YANMAR®

TNV series

APPLICATION MANUAL

2TNV70
3TNV70 · 3TNV76
3TNV82A · 3TNV82A-B
3TNV84 · 3TNV84T · 3TNV84T-B
3TNV88 · 3TNV88-B · 3TNV88-U
4TNV84 · 4TNV84T · 4TNV84T-Z
4TNV88 · 4TNV88-B · 4TNV88-U
4TNV94L
4TNV98 · 4TNV98-Z · 4TNV98-E
4TNV98T · 4TNV98T-Z
4TNV106 · 4TNV106T

P/N: 0DTNV-G00302

INDUSTRIAL
ENGINES

Section 1

APPLICATION STANDARD

Page

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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="6">Application Standard</th><th>Remarks</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Engine type</td><td colspan="3">Special swirl combustion chamber system engines (IDI engines)</td><td colspan="3">Engines with cylinder bore of 76 mm or less</td><td rowspan="2">TNV series</td></tr>
<tr><td colspan="3">Direct injection system engines (DI engines)</td><td colspan="3">Engines with cylinder bore of 82 mm or more</td></tr>
<tr><td rowspan="5">2</td><td rowspan="5">Output/rpm</td><td colspan="3">Output rpm</td><td colspan="3">See Specifications on page 3-5.
Engine Specifications</td><td></td></tr>
<tr><td rowspan="3">Output Setting conditions</td><td colspan="2">Ambient temperature</td><td colspan="3">25°C (77°F)</td><td rowspan="4">Same as in JIS and ISO</td></tr>
<tr><td colspan="2">Atmospheric pressure</td><td colspan="3">100 kPa (750 mmHg)</td></tr>
<tr><td colspan="2">Relative humidity</td><td colspan="3">30%</td></tr>
<tr><td colspan="3">Output power correction</td><td colspan="3">See Power Corrections on page 4-3.</td></tr>
<tr><td rowspan="5">3</td><td rowspan="5">Special operating environment</td><td colspan="3">Precautions against sand dust</td><td colspan="3" rowspan="5">See Special Operating Environment on page 1-5.</td><td rowspan="5"></td></tr>
<tr><td colspan="3">Precautions for outdoor installation</td></tr>
<tr><td colspan="3">Precautions against sea air and snow melting agents</td></tr>
<tr><td colspan="3">Precautions against cold environment</td></tr>
<tr><td colspan="3">Precautions against hot environment</td></tr>
<tr><td rowspan="8">4</td><td rowspan="8">Fuel oil</td><td colspan="2">Fuel oil</td><td colspan="2">Ambient temperature °C (°F)</td><td colspan="2">Equivalent fuel</td><td rowspan="8">See Standard Diesel Fuel Line Layout on page 10-7 for the fuel specifications in each country.</td></tr>
<tr><td colspan="2" rowspan="3">Diesel fuel</td><td colspan="2">≥ -5 (23)</td><td colspan="2">JIS No. 2</td></tr>
<tr><td colspan="2">15 to -20 (59 to -4)</td><td colspan="2">JIS No. 3</td></tr>
<tr><td colspan="2"><-20 (<-4)</td><td colspan="2">JIS special No. 3</td></tr>
<tr><td colspan="2">Kerosene</td><td colspan="4">Not allowed</td></tr>
<tr><td colspan="2">Heavy oil</td><td colspan="4">Not allowed</td></tr>
<tr><td colspan="2">JP-4</td><td colspan="4">Not allowed</td></tr>
<tr><td colspan="2">JP-8, JP-5</td><td colspan="4">Contact Yanmar for consideration</td></tr>
<tr><td rowspan="4">5</td><td rowspan="4">Engine oil</td><td colspan="6">See 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 colspan="2">Lubricating oil class</td><td colspan="2">Lubricating oil replacement interval (hr)</td><td colspan="2">Lubricating oil filter replacement interval (hr)</td></tr>
<tr><td colspan="2">CD, CF, CF-4, CI-4
E-3, E-4, E-5, DH-1</td><td colspan="2">Every 250</td><td colspan="2">Every 250</td></tr>
<tr><td colspan="3">Allowable maximum engine oil temperature</td><td colspan="3">≤120°C (248°F)</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 colspan="3">Allowable cooling water temperature at engine outlet</td><td colspan="2">≤105°C (221°F)</td><td>See Cooling System on page 9-1.</td></tr>
<tr><td colspan="3">Water quality</td><td colspan="3">Soft water</td><td>See Engine Coolant on page 9-4.</td></tr>
<tr><td colspan="3">Antifreeze mixing ratio%</td><td colspan="3">Atmospheric temperature °C (°F)</td><td rowspan="4">See Radiator on page 9-8.</td></tr>
<tr><td colspan="3">30</td><td colspan="3">0 to -15 (32 to 5)</td></tr>
<tr><td colspan="3">40</td><td colspan="3">-15 to -25 (5 to -13)</td></tr>
<tr><td colspan="3">50</td><td colspan="3">-25 to -40 (-3 to -40)</td></tr>
</table>

<table>
<tr><th>No.</th><th>Item</th><th colspan="4">Application Standard</th><th>Remarks</th></tr>
<tr><td>7</td><td>Power take-off (PTO)</td><td colspan="4">See P.T.O. Systems on page 16-1.</td><td></td></tr>
<tr><td>8</td><td>Low-temperature startability</td><td colspan="4">See Low-temperature startability on page 1-7.</td><td></td></tr>
<tr><td rowspan="4">9</td><td rowspan="4">Allowable inclination angle</td><td rowspan="2">Continuous operation</td><td rowspan="2">All directions</td><td>IDI</td><td>≤25°</td><td rowspan="4">See Crankcase Breather System on page 11-18.</td></tr>
<tr><td>DI</td><td>≤30°</td></tr>
<tr><td rowspan="2">Instantaneous operation (within 3 minutes)</td><td rowspan="2">All directions</td><td>IDI</td><td>≤30°</td></tr>
<tr><td>DI</td><td>≤35°</td></tr>
<tr><td>10</td><td>Allowable exhaust back pressure</td><td colspan="4" rowspan="2">See Allowable Air Intake Restriction and Exhaust Back Pressures on page 1-30.</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
	Alternator	Dust-proof type may be required for preventing entry of sand and dust.
	Starting motor	
	Breather air reservoir (for turbocharged engine only)	Since dust can enter from the breather pipe while the engine is stopped, an air reservoir may be installed at the end of the breather pipe.
	Cooling fan	to improve the wear resistance, a fan made of nylon 6 (reinforced with glass fiber) or steel may be required.
	V pulley	To improve the wear resistance, a hardened pulley may be required.
	V-belt	To counteract belt wear, a larger type V-belt may be required.
	Radiator	Changing the core type and fin material may be required. Heat balance check after the modification is required.

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, well-ventilated place

(*) 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.
	Speed control lever shaft	
	Stop lever shaft	
	Exhaust manifold bolts	
	Stop lever return spring	
	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
-30°C (-22°F) or above	Battery (high CCA)	Specification must be changed.	See *Low-temperature startability on page 1-7* for startability.
	Starting motor		
-30°C to -40°C (-22°F to -40°F)	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		
	Fuel feed pump	An electric feed pump is required.	
	Starting aid	A block heater should be used.	
-40°C (-40°F) or below		Not recommended.	

Precautions Against Hot Environment

Environmental temperature	Part	Countermeasure
Below 40°C (104°F)	Electrical parts	The temperature inside the engine hood must be kept below 80°C (176°F) to protect the electrical parts. Provide ventilation around electrical parts.
Above 40°C (104°F)	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 (176°F) to protect the electrical parts. Provide ventilation around electrical parts.

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 (5°F) 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, generator, mower, tractor (with clutch), combine and so on. HST specification refers to the driven machines that have parasitic load when engine starts, for example, excavator, loader (with direct coupled hydraulic pump), 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, muffler and radiator are not included. Please contact Yanmar for further details.

Combination of Starting Devices for Each Driven Machine

IDI Series

2TNV70 (complies with EPA Tier4)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)		> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
Starter	12V 1.0 kW, 119515-77010 DENSO		✔	✔	✔		Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.1 kW, 119717-77010 DENSO					✔	
	12V 1.4 kW, 119740-77020 DENSO						
Battery	46B24	CCA: 325	✔	✔			
	55B24 (NX100-S6)	CCA: 433			✔	✔	
	80D26 (NX110-5)	CCA: 582					
Starting Aid	Without energizing glow plug (only simulta-neous energizing)						
	Glow-plug 4 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			5W-20	

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

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe.

Item	Temperature °C (°F)		> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
Starter	12V 1.0 kW, 119515-77010 DENSO						Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.1 kW, 119717-77010 DENSO		✔	✔	✔	✔	
	12V 1.4 kW, 119740-77020 DENSO						
Battery	46B24	CCA: 325	✔	✔	✔		
	55B24 (NX100-S6)	CCA: 433				✔	
	80D26 (NX110-5)	CCA: 582					
Starting Aid	Without energizing glow plug (only simultaneous energizing)						
	Glow-plug 4 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			5W-20	

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

3TNV70 (complies with EPA Tier4)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)	> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
Starter	12V 1.0 kW, 119515-77010 DENSO	✔	✔	✔		Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.1 kW, 119717-77010 DENSO				✔	
	12V 1.4 kW, 119740-77020 DENSO					
Battery	46B24 CCA: 325	✔	✔			
	55B24 (NX100-S6) CCA: 433			✔	✔	
	80D26 (NX110-5) CCA: 582					
Starting Aid	Without energizing glow plug (only simultaneous energizing)					
	Glow-plug 4 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			5W-20	

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

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe.

Item	Temperature °C (°F)	> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
Starter	12V 1.0 kW, 119515-77010 DENSO					Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.1 kW, 119717-77010 DENSO	✔	✔			
	12V 1.4 kW, 119740-77020 DENSO			✔	✔	
Battery	46B24 CCA: 325	✔	✔	✔		
	55B24 (NX100-S6) CCA: 433				✔	
	80D26 (NX110-5) CCA: 582					
Starting Aid	Without energizing glow plug (only simultaneous energizing)					
	Glow-plug 4 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			5W-20	

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

APPLICATION STANDARD

3TNV76 (complies with EPA Tier4)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)	> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
Starter	12V 1.0 kW, 119515-77010 DENSO					Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.1 kW, 119717-77010 DENSO	✔	✔	✔	✔	
	12V 1.4 kW, 119740-77020 DENSO					
Battery	46B24 CCA: 325					
	55B24 (NX100-S6) CCA: 433	✔	✔	✔	✔	
	80D26 (NX110-5) CCA: 582					
Starting Aid	Without energizing glow plug (only simultaneous energizing)					
	Glow-plug 4 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			5W-20	

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

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe.

Item	Temperature °C (°F)	> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
Starter	12V 1.0 kW, 119515-77010 DENSO					Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.1 kW, 119717-77010 DENSO	✔				
	12V 1.4 kW, 119740-77020 DENSO		✔	✔	✔	
Battery	46B24 CCA: 325					
	55B24 (NX100-S6) CCA: 433	✔	✔			
	80D26 (NX110-5) CCA: 582			✔	✔	
Starting Aid	Without energizing glow plug (only simultaneous energizing)					
	Glow-plug 4 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			5W-20	

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

DI Series

3TNV82A (complies with EPA Tier2)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)		> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI						
	12V 2.3 kW, 129136-77011 HITACHI						
Battery	80D26 (NX110-5)	CCA: 413	✔	✔	✔		
	75D31 (N70Z)	CCA: 447					
	95D31 (NX120-7)	CCA: 622				✔	
	115D31						
	130E41 (NX200-10)	CCA: 799					
Starting Aid	Without air heater (only simultaneous energizing)		✔				
	Air heater	400 W x 15 sec		✔	✔		
		400 W x 20 sec					
		400 W x 30 sec				✔	
		800 W x 30 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			5W-20	

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

3TNV82A (complies with EPA Tier2)

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe, vibrating roller, or loader.

Item	Temperature °C (°F)	> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
Starter	12V 1.2 kW, 129129-77010 DENSO					Consult with driven machine manufacturer about specification in consideration of startability of actual machines
	12V 1.2 kW, 129129-HITACHI					
	12V 1.4 kW, 129608-77010 HITACHI					
	12V 1.4 kW, 129207-77010 DENSO					
	12V 1.7 kW, 129242-77010 HITACHI	✔	✔	✔		
	12V 2.0 kW, 129400-77012 HITACHI				✔	
	12V 2.3 kW, 129136-77011 HITACHI					
Battery	80D26 (NX110-5) CCA: 413	✔	✔	✔		
	75D31 (N70Z) CCA: 447					
	95D31 (NX120-7) CCA: 622				✔	
	115D31					
	130E41 (NX200-10) CCA: 799					
Starting Aid	Without air heater (only simultaneous energizing)	✔				
	Air heater 400 W x 15 sec		✔	✔		
	400 W x 20 sec					
	400 W x 30 sec				✔	
	800 W x 30 sec					
Battery Cable	Total allowable resistance (YIS G30-7900J)	0.002 Ω			0.0012 Ω	
F.O.	Fuel oil	JIS 2nd.	JIS 3rd.	JIS 3rd. Sp.		
L.O.	Lubricating oil	10W-30			5W-20	

* Standard specification shown in *Specifications of Standard Engines for Driven Machines on page 2-7.* (Yanmar standard timer is set to 15 sec.)

3TNV82A-B/3TNV82A-Z (complies with EPA Interim Tier4)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)		> -5 (23)	-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI						
	12V 2.3 kW, 129136-77011 HITACHI						
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	5 sec					
		10 sec		✔			
		15 sec			✔	✔	
		20 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			5W-20	

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

3TNV82A-B/3TNV82A-Z (complies with EPA Interim Tier4)

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe, vibrating roller, or loader.

Item	Temperature °C (°F)	> -5 (23)	-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI				✔	
	12V 2.3 kW, 129136-77011 HITACHI					
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 5 sec					
	10 sec		✔			
	15 sec			✔	✔	
	20 sec					
Battery Cable	Total allowable resistance (YIS G30-7900J)	0.0002 Ω			0.0012 Ω	
F.O.	Fuel oil	JIS 2nd.	JIS 3rd.	JIS 3rd. Sp.		
L.O.	Lubricating oil	10W-30			5W-20	

* Standard specification shown in *Specifications of Standard Engines for Driven Machines on page 2-7.* (Yanmar standard timer is set to 15 sec.)

3TNV84/3TNV88/3TNV84T (complies with EPA Tier2)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)	> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI					
	12V 2.3 kW, 129136-77011 HITACHI					
Battery	80D26 (NX110-5) CCA: 413	✔	✔	✔		
	75D31 (N70Z) CCA: 447					
	95D31 (NX120-7) CCA: 622				✔	
	115D31					
	130E41 (NX200-10) CCA: 799					
Starting Aid	Without air heater (only simultaneous energizing)	✔				
	Air heater 400 W x 15 sec		✔	✔		
	400 W x 20 sec					
	400 W x 30 sec				✔	
	800 W x 30 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			5W-20	

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

3TNV84/3TNV88/3TNV84T (complies with EPA Tier2)

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe, vibrating roller, or loader.

Item	Temperature °C (°F)	> -5 (23)	-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI					
	12V 2.3 kW, 129136-77011 HITACHI	✔	✔	✔	✔	
Battery	80D26 (NX110-5) CCA: 413					
	75D31 (N70Z) CCA: 447					
	95D31 (NX120-7) CCA: 622	✔	✔	✔		
	115D31					
	130E41 (NX200-10) CCA: 799				✔	
Starting Aid	Without air heater (only simultaneous energizing)	✔				
	Air heater 400 W 15 sec		✔	✔		
	400 W 20 sec					
	400 W 30 sec				✔	
	800 W 30 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			5W-20	

* Standard specification shown in *Specifications of Standard Engines for Driven Machines on page 2-7.* (Yanmar standard timer is set to 15 sec.)

3TNV88-B/3TNV88-U/3TNV84T-Z/3TNV88-Z/3TNV88-E/3TNV84T-B (complies with EPA Interim Tier4)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)	> -5 (23)	-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI				
	12V 2.3 kW, 129136-77011 HITACHI				
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 5 sec				
	10 sec		✔		
	15 sec			✔	
	20 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.* (Yanmar standard timer is set to 15 sec.)

3TNV88-B/3TNV88-U/3TNV84T-Z/3TNV88-Z/3TNV88-E/3TNV84T-B (complies with EPA Interim Tier4)

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe, vibrating roller, or loader.

Item	Temperature °C (°F)	> -5 (23)	-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI				
	12V 2.3 kW, 129136-77011 HITACHI				
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 5 sec				
	10 sec		✔		
	15 sec			✔	
	20 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.* (Yanmar standard timer is set to 15 sec.)

4TNV84/4TNV88 (complies with EPA Tier2)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)	> -5 (23)	-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI					
	12V 2.3 kW, 129136-77011 HITACHI					
Battery	80D26 (NX110-5) CCA: 413					
	75D31 (N70Z) CCA: 447					
	95D31 (NX120-7) CCA: 622	✔	✔	✔		
	115D31					
	130E41 (NX200-10) CCA: 799				✔	
Starting Aid	Without air heater (only simultaneous energizing)	✔				
	Air heater 400 W 15 sec		✔	✔		
	400 W 20 sec					
	400 W 30 sec				✔	
	800 W 30 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			5W-20	

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

4TNV84/4TNV88 (complies with EPA Tier2)

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe, vibrating roller, or loader.

Item	Temperature °C (°F)	> -5 (23)	*-5 to -15 (23 to 5)	-15 to -20 (5 to -4)	-21 to -25 (-6 to -13)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI					
	12V 2.3 kW, 129136-77011 HITACHI	✔	✔	✔	✔	
Battery	80D26 (NX110-5) CCA: 413					
	75D31 (N70Z) CCA: 447					
	95D31 (NX120-7) CCA: 622					
	115D31	✔	✔	✔		
	130E41 (NX200-10) CCA: 799				✔	
Starting Aid	Without air heater (only simultaneous energizing)	✔				
	Air heater 400 W 15 sec		✔	✔		
	400 W 20 sec					
	400 W 30 sec				✔	
	800 W 30 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			5W-20	

* Standard specification shown in *Specifications of Standard Engines for Driven Machines on page 2-7.* (Yanmar standard timer is set to 15 sec.)

4TNV88-B/4TNV88-U/4TNV88-Z/4TNV88-E (complies with EPA Interim Tier4)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)		> -5 (23)	-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI					
	12V 2.3 kW, 129136-77011 HITACHI					
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	5 sec				
		10 sec		✔		
		15 sec			✔	
		20 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.* (Yanmar standard timer is set to 15 sec.)

4TNV88-B/4TNV88-U/4TNV88-Z/4TNV88-E (complies with EPA Interim Tier4)

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe, vibrating roller, or loader.

Item	Temperature °C (°F)		> -5 (23)	-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI					
	12V 2.3 kW, 129136-77011 HITACHI		✔	✔	✔	
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	5 sec				
		10 sec		✔		
		15 sec			✔	
		20 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.* (Yanmar standard timer is set to 15 sec.)

APPLICATION STANDARD

4TNV84T (complies with EPA Tier2)

4TNV84T-Z/4TNV84T-B (complies with EPA Interim Tier4)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)	> -5 (23)	**-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI				
	12V 2.3 kW, 129136-77011 HITACHI				
Battery	80D26 (NX110-5) CCA: 413				
	75D31 (N70Z) CCA: 447				
	95D31 (NX120-7) CCA: 622	✔	✔	✔	
	115D31				
	130E41 (NX200-10) CCA: 799				
Starting Aid	Air heater none				
	Air heater 400 W x 15 sec				
	400 W x 20 sec				
	400 W x 30 sec				
	800 W x 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 4TNV84T-Z *Specifications of Standard Engines for Driven Machines on page 2-7*.
(Yanmar standard timer is set to 15 sec.)
** Standard specification shown in 4TNV84T *Specifications of Standard Engines for Driven Machines on page 2-7*.

4TNV84T (complies with EPA Tier2)

4TNV84T-Z/4TNV84T-B (complies with EPA Interim Tier4)

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe, vibrating roller, or loader.

Item	Temperature °C (°F)		> -5 (23)	**-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	<-25 (-13)
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 2.0 kW, 129400-77012 HITACHI					
	12V 2.3 kW, 129136-77011 HITACHI		✔	✔	✔	
Battery	80D26 (NX110-5)	CCA: 413				
	75D31 (N70Z)	CCA: 447				
	95D31 (NX120-7)	CCA: 622				
	115D31		✔	✔	✔	
	130E41 (NX200-10)	CCA: 799				
Starting Aid	Air heater none					
	Air heater	400 W x 15 sec				
		400 W x 20 sec				
		400 W x 30 sec				
		800 W x 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 4TNV84T-Z *Specifications of Standard Engines for Driven Machines on page 2-7*. (Yanmar standard timer is set to 15 sec.)

** Standard specification shown in 4TNV84T *Specifications of Standard Engines for Driven Machines on page 2-7*.

4TNV94L/4TNV98/4TNV98T (complies with EPA Tier2)

4TNV98-Z/4TNV98-E (complies with EPA Interim Tier4)

4TNV98T-Z (complies with EPA Tier3)

① Standard specification: For driven machine with less parasitic load when engine starts; for example, generator, mower, tractor, or combine.

Item	Temperature °C (°F)		> -5 (23)	**-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	<-25 (-13)
Starter	12V 2.3 kW, 129900-77010		✔	✔	✔	Consult with driven machine manufacturer about specification in consideration of startability of actual machines * indicates settings of ECU
	12V 3.0 kW, 123900-77010					
Battery	80D26 (NX110-5)	CCA: 413				
	75D31 (N70Z)	CCA: 447				
	95D31 (NX120-7)	CCA: 622	✔	✔	✔	
	130E41 (NX200-10)	CCA: 799				
Starting Aid	Air heater none		✔			
	Air heater	500 W x 15 sec		✔	✔	
		500 W x 20 sec			*✔	
		500 W x 30 sec				
		1000 W x 15 sec				
		1000 W x 30 sec				
Battery Cable	Total allowable resistance (YIS G30-7900J)		0.0012 Ω			
F.O.	Fuel oil		JIS 2nd.	JIS 2rd.	JIS 3rd. Sp.	
L.O.	Lubricating oil		10W-30			

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

4TNV94L/4TNV98/4TNV98T (complies with EPA Tier2)

4TNV98-Z/4TNV98-E (complies with EPA Interim Tier4)

4TNV98T-Z (complies with EPA Tier3)

② HST specification: For driven machine with parasitic load when engine starts; for example, backhoe, vibrating roller, or loader.

Item	Temperature °C (°F)	> -5 (23)	**-5 to -15 (23 to 5)	*-15 to -20 (5 to -4)	<-25 (-13)
Starter	12V 2.3 kW, 129900-77010	✔			Consult with driven machine manufacturer about specification in consideration of startability of actual machines * indicates settings of ECU
	12V 3.0 kW, 123900-77010		✔	✔	
Battery	80D26 (NX110-5) CCA: 413				
	75D31 (N70Z) CCA: 447				
	95D31 (NX120-7) CCA: 622				
	130E41 (NX200-10) CCA: 799	✔	✔	✔	
Starting Aid	Without air heater (only simultaneous energizing)	✔			
	Air heater 500 W x 15 sec		✔		
	500 W x 20 sec				
	500 W x 30 sec				
	1000 W x 15 sec		*✔	✔	
	1000 W x 20 sec			*✔	
	1000 W x 30 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 4TNV98-Z/4TNV98-E/4TNV98T-Z Specifications of Standard Engines for Driven Machines on page 2-7.*

*** Standard specification shown in 4TNV94L/4TNV98/4TNV98T 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 muffler. The upper limits for air cleaner replacement and exhaust system cleaning (including the exhaust tube and muffler) are the limit values for operation.

Allowable Air Intake Restriction

Applicable model	Allowable depression at engine manifold ≤ kPa (mmAq)	
	Initial upper limit	Upper limit for air cleaner replacement
All TNV series	2.94 (300)	6.23 (635)

Allowable Exhaust Back Pressure

Applicable model	Allowable exhaust back pressure ≤ kPa (mmAq)	
	Initial upper limit	Upper limit for exhaust system cleaning
2TNV70	4.90 (500)	5.88 (600)
3TNV70 3TNV76	9.81 (1000)	11.77 (1200)
3TNV82A 3TNV82A-B 3TNV84/88 3TNV88-B,-U 4TNV84/88 4TNV88-B,-U 4TNV94L 4TNV98	12.75 (1300)	15.30 (1560)
3TNV84T	7.85 (800)	9.81 (1000)
4TNV84T 4TNV98T	9.81 (1000)	11.77 (1200)
4TNV84T-ZVM	**Figure 1-6**: EGR Equipped Engines	
4TNV98-ZCL	**Figure 1-7**: EGR Equipped Engines	
4TNV98-E/ZVM	**Figure 1-8**: EGR Equipped Engines	
4TNV98T-ZVM	**Figure 1-9**: EGR Equipped Engines	
4TNV98T-ZCL	**Figure 1-10**: EGR Equipped Engines	

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. (See **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, 4TNV84T-Z, 4TNV98-E/Z and 4TNV98T-Z is as follows:

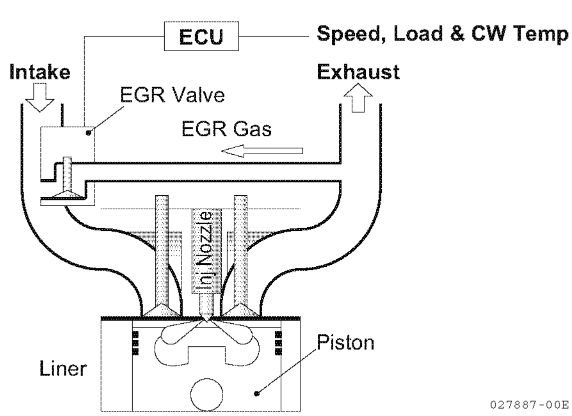


Figure 1-1

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. See **Figure 1-2** below as the example. It is also changed depending on the engine rated speed.

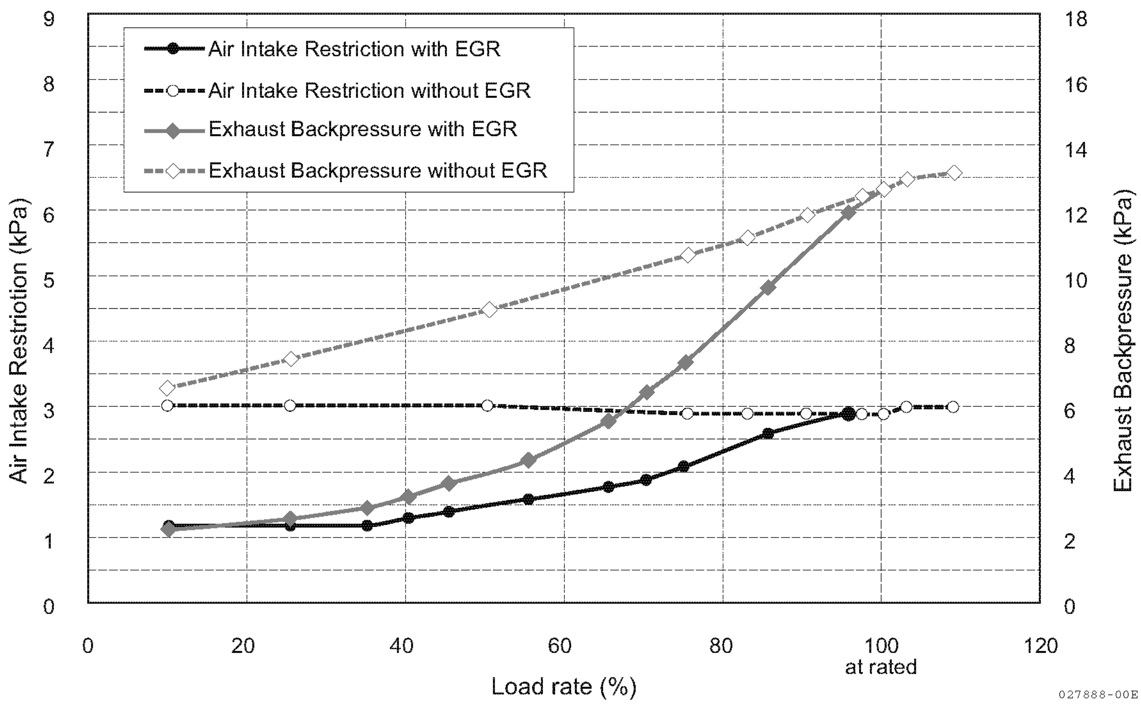


Figure 1-2

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

- Please measure at the condition of the rated speed and power as close as possible at the Intake /Exhaust pressure matching test.
- 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 supplied from YANMAR. Please inform YANMAR representative in detail.

About the Measurement point

The measurement points of intake/exhaust pressure are shown in the following respectively in the N/A Engine and T/C engine.

- **N/A engine**

1. Intake Pressure of N/A Engine

   Please make the hole on the bend of the intake manifold and measure the intake pressure. (See **Figure 1-3**) In that time, please note that the tip of the nipple doesn't push out as possible.

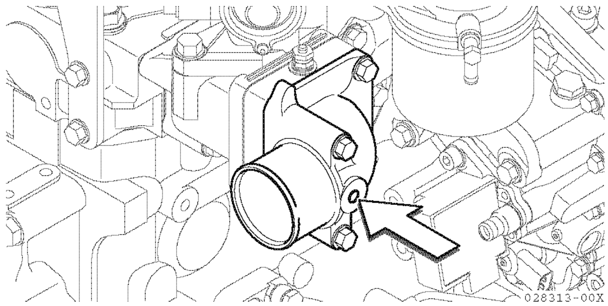


Figure 1-3

2. Exhaust Pressure of N/A Engine

   Please make the hole on the point of exhaust manifold as shown in **Figure 1-4** or more downstream than there between silencer connecting ducts and measure.

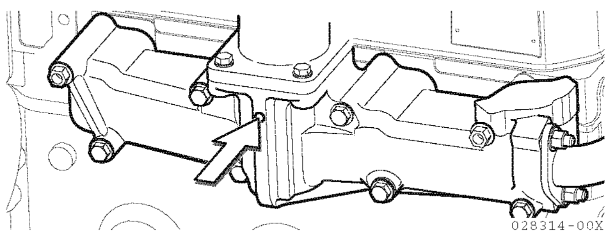


Figure 1-4

- **Engine with the T/C**

3. Intake Pressure of the Engine with T/C

   Please make the hole between the turbine and the air cleaner, less than 600mm from the turbine. We recommend the indicator hole of the air cleaner, if the air cleaner is installed within 600mm from the turbine. In that time, Please note that there is not squeezing on the way.

4. Exhaust Pressure of the Engine with T/C

   Please make the hole A or B on the silencer as shown in **Figure 1-5** and measure.
   If the silencer has 2 or 3 chambers, Please make the hole on the first chamber.

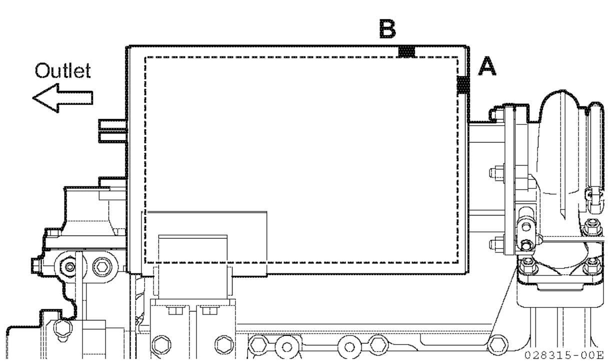
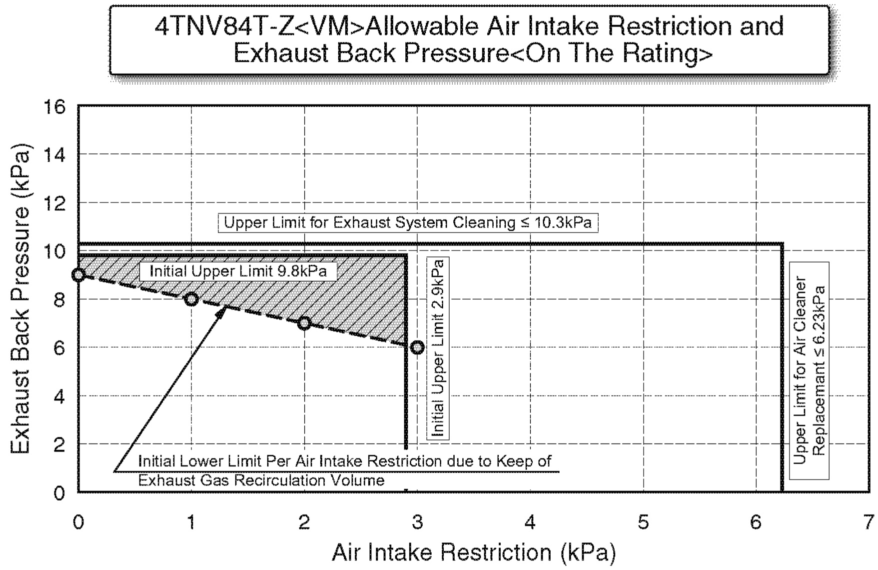


Figure 1-5

4TNV84T-Z<VM>: Allowable Intake/Exhaust Pressure Settings (at rated output)



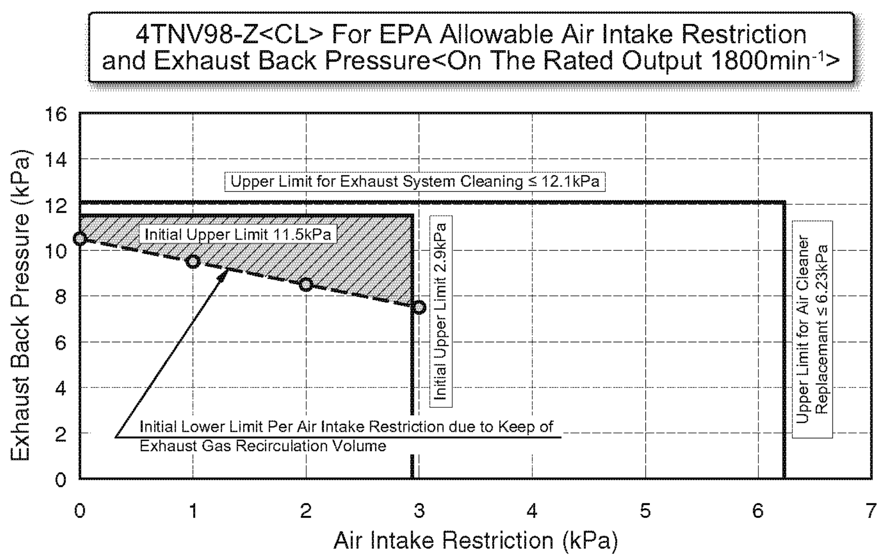
Lower Limit of Exhaust Back Pressure set by Air Intake Restriction

Air Intake Restriction (kPa)	0	1	2	3
Exhaust Back Pressure (kPa)	9	8	7	6

022182-01E

Figure 1-6

4TNV98-Z<CL>: Allowable Intake/Exhaust Pressure Settings (at rated output)



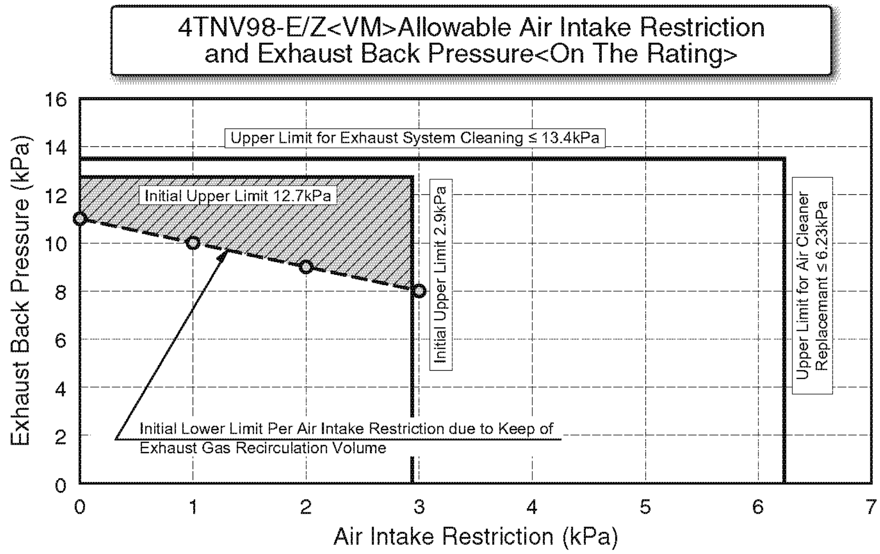
Lower Limit of Exhaust Back Pressure set by Air Intake Restriction

Air Intake Restriction (kPa)	0	1	2	3
Exhaust Back Pressure (kPa)	10.5	9.5	8.5	7.5

022286-01E

Figure 1-7

4TNV98-E/Z<VM>: Allowable Intake/Exhaust Pressure Settings (at rated output)



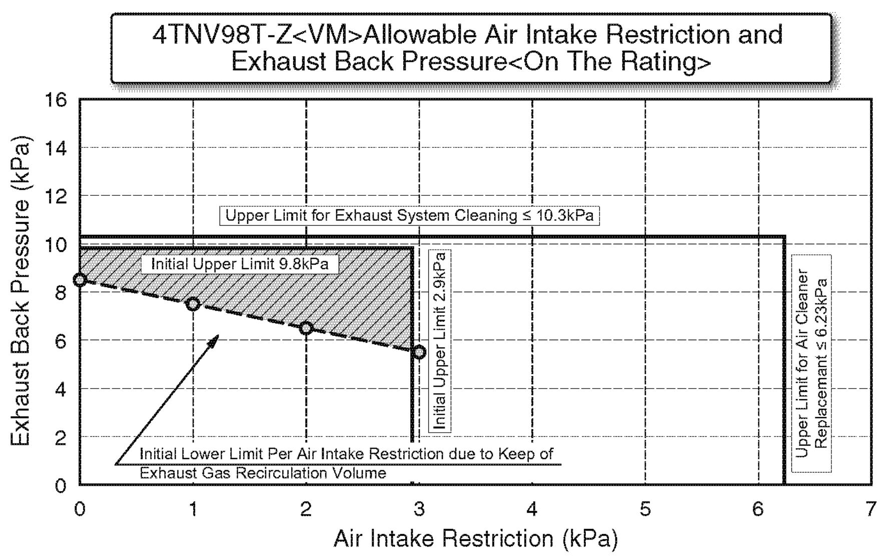
Lower Limit of Exhaust Back Pressure set by Air Intake Restriction

Air Intake Restriction (kPa)	0	1	2	3
Exhaust Back Pressure (kPa)	11	10	9	8

022183-01E

Figure 1-8

4TNV98T-Z<VM>: Allowable Intake/Exhaust Pressure Settings (at rated output)



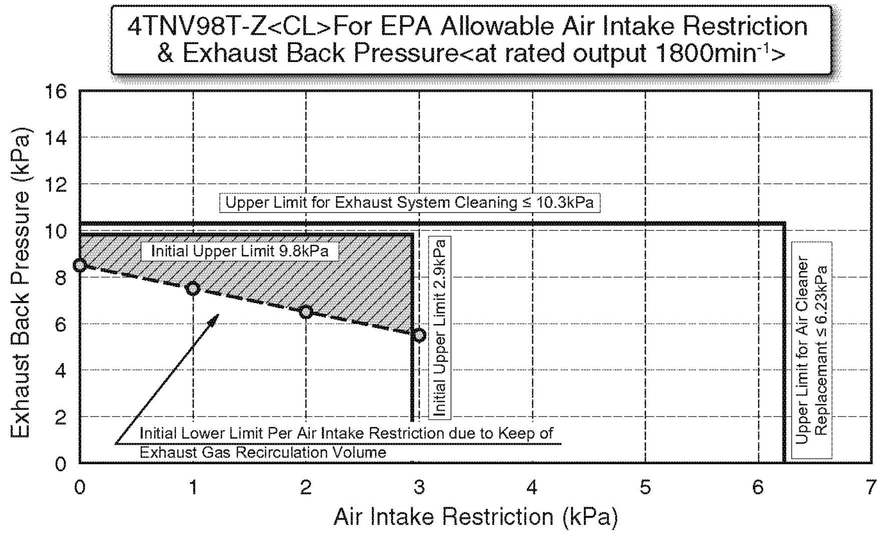
Lower Limit of Exhaust Back Pressure set by Air Intake Restriction

Air Intake Restriction (kPa)	0	1	2	3
Exhaust Back Pressure (kPa)	8.5	7.5	6.5	5.5

022184-01E

Figure 1-9

4TNV98T-Z<CL>: Allowable Intake/Exhaust Pressure Settings (at rated output)



Lower Limit of Exhaust Back Pressure set by Air Intake Restriction

Air Intake Restriction (kPa)	0	1	2	3
Exhaust Back Pressure (kPa)	8.5	7.5	6.5	5.5

022185-01E

Figure 1-10

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

This regulation applies to non-road compression-ignition engines that are used for any purpose, and enforces regulations concerning new and in-use engines that are produced on or after the implementation date and used in the United States.

The driven machine manufacturers must provide Yanmar with evidence that their application complies with EPA regulations. The following is a brief description of the responsibilities introduced by the regulation.

Driven machine manufacturers should contact Yanmar for details.

Engine Output

EPA-authorized engine output is based on "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.

Therefore, the settings cannot exceed this gross power rating.

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.

Emission Control Label

If you install the engine in a way that makes the engine's emission control information label hard to read during normal engine maintenance, you must place a duplicate label on the equipment, as described in 40 CFR 1068.105.

