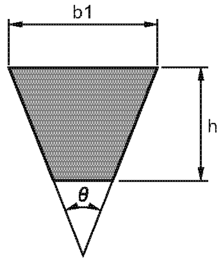


Figure 16-13

Service factor (K_0)

Example of machine using V-belt	Multiple-cylinder engine		
	Operating Hours		
	Intermittent use for 3 to 5 hours a day	Ordinary use for 8 to 10 hours a day	Continuous use for 16-24 hours a day
Agitator (fluid) Blower (7.5 kW or under) Centrifugal pump/compressor Light load conveyer	1.0	1.1	1.2
Belt conveyer (sand, grain) Dough mixer Blower (over 7.5 kW) Generator Line shaft Laundry machine Machine tool Punch/press/shear Printing press Rotary pump Rotary/vibrating screen	1.1	1.2	1.3
Bucket elevator Exciter Compressor (reciprocating type) Conveyer (bucket/screw) Hammer mill Paper mill/beater Piston pump Roots blower Crusher Woodworking machinery Textile machinery	1.2	1.3	1.4
Crusher Mill (ball/rod) Hoist Rubber processing machinery (roll/calendar/extruder)	1.3	1.4	1.5

Note: Determine the service factor by using the table above as the reference for any driven machine other than those listed in the table.

NOTICE

Add 0.2 to each of the values above when the start/stop operation frequency is high, when maintenance/ inspection is not easy, if wear is likely to occur due to contamination with dirt, when used in a hot location or when the belt is likely to be exposed to oil or water.

Idler correction factor (K_i)

No.	Idler position	Factor
1	Use from inside of V-belt on loose side	0
2	Use from outside of V-belt on loose side	0.1
3	Use from inside of V-belt on tight side	0.1
4	Use from outside of V-belt on tight side	0.2

Note: No. 4 is not recommended.

V-belt length

(mm)

Nominal No.	Belt length (L)			
	A	B	C	D
20	508	–	–	–
21	533	–	–	–
22	559	–	–	–
23	584	–	–	–
24	610	–	–	–
25	635	635	–	–
26	660	660	–	–
27	686	686	–	–
28	711	711	–	–
29	737	737	–	–
30	762	762	–	–
31	787	787	–	–
32	813	813	–	–
33	838	838	–	–
34	864	864	–	–
35	889	889	–	–
36	914	914	–	–
37	940	940	–	–
38	965	965	–	–
39	991	991	–	–
40	1016	1016	–	–
41	1041	1041	–	–
42	1067	1067	–	–
43	1092	1092	–	–
44	1118	1118	–	–
45	1143	1143	1143	–
46	1168	1168	–	–
47	1194	1194	–	–
48	1219	1219	1219	–
49	1245	1245	–	–
50	1270	1270	1270	–
51	1295	1295	–	–
52	1321	1321	1321	–
53	1346	1346	–	–
54	1372	1372	1372	–
55	1397	1397	1397	–
56	1422	1422	–	–
57	1448	1448	–	–
58	1473	1473	1473	–
59	1499	1499	–	–

(mm)

Nominal No.	Belt length (L)			
	A	B	C	D
60	1524	1524	1524	–
61	1549	1549	–	–
62	1575	1575	1575	–
63	1600	1600	–	–
64	1626	1626	–	–
65	1651	1651	1651	–
66	1676	1676	–	–
67	1702	1702	–	–
68	1727	1727	1727	–
69	1753	1753	–	–
70	1778	1778	1778	–
71	1803	1803	–	–
72	1829	1829	1829	–
73	1854	1854	–	–
74	1880	1880	–	–
75	1905	1905	1905	–
76	1930	1930	–	–
77	1956	1956	–	–
78	1981	1981	1981	–
79	2007	2007	–	–
80	2032	2032	2032	–
81	2057	2057	–	–
82	2083	2083	2083	–
83	2108	2108	–	–
84	2134	2134	–	–
85	2159	2159	2159	–
86	2184	2184	–	–
87	2210	2210	–	–
88	2235	2235	2235	–
89	2261	2261	–	–
90	2286	2286	2286	–
91	2311	2311	–	–
92	2337	2337	2337	–
93	2362	2362	–	–
94	2338	2338	–	–
↓	↓	↓	↓	↓
360	–	–	–	9144
390	–	–	–	–
420	–	–	–	–

Minimum Adjusting Margin

Obtain the minimum adjusting margin from the table below, considering the V-belt installation and tensioning margin.

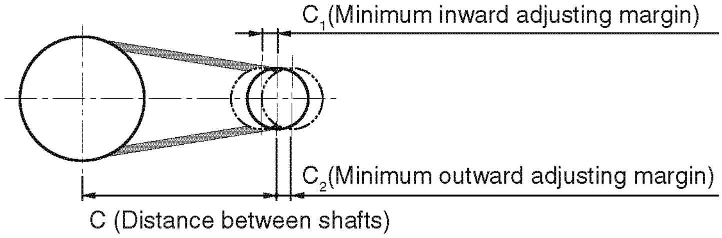


Figure 16-14

Minimum adjusting margin

(mm)

<table>
<tr><th rowspan="2">V-belt nominal No.</th><th colspan="4">Minimum inward adjusting margin (C_1)</th><th rowspan="2">Minimum outward adjusting margin (C_2)</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>38 or below</td><td rowspan="3">20</td><td rowspan="2">25</td><td>–</td><td rowspan="3">–</td><td>25</td></tr>
<tr><td>39 to 60</td><td rowspan="4">40</td><td>40</td></tr>
<tr><td>61 to 90</td><td rowspan="4">35</td><td>50</td></tr>
<tr><td>91 to 120</td><td rowspan="3">25</td><td rowspan="4">50</td><td>65</td></tr>
<tr><td>122 to 155</td><td>75</td></tr>
<tr><td>160 to 190</td><td rowspan="3">50</td><td>90</td></tr>
<tr><td>200 to 240</td><td rowspan="4">–</td><td>40</td><td>100</td></tr>
<tr><td>250 to 270</td><td rowspan="3">–</td><td rowspan="2">65</td><td>115</td></tr>
<tr><td>280 to 330</td><td rowspan="2">–</td><td>130</td></tr>
<tr><td>360 to 420</td><td>75</td><td>160</td></tr>
</table>

Length Correction Factor (K_L)

Nominal No.	Type			
	A	B	C	D
20 to 25	0.80	0.78		
26 to 30	0.81	0.79		
31 to 34	0.84	0.80		
35 to 37	0.87	0.81		
38 to 41	0.88	0.83		
42 to 45	0.90	0.85	0.78	
46 to 50	0.92	0.87	0.79	
51 to 54	0.94	0.89	0.80	
55 to 59	0.96	0.90	0.81	
60 to 67	0.98	0.92	0.82	
68 to 74	1.00	0.95	0.85	
75 to 79	1.02	0.97	0.87	
80 to 84	1.04	0.98	0.89	
85 to 89	1.05	0.99	0.90	
90 to 95	1.06	1.00	0.91	
96 to 104	1.08	1.02	0.92	0.83
105 to 111	1.10	1.04	0.94	0.84
112 to 119	1.11	1.05	0.95	0.85
120 to 127	1.13	1.07	0.97	0.86
128 to 144	1.14	1.08	0.98	0.87
145 to 154	1.15	1.11	1.00	0.90
155 to 169	1.16	1.13	1.02	0.92
170 to 179	1.17	1.15	1.04	0.93
180 to 194	1.18	1.16	1.05	0.94
195 to 209		1.18	1.07	0.96
210 to 239		1.19	1.08	0.98
240 to 269			1.11	1.00
270 to 299			1.14	1.03
300 to 329				1.05
330 to 359				1.07
360 to 389				1.09
390 to 419				
420				

Note: The 1.00 type V-belt is the reference length V-belt.

Contact angle correction Factor (K_θ)

$\frac{d_2 - d_1}{C}$	**Contact angle at Small V-pulley θ (°)**	**Contact angle correction factor K_θ**
0.00	180	1.00
0.10	174	0.99
0.20	169	0.98
0.30	163	0.96
0.40	157	0.94
0.50	151	0.93
0.60	145	0.91
0.70	139	0.89
0.80	133	0.87
0.90	127	0.85
1.00	120	0.82
1.10	113	0.79
1.20	106	0.77
1.30	99	0.74
1.40	91	0.70
1.50	83	0.66

Constants (C_1, C_2, C_3)

Type	C_1	C_2	C_3
A	3.1149×10^{-2}	1.0399	1.1108×10^{-8}
B	5.4974×10^{-2}	2.7266	1.9120×10^{-8}
C	1.0205×10^{-1}	7.5815	3.3961×10^{-8}
D	2.1805×10^{-1}	2.6894×10	6.9287×10^{-8}

Correction factor by rotation ratio (K_r)

Rotation ratio	K_r
1.00 to 1.01	1.0000
1.02 to 1.04	1.0136
1.05 to 1.08	1.0276
1.09 to 1.12	1.0419
1.13 to 1.18	1.0567
1.19 to 1.24	1.0719
1.25 to 1.34	1.0875
1.35 to 1.51	1.1036
1.52 to 1.99	1.1202
2.0 or above	1.1373

Constant (A)

For new belt	For tension adjustment
1.5	1.3

V-belt mass per unit length and constant (Y)

Type	M	A	B	C	D	E
m (kg/m)	0.06	0.12	0.20	0.36	0.66	1.02
Y	10	15	20	30	60	110

V-belt weight per unit length and constant (Y')

Type	M	A	B	C	D	E
W (kg/m)	0.06	0.12	0.20	0.36	0.66	1.02
Y'	1.0	1.6	2.0	3.1	6.1	11.2

Applicable V-belt length limit (allowable difference)

Belt length	Applicable limit length (allowable difference)
150 cm or less	4 mm
150 cm to 230 cm	6 mm

Allowable Side Load for Main P.T.O.

DI Series

3TNV88C, 3TNV86CT, 4TNV88C, 4TNV86CT

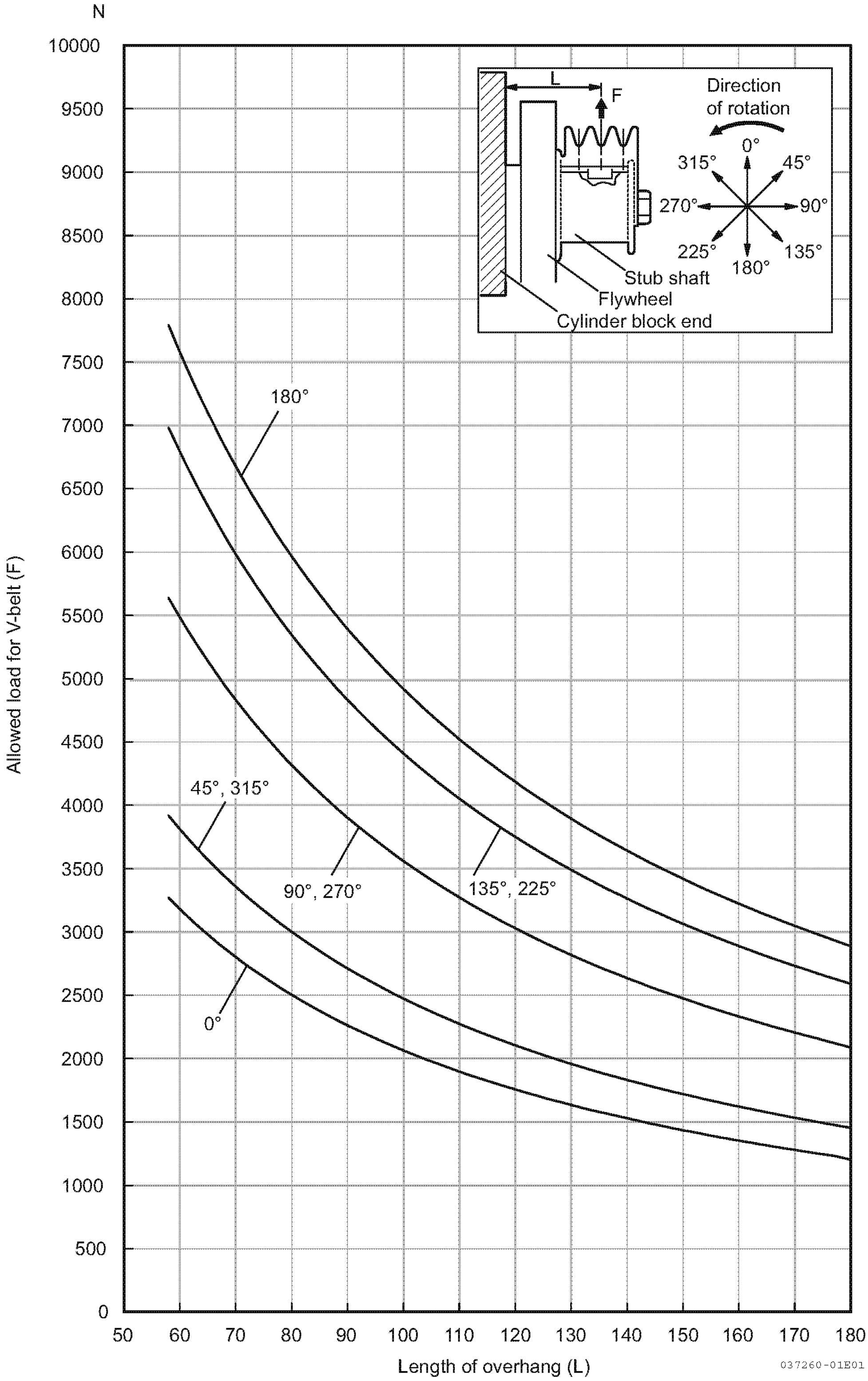


Figure 16-15

4TNV98C, 4TNV98CT

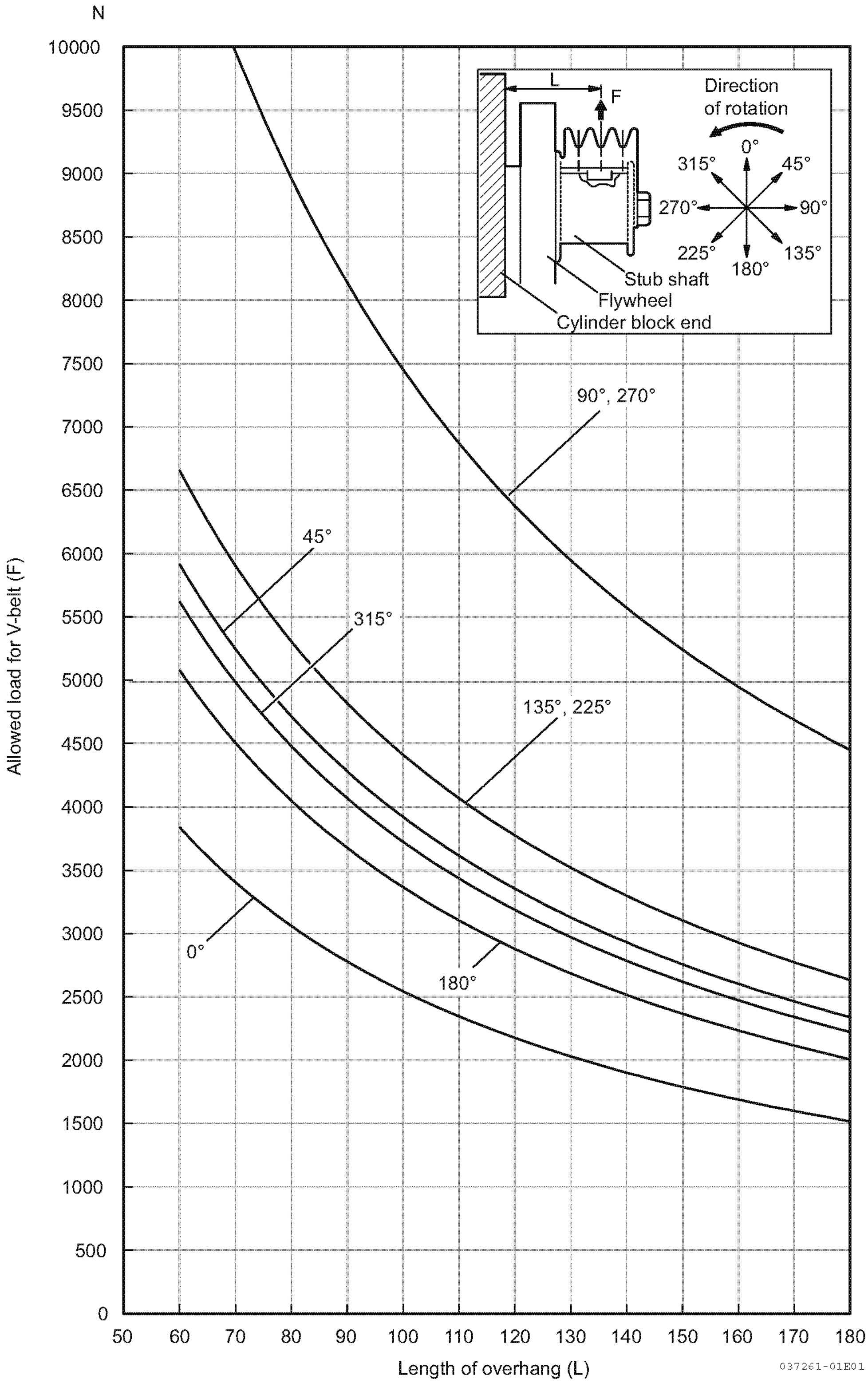


Figure 16-16

Allowable Side Load for Front P.T.O.

DI Series

3TNV88C, 3TNV86CT, 4TNV88C, 4TNV86CT

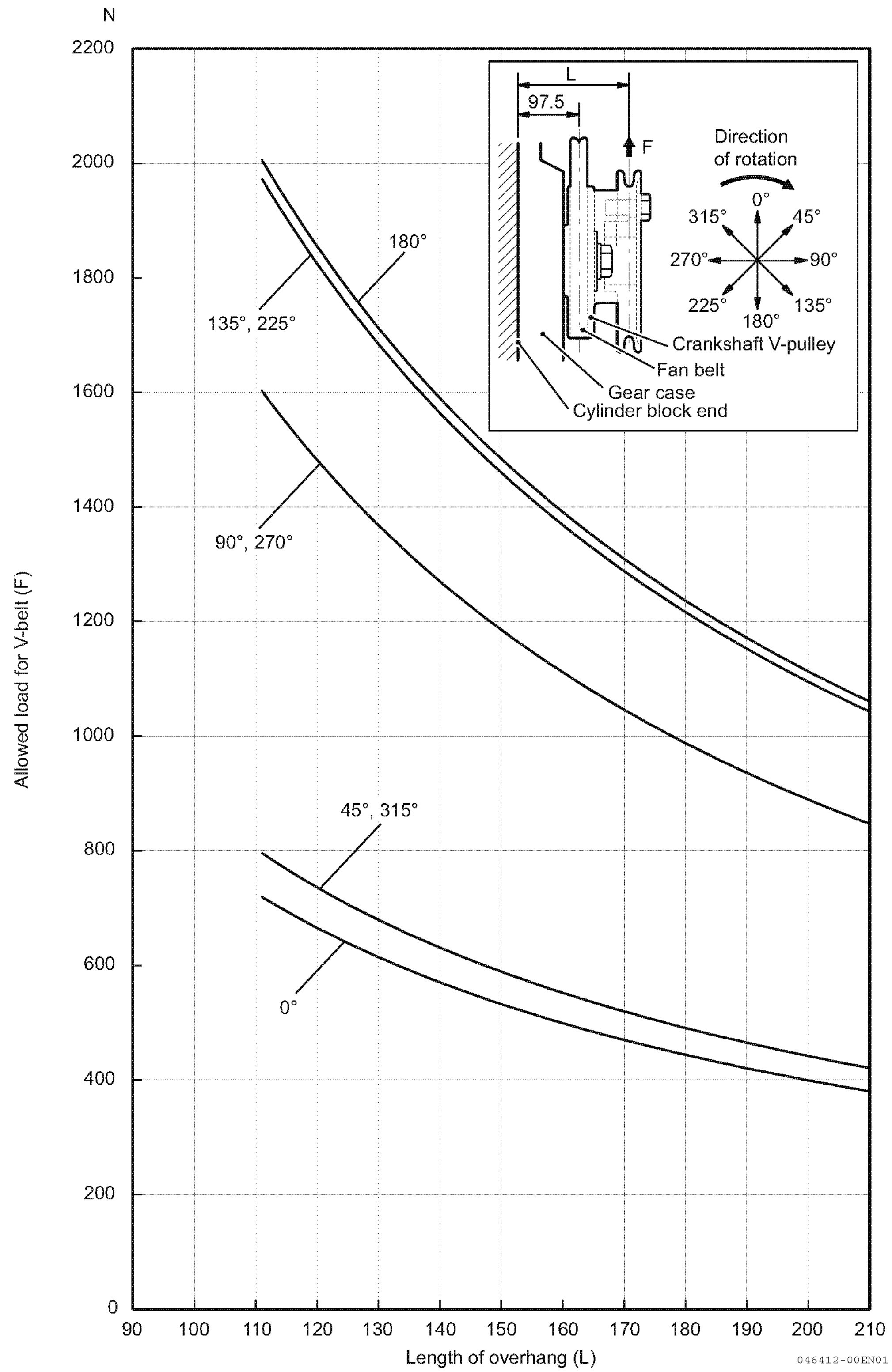


Figure 16-17

4TNV98C, 4TNV98CT

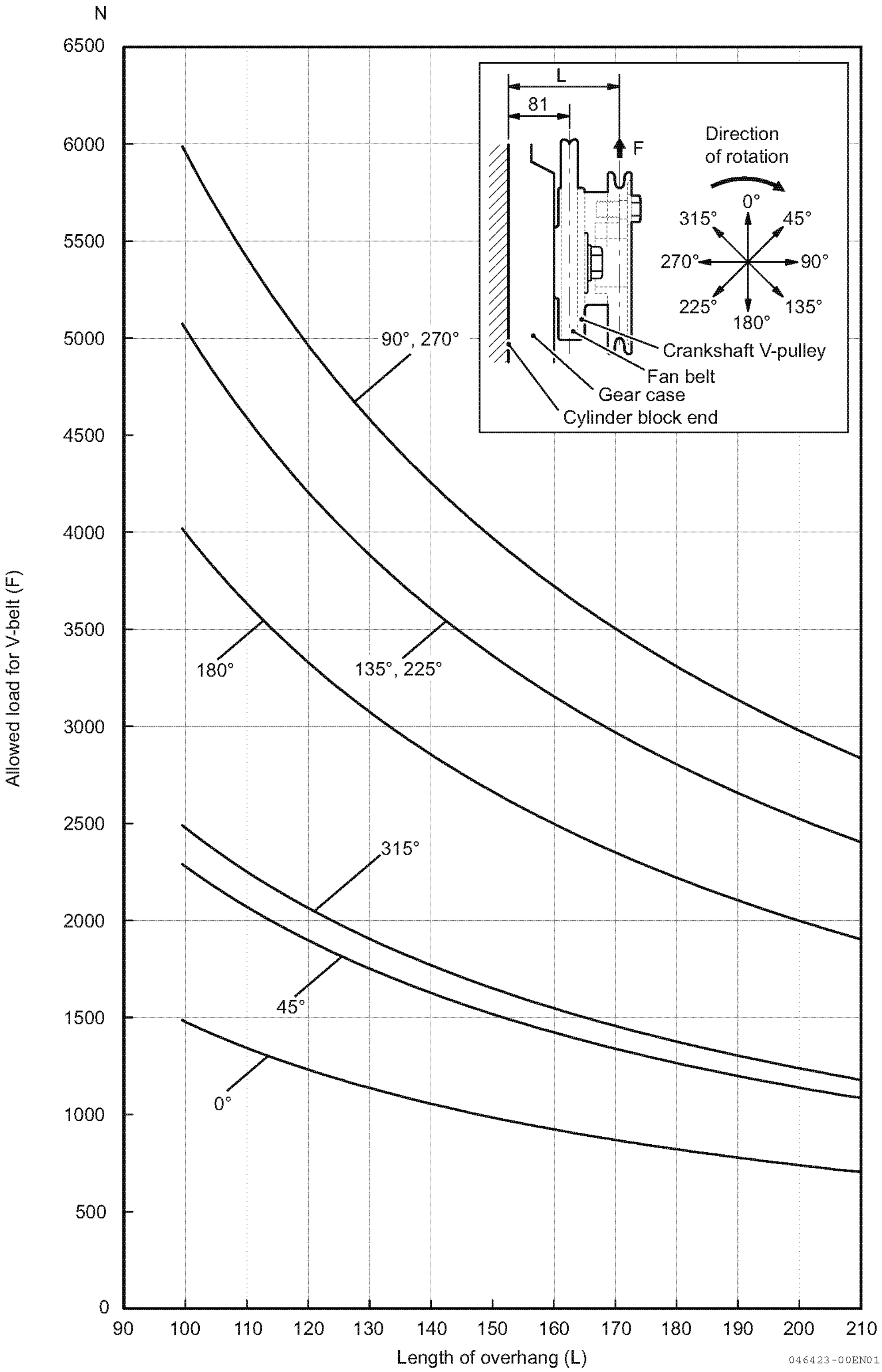


Figure 16-18

Cautions for Hydraulic Pump Drive P.T.O. on the Gear Case

The hydraulic pump drive P.T.O. is positioned on the exhaust side of the engine gear case. Since the output of the hydraulic pump drive P.T.O. is determined by the strength of the P.T.O. gear on the engine side, select the pump that is within the allowable output range by referring to *Allowable Load for Hydraulic Pump Drive P.T.O. on page 16-33*.

Prepare the following data before you do the calculations:

- Hydraulic pump type and manufacturer
- Pump capacity (Q)
- Pump speed (min^{-1})
- Delivery pressure (relief pressure) (kPa)
- Hydraulic pump shaft end shape and mounting dimensions on engine side (Refer to the *YANMAR TNV Option Menu* for the mounting dimensions.)

Required Power

The hydraulic pump driving power (required power) is the power required for the engine to drive the hydraulic pump. The required power is calculated with the following equation:

$$kW = \frac{Q \times P \times N}{60 \times \eta} \times 10^{-6} (kW)$$

Where,

kW	:	Required power	(kW)
Q	:	Pump capacity	(cc/rev.)
P	:	Delivery pressure (relief pressure)	(kPa)
N	:	Pump speed	(min^{-1})
η	:	Pump efficiency	(Refer to the manufacturer's catalog for the pump efficiency. If unknown, assume it is 0.9 for the calculation.

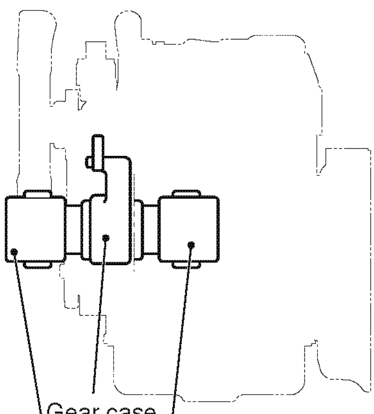


Figure 16-19

Gear Train

Code	Name		Number of teeth	
			3TNV88C/86CT 4TNV88C/86CT	4TNV98C/98CT
A	Crank gear	❐	28	32
B1	Idle gear	❐	37	50
B2	Idle gear	❐	31	33
C	Fuel pump drive gear	❐	28	32
D	Cam gear	❐	56	64
E	Hydraulic pump drive gear	✔	31	26
F	Lubricating oil pump drive gear	❐	29	29
Gear ratio: A/E			0.903	1.231
Hydraulic pump position: W/H (mm)			162.3/65.979	178.5/1075

❐: Standard part
✔: Option part

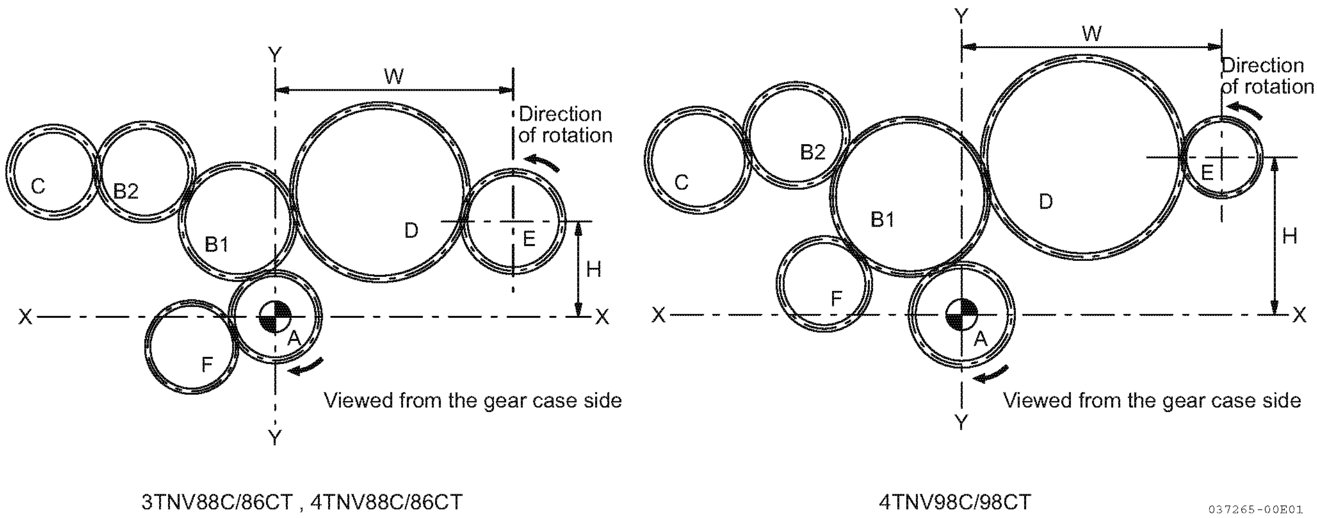
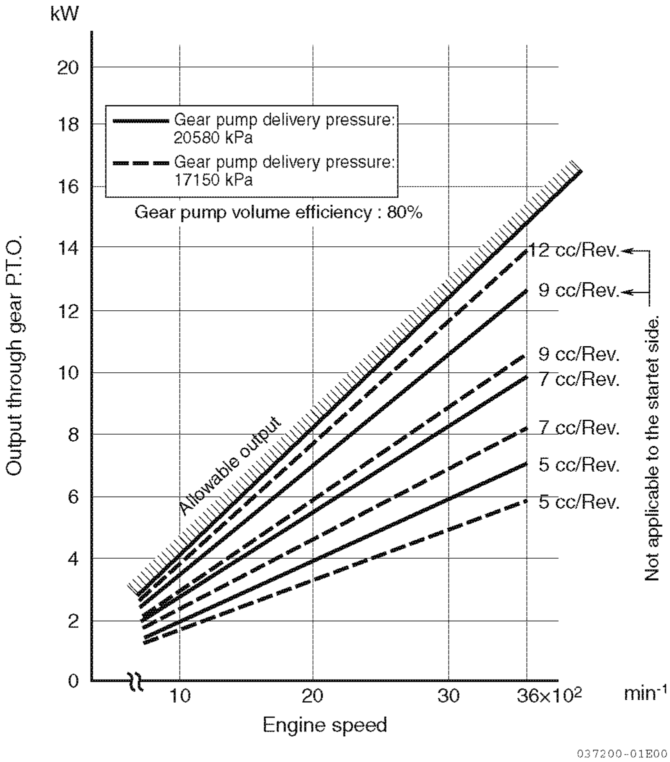