Fuel Inlet Label

Unless otherwise specified, Yanmar will also provide a supplemental fuel inlet label with each certified engine for installation on the equipment.
Permanently attach this label to the equipment near the fuel inlet.

Installation Evaluation

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.

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

Engine Maintenance

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

Tamper Resistance

Dealers who are authorized by Yanmar to re-adjust the diesel fuel limiter or high idle speed limit screw for market service on in-use engines, must install a tamper resistance device for preventing illegal change by the end purchaser.

Report on Sales in the USA

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.

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.

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Section 2

ENGINE MODEL SELECTION

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MODEL DESIGNATION

O TNV O O (A) (T) – O O O

- O O O — Configuration code
- (T) — Turbocharger
- (A) — Model subcode
- O O — Cylinder bore (mm)
- TNV — Model code
- O — Number of cylinders (2 to 4)

Configuration code = Engine Speed code and Driven Machine code (see *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, see *Specifications on page 3-5*.

Classification with Injection System

Abbreviation	Means
IDI	Indirect injection system (Special swirl chamber system)
DI	Direct injection system

Classification with Displacement

Abbreviation	Means
NV1	Engine displacement is roughly 1 liter
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 water pumps
VM (Variable, medium speed)	2000 to 3000 min^{-1}	Agriculture machines, construction machines and other general machines
CH (Constant, high speed)	3000 or 3600 min^{-1}	2 pole generators, compressors, water pumps and welders
VH (Variable, high speed)	3000 to 3600 min^{-1}	Compressors and lawn mowers

Engine Classification with Above Mentioned Conditions

No.	Model	Combustion chamber type	Group	Classification			
				CL	VM	CH	VH
1	2TNV70	IDI	NV1	—	O	O	O
2	3TNV70			O	O	O	O
3	3TNV76			O	O	O	O
4	3TNV82A	DI	NV2	O	O	—	—
5	3TNV84			O	O	—	—
6	3TNV84T			O	O	—	—
7	3TNV88			O	O	—	—
8	4TNV84			O	O	—	—
9	4TNV84T			O	O	—	—
10	4TNV88			O	O	—	—
11	4TNV94L		NV3	O	*O	—	—
12	4TNV98			O	*O	—	—
13	4TNV98T			O	*O	—	—

Note: 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 application engineers will quickly setup a conference with you to review your specifications and prepare an estimate. Yanmar recommends that you consider using a standard engine 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.
- Using standard engines makes the process of submitting and preparing cost estimates more efficient.
- Standard engines use standard Yanmar components which provide cost advantages for driven machine manufacturers.
- Using standard engines allows for cost reduction and shorter delivery times.

Classification of Standard Engines for Driven Machines

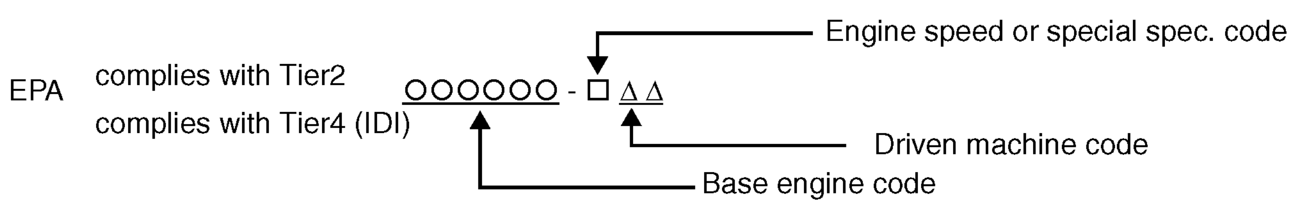
The classification of standard engines is based on the driven machine application and the speed the engine runs at (in rpm). The machine model name and principal differences are described below.

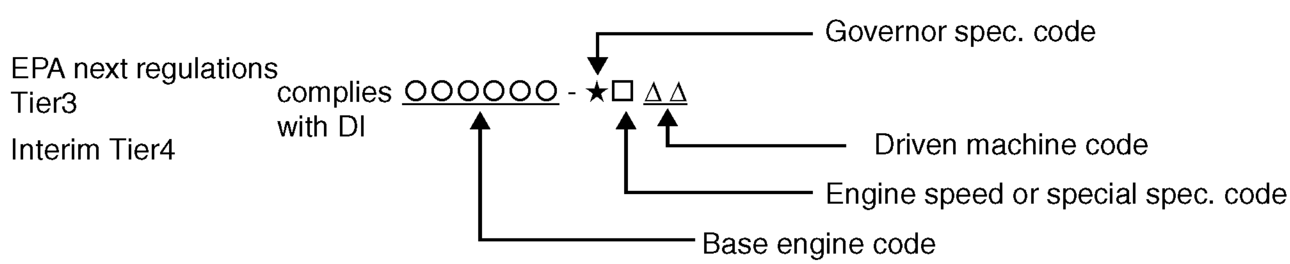
Engine Model Nomenclature

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 Tier2 and engines which comply with next regulations such as Tier3 (>56kW), Interim Tier4 (19-56kW), and Tier4 (<19kW).

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





Engine speed code or special spec code	Engine speed min^{-1}
G	1800/1500
S	2200
N	2500
M	2600
L	2700
K	2800
D	3000
C	3200
H	3600/3000
X	Special spec.

Governor spec. code	Governor specification	Engine output specification
Z	Electronic governor (eco governor)	Standard output specification
B	Mechanical governor	
E	Electronic governor (eco governor)	Derating output specification
U	Mechanical governor	

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, Wheel loaders, SSLs, Carriers, Forklifts, Refrigerators, Air compressors
2	WL	Construction use, at higher speed	Excavators, Wheel loaders, SSLs, Carriers, Forklifts, Refrigerators, 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
9	SA3		Back plates

Specifications of Standard Engines for Driven Machines

Machine standard engine (NV1 to complies with EPA Tier4)

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

Category	Model Name	Model Category	Applicable machine	Parasitic load	Injection pump	Main specification	NV1					
							2TNV70		3TNV70		3TNV76	
							Rated speed		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	Cold start spec.	• Semi SAE 5 housing • Semi SAE 6 for 2TNV70 • Shallow oilpan • Puller fan	●	2500	●	2500	●	2500
	WL	Construction machine at higher speed					—	—	—	—	—	—
	GE	Constant speed use at lower speed	• 4P Generator	Small	STD	• Full SAE 5 housing • Shallow oilpan • Pusher fan	—	—	●	1500 / 1800	●	1500 / 1800
		Constant speed use at higher speed	• 2P Generator • Welder	Small	STD	• Full SAE 5 housing • Semi SAE 6 housing for 2TNV70 • Deep oilpan • Pusher fan	●	3000 / 3600	●	3000 / 3600	●	3000 / 3600
	MW	Utility use at high speed		Medium			—	—	—	—	—	—
	U1	Agricultural use	• Tractor 1 • Mower • Utility vehicle • Speed sprayer • Pump	Medium	STD	• Backplate • Steel oilpan • Puller fan • HO-P	—	—	●	3000	●	3000
	U2	Agricultural use	• Tractor 2 • Mono-cock frame	Medium			—	—	—	—	—	—
General Use	SA	Utility use		Medium	STD	• Full SAE 5 housing • Shallow oilpan • HO-P flange • Puller fan	○∗	3600	○	3600	○	3200
	SA2					• Semi SAE 5 housing • Shallow oilpan • HO-P flange • Puller fan	—	—	—	—	—	—
	SA3					• Backplate • Shallow oilpan • HO-P flange • Puller fan	—	—	○	3600	○	3200

∗ Semi SAE 5 housing

Machine standard engine (NV2 to complies with EPA Tier2)

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

Category	Model Name	Model Category	Applicable machine	Parasitic load	Injection pump	Injection nozzle	Main specification	NV2													
								3TNV82A		3TNV84		3TNV88		3TNV84T		4TNV84		4TNV88		4TNV84T	
								Rated speed		Rated speed		Rated speed		Rated speed		Rated speed		Rated speed		Rated speed	
Machine standard engine	BK	Construction use at lower speed	• Backhoe • Crane • Carrier • Forklift • Refrigerator	Heavy	Cold start spec.	Cold start spec.	• Semi SAE 5 housing • Deep oilpan • Puller fan • Larger starter	●	2500	●	2500	●	2500	—	—	●	2500	●	2500	—	—
	WL	Construction machine at higher speed	• Wheel loader • SSL • Dozer • Damper • Carrier • Vibrator • Compressor • Snow blower	Heavy	Cold start spec.	Cold start spec.	• Semi SAE 5 housing • Deep oilpan • Extension type dipstick • Pusher fan • Oil cooler • Larger starter	●	2800	●	2800	●	2800	●	2800	●	2800	●	2800	●	2800
	GE	Constant speed use at lower speed	• 4P Generator	Small	STD	STD	• Semi SAE 4 housing • Deep oilpan • Pusher fan	●	1500 / 1800	●	1500 / 1800	●	1500 / 1800	●	1500 / 1800	●	1500 / 1800	●	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	STD	STD	• Backplate • Shallow oilpan • HO-P • Oil cooler • Puller fan	●	3000	●	3000	●	3000	●	3000	●	3000	●	3000	●	3000
	U1	Agricultural use	• Tractor 1	Medium	STD	STD	• Backplate • Steel oilpan • HO-P • Puller fan	●	2600	●	2500	●	2500	—	—	—	—	—	—	—	—
	U2	Agricultural use	• Tractor 2 • Mono-cock frame	Medium	STD	STD	• Backplate • Cast iron oilpan • Balancer for 4 cylinder • HO-P • Puller fan	—	—	●	2600	●	2600	●	2700	●	2700	●	2700	—	—
General Use	SA		In case of the machine with heavy parasitic load, please use -NBK or -XWL engine				• Full SAE 5 housing • Deep oilpan • HO-P flange • Puller fan	○	3000	—	—	○	3000	○	2800	—	—	○	3000	○	3000
	SA2	Utility use		Medium	STD	STD	• Semi SAE 5 housing • Deep oilpan • HO-P flange • Oil cooler • Puller fan	○	3000	—	—	○	3000	○	2800	—	—	○	3000	○	3000
	SA3						• Backplate • Deep oilpan • HO-P flange • Oil cooler • Puller fan	○	3000	—	—	○	3000	○	2800	—	—	○	3000	○	3000

Machine standard engine (NV2 to complies with EPA Interim Tier4)

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

Category	Model Name	Model Category	Applicable machine	Parasitic load	Main specification	NV2									
						3TNV82A		3TNV88		3TNV84T		4TNV88		4TNV84T	
						Rated speed		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 • Shallow oilpan • Puller fan • Larger starter	●	2500	●	2500	—	—	●	2500	—	—
	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	●	2800	●	2800	●	2800	●	2800	●	2800
	GE	Constant speed use at lower speed	• 4P Generator	Small	• Full SAE 4 housing • Shallow oilpan • Pusher fan	—	—	●	1500 / 1800	—	—	●	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	• Backplate • Shallow oilpan • HO-P • Oil cooler • Puller fan	—	—	—	—	—	—	—	—	—	—
	U1	Agricultural use	• Tractor 1	Medium	• Backplate • Steel oilpan • HO-P • Puller fan	●	3000	●	3000	●	2800	—	—	—	—
	U2	Agricultural use	• Tractor 2 • Mono-cock frame	Medium	• Backplate • Steel oilpan • Balancer for 4 cylinder • HO-P • Puller fan	●	2600	●	2500	—	—	—	—	—	—
General Use	SA	Utility use		Medium	• Full SAE 5 housing • Deep oilpan • HO-P flange • Puller fan	○	3000	○	3000	○	2800	○	3000	○	3000
	SA2				• Semi SAE 5 housing • Deep oilpan • HO-P flange • Oil cooler • Puller fan	○	3000	○	3000	○	2800	○	3000	○	3000
	SA3				• Backplate • Deep oilpan • HO-P flange • Oil cooler • Puller fan	○	3000	○	3000	○	2800	○	3000	○	3000

ENGINE MODEL SELECTION

Machine standard engine (NV3 to complies with EPA Tier2)

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

Category	Model Name	Model Category	Applicable machine	Parasitic load	Injection pump	Main specification	NV3					
							4TNV94L		4TNV98		4TNV98T	
							Rated speed		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	Cold start spec.	• Semi SAE 4 housing • Deep oilpan • Puller fan • Larger starter	●	2200	●	2200	●	2200
	WL	Construction machine at higher speed		Heavy			—	—	—	—	—	—
	GE	Constant speed use at lower speed	• 4P Generator	Small	STD	• Semi SAE 3 housing • Deep oilpan • Pusher fan	—	1500 / 1800	●	1500 / 1800	●	1500 / 1800
		Constant speed use at higher speed		Small			—	—	—	—	—	—
	MW	Utility use at high speed		Medium			—	—	—	—	—	—
	U1	Agricultural use	•	Medium			—	—	—	—	—	—
	U2	Agricultural use	• Tractor 2	Medium	Cold start spec.	• Backplate • Steel oilpan • Balancer • Puller fan • HO-P	●	2500	●	2500	●	2500
General Use	SA	Utility use		Medium	Cold start spec.	• Full SAE 4 housing • Deep oilpan • Puller fan	—	—	○	2500	○	2500
	SA2					• Full SAE 4 housing • Deep oilpan • Puller fan	—	—	○	2500	○	2500
	SA3						—	—	—	—	—	—

Machine standard engine (NV3 to complies with EPA Interim Tier4, Tier3)

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

Category	Model Name	Model Category	Applicable machine	Parasitic load	Main specification	NV3 4TNV98 Rated speed		NV3 4TNV98T 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		Medium		—	—	—	—
	U2	Agricultural use	• Tractor 2	Medium	• Backplate • Steel oilpan • Balancer • Puller fan • HO-P	●	2500	●	2500
General Use	SA	Utility use		Medium	• Full SAE 4 housing • Deep oilpan • Puller fan	○	2500	○	2500
	SA2				• Full SAE 4 housing • Deep oilpan • Puller fan	○	2500	○	2500
	SA3					—	—	—	—

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Section 3

SPECIFICATIONS

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ATMOSPHERIC CONDITIONS AND ENGINE CONFIGURATION AFFECT ENGINE OUTPUT

Atmospheric conditions and engine configuration affect the rated output of a TNV engine. TNV engines are tested using the methods established by the Society of Automotive Engineers (SAE) J1349 and International Organization for Standardization (ISO) 3046/1. These standards state that engine output (net power rating) should be determined under the following atmospheric conditions (called the standard conditions). If the operating environment for your application differs from these standard conditions see *Correcting Observed Power on page 4-1*:

Atmospheric pressure:	100 kPa (750 mmHg)
Atmospheric temperature:	25°C (77°F)
Relative humidity:	30%

Engine configuration also affects TNV engine output. The engine output specified in *Specifications on page 3-5* assumes a “standard” engine configuration. A “standard” configuration means that a “standard” Yanmar cooling fan, radiator, muffler and air cleaner are installed. See 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.” Note that the cooling fan and pulley listed in *Specifications on page 3-5* are considered part of a standard TNV engine specification. Optional equipment is available from Yanmar. If your application uses optional equipment, please tell your Yanmar application engineer the fan type, pulley ratio and engine rpm range (see the Yanmar Option Menu) so the engineer can determine the engine's output.

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 or VH specifications in *Engine Classification on page 2-3*. Most driven machines conforming to VM or VH 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.

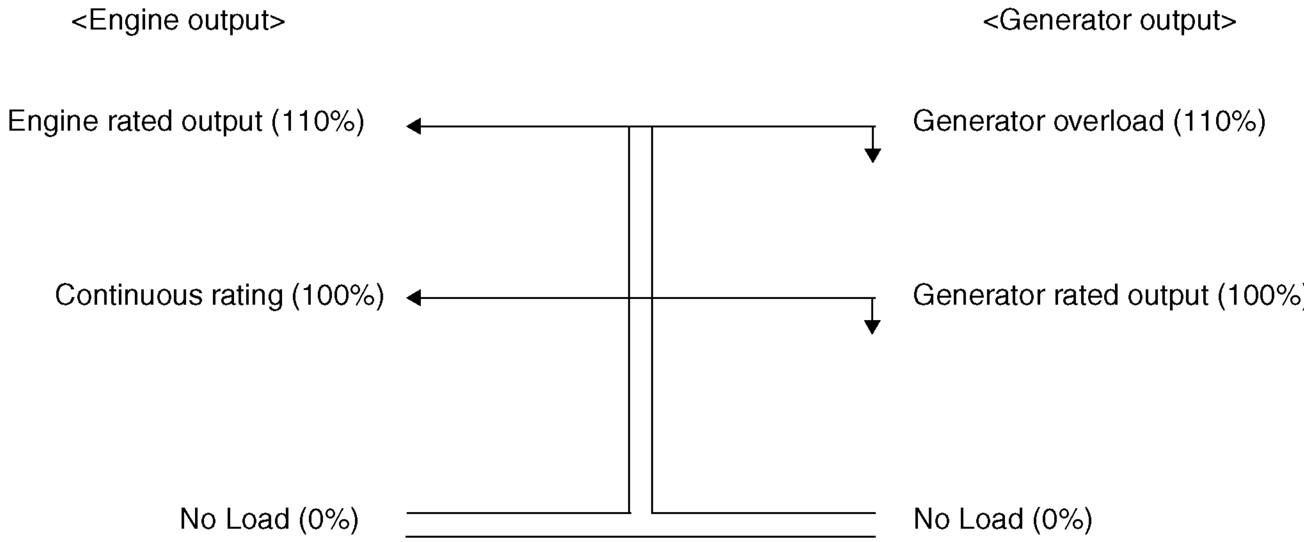
Some driven machines require the maximum output for a long period because of a fixed revolution range. In this case, select an engine so 90% of its rated output equals the continuous maximum output requirement of the driven machine.

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

IDI Series

2TNV70 (complies with EPA Tier4)

	Engine model			2TNV70											
	Engine classification			VM							CH		VH		
1	Type		—	Vertical, 4-cycle water-cooled diesel engine											
2	Combustion system		—	Spherical swirl chamber system (IDI)											
3	No. of cylinders - Bore × Stroke		n - mm × mm	2 - 70 × 74											
4	Displacement		ℓ	0.570											
5	Rated engine speed		min^{-1}	2000	2200	2400	2500	2600	2800	3000	3000	3600	3200	3400	3600
	Output (Gross)	Cont. rating	kW								8.3	10.0			
		Rated output	kW	6.2	6.9	7.7	8.0	8.3	9.1	9.8	9.1	10.9	10.2	10.7	11.4
	Output (NET)	Cont. rating	kW								7.7	9.1			
		Rated output	kW	6.0	6.6	7.3	7.6	7.9	8.5	9.1	8.5	10.0	9.3	9.6	9.9
6	Maximum idling speed		min^{-1} ±25	2160	2375	2570	2675	2780	2995	3210	–	3800	3400	3600	3815
7	Specific fuel consumption		g/kWh	≤279		≤286			≤292		≤313		≤299	≤306	≤313
8	Exhaust gas temp.		°C (°F)	≤460 (860)	≤480 (896)	≤500 (932)	≤520 (968)			≤580 (1076)	≤550 (1022)		≤500 (932)	≤540 (1004)	≤550 (1022)
9	Compression ratio		—	23.4											
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$12.3^{+0.98}_{0}$ (125^{+10}_{0})											
11	Main shaft side		—	Flywheel side											
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)											
13	Governor		—	Mechanical centrifugal governor (All-speed governor)											
14	Aspiration		—	Natural aspiration											
15	Cooling system		—	Force-feed circulation radiator type cooling system											
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump											
17	Starting system		—	Electric starting											
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)											
19	Starting aid device		—	Super-quick Heating Glow plug											
20	Engine oil pressure	Rated speed	MPa	0.3 to 0.45											
21	Oil pan capacity	Full	ℓ	1.7							2.3		1.7		
		Useful	ℓ	0.7							1.0		0.7		
22	Engine coolant capacity		ℓ	0.6											
23	Cooling fan type - dia. × No. of blades		mm	Pusher, F type - ϕ260 x 5											
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm	ϕ110 / ϕ110											

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

3TNV70 (complies with EPA Tier4)

Engine model				3TNV70													
Engine classification				CL		VM							CH		VH		
1	Type		—	Vertical, 4-cycle water-cooled diesel engine													
2	Combustion system		—	Spherical swirl chamber system (IDI)													
3	No. of cylinders – Bore × Stroke		n – mm × mm	3 – 70 × 74													
4	Displacement		ℓ	0.854													
5	Rated engine speed		min^{-1}	1500	1800	2000	2200	2400	2500	2600	2800	3000	3000	3600	3200	3400	3600
	Output (Gross)	Cont. rating	kW	6.2	7.5								13.1	16.1			
		Rated output	kW	6.8	8.2	9.3	10.3	11.5	12	12.5	14.1	14.6	14.3	17.6	15.1	16.1	17
	Output (NET)	Cont. rating	kW	6.1	7.3								12.1	14.5			
		Rated output	kW	6.7	8	9	9.9	11	11.4	11.8	12.8	13.7	13.3	16	14	14.7	15.4
6	Maximum idling speed		min^{-1} ±25	1600	1895	2160	2375	2570	2675	2780	2995	3210	–	3800	3400	3600	3815
7	Specific fuel consumption		g/kWh	≤265		≤272		≤279			≤286		≤300		≤286		
8	Exhaust gas temp.		°C (°F)	≤400 (752)	≤430 (806)	≤440 (824)	≤460 (860)	≤490 (914)	≤510 (950)			≤540 (1004)	≤580 (1076)		≤530 (986)	≤570 (1058)	≤580 (1076)
9	Compression ratio		—	23.4													
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$12.3^{+0.98}_{0}$ (125^{+10}_{0})													
11	Main shaft side		—	Flywheel side													
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)													
13	Governor		—	Mechanical centrifugal governor (All-speed governor)													
14	Aspiration		—	Natural aspiration													
15	Cooling system		—	Force-feed circulation radiator type cooling system													
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump													
17	Starting system		—	Electric starting													
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)													
19	Starting aid device		—	Super-quick Heating Glow plug													
20	Engine oil pressure	Rated speed	MPa	0.3 to 0.45													
21	Oil pan capacity	Full	ℓ	2.8									3.8		2.8		
		Useful	ℓ	1.3									1.7		1.3		
22	Engine coolant capacity		ℓ	0.9 (Engine only)													
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ310 × 5													
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm	ϕ110 / ϕ100													

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

3TNV76 (complies with EPA Tier4)

Engine model				3TNV76													
Engine classification				CL		VM							CH		VH		
1	Type		—	Vertical, 4-cycle water-cooled diesel engine													
2	Combustion system		—	Spherical swirl chamber system (IDI)													
3	No. of cylinders – Bore × Stroke		n – mm × mm	3 – 76 × 82													
4	Displacement		ℓ	1.116													
5	Rated engine speed		min^{-1}	1500	1800	2000	2200	2400	2500	2600	2800	3000	3000	3600	3200	3400	3600
	Output (Gross)	Cont. rating	kW	8.4	10.1								16.5	19.9			
		Rated output	kW	9.2	11	12.3	13.8	15.1	15.8	16.5	17.8	19.2	17.9	21.7	19.9	21.2	22.3
	Output (NET)	Cont. rating	kW	8.2	9.8								15.1	17.7			
		Rated output	kW	9	10.7	11.8	13.2	14.3	14.9	15.5	16.7	17.9	16.5	19.5	18.2	19.3	19.5
6	Maximum idling speed		min^{-1} ±25	1600	1895	2160	2375	2570	2675	2780	2995	3210	–	3800	3400	3600	3815
7	Specific fuel consumption		g/kWh	≤265		≤272		≤279			≤286		≤306		≤292	≤299	≤306
8	Exhaust gas temp.		°C (°F)	≤390 (734)	≤410 (770)	≤460 (860)	≤480 (896)	≤500 (932)	≤530 (986)		≤550 (1022)	≤590 (1094)	≤580 (1076)		≤530 (986)	≤570 (1058)	≤580 (1076)
9	Compression ratio		—	23.5													
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$12.3^{+0.98}_{0}$ (125^{+10}_{0})													
11	Main shaft side		—	Flywheel side													
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)													
13	Governor		—	Mechanical centrifugal governor (All-speed governor)													
14	Aspiration		—	Natural aspiration													
15	Cooling system		—	Force-feed circulation radiator type cooling system													
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump													
17	Starting system		—	Electric starting													
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)													
19	Starting aid device		—	Super-quick Heating Glow plug													
20	Engine oil pressure	Rated speed	MPa	0.3 to 0.45													
21	Oil pan capacity	Full	ℓ	3.5										4.4		3.5	
		Useful	ℓ	1.6										2.1		1.6	
22	Engine coolant capacity		ℓ	0.9 (Engine only)													
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ335 × 6													
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm	ϕ110 / ϕ100													

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

DI Series

3TNV82A (complies with EPA Tier2)

Engine model				3TNV82A								
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 – 82 × 84								
4	Displacement		ℓ	1.331								
5	Rated engine speed		min^{-1}	1500	1800	2000	2200	2400	2500	2600	2800	3000
	Output (Gross)	Cont. rating	kW	10.3	12.6							
		Rated output	kW	11.3	13.8	15	16.5	18.1	18.9	19.7	21.3	23
	Output (NET)	Cont. rating	kW	9.9	12							
		Rated output	kW	11	13.2	14.6	16	17.5	18.2	19	20.4	21.9
6	Maximum idling speed		min^{-1} ±25	1600	1895	2180	2375	2570	2675	2780	2995	3180
7	Specific fuel consumption		g/kWh	≤245					≤252			≤258
8	Exhaust gas temp.		°C (°F)	≤490 (914)	≤550 (1022)	560 (1040)	≤570 (1058)	≤580 (1076)	≤580 (1076)	≤620 (1148)	≤630 (1166)	≤650 (1202)
9	Compression ratio		—	19.2								
10	Diesel fuel injection pressure		MPa (kgf/cm²)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})		$21.6^{+1.0}_{0}$ (220^{+10}_{0})						
11	Main shaft side		—	Flywheel side								
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)								
13	Governor		—	Mechanical centrifugal governor (All-speed governor)								
14	Aspiration		—	Natural aspiration								
15	Cooling system		—	Force-feed circulation radiator type cooling system								
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump								
17	Starting system		—	Electric starting								
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)								
19	Starting aid device		—	Air heater (12 VDC/400 W)								
20	Engine oil pressure	Rated speed	MPa (kgf/cm²)	$0.441^{+0.098}_{-0.049}$ ($4.5^{+1.0}_{-0.5}$)							$0.441^{+0.098}_{-0.049}$ ($4.5^{+1.0}_{-0.5}$)	
21	Oil pan capacity	Full	ℓ	5.5								
		Useful	ℓ	1.9								
22	Engine coolant capacity		ℓ	1.8 (Engine only)								
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ335 × 6								
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120 / ϕ90		ϕ110 / ϕ110						

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

3TNV82A-B/-Z (complies with EPA Interim Tier4)

Engine model				3TNV82A-B/-Z												
Engine classification				CL		VM										
1	Type		—	Vertical, 4-cycle water-cooled diesel engine												
2	Combustion system		—	Direct injection												
3	No. of cylinders – Bore × Stroke		n – mm × mm	ϕ82 × 84												
4	Displacement		ℓ	1.331												
5	Rated engine speed		min^{-1}					2200	2300	2400	2500	2600	2700	2800		3000
5	Output (Gross)	Cont. rating	kW													
5	Output (Gross)	Rated output	kW					16.5	17.3	18.1	18.9	19.7	20.5	21.3		23.0
5	Output (NET)	Cont. rating	kW													
5	Output (NET)	Rated output	kW					16.0	16.8	17.5	18.2	19.0	19.7	20.4		21.9
6	Maximum idling speed		min^{-1} ±25					2375	2485	2570	2675	2780	2890	2995		3180
7	Specific fuel consumption		g/kWh	≤245							≤252				≤258	
8	Exhaust gas temp.		°C (°F)					≤580 (1076)	≤590 (1094)	≤600 (1112)	≤610 (1130)	≤620 (1148)	≤630 (1166)	≤640 (1184)		≤660 (1220)
9	Compression ratio		—	19.2												
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	Main shaft side		—	Flywheel side												
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)												
13	Governor		—	Mechanical governor (All-speed governor) / Electronic governor (All-speed governor)												
14	Aspiration		—	Natural aspiration												
15	Cooling system		—	Radiator type cooling system												
16	Lubricating system		—	Forced lubrication with trochoid pump												
17	Starting system		—	Electric starting												
18	Charging system		—	Alternator (12 VDC/40 A)												
19	Starting aid device		—	Super-quick Heating Glow plug												
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.36^{+0.10}_{-0.05}$ $(3.7^{+1.0}_{-0.5})$											$0.41^{+0.10}_{-0.05}$ $(4.2^{+1.0}_{-0.5})$	
21	Oil pan capacity	Full	ℓ	5.5												
21	Oil pan capacity	Useful	ℓ	1.9												
22	Engine coolant capacity		ℓ	1.8 (Engine only)												
23	Cooling fan type – dia. × No. of blades		mm	Resin F type pusher fan - ϕ335(NF) x 6												
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm			ϕ110 / ϕ110										

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

3TNV82A-B
3TNV82A-Z (Electronically controlled)

Engine Model				3TNV82A-B/3TNV82A-Z												
Version				CL		VM										
1	Type		—	Vertical In-line Diesel Engine												
2	Combustion System		—	Direct Injection												
3	No. of Cylinders - Bore x Stroke		n - mm x mm	3 - 82~84												
4	Displacement		ℓ	1.331												
5	Engine Speed		min^{-1}					2200	2300	2400	2500	2600	2700	2800		3000
	Power Output (Gross) *1	Cont. Rating	kW													
		Max. Rating	kW					16.5	17.3	18.1	18.9	19.7	20.5	21.3		23.0
	Power Output (Net)	Cont. Rating	kW													
		Max. Rating	kW					16.0	16.8	17.5	18.2	19.0	19.7	20.4		21.9
6	High Idling		min^{-1} ±25					2375	2485	2570	2675	2780	2890	2995		3180
7	Fuel Consumption		g/kWh	≤245							≤252				≤258	
8	Exhaust Temperature		°C					≤580	≤590	≤600	≤610	≤620	≤630	≤640		≤660
9	Compression Ratio		—	19.2												
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	PTO Position		—	Flywheel End												
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)												
13	Governor		—	Mechanical (all-speed governor) / Electronic (all-speed governor)												
14	Aspiration		—	Natural												
15	Cooling System		—	Liquid-cooled with Radiator												
16	Lubricating System		—	Forced Lubrication with Trochoid Pump												
17	Starting System		—	Electric Starting												
18	Charging System		—	Charging with Alternator (12VDC, 40A)												
19	Starting Aid		—	Quick Heat Glow Plugs												
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)												
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	5.5												
		Dipstick Lower Limit	ℓ	1.9												
22	Engine Coolant Capacity		ℓ	1.8 (Engine Only)												
23	Cooling Fan		mm	335 mm O.D., 6 Blade Pusher-Type												
24	Crank Pulley Dia./Fan Pulley Dia.		mm/mm	ø120 / ø90		ø110 / ø110										

Note: * Applies to basic models/versions and may vary depending on specific applications.

3TNV84 (complies with EPA Tier2)

No.	Item		Unit									
	Engine model			3TNV84								
	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 – 84 × 90								
4	Displacement		ℓ	1.496								
5	Rated engine speed		min^{-1}	1500	1800	2000	2200	2400	2500	2600	2800	3000
	Output (Gross)	Cont. rating	kW	11.6	14.1							
		Rated output	kW	12.7	15.4	16.8	18.6	20.3	21.2	22.1	23.9	25.7
	Output (NET)	Cont. rating	kW	11.3	13.5							
		Rated output	kW	12.4	14.8	16.4	18.1	19.7	20.5	21.3	23	24.6
6	Maximum idling speed		min-1 ±25	1600	1895	2180	2400	2590	2690	2810	2995	3210
7	Specific fuel consumption		g/kWh	≤245					≤252			≤258
8	Exhaust gas temp.		°C (°F)	≤510 (950)	≤540 (1004)	≤530 (986)	≤560 (1040)	≤590 (1094)	≤600 (1112)	≤610 (1130)	≤670 (1238)	≤670 (1238)
9	Compression ratio		—	19								
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})		$21.6^{+1.0}_{0}$ (220^{+10}_{0})						
11	Main shaft side		—	Flywheel side								
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)								
13	Governor		—	Mechanical centrifugal governor (All-speed governor)								
14	Aspiration		—	Natural aspiration								
15	Cooling system		—	Force-feed circulation radiator type cooling system								
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump								
17	Starting system		—	Electric starting								
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)								
19	Starting aid device		—	Air heater (12 VDC/400 W)								
20	Engine oil pressure	Rated speed	MPa (kgf/cm2)	$0.392^{+0.098}_{-0.049}$ ($4.0^{+1.0}_{-0.5}$)		$0.441^{+0.098}_{-0.049}$ ($4.5^{+1.0}_{-0.5}$)						
21	Oil pan capacity	Full	ℓ	6.7								
		Useful	ℓ	2.8								
22	Cooling water capacity		ℓ	2.0 (Engine only)								
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ335 × 6								
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120 / ϕ90		ϕ110/ ϕ110						

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

3TNV84T-Z (Electronically controlled)

Engine Model				3TNV84T-Z												
Version				CL		VM										
1	Type		—	Vertical In-line Diesel Engine												
2	Combustion System		—	Direct Injection												
3	No. of Cylinders - Bore x Stroke		n - mm x mm	ø 84×90												
4	Displacement		ℓ	1.496												
5	Engine Speed		min^{-1}							2400	2500	2600	2700	2800		
	Power Output (Gross) *1	Cont. Rating	kW													
		Max. Rating	kW							25.7	26.7	27.7	28.9	30.1		
	Power Output (Net)	Cont. Rating	kW													
		Max. Rating	kW							25.0	26.0	26.8	27.9	29.1		
6	High Idling		min^{-1} ±25							2590	2700	2810	2920	2995		
7	Fuel Consumption		g/kWh							≤245	≤252					
8	Exhaust Temperature		°C							≤620	≤630	≤635	≤650	≤650		
9	Compression Ratio		—			19.0										
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})												
11	PTO Position		—	Flywheel End												
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)												
13	Governor		—	Electronic (all-speed governor)												
14	Aspiration		—	Turbocharged												
15	Cooling System		—	Liquid-cooled with Radiator												
16	Lubricating System		—	Forced Lubrication with Trochoid Pump												
17	Starting System		—	Electric Starting												
18	Charging System		—	Charging with Alternator (12VDC, 40A)												
19	Starting Aid		—	Quick Heat Glow Plugs												
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)							$0.39^{+0.10}_{-0.05}$ ($4.0^{+1.0}_{-0.05}$)				$0.44^{+0.10}_{-0.05}$ ($4.5^{+1.0}_{-0.5}$)		
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	6.7												
		Dipstick Lower Limit	ℓ	2.8												
22	Engine Coolant Capacity		ℓ	2.0(Engine Only)												
23	Cooling Fan		mm	350 mm O.D., 6 Blade Pusher-Type												
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm			ø110 / ø110										

Note: * Applies to basic models/versions and may vary depending on specific applications.

3TNV88 (complies with EPA Tier2)

Engine model				3TNV88								
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}	1500	1800	2000	2200	2400	2500	2600	2800	3000
	Output (Gross)	Cont. rating	kW	12.7	15.4							
		Rated output	kW	13.9	16.9	18.4	20.3	22.2	23.2	24.2	26	27.4
	Output (NET)	Cont. rating	kW	12.3	14.8							
		Rated output	kW	13.5	16.3	18	19.9	21.6	22.6	23.5	25.2	26.3
6	Maximum idling speed		min-1 ±25	1600	1895	2180	2400	2590	2700	2810	2995	3210
7	Specific fuel consumption		g/kWh	≤245					≤252			≤258
8	Exhaust gas temp.		°C (°F)	≤540 (1004)	≤590 (1094)	≤570 (1058)	≤580 (1076)	≤600 (1112)	≤620 (1148)	≤650 (1202)	≤650 (1202)	≤670 (1238)
9	Compression ratio		—	19.1								
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})		$21.6^{+1.0}_{0}$ (220^{+10}_{0})						
11	Main shaft side		—	Flywheel side								
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)								
13	Governor		—	Mechanical centrifugal governor (All-speed governor)								
14	Aspiration		—	Natural aspiration								
15	Cooling system		—	Force-feed circulation radiator type cooling system								
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump								
17	Starting system		—	Electric starting								
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)								
19	Starting aid device		—	Air heater (12 VDC/400 W)								
20	Engine oil pressure	Rated speed	MPa (kgf/cm2)	$0.392^{+0.098}_{-0.049}$ ($4.0^{+1.0}_{-0.5}$)		$0.441^{+0.098}_{-0.049}$ ($4.5^{+1.0}_{-0.5}$)						
21	Oil pan capacity	Full	ℓ	6.7								
		Useful	ℓ	2.8								
22	Cooling water capacity		ℓ	2.0 (Engine only)								
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ335 × 6								
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120 / ϕ90		ϕ110/ ϕ110						

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

3TNV88-U/-E (complies with EPA Interim Tier4)

Engine model				3TNV88-U/-E												
Engine classification				CL		VM										
1	Type		—	Vertical, 4-cycle water-cooled diesel engine												
2	Combustion system		—	Direct injection												
3	No. of cylinders – Bore × Stroke		n – mm × mm	ϕ88 × 90												
4	Displacement		ℓ	1.642												
5	Rated engine speed		min^{-1}					2200	2300	2400	2500	2600	2700	2800		3000
	Output (Gross)	Cont. rating	kW													
		Rated output	kW					18.6	19.4	20.3	21.2	22.1	23.0	23.9		25.7
	Output (NET)	Cont. rating	kW													
		Rated output	kW					18.1	18.9	19.7	20.5	21.3	22.2	23.0		24.6
6	Maximum idling speed		min^{-1} ±25					2400	2510	2590	2700	2810	2920	2995		3210
7	Specific fuel consumption		g/kWh	≤245							≤252				≤258	
8	Exhaust gas temp.		°C (°F)					≤580 (1076)	≤590 (1094)	≤600 (1112)	≤610 (1130)	≤620 (1148)	≤630 (1166)	≤640 (1184)		≤660 (1220)
9	Compression ratio		—	19.1												
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	Main shaft side		—	Flywheel side												
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)												
13	Governor		—	Mechanical governor (All-speed governor) / Electronic governor (All-speed governor)												
14	Aspiration		—	Natural aspiration												
15	Cooling system		—	Radiator type cooling system												
16	Lubricating system		—	Forced lubrication with trochoid pump												
17	Starting system		—	Electric starting												
18	Charging system		—	Alternator (12 VDC/40 A)												
19	Starting aid device		—	Super-quick Heating Glow plug												
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.39^{+0.10}_{-0.05}$ ($4.0^{+1.0}_{-0.5}$)											$0.44^{+0.10}_{-0.05}$ ($4.5^{+1.0}_{-0.5}$)	
21	Oil pan capacity	Full	ℓ	6.7												
		Useful	ℓ	2.8												
22	Engine coolant capacity		ℓ	2.0 (Engine only)												
23	Cooling fan type – dia. × No. of blades		mm	Resin F type pusher fan - ϕ335(NF) x 6												
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm			ϕ110 / ϕ110										

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

3TNV88-U
3TNV88-E (Electronically controlled)

Engine Model				3TNV88-U/3TNV88-E												
Version				CL		VM										
1	Type		—	Vertical In-line Diesel Engine												
2	Combustion System		—	Direct Injection												
3	No. of Cylinders - Bore x Stroke		n - mm x mm	3 - 88~90												
4	Displacement		ℓ	1.642												
5	Engine Speed		min^{-1}				2100	2200	2300	2400	2500	2600	2700	2800		3000
	Power Output (Gross) *1	Cont. Rating	kW													
		Max. Rating	kW				17.7	18.6	19.4	20.3	21.2	22.1	23.0	23.9		25.7
	Power Output (Net)	Cont. Rating	kW													
		Max. Rating	kW				17.3	18.1	18.9	19.7	20.5	21.3	22.2	23.0		24.6
6	High Idling		min^{-1} ±25				2290	2400	2510	2590	2690	2810	2920	2995		3210
7	Fuel Consumption		g/kWh	≤245							≤252				≤258	
8	Exhaust Temperature		°C				≤570	≤580	≤590	≤600	≤610	≤620	≤630	≤640		≤660
9	Compression Ratio		—	19.1												
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	PTO Position		—	Flywheel End												
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)												
13	Governor		—	Mechanical (all-speed governor) / Electronic (all-speed governor)												
14	Aspiration		—	Natural												
15	Cooling System		—	Liquid-cooled with Radiator												
16	Lubricating System		—	Forced Lubrication with Trochoid Pump												
17	Starting System		—	Electric Starting												
18	Charging System		—	Charging with Alternator (12VDC, 40A)												
19	Starting Aid		—	Quick Heat Glow Plugs												
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)												
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	6.7												
		Dipstick Lower Limit	ℓ	2.8												
22	Engine Coolant Capacity		ℓ	2.0 (Engine Only)												
23	Cooling Fan		mm	335 mm O.D., 6 Blade Pusher-Type												
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm	ø120 / ø90		ø110 / ø110										

Note: * Applies to basic models/versions and may vary depending on specific applications.