Figure 16-20

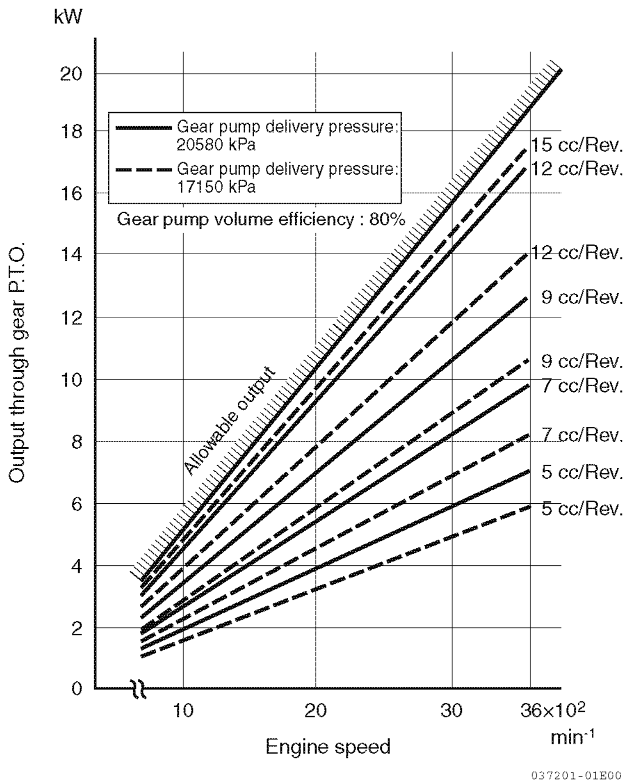
Allowable Load for Hydraulic Pump Drive P.T.O.

DI Series

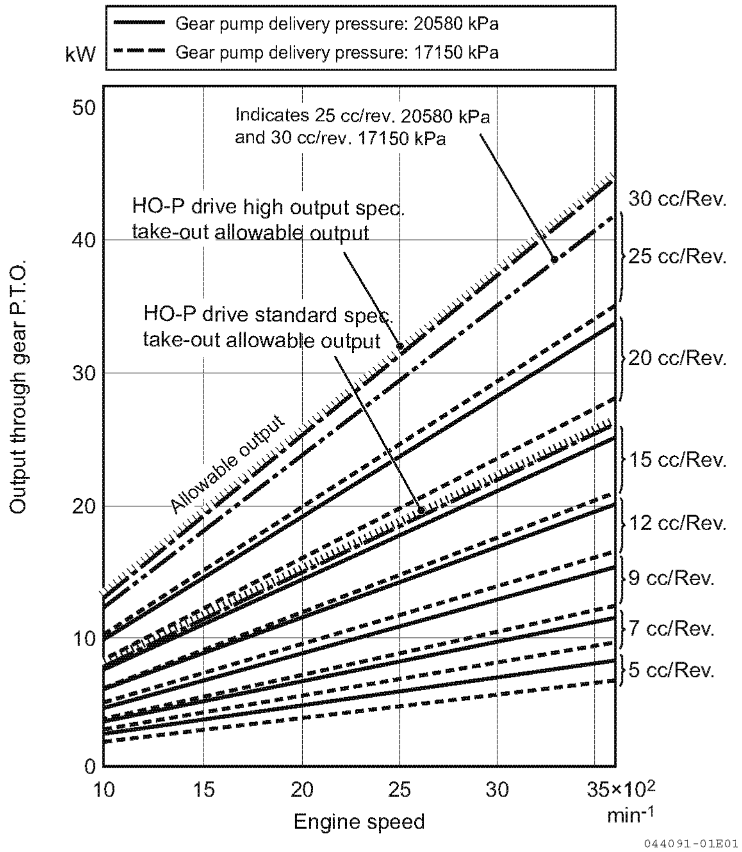
3TNV88C, 3TNV86CT



4TNV88C, 4TNV86CT



4TNV98C, 4TNV98CT



Section 17

VIBRATION ISOLATION SYSTEM

Page

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Principle of Vibration Isolation and Vibration Transmissibility ... 17-4
Frequency Ratio and Vibration Damping Effect 17-5
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The function of the vibration isolation system is to prevent the vibratory force F_0 (on the left side of the **Figure 17-1**) to be transmitted to the base, and the vibration A_0 in the base from being transferred to the engine (on the right side of the **Figure 17-1**).

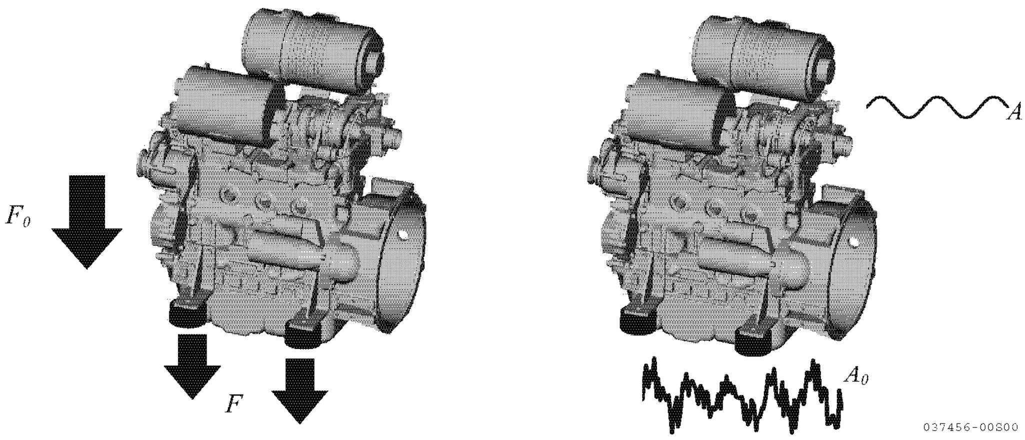

Figure 17-1

Vibratory forces in the engine stem from reciprocating motion (e.g. of the piston) and explosions in the combustion chamber. These vibrations are kept to a minimum at the design stage, but it is impossible to fully remove all vibrations. The vibration isolation system is necessary to reduce the force F on the base to a minimum.

The vibration isolation system reduces the force on the base (e.g. chassis), but the vibrations on the engine and the connected piping at engine start and when the implement shakes, can become larger.
It is necessary to match it with the natural frequency. Normally the natural frequency (refer to below) is set lower than the vibration frequency, but depending on the use of the implement, a rather large displacement can occur. Therefore, the vibration evaluation must be done by the manufacturer of the implement.

When damping engine vibration, an elastic coupling is necessary to connect the output shaft and a flexible tube is necessary to connect the separate exhaust silencer. The effect of the vibration damping does not depend on the rubber isolator alone, but changes with the stiffness of all shafts and piping that are connected to the engine.

Consider the base as a fixed wall when calculating the vibration. If the base is a chassis with insufficient stiffness, problems such as an increase in chassis vibration occur, so the location of the chassis damping requires sufficient stiffness.

Principle of Vibration Isolation

Principle of Vibration Isolation and Vibration Transmissibility

The diagram below shows a spring having a spring constant K mounted on a fixed wall on which a weight m is loaded. When the weight is gently pulled up and then released suddenly, it vibrates cyclically. This is called natural vibration, and the period is called natural frequency. On the other hand, when cyclic external force F_0 is applied to this weight periodically, the vibration is called forced vibration and the period is called forced frequency.
When this external force acts, it is possible to make the force F that is transmitted to the fixed wall smaller than the external force F_0 by choosing an appropriate spring constant K.

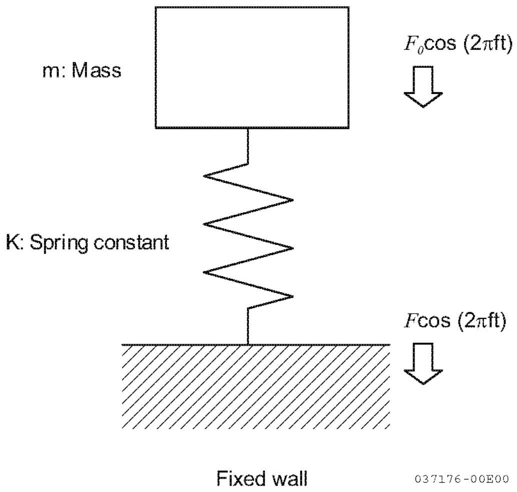

Figure 17-2

When a machine is provided with a vibro-isolating support, assume the vibratory force of the machine as F_0 and the force transferred to the base as F. The ratio of transferred force is called the vibration transmission rate and is expressed by the following equation:
The same applies when the base vibrates and the vibration is transferred to the engine.

$$\tau = \frac{F}{F_0} = \frac{A}{A_0} = \left| \frac{1}{1-\left(\frac{f}{f_n}\right)^2} \right|$$

τ : Vibration transmission rate
F_0 : Vibratory force of machine
F : Force transferred to the base
A_0 : Forced excitation amplitude of the base
A : Amplitude transferred to the machine
f : Frequency of vibratory force or vibration frequency of the base
f_n : Natural frequency when vibro-isolating support is provided

The variables in the formula are frequency functions. The curve in **Figure 17-3** is the vibration transmission rate calculated for each frequency on the x-axis.
The ratio of the frequency of the vibratory force and the natural frequency is shown on the x-axis. When that value becomes 1, both are in total resonance.
The proportion of the engine's vibration that is transferred to the base is shown on the y-axis. A small value indicates effective vibration damping.

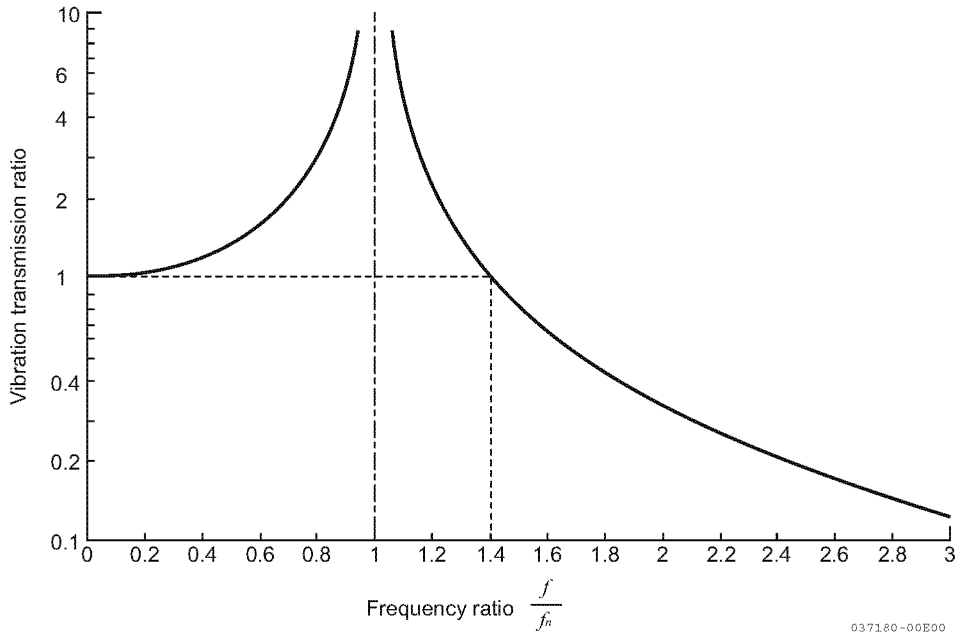

Figure 17-3

Frequency Ratio and Vibration Damping Effect

The vibration transmission ratio is determined by the frequency of the vibratory force f and natural frequency f_n with vibro-isolating support. Normally, select 2 to 3 for f / f_n. But the correct ratio can vary depending on how the engine is used (a lot of shaking during running, shocks, etc.).

Vibration ratio f / f_n	Transmission ratio τ	Damping effect
1	∞ (If not dampened)	Resonance Ineffective damping
≤ 1.4	≥ 1	Ineffective damping
> 1.4	< 1	Effective damping

How to Obtain Natural Frequency when Supported with Rubber Isolator

The natural frequency can be obtained from the following equation using the machine weight and the spring constant of the rubber isolator.

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

f	:	Natural frequency	Hz
k	:	Spring constant of the rubber isolator	N/mm
m	:	Weight held by the rubber isolator	kg

The graphic representation of the equation above is shown in **Figure 17-4**.

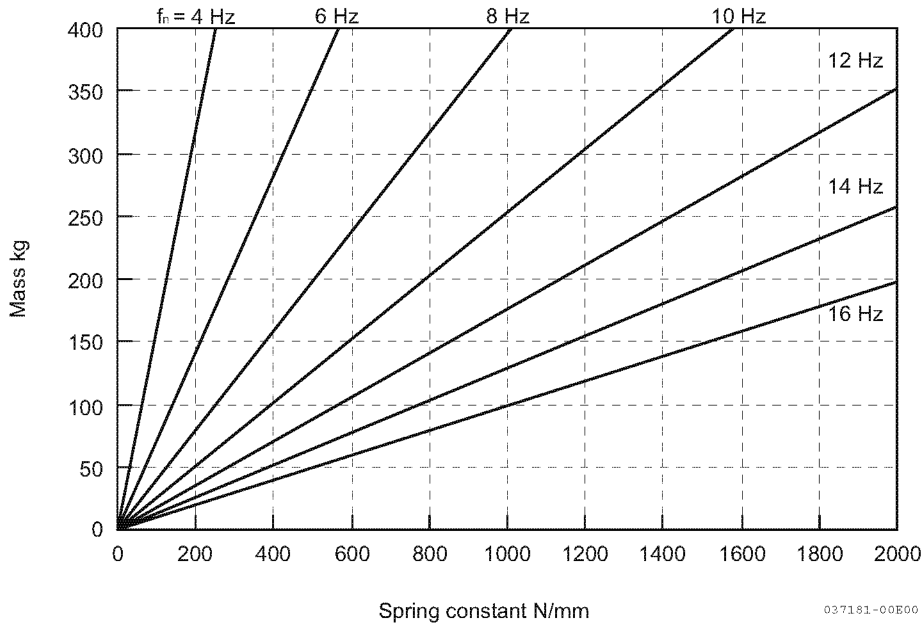

Figure 17-4

Calculation of Rubber Isolator

Selection Procedures of Vibro-isolating Support

Checking the vibratory force frequency	Refer to the separate table.
Determination of vibro-isolating support position	The support points are determined so that the static load of every support point is distributed as equally as possible.
Determination of natural frequency and spring constant	Obtain according to *Principle of Vibration Isolation on page 17-4.* The elastic coupling of the output shaft and the stiffness of the piping are included in the actual vibration calculation as the spring constant.
Selection of rubber isolator	Select the appropriate type of rubber isolator from the manufacturer's catalog according to the spring constant of the rubber isolator, allowable load and mounting method.

Calculation Example

The following is an example of the calculation method used to select the rubber isolator. Note that the calculation is solely for estimating the rubber specifications. The final selection of the optimal rubber isolator to be used is made after conducting an testing on a prototype machine using rubber with the specifications obtained from the calculation and those preceding or following them.

Figure 17-5 is a simplified drawing of the dampened engine.
When you calculate the mass (inertia moment) and its center, do not just consider the engine, but also consider the accessories attached to the engine (refer to the left figure). When you calculate the spring constant, do not just consider the rubber isolator, but also consider the elastic coupling of the output shaft and the stiffness of the piping.

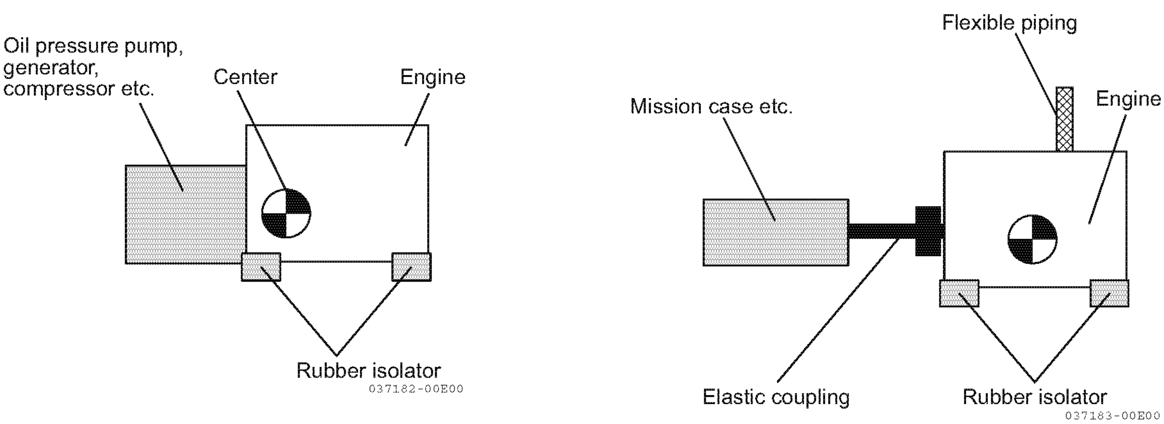

Figure 17-5

The table shows example settings. It is an example for **Figure 17-5** left figure.

Design specification

Machine	: Refrigerator		
Weight	: Engine	:	200 kg
	Compressor	:	100 kg
			Total m = 300 kg
Engine speed	: Rating	:	2,400 min^{-1}
	Low idle	:	1,000 min^{-1}
Support point	: n = 4 points		

Checking the vibratory force frequency

On 4-cylinder engines, the twofold vertical translational force and the twofold rolling moment are the vibratory forces with the lowest frequency.

Rating	: 2400 × 2/60 = 80 Hz
Low idle	: 1400 × 2/60 = 33.3 Hz

Within the operation range of this engine, the lowest vibratory force frequency is 33.3 Hz.
In this context, “twofold” means that 1 engine rotation causes 2 vibrations.

Support load

Average static load (W) at each support point is obtained from the following equation:

$$W = \frac{300 \times 9.807}{4} = 736N$$

To spread the strain on the rubber insulator evenly, place them in symmetry to the center of mass so that the support load is the same for all support points.

Determination of natural frequency

If the vibration transmission rate should be close to 10 %, the vibration ratio is f / f_n = 3 and the natural frequency is ...

$$f_n = \frac{f}{3} = 11\ Hz$$

Calculation of spring constant

Spring constant k can be calculated from:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{n \times k}{m}}$$

$$k = (2\pi f_n)^2 \times \frac{m}{n} = (2 \times 3.14 \times 11)^2 \times \frac{300}{4} = 365.541 \quad N/cm \rightarrow 366\ N/mm$$

Note: *To simplify the above calculation example, only the calculation of the vertical translational force is shown. To calculate the rolling moment vibration, it is necessary to solve the simultaneous equations that include the inertia moment and the reactive force moment of the rubber insulator.*

Selection of rubber isolator

The result of the above calculation:

Static load per support point of rubber isolator	: 736 N
Spring constant	: 366 N/mm

The spring constant under actual vibration is up to twice as high as the spring constant measured under static load. Ask the manufacturer of the rubber insulator for detailed data.

Verification of vibration isolation effect

Choose a rubber insulator depending on the results of the above calculation. Use the spring constant of the rubber insulator that you choose and calculate the natural frequency. Check whether there is a discrepancy to the target natural frequency.

Verification by the on-board installation test

Verify that the same effect is obtained as calculated from the actual machine test. If the effect is insufficient, conduct further verification with machine tests by using various rubber isolators with differing stiffness (spring constant) to find the most effective rubber vibration isolator.
The above calculation is introduced as a simple single-degree-of-freedom system (when only the vertical vibration is considered).
Because the actual structure has six degrees of freedom (moving up/down, forward/backward, left/right, rolling, pitching, yawing), in theory there are six natural frequencies. Generally, three of those resonate due to the vibratory force of the engine (rolling, pitching and moving up/down).
An effective method to measure the damping efficiency is to check how the vibration changed on the chassis that supports the engine. Measure and compare the vibration as close to the rubber insulators as possible and where the chassis is sufficiently rigid.
Damping the engine generally reduces engine noise. But since engine noise has many causes other than vibration, the damping effectiveness can not be determined by comparing the noise alone.

Vibration Improvement

If the damping effectiveness is insufficient, slowly increase the engine speed and examine the change in vibrational acceleration of the engine body. Engine vibration is largest when the vibratory force frequency and the natural frequency match (= resonance). Examine the difference to the resonance frequency target and adjust the placement of the rubber insulators. Also, if there is a lot of vibration in distance to the rubber insulators (e.g. steering vibration), in that vicinity the material of the structure itself may be in resonance and it is necessary to analyze the vibration on the vehicle side.

The engine's vibratory force frequency and direction of an engine vibration differs with the number of cylinders. The table below indicates the vibration characteristics of an engine. When examining vibration improvement, use this table to find the spring constant of a rubber isolator having the characteristics you need.

Vibration isolation materials

The force, frequency and direction of vibration differ between engine models depending on the number of cylinders. Refer to these vibratory forces outlined in a separate table when you try to improve the vibration characteristics.

Degree and direction of vibratory force to be avoided by damping system

In the damping calculation, among the below vibratory forces, set the natural frequency as the lowest frequency.

Unit: vibration per engine rotation

Number of cylinders	Vertical transitional force	Rolling moment	Pitching moment	Yawing moment
1	1.0, 2.0	0.5, 1.0, 1.5, 2.0, ...	–	–
2 (180 degree crank)	2.0	0.5, 1.5	1.0	1.0
3	–	1.5, 3.0, 4.5	1.0	1.0
4 (180 degree crank)	2.0	2.0, 4.0	–	–

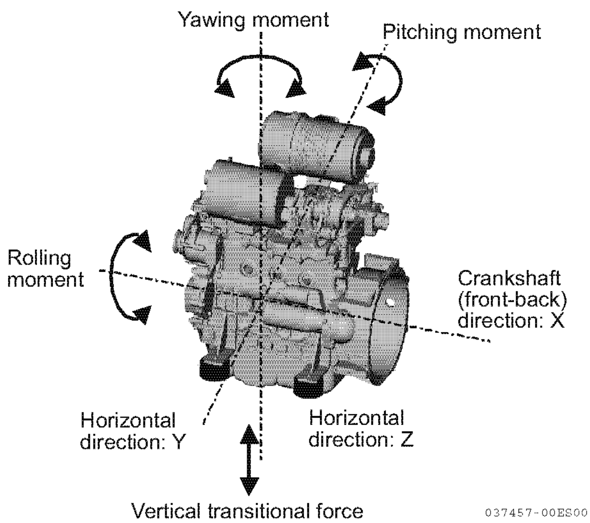

Figure 17-6

Vibratory Force

This will be printed at a later date. Please contact YANMAR if necessary.

Engine Weight and Center of Gravity

G : Center of gravity
X : Distance from the end face on the block's flywheel housing side (crankshaft direction)
Y : Distance from crankshaft center line (horizontal direction)
Z : Distance from crankshaft center line (vertical direction)
m : Weight (including lubricating oil)

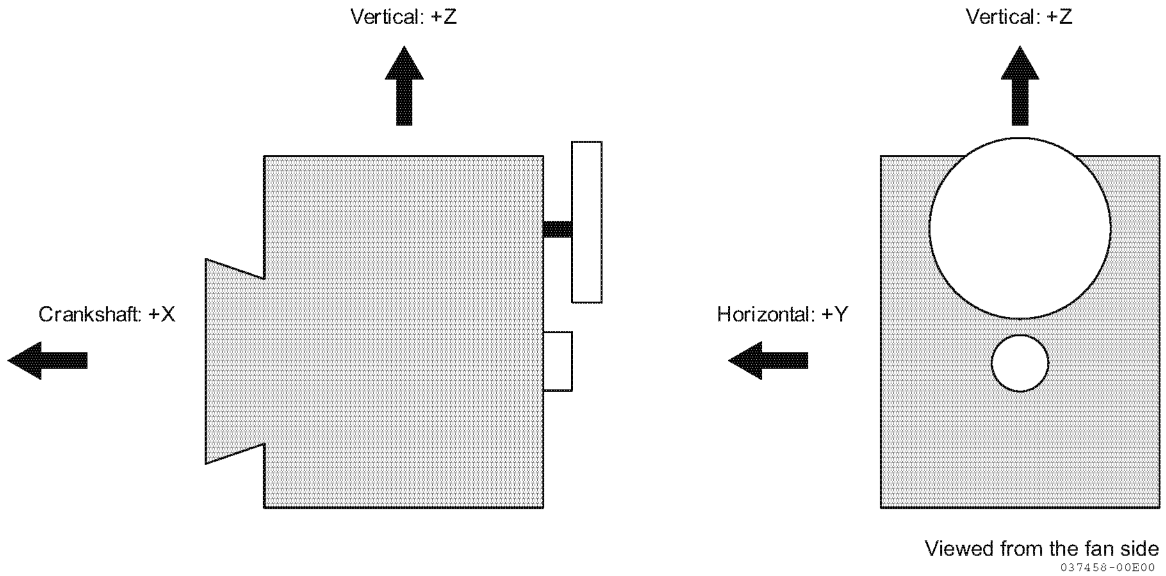

Figure 17-7

The data in the table below is based on the outlines of the standard dimensions.
The DPF is not included. For materials including the Diesel Particulate Filter (DPF), please contact YANMAR.

	X (mm)	Y (mm)	Z (mm)	m (kg)
3TNV88C	146.4	0.6	103.6	162.2
3TNV86CT	149.1	-1.4	110.2	167.4
4TNV88C	194.6	-2.6	108.2	194.2
4TNV86CT	195.7	-6.0	115.2	201.4
4TNV98C	204.0	-9.2	112.3	245.4
4TNV98CT	204.9	-10.9	120.1	254.1

Note: F-F specs., (excluding radiator, air cleaner) including intake manifold, exhaust manifold and flywheel housing.

Engine Moment of Inertia

	Inertia moment ($kgmm^2$)		
	I_x	I_y	I_z
3TNV88C	4,954,162	6,579,690	4,504,529
3TNV86CT	5,424,863	6,936,275	4,666,238
4TNV88C	5,618,997	9,323,896	6,860,894
4TNV86CT	6,245,806	9,732,747	7,104,636
4TNV98C	8,834,936	14,426,048	10,397,943
4TNV98CT	9,842,035	15,261,679	10,824,484

Section 18

TORSIONAL VIBRATION

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On average, the engine ignites and creates an even output among all cylinders. But the output on a 4-stroke engine is created through one ignition every two revolutions of the crankshaft, so the actual force that turns the crankshaft changes cyclically. It changes the reciprocating motion of the pistons to the rotary motion of the crankshaft. Therefore, the crankshaft is constantly loaded with bending, torsion or a combination of these.

If the load that is created by this bending and torsion matches (resonates with) the natural vibration of the crankshaft's bending and torsion, the load on the crankshaft increases.

Therefore, a very careful consideration of torsional vibration must be given during the design of the machine.

What is Torsional Vibration?

Assume an elastic round bar with a disc on one end and the other end is attached to a wall (called one-degree-of freedom system) as shown in **(Figure 18-1)**. When the disc is twisted a little and released suddenly, the disc tends to return to its original position. Because of the inertia force of the disc, however, the disc overruns the original position and again tends to return to the original position.

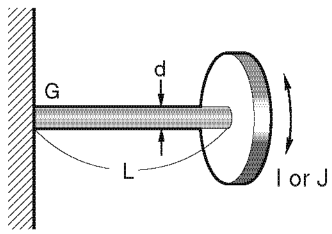


Figure 18-1

The disc vibrates in this way around its axis.

Then the natural frequency is determined depending on the ratio of the moment of disc inertia (generally expressed with I or J) and the elasticity of the bar (determined by the shear modulus G, diameter d and the length (L) of the bar material).
Consequently, in the above figure, one end of the shaft is fixed, but if it is not fixed in the same manner as the crankshaft, natural vibration occurs depending on the inertia moment and the elasticity of the shaft.

Natural frequency decreases as the moment of inertia of the disc increases or the elasticity of the bar decreases, and vice versa. For the inertia moment and the elasticity of the rod, it is necessary to consider the direct coupled AC alternators connected directly with the crankshaft. In case of a large inertial moment, careful examination is necessary.

Resonance Curve

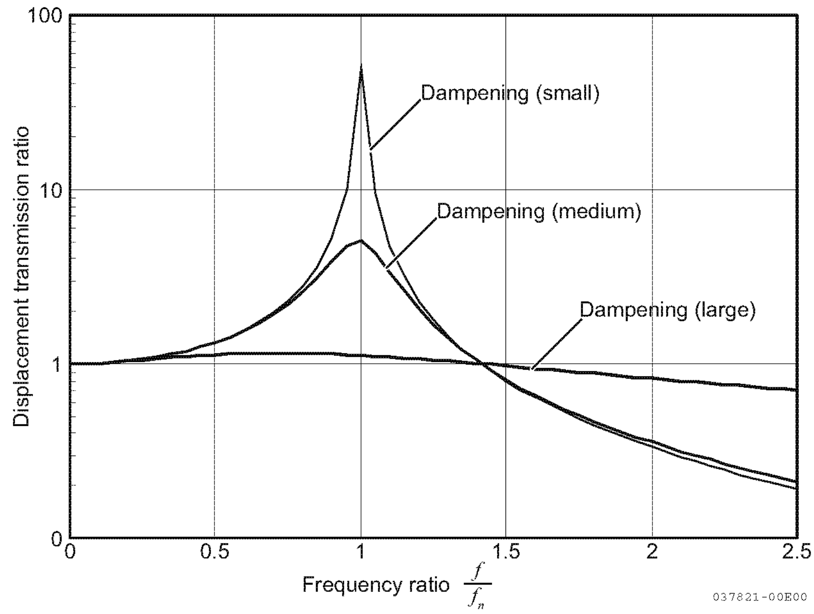


Figure 18-2

Figure 18-2 shows how amplitude of the vibratory system varies by the relation between the frequency f of exciting force and natural frequency f_n of the vibratory system. These curves are generally called resonance curves.

The vibration transmission rate becomes infinite at the resonance point f/f_n 1.0 if there is no decay. Actually it does not become infinite because some form of damping occurs. Nevertheless, in general, the amplitude will be several times the static angle of torsion.