3TNV88-B/-Z (complies with EPA Interim Tier4)

Engine model				3TNV88-B/-Z												
Engine classification				CL		VM										
1	Type		—	Vertical, 4-cycle water-cooled diesel engine												
2	Combustion system		—	Direct injection												
3	No. of cylinders – Bore × Stroke		n – mm × mm	ϕ88 × 90												
4	Displacement		ℓ	1.642												
5	Rated engine speed		min^{-1}	1500	1800			2200	2300	2400	2500	2600	2700	2800		3000
	Output (Gross)	Cont. rating	kW	12.7	15.4											
		Rated output	kW	13.9	16.9			20.3	21.3	22.2	23.2	24.2	25.1	26.0		28.1
	Output (NET)	Cont. rating	kW	12.3	14.8											
		Rated output	kW	13.5	16.3			19.9	20.7	21.6	22.6	23.5	24.3	25.2		27.1
6	Maximum idling speed		min^{-1} ±25	1600	1895			2400	2510	2590	2700	2810	2920	2995		3210
7	Specific fuel consumption		g/kWh	≤245							≤252				≤258	
8	Exhaust gas temp.		°C (°F)	≤540 (1004)	≤560 (1040)			≤590 (1094)	≤600 (1112)	≤610 (1130)	≤620 (1148)	≤630 (1166)	≤640 (1184)	≤650 (1202)		≤670 (1238)
9	Compression ratio		—	19.1												
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	Main shaft side		—	Flywheel side												
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)												
13	Governor		—	Mechanical governor (All-speed governor) / Electronic governor (All-speed governor)												
14	Aspiration		—	Natural aspiration												
15	Cooling system		—	Radiator type cooling system												
16	Lubricating system		—	Forced lubrication with trochoid pump												
17	Starting system		—	Electric starting												
18	Charging system		—	Alternator (12 VDC/40 A)												
19	Starting aid device		—	Super-quick Heating Glow plug												
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.34^{+0.10}_{-0.05}$ ($3.5^{+1.0}_{-0.5}$)		$0.39^{+0.10}_{-0.05}$ ($4.0^{+1.0}_{-0.5}$)									$0.44^{+0.10}_{-0.05}$ ($4.5^{+1.0}_{-0.5}$)	
21	Oil pan capacity	Full	ℓ	6.7												
		Useful	ℓ	2.8												
22	Engine coolant capacity		ℓ	2.0 (Engine only)												
23	Cooling fan type – dia. × No. of blades		mm	Resin F type pusher fan - ϕ335(NF) x 6												
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120 / ϕ90		ϕ110 / ϕ110										

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

3TNV88-B
3TNV88-Z (Electronically controlled)

Engine Model				3TNV88-B/3TNV88-Z												
Version				CL		VM										
1	Type		—	Vertical In-line Diesel Engine												
2	Combustion System		—	Direct Injection												
3	No. of Cylinders - Bore x Stroke		n - mm x mm	3 - 88~90												
4	Displacement		ℓ	1.642												
5	Engine Speed		min^{-1}	1500	1800			2200	2300	2400	2500	2600	2700	2800		3000
	Power Output (Gross) *1	Cont. Rating	kW	12.7	15.4											
		Max. Rating	kW	13.9	16.9			20.3	21.3	22.2	23.2	24.2	25.1	26.0		28.1
	Power Output (Net)	Cont. Rating	kW	12.3	14.8											
		Max. Rating	kW	13.5	16.3			19.9	20.7	21.6	22.6	23.5	24.3	25.2		27.1
6	High Idling		min^{-1} ±25	1600	1895			2400	2510	2590	2690	2810	2920	2995		3210
7	Fuel Consumption		g/kWh	≤245							≤252				≤258	
8	Exhaust Temperature		°C	≤540	≤560			≤590	≤600	≤610	≤620	≤630	≤640	≤650		≤670
9	Compression Ratio		—	19.1												
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	PTO Position		—	Flywheel End												
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)												
13	Governor		—	Mechanical (all-speed governor) / Electronic (all-speed governor)												
14	Aspiration		—	Natural												
15	Cooling System		—	Liquid-cooled with Radiator												
16	Lubricating System		—	Forced Lubrication with Trochoid Pump												
17	Starting System		—	Electric Starting												
18	Charging System		—	Charging with Alternator (12VDC, 40A)												
19	Starting Aid		—	Quick Heat Glow Plugs												
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)												
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	6.7												
		Dipstick Lower Limit	ℓ	2.8												
22	Engine Coolant Capacity		ℓ	2.0 (Engine Only)												
23	Cooling Fan		mm	335 mm O.D., 6 Blade Pusher-Type												
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm	ø120 / ø90		ø110 / ø110										

Note: * Applies to basic models/versions and may vary depending on specific applications.

3TNV84T (complies with EPA Tier2)

Engine model				3TNV84T							
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 – 84 × 90							
4	Displacement		ℓ	1.496							
5	Rated engine speed		min^{-1}	1500	1800	2000	2200	2400	2500	2600	2800
	Output (Gross)	Cont. rating	kW	14.4	17.3						
		Rated output	kW	16.3	19.5	—	—	25.7	26.7	27.7	30.1
	Output (NET)	Cont. rating	kW	14	16.5	—	—				
		Rated output	kW	15.8	18.8	—	—	25	26	26.8	29.1
6	Maximum idling speed		min-1 ±25	1600	1895	—	—	2590	2700	2810	2995
7	Specific fuel consumption		g/kWh	≤245					≤252		
8	Exhaust gas temp.		°C (°F)	≤570 (1058)		—		≤630 (1166)		≤640 (1184)	≤650 (1202)
9	Compression ratio		—	19							
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})		$21.6^{+1.0}_{0}$ (220^{+10}_{0})					
11	Main shaft side		—	Flywheel side							
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)							
13	Governor		—	Mechanical centrifugal governor (All-speed governor)							
14	Aspiration		—	Turbocharged aspiration							
15	Cooling system		—	Force-feed circulation radiator type cooling system							
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump							
17	Starting system		—	Electric starting							
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)							
19	Starting aid device		—	Air heater (12 VDC/400 W)							
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.343^{+0.098}_{-0.049}$ ($3.5^{+1.0}_{-0.5}$)		—		$0.392^{+0.098}_{-0.049}$ ($4.0^{+1.0}_{-0.5}$)			$0.441^{+0.098}_{-0.049}$ ($4.5^{+1.0}_{-0.5}$)
21	Oil pan capacity	Full	ℓ	6.7							
		Useful	ℓ	2.8							
22	Engine coolant capacity		ℓ	2.0 (Engine only)							
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ350 × 6							
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120 / ϕ90		ϕ110/ ϕ110					

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

3TNV84T-B (complies with EPA Interim Tier4)

Engine model				3TNV84T-B												
Engine classification				CL		VM										
1	Type		—	Vertical, 4-cycle water-cooled diesel engine												
2	Combustion system		—	Direct injection												
3	No. of cylinders – Bore × Stroke		n – mm × mm	ϕ84 × 90												
4	Displacement		ℓ	1.496												
5	Rated engine speed		min^{-1}							2400	2500	2600	2700	2800		
	Output (Gross)	Cont. rating	kW													
		Rated output	kW							25.7	26.7	27.7	28.9	30.1		
	Output (NET)	Cont. rating	kW													
		Rated output	kW							25.0	26.0	26.8	27.9	29.1		
6	Maximum idling speed		min^{-1} ±25							2590	2700	2810	2920	2995		
7	Specific fuel consumption		g/kWh							≤245	≤252					
8	Exhaust gas temp.		°C (°F)							≤620 (1148)	≤630 (1166)	≤635 (1175)	≤650 (1202)	≤650 (1202)		
9	Compression ratio		—	19.0												
10	Diesel fuel injection pressure		MPa (kgf/cm²)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})												
11	Main shaft side		—	Flywheel side												
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)												
13	Governor		—	Mechanical governor (All-speed governor)												
14	Aspiration		—	Turbocharged aspiration												
15	Cooling system		—	Radiator type cooling system												
16	Lubricating system		—	Forced lubrication with trochoid pump												
17	Starting system		—	Electric starting												
18	Charging system		—	Alternator (12 VDC/40 A)												
19	Starting aid device		—	Super-quick Heating Glow plug												
20	Engine oil pressure	Rated speed	MPa (kgf/cm²)							$0.39^{+0.10}_{-0.05}$ $(4.0^{+1.0}_{-0.05})$					$0.44^{+0.10}_{-0.05}$ $(4.5^{+1.0}_{-0.5})$	
21	Oil pan capacity	Full	ℓ	6.7												
		Useful	ℓ	2.8												
22	Engine coolant capacity		ℓ	2.0 (Engine only)												
23	Cooling fan type – dia. × No. of blades		mm	Resin F type pusher fan - ϕ335(NF) x 6												
24	Crank V-pulley dia./ Fan V-pulley dia.		mm/mm			ϕ110 / ϕ110										

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

4TNV84 (complies with EPA Tier2)

Engine model				4TNV84								
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 – 84 × 90								
4	Displacement		ℓ	1.995								
5	Rated engine speed		min^{-1}	1500	1800	2000	2200	2400	2500	2600	2800	3000
	Output (Gross) *1	Cont. rating	kW	15.5	18.6							
		Rated output	kW	16.9	20.3	22.4	24.8	27.2	28.3	29.5	31.9	
	Output (NET)	Cont. rating	kW	14.9	17.7							
		Rated output	kW	16.4	19.5	21.9	24.1	26.3	27.4	28.5	30.7	
6	Maximum idling speed		min^{-1} ±25	1600	1895	2180	2400	2590	2700	2810	2995	3210
7	Specific fuel consumption		g/kWh	≤245					≤252			≤258
8	Exhaust gas temp.		°C (°F)	≤500 (932)	≤550 (1022)	≤540 (1004)	≤560 (1040)	≤590 (1094)	≤600 (1112)	≤610 (1130)	≤620 (1148)	≤650 (1202)
9	Compression ratio		—	19								
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})		$21.6^{+1.0}_{0}$ (220^{+10}_{0})						
11	Main shaft side		—	Flywheel side								
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)								
13	Governor		—	Mechanical centrifugal governor (All-speed governor)								
14	Aspiration		—	Natural aspiration								
15	Cooling system		—	Force-feed circulation radiator type cooling system								
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump								
17	Starting system		—	Electric starting								
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)								
19	Starting aid device		—	Air heater (12 VDC/400 W)								
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.392^{+0.098}_{-0.049}$ ($4.0^{+1.0}_{-0.5}$)		$0.441^{+0.098}_{-0.049}$ ($4.5^{+1.0}_{-0.5}$)						
21	Oil pan capacity	Full	ℓ	7.4								
		Useful	ℓ	3.4								
22	Engine Coolant capacity		ℓ	2.7 (Engine only)								
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ370 × 6								
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120 / ϕ90		ϕ110/ ϕ110						

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

4TNV88 (complies with EPA Tier2)

Engine model				4TNV84								
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	2.190								
5	Rated engine speed		min^{-1}	1500	1800	2000	2200	2400	2500	2600	2800	3000
	Output (Gross) *1	Cont. rating	kW	16.9	20.5							
		Rated output	kW	18.5	22.5	24.6	27.1	29.7	31	32.3	35	36.9
	Output (NET)	Cont. rating	kW	16.4	19.6							
		Rated output	kW	18	21.6	24.1	26.5	28.8	30.1	31.3	33.7	35.4
6	Maximum idling speed		min^{-1} ±25	1600	1895	2180	2400	2590	2700	2810	2995	3210
7	Specific fuel consumption		g/kWh	≤245						≤252		
8	Exhaust gas temp.		°C (°F)	≤500 (932)	≤550 (1022)	≤580 (1076)	≤600 (1112)		≤620 (1148)		≤650 (1202)	≤670 (1238)
9	Compression ratio		—	19.1								
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})		$21.6^{+1.0}_{0}$ (220^{+10}_{0})						
11	Main shaft side		—	Flywheel side								
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)								
13	Governor		—	Mechanical centrifugal governor (All-speed governor)								
14	Aspiration		—	Natural aspiration								
15	Cooling system		—	Force-feed circulation radiator type cooling system								
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump								
17	Starting system		—	Electric starting								
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)								
19	Starting aid device		—	Air heater (12 VDC/400 W)								
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.392^{+0.098}_{-0.049}$ ($4.05^{+1.0}_{-0.5}$)		$0.441^{+0.098}_{-0.049}$ ($4.52^{+1.0}_{-0.5}$)						
21	Oil pan capacity	Full	ℓ	7.4								
		Useful	ℓ	3.4								
22	Engine Coolant capacity		ℓ	2.7 (Engine only)								
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ37 × 6								
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120 / ϕ90		ϕ110/ ϕ110						

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

4TNV88-U/-E (complies with EPA Interim Tier4)

Engine model				4TNV88-U/-E												
Engine classification				CL		VM										
1	Type		—	Vertical, 4-cycle water-cooled diesel engine												
2	Combustion system		—	Direct injection												
3	No. of cylinders – Bore × Stroke		n – mm × mm	ϕ88 × 90												
4	Displacement		ℓ	2.190												
5	Rated engine speed		min^{-1}										2700	2800		
	Output (Gross) *1	Cont. rating	kW													
		Rated output	kW										30.7	31.9		
	Output (NET)	Cont. rating	kW													
		Rated output	kW										29.6	30.7		
6	Maximum idling speed		min^{-1} ±25										2920	2995		
7	Specific fuel consumption		g/kWh								≤252					
8	Exhaust gas temp.		°C (°F)										≤630 (1166)	≤640 (1184)		
9	Compression ratio		—	19.1												
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	Main shaft side		—	Flywheel side												
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)												
13	Governor		—	Mechanical governor (All-speed governor) / Electronic governor (All-speed governor)												
14	Aspiration		—	Natural aspiration												
15	Cooling system		—	radiator type cooling system												
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump												
17	Starting system		—	Electric starting												
18	Charging system		—	Alternator (12 VDC/40 A)												
19	Starting aid device		—	Super-quick Heating Glow plug												
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)			$0.37^{+0.10}_{-0.05}$ ($3.8^{+1.0}_{-0.5}$)										
21	Oil pan capacity	Full	ℓ	7.4												
		Useful	ℓ	3.4												
22	Engine Coolant capacity		ℓ	2.7 (Engine only)												
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ37 × 6												
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm			ϕ110/ ϕ110										

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

4TNV88-U
4TNV88-E (Electronically controlled)

Engine Model				4TNV88-U/4TNV88-E												
Version				CL		VM										
1	Type		—	Vertical In-line Diesel Engine												
2	Combustion System		—	Direct Injection												
3	No. of Cylinders - Bore x Stroke		n - mm x mm	4 - 88~90												
4	Displacement		ℓ	2.189												
5	Engine Speed		min^{-1}										2700	2800		
	Power Output (Gross) *1	Cont. Rating	kW													
		Max. Rating	kW										30.7	31.9		
	Power Output (Net)	Cont. Rating	kW													
		Max. Rating	kW										29.6	30.7		
6	High Idling		min^{-1} ±25										2920	2995		
7	Fuel Consumption		g/kWh	≤245							≤252				≤258	
8	Exhaust Temperature		°C										≤630	≤640		
9	Compression Ratio		—	19.1												
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	PTO Position		—	Flywheel End												
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)												
13	Governor		—	Mechanical (all-speed governor) / Electronic (all-speed governor)												
14	Aspiration		—	Natural												
15	Cooling System		—	Liquid-cooled with Radiator												
16	Lubricating System		—	Forced Lubrication with Trochoid Pump												
17	Starting System		—	Electric Starting												
18	Charging System		—	Charging with Alternator (12VDC, 40A)												
19	Starting Aid		—	Quick Heat Glow Plugs												
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)												
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	7.4												
		Dipstick Lower Limit	ℓ	3.4												
22	Engine Coolant Capacity		ℓ	2.7 (Engine Only)												
23	Cooling Fan		mm	370 mm O.D., 6 Blade Pusher-Type												
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm	ø120 / ø90		ø110 / ø110										

Note: * Applies to basic models/versions and may vary depending on specific applications.

4TNV88-B/-Z (complies with EPA Interim Tier4)

Engine model				4TNV88-B/-Z												
Engine classification				CL		VM										
1	Type		—	Vertical, 4-cycle water-cooled diesel engine												
2	Combustion system		—	Direct injection												
3	No. of cylinders – Bore × Stroke		n – mm × mm	4 – 88 × 90												
4	Displacement		ℓ	2.190												
5	Rated engine speed		min^{-1}	1500	1800	2000	2100	2200	2300	2400	2500	2600	2700	2800		3000
	Output (Gross) *1	Cont. rating	kW	16.9	20.5											
		Rated output	kW	18.5	22.5	24.6	25.9	27.1	28.4	29.7	31.0	32.3	33.6	35.0		36.9
	Output (NET)	Cont. rating	kW	16.4	19.6											
		Rated output	kW	18.0	21.6	24.1	25.3	26.5	27.7	28.8	30.1	31.3	32.5	33.7		35.4
6	Maximum idling speed		min^{-1} ±25	1600	1895	2180	2290	2400	2510	2590	2700	2810	2920	2995		3210
7	Specific fuel consumption		g/kWh	≤245								≤252				
8	Exhaust gas temp.		°C (°F)	≤520 (968)	≤540 (1004)	≤560 (1040)	≤570 (1058)	≤580 (1076)	≤590 (1094)	≤600 (1112)	≤610 (1130)	≤620 (1148)	≤630 (1166)	≤640 (1184)		≤660 (1220)
9	Compression ratio		—	19.1												
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	Main shaft side		—	Flywheel side												
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)												
13	Governor		—	Mechanical governor (All-speed governor) / Electronic governor (All-speed governor)												
14	Aspiration		—	Natural aspiration												
15	Cooling system		—	radiator type cooling system												
16	Lubricating system		—	Forced lubrication with trochoid pump												
17	Starting system		—	Electric starting												
18	Charging system		—	Alternator (12 VDC/40 A)												
19	Starting aid device		—	Super-quick Heating Glow plug												
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.34^{+0.10}_{-0.05}$ $(3.5^{+1.0}_{-0.5})$		$0.37^{+0.10}_{-0.05}$ $(3.8^{+1.0}_{-0.5})$										
21	Oil pan capacity	Full	ℓ	7.4												
		Useful	ℓ	3.4												
22	Engine Coolant capacity		ℓ	2.7 (Engine only)												
23	Cooling fan type – dia. × No. of blades		mm	Pusher (resin), F type - ϕ370(EF) x 6												
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120/ ϕ90		ϕ110/ ϕ110										

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

4TNV88-B
4TNV88-Z (Electronically controlled)

Engine Model				4TNV88-B/4TNV88-Z												
Version				CL		VM										
1	Type		—	Vertical In-line Diesel Engine												
2	Combustion System		—	Direct Injection												
3	No. of Cylinders - Bore x Stroke		n - mm x mm	4 - 88~90												
4	Displacement		ℓ	2.189												
5	Engine Speed		min^{-1}	1500	1800	2000	2100	2200	2300	2400	2500	2600	2700	2800		3000
	Power Output (Gross) *1	Cont. Rating	kW	16.9	20.5											
		Max. Rating	kW	18.5	22.5	24.6	25.9	27.1	28.4	29.7	31.0	32.3	33.6	35.0		36.9
	Power Output (Net)	Cont. Rating	kW	16.4	19.6											
		Max. Rating	kW	18.0	21.6	24.1	25.3	26.5	27.7	28.8	30.1	31.3	32.5	33.7		35.4
6	High Idling		min^{-1} ±25	1600	1895	2180	2290	2400	2510	2590	2700	2810	2920	2995		3210
7	Fuel Consumption		g/kWh	≤245								≤252				
8	Exhaust Temperature		°C	≤520	≤540	≤560	≤570	≤580	≤590	≤600	≤610	≤620	≤630	≤640		≤660
9	Compression Ratio		—	19.1												
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})												
11	PTO Position		—	Flywheel End												
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)												
13	Governor		—	Mechanical (all-speed governor) / Electronic (all-speed governor)												
14	Aspiration		—	Natural												
15	Cooling System		—	Liquid-cooled with Radiator												
16	Lubricating System		—	Forced Lubrication with Trochoid Pump												
17	Starting System		—	Electric Starting												
18	Charging System		—	Charging with Alternator (12VDC, 40A)												
19	Starting Aid		—	Quick Heat Glow Plugs												
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)												
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	7.4												
		Dipstick Lower Limit	ℓ	3.4												
22	Engine Coolant Capacity		ℓ	2.7 (Engine Only)												
23	Cooling Fan		mm	370 mm O.D., 6 Blade Pusher-Type												
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm	ø120 / ø90		ø110 / ø110										

Note: * Applies to basic models/versions and may vary depending on specific applications.

4TNV84T (complies with EPA Tier2)

Engine model				4TNV84T								
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 – 84 × 90								
4	Displacement		ℓ	1.995								
5	Rated engine speed		min^{-1}	1500	1800	2000	2200	2400	2500	2600	2800	3000
	Output (Gross)	Cont. rating	kW	19.6	25.1							
		Rated output	kW	21.8	27.7	28.5	31.2	34.3	35.5	36.7	39.9	
	Output (NET)	Cont. rating	kW	19.1	24.3							
		Rated output	kW	21.3	26.9	27.9	30.5	33.5	34.5	35.7	38.6	
6	Maximum idling speed		min^{-1} ±25	1600	1895	2180	2400	2590	2700	2810	2995	3210
7	Specific fuel consumption		g/kWh	≤238				≤245	≤252		≤258	
8	Exhaust gas temp.		°C (°F)	≤550 (1022)	≤560 (1040)	≤530 (986)	≤550 (1022)	≤570 (1058)			≤590 (1094)	≤630 (1166)
9	Compression ratio		—	18.9								
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$19.6^{+1.0}_{0}$ (200^{+10}_{0})		$21.6^{+1.0}_{0}$ (220^{+10}_{0})						
11	Main shaft side		—	Flywheel side								
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)								
13	Governor		—	Mechanical centrifugal governor (All-speed governor)								
14	Aspiration		—	Turbocharged aspiration								
15	Cooling system		—	Force-feed circulation radiator type cooling system								
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump								
17	Starting system		—	Electric starting								
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)								
19	Starting aid device		—	Air heater (12 VDC/400 W)								
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.343^{+0.098}_{-0.049}$ ($3.5^{+1.0}_{-0.5}$)		$0.412^{+0.098}_{-0.049}$ ($4.2^{+1.0}_{-0.5}$)						
21	Oil pan capacity	Full	ℓ	7.4								
		Useful	ℓ	3.4								
22	Engine Coolant capacity		ℓ	3.2 (Engine only)								
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ370 × 6								
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120 / ϕ90 ϕ110/ ϕ110								

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

4TNV84T-Z/-B (complies with EPA Interim Tier4)

Engine model				4TNV84T-Z/-B												
Engine classification				CL		VM										
1	Type		—	Vertical, 4-cycle water-cooled diesel engine												
2	Combustion system		—	Direct injection												
3	No. of cylinders – Bore × Stroke		n – mm × mm	ϕ84 × 90												
4	Displacement		ℓ	1.995												
5	Rated engine speed		min^{-1}	1500	1800					2400	2500		2700	2800		3000
5	Output (Gross)	Cont. rating	kW	19.6	25.1											
5	Output (Gross)	Rated output	kW	21.8	27.7					34.3	35.5		38.3	39.9		42.7
5	Output (NET)	Cont. rating	kW	19.1	24.3											
5	Output (NET)	Rated output	kW	21.3	26.9					33.5	34.5		37.1	38.6		41.2
6	Maximum idling speed		min^{-1} ±25	1600	1895					2590	2700		2850	2950		3150
7	Specific fuel consumption		g/kWh	≤238		≤245					≤252					
8	Exhaust gas temp.		°C (°F)	≤560 (1040)						≤575 (1067)	≤580 (1076)		≤595 (1103)	≤600 (1112)		≤640 (1184)
9	Compression ratio		—	18.9												
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})												
11	Main shaft side		—	Flywheel side												
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)												
13	Governor		—	Mechanical governor (All-speed governor) / Electronic governor (All-speed governor)												
14	Aspiration		—	Turbocharged aspiration												
15	Cooling system		—	radiator type cooling system												
16	Lubricating system		—	Forced lubrication with trochoid pump												
17	Starting system		—	Electric starting												
18	Charging system		—	Alternator (12 VDC/40 A)												
19	Starting aid device		—	Air heater (12 VDC/400 W)												
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	$0.34^{+0.10}_{-0.05}$ $(3^{+1.0}_{-0.5})$		$0.41^{+0.10}_{-0.05}$ $(4.2^{+1.0}_{-0.5})$										
21	Oil pan capacity	Full	ℓ	7.4												
21	Oil pan capacity	Useful	ℓ	3.4												
22	Engine Coolant capacity		ℓ	3.2 (Engine only)												
23	Cooling fan type – dia. × No. of blades		mm	Pusher (resin), F type - ϕ370(EF) x 6												
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ120/ ϕ90		ϕ110/ ϕ110										

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

4TNV84T-Z

Engine Model				4TNV84T-Z												
Version				CL		VM										
1	Type		—	Vertical In-line Diesel Engine												
2	Combustion System		—	Direct Injection												
3	No. of Cylinders - Bore x Stroke		n - mm x mm	ø84×90												
4	Displacement		ℓ	1.995												
5	Engine Speed		min^{-1}	1500	1800					2400	2500		2700	2800		3000
	Power Output (Gross) *1	Cont. Rating	kW	19.6	25.1											
		Max. Rating	kW	21.8	27.7					34.3	35.5		38.3	39.9		42.7
	Power Output (Net)	Cont. Rating	kW	19.1	24.3											
		Max. Rating	kW	21.3	26.9					33.5	34.5		37.1	38.6		41.2
6	High Idling		min^{-1} ±25	1600	1895					2550	2650		2850	2950		3150
7	Fuel Consumption		g/kWh	≤238		≤245					≤252					
8	Exhaust Temperature		°C	≤560						≤575	≤580		≤595	≤600		≤640
9	Compression Ratio		—	18.9												
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})												
11	PTO Position		—	Flywheel End												
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)												
13	Governor		—	Electronic (all-speed governor) / Mechanical (all-speed governor)												
14	Aspiration		—	Turbocharged												
15	Cooling System		—	Liquid-cooled with Radiator												
16	Lubricating System		—	Forced Lubrication with Trochoid Pump												
17	Starting System		—	Electric Starting												
18	Charging System		—	Charging with Alternator (12VDC, 40A)												
19	Starting Aid		—	Air Heater (12VDC, 400W)												
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	$0.34^{+0.10}_{-0.05}$ ($3^{+1.0}_{-0.5}$)		$0.41^{+0.10}_{-0.05}$ ($4.2^{+1.0}_{-0.5}$)										
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	7.4												
		Dipstick Lower Limit	ℓ	3.4												
22	Engine Coolant Capacity		ℓ	3.2 (Engine Only)												
23	Cooling Fan		mm	370 mm O.D., 6 Blade Pusher-Type												
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm	ø120 / ø90		ø110 / ø110										

Note: * Applies to basic models/versions and may vary depending on specific applications.

4TNV94L (complies with EPA Tier2)

Engine model				4TNV94L							
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 – 94 × 110							
4	Displacement		ℓ	3.053							
5	Rated engine speed		min^{-1}	1500	1800	2000	2100	2200	2300	2400	2500
	Output (Gross)	Cont. rating	kW	26.4	31.7						
		Rated output	kW	29.3	35	35.9	37.4	39	40.5	42.4	44
	Output (NET)	Cont. rating	kW	26.1	31.3						
		Rated output	kW	29.1	34.6	35.3	36.8	38.2	39.7	41.6	43
6	Maximum idling speed		min^{-1} ±25	1600	1895	2180	2290	2400	2510	2590	2700
7	Specific fuel consumption		g/kWh	≤231					≤238		
8	Exhaust gas temp.		°C (°F)	≤590 (1094)		≤580 (1076)	≤590 (1094)	≤600 (1112)	≤610 (1130)	≤620 (1148)	≤640 (1184)
9	Compression ratio		—	19							
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	Main shaft side		—	Flywheel side							
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)							
13	Governor		—	Mechanical centrifugal governor (All-speed governor)							
14	Aspiration		—	Natural aspiration							
15	Cooling system		—	Force-feed circulation radiator type cooling system							
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump							
17	Starting system		—	Electric starting							
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)							
19	Starting aid device		—	Air heater (12 VDC/500 W)							
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Oil pan capacity	Full	ℓ	10.5							
		Useful	ℓ	4.5							
22	Engine Coolant capacity		ℓ	4.2 (Engine only)							
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ410 × 6							
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ130 / ϕ130							

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

4TNV98 (complies with EPA Tier2)

Engine model				4TNV98							
Engine classification				CL		VM					
1	Type		—	Vertical, 4-cycle water-cooled diesel engine							
2	Combustion system		—	Direct injection (DI)							
3	No. of cylinders – Bore x Stroke		n – mm x mm	4 – 98 x 110							
4	Displacement		ℓ	3.319							
5	Rated engine speed		min^{-1}	1500	1800	2000	2100	2200	2300	2400	2500
	Output (Gross)	Cont. rating	kW	31.2	37.2						
		Rated output	kW	34.9	41.6	42.5	44.4	46.3	48.2	50.2	52.1
	Output (NET)	Cont. rating	kW	30.9	36.8						
		Rated output	kW	34.6	41.2	41.9	43.8	45.6	47.4	49.3	51.1
6	Maximum idling speed		min^{-1} ±25	1600	1895	2180	2290	2400	2510	2590	2700
7	Specific fuel consumption		g/kWh	≤231					≤238		
8	Exhaust gas temp.		°C (°F)	≤600 (1112)		≤590 (1094)	≤600 (1112)	≤610 (1130)	≤620 (1148)	≤630 (1166)	≤650 (1202)
9	Compression ratio		—	18.5							
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	Main shaft side		—	Flywheel side							
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)							
13	Governor		—	Mechanical centrifugal governor (All-speed governor)							
14	Aspiration		—	Natural aspiration							
15	Cooling system		—	Force-feed circulation radiator type cooling system							
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump							
17	Starting system		—	Electric starting							
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)							
19	Starting aid device		—	Air heater (12 VDC/500 W)							
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Oil pan capacity	Full	ℓ	10.5							
		Useful	ℓ	4.5							
22	Engine Coolant capacity		ℓ	4.2 (Engine only)							
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type – ϕ410 x 6							
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ130 / ϕ130							

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

4TNV98-E (complies with EPA Interim Tier4)

Engine model				4TNV98-E							
Engine classification				CL		VM					
1	Type		—	Vertical, 4-cycle water-cooled diesel engine							
2	Combustion system		—	Direct injection							
3	No. of cylinders – Bore x Stroke		n – mm x mm	4 – 98 x 110							
4	Displacement		ℓ	3.319							
5	Rated engine speed		min^{-1}				2100	2200	2300	2400	2500
	Output (Gross)	Cont. rating	kW								
		Rated output	kW				37.4	39.0	40.5	42.4	44.0
	Output (NET)	Cont. rating	kW								
		Rated output	kW				36.8	38.2	39.7	41.6	43.0
6	Maximum idling speed		min^{-1} ±25				2250	2350	2400	2550	2650
7	Specific fuel consumption		g/kWh	≤224						≤231	
8	Exhaust gas temp.		°C (°F)				≤610 (1130)	≤620 (1148)	≤630 (1166)	≤640 (1184)	≤650 (1202)
9	Compression ratio		—	18.5							
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	Main shaft side		—	Flywheel side							
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)							
13	Governor		—	Mechanical governor (All-speed governor)							
14	Aspiration		—	Natural aspiration							
15	Cooling system		—	radiator type cooling system							
16	Lubricating system		—	Forced lubrication with trochoid pump							
17	Starting system		—	Electric starting							
18	Charging system		—	Alternator (12 VDC/40 A)							
19	Starting aid device		—	Air heater (12 VDC/500 W)							
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Oil pan capacity	Full	ℓ	10.2							
		Useful	ℓ	4.5							
22	Engine Coolant capacity		ℓ	4.2 (Engine only)							
23	Cooling fan type – dia. × No. of blades		mm	Pusher (resin), F type - ϕ410(Al) x 6							
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ130 / ϕ130							

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

A blank column indicates that there is no setting.

4TNV98-E

Engine Model				4TNV98-E							
Version				CL		VM					
1	Type		—	Vertical In-line Diesel Engine							
2	Combustion System		—	Direct Injection							
3	No. of Cylinders - Bore x Stroke		n - mm x mm	4 - 98~110							
4	Displacement		ℓ	3.318							
5	Engine Speed		min^{-1}				2100	2200	2300	2400	2500
	Power Output (Gross) *1	Cont. Rating	kW								
		Max. Rating	kW				37.4	39.0	40.5	42.4	44.0
	Power Output (Net)	Cont. Rating	kW								
		Max. Rating	kW				36.8	38.2	39.7	41.6	43.0
6	High Idling		min^{-1} ±25				2290	2400	2510	2590	2700
7	Fuel Consumption		g/kWh	≤224						≤231	
8	Exhaust Temperature		°C				≤610	≤620	≤630	≤640	≤650
9	Compression Ratio		—	18.5							
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	PTO Position		—	Flywheel End							
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)							
13	Governor		—	Electronic (all-speed governor)							
14	Aspiration		—	Natural							
15	Cooling System		—	Liquid-cooled with Radiator							
16	Lubricating System		—	Forced Lubrication with Trochoid Pump							
17	Starting System		—	Electric Starting							
18	Charging System		—	Charging with Alternator (DC12VDC, 40A)							
19	Starting Aid		—	Air Heater (12VDC, 500W)							
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	10.2							
		Dipstick Lower Limit	ℓ	4.5							
22	Engine Coolant Capacity		ℓ	4.2 (Engine Only)							
23	Cooling Fan		mm	410 mm O.D., 6 Blade Pusher-Type							
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm	ø130 / ø130							

Note: * Applies to basic models/versions and may vary depending on specific applications.

4TNV98-Z (complies with EPA Interim Tier4)

Engine model				4TNV98-Z							
Engine classification				CL		VM					
1	Type		—	Vertical, 4-cycle water-cooled diesel engine							
2	Combustion system		—	Direct injection							
3	No. of cylinders – Bore x Stroke		n – mm x mm	4 – 98 x 110							
4	Displacement		ℓ	3.319							
5	Rated engine speed		min^{-1}	1500	1800	2000	2100	2200	2300	2400	2500
5	Output (Gross)	Cont. rating	kW	31.2	37.2						
5	Output (Gross)	Rated output	kW	34.9	41.6	42.5	44.4	46.3	48.2	50.2	52.1
5	Output (NET)	Cont. rating	kW	30.9	36.8						
5	Output (NET)	Rated output	kW	34.6	41.2	41.9	43.8	45.6	47.4	49.3	51.1
6	Maximum idling speed		min^{-1} ±25	1530	1830	2150	2250	2350	2450	2550	2650
7	Specific fuel consumption		g/kWh	≤224						≤231	
8	Exhaust gas temp.		°C (°F)	≤580 (1076)	≤600 (1112)	≤600 (1112)	≤610 (1130)	≤620 (1148)	≤630 (1166)	≤640 (1184)	≤650 (1202)
9	Compression ratio		—	18.5							
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	Main shaft side		—	Flywheel side							
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)							
13	Governor		—	Mechanical governor (All-speed governor)							
14	Aspiration		—	Natural aspiration							
15	Cooling system		—	radiator type cooling system							
16	Lubricating system		—	Forced lubrication with trochoid pump							
17	Starting system		—	Electric starting							
18	Charging system		—	Alternator (12 VDC/40 A)							
19	Starting aid device		—	Air heater (12 VDC/500 W)							
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Oil pan capacity	Full	ℓ	10.2							
21	Oil pan capacity	Useful	ℓ	4.5							
22	Engine Coolant capacity		ℓ	4.2 (Engine only)							
23	Cooling fan type – dia. × No. of blades		mm	Pusher (resin), F type - ϕ410(Al) x 6							
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ130 / ϕ130							

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

4TNV98-Z

Engine Model				4TNV98-Z							
Version				CL		VM					
1	Type		—	Vertical In-line Diesel Engine							
2	Combustion System		—	Direct Injection							
3	No. of Cylinders - Bore x Stroke		n - mm x mm	4 - 98~110							
4	Displacement		ℓ	3.318							
5	Engine Speed		min^{-1}	1500	1800	2000	2100	2200	2300	2400	2500
	Power Output (Gross) *1	Cont. Rating	kW	31.2	37.2						
		Max. Rating	kW	34.9	41.6	42.5	44.4	46.3	48.2	50.2	52.1
	Power Output (Net)	Cont. Rating	kW	30.9	36.8						
		Max. Rating	kW	34.6	41.2	41.9	43.8	45.6	47.4	49.3	51.1
6	High Idling		min^{-1} ±25	1600	1895	2180	2290	2400	2510	2590	2700
7	Fuel Consumption		g/kWh	≤224						≤231	
8	Exhaust Temperature		°C	≤580	≤600	≤600	≤610	≤620	≤630	≤640	≤650
9	Compression Ratio		—	18.5							
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	PTO Position		—	Flywheel End							
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)							
13	Governor		—	Electronic (all-speed governor)							
14	Aspiration		—	Natural							
15	Cooling System		—	Liquid-cooled with Radiator							
16	Lubricating System		—	Forced Lubrication with Trochoid Pump							
17	Starting System		—	Electric Starting							
18	Charging System		—	Charging with Alternator (12VDC, 40A)							
19	Starting Aid		—	Air Heater (12VDC, 500W)							
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	10.2							
		Dipstick Lower Limit	ℓ	4.5							
22	Engine Coolant Capacity		ℓ	4.2 (Engine Only)							
23	Cooling Fan		mm	410 mm O.D., 6 Blade Pusher-Type							
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm	ø130 / ø130							

Note: * Applies to basic models/versions and may vary depending on specific applications.

4TNV98T (complies with EPA Tier2)

Engine model				4TNV98T							
Engine classification				CL		VM					
1	Type		—	Vertical, 4-cycle water-cooled diesel engine							
2	Combustion system		—	Direct injection (DI)							
3	No. of cylinders – Bore x Stroke		n – mm x mm	4 – 98 x 110							
4	Displacement		ℓ	3.319							
5	Rated engine speed		min^{-1}	1500	1800	2000	2100	2200	2300	2400	2500
	Output (Gross)	Cont. rating	kW	38.2	46.2						
		Rated output	kW	42.3	51.0	51.6	54.1	56.6	59.2	61.8	64.1
	Output (NET)	Cont. rating	kW	37.9	45.6						
		Rated output	kW	41.9	50.4	50.7	53.2	55.5	58.0	60.3	62.5
6	Maximum idling speed		min^{-1} ±25	1600	1895	2180	2290	2400	2510	2590	2700
7	Specific fuel consumption		g/kWh	≤238					≤245		
8	Exhaust gas temp.		°C (°F)	≤580 (1076)		≤560 (1040)	≤570 (1058)	≤580 (1076)	≤590 (1094)	≤600 (1112)	≤620 (1148)
9	Compression ratio		—	18.1							
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	Main shaft side		—	Flywheel side							
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)							
13	Governor		—	Mechanical centrifugal governor (All-speed governor)							
14	Aspiration		—	Turbocharged aspiration							
15	Cooling system		—	Force-feed circulation radiator type cooling system							
16	Lubricating system		—	Forced lubrication with multi-stage trochoid pump							
17	Starting system		—	Electric starting							
18	Charging system		—	Alternator (12 VDC/40 A, Standard spec.)							
19	Starting aid device		—	Air heater (12 VDC/500 W)							
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Oil pan capacity	Full	ℓ	10.5							
		Useful	ℓ	4.5							
22	Engine Coolant capacity		ℓ	4.2 (Engine only)							
23	Cooling fan type – dia. × No. of blades		mm	Pusher, F type - ϕ430 × 8							
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ130 / ϕ130							

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

4TNV98T-Z (complies with EPA Tier3)

Engine model				4TNV98T-Z							
Engine classification				CL		VM					
1	Type		—	Vertical, 4-cycle water-cooled diesel engine							
2	Combustion system		—	Direct injection							
3	No. of cylinders – Bore x Stroke		n – mm x mm	4 – 98 x 110							
4	Displacement		ℓ	3.319							
5	Rated engine speed		min^{-1}	1500	1800			2200	2300	2400	2500
	Output (Gross)	Cont. rating	kW	38.2	46.2						
		Rated output	kW	42.3	51.0			56.6	59.2	61.8	64.1
	Output (NET)	Cont. rating	kW	37.9	45.6						
		Rated output	kW	41.9	50.4			55.5	58.0	60.3	62.5
6	Maximum idling speed		min^{-1} ±25	1530	1830			2350	2450	2550	2650
7	Specific fuel consumption		g/kWh	≤231				≤231		≤235	
8	Exhaust gas temp.		°C (°F)	≤620 (1148)	≤620 (1148)			≤610 (1130)	≤620 (1148)	≤625 (1157)	≤630 (1166)
9	Compression ratio		—	18.1							
10	Diesel fuel injection pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	Main shaft side		—	Flywheel side							
12	Rotation direction		—	Counterclockwise (Viewed from flywheel side)							
13	Governor		—	Mechanical governor (All-speed governor)							
14	Aspiration		—	Turbocharged aspiration							
15	Cooling system		—	radiator type cooling system							
16	Lubricating system		—	Forced lubrication with trochoid pump							
17	Starting system		—	Electric starting							
18	Charging system		—	Alternator (12 VDC/40 A)							
19	Starting aid device		—	Air heater (12 VDC/400 W)							
20	Engine oil pressure	Rated speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Oil pan capacity	Full	ℓ	10.2							
		Useful	ℓ	4.5							
22	Engine Coolant capacity		ℓ	4.2 (Engine only)							
23	Cooling fan type – dia. × No. of blades		mm	Puller (resin), F type - ϕ430(Al) x 8							
24	Crank V -pulley dia./ Fan V-pulley dia.		mm/mm	ϕ130 / ϕ130							

Note: The above table shows the specification of a base model.

The net power rating may be different in each individual model depending on the type of applications.

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4TNV98T-Z

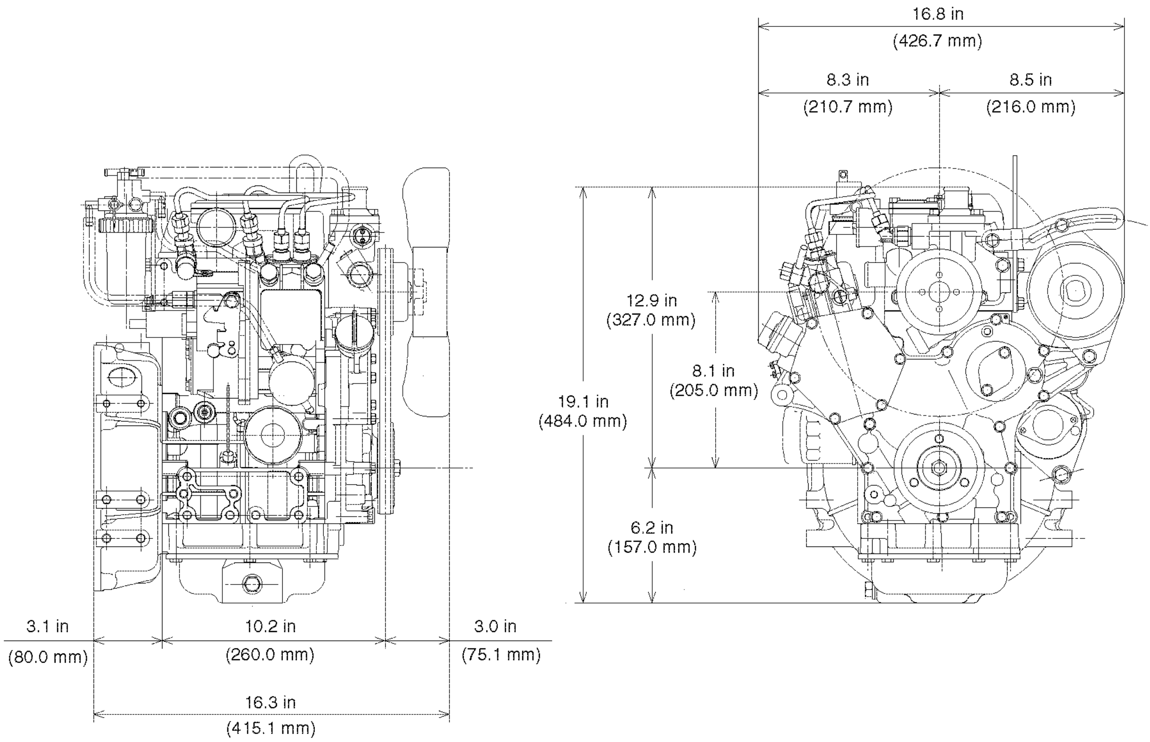
Engine Model				4TNV98T-Z							
Version				CL		VM					
1	Type		—	Vertical In-line Diesel Engine							
2	Combustion System		—	Direct Injection							
3	No. of Cylinders - Bore x Stroke		n - mm x mm	4 - 98~110							
4	Displacement		ℓ	3.318							
5	Engine Speed		min^{-1}	1500	1800			2200	2300	2400	2500
	Power Output (Gross) *1	Cont. Rating	kW	38.2	46.2						
		Max. Rating	kW	42.3	51.0			56.6	59.2	61.8	64.1
	Power Output (Net)	Cont. Rating	kW	37.9	45.6						
		Max. Rating	kW	41.9	50.4			55.5	58.0	60.3	62.5
6	High Idling		min^{-1} ±25	1600	1895			2350	2450	2550	2650
7	Fuel Consumption		g/kWh	≤231				≤231		≤235	
8	Exhaust Temperature		°C	≤620	≤620			≤610	≤620	≤625	≤630
9	Compression Ratio		—	18.1							
10	Fuel Injection Pressure		MPa (kgf/cm^2)	$21.6^{+1.0}_{0}$ (220^{+10}_{0})							
11	PTO Position		—	Flywheel End							
12	Direction of Rotation		—	Counterclockwise (viewed from flywheel end)							
13	Governor		—	Electronic (all-speed governor)							
14	Aspiration		—	Turbocharged							
15	Cooling System		—	Liquid-cooled with Radiator							
16	Lubricating System		—	Forced Lubrication with Trochoid Pump							
17	Starting System		—	Electric Starting							
18	Charging System		—	Charging with Alternator (12VDC, 40A)							
19	Starting Aid		—	Air Heater (12VDC, 500W)							
20	Engine Oil Pressure	Rated Speed	MPa (kgf/cm^2)	0.34 ± 0.05 (3.5 ± 0.5)							
21	Engine Oil Pan Capacity	Dipstick Upper Limit	ℓ	10.2							
		Dipstick Lower Limit	ℓ	4.5							
22	Engine Coolant Capacity		ℓ	4.2 (Engine Only)							
23	Cooling Fan		mm	430 mm O.D., 8 Blade Suction-Type							
24	Crank Pulley Dia./ Fan Pulley Dia.		mm/mm	ø130 / ø130							

Note: * Applies to basic models/versions and may vary depending on specific applications.

DIMENSIONS

IDI Series

2TNV70



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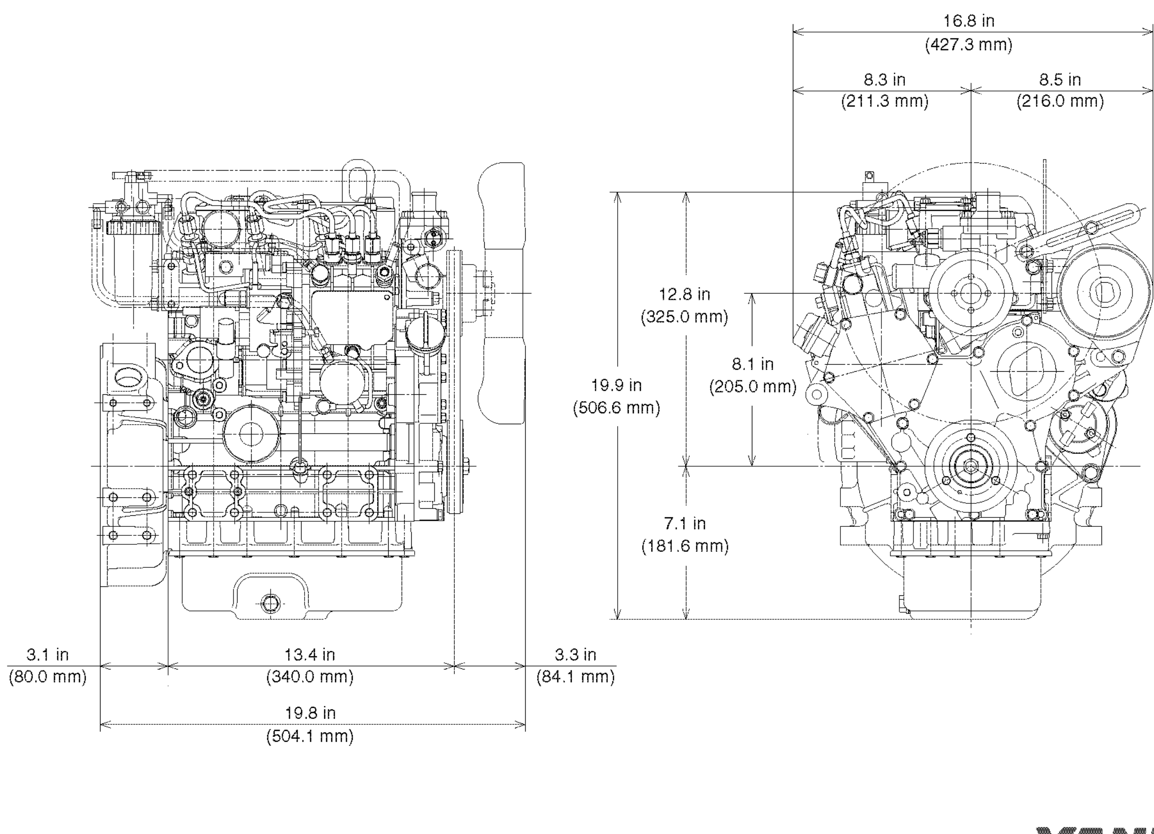

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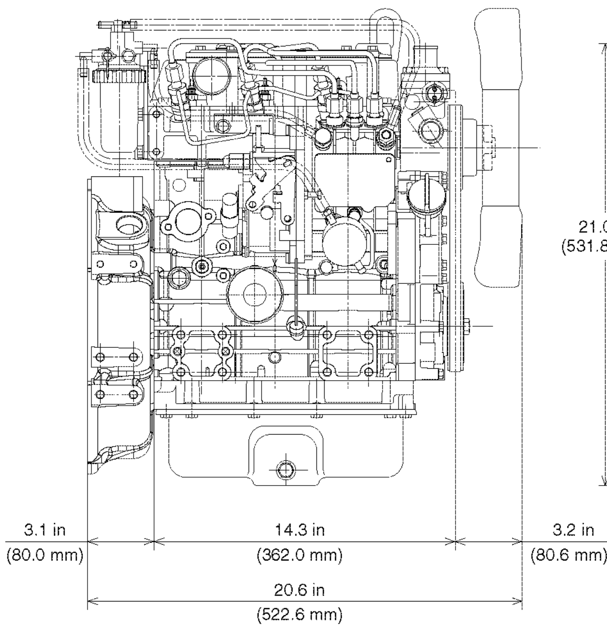

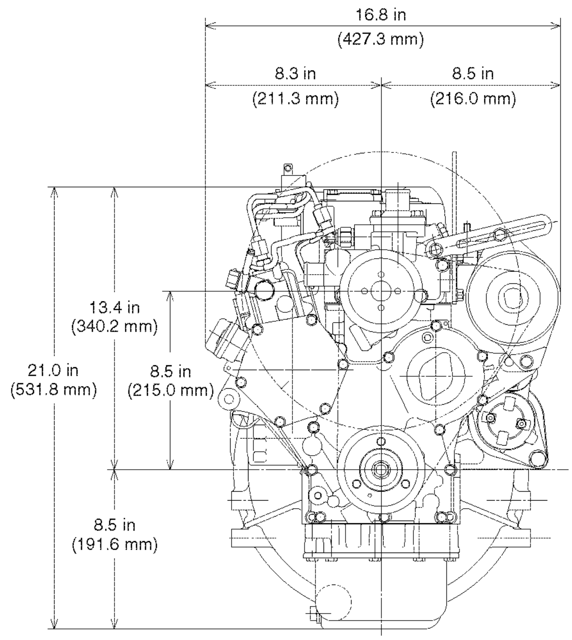

DI Series

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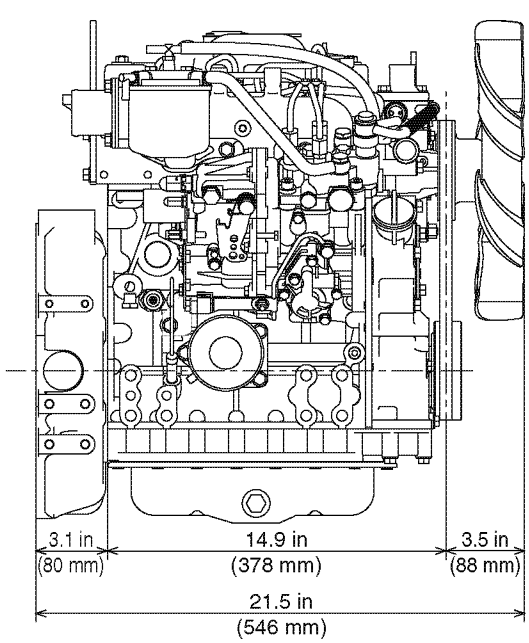

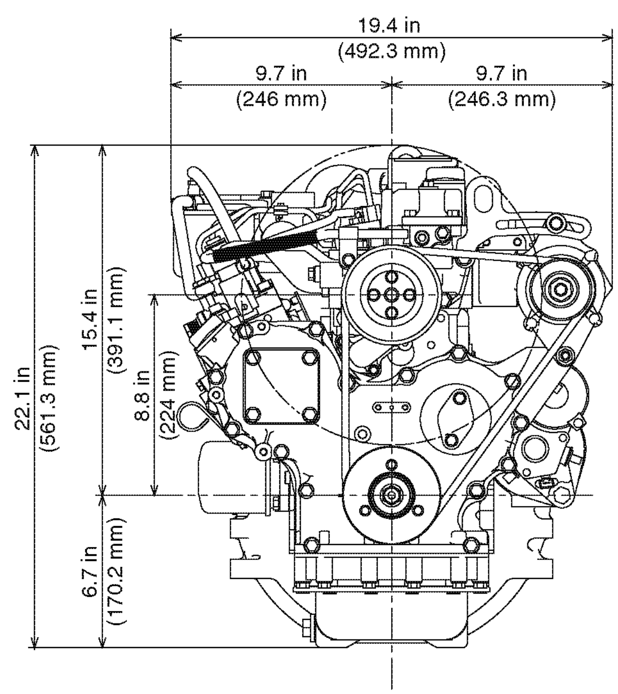

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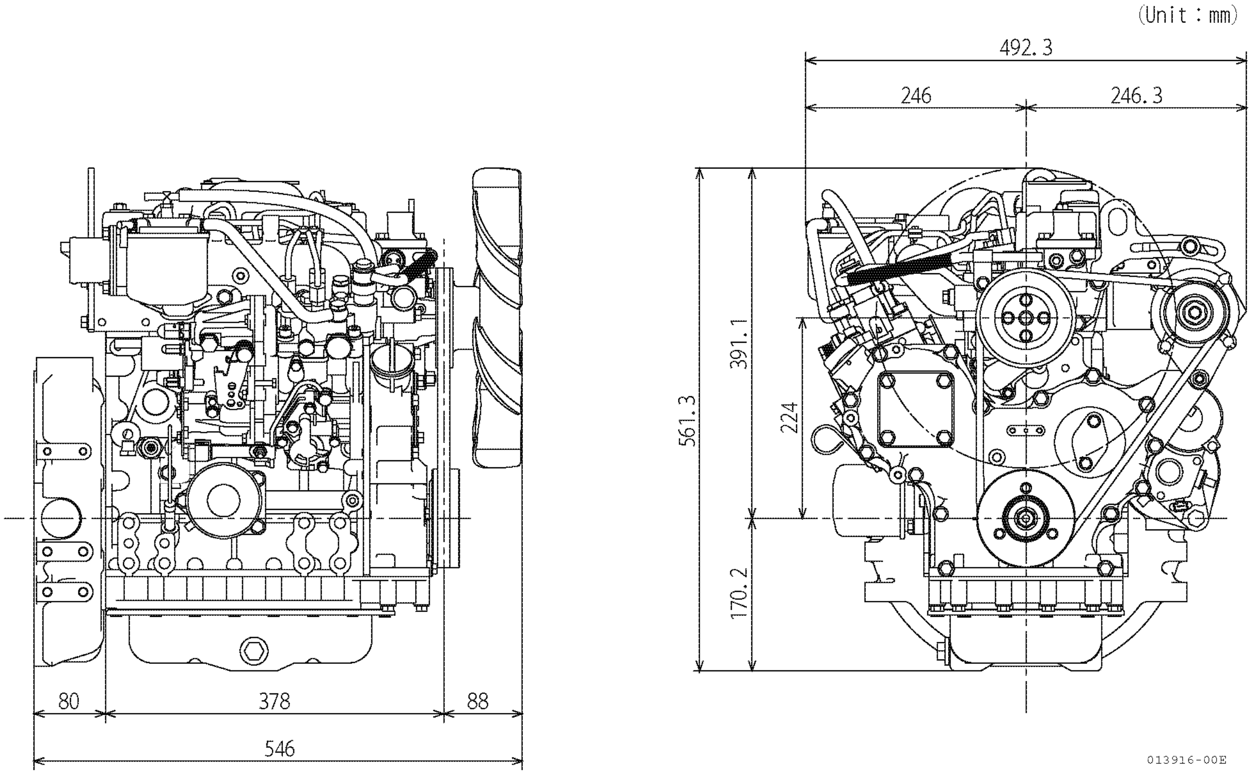

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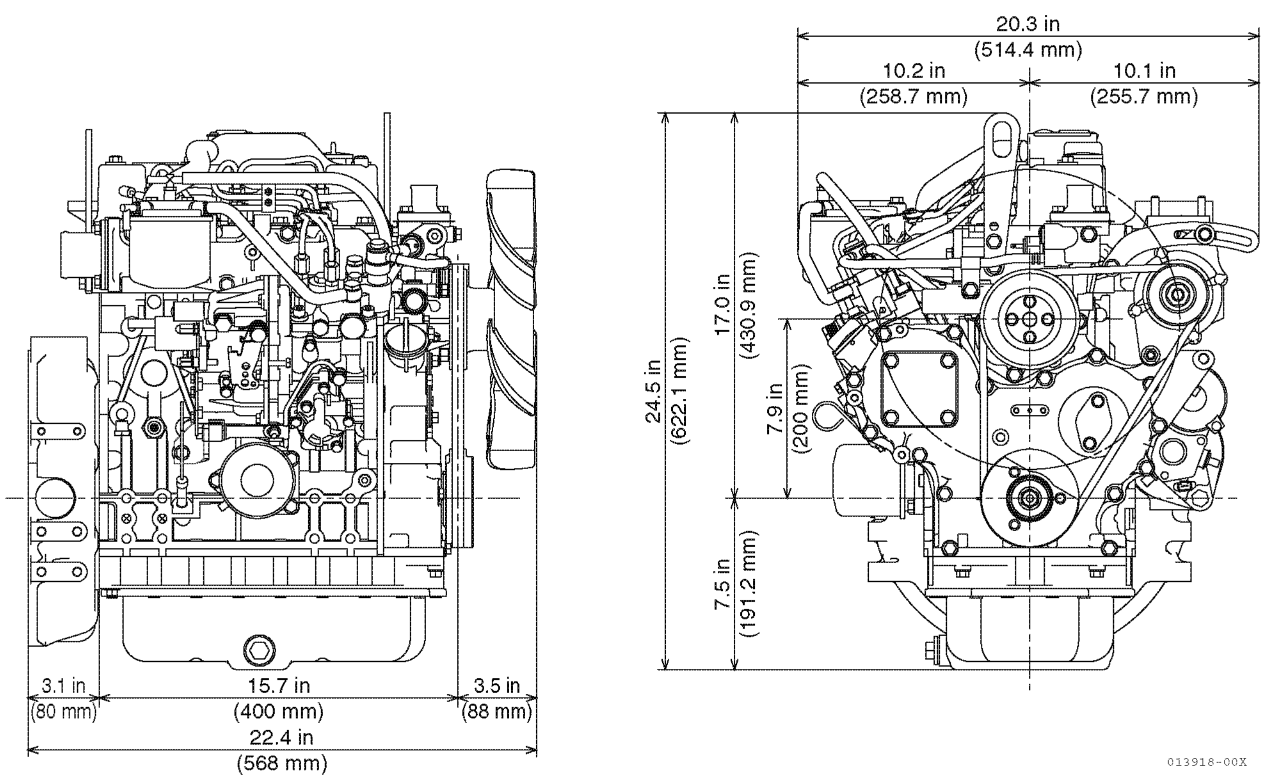

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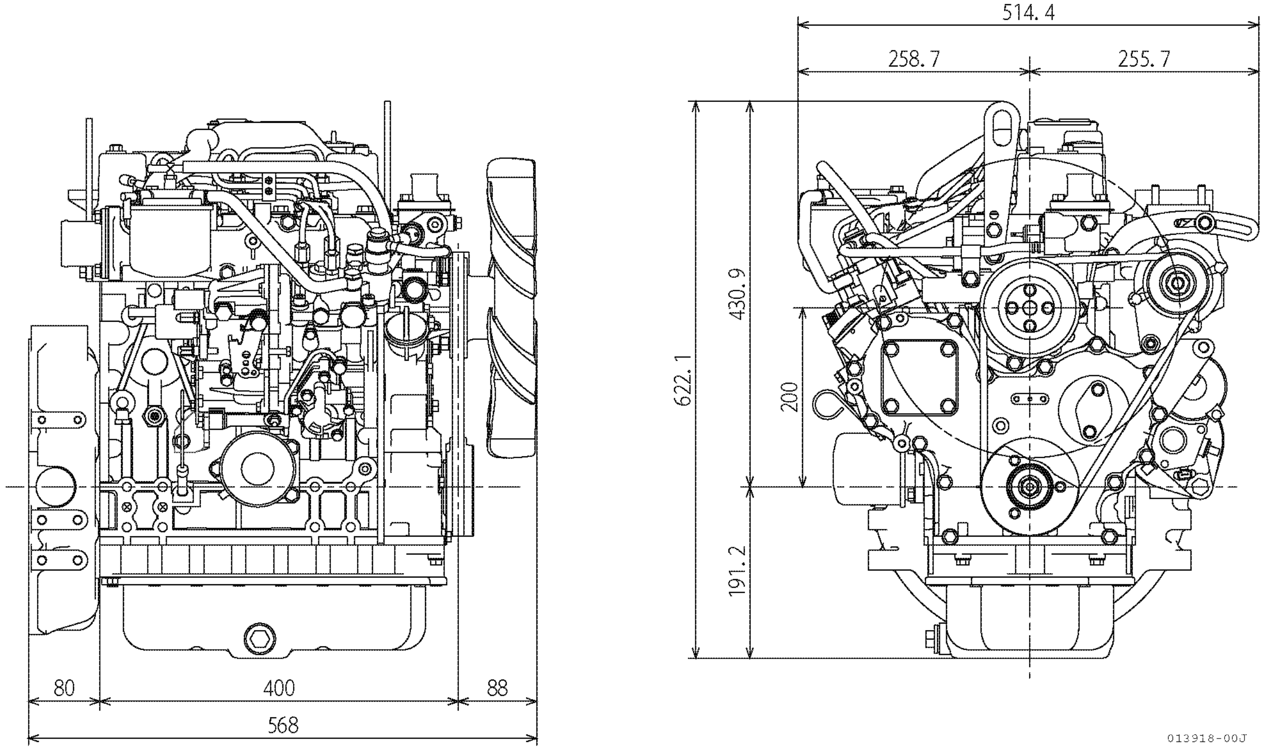
3TNV88-E/3TNV88-Z (Electronically controlled)



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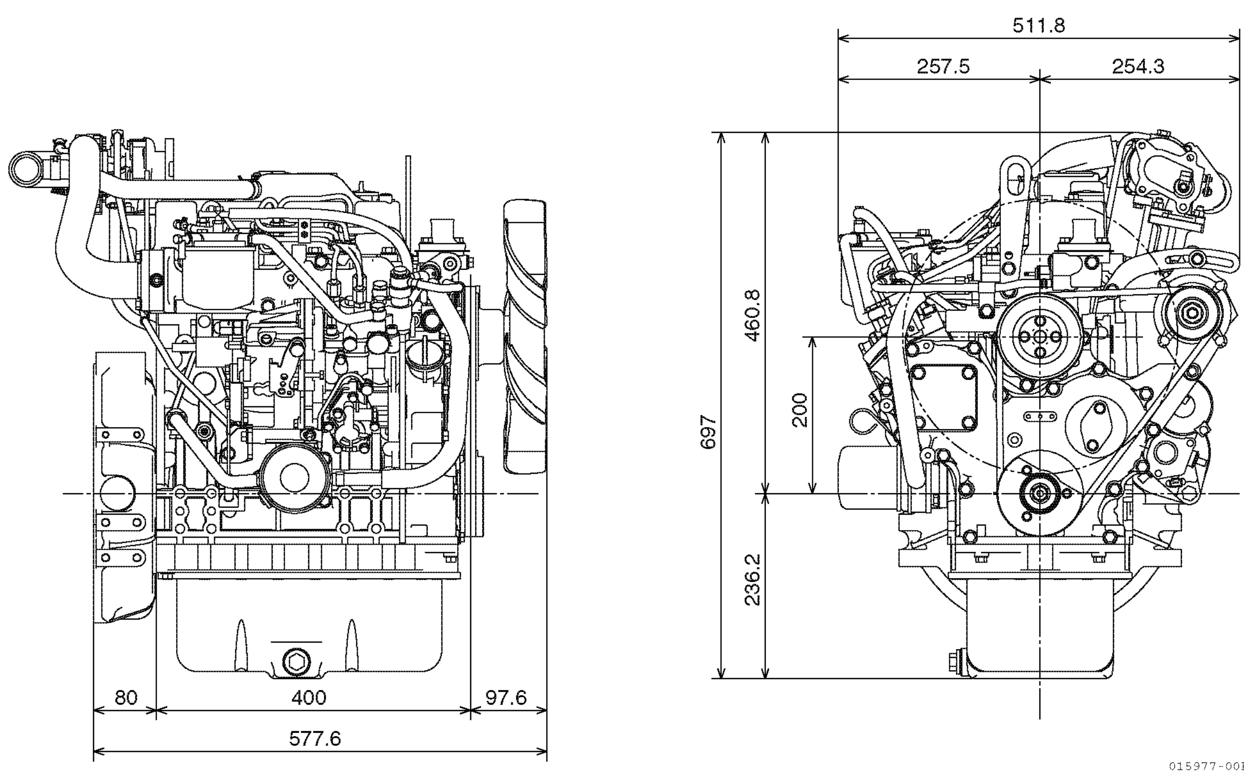

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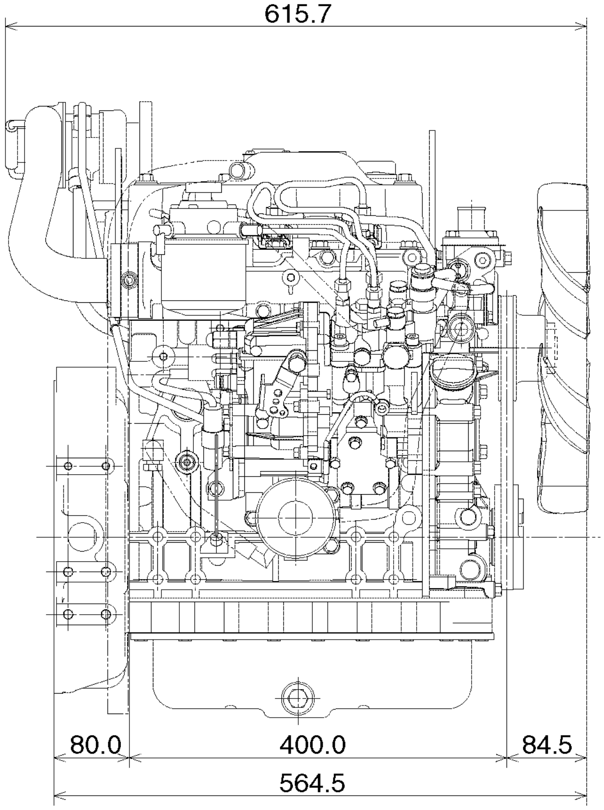

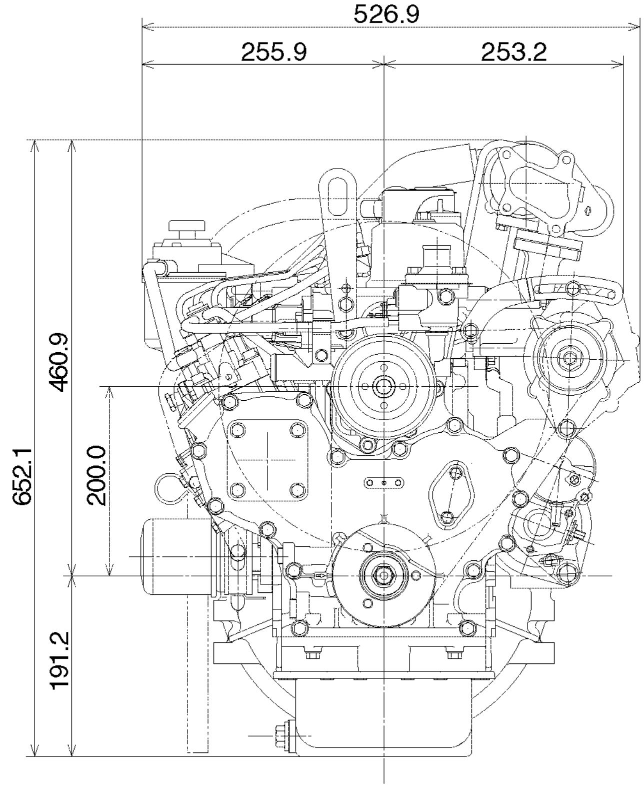

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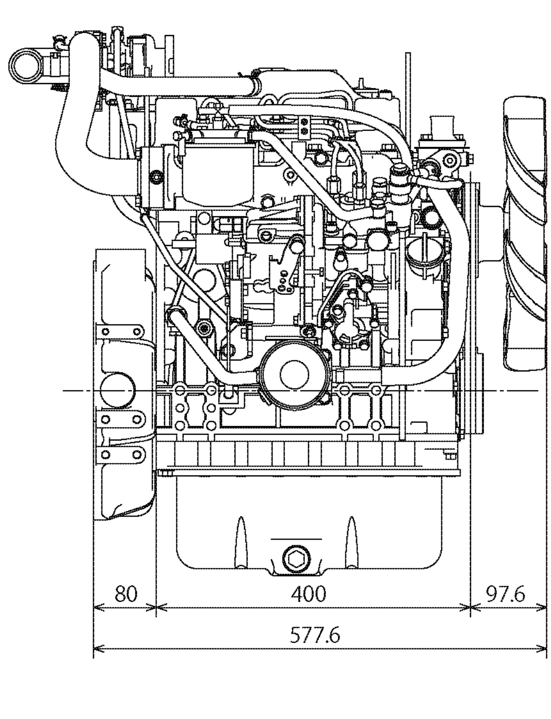

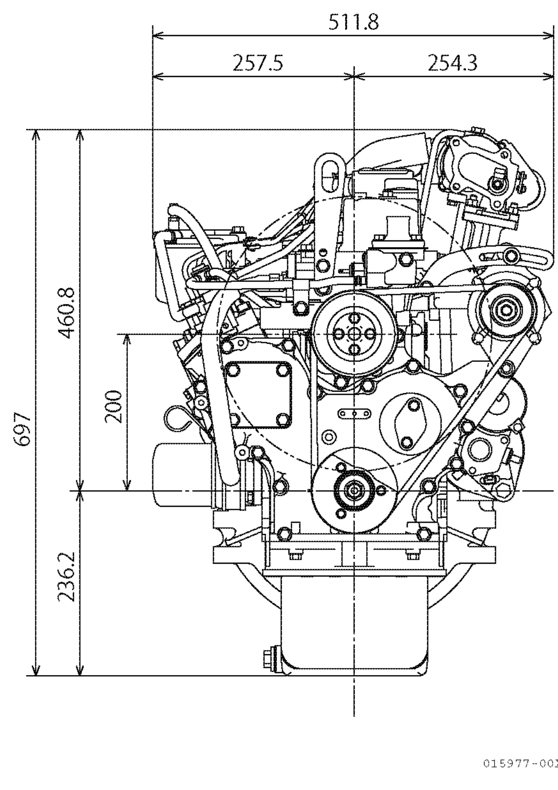

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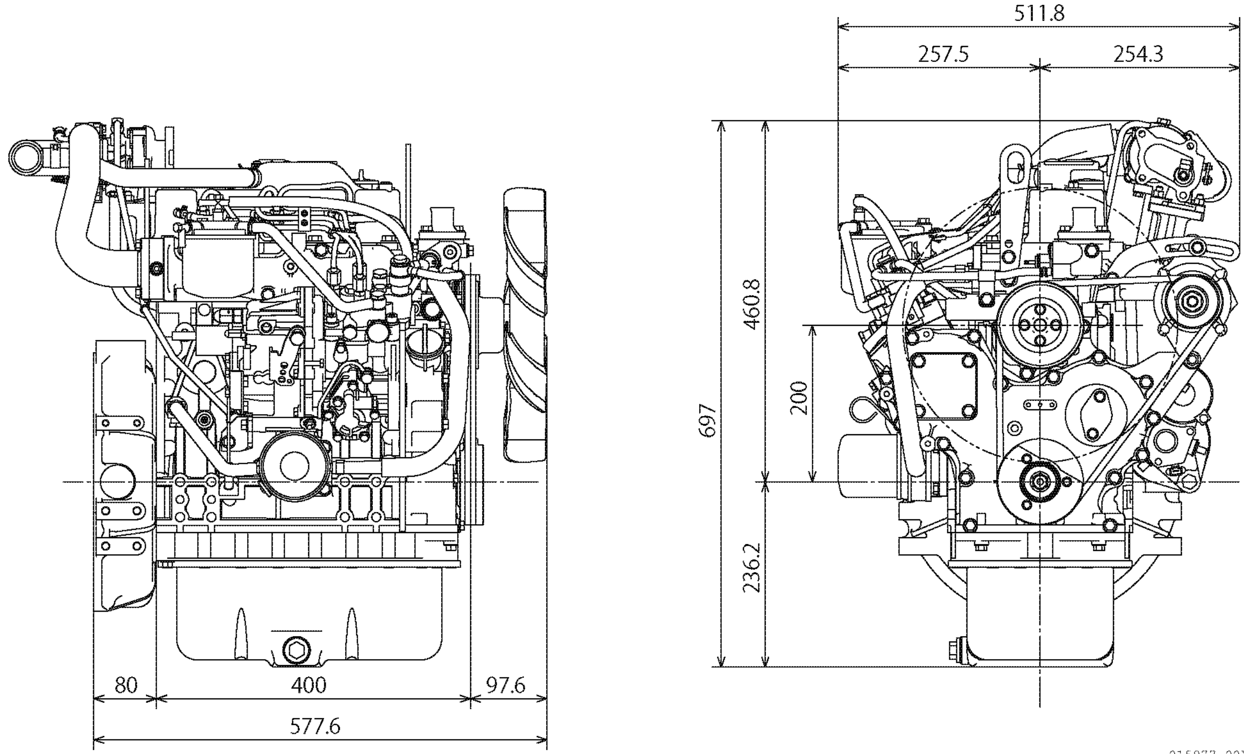

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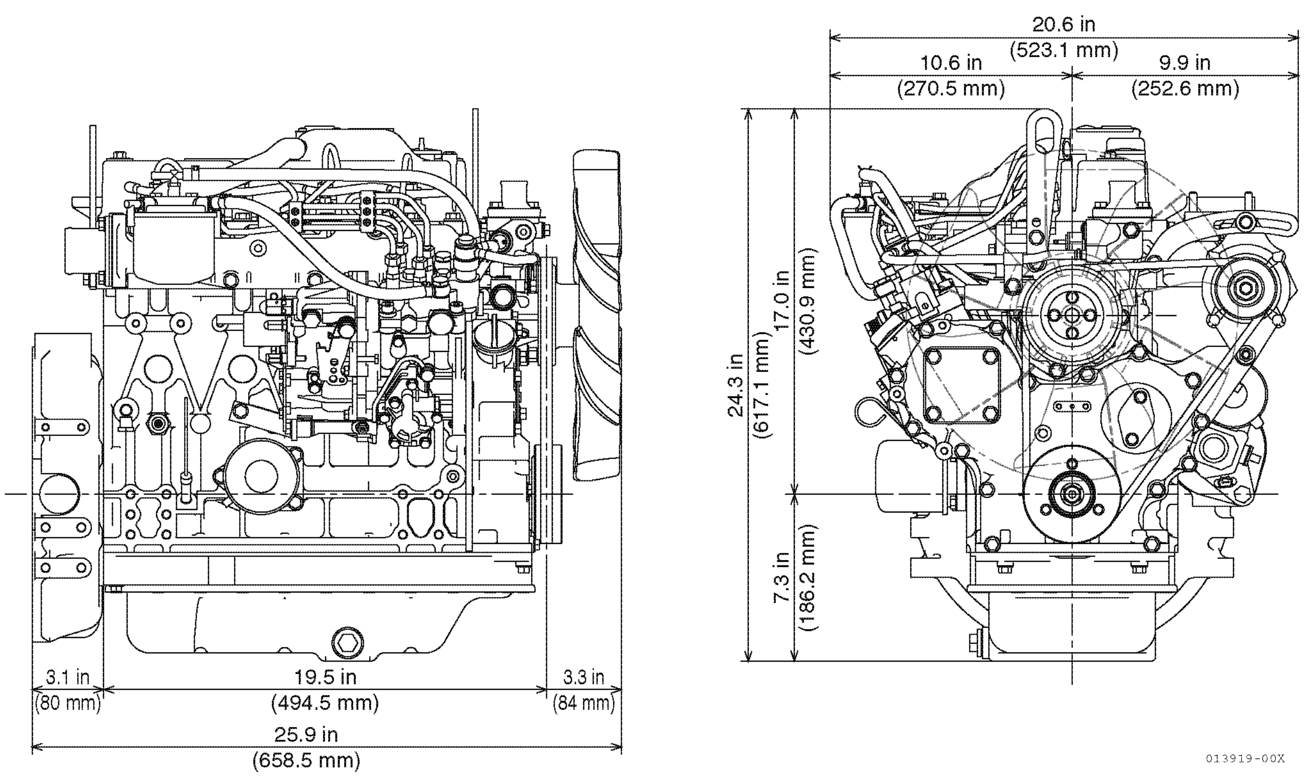

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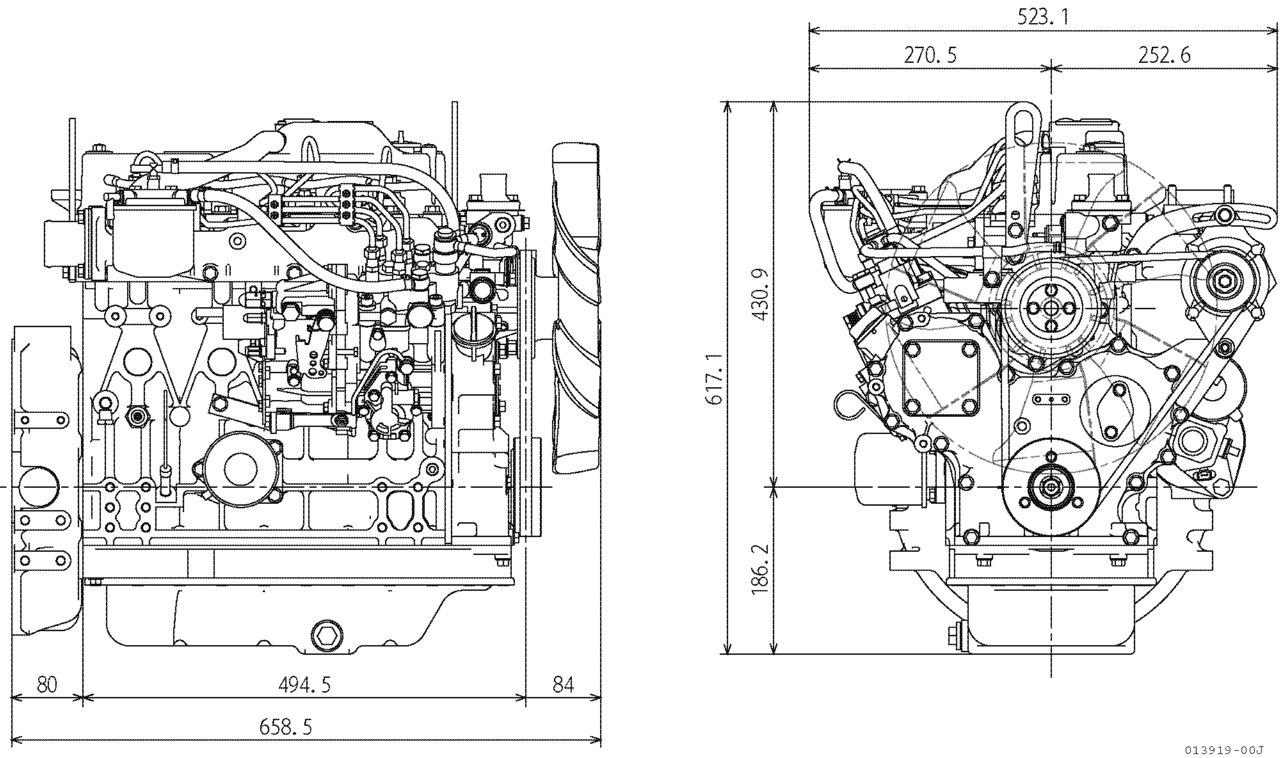