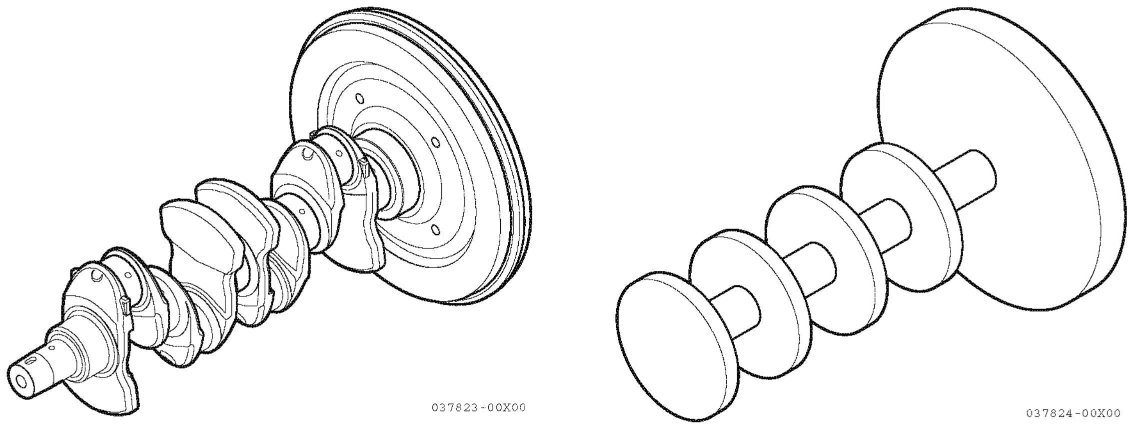
As damping increases, the amplitude at the resonance point decreases.

As described, the resonance phenomenon has to be avoided since the amplitude at the resonance point becomes quite large in forced vibration even if it is reduced by a certain level of damping. This is not merely confined to torsional vibration but applies to all machine parts in general. To avoid resonance, it is necessary to calculate the natural frequency.

Torsional Vibration of Multi-cylinder Engine

Equivalent Vibration System

When calculating the natural frequency for the crankshaft's torsional vibration, the actual crankshaft as shown in the left figure is simplified to a shafting as shown in the right figure. This is called an equivalent vibration system.



Actual crankshaft **Equivalent vibration system**

***Figure* 18-3**

When substituting for equivalent vibration system, substitute the crankshaft and transmission shaft for equivalent shafts having a diameter of 18.72 cm (in the case of a forged steel shaft) and the equivalent torsional stiffness (kg·cm/rad). The length of equivalent shaft is called equivalent length, which represents the size of elasticity of the equivalent vibration system. Also you can replace the crankshaft (including the crankpin, crank arm, balance weight), flywheel, generator/alternator rotor, gear, front pulley, with the equivalent discs (equivalent mass) having the moment of inertia equivalent to them.

Free Vibration of Multi-cylinder Engine

(Figure 18-4) shows how the shaft of a multi-cylinder engine vibratory system replaced with the equivalent vibration system twists during free vibration (generally referred to as an elastic curve).

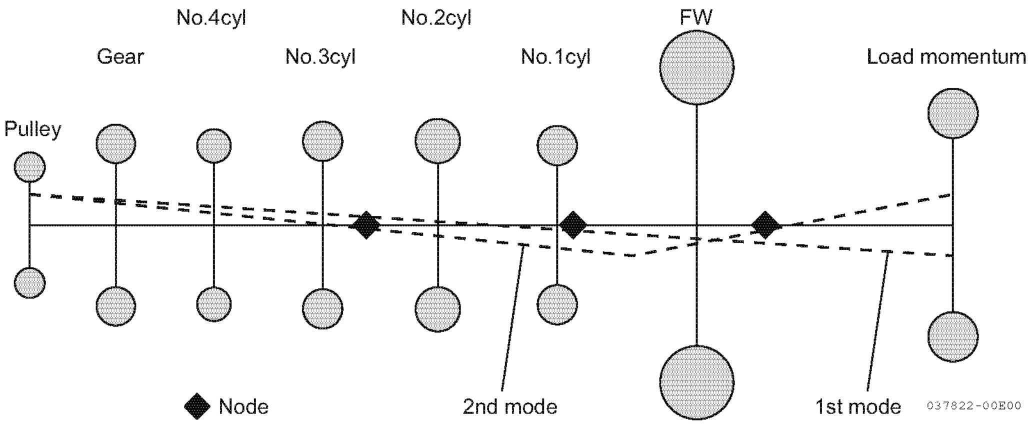


Figure 18-4

(Figure 18-4) shows the forms of two free vibrations including so-called first mode vibration having only one node (beyond this node the shaft twists in the reverse direction) and second mode vibration having nodes at two locations. Theoretically, there are a number of free vibration forms such as 3rd mode, 4th mode and so forth. But generally speaking, the first and second mode vibrations cause most of the problem, followed by the 3rd mode vibration which occasionally causes a problem. The natural frequency of these forms rises as the number of nodes increase.

Forced Vibration of a Multi-cylinder Engine

On 4-stroke engines, there is 1 combustion for every 2 rotations of the crankshaft. The pressure change from the combustion affects the rotational force on the crankshaft. which causes the vibratory force of the torsional vibration. This vibratory force includes the higher harmonics (the engine rotation's rate of 0.5, 1.0, 1.5 and so forth).
Consequently, even if the natural frequency in a torsional vibration system is 1 (for example, resonance with 1.5-fold vibratory force at ○ rotation or resonance with 3-fold vibratory force at △ rotation), there are multiple resonance rotation numbers (principal critical rotation number).

In the case of a multi-cylinder engine, the criticality at critical speed is determined by the size of the vibratory force as calculated in consideration of the cylinder ignition order.
Concerning this critical speed, consider only the order of the vibratory force of a certain size.

Generally, with 4-cycle engines, the resonance rotation number depending on the vibratory force of the degree of order equivalent to one half of the number of cylinders multiplied by an integer is called the principal critical speed. Resonance should be avoided.

With a 4-cycle engine,

$$\text{Major critical speed} = \frac{\text{Natural frequency}}{1/2 \times \text{Number of cylinders} \times \text{Integer}}$$

(Integer: 1, 2, 3, ...)

(The denominator represents a degree of order.)

Beside the major critical speed, torque harmonics of other degrees of order t may become the object of criticality depending on the crank layout and/or firing order. Avoid critical speed for the degrees of order shown in the following table.

Number of cylinders (crank layout)	First mode vibration	Second mode vibration
2 (180 degree crank)	No consideration required for practical application	
3	1.5, 3.0, 4.5	No consideration required
4 (180 degree crank)	2.0, 4.0, 6.0	No consideration required

Actual Processing for Torsional Vibration

This section describes how to process the torsional vibration for practical application.

In the installation plan, it is important to ensure that no critical speed (natural frequency) is present within or in the vicinity of the range of revolution at which the driven machine, whether a generator, a pump or other equipment, is driven.

Generally, a desired natural frequency is achieved by changing the equivalent length of the generator shaft or the transmission shaft of a pump or fan so it does not cause resonance with engine torque harmonics. Therefore, when a rough plan for the machine is completed, it is necessary to consider in the design phase of the driven machine the various models needed to study the torsional vibration of the engine, driven machine and the moment of inertia of the rotors (such as the generator rotor, pump vanes, or cooling fan) that are part of the driven machine.
This is laborious work but it has to be done to prevent problems caused by torsional vibration. To do this, the driven machine manufacturer's cooperation is imperative.

Avoidance and Suppression of Torsional Vibration

To avoid the risk of torsional vibration, it is necessary, as already described, to either avoid the critical speed by changing the natural frequency or to suppress the amplitude of vibration to a lower level.

There are three methods to change the natural frequency; by changing the driven shaft system as described, by changing the equivalent length of the shaft system by inserting a flexible joint between the engine and the driven machine or by changing the equivalent mass by adding mass to the front pulley. To change the amplitude of vibration, a rubber damper and/or viscous damper is used. If a damper is used for a constant-speed engine, the damper absorbs vibration energy constantly. Considering the durability of the damper that is required, use of a damper for a constant-speed engine is not recommended.

Torsional Vibration Equivalent Vibration System

DI Series

3TNV86CT

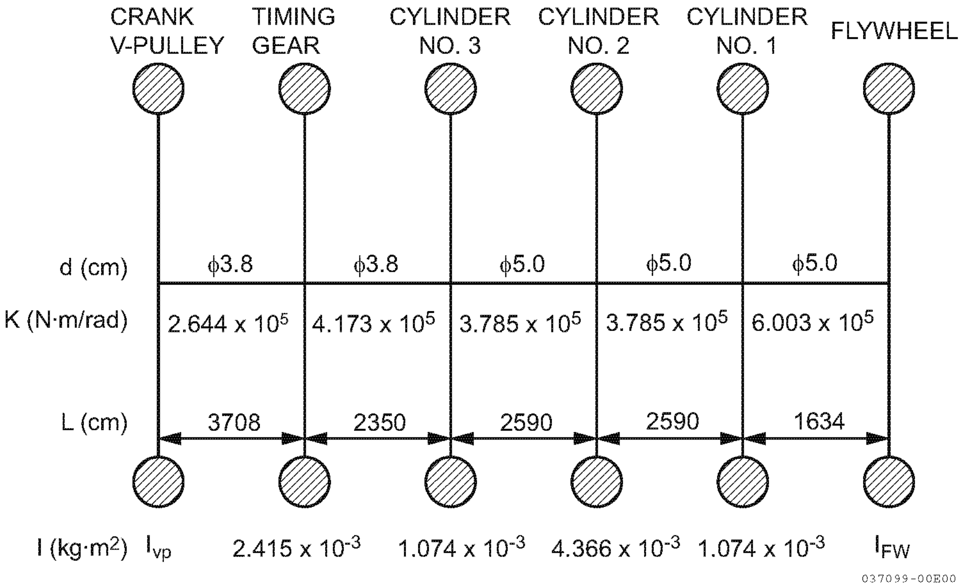


Figure 18-5

I	:	Moment of inertia	kg·m²
K	:	Spring constant	N·m/rad
L	:	Equivalent length	cm
d	:	Shaft diameter	cm
I_{VP}	:	Moment of inertia of crank V-pulley	
I_{FW}	:	Moment of inertia of flywheel	

Equivalent shaft diameter: 18.72 cm

Crankshaft V-pulley moment of inertia

I_{VP} [kg·m²]	Code No.	GD^2 [kg·m²]
2.166×10^{-3}	129004-21650 (ϕ 110)	0.0086
3.356×10^{-3}	129005-21650 (ϕ 120)	0.0134

Flywheel moment of inertia

I_{FW} [kg·m²]	Code No.	GD^2 [kg·m²]
0.199	529A00-21580 (VM standard)	0.80

3TNV88C

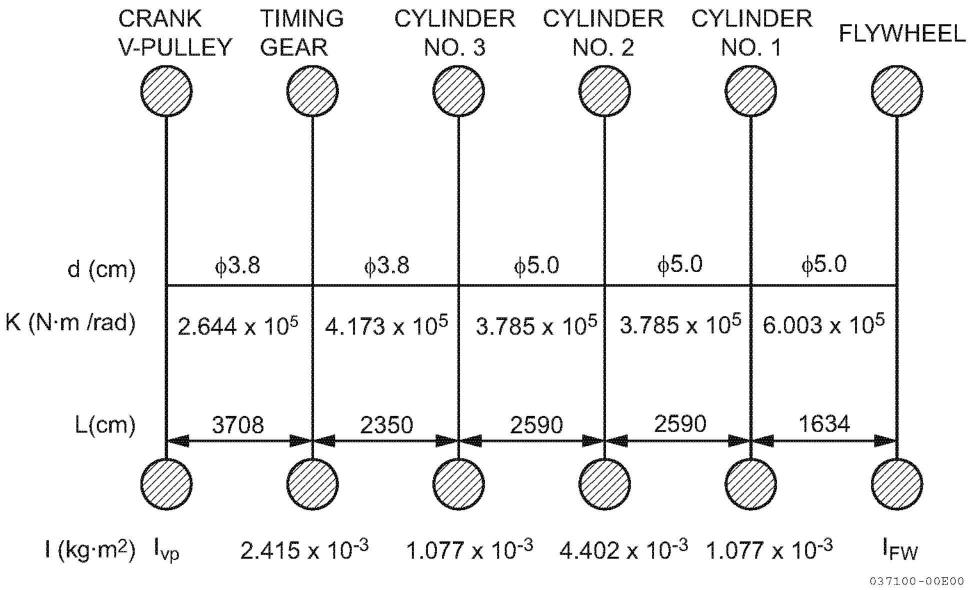


Figure 18-6

I	: Moment of inertia	$kg \cdot m^2$
K	: Spring constant	N·m/rad
L	: Equivalent length	cm
d	: Shaft diameter	cm
I_{VP}	: Moment of inertia of crank V-pulley	
I_{FW}	: Moment of inertia of flywheel	

Equivalent shaft diameter: 18.72 cm

Crankshaft V-pulley moment of inertia

I_{VP} [$kg \cdot m^2$]	Code No.	GD^2 [$kg \cdot m^2$]
2.166×10^{-3}	129004-21650 (ϕ110)	0.0086
3.356×10^{-3}	129005-21650 (ϕ120)	0.0134

Flywheel moment of inertia

I_{FW} [$kg \cdot m^2$]	Code No.	GD^2 [$kg \cdot m^2$]
0.199	529A00-21580 (VM standard)	0.80

4TNV86CT

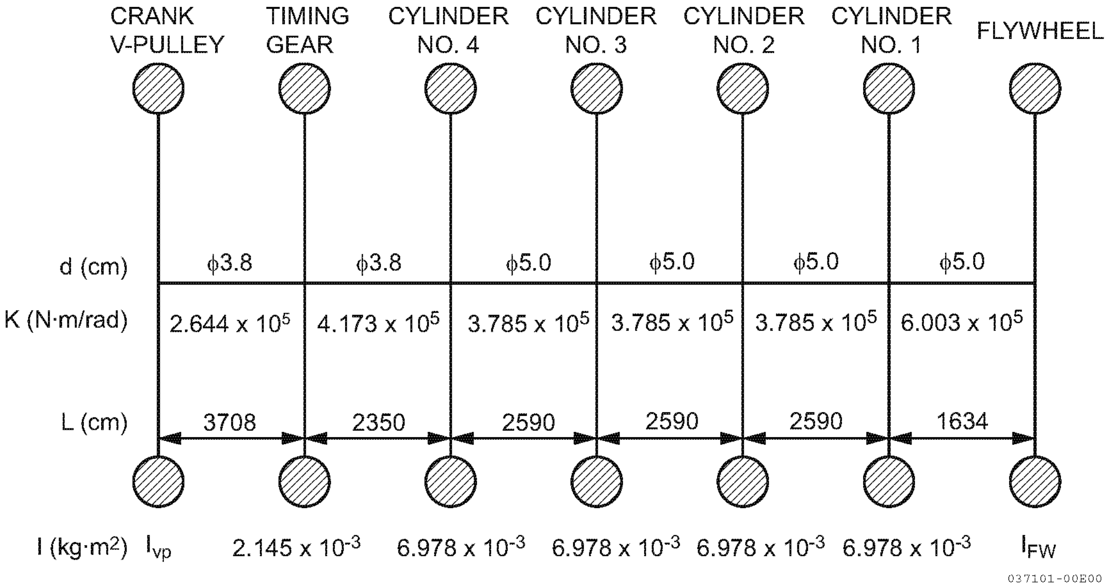


Figure 18-7

I	:	Moment of inertia	kg·m^2
K	:	Spring constant	N·m/rad
L	:	Equivalent length	cm
d	:	Shaft diameter	cm
I_{VP}	:	Moment of inertia of crank V-pulley	
I_{FW}	:	Moment of inertia of flywheel	