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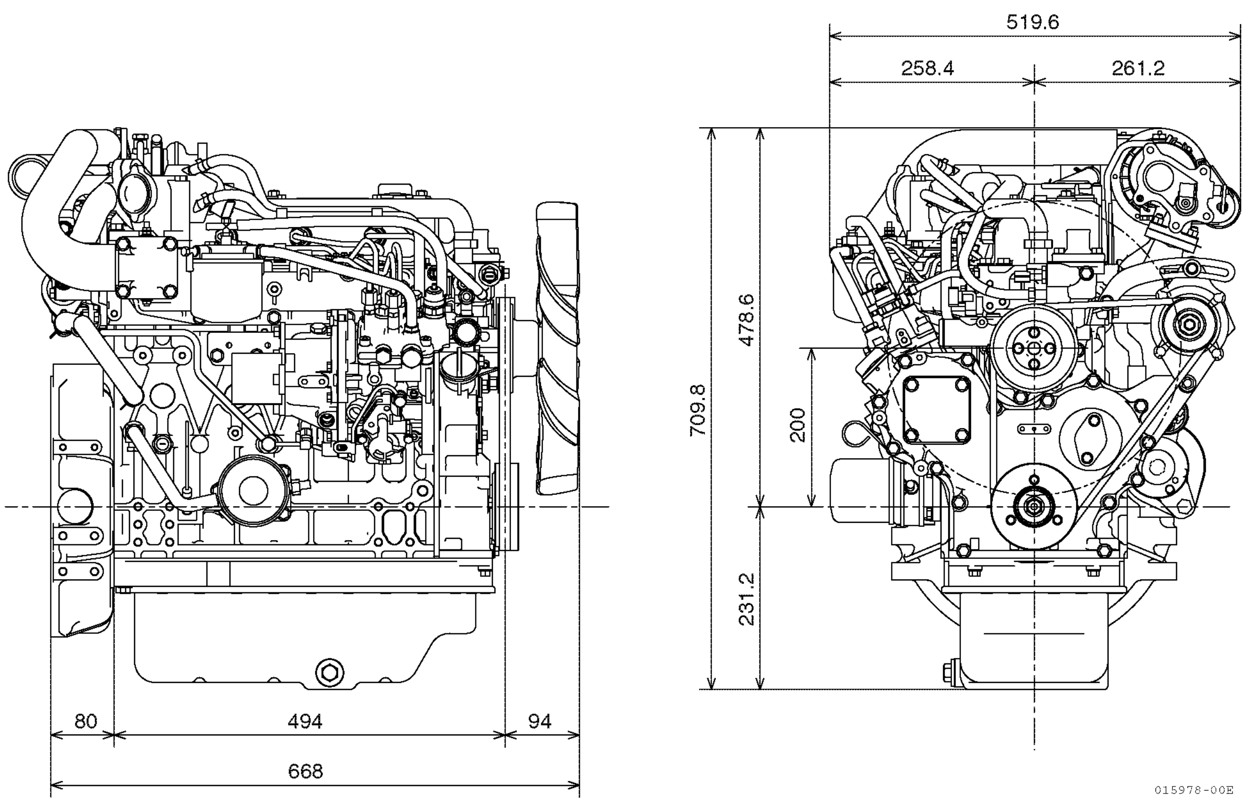

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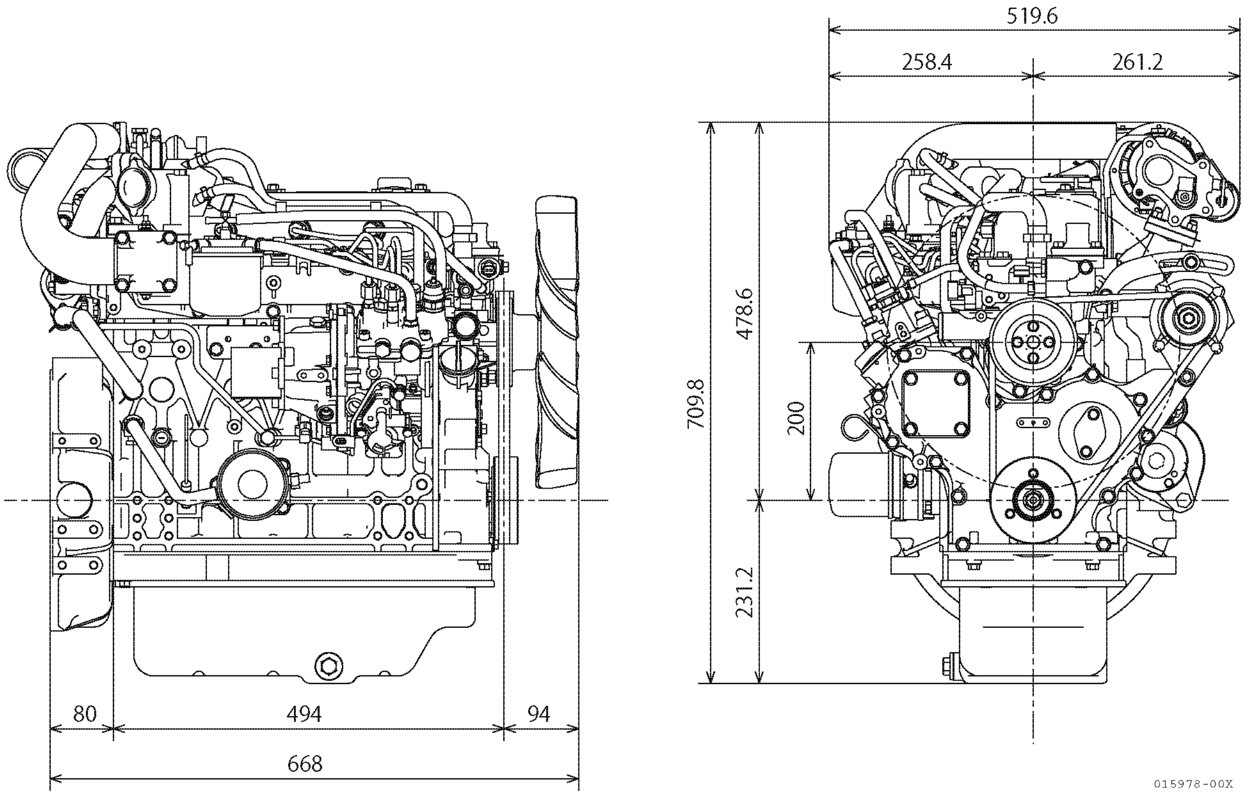

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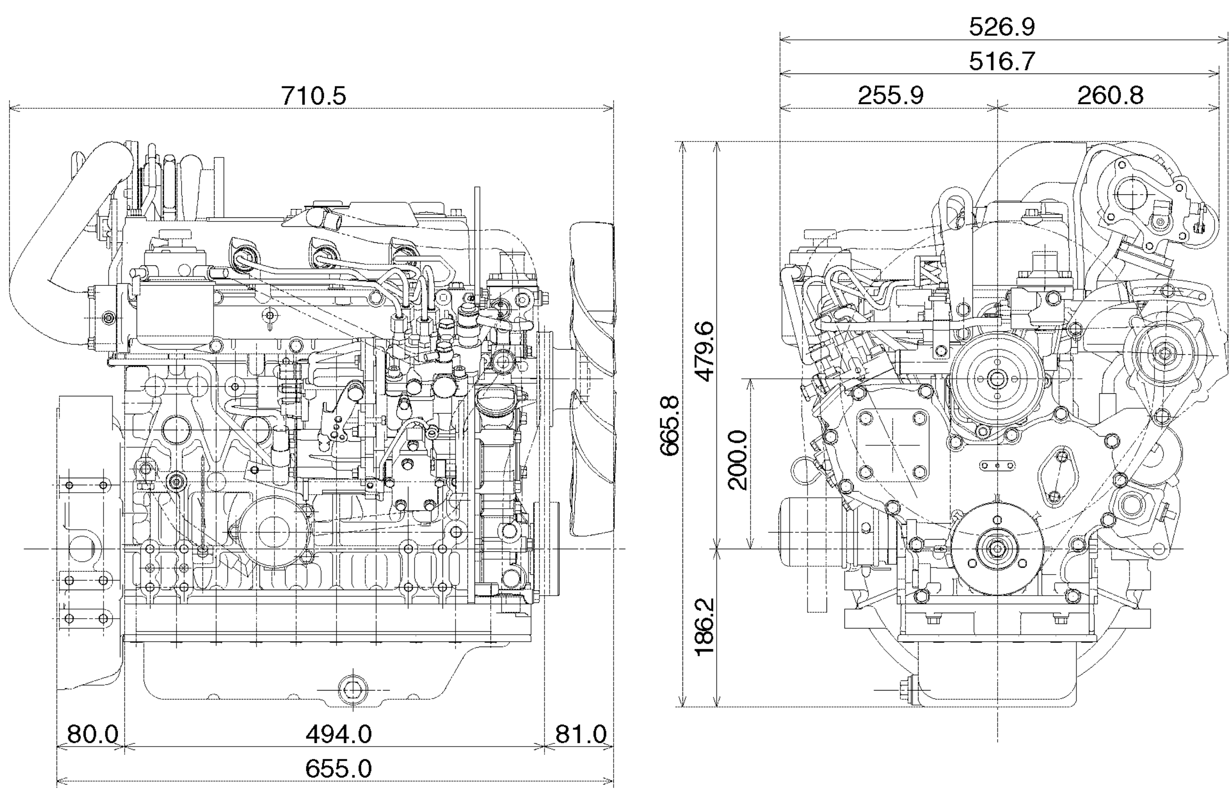

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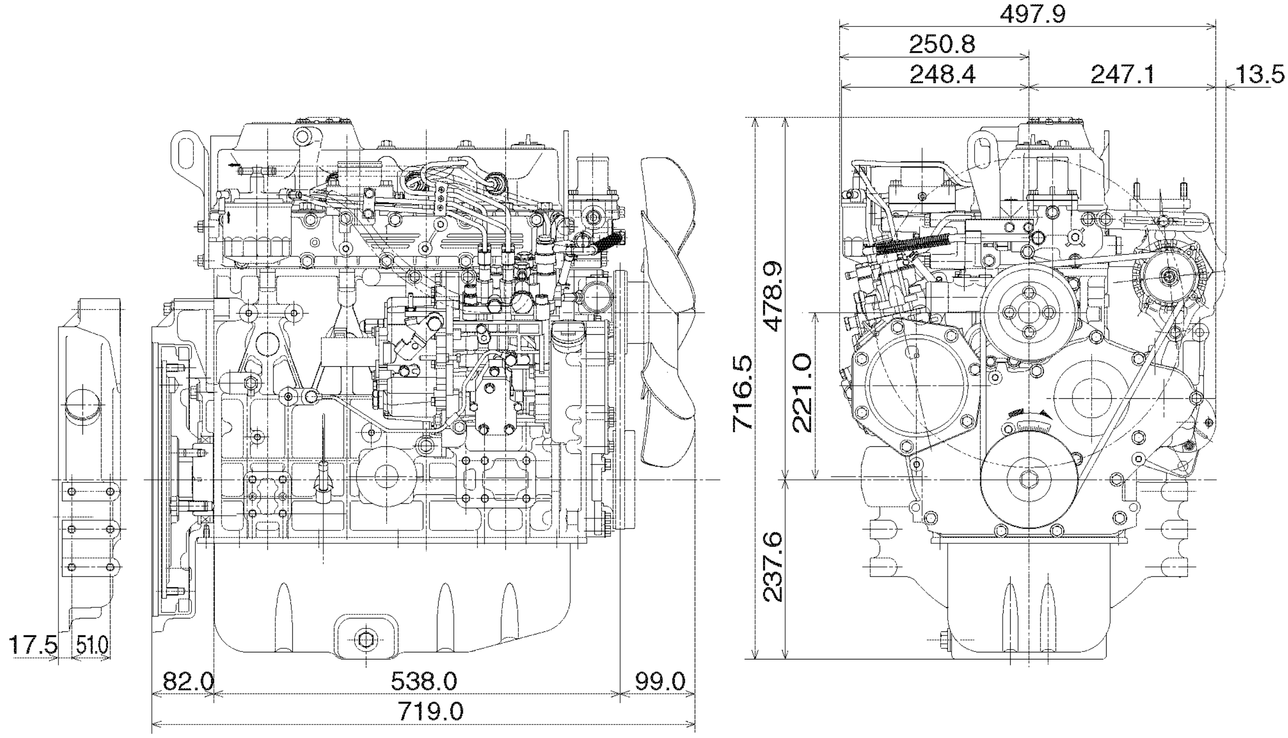

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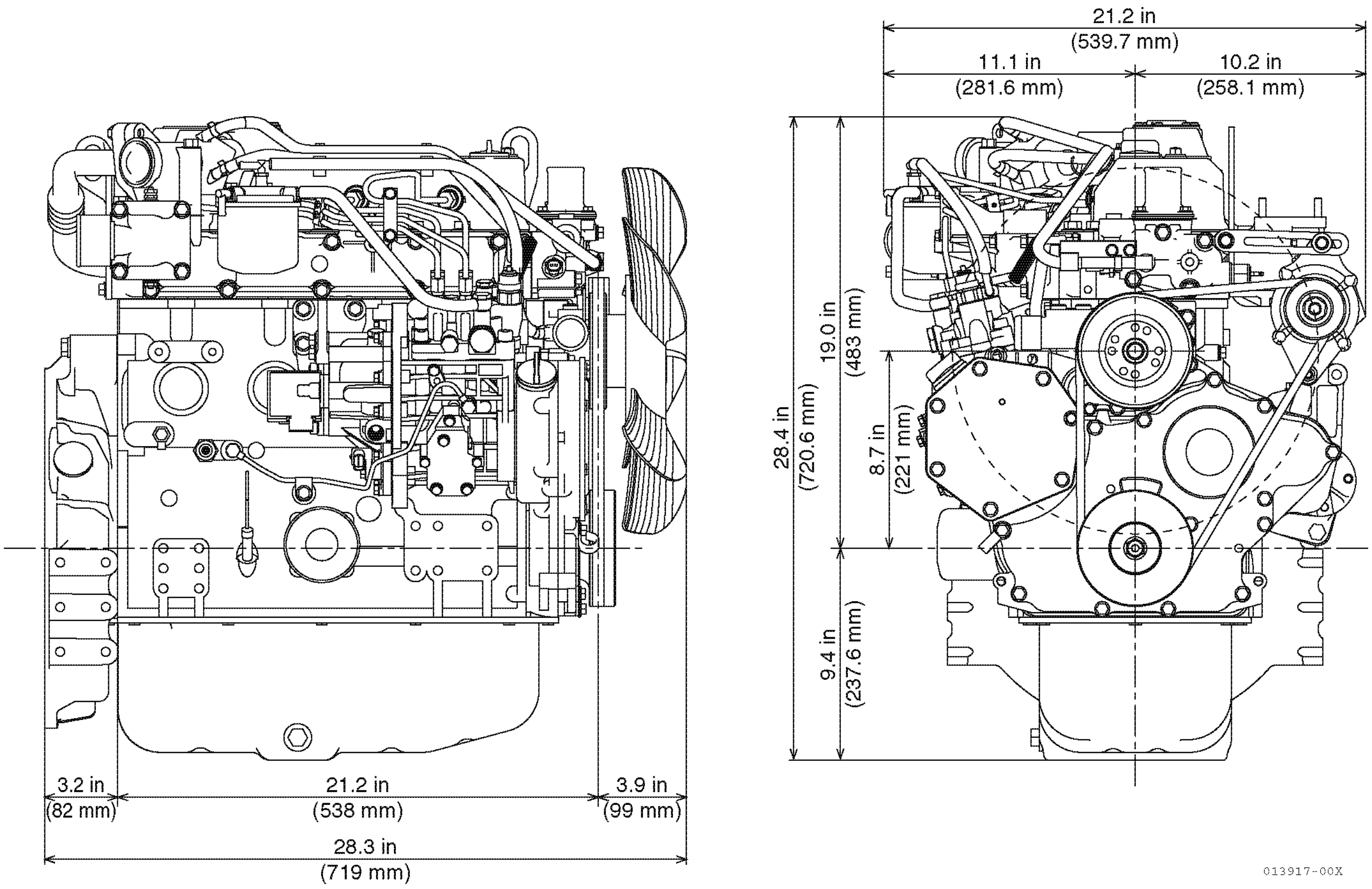

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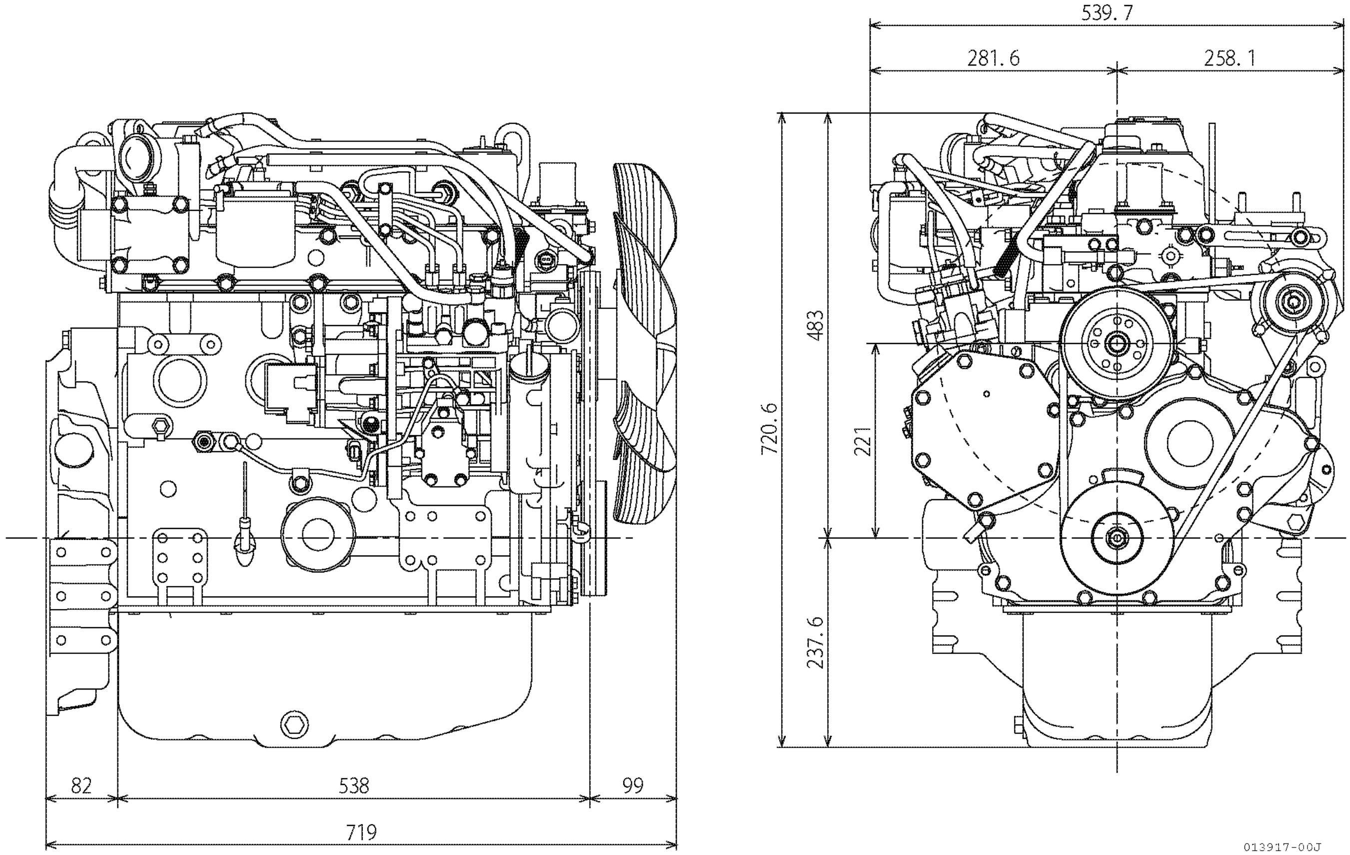

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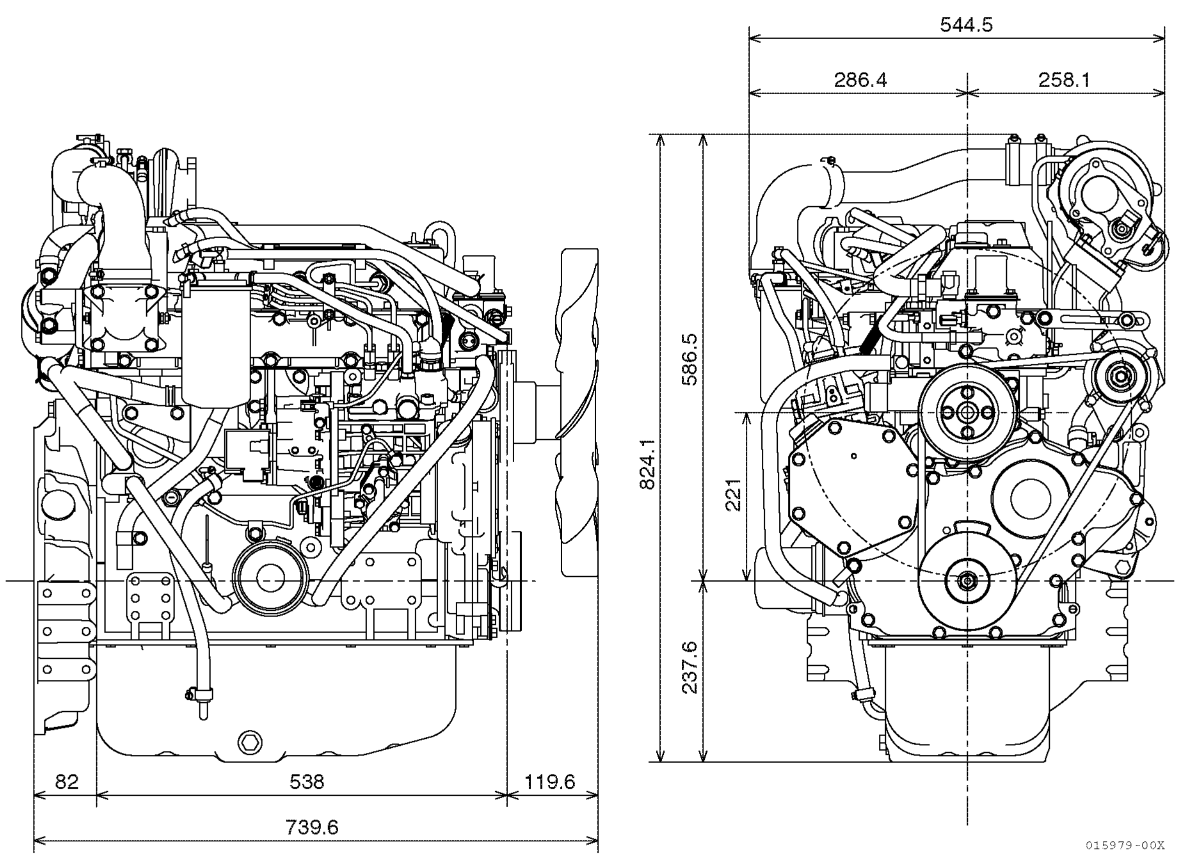

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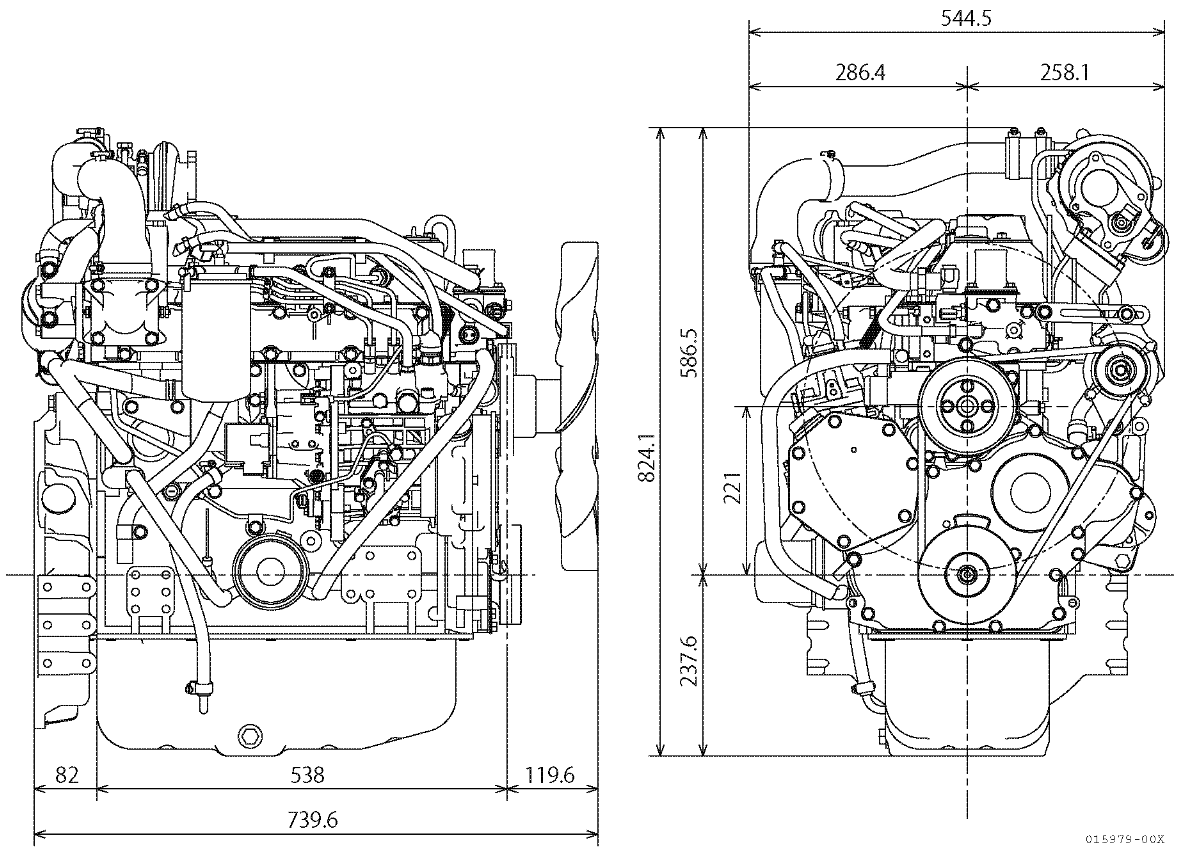

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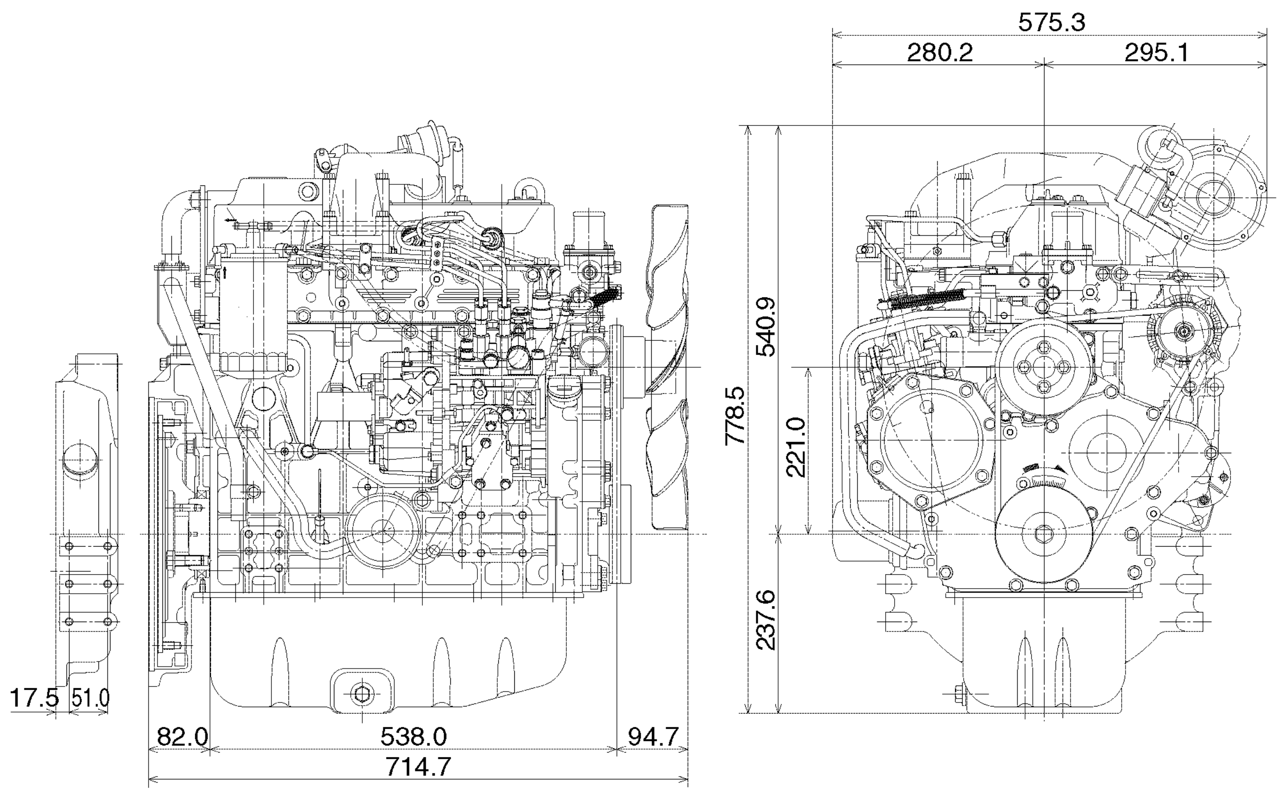

Section 4

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 tends to be higher 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) on page 4-4* when atmospheric conditions are judged to be relatively close to standard conditions:

Standard atmospheric conditions:	Engine intake air temperature: 10 to 40°C (50 to 104°F)
25°C (77°F) 100 kPa (750 mmHg) 30%	Dry intake air pressure (may simply be regarded as atmospheric pressure): 80 to 110 kPa (600 to 825 mmHg) (at 2,000 m or less in altitude)

  Correction factor *k*:
  0.9 to 1.1 [See calculation in *Obtain correction factor k. on page 4-6*.]

- Use the power calculation formula (B) in *Correction Formula (B) on page 4-8* when atmospheric conditions are much different from standard atmospheric conditions.

Correction Formula (A)

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.

   (a) For a naturally aspirated engine

$$f_a = \left(\frac{P_r - \phi_r \bullet P_{sr}}{P_x - \phi_x \bullet P_{sx}}\right)\left(\frac{T_x}{T_r}\right)^{0.7}$$

   (b) For a turbocharged engine

$$f_a = \left(\frac{P_r - \phi_r \bullet P_{sr}}{P_x - \phi_x \bullet P_{sx}}\right)\left(\frac{T_x}{T_r}\right)^{0.7}\left(\frac{T_x}{T_r}\right)^{1.5}$$

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

P_r	:	Standard atmospheric pressure	100 kPa (750 mmHg)
Φ_r	:	Relative humidity under standard atmospheric conditions	0.30 (30%)
T_r	:	Intake air temperature under atmospheric standard conditions	298 K (25°C [77°F])
P_{sr}	:	Saturation vapor pressure under standard atmospheric conditions	3.172 kPa (23.80 mmHg) (Obtain from the table *on page 4-12*.)
P_x	:	Atmospheric pressure under actual test conditions	kPa (mmHg)
Φ_x	:	Relative humidity under actual test conditions	%
T_x	:	Intake air temperature under actual test conditions	K (°C)
P_{sx}	:	Saturation vapor pressure under actual test conditions	kPa (mmHg) (Obtain from the table *on page 4-12*.)

   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_x and P_{sx} must also be expressed in kPa. Similarly when mmHg is used, all other pressures must be expressed in mmHg.

   Always use absolute temperature in K [Kelvin without degrees (×)] for representing the intake air temperatures T_r and T_x. 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.

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	3200	3400	3600	1500	1800	3000	3600
2TNV70	0.516	0.539	0.591	0.601	0.593	0.63	0.69	0.598	0.584	0.591	——	——	0.389	0.456
3TNV70	0.473	0.496	0.541	0.545	0.55	0.582	0.605	0.563	0.591	0.573	0.323	0.325	0.402	0.507
3TNV76	0.446	0.518	0.513	0.526	0.533	0.585	0.605	0.548	0.624	0.549	0.287	0.294	0.294	0.393
3TNV82A	0.426	0.427	0.444	0.455	0.487	0.515	0.551	——	——	——	0.2	0.254	——	——
3TNV84	0.36	0.391	0.44	0.458	0.47	0.52	0.531	——	——	——	0.232	0.274	——	——
3TNV88	0.386	0.407	0.432	0.459	0.472	0.471	0.487	——	——	——	0.256	0.296	——	——
3TNV84T	——	——	0.2	0.2	0.2	0.2	0.2	——	——	——	0.2	0.2	——	——
4TNV84	0.381	0.402	0.416	0.449	0.456	0.482	0.503	——	——	——	0.234	0.244	——	——
4TNV88	0.412	0.431	0.432	0.437	0.437	0.456	0.464	——	——	——	0.2	0.218	——	——
4TNV84T	0.2	0.2	0.2	0.2	0.2	0.2	0.2	——	——	——	0.2	0.2	——	——
4TNV94L	0.323	0.28	0.236	0.264	——	——	——	——	——	——	0.268	0.295	——	——
4TNV98	0.481	0.471	0.501	0.501	——	——	——	——	——	——	0.432	0.464	——	——
4TNV98T	0.2	0.2	0.2	0.2	——	——	——	——	——	——	0.286	0.2	——	——

2. Obtain correction factor k.

   $k = f_a^{\,fm}$

   Proceed with the calculation if the value of k satisfies the condition $0.9 < k < 1.1$.

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

   $P = P_0 / k$

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

> Example:
>
> The rated output of the 3TNV88 engine under standard atmospheric conditions is 27.1 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 313K (40°C [104°F]), atmospheric temperature of 309K (36°C [96.8°F)) and relative humidity of 40%?

First determine the power correction formula to be applied according to *Correction Formula (A) on page 4-4* or *Correction Formula (B) on page 4-8*.

Since the engine intake air temperature and atmospheric pressure are in the ranges of 10 to 40°C and 80 to 110 kPa, respectively, the correction formula (A) in *Correction Formula (A) 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	100kPa (750 mmHg}
F_r	:	Relative humidity under standard atmospheric conditions	0.30 (30%)
T_r	:	Intake air temperature under standard atmospheric conditions	298K (25°C [77°F])
P_{sr}	:	Saturation vapor pressure under standard atmospheric conditions	3.172 kPa (23.80 mmHg) (Obtain from the table *on page 4-12*.)
P_x	:	Atmospheric pressure under actual test conditions	98 kPa (735 mmHg)
F_x	:	Relative humidity under actual test conditions	0.40 (40%)
T_x	:	Intake air temperature under actual test conditions	313K (40°C [104°F])
P_{sx}	:	Saturation vapor pressure under actual test conditions	7.377 kPa (55.35 mmHg) (Obtain from the table *on page 4-12*.)

1. Obtain atmospheric factor f_a. Since 3TNV88 is a naturally aspirated engine,

$$f_a = \left(\frac{P_r - \phi_r \times P_{sr}}{P_x - \phi_x \times P_{sx}}\right)\left(\frac{T_x}{T_r}\right)0.7$$

$$= \frac{100 - 0.30 \times 3.172}{98 - 0.40 \times 7.377}\left(\frac{313}{298}\right) 0.7$$

$$= \frac{99.0484}{95.0492} \times 1.0350$$

$$= 1.0785$$

2. Obtain engine factor f_m.

   It is 0.487 for 3TNV88 at 3,000 min^{-1} from the engine factor table.

3. Obtain correction factor k.

   $k = f_a^{fm} = 1.0785^{\ 0.487} = 1.0375$

   Since this value of k satisfies the condition $0.9 < k < 1.1$ for application of the example formula, proceed with the calculation.

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

   P = P0 / k = 27.1 / 1.0375

   = 26.1 kW

   Therefore, the output is down by 1.0 kW or approximately 3.6% in this example.

Correction Formula (B)

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.

   (a) For naturally aspirated engine

$$K = \frac{P_x - \phi_x \times P_{sx}}{P_r - \phi_r \times P_{sr}} \times \left(\frac{T_r}{T_x}\right)^{0.75}$$

   (b) 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	100kPa (750 mmHg)
Φ_r	: Relative humidity under standard atmospheric conditions	0.30 (30%)
T_r	: Intake air temperature under standard atmospheric conditions	298K (25°C [77°F])
P_{sr}	: Saturation vapor pressure under standard atmospheric conditions	3.172 kPa (23.80 mmHg) (Obtain from the table *on page 4-12*.)
P_x	: Atmospheric pressure under actual test conditions	kPa (mmHg)
Φ_x	: Relative humidity under actual test conditions	%
T_x	: Intake air temperature under actual test conditions	K (°C)
P_{sx}	: Saturation vapor pressure under actual test conditions	kPa (mmHg) (Obtain from the table *on page 4-12*.)

2. Obtain correction factor α as follows:

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

   $= K - 0.175\,(1 - K)$

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

   $P = \alpha \bullet P_0$

   Where,

P_0	: Rated output under standard conditions	kW
P	: Output under actual test conditions	kW
α	: Correction factor	

Example: The rated output of the 3TNV88 engine under standard conditions is 27.1 kW at 3,000 min^{-1}. What will be the output under actual test conditions of any atmospheric state, 90 kPa (approximately 1000 m), intake air temperature of 323 K (50°C [122°F]), atmospheric temperature of 313 K (40°C [104°F]) and relative humidity of 80%?

First study which power correction formula is to be applied according to *Correction Formula (A) on page 4-4* or *Correction Formula (B) on page 4-8*.

Since the atmospheric pressure is in the range of 80 to 110 Kpa but the engine intake air temperature is far above the range of 10 to 40°C (50 to 104°F), the correction formula (B) in *Correction Formula (B) on page 4-8* applies.

The atmospheric temperature is not taken into consideration in the application of the power correction formula.

P_r	:	Standard atmospheric pressure	100 kPa (750 mmHg)
Φ_r	:	Relative humidity under standard atmospheric conditions	0.30 (30%)
T_r	:	Intake air temperature under standard atmospheric conditions	298 K (25°C [77°F])
P_{sr}	:	Saturation vapor pressure under standard atmospheric conditions	3.172 kPa (23.80 mmHg) (Obtain from the table *on page 4-12*.)
P_x	:	Atmospheric pressure under actual test conditions	90 kPa (675 mmHg)
Φ_x	:	Relative humidity under actual test conditions	0.8 (80%)
T_x	:	Intake air temperature under actual test conditions	323 K (50°C [122°F])
P_{sx}	:	Saturation vapor pressure under actual test conditions	12.338kPa (92.56 mmHg) (Obtain from the table *on page 4-12*.)

1. First obtain the K-value. Since the 3TNV88 is a naturally aspirated engine,

$$K = \frac{P_x - \phi_x \times P_{sx}}{P_r - \phi_r \times P_{sr}}\left(\frac{T_r}{T_x}\right)0.75$$

$$= \frac{90 - 0.38 \times 12.338}{100 - 0.30 \times 3.172}\left(\frac{298}{323}\right)0.75$$

$$= \frac{80.1296}{99.0484} \times 0.9414$$

$$= 0.7616$$

2. Obtain correction factor α as follows:

$\alpha = K - 0.175\ (1 - K) = 0.7616 - 0.175\ (1 - 0.7616)$

$= 0.7616 - 0.0417 = 0.7199$

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

   $P = \alpha \times P_0 = 0.7199 \times 27.1$

   $= 19.5$ kW

   The output is down by 7.6 kW or approximately 28.0% in this example.

Corrections for Reducing Exhaust Smoke Density at Altitude

The power correction explained so far is based on the physical phenomenon that the oxygen concentration in the air decreases under certain atmospheric conditions to cause incomplete combustion and a drop in output. In such cases, a decrease in output due to incomplete combustion and an increase of exhaust smoke density may occur.

To prevent an increase in engine exhaust smoke density, decrease the diesel fuel to match the decreased oxygen concentration. Decreasing the diesel fuel injection volume means a corresponding decrease in output. It is necessary to add power correction for reducing exhaust smoke density to the power correction calculated before and to keep the required output of the driven machine under the corrected output level.

This study is not for lessening the exhaust smoke density at the time of starting or upon sudden change in the load.

The following empirical equation has been obtained to reduce the exhaust smoke density:

Power correction for reducing exhaust smoke density = 0.5% per each 100 m in altitude

This % should be added to the calculation result of power correction in *Power Corrections on page 4-3*. Though the factors influencing an increase of exhaust smoke density are not limited to the altitude or the atmospheric pressure, the altitude is used instead of the atmospheric pressure because it has the greatest influence and simplifies the calculation.

> Example:
>
> The rated output of the 3TNV88 engine under standard atmospheric conditions is 27.1 kW at 3,000 min^{-1}.
>
> The rated output of the 3TNV88 engine under standard conditions is 27.1 kW at 3,000 min^{-1}. What will be the output under actual test conditions of 90 kPa (approximately 1000 m), intake air temperature of 323 K (50°C [122°F]), and relative humidity of 80%? What will be the available output without worsening the exhaust smoke density?

The example is the same as that in *Correction Formula (A) on page 4-4*. The calculation result was down by 7.6 kW or approximately 28.0% in engine output. This means that the rated output under standard conditions is 27.1 kW and the exhaust smoke density increases by 19.5 kW under the above conditions.

To reduce exhaust smoke density, further correction for 1,000 m in altitude is necessary.

Correction for reducing exhaust smoke density

$= 0.5\%$ for each 100 m in altitude $\times$ 1,000 m

$= 5\%$

Therefore, the required output reduction is 28.0% + 5% = 33.0%.

In other words, the 3TNV88 engine can be operated without excessive smoke provided the required output for the driven machine or the load does not exceed the following value:

$27.1 - 27.1 \times 0.33 = 18.2$ kW

ATMOSPHERIC PRESSURE CALCULATION FOR CHANGE IN ALTITUDE

$P_x = P_r (1 - 0.00002257h)^{5.256}$

Where,

P_x : Atmospheric pressure in kPa (mmHg) at h (m) above sea level

P_r : Standard atmospheric pressure 100 kPa (750 mmHg) at 0 (m) above sea level

h : Altitude (m)

ATMOSPHERIC TEMPERATURE CALCULATION FOR CHANGE IN ALTITUDE

$T_x = T_r – 0.0065h$

Where,

T_x : Atmospheric temperature (°C [°F]) at h (m) above sea level

T_r : Standard atmospheric temperature (25°C [77°F]) at 0 (m) above sea level

h : Altitude (m)

RELATIONSHIPS AMONG ALTITUDE, ATMOSPHERIC PRESSURE AND ATMOSPHERIC TEMPERATURE

Altitude (m)	Atmospheric pressure kPa (mmHg)	Altitude (m)	Atmospheric pressure kPa (mmHg)
0	101.3 (759.81)	2600	73.7 (552.80)
100	100.0 (750.06)	2800	71.9 (539.30)
200	96.9 (741.81)	3000	70.7 (530.30)
400	96.7 (725.31)	3200	68.4 (513.04)
600	94.4 (708.06)	3400	66.7 (500.29)
800	92.1 (690.81)	3600	64.9 (486.79)
1000	89.9 (674.31)	3800	63.2 (474.04)
1200	87.7 (657.81)	4000	61.5 (461.29)
1400	85.6 (642.05)		
1600	83.5 (626.30)		
1800	81.5 (611.30)		
2000	79.5 (596.30)		
2200	77.6 (582.05)		
2400	75.6 (567.05)		

HOW TO OBTAIN RELATIVE HUMIDITY BY DRY AND WET-BULB THERMOMETER

* Relative humidity is given by the following table when the wet bulb is not frozen.