Equivalent shaft diameter: 18.72 cm

Crankshaft V-pulley moment of inertia

I_{VP} [kg·m^2]	Code No.	GD^2 [kg·m^2]
2.664×10^{-3}	119802-21650 (ϕ110)	0.0107
3.739×10^{-3}	119802-21660 (ϕ120)	0.0150

Flywheel moment of inertia

I_{FW} [kg·m^2]	Code No.	GD^2 [kg·m^2]
0.199	529C00-21580 (VM standard)	0.80

4TNV88C

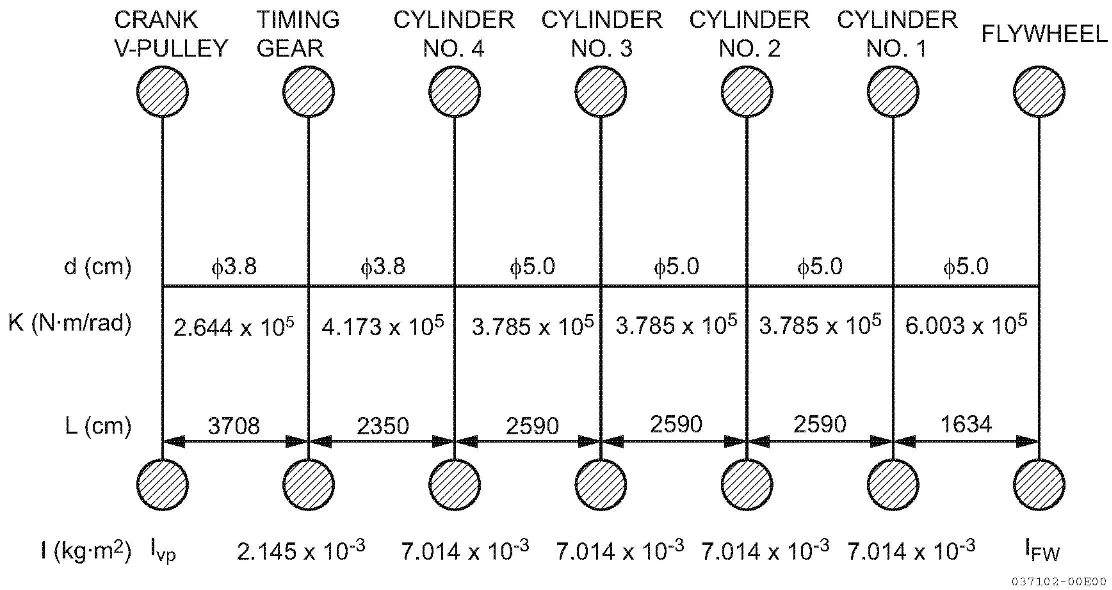


Figure 18-8

I	:	Moment of inertia	kg·m[2]
K	:	Spring constant	N·m/rad
L	:	Equivalent length	cm
d	:	Shaft diameter	cm
I_{VP}	:	Moment of inertia of crank V-pulley	
I_{FW}	:	Moment of inertia of flywheel	

Equivalent shaft diameter: 18.72 cm

Crankshaft V-pulley moment of inertia

I_{VP} [kg·m^2]	Code No.	GD^2 [kg·m^2]
2.664×10^{-3}	119802-21650 (ϕ110)	0.0107
3.739×10^{-3}	119802-21660 (ϕ120)	0.0150

Flywheel moment of inertia

I_{FW} [kg·m^2]	Code No.	GD^2 [kg·m^2]
0.199	529C00-21580 (VM standard)	0.80

4TNV98C, 4TNV98CT

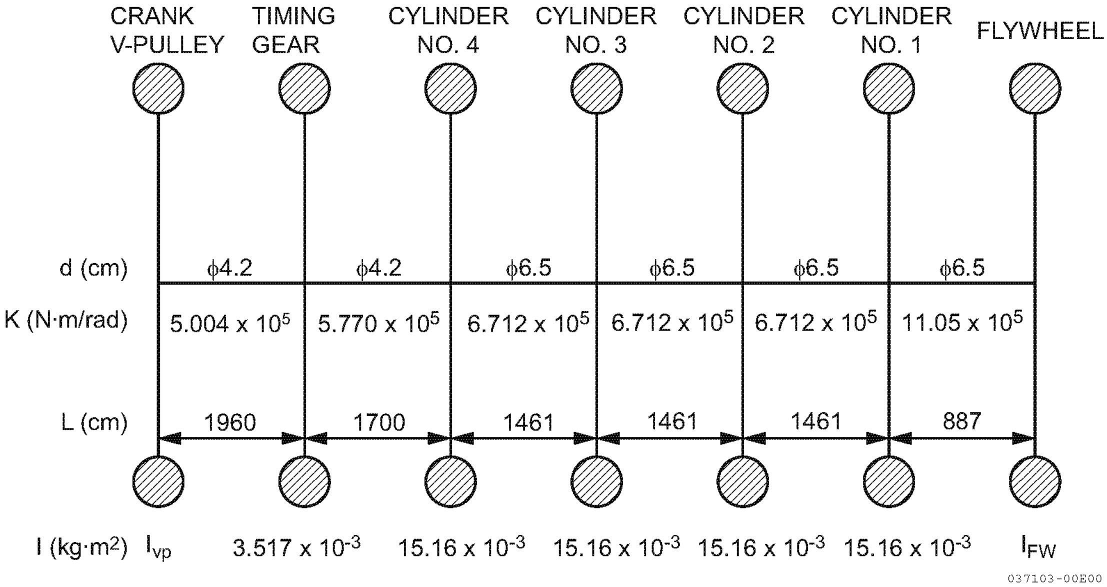


Figure 18-9

I	:	Moment of inertia	kg·m²
K	:	Spring constant	N·m/rad
L	:	Equivalent length	cm
d	:	Shaft diameter	cm
I_{VP}	:	Moment of inertia of crank V-pulley	
I_{FW}	:	Moment of inertia of flywheel	

Equivalent shaft diameter: 18.72 cm

Crankshaft V-pulley moment of inertia

I_{VP} [kg·m²]	Code No.	GD^2 [kg·m²]
1.323×10^{-3}	129900-21690 (ϕ110)	0.0053
1.646×10^{-3}	129900-21650 (ϕ120)	0.0055
2.127×10^{-3}	129900-21660 (ϕ130)	0.0085
2.499×10^{-3}	129900-21670 (ϕ130)	0.0100

Flywheel moment of inertia

I_{FW} [kg·m²]	Code No.	GD^2 [kg·m²]
0.268	529E00-21580 (VM standard)	1.07

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Section 19

REFERENCE MATERIALS

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Part of this technical reference is simplified to facilitate on-site calculation. Care should be taken when using this section when a high level of precision is required for design and tests.

Principal Conversion Table for the Engine Specifications

Output

The output is in kW in principle, but hp and PS are also often used. Conversion factors are as follows:

kW	hp	PS
1	1.3410	1.3596
0.7457	1	1.0143
0.7355	0.9859	1

Pressure

Irrespective of lubricant pressure, JIS and SAE use only kPa (kilo Pascal) as the unit of pressure for engine performance.

kPa	mPa	kgf/cm^2	mmAq (H_2O)	mmHg (Torr)
1	1×10^{-3}	1.01972×10^{-2}	1.01972×10^{2}	7.50062
1×10^{3}	1	1.01972×10	1.01972×10^{5}	7.50062×10^{3}
9.80665×10	9.80665×10^{-2}	1	1×10^{4}	7.35559×10^{2}
9.80665×10^{-3}	9.80665×10^{-5}	1×10^{-4}	1	7.35559×10^{-2}
1.33322×10^{-1}	1.33322×10^{-4}	1.35951×10^{-3}	1.35951×10	1

1 kgf/cm^2 = 98 kPa
= 0.098 MPa
750 mmHg = 100 kPa

1 kPa = 0.0102 kgf/cm^2
1 MPa = 10.2 kgf/cm^2
1 Pa = 1 N/m^2

Specific fuel and lubrication oil consumption

g/kW·h	g/hp·h	g/PS·h
10	0.7457	0.7355
1.3410	1	0.9863
1.3596	1.0139	1

Torque

N·m	kgf·m
1	1.01972×10^{-1}
9.80665	1

1 kgf = 9.80665 N

Fuel Tank

Fuel Tank Capacity

The fuel consumption by the engine is given by the following equation:

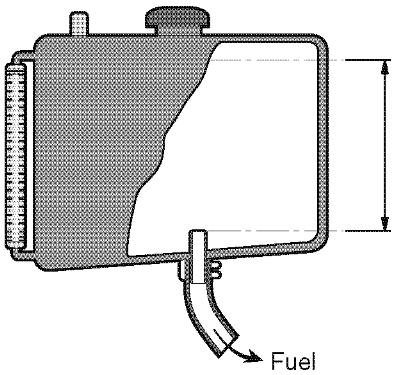
$$Q = \frac{b \times P_e}{1000 \times d}$$

Where,

Q	:	Fuel consumption by engine	ℓ/h
b	:	Specific fuel consumption	g/kW·h
P_e	:	Engine output	kW
d	:	Specific gravity of fuel	approx. 0.83

Calculation example

Calculate the fuel tank capacity by multiplying the fuel consumption per hour calculated by the equation above by the driven machine operating hours. The effective fuel tank capacity must be determined by providing a sufficient margin as shown by the height (h) shown in the figure below:



Calculate the fuel consumption per hour when b = 270 g/kW·h, P_e = 20 kW and d = 0.83.

$$Q = \frac{270 \times 20}{1000 \times 0.83} = \text{Approximately 6.5 liters per hour}$$

Fuel Tank Holding Time

Fuel consumption (ℓ/h)

$$B = \frac{b \times P_e}{d} \times 10^{-3}$$

B	:	Fuel consumption	ℓ/h
b	:	Specific fuel consumption	g/kW·h
P_e	:	Rated output	kW
d	:	Specific gravity of fuel	Diesel fuel 0.83

Fuel tank holding time (h)

$$t = \frac{V}{B}$$

t	:	Fuel tank holding time	h
V	:	Effective fuel capacity	ℓ
B	:	Fuel consumption	ℓ/h

Example

According to the specification sheet for the 4TNV98C series diesel engine, the continuous rating at 1800 min^{-1} should be 36.4 kW and the fuel consumption should be 224 g/kW·h. For how many hours will a fuel tank having an effective capacity of 40 ℓ last at the continuous rating?

Fuel consumption (ℓ/h)

$$B = \frac{b \times P_e}{d} \times 10^{-3}$$

$$= \frac{224 \times 36.4}{0.83} \times 10^{-3}$$

$$= 9.82 \ \ell/h$$

B	:	Fuel consumption	ℓ/h
b	:	Specific fuel consumption	224 g/kW·h
P_e	:	Rated output	36.4 kW
d	:	Specific gravity of fuel	Diesel fuel 0.83

Fuel tank holding time (h)

$$t = \frac{V}{B}$$

$$= \frac{40}{9.82}$$

$$= 4.1\ h$$

t	: Fuel tank holding time	h
V	: Effective fuel capacity	40 ℓ
B	: Fuel consumption	9.82 ℓ/h

Oil Pan Holding Time

Lubricating oil consumption (ℓ/h)

$$C = \frac{c \times P_e}{d} \times 10^{-3}$$

C	: Lubricating oil consumption	ℓ/h
c	: Specific engine oil consumption	g/kW·h
P_e	: Rated output	kW
d	: Specific gravity of engine oil	0.89

Oil pan holding time (h)

$$t = \frac{V}{C}$$

t	: Oil pan holding time	h
V	: Effective capacity of oil pan	ℓ
C	: Lubrication oil consumption	ℓ/h

Example

According to the specification sheet for the 4TNV98C series diesel engine, the effective capacity of the standard oil pan in CL specifications is 5.5 ℓ.
When driven at the continuous rating of 36.4 kW for 1800 min^{-1}, for how many hours will the oil pan last? The specific engine oil consumption should be 0.05 g/kW·h.

Engine oil consumption (ℓ/h)

$$C = \frac{c \times P_e}{d} \times 10^{-3}$$

$$= \frac{0.05 \times 36.4}{0.89} \times 10^{-3}$$

$$= 2.04 \times 10^{-3} \ \ell/h$$

C	:	Engine oil consumption	ℓ/h
c	:	Specific engine oil consumption	0.05 g/kW·h
P_e	:	Continuous rating	36.4 kW
d	:	Specific gravity of engine oil	0.89

Oil pan holding time (ℓ/h)

$$t = \frac{V}{C}$$

$$= \frac{5.5}{2.04 \times 10^{-3}}$$

$$= 2696\ h$$

t	:	Oil pan holding time	h
V	:	Effective capacity of oil pan	5.5 ℓ
C	:	Engine oil consumption	2.04×10^{-3} ℓ/h

Mean Piston Speed

Mean piston speed (m/s)

$$V_m = \frac{2S \times n}{60} \times 10^{-3}$$

V_m	:	Mean piston speed	m/s
S	:	Engine stroke	mm
n	:	Engine speed	min^{-1}

Example

According to the specification sheet for the 4TNV88C series diesel engine, the piston stroke is 90 mm. What is the mean piston speed for 3000 min^{-1} of engine speed in VM specifications.

$$V_m = \frac{2S \times n}{60} \times 10^{-3}$$

$$= \frac{2 \times 90 \times 3000}{60} \times 10^{-3}$$

$$= 9.0 \ m/s$$

V_m	:	Mean piston speed	m/s
S	:	Engine stroke	90 mm
n	:	Engine speed	3000 min^{-1}

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Total Displacement

Total displacement (ℓ)

$$V_{st} = \frac{\pi}{4} D^2 SN \times 10^{-3}$$

V_{st}	:	Total displacement	ℓ
D	:	Bore	mm
S	:	Stroke	mm
N	:	Number of cylinders	

> ***Example***
> According to the specification sheet for the 3TNV88C series diesel engine, the cylinder bore is 88 mm, and the piston stroke is 90 mm. What is the total displacement of this engine?

$$V_{st} = \frac{\pi}{4} D^2 SN \times 10^{-3}$$

$$= \frac{\pi}{4} \times 88^2 \times 90 \times 3 \times 10^{-3}$$

$$= 1642 \ cc$$

V_{st}	:	Total displacement	ℓ
D	:	Bore	88 mm
S	:	Stroke	90 mm
N	:	Number of cylinders	3
π	:		3.1416

Note: Japan and America have different approaches to the processing of the decimal point.
Japanese system: Omits the figures below the decimal point.
American system: Counts fractions of 0.5 and over as a unit and discards the rest.

Torque

Torque (T_{tq})

Output unit P_e		Torque T_{tq}	
		N·m	kgf·m
(a)	kW	$9550 \times \frac{P_e}{n}$	$973.8 \times \frac{P_e}{n}$
(b)	hp	$7121 \times \frac{P_e}{n}$	$726.1 \times \frac{P_e}{n}$
(c)	PS	$7024 \times \frac{P_e}{n}$	$716.2 \times \frac{P_e}{n}$

T_{tq} : Torque — N·m (kgf·m)
P_e : Output — kW (hp or PS)
n : Engine speed — min^{-1}

1kgf·m = 9.80665 N·m

Example

According to the specification sheet for the 4TNV86CT series diesel engine, the rated output for a rated speed of 2400 min^{-1} is 35.5 kW. What is the rated torque?

Since the output is in units of kW, equation (a) is used.