Relative humidity (%)

Dry bulb temperature t	Difference between dry and wet bulb temperatures t–t'																				
	(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 (104)	100	97	94	91	88	85	82	79	76	73	71	68	66	63	61	58	56	53	51	49	47
35 (95)	100	97	93	90	87	83	80	77	74	71	68	65	63	60	57	55	52	49	47	44	42
30 (86)	100	96	92	89	85	82	78	75	72	68	65	62	59	56	53	50	47	44	41	39	36
25 (77)	100	96	92	88	84	80	76	72	68	65	61	57	54	51	47	44	41	38	34	31	28
20 (68)	100	95	91	86	81	77	73	68	64	60	56	52	48	44	40	36	32	29	25	21	18
1 (33.8)	100	95	89	84	78	73	68	63	58	53	48	44	39	34	30	25	21	16	12	8	4
10 (50)	100	93	87	81	74	68	62	56	50	44	38	32	27	21	16	10	5				
5 (41)	100	92	84	76	68	60	53	46	38	31	24	16	9	2							
0 (32)	100	90	80	70	60	50	40	31	21	12	3										
-5 (23)	100	87	74	61	48	35	22	9													
-10 (14)	100	82	64	47	29	12															

t:Dry bulb temperature °C (°F)

t':Wet bulb temperature °C (°F)

RELATIONSHIP BETWEEN ATMOSPHERIC TEMPERATURE AND SATURATION VAPOR PRESSURE

Atmospheric temperature K (°C [°F])	Saturation vapor pressure kPa (mmHg)	Atmospheric temperature K (°C)	Saturation vapor pressure kPa (mmHg)
263 (–10 [14])	0.260 (1.948)	295 (22 [71.6])	2.642 (19.82)
265 (–8 [17.6])	0.310 (2.323)	297 (24 [75.2])	2.983 (22.38)
267 (–6 [21.2])	0.368 (2.764)	299 (26 [78.8])	3.360 (25.21)
269 (–4 [24.8])	0.437 (3.279)	301 (28 [82.4])	3.779 (28.35)
271 (–2 [28.4])	0.517 (3.880)	303 (30 [86])	4.243 (31.83)
273 (0 [32])	0.611 (4.581)	305 (32 [89.6])	4.755 (35.67)
275 (2 [35.6])	0.705 (5.292)	307 (34 [93.2])	5.319 (39.90)
277 (4 [39.2])	0.813 (6.098)	309 (36 [96.8])	5.941 (44.57)
279 (6 [42.8])	0.934 (7.010)	311 (38 [100.4])	6.625 (49.70)
281 (8 [46.4])	1.072 (8.042)	313 (40 [104])	7.377 (55.34)
283 (10 [50])	1.227 (9.205)	315 (42 [107.6])	8.201 (61.52)
285 (12 [53.6])	1.402 (10.51)	317 (44 [111.2])	9.103 (68.29)
287 (14 [57.2])	1.597 (11.98)	319 (46 [114.8])	10.088 (75.68)
289 (16 [60.80])	1.814 (13.61)	321 (48 [118.4])	11.164 (83.75)
291 (18 [64.4])	2.062 (15.47)	323 (50 [122])	12.338 (92.56)
293 (20 [68])	2.337 (17.53)		

ALTITUDE CHARACTERISTICS

Engine output drops as the altitude increases, resulting in an increase of the exhaust smoke density as described in *Power Corrections on page 4-3*. Other problems at high altitudes are engine startability, exhaust white smoke and misfire.

These problems must be considered when using engines at high altitude.

Generally, the practical upper limit of operation altitude is as shown below, considering the production of black smoke and reduction of output due to increased altitude or decreased air density and engine durability.

Naturally aspirated engine: 1200 m

Turbocharged engines: 2000 m.

When operating the engines at an altitude higher than the above, if possible limit the load of the driven machines (for backhoes, use bucket with smaller capacity) or use machines equipped with an engine of higher displacement.

Reduction of Output

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

Note: The table below shows the value assuming that environmental temperature does not change even if the operating altitude increases.

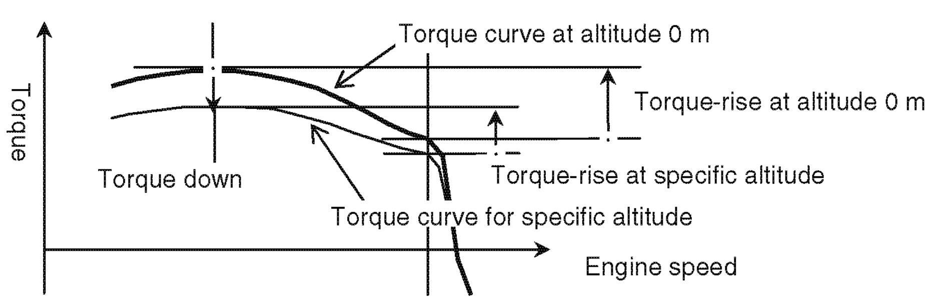
Altitude (m)		0	1000	2000	3000
Reduction of rated output (%)	Naturally aspirated engines	0%	2.5%	7.0%	13.5%
	Turbocharged engines	0%	0.5%	2.0%	4.5%

Reduction of Torque-rise (Reduction of Maximum Torque)

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 the torque-rise (maximum torque) is described below.

Naturally aspirated engines:

Altitude (m)	0	1000	2000	3000
Torque down (%)	0	2.5	6.5	12
Torque-rise (%)	20	17.0	12.0	5.5



A turbocharged engine is less affected by the altitude.

Startability at Each Altitude

As the altitude increases, the atmospheric pressure is reduced, and the engine starting becomes more difficult due to the lack of air relative to the amount of diesel fuel injection, resulting in the lack of power for starting the engine.

A rough guideline of standard minimum starting temperatures with regard to the altitude is shown in the following table. Since various machines may be connected to the engine, it is necessary to study the altitude limit for startability for each application.

		Altitude (m)			
		0	1000	2000	3000
Minimum starting temperature	K	253	253	258	263
	°C (°F)	–20 (68)	–20 (68)	–15 (59)	–10 (50)

The above table represents the standard specification.

Exhaust White Smoke

White smoke generation immediately after starting the engine increases and lasts longer at higher altitudes due to ignition delay caused by 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 or air heater after starting: 3 minutes or longer
  (Requires alteration such as addition of wiring and controller.)

The diesel fuel injection timing cannot be advanced because of compliance with emission control regulations such as EPA or EC.

Misfire at High Altitude

If 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 4-14* 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	Indirect injection system	0%	10%	25%	36%
	Direct injection system	0%	10%	20%	28%

Engines can have a durability problem at altitudes higher than the operable altitude.

- **Deterioration of performance due to accumulation of carbon in and around the combustion chamber and/or clogging of muffler with carbon**

  To avoid this problem, set the maintenance interval to half that for altitude 0 m as follows:

  Cleaning of combustion chamber and exhaust port/manifold related areas: every 1000 hours

  Replacement of muffler: every 1000 hours

Section 5

ENGINE PERFORMANCE

Page

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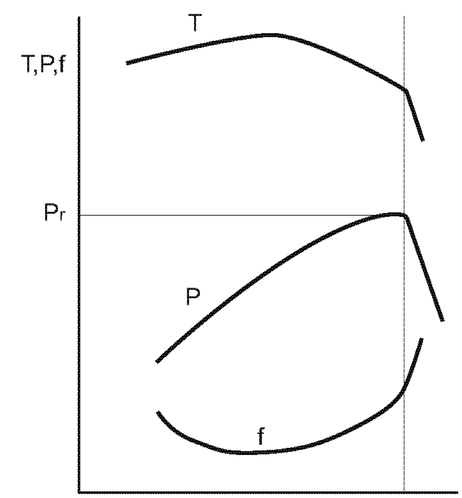
PERFORMANCE CURVES

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 or kgf·m)

P: Output (kW)

f: Specific fuel consumption (g/kW·h)

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

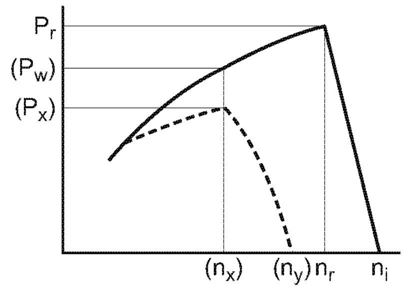
P_r: Rated output (kW)

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



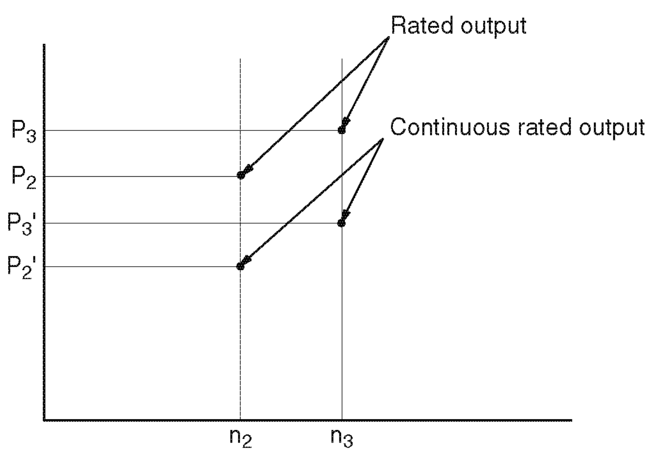
The figure to the left shows a performance curve of an engine set to rated speed n_r and rated output P_r. It shows the maximum speed is n_i at no load.

For example, the output curve of a 3TNV84 diesel engine shows the no-load maximum speed n_i of 2810 min^{-1} and the rated output P_r of 21.3 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 3TNV84 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 19.7 kW. This is shown as the “broken line” in the performance curve. The no-load maximum speed (n_y) is 2590 min^{-1} from the specification tables in *3TNV84 (complies with EPA Tier2) on page 3-11*.

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.

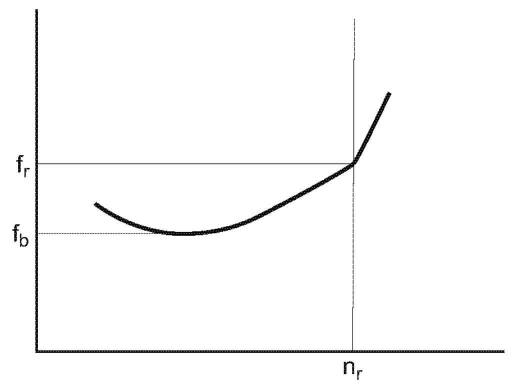


Generators are often driven continuously under load. The engine output to meet this demand is termed the continuous rated output. The rated output of a generator should be less than or equal to the continuous rated output of the engine (P'_2, P'_3). Generators frequently work under an overload condition 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: f



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

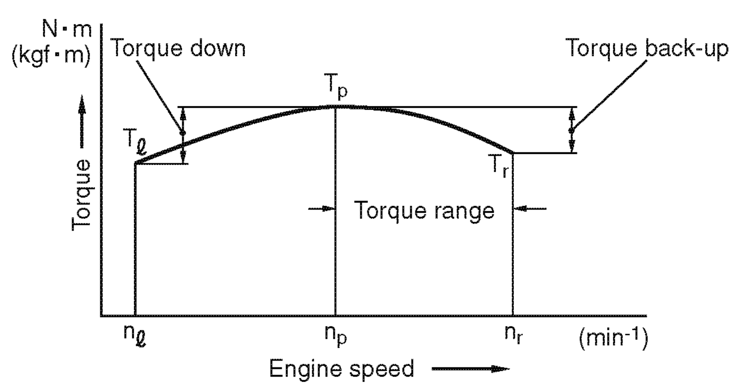
TORQUE CURVE: T

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.



T_ℓ	:	Torque at low idling speed	N-m (kgf-m)
T_p	:	Maximum torque	N-m (kgf-m)
T_r	:	Rated torque at rated output	N-m (kgf-m)
n_ℓ	:	Low idling speed	min^{-1}
n_p	:	Speed at maximum torque (T_p)	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.

$$\text{Torque backup} = \text{Maximum torque } (T_p) - \text{torque at rated output } (T_r)$$

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

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

$$\text{Torque down} = T_p - T_\ell$$

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

- Torque range refers to the difference (n_r-n_p) between the speed (n_p) at maximum torque (T_p) and the rated speed (n_r),

PARTIAL RECOVERY RATIO

Partial recovery ratio refers 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 5-1)**.

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 5-1,** dashed line.**)**

The TNV engine has a partial recovery ratio of 90% or more for standard specifications, but the user must check the characteristics after installing it in the driven machine.

Partial recovery ratio curve

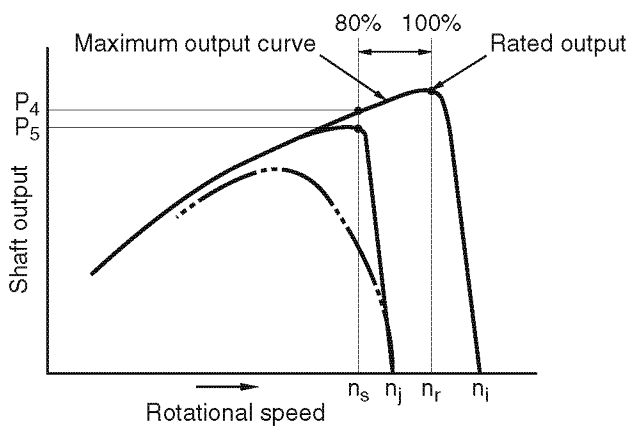


Figure 5-1

n_r : Rated engine speed

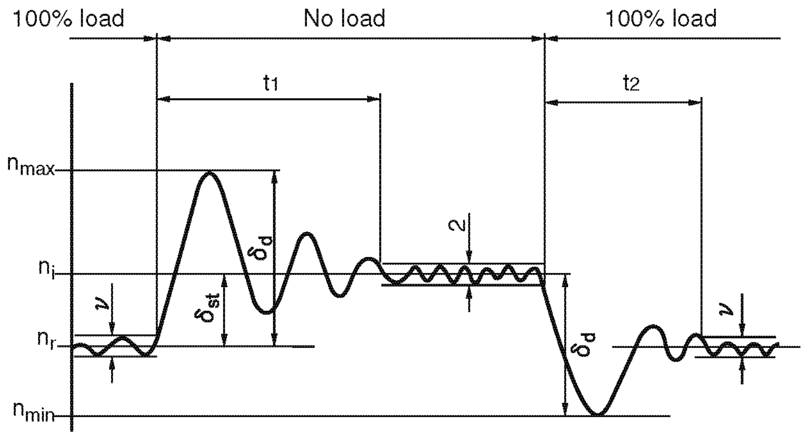
n_i : No-load maximum speed

n_s : n_r x 0.8

n_j : n_i x 0.8

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

GOVERNOR PERFORMANCE



$n_{max.}$
$n_{min.}$ Transient Engine speeds under varying loads

n_r: Rated speed

n_i: No-load speed

ν: Steady-state governed speed band (Range of speed variation in steady state expressed as a percentage of the rated speed. The width of variation expressed in min-1 is called the speed variation.)

t_1, t_2: 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 n to entry to band n.)

δ_{st}: 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.)

$$\delta_{st} = \frac{n_i - n_r}{n_r} \times 100\ (\%)$$

δ_d: 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.

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

$$\delta_d^{+} = \frac{n_{max} - n_r}{n_r} \times 100\ (\%)$$

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

$$\delta_d^{-} = \frac{n_{min} - n_i}{n_r} \times 100\ (\%)$$

Governor Performance of TNV Series Engines

1. All Tier2 compatible series engines and Interim Tier4 compatible engines (except for those in (2) below) which are specified for mechanical governor.

		Constant speed specification			Variable speed specification		
		IDI		DI	IDI		DI
		CL	CH	CL	VM	VH	VM
Instantaneous speed difference (δ_d^+, δ_d^-)	%	≤8 to 10	≤8 to 10	≤8 to 10	≤12	≤12	≤12
Speed droop (δ_{st})	%	≤4 to 5	≤4 to 5	≤4 to 5	≤7 to 8	≤6	≤6 to 9
Recovery time (t_1, t_2)	sec.	≤5	6	≤5	≤6	≤6	≤6
Speed variation (ν)	min^{-1}	≤15	≤20	≤15	≤30	≤30	≤22

2. Interim Tier4 compatible engines and Tier3 compatible engines which are specified for electronic governor equipped <3TNV84T-Z, 4TNV84T-Z, 4TMV98-Z, 4TNV98-E, 4TNV98T-Z>

		Constant speed specification	Variable speed specification
		DI	
		CL	VM
Instantaneous speed difference (δ_d^+, δ_d^-)	%	≤8 to 10	≤12
Speed droop (δ_{st})	%	≤1	≤4 to 6
Recovery time (t_1, t_2)	sec.	≤5	≤6
Speed variation (ν)	min^{-1}	≤15	≤22

Section 6

COLD STARTING AIDS

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TNV series engines are equipped with cold starting aids.There are two types of cold starting aids; glow plugs and air heaters.Engines which are equipped with glow plugs can be started without energizing the plugs if the atmospheric temperature is equal to or above 5°C (41°F).Engines which are equipped with air heaters can be started without using the inlet air heater if the atmospheric temperature is equal to or above -5°C (23°F).

If an optional block heater is applied, the engine can be started with ease even at very low temperature.

For use of cold starting aids by ambient temperature, see *Low-temperature startability on page 1-7*.

This section describes the cold starting aids shown in the tables below and their control circuits.

<table>
<tr><td rowspan="2">Applicable model</td><td>IDI</td><td colspan="3">DI</td></tr>
<tr><td>2/3TNV70
3TNV76</td><td>3TNV82A-B
3/4TNV88-B,U</td><td>3TNV82A
3/4TNV84
3/4TNV88
3TNV84T(-B)</td><td>4TNV84T-Z
4TNV98-Z,E
4TNV98T-Z</td></tr>
<tr><td>Starting aid
Control Circuit</td><td>Glow plug</td><td>Glow plug</td><td>Inlet Air Heater</td><td>Inlet Air Heater</td></tr>
<tr><td>Standard (preheat) control mechanical/eco governor</td><td colspan="2">• Control Circuit Diagram for Standard Glow Plug (Figure 6-2)</td><td colspan="2">• Control Circuit Diagram for Standard Inlet Air Heater, (Figure 6-12) (400/500W)
• Inlet Air Heater Capacity and Power Relay, (Figure 6-13) (800/1000W)
• After-Heat (Eco Governor Option),(Figure 6-15)</td></tr>
<tr><td>On-Glow control mechanical governor</td><td colspan="2">• Control Circuit Diagram for On-Glow (Figure 6-4)</td><td rowspan="2">-</td><td>-</td></tr>
<tr><td>On-Glow control eco governor</td><td>-</td><td>• Control Circuit Diagram for On-Glow (eco governor) (Figure 6-9)</td><td>• Control Circuit Diagram for On-Glow (eco governor) (Figure 6-16)</td></tr>
</table>

GLOW PLUG

The glow plug is an electrically heated coil that is installed in the swirl chamber of the IDI engine. 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		IDI (2,3TNB20, 3TNV76)	DI (3TNV82A-B, 3TNV88-U, B, 4TNV88-U, B)
Nominal voltage	V	12	12
Type name		Standard glow plug	Standard glow plug
Part code		119717-77800	129008-77800
Standard preheating time	Sec	4	15
Rated capacity	V/A	11/ 9.0 ± 1.0	11/ 9.0 ± 1.0
Identification color		Red	Red

When using the IDI glow plug, it is recommended to equip it with a 4-second timer (Part Code: 129155-77925).

When using the DI glow plug, it is recommended to equip it with a 15-second timer (Part Code: 128300-77920).

Glow Plug Structure

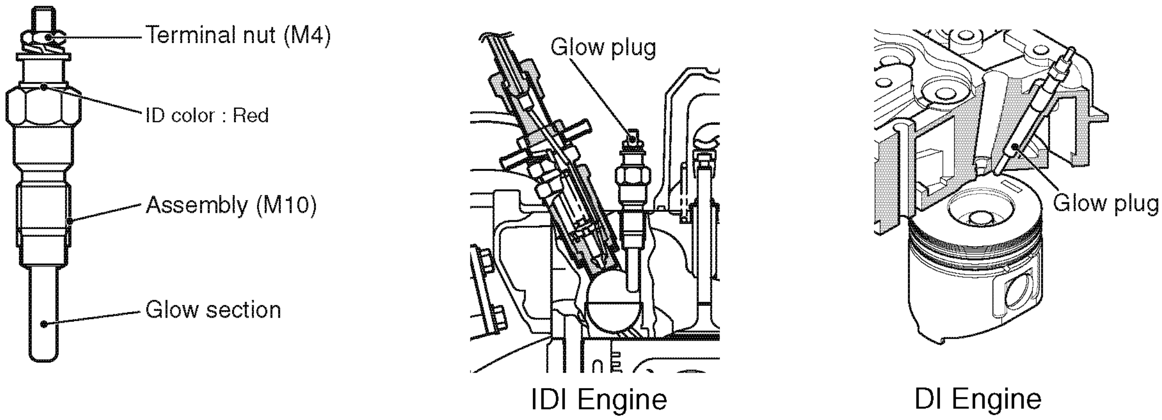


Figure 6-1

Control Circuit Diagram for Standard Glow Plug

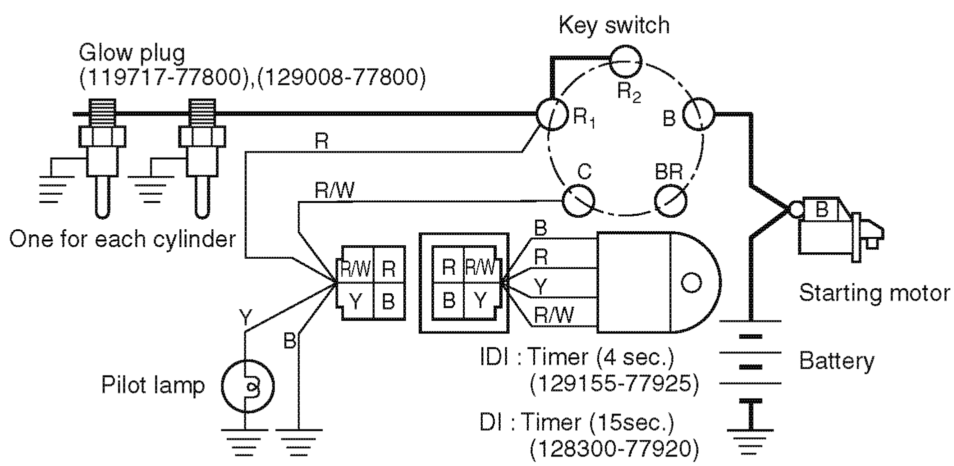


Figure 6-2

Control Circuit Parts for Glow Plug

Pattern of Key Switch Terminal: Yanmar Part No. 129115 - 91250

The key switch terminal connection patterns illustrated in *Control Circuit Diagram for Standard Glow Plug on page 6-4* are as follows:

	B	R_1	ACC	R_2	BR	C
Preheat	O	O			O	
OFF	O					
ON	O		O		O	
Start	O		O	O	O	O

In the *Control Circuit Diagram for Standard Glow Plug on page 6-4* circuit diagram, the current flow for the preheating operation starts at the battery and flows to the glow plug via B, R_2, and external wiring and R_1.

The key switch is available in a variety of configurations. Terminal connection patterns and terminal codes differ by manufacturer. Installation should be performed only if the terminal connection patterns and codes are fully understood.

Timer and Preheat Indicator

When the key switch is in the PREHEAT position, the timer (part code: 129155-77925 or 128300-77920) starts counting down for the specified time. The preheat indicator (pilot lamp) stays lit during the countdown process.After about 4 or 15 seconds of preheating (may fluctuate slightly depending on the ambient temperature), the timer turns off the preheat indicator.Refer to the specifications supplied by the operator's console manufacturer for the actual key switch label that indicates the PREHEAT key switch position.

During cold weather, the operator may continue to hold the switch in PREHEAT after the preheat indicator goes out. Note that the timer illustrated in *Control Circuit Diagram for Standard Glow Plug on page 6-4* circuit diagram only controls the length of time the preheat indicator stays lit.

Turn the key switch to the START position immediately after the preheating cycle has completed. The preheat indicator does not light during the starting operation because terminal R_1 of the key switch is not powered during the START mode.

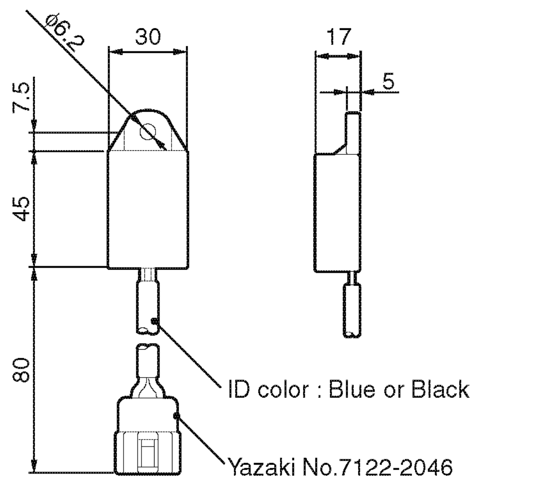


Figure 6-3

Applicable Model	IDI	DI
Rated voltage (V)	12	12
Part code	129155-77925	128300-77920
Set time (sec)	4	15
ID color	Blue	Black
Manufacturer's model	HC0107	HC0108
Applicable preheat lamp	3.4W/DC12V	3.4W/DC12V

Relay for Starting Aids (Power Relay)

Use a power relay if the wiring distance between the engine and the key switch is too long. As the length of wire between the engine and key switch increases, so does the resistance of the wire. This will cause a voltage drop and reduce glow plug performance. Install a power relay between the glow plug and the key switch as a countermeasure. See the description on inlet air heaters in *Control Circuit for Specific Driven Machine Applications on page 6-12* for details.

Control Circuit Diagram for On-Glow® (Mechanical Governor)

Some key switches are turned counterclockwise for the preheat mode. After the preheat cycle has completed, the operator turns the key switch clockwise to the START position.

On-Glow® control refers to a method of automatically initiating the preheat cycle by turning the key switch clockwise to the ON position. With this configuration the timer controls the length of time the glow plugs and preheat indicator are energized. When the preheat indicator goes out continue turning the key switch clockwise to the START position to start the engine.

The key switch returns to the ON position after start procedure is completed. To disable the preheating circuit, a special controller is needed for controlling the On-Glow®.

The circuit of a currently available On-Glow® system is shown below. It is a combination of a super quick glow plug, engine coolant temperature switch and power relay to control the preheating time with a special controller.

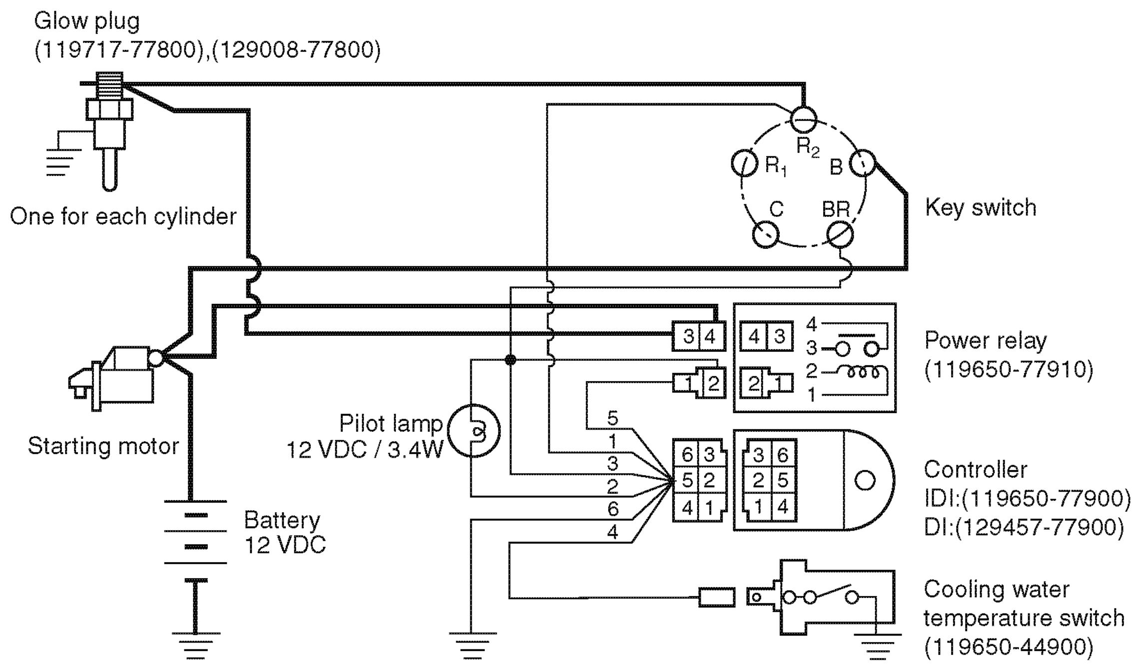


Figure 6-4

Controller (IDI)

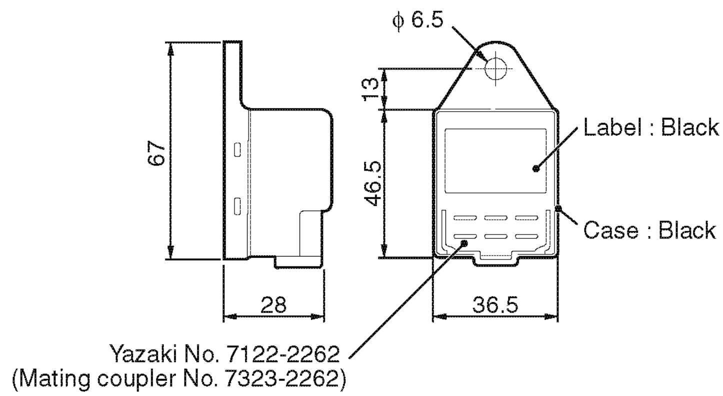


Figure 6-5

Part code		119650-77900	
Glow plug applied voltage	Voltage V	Cooling water temperature	Lamp and power relay control time (sec)
	12	5°C (41°F) and over	$0.7 \pm ^{0.6}_{0.3}$
	10		$1.0 \pm ^{0.8}_{0.3}$
	8		$1.6 \pm ^{1.1}_{0.6}$
	12	Under 5°C (41°F)	$2.1 \pm ^{1.2}_{0.3}$
	10		$4.0 \pm ^{1.6}_{1.4}$
	8		$7.5 \pm ^{5.0}_{2.5}$

Controller (IDI)

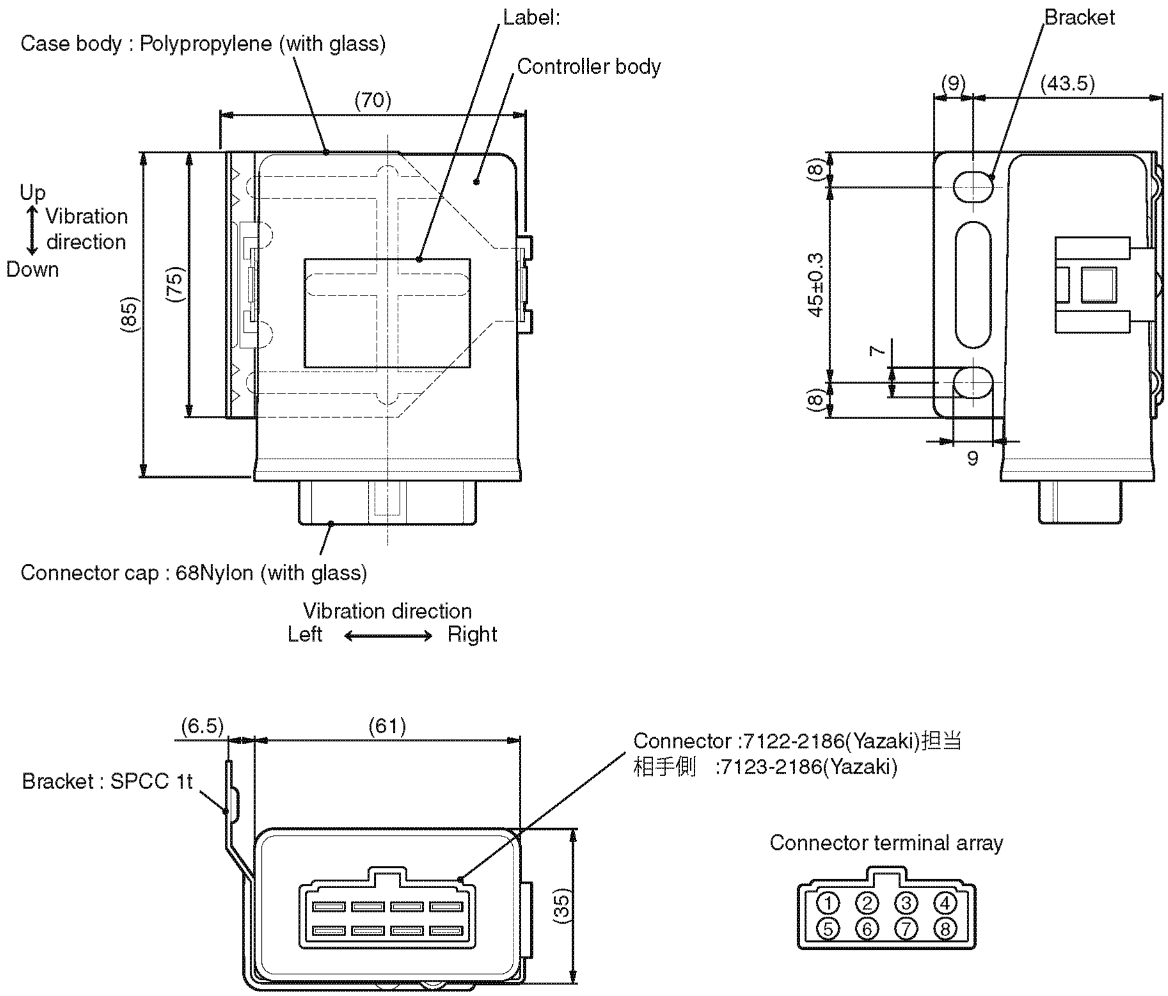


Figure 6-6

Characteristics

Part code		129457-77900		
Property 1	Item	Specific resistance	Time (sec)	NOTE
	Indicator/ preheat time	28.5 (-30°C)	25.0±3.0	Power supply voltage: 12V
		12.1 (-15°C)	20.0±4.0	
		3.8 (+10°C)	1.0±0.4	

Power Relay

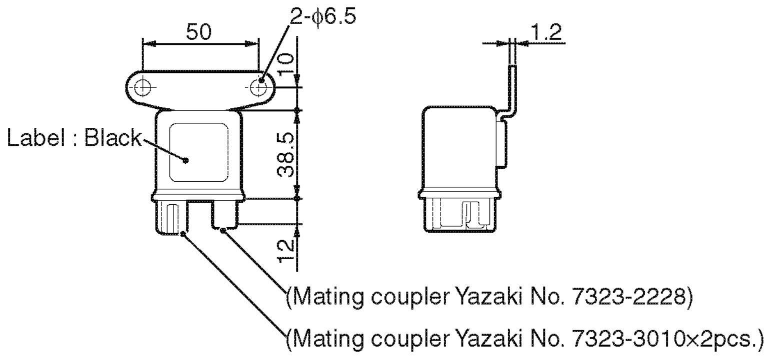


Figure 6-7

Part code	119650-77910
Rating	12 VDC / 10 min
Contact capacity	40 A / a-Contact
Exciting current	0.5 A

Engine Coolant Temperature Switch

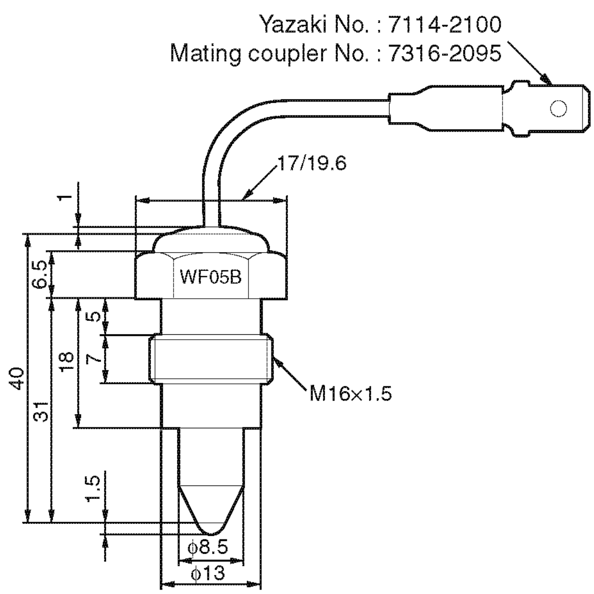
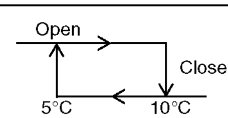


Figure 6-8

Part code	119650-44900
Operating temperature	
Contact capacity	0.7 A/12 VDC (signal use only)

Control Circuit Diagram for On-Glow (Eco Governor)

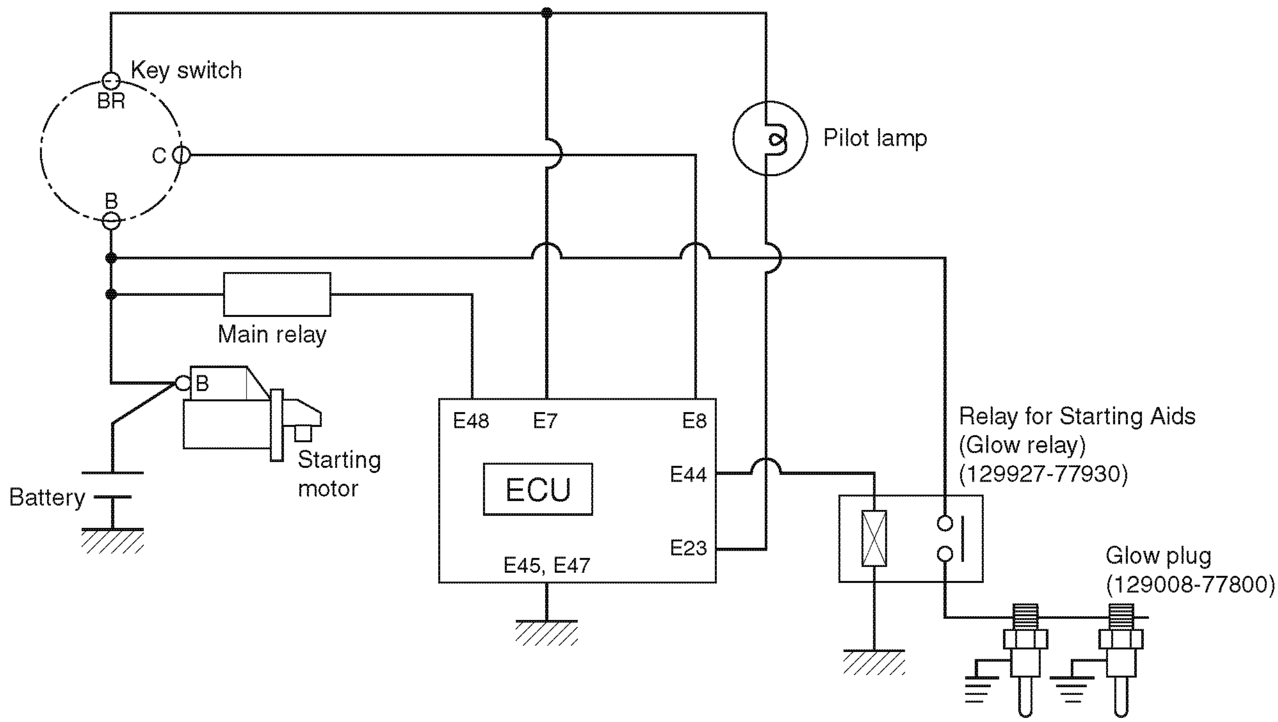


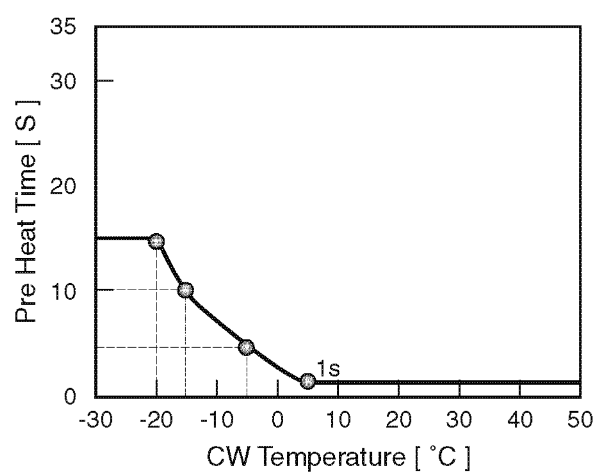
Figure 6-9

Timer and Preheat Indicator

When turn the key switch ON, ECU detect the temperature of coolant, then indicate the pilot lamp and preheating during a pre-set heating time. **(Figure 6-10)**.