T_{tq} : Torque — N·m
P_e : Output — 35.5 kW
n : Engine speed — 2400 min^{-1}

To obtain the rated torque in N·m:

$$T_{tq} = 9550 \times \frac{P_e}{n}$$

$$= 9550 \times \frac{35.5}{2400}$$

$$= 141 \ N{\cdot}m$$

To obtain the rated torque in kgf·m:

$$T_{tq} = 973.8 \times \frac{P_e}{n}$$

$$= 973.8 \times \frac{35.5}{2400}$$

$$= 14.4 \ kgf{\cdot}m$$

Net Mean Effective Pressure

Net mean effective pressure (P_{me})

Output unit P_e		Net mean effective pressure P_{me}	
		kPa	kgf/cm2
(a)	kW	$\frac{120.0 \times P_e}{V_{st} \times n} \times 10^3$	$\frac{1224 \times P_e}{V_{st} \times n}$
(b)	hp	$\frac{89.49 \times P_e}{V_{st} \times n} \times 10^3$	$\frac{912.5 \times P_e}{V_{st} \times n}$
(c)	PS	$\frac{88.26 \times P_e}{V_{st} \times n} \times 10^3$	$\frac{900 \times P_e}{V_{st} \times n}$

P_{me}	: Brake mean effective pressure	kPa (kgf/cm^2)
P_e	: Output	kW (hp or PS)
V_{st}	: Total displacement	ℓ (here no cc (metric) unit is in use)
n	: Engine speed	min^{-1}

1kgf/cm^2 = 9.80665 × 10 kPa

> ***Example***
> According to the specification sheet for the 4TNV86CT series diesel engine, the rated output for the rated speed of 2400 min^{-1} is 35.5 kW. What is the net mean effective pressure? The total displacement of the engine is 2091 cc.

Since the unit is in kW, equation (a) is used.

P_e	: Output	35.5 kW
V_{st}	: Total displacement	2091 ℓ
n	: Engine speed	2400 min^{-1}

To obtain the net mean effective pressure in kPa:

$$P_{me} = \frac{120.0 \times P_e}{V_{st} \times n} \times 10^3$$

$$= \frac{120.0 \times 35.5}{2091 \times 2400} \times 10^3$$

$$= 849\ kPa$$

To obtain the net mean effective pressure in kgf/cm^2:

$$P_{me} = \frac{1224 \times P_e}{V_{st} \times n}$$

$$= \frac{1224 \times 35.5}{2091 \times 2400}$$

$$= 8.66\ kgf/cm^2$$

Fuel Injection

This value represents the fuel injection per 1000 strokes of one plunger of a fuel injection pump in weight.

Fuel injection (g/1000 st)

$$Q = \frac{b \times P_e}{60 \times (n/2) \times N} \times 10^3$$

Q	:	Fuel injection quantity	g/1000 st
b	:	Specific fuel consumption	g/kWh
P_e	:	Output	kW
n	:	Engine speed	min^{-1}
N	:	Number of engine cylinders	

> ***Example***
>
> According to the specifications sheet for the 4TNV88C series diesel engine, the rated output for the rated speed of 2500 min^{-1} is 30.5 kW and the specific fuel consumption is 238 g/kWh. What is the injection quantity?

Q	:	Fuel injection quantity	g/1000 st
b	:	Specific fuel consumption	238 g/kWh
P_e	:	Output	30.5 kW
n	:	Engine speed	2500 min^{-1}
N	:	Number of engine cylinders	4

$$Q = \frac{b \times P_e}{60 \times (n/2) \times N} \times 10^3$$

$$= \frac{238 \times 30.5}{60 \times (2500/2) \times 4} \times 10^3$$

$$= \frac{24.1}{1000}\frac{g}{st}$$

Cyclic Irregularity (or Coefficient of Speed Fluctuation)

Meaning of Cyclic Irregularity

$$\delta = \frac{\omega_{max} - \omega_{min}}{\omega_{mean}} \times 100$$

δ	:	Cyclic irregularity	%
ω_{max}	:	Maximum angular velocity during 1 cycle	rad/sec
ω_{min}	:	Minimum angular velocity during 1 cycle	rad/sec
ω_{mean}	:	Mean angular velocity during 1 cycle	rad/sec

The revolution angular velocity of an engine fluctuates cyclically during one cycle. The cyclic irregularity represents the percentage of fluctuation from the mean angular velocity (JIS B 0108-8.13). A theoretical formula can be derived from this, but generally Sass's empirical formula as follows is used.

Cyclic Irregularity by Sass's Empirical Formula

The cyclic irregularity by Sass's empirical formula is expressed as a fraction with a numerator of 1. This is customarily used.

Number of cylinders	Crank angle	Effect of supercharger	Sass's constant K
1	–	–	51×10^6
2	–	–	21×10^6
3	–	–	12.5×10^6
4	90°	–	11.8×10^6
	180°	–	2.7×10^6
5	–	–	4.8×10^6
6	–	None	1.6×10^6
	–	T	1.2×10^6
	–	HT, DT, UT	0.96×10^6

If output is in kW:

$$\delta = \frac{1}{\dfrac{n^3 \times GD^2}{K \times P_i} \times 0.7355}$$

δ	:	Cyclic irregularity	
n	:	Engine speed	min^{-1}
GD^2	:	Inertia weight of flywheel	$kg{\cdot}m^2$
K	:	Sass's constant	
P_i	:	Indicated output of engine $P_i = P_e / 0.8$	kW
P_e	:	Rated output of engine	kW

If output is in hp:

$$\delta = \frac{1}{\dfrac{n^3 \times GD^2}{K \times P_i} \times 1.0139}$$

P_i	: Indicated output of engine $P_i = P_e / 0.8$	hp
P_e	: Rated output of engine	hp

If output is in PS:

$$\delta = \frac{1}{\dfrac{n^3 \times GD^2}{K \times P_i}}$$

P_i	: Indicated output of engine $P_i = P_e / 0.8$	PS
P_e	: Rated output of engine	PS

> ***Example***
> According to the specification sheet for the 4TNV88C series diesel engine, the rated output for a rated speed of 2200 min^{-1} is 26.7 kW. Based on the torsional vibration materials in *Torsional Vibration on page 18-1*, the inertia weight GD^2 of a flywheel is 0.80 kg·m^2. What is cyclic irregularity for this combination?

To find the cyclic irregularity when output is in kW:

$$\delta = \frac{1}{\dfrac{n^3 \times GD^2}{K \times P_i} \times 0.7355}$$

$$= \frac{1}{\dfrac{2200^3 \times 0.80}{2.7 \times 10^6 \times 33.38} \times 0.7355}$$

$$= \frac{1}{52}$$

δ	: Cyclic irregularity	
n	: Engine speed	2200 min^{-1}
GD^2	: Inertia weight of flywheel	0.80 kg·m^2
K	: Sass's constant (4-cylinder, 180° crank)	2.7×10^6
P_i	: Indicated output of engine $P_i = P_e / 0.8$	33.38 kW (26.7/0.8)
P_e	: Rated output of engine	26.7 kW

Thermal Efficiency and Heat Loss

Thermal Efficiency (η)

If specific fuel consumption is in kW:

$$\eta = \frac{8.6000 \times 10^2 \times P_e}{H_u \times b \times P_e \times 10^{-3}} \times 10^2$$

$$= \frac{83.50}{b} \times 10^2$$

η	:	Thermal efficiency	%
P_e	:	Engine output	hp
H_u	:	Lower calorific value of diesel fuel	10300 kcal/kg
b	:	Specific fuel consumption	g/hph

1 kW = 8.6000×10^2 kcal/h

If specific fuel consumption is in hp:

$$\eta = \frac{6.23610 \times 10^2 \times P_e}{H_u \times b \times P_e \times 10^{-3}} \times 10^2$$

$$= \frac{60.54}{b} \times 10^2$$

η	:	Thermal efficiency	%
P_e	:	Engine output	hp
H_u	:	Lower calorific value of diesel fuel	10300 kcal/kg
b	:	Specific fuel consumption	g/hph

1 hp = 6.23610×10^2 kcal/h

If specific fuel consumption is in PS:

$$\eta = \frac{6.32529 \times 10^2 \times P_e}{H_u \times b \times P_e \times 10^{-3}} \times 10^2$$

$$= \frac{61.41}{b} \times 10^2$$

η	:	Thermal efficiency	%
P_e	:	Engine output	PS
H_u	:	Lower calorific value of diesel fuel	10300 kcal/kg
b	:	Specific fuel consumption	g/PSh

1 PS = 6.32529×10^2 kcal/h

> ***Example***
> The specific fuel consumption for the 4TNV88C series diesel engine for a rated output of 30.5 kW at the rated speed of 2500 min^{-1} should be 224 g/kWh. What is the thermal efficiency?

To find thermal efficiency when specific fuel consumption is in kW:

η	:	Thermal efficiency	%
P_e	:	Engine output	30.5 kW
H_u	:	Lower calorific value of diesel fuel	10300 kcal/kg
b	:	Specific fuel consumption	224 g/kWh

$$\eta = \frac{83.50}{b} \times 10^2$$

$$= \frac{83.50}{224} \times 10^2$$

$$= 0.373 \times 10^2$$

$$= 37\%$$

Exhaust loss ϕ_{ex}

$$\phi_{ex} = \frac{\{n_t \times V_{st} \times 10^{-3} \times n/(2 \times 60)\} \times c \times t_{ex}}{H_u \times b \times 10^{-3} \times P_e/3600} \times 10^2$$

ϕ_{ex}	:	Exhaust loss	%
V_{st}	:	Total displacement	ℓ
n	:	Engine speed	rpm
η_t	:	Intake efficiency	if unknown, use 0.85
C_p	:	Specific heat at constant pressure	kcal/Nm^3°C
t_{ex}	:	Exhaust temperature	°C

Exhaust temperature t_{ex} °C	Mean specific heat C kcal/Nm^3 °C
200	0.313
300	0.315
400	0.318
500	0.321
600	0.324

H_u	:	Lower calorific value of diesel fuel	10300 kcal/kg
b	:	Specific fuel consumption	g/kWh (g/hph, g/PSh)
P_e	:	Engine output	kW (hp, PS)

$$\phi_{ex} = 2.9126 \times 10^{-3} \times \frac{V_{st} \times n \times \eta_t \times c \times t_{ex}}{b \times P_e} \times 10^2$$

Example

The specific fuel consumption of the 4TNV88C series diesel engine for the rated output of 30.5 kW at the rated speed of 2500 min^{-1} should be 238 g/kWh, and the exhaust temperature should be 500 °C. What is the exhaust loss?

ϕ_{ex}	:	Exhaust loss	%
V_{st}	:	Total displacement	2.189 ℓ
n	:	Engine speed	2500 min^{-1}
η_t	:	Intake efficiency	0.85
c_p	:	Specific heat at constant pressure	0.321 $kcal/Nm^3$ °C
t_{ex}	:	Exhaust temperature	500 °C
b	:	Specific fuel consumption	238 g/kWh
P_e	:	Engine output	30.5 kW

$$\phi_{ex} = 2.9126 \times 10^{-3} \times \frac{V_{st} \times n \times \eta_t \times c_p \times t_{ex}}{b \times P_e} \times 10^2$$

$$= 2.9126 \times 10^{-3} \times \frac{2.189 \times 2500 \times 0.85 \times 0.321 \times 500}{238 \times 30.5} \times 10^2$$

$$= 0.300 \times 10^2$$

$$= 30 \ \%$$

Cooling loss ϕ_{cw}

$$\phi_{cw} = \frac{(Q_p/60) \times \rho \times C_p \times (t_{wo} - t_{wi})}{H_u \times b \times 10^{-3} \times P_e/3600} \times 10^2$$

ϕ_{cw}	:	Cooling loss	%
Q_p	:	Cooling water pump discharge	ℓ/min
ρ	:	Specific weight	1 kg/ℓ
C_p	:	Specific heat at constant pressure	1 kcal/kg °C
t_{wo}	:	Cooling water temperature at engine outlet	°C
t_{wi}	:	Cooling water temperature at engine inlet	°C
H_u	:	Lower calorific value of diesel fuel	10300 kcal/kg
b	:	Specific fuel consumption	g/kWh
P_e	:	Engine output	kW

$$\phi_{cw} = 5.8252 \times \frac{Q_p \times (t_{wo} - t_{wi})}{b \times P_e} \times 10^2$$

Example

The specific fuel consumption of the 3TNV88C series diesel engine for the rated output of 22.8 kW at the rated speed of 2500 min^{-1} is 238 g/kWh. According to separate materials, the pump discharge is 34 ℓ/min. If the difference of engine cooling water temperature between the outlet and inlet of the engine is 5 °C, what is the cooling water loss of the engine?

ϕ_{cw}	:	Cooling loss	%
Q_p	:	Cooling water pump discharge	34 ℓ/min
$(t_{wo}-t_{wi})$	:	Temperature difference of cooling water between the outlet and inlet of the engine	5 °C
b	:	Specific fuel consumption	238 g/kWh
P_e	:	Engine output	22.8 kW

$$\phi_{cw} = 5.8252 \times \frac{Q_p \times (t_{wo} - t_{wi})}{b \times P_e} \times 10^2$$

$$= 5.8252 \times \frac{34 \times 5}{238 \times 22.8} \times 10^2$$

$$= 0.182 \times 10^2$$

$$= 18\ \%$$

Other loss ϕ_0

$$\phi_0 = 100 - (\eta + \phi_{ex} + \phi_{cw})$$

ϕ_o	:	Other loss	%
η	:	Thermal efficiency	%
ϕ_{ex}	:	Exhaust loss	%
ϕ_{cw}	:	Cooling loss	%

Generator

Relation of Capacity (Output), Voltage and Current of AC Generator

Single phase AC generator

$$C = E \times I \times 10^{-3}$$

$$O = C \times pf$$

C	: Capacity	kVA
O	: Output	kW
E	: Voltage	V
I	: Current	A
pf	: Power factor	1.0 for single-phase AC generator

3-phase AC generator

$$C = \sqrt{3} \times E \times I \times 10^{-3}$$

$$O = C \times pf$$

C	: Capacity	kVA
O	: Output	kW
E	: Voltage	V
I	: Current	A
pf	: Power factor	0.8 for 3-phase AC generator

Power Factor

Power factor is a term for expressing the property of the load, and not for matters concerning the characteristics of a generator.

The efficiency of a generator is affected if the power factor is different even if the output is the same. If an AC voltage is applied to capacitors, coil and resistors provided in series in the machine on the load side, the alternating current does not synchronize, resulting in a phase shift. This shift of phase is called power factor. (For more detailed descriptions, please refer to technical references.) The power factor varies by machine; a rough guideline is as follows. If more detailed studies are necessary when selecting generator, check with the electric machine manufacturer.

Electric equipment	Power factor %
Incandescent lamp	100
Electric heater	100
3-phase induction motor	70 to 90
Fluorescent lamp (with safety device)	55
Neon tube lamp	40 to 50
Resistance welding machine	40 to 50
AC arc welding machine	40 to 50
DC arc welding machine	50 to 80

When trying to decide on generator specifications, the type of load is unknown in advance. Therefore, the power factor of 1.0 is applied to a single-phase AC generator assuming the resistance load of an incandescent lamp and the heater for which the generator is comparatively frequently used.

In the case of a 3-phase AC generator, a power factor of 0.8 is customarily used as it is frequently used for the motor load.

Generator Capacity and Engine Output

$$O_G = C_G \times pf$$

$$O_E = O_G / E_G$$

O_G	:	Generator output	kW
C_G	:	Generator capacity	kVA
pf	:	power factor	
		single-phase AC generator	1.0
		3-phase AC generator	0.8
O_E	:	Engine output	kW
E_G	:	Generator efficiency	η

Strictly speaking, it is not possible to select an engine without knowing the power factor (pf) and the generator efficiency (E_G) even if a certain generator capacity only is specified. If a generator manufacturer needs to select an engine for a new application, always check on the generator efficiency and the power factor.

Since it is customary to use 0.8 as the power factor of a 3-phase AC generator, the required engine output can be obtained by using the generator efficiency (E_G) guideline as follows.

Select the engine so that the required engine output will be equivalent to or less than the continuous rated output.

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Generator capacity C_G		Generator efficiency	Engine output O_E	Generator capacity C_G		Generator efficiency	Engine output O_E
kVA	kW	h	kW	kVA	kW	h	kW
1	0.8	68.0	1.2	37.5	30	86.8	34.6
2	1.6	70.0	2.3	40	32	87.0	36.8
3	2.4	72.0	3.3	45	36	87.4	41.2
5	4	77.0	5.2	50	40	87.8	45.6
6	4.8	78.0	6.2	56.25	45	88.2	51.0
6.25	5	79.0	6.3	60	48	88.4	54.3
7.5	6	82.0	7.3	62.5	50	88.5	56.5
10	8	82.0	9.8	75	60	89.1	67.3
12.5	10	82.0	12.2	80	64	89.3	71.7
15	12	83.0	14.5	100	80	90.0	88.9
18.75	15	83.0	18.1	120	96	90.0	107
20	16	84.0	19.0	125	100	90.0	111
25	20	85.2	23.5	130	104	90.0	116
30	24	85.9	27.9	140	112	90.0	124
31.25	25	86.0	29.1	150	120	90.5	133
35	28	86.5	32.4	160	128	90.5	141

Relation of number of poles, frequency and speed of the generator

$$n = \frac{120f}{p}$$

n	: Generator speed	min^{-1}
f	: Frequency	Hz
p	: Number of poles (2, 4, 6, ...even number)	

Hydraulic Pump (Gear)

Discharge ℓ/min

Theoretical discharge

$$Q_t = 2\pi \times Z \times b \times m^2 \times N \times 10^{-6}$$

Real discharge

$$Q_r = \eta_v \times Q_t$$

Q_t	: Theoretical discharge	ℓ/min
Q_r	: Real discharge	ℓ/min
Z	: Number of drive gear teeth	
b	: Face width	
m	: Module	
N	: Drive gear speed	min^{-1}
η_v	: Volume efficiency	

Driving Horsepower (Required Horsepower)

Theoretical driving horsepower (theoretical required horsepower)

		Discharge pressure P	
		kPa	kgf/cm²
Theoretical driving horsepower L_t	kW	$\frac{P \times Q_t}{60} \times 10^{-3}$	$\frac{P \times Q_t}{6 \times 102.0}$
	hp	$\frac{P \times Q_t}{60 \times 0.7457} \times 10^{-3}$	$\frac{P \times Q_t}{6 \times 76.04}$
	PS	$\frac{P \times Q_t}{60 \times 0.7355} \times 10^{-3}$	$\frac{P \times Q_t}{6 \times 75}$

P : Discharge pressure — kPa (kgf/cm²)

Q_t : Theoretical discharge — ℓ/min

1 kW = 1.0000 × 10³ × N·m/s = 102.0 kgf·m/s

1 hp = 0.7457 × 10³ × N·m/s = 76.04 kgf·m/s

1 PS = 0.7355 × 10³ × N·m/s = 75 kgf·m/s

Real driving horsepower (real required horsepower)

$$L_r = L_t / \eta_p$$

L_r : Real driving horsepower (real required horsepower)

L_t : Theoretical driving horsepower (theoretical required horsepower)

η_p : Total pump efficiency — $\eta_p = \eta_v \times \eta_m$

η_v : Volumetric efficiency of pump

η_m : Mechanical efficiency of pump

Guideline for efficiency

	Volumetric efficiency η_v	Overall efficiency η_p
Gear pump	75 to 85	65 to 80
Vane pump	85 to 93	75 to 85
Plunger pump	90 to 98	85 to 90

Actual Calculation Method

Theoretical discharge Q_t is calculated by the hydraulic pump manufacturer. The driving horsepower (required horsepower) is examined by using discharge cc/rev per pump revolution which is usually stated in the hydraulic pump specification.

Discharge cc/rev already includes estimated volumetric efficiency. Therefore, the driving horsepower (required horsepower) is obtained by only taking the mechanical efficiency m of the pump into consideration.

Discharge Q (ℓ/min)

$$Q = q \times n \times 10^{-3}$$

Q	:	Discharge	ℓ/min
q	:	Discharge per revolution of hydraulic pump	cc/rev
n	:	Hydraulic pump speed	min^{-1}

Driving horsepower (required horsepower)

		Discharge pressure P	
		kPa	kgf/cm^2
Driving horsepower L_h	kW	$\frac{P \times Q \times 10^{-3}}{60 \times \eta_m}$	$\frac{P \times Q_t}{6 \times 102.0 \times \eta_m}$
	hp	$\frac{P \times Q \times 10^{-3}}{60 \times 0.7457 \times \eta_m}$	$\frac{P \times Q_t}{6 \times 76.04 \times \eta_m}$
	PS	$\frac{P \times Q \times 10^{-3}}{60 \times 0.7355 \times \eta_m}$	$\frac{P \times Q_t}{6 \times 75 \times \eta_m}$

L_h	:	Driving horsepower (required horsepower)	kW (hp, PS)
P	:	Discharge pressure	kPa (kgf/cm^2)
Q	:	Hydraulic pump discharge	ℓ/min
η_m	:	Mechanical efficiency of hydraulic pump	if unknown, 0.9

Water Pump Driving Horsepower (Required Horsepower)

Driving horsepower L_w	kW	$\dfrac{\gamma \times Q \times H}{60 \times 102.0 \times \eta_m}$
	hp	$\dfrac{\gamma \times Q \times H}{60 \times 76.04 \times \eta_m}$
	PS	$\dfrac{\gamma \times Q \times H}{60 \times 75 \times \eta_m}$

L_w : Driving horsepower (required horsepower) kW (hp, PS)

γ : Specific weight 1 kg/ℓ

Q : Water pump discharge ℓ/min

H : Head m

η_m : Mechanical efficiency of water pump
Check the efficiency with the manufacturer as it varies greatly with the model.

Relation between water temperature and suction head

Water temperature °C (°F)	Suction head (m)
0 (32)	6.7
20 (68)	6.8
40 (104)	4.7
60 (140)	2.3
70 (158)	0

(Under normal atmospheric conditions)

Form Characteristics of Cooling Fan

Required horsepower $\propto n^3 \cdot D^5$
Air capacity $\propto n \cdot D^3$
Back pressure $\propto n^2 \cdot D^2$
Noise $\propto n^5 \cdot D^7$

n : Fan speed
D : Fan diameter

This proportional expression is used for an estimation calculation if either n or D varies within a minor range.

Mesh Number and Size of Mesh

American system (Tyler)		German standard	
Mesh (number of mesh/inch)	Size of mesh (mm)	Mesh (number of mesh hole/cm^2)	Size of mesh (mm)
10	1.65	16	1.5
12	1.40	25	1.2
14	1.17	36	1.0
16	0.99	64	0.75
20	0.83	100	0.60
24	0.70	121	0.54
28	0.69	141	0.49
32	0.50	196	0.43
35	0.417	256	0.385
42	0.351	400	0.300
48	0.295	576	0.250
60	0.240	900	0.200
65	0.208	1600	0.150
80	0.175	2500	0.120
100	0.147	3600	0.102
150	0.104	4900	0.088
200	0.074	6400	0.075
250	0.062	10000	0.060
300	0.046		

Centigrade-Fahrenheit Temperature Conversion

$$°C = \frac{5}{9} \times (°F - 32) \qquad °F = \frac{9}{5} \times °C + 32$$

Centigrade (°C)	Fahrenheit (°F)	Centigrade (°C)	Fahrenheit (°F)	Centigrade (°C)	Fahrenheit (°F)
-40	-40.0	30	86.0	74	165.2
-35	-31.0	31	87.8	75	167.0
-30	-22.0	32	89.6	76	168.8
-25	-13.0	33	91.4	77	170.6
-20	-4.0	34	93.2	78	172.4
-18	-0.4	35	95.0	79	174.2
-16	3.2	36	96.8	80	176.0
-14	6.8	37	98.6	81	177.8
-12	10.4	38	100.4	82	179.6
-10	14.0	39	102.2	83	181.4
-8	17.6	40	104.0	84	183.2
-6	21.2	41	105.8	85	185.0
-4	24.8	42	107.6	86	186.6
-2	28.4	43	109.4	87	188.6
0	32.0	44	111.2	88	190.4
1	33.8	45	113.0	89	192.2
2	35.6	46	114.8	90	194.0
3	37.4	47	116.6	91	195.8
4	39.2	48	118.4	92	197.6
5	41.0	49	120.2	93	199.4
6	42.8	50	122.0	94	202.2
7	44.6	51	123.8	95	203.0
8	46.4	52	125.6	96	204.8
9	48.2	53	127.4	97	206.6
10	50.0	54	129.2	98	208.4
11	51.8	55	131.0	99	210.2
12	53.6	56	132.8	100	212.0
13	55.4	57	134.6	101	213.8
14	57.2	58	136.4	102	215.6
15	59.0	59	138.2	103	217.4
16	61.8	60	140.0	104	219.2
17	63.6	61	141.8	105	221.0
18	65.4	62	143.6	106	222.8
19	67.2	63	145.4	107	224.6
20	68.0	64	147.2	108	226.4
21	69.8	65	149.0	109	228.2
22	71.6	66	150.8	110	230.0
23	73.4	67	152.6	112	233.6
24	75.2	68	154.4	114	237.2
25	77.0	69	156.2	116	240.8
26	78.8	70	158.0	118	244.4
27	80.6	71	159.8	120	248.0
28	82.4	72	161.6	122	251.6
29	84.2	73	163.4	124	255.2

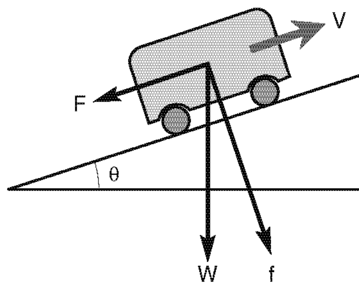
Hill Climbing Horsepower and Allowable Climbing Angle

The required horsepower of a mobile driven machine can be divided into working, traveling and hill climbing horsepower. The working horsepower refers to the horsepower at which the driven machine works at its maximum, and varies according to the workload. The traveling horsepower refers to the horsepower needed for moving the driven machine, which fluctuates sharply with the speed level and running resistance generated by the travel device (such as crawler, tire, etc.) and the road surface conditions (asphalt, soil, sand, farmland, etc.)

The required horsepower for both the working and the traveling must be measured with an actual machine test. The hill climbing horsepower can be calculated in advance. If the road surface conditions are assumed to be the same, the running resistance, that is, the traveling horsepower is assumed to remain unchanged for both the level and grade running.

Hill Climbing Horsepower

The required horsepower for a driven machine having gross vehicle weight W to climb a grade of incline angle θ at running speed V can be obtained from the calculation formula given in the table below:



W : Gross vehicle weight N (kgf)

θ : Incline angle of a grade rad (deg)

V : Running speed m/sec

$$F = W\sin\theta$$
$$f = W\cos\theta$$

1 kW = 1.0000×10^3 N·m/s = 102.0 kgf·m/s

1 hp = 0.7457×10^3 N·m/s = 76.04 kgf·m/s

1 PS = 0.7355×10^3 N·m/s = 75 kgf·m/s

	Gross vehicle weight W	
	N	kgf
kW	$V \times W\sin\theta \times 10^{-3}$	$\frac{V \times W\sin\theta}{102.0}$
hp	$\frac{V \times W\sin\theta}{0.7457} \times 10^{-3}$	$\frac{V \times W\sin\theta}{76.04}$
PS	$\frac{V \times W\sin\theta}{0.7355} \times 10^{-3}$	$\frac{V \times W\sin\theta}{75}$

Allowable Hill Climbing Angle

A driven machine that has an engine that meets the required hill climbing horsepower does not necessarily climb the hill. Another point that must be considered is the limit of climbing angle generated from the coefficient of friction between the traveling device or from the characteristics of the road surface itself.

In other words, it is meaningless to consider the hill climbing horsepower beyond the limit of slipping between the traveling device and the road surface or in case of collapse of the road surface itself.

The driven machine manufacturer's data are needed for the dynamic coefficient of friction between the traveling device and various road surface conditions and the characteristics of the road surface material itself. Supposing that the coefficient is, the allowable hill climbing angle will be as follows:

$$F < \mu \times f$$

$$W \sin\theta < \mu \times W \cos\theta$$

$$\tan\theta < m$$

$$\theta < \tan^{-1}\mu$$

If coefficient μ (determined by the environment of the driven machine) is known, a target limit of the climbing angle can be calculated regardless of the weight of the driven machine.

Section 20

CONVERSION FACTORS FOR SI UNITS

To convert from english (A)	To S.I. metric (B)	Multiply by (C)	To old metric (D)	Multiply by (E)
sq in	mm^2	645.16	cm^2	6.4516
sq ft	m^2	0.0929	m^2	0.0929
lb/cu ft	kg/m^3	16.0185	kg/m^3	16.0185
lbf	N	4.4482	N	4.4482
lbf/ft	N/m	14.5939	N/m	14.5939
Btu	kJ	1.0551	kcal	0.252
Btu/hr	W	0.2931	kcal/hr	0.252
Btu/scf	kJ/nm^3	37.2590	$kcal/nm^3$	0.1565
in	mm	25.400	cm	2.540
ft	m	0.3048	m	0.3048
yd	m	0.914	m	0.914
lb	kg	0.4536	kg	0.4536
hp	kW	0.7457	kW	0.7457
psi	kPa	6.8948	kg/cm^2	0.070
psia	kPa abs	6.8948	bars abs	0.0716
psig	kPa gage	6.8948	ata	0.070
in Hg	kPa	3.3769	cm Hg	2.540
in H_2O	kPa	0.2488	cm H_2O	2.540
°F	°C	(°F-32) 5/9	°C	(°-32) 5/9
°F (interval)	°C (interval)	5/9	°C (interval)	5/9
ft-lb	N-m	1.3558	N-m	1.3558
ft-lb	–	–	kgf•m	0.1383
mph	km/hr	1.6093	km/hr	1.6093
ft/sec	m/sec	0.3048	m/sec	0.3048
cu ft	m^3	0.0283	m^3	0.0283
gal (US)	ℓ	3.7854	ℓ	3.7854
cfm	m^3/min	0.0283	m^3/min	0.0283
scfm	nm^3/min	0.0268	nm^3/hr	1.61

CONVERSION FACTORS FOR SI UNITS

To convert from english	To S.I. metric	Multiply by	To old metric	Multiply by
cm^2	mm^2	100		
kcal	kJ	4.1868		
kcal/hr	W	1.16279		
cm	mm	10		
kg/cm^2	kPa	98.0665		
bars	kPa	100		
atm	kPa	101.325		
cm Hg	kPa	1.3332		
cm H_2O	kPa	9.8064		
nm^3/hr	nm^3/min	0.0176		

How to use this table.

- If you want to convert from A to B, you have to multiply A and C together. (B = A × C)
- If you want to convert from A to D, you have to multiply A and E together. (D = A × E)

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