Relay for Starting Aids

If On-Glow control is conducted for eco governor option, use the relay for starting aid. **(Figure 6-18 to Figure 6-20)**.



Preheat timer control for glow plug

Figure 6-10

After-Heat (Eco Governor Option)

Subject model: 3TNV82A-Z, 3/4TNV88-E,Z

The time until the whit smoke goes out can be reduced by changing the setting of eco governor controller to keep energizing the glow plug even after the engine is started.

INLET AIR HEATER

An inlet air heater is installed in the intake manifold of an engine to heat the intake air to help the engine start in cold temperatures.

Capacities differ by the engine model.Refer to the *Yanmar TNV Option Menu* for details on the change of inlet air heater capacity, combination of 24V specification and wiring method.

Applicable engine	Rated voltage (V) / Capacity (W)	Standard preheat time (sec)	Standard inlet air heater
3TNV82A, 3TNV84(T)(T-B) 3TNV88, 4TNV84(T) 4TNV88, 4TNV84T-Z	12 VDC/400 W	15	129120-77501
4TNV94L, 4TNV98-E,Z 4TNV98, 4TNV98T-Z	12 VDC/500 W	15	129915-77050

Installation of a 15-second timer (part code: 128300-77920) is recommended on the standard inlet air heater.

Inlet Air Heater Structure

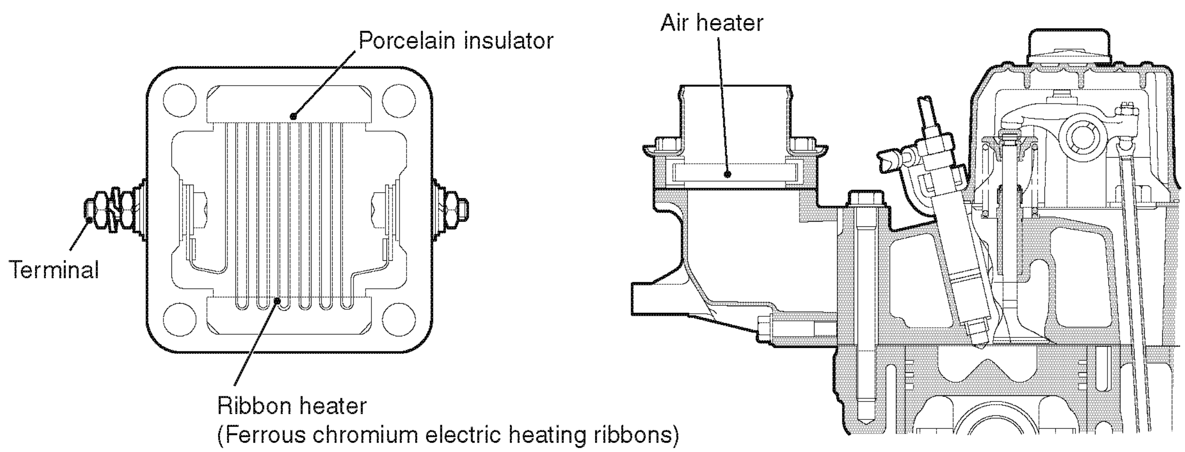


Figure 6-11

Control Circuit Diagram for Standard Inlet Air Heater

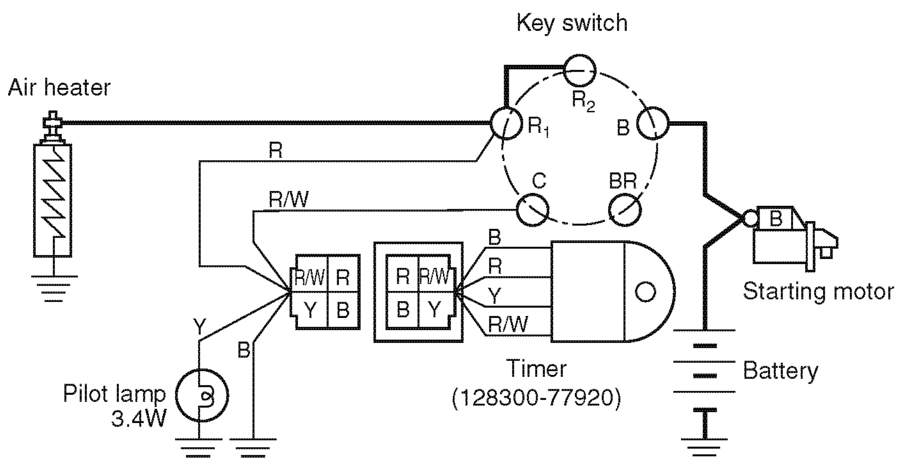


Figure 6-12

Inlet Air Heater Capacity and Power Relay

Figure 6-12 shows the basic inlet air heater wiring connection. A large current flows in the standard type inlet air heater. Depending on conditions, a larger capacity is produced by combining various types of inlet air heaters to improve engine startability.

Before starting, check the contact capacity of the key switch preheating circuit B-R and B-R_2 to determine if it is sufficient for the required current flow from the inlet air heaters.

If the contact capacity (allowable current) of the key switch preheating circuit is smaller than the required current of the inlet air heater, the current to the inlet air heater will be suppressed, causing insufficient preheating. Damage to the key switch contacts and other problems may occur.

If the contact capacity of the key switch preheating circuit seems to be insufficient, install a power relay.

Application of the power relay is not limited to covering the lack of key switch contact capacity. It is also used to prevent the voltage drop that occurs as the distance between the engine installation point and the key switch location increases.

A typical wiring example is shown **(Figure 6-13)**. Refer to the separate *Yanmar TNV Option Menu* for combinations of various types of inlet air heater capacity.

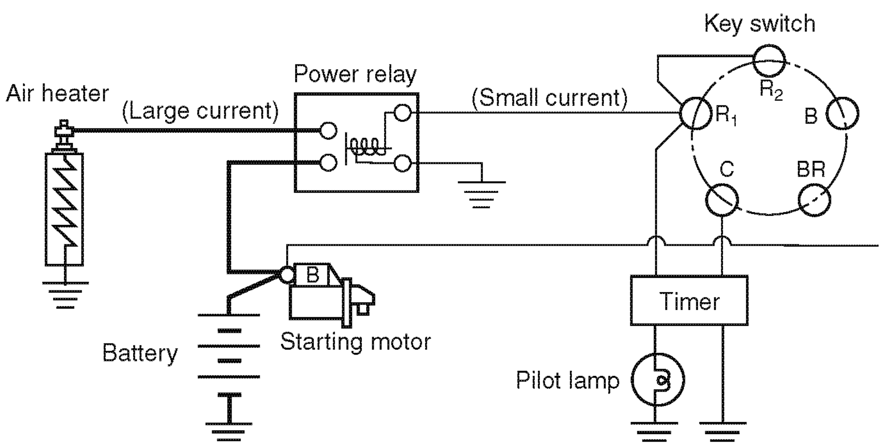


Figure 6-13

Refer to the *Yanmar TNV Option Menu* for the various types of power relay and key switches manufactured by Yanmar.

Control Circuit for Specific Driven Machine Applications

The typical control circuits we discussed previously are commonly used for driven machines where the current flows to the inlet air heater when the key switch is in the START position. Startability improves significantly if the current to the inlet air heater is cut off while the engine is cranking. For example, if a driven machine application has a large drag torque and will experience severe cold starting conditions, cutting the off the current flow to the inlet air heater while the engine is cranking increases the amount of current available for the starter motor. This provides better starting efficiency by increasing the cranking torque.

Use actual vehicle tests done under cold conditions to determine whether or not the inlet air heater current should be cut off during cranking.

Inlet Air Heater Control Circuit Components

Key Switch Terminal Pattern

The key switch terminal pattern used with an inlet air heater is identical to the one shown in *Control Circuit Diagram for On-Glow® (Mechanical Governor) on page 6-6*.

Key switches are available in various configurations and terminal connecting patterns. Terminal codes differ by manufacturer. Installation should be performed only if the terminal connection patterns and codes are fully understood. This is especially important if the application will use an inlet air heater. The amount of current required to energize an inlet air heater is considerably greater than a glow plug so you must carefully consider the contact rating of the key switch during the selection process.

Timer and Preheat Indicator

When the key switch is in the PREHEAT position, the timer (part code: 128300-77920) starts counting down for the specified time. The preheat indicator (pilot lamp) stays lit during the countdown process. After about 15 seconds of preheating (may fluctuate slightly depending on outside temperature), the timer turns off the preheat indicator. Refer to the specifications supplied by the operator's console manufacturer for the actual key switch label that indicates the PREHEAT key switch position.

During cold weather, the operator may continue to hold the switch in PREHEAT after the preheat indicator goes out. Note that the timer illustrated in the *Control Circuit Diagram for Standard Glow Plug on page 6-4* circuit diagram only controls the length of time the preheat indicator stays lit.

Turn the key switch to the START position immediately after the preheating cycle has completed. The preheat indicator does not light during the starting operation because terminal R_1 of the key switch is not powered during the START mode.

12 VDC 15-sec Timer

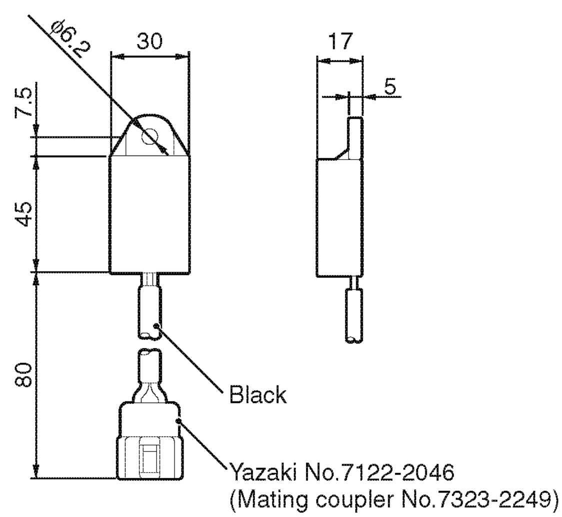


Figure 6-14

Rated voltage	12 VDC
Part code	128300-77920
Set time (sec)	15
ID color	Black (tube)
Manufacturer's model	HC0108
Applicable pilot lamp	3.4 W

After-Heat (Eco Governor Option)

Subject model: 4TNV98-E, 4TNV98-Z, 4TNV98T-Z, 4TNV84T-Z

The time until the whit smoke goes out can be reduced by changing the setting of eco governor controller to keep energizing the air heater even after the engine is started.

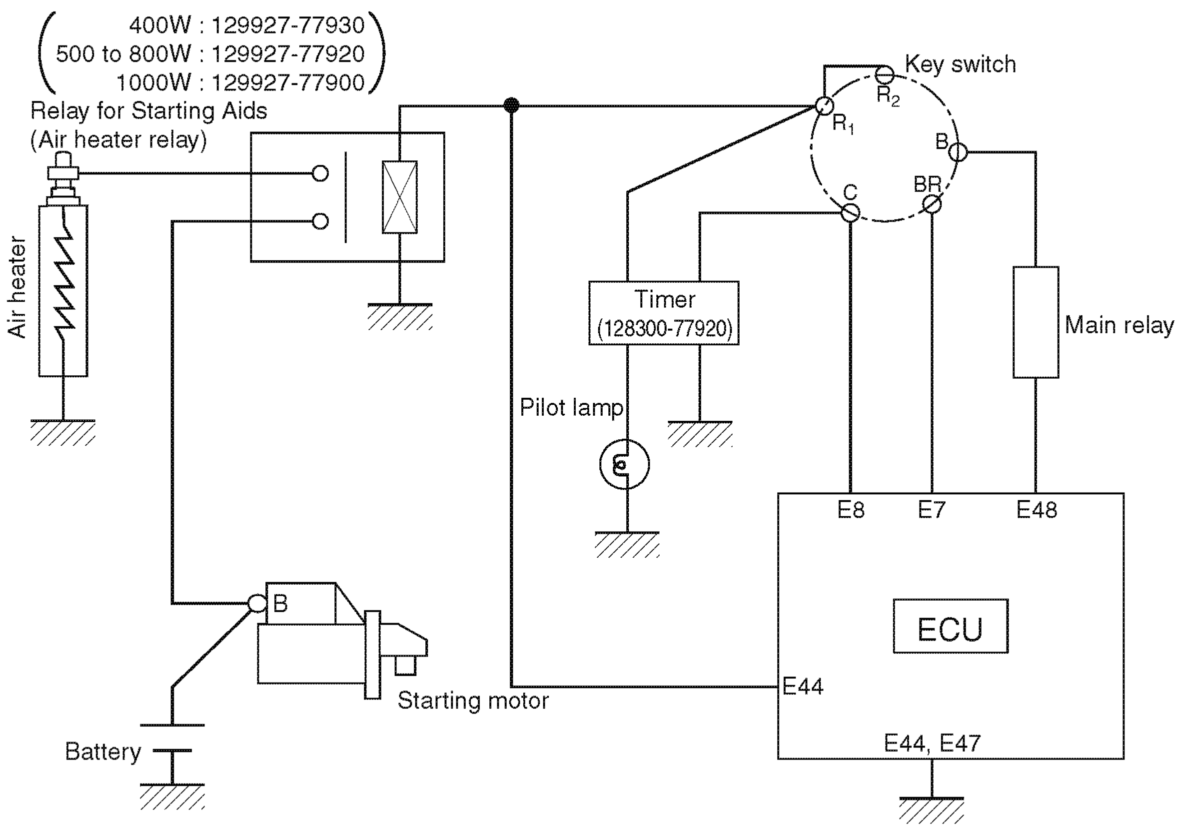


Figure 6-15

Relay for Starting Aids

Use a relay for starting aids when using the after heat function for eco governor specific engines. **(Figure 6-18 to Figure 6-20)**

Control Circuit Diagram for On-Glow (Eco Governor)

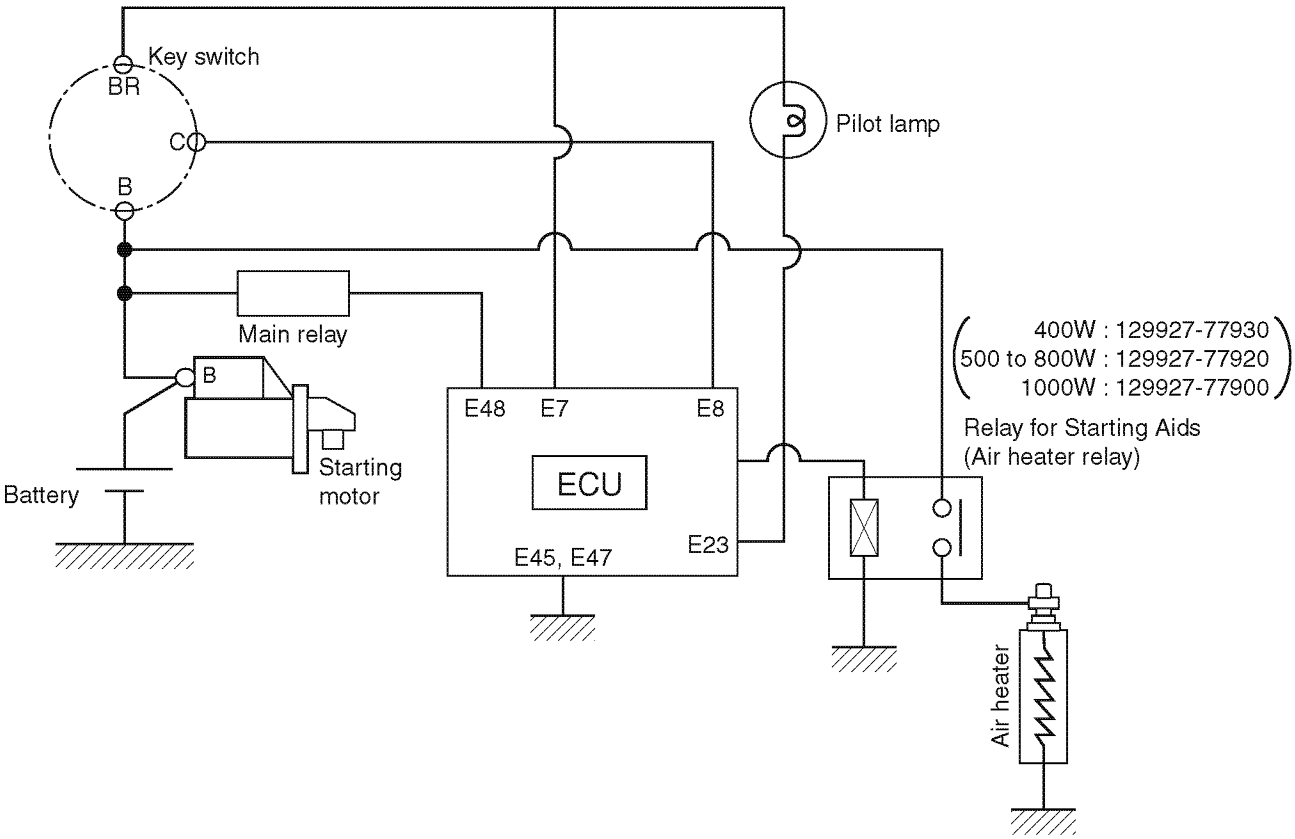


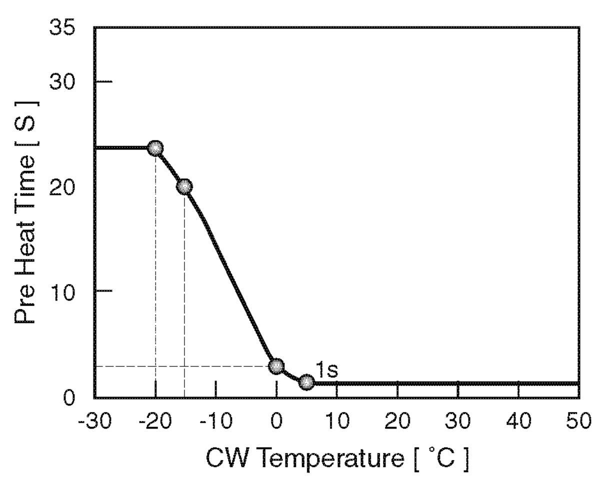
Figure 6-16

Timer and Preheat Indicator

When turn the key switch ON, ECU detect the temperature of coolant, then indicate the pilot lamp and preheating during a pre-set heating time.**(Figure 6-17)**.

Relay for Starting Aids

If On-Glow control is conducted for eco governor option, use the relay for starting aid. **(Figure 6-18 to Figure 6-20)**.



Preheat timer control for air heater

Figure 6-17

After-Heat (Eco Governor Option)

Subject model: 4TNV84T-Z, 4TNV98-E, 4TNV98-Z, 4TNV98T-Z

The time until the whit smoke goes out can be reduced by changing the setting of eco governor controller to keep energizing the glow plug even after the engine is started.

Relay for Starting Aids

Application	Glow Plug 400W Air heater	500 to 800W Air heater	1000W Air heater
Part code	129927-77930	129927-77920	129927-77900
Rating	12 VDC/Cont.	12 VDC/Cont.	12 VDC / 4 min
Contact capacity	40A / a-Contact	70A / a-Contact	90A / a-Contact
Exciting current	0.117A	0.117A	0.2A or less

Installation of a 15-second timer (part code: 128300-77920) is recommended on the standard inlet air heater.

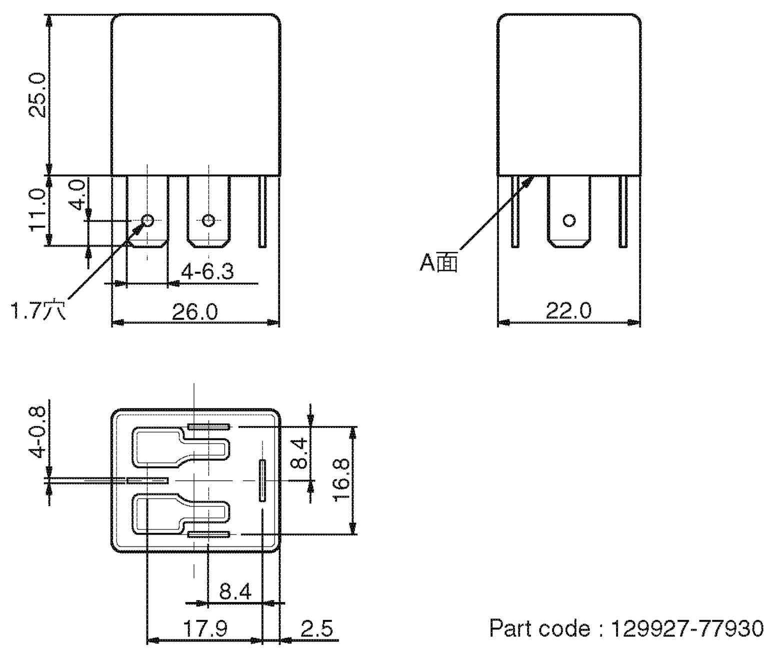
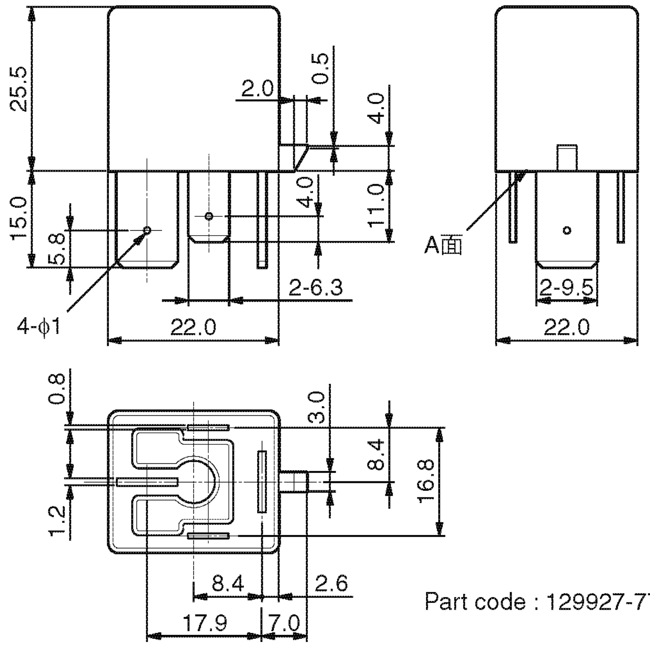
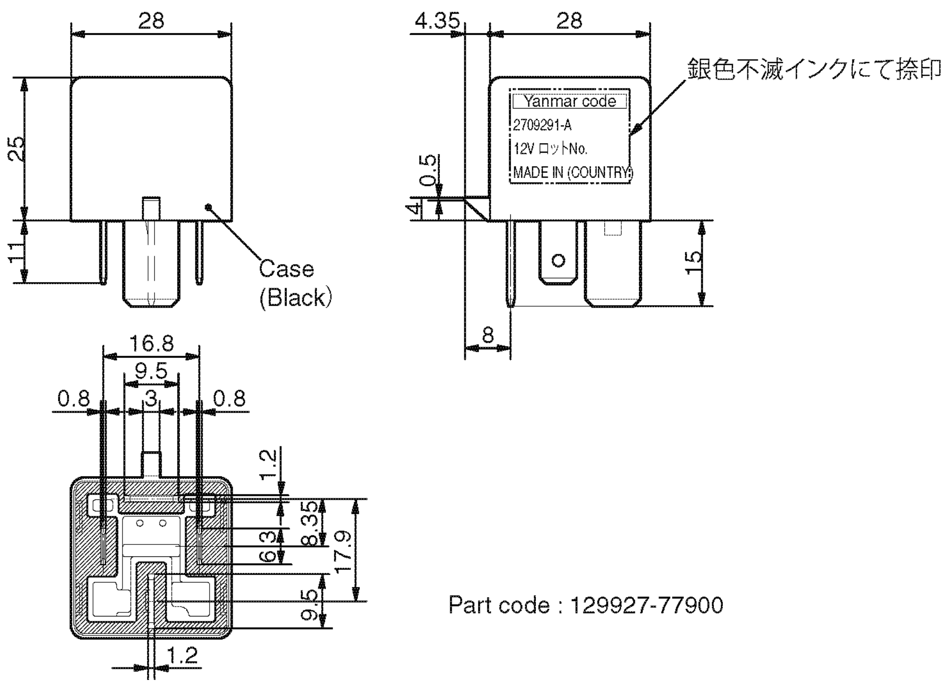


Figure 6-18



Part code : 129927-77920

Figure 6-19



Part code : 129927-77900

Figure 6-20

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 [-4°F]) 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.To prevent this hazard, use an automatic control circuit that will turn the engine block heater power supply On or Off to control the duration of energization.

Automatic block heater control option is also available for eco governor specific engines.Refer to Electronic Control Manual for more information.

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 VAC/400 W
	124097-77900	Rated capacity: 200 VAC/200 W
Connecting code	171015-77910	Approx. 300 mm long
Bracket	119621-11950	For IDI system engines only. For more details, see the *Yanmar Option Menu*.

NOTE

- 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

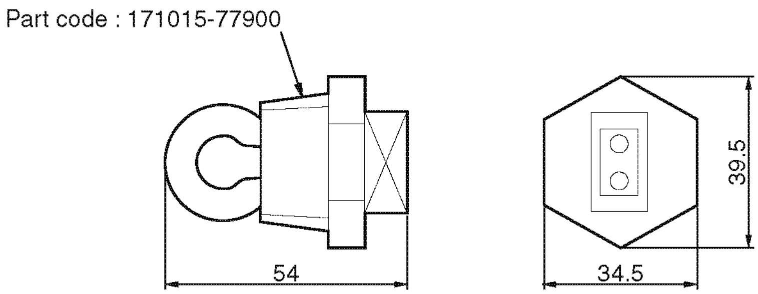


Figure 6-21

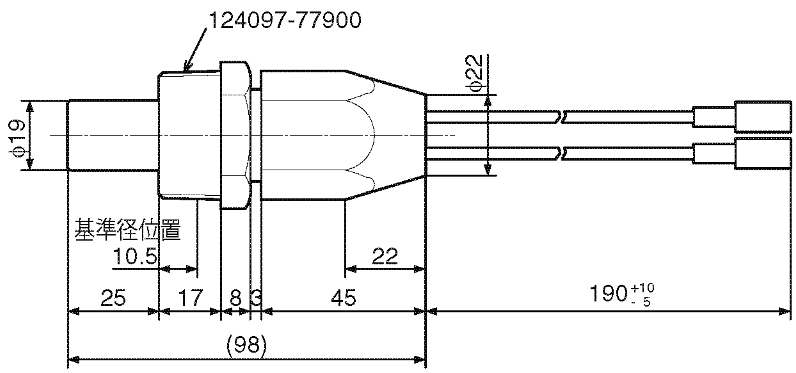


Figure 6-22

Block Heater Connection Diagram

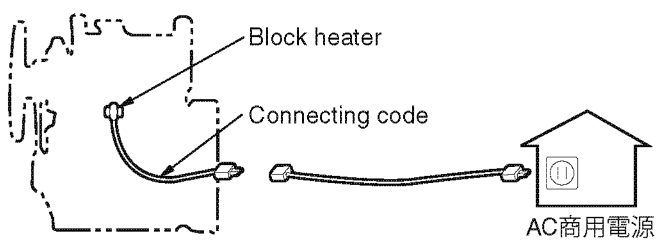


Figure 6-23

COLD START DEVICE (CSD) FOR MP PUMP

TNV engine has several diesel fuel injection timing control devices for exhaust emission reduction. The Cold Start Device (CSD) presents some safety concerns that you should be aware of.

Features of CSD

At cold start (engine coolant temperature below 5°C [41°F]), diesel fuel injection timing is advanced and diesel fuel injection volume is increased with CSD.This has the following effects on engine:

- High idle/low idle speed will be increased
- Engine output will be increased
- Some black smoke will be visible during acceleration
- Engine will be somewhat noisy

Confirmation of Safety at Cold Start

- When the TNV engine is installed, check the idle-up revolution speed of the engine at low temperature and perform creep characteristics to make sure there are no safety problem.
- Instruct the user that the idling engine speed of the TNV engine will increase when the engine is cold and the engine should warm-up for at least five minutes before operating the driven machine. The specific warning is shown in the TNV Operation Manual.

Section 7

AIR INTAKE SYSTEM

Page

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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:

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

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 h_V differs slightly depending on the range of engine speeds encountered during actual use but h_V can assumed to be constant when you calculate air capacity. If η_V is 0.9 for the naturally aspirated engine and 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: liter	Required air capacity Q_1 for combustion: m^3/min (cfm)
1	2TNV70	0.569	2.56×10^{-4} x N (9.04×10^{-3} x N)
2	3TNV70	0.854	3.84×10^{-4} x N (1.356×10^{-2} x N)
3	3TNV76	1.115	5.02×10^{-4} x N (1.773×10^{-2} x N)
4	3TNV82A	1.331	5.99×10^{-4} x N (2.115×10^{-2} x N)
5	3TNV84	1.496	6.73×10^{-4} x N (2.377×10^{-2} x N)
6	3TNV88	1.642	7.39×10^{-4} x N (2.610×10^{-2} x N)
7	4TNV84	1.995	8.98×10^{-4} x N (3.171×10^{-2} x N)
8	4TNV88	2.190	9.85×10^{-4} x N (3.479×10^{-2} x N)
9	3TNV84T	1.496	9.72×10^{-4} x N (3.433×10^{-2} x N)
10	4TNV84T	1.995	1.30×10^{-3} x N (4.591×10^{-2} x N)
11	4TNV94L	3.054	1.37×10^{-3} x N (4.838×10^{-2} x N)
12	4TNV98	3.319	1.49×10^{-3} x N (5.262×10^{-2} x N)
13	4TNV98T	3.319	2.16×10^{-3} x N (7.628×10^{-2} x N)

Example:

How many cubic meters of air capacity will be required per minute for burning diesel fuel in a 3TNV84 diesel engine at 21.3 kW/2600 min^{-1}?

From the above table, the calculation formula for the air capacity required for burning diesel fuel in the 3TNV84 diesel engine is

$$Q_1 = 6.73 \times 10^{-4} N$$

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

$$\begin{aligned} Q_1 &= 6.73 \times 10^{-4} \times 2600 \\ &= 1.75\ (m^3/min) \end{aligned}$$

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	
	:	2 cylinders: 2.0	
	:	3 cylinders: 1.7	
	:	4 cylinders: 1.0	

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><td colspan="2">Air cleaner</td><td colspan="12">Single element</td></tr>
<tr><td colspan="2">Engine</td><td colspan="2">CL</td><td colspan="7">VM</td><td colspan="3">VH/CH</td></tr>
<tr><td></td><td>min^{-1}</td><td>1500</td><td>1800</td><td>2000</td><td>2200</td><td>2400</td><td>2500</td><td>2600</td><td>2800</td><td>3000</td><td>3200</td><td>3400</td><td>3600</td></tr>
<tr><td colspan="2">2TNV70</td><td colspan="12">4 inch</td></tr>
<tr><td colspan="2">3TNV70</td><td colspan="12">4 inch</td></tr>
<tr><td colspan="2">3TNV76</td><td colspan="8">4 inch</td><td colspan="4">5 inch (include 2900 min^{-1})</td></tr>
<tr><td colspan="2">3TNV82A</td><td colspan="9" rowspan="3">5 inch</td></tr>
<tr><td colspan="2">3TNV84</td></tr>
<tr><td colspan="2">3TNV88</td></tr>
<tr><td colspan="2">3TNV84T</td><td colspan="8">5 inch</td></tr>
<tr><td colspan="2">4TNV84</td><td colspan="9">5 inch</td></tr>
<tr><td colspan="2">4TNV88</td><td colspan="6">5 inch</td><td colspan="3">6 inch</td></tr>
<tr><td colspan="2">4TNV84T</td><td colspan="9">6 inch</td></tr>
<tr><td colspan="2">4TNV94L</td><td colspan="6">6 inch</td></tr>
<tr><td colspan="2">4TNV98</td><td colspan="6">7 inch</td></tr>
<tr><td colspan="2">4TNV98T</td><td colspan="6">7 inch</td></tr>
</table>

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

<table>
<tr><td colspan="2">Air cleaner</td><td colspan="12">Double element</td></tr>
<tr><td colspan="2">Engine</td><td colspan="2">CL</td><td colspan="7">VM</td><td colspan="3">VH/CH</td></tr>
<tr><td></td><td>min^{-1}</td><td>1500</td><td>1800</td><td>2000</td><td>2200</td><td>2400</td><td>2500</td><td>2600</td><td>2800</td><td>3000</td><td>3200</td><td>3400</td><td>3600</td></tr>
<tr><td colspan="2">2TNV70</td><td colspan="12">4 inch</td></tr>
<tr><td colspan="2">3TNV70</td><td colspan="10">4 inch</td><td colspan="2">5 inch</td></tr>
<tr><td colspan="2">3TNV76</td><td colspan="5">4 inch</td><td colspan="7">5 inch</td></tr>
<tr><td colspan="2">3TNV82A</td><td colspan="9">5 inch</td></tr>
<tr><td colspan="2">3TNV84</td><td colspan="7">5 inch</td><td colspan="2">6 inch</td></tr>
<tr><td colspan="2">3TNV88</td><td colspan="7">5 inch</td><td colspan="2">6 inch</td></tr>
<tr><td colspan="2">3TNV84T</td><td colspan="4">5 inch</td><td colspan="4">6 inch</td></tr>
<tr><td colspan="2">4TNV84</td><td colspan="9">5 inch</td></tr>
<tr><td colspan="2">4TNV88</td><td colspan="4">5 inch</td><td colspan="5">6 inch</td></tr>
<tr><td colspan="2">4TNV84T</td><td colspan="9">6 inch</td></tr>
<tr><td colspan="2">4TNV94L</td><td colspan="6">6 inch</td></tr>
<tr><td colspan="2">4TNV98</td><td colspan="6">7 inch</td></tr>
<tr><td colspan="2">4TNV98T</td><td colspan="6">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, 4, 5, 6, and 7 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).

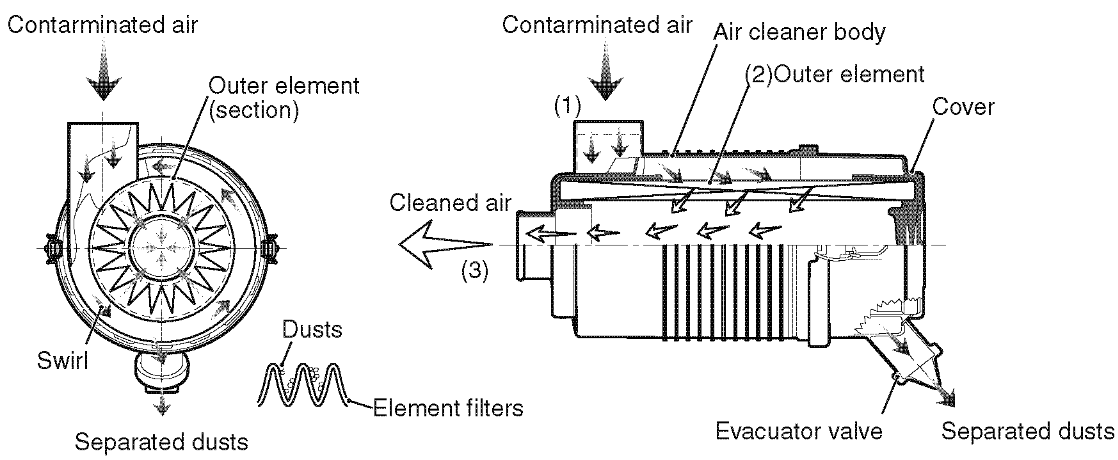

Figure 7-1

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:

1. Be sure to perform periodic maintenance/replacement for both element types.
2. 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.)
3. Also for the single element type, be careful not to allow the entrance of dust or foreign matters inside the engine during the maintenance.
4. 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.)

Structure of Single Element Type

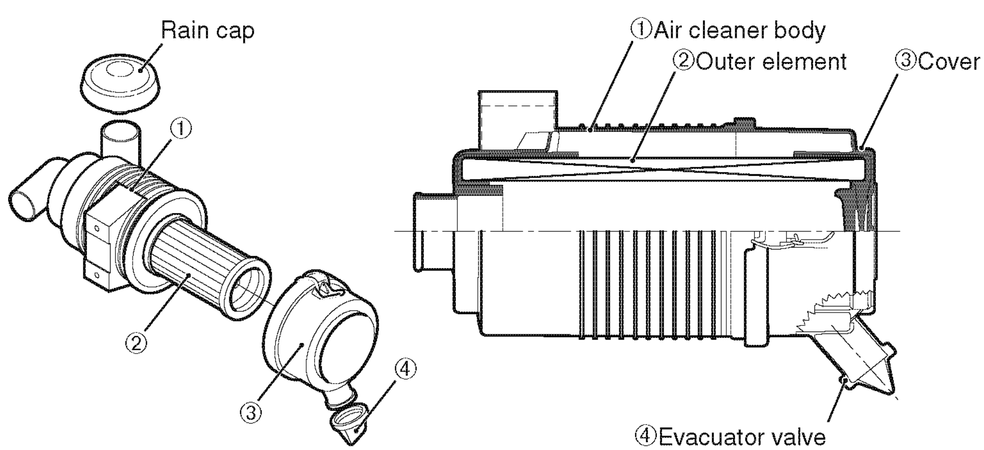

Figure 7-2

Structure of Double Element Type

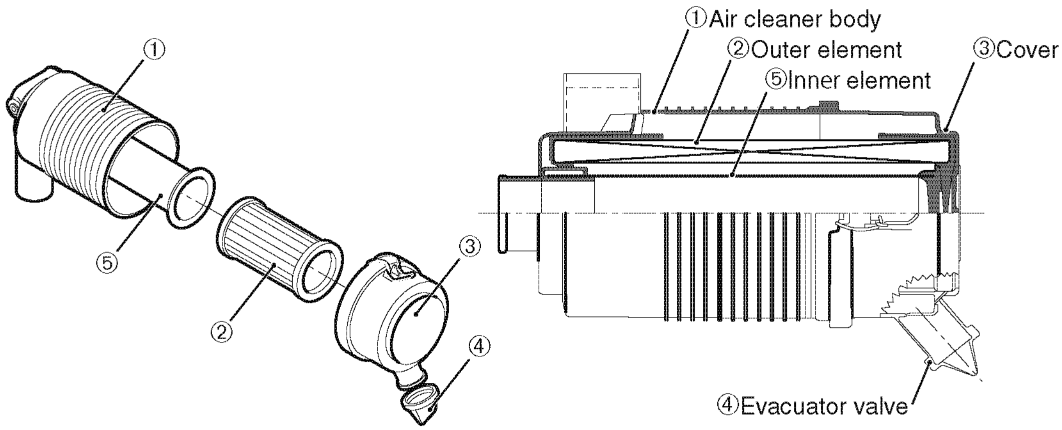

Figure 7-3

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 (635 mmAq). 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.

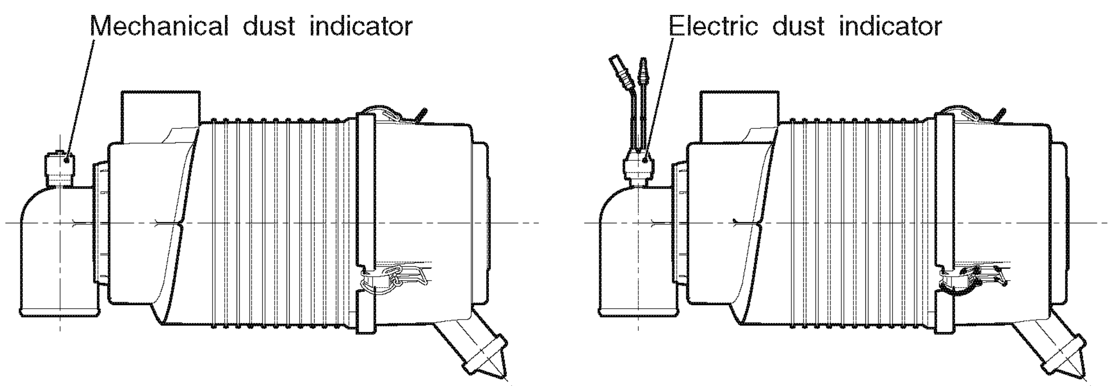

Figure 7-4

Mechanical Dust Indicator: Part Code: 126650-12680

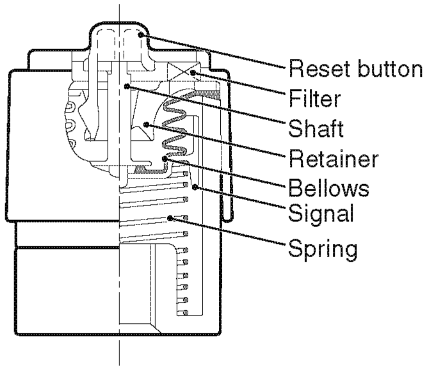

Figure 7-5

Electric Dust Indicator: Part Code: 119140-12680

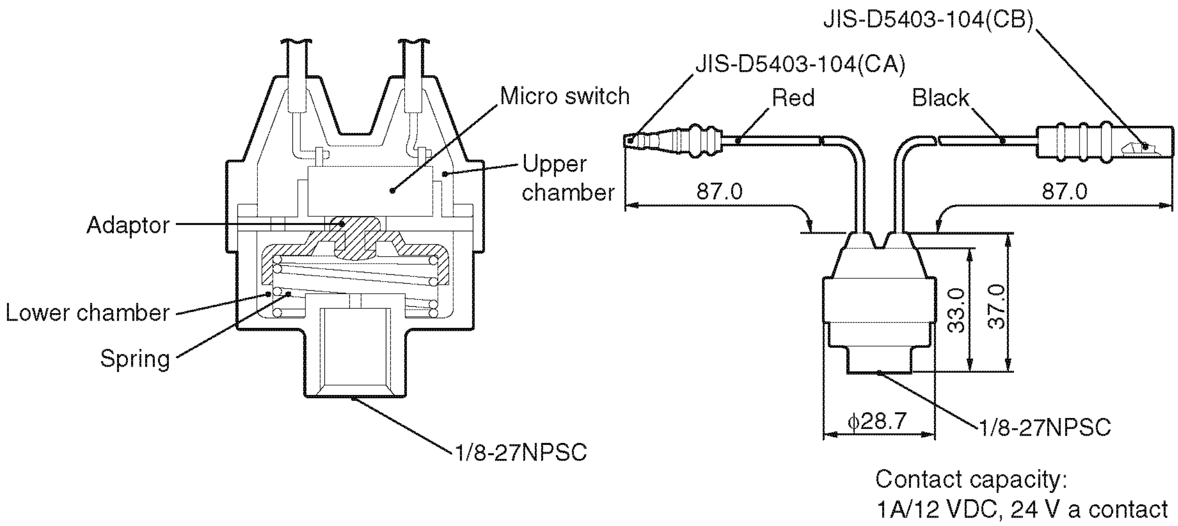

Figure 7-6

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 78 m/sec^2 (8G) for an air cleaner made of steel or 88 m/sec^2 (9G) for an air cleaner made of plastic. 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 *Heat Balance Evaluation on page 12-16*, reconsider the air intake position. Make sure that no water, snow or dust can enter from the intake port.

Intake Port Position

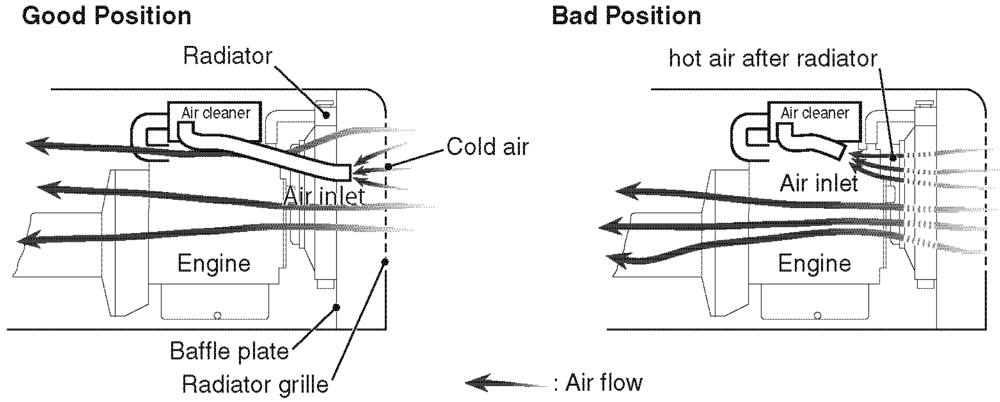

Figure 7-7

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

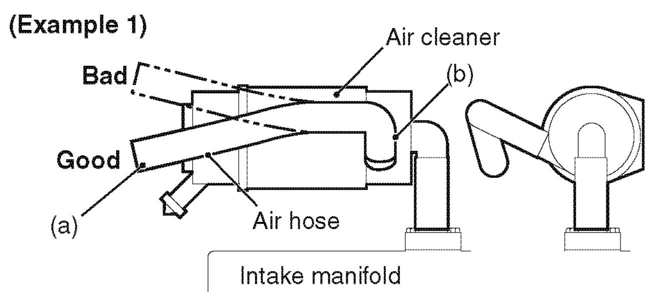

Figure 7-8

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

		Naturally aspirated engine	Turbocharged engine
Heat resistance		120°C (248°F) or higher	
Pressure resistance	Negative pressure	13 kPa (0.13 kgf/cm^2) or higher (air cleaner to air intake manifold)	29 kPa (0.3 kgf/cm^2) or higher (air cleaner to turbocharger)
	Positive pressure	—	196 kPa (2 kgf/cm^2) or higher (turbocharger to air intake manifold)
Materials		Ethylenepropylene rubber (EPDM)	

Note: 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 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

Air intake restriction is measured between the air cleaner outlet and the beginning of the engine intake manifold. Typically, a negative pressure sensor is attached to the hose that runs between the air cleaner output and the intake manifold. Negative pressure is measured by a manometer that is connected to the sensor with a piece of hose. Be sure that there is no water in the hose as it will affect the accuracy of the measurement.

The measuring device is typically configured as follows:

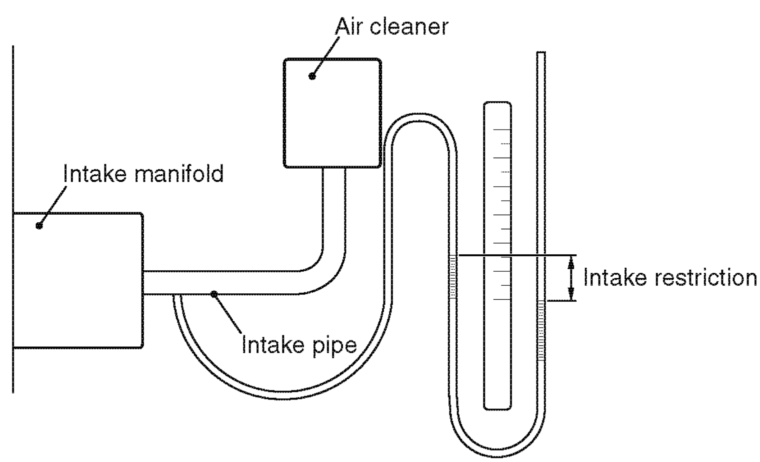

Figure 7-9

Allowable Air Intake Restriction

If air intake restriction exceeds the allowable value, review the air intake system before starting production of the driven machine. For the values of allowable restriction, See *Allowable Air Intake Restriction and Exhaust Back Pressures on page 1-30.*

Allowable restriction consists of the initial upper limit and the upper limit for air cleaner replacement. 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.

Section 8

EXHAUST SYSTEM

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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, 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 and can cause increase of fuel consumption, reduction of engine output, and worsened exhaust gas emissions/smoke density. In addition, engine performance can also be adversely affected.

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

Exhaust systems should be designed so that a 20 cm (7.87 in) extension can be installed to the end of the exhaust pipe for purposes of sampling emissions. 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 Tier3 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 step motors and they adjust the EGR rate according to the appropriate opening indicated by the E-ECU (Electronic Engine Control Unit, see "Electronic Control Manual") depending on engine speed or load conditions.

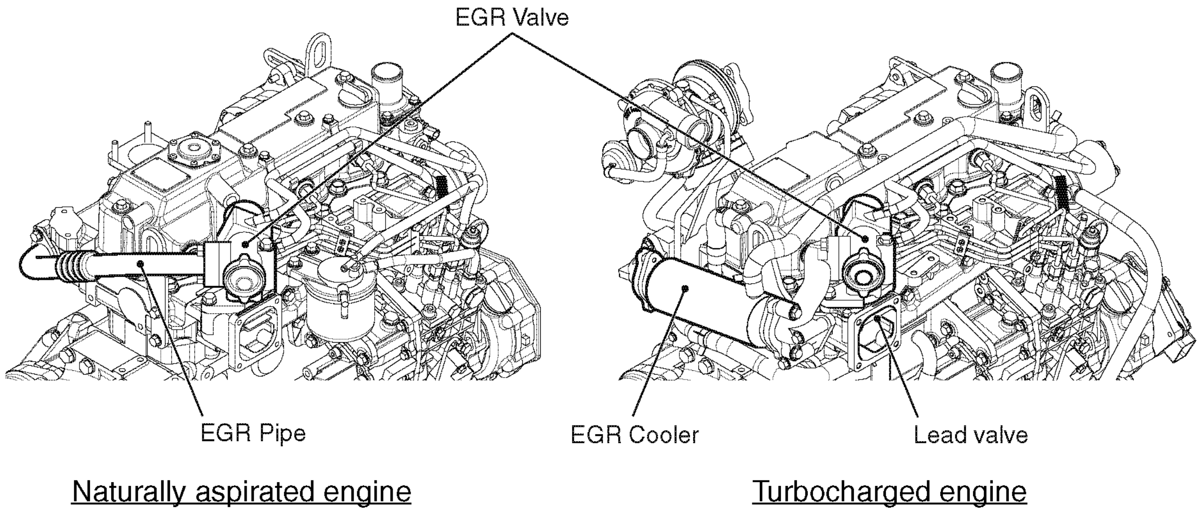


Figure 8-1

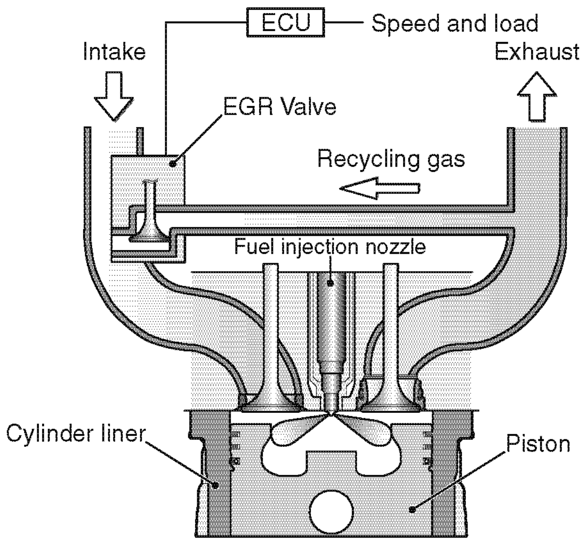


Figure 8-2

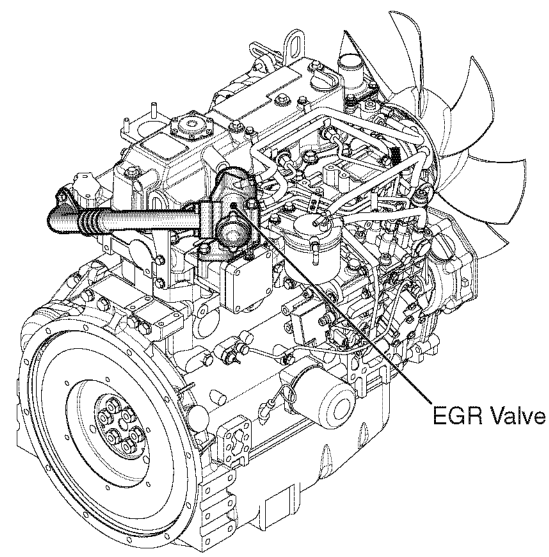


Figure 8-3

Structure of Each Device

EGR Valve

- **EGR Operation Principle**

Employ the EGR valve of step 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:

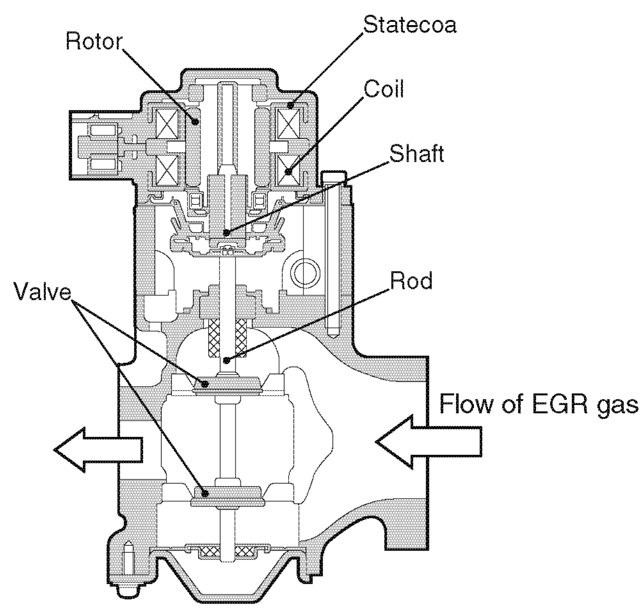


Figure 8-4

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

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.

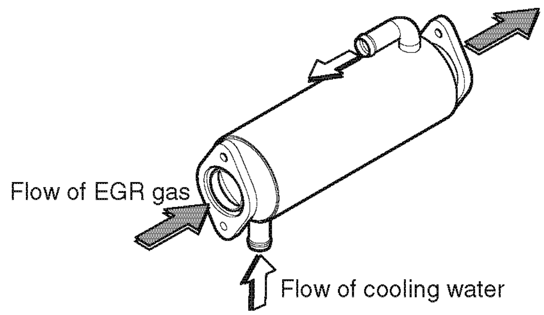
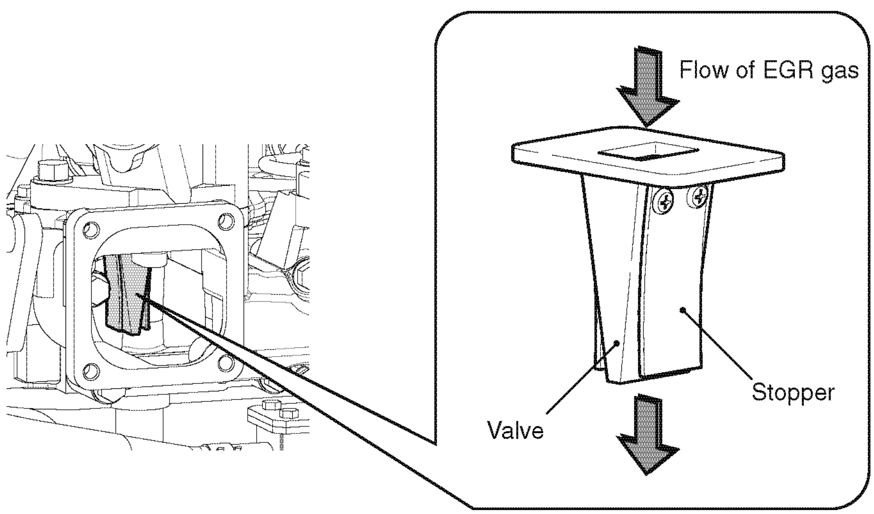


Figure 8-5

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 intake restriction can be higher than the exhaust back pressure in the middle speed range, and it may cause the EGR gas to flow back into the exhaust side without flowing into 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.



Lead valve

Figure 8-6

INTAKE/EXHAUST PRESSURE

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.

The EGR rate is determined basically by the difference between the intake pressure and exhaust pressure (intake/exhaust differential pressure). The EGR valve is only adjusting it according to the operating conditions of the engine.Therefore, the EGR system cannot operate properly as an emission control equipment unless the intake/exhaust differential pressure is within a certain range.

The intake restriction and exhaust back pressure in the initial condition must be set within the range indicated by the diagonal lines. For the actual measurement instructions, refer to 12. Matching Test Procedure.For the allowable values of each model, refer to 1. Application Standard.

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

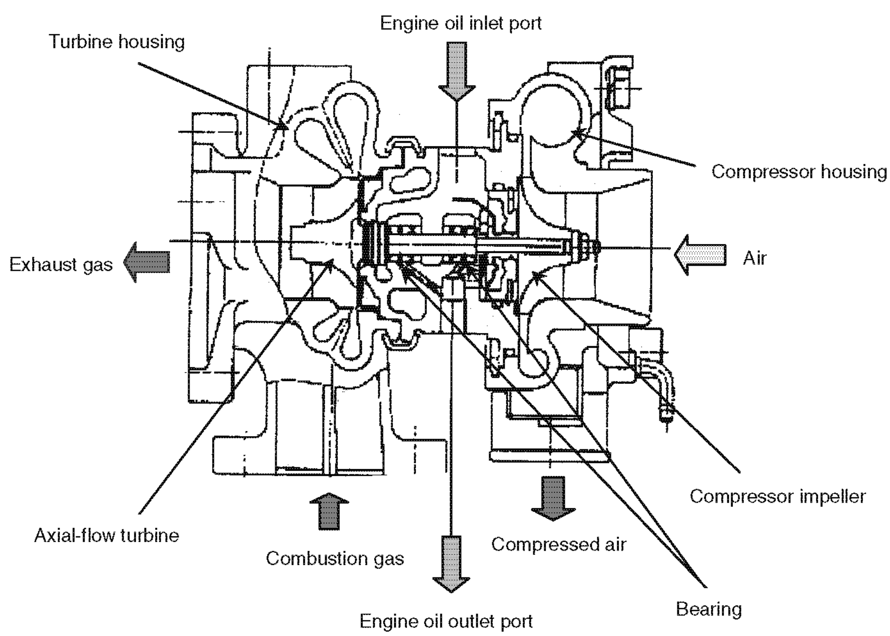


Figure 8-7

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 [32°F])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 8-8)**. Provide enough space around the waste gate valve to prevent interference.

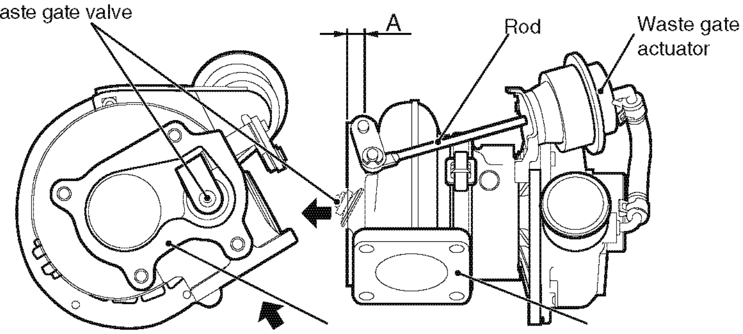
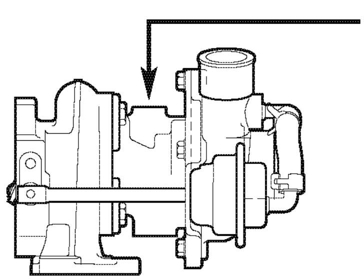


Figure 8-8

Applicable Model	Protrusion (A)	Required space
3TNV84T	4.5 mm	8.0 mm
4TNV84T 4TNV98T	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 [176°F]). A deformed hose can cause the turbocharger to overload and damage internal turbocharger components.
- Allowable vibration of turbocharger



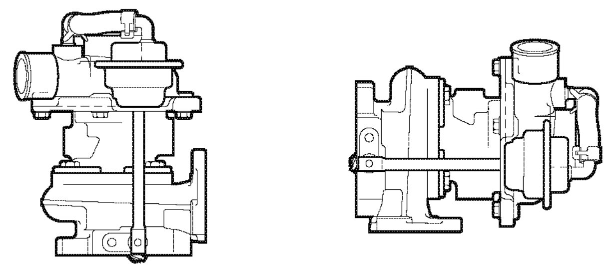
Engine oil inlet : Allowable acceleration...5.0 G

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

Figure 8-9

- 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 8-10)**.
  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 8-10

- 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
- Muffler capacity and type
- 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. See *Exhaust Gas Volume and Exhaust Back Pressure on page 8-14* 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, items b), c), and d) above must be reconsidered.

Allowable Exhaust Back Pressure

If the measured exhaust back pressure (see *Measurement of Exhaust Back Pressure on page 12-9*) exceeds the allowable exhaust back pressure, review the exhaust system before putting the driven machine into production. See *Allowable Air Intake Restriction and Exhaust Back Pressures on page 1-30* 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.

Refer to *Intake/Exhaust Pressure on page 8-7* for engines with EGR equipment.

EXHAUST MUFFLER

The purpose of the exhaust muffler is to reduce the amount of exhaust noise to an allowable level.

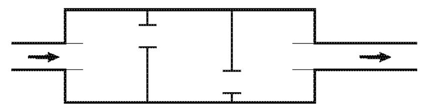
The structure and appearance of exhaust mufflers may vary, but in general they fall into three types: expansion, resonance and absorption. The following is a description of how each type of muffler attenuates exhaust system noise:

- **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.

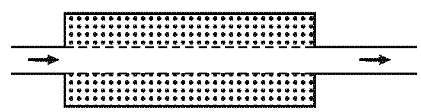


Figure 8-11

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.

To reduce exhaust noise, examine the length of the tailpipe and installation of the muffler.

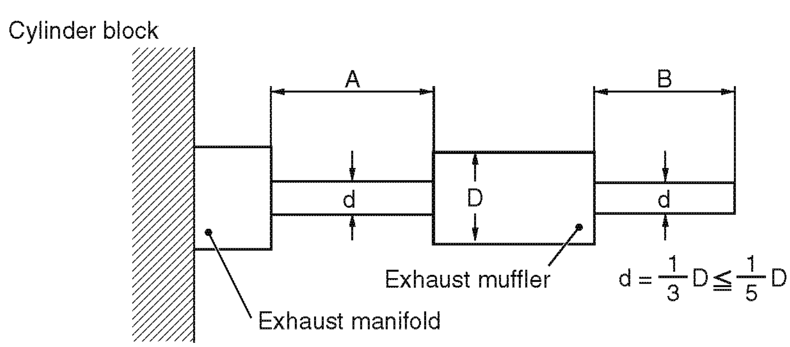


Figure 8-12

For a standard installation, the tail pipe should have a diameter “d” that is 1/3 to 1/5 the diameter “D” of the exhaust muffler. The greater the ratio, the greater the silencing effect, but make sure that the exhaust resistance does not increase too much. Another way to reduce the amount of exhaust noise is to you balance the length of exhaust pipe (“A” that connects the exhaust manifold to the muffler) with the length of length of tail pipe “B.”. The length needed for maximum silencing is determined as part of the noise reduction measure test.

Arrange the exhaust pipe and the tail pipe as straight as possible. If bending is necessary, use as large a corner radius (R) as possible for maximum noise reduction,. For the best effect, machine the end of the tail pipe diagonally rather than at right angles. The standard length of the cut section of the tail pipe is approximately three times the tail pipe diameter (d).

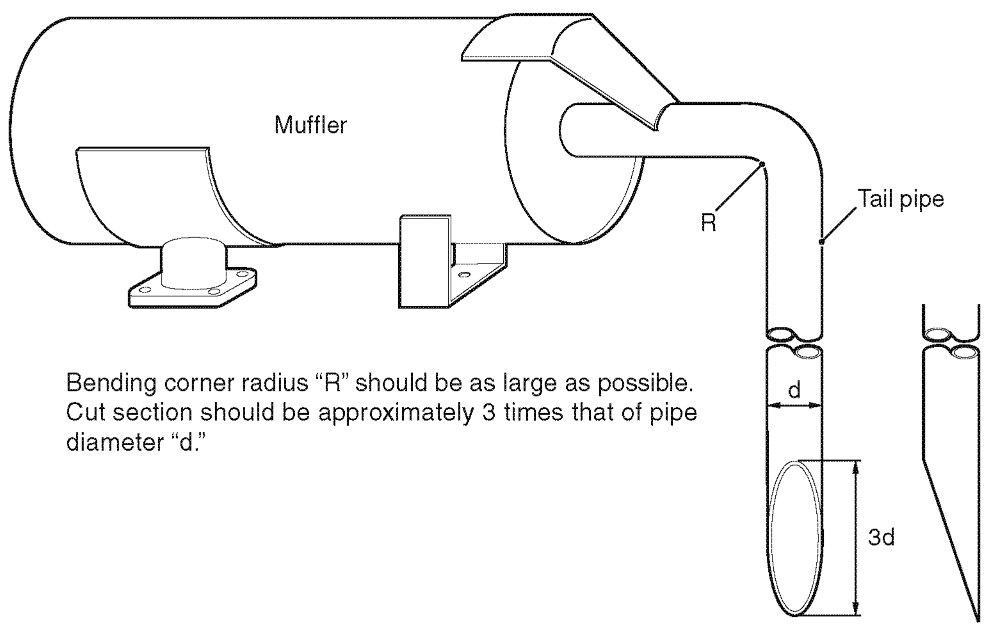


Figure 8-13

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.

Installation of Exhaust Muffler

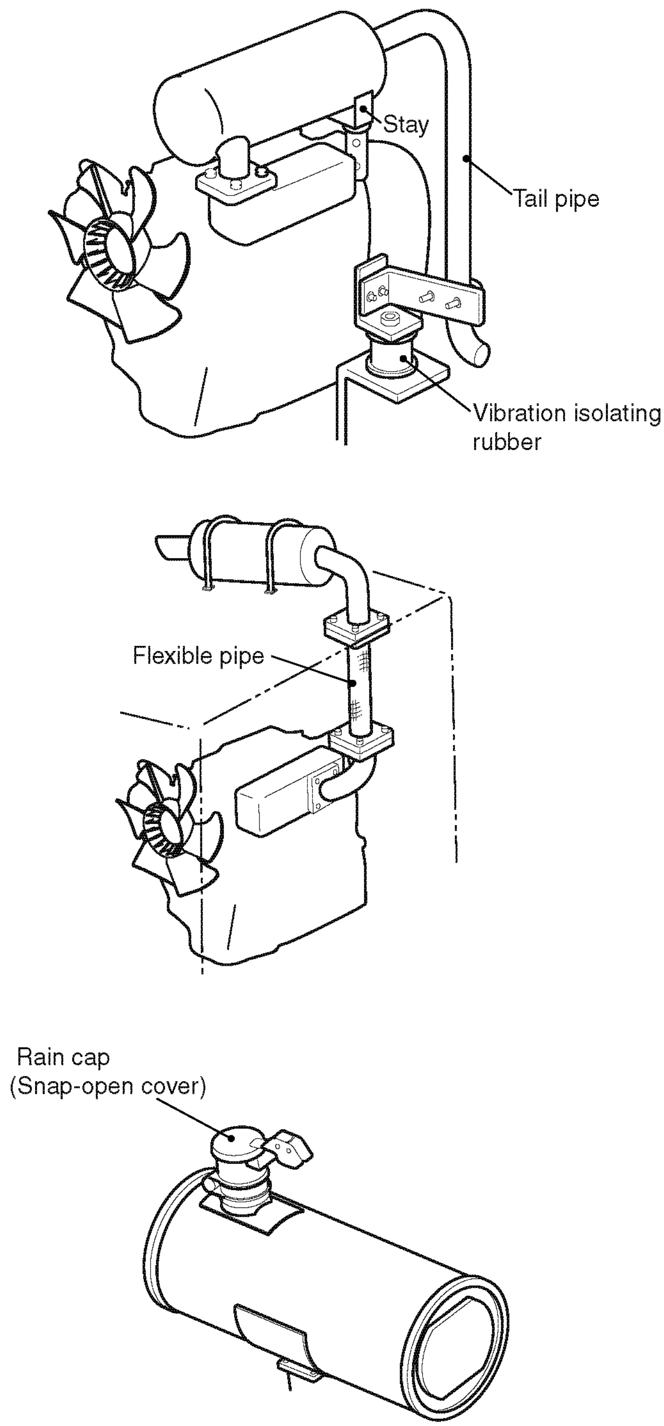


Figure 8-14

The exhaust muffler should be installed on the driven machine to reduce the amount of vibration as much as possible. When installing the muffler on the engine, mount the muffler and tail pipe with highly rigid brackets. Mount the brackets to the engine block.

If the exhaust muffler is not installed on the engine, insert a flexible pipe between the engine and exhaust muffler. If the engine is equipped with a turbocharger, do not connect the rigid pipe directly to the turbocharger. Use a flexible exhaust interconnecting pipe. (Refer to *Turbocharger on page 8-8* for turbocharger installations.)

Deposits of water inside the exhaust muffler will corrode it. Install the muffler so rainwater cannot enter the exhaust outlet or tail pipe. Special care should be taken when installing the muffler outdoors or the machine is driven outdoors.

Arrange the exhaust muffler to prevent contact with the body to prevent fire or burns.

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. See *Matching Test Procedure 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 [32°F]).

- **Naturally aspirated engine**

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

- **Normal turbocharged engine**

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

- **High turbocharged engine (with intercooler)**

$$V_d = 26.00 \times b \times P_e \times 10^{-3}/3600 \qquad \text{m}^3/\text{sec}$$

Where,

V_d	:	Combustion gas volume	m^3/sec (273 K (0°C [32°F]), 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.

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

Where,

V	:	Exhaust gas volume	m^3/sec
V_d	:	Combustion gas volume	m^3/sec (273 K (0°C [32°F]), 1 atm)
T_{ex}	:	Exhaust gas temperature K = 273 + t	K
t	:	Exhaust gas temperature	°C (°F)

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.

Note: 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 [32°F]), 1 atm)	1.29 kg/m^2
K	: Exhaust gas temperature K = 273 + t	K
t	: Exhaust gas temperature	°C (°F)
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 (see *Materials for Calculating Exhaust Back Pressure on page 8-18*)	m^2
d:	: Inside diameter of exhaust pipe (see *Materials for Calculating Exhaust Back Pressure on page 8-18*)	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.

See *Materials for Calculating Exhaust Back Pressure on page 8-18* for a summary of the coefficients and data to be used for calculation.

- **Straight pipe resistance: ΔP_1**

$$\Delta P_1 = 2\mu \bullet \frac{\gamma \bullet v^2}{g \bullet d} \bullet L \quad \text{mmAq}$$

- **Pipe joint resistance: ΔP_2**

$$P_2 = 2\mu \bullet \frac{\gamma \bullet v^2}{g \bullet d} \bullet (d \bullet A \bullet n) \quad \text{mmAq}$$

Where,

m	:	Pipe friction coefficient (see *Materials for Calculating Exhaust Back Pressure on page 8-18*)	
g	:	Specific weight of exhaust gas	kg/m^3
v	:	Exhaust gas speed	m/sec
g	:	Acceleration of gravity	9.8 m/sec^2
d	:	Inside diameter of exhaust pipe (see *Materials for Calculating Exhaust Back Pressure on page 8-18*)	m
L	:	Total length of straight portion of exhaust pipe	m
A	:	Resistance-equivalent length of joint (see *Materials for Calculating Exhaust Back Pressure on page 8-18*)	m
n	:	Number of joints	

- **Muffler resistance: ΔP_3**

(Examples)

Expansion type silencer	:	60 mmAq
Non-resistance type silencer	:	20 mmAq

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

40 mmAq

Total Back Pressure of Exhaust System: P

$$P = \Delta P_1 + \Delta P_2 + \Delta P_3 + \Delta P_4 \qquad \text{mmAq}$$

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 1-30,* 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

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

R: Radius of bending

BLACK SMOKE EXHAUST

After long periods of use, improper maintenance, or poor installation, engine performance may deteriorate and the engine may begin to discharge black smoke. Service the engine at specified maintenance intervals to reduce this emission and ensure continued compliance with EPA and EC emission control regulations and Japanese special vehicle emission control regulations.

Characteristic Factors of Black Smoke Generation

Characteristic factors of black smoke generation are shown in **Figure 8-15**.

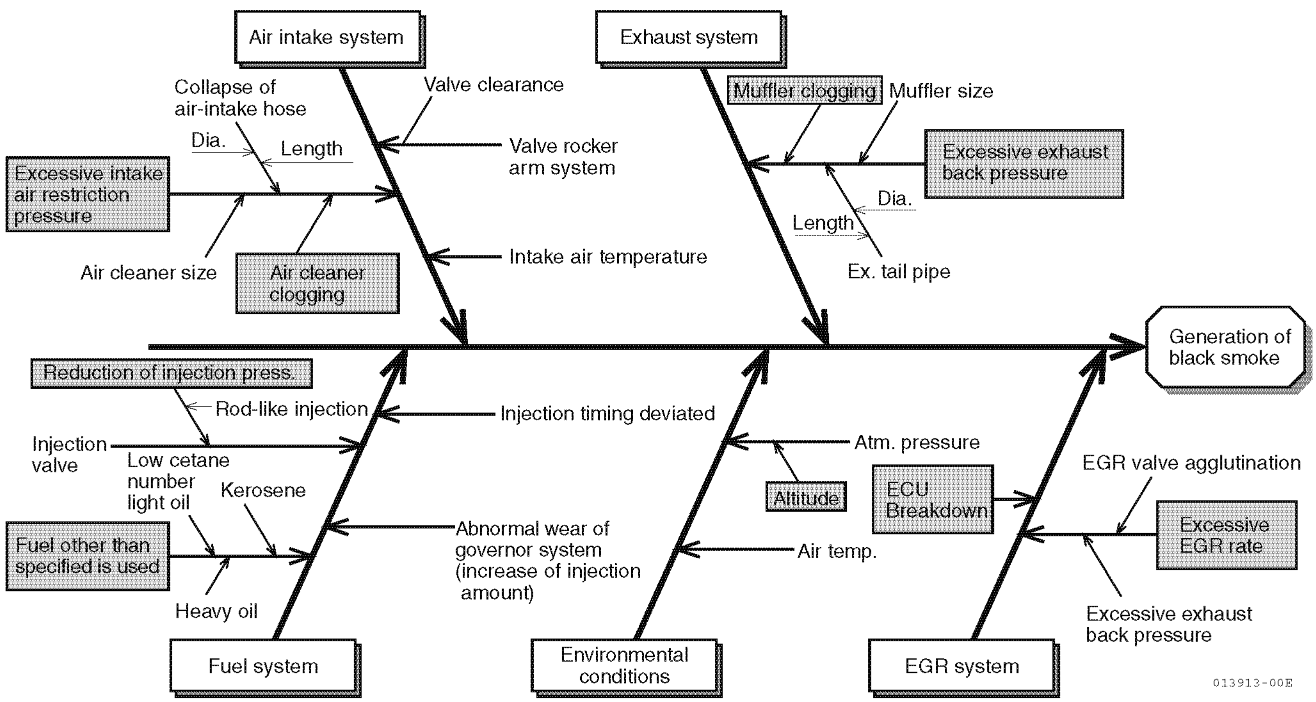


Figure 8-15

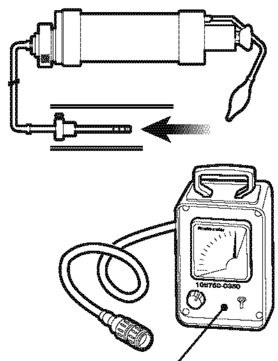
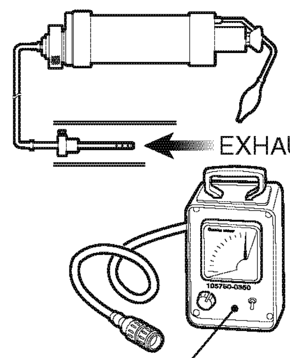
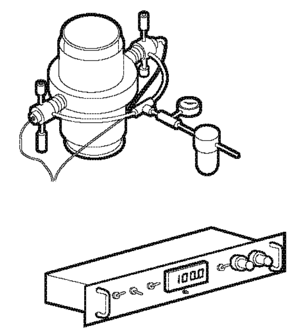
Generation of black smoke is typically caused by insufficient intake air in comparison with the amount of diesel fuel injection.

When the black smoke is generated, check the above causes **(Figure 8-15)**, especially those enclosed by a rectangle.

The allowable limit of intake air restriction pressure and exhaust back pressure are as presented in *Allowable Air Intake Restriction and Exhaust Back Pressures on page 1-30*. Users must maintain the values within the range of the allowable limits.

Measurement of Smoke Density

The methods of measuring smoke density are described below. The method used depends upon the emission control regulations that are in effect in the service area.

Instrument type	Bosch's system	Reflection system	Celesco's system (Opacity meter)
Measuring system	Filter reflection type	Filter reflection type	Light penetration type
Measuring unit	BSU	Degree of pollution (%)	Degree of transmission (%)
Measuring equipment	 Smoke meter	 Smoke meter	
Conversion (approx.)	See **Figure 8-16**.		
Application	For evaluation of general performance	Ministry of Land, Infrastructure and Transport Special vehicle emission control regulations Ministry of Land, Infrastructure and Transport Construction machinery emission secondary designation system	EPA ECE-R24 ECE-77/537

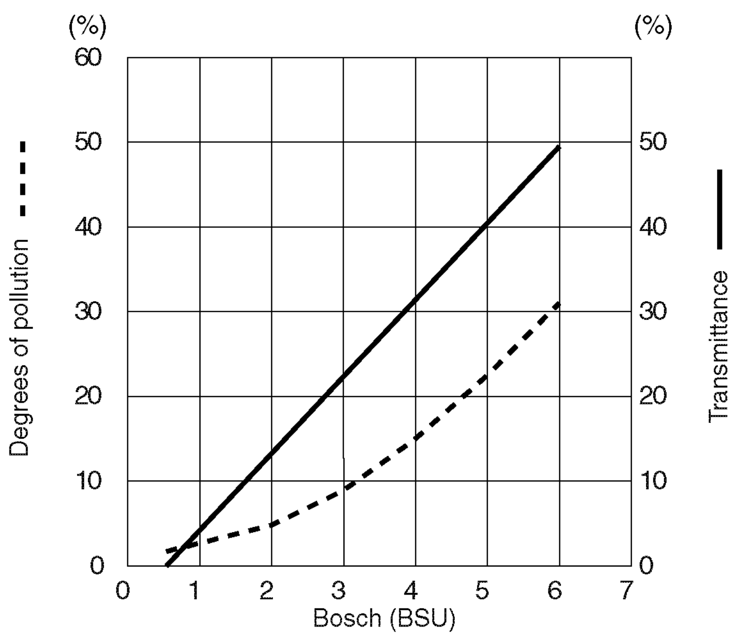


Figure 8-16

Section 9

COOLING SYSTEM

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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.

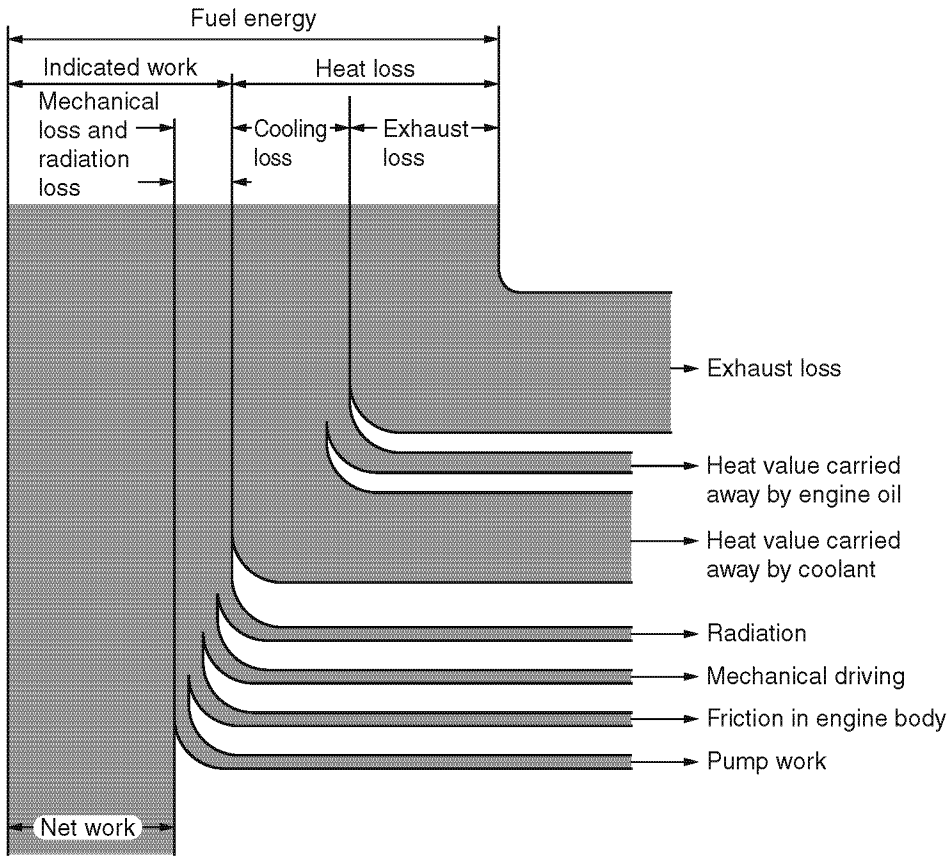


Figure 9-1

As compared with the DI system engine, the special swirl chamber system engine involves an additional cooling loss of 8 to 10%. This is because the combustion chamber, including the special swirl chamber, has a greater surface area that needs to be cooled. In addition, there is a loss of work as the gas intake and exhaust goes to and from the special swirl chamber.

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 equipped with an MP pump.

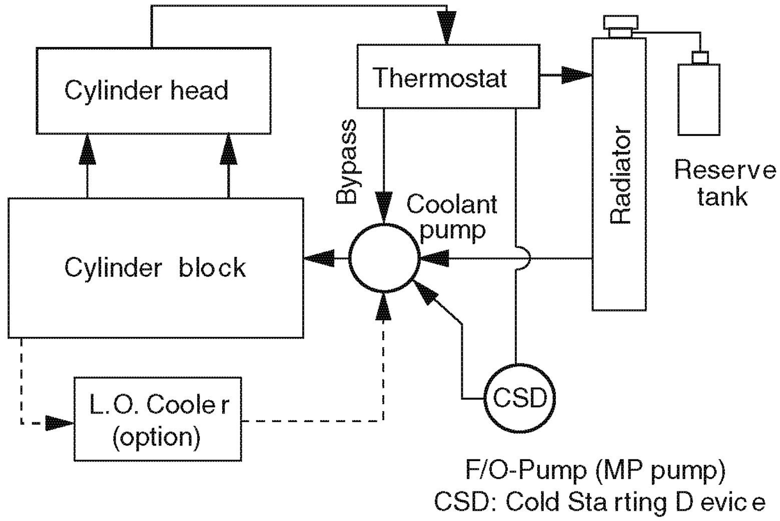


Figure 9-2

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

Note: 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/cm2, the boiling point can be raised to approximately 118°C (244°F).
- 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. (Refer to *TNV Installation Evaluation Sheets*.)

Water Quality Needed to Prepare Engine Coolant

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 (CaCO3)*	<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 (MaCO3)	<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 (SiO2)	<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		✔	

* 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.

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.

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)

IMPORTANT

- 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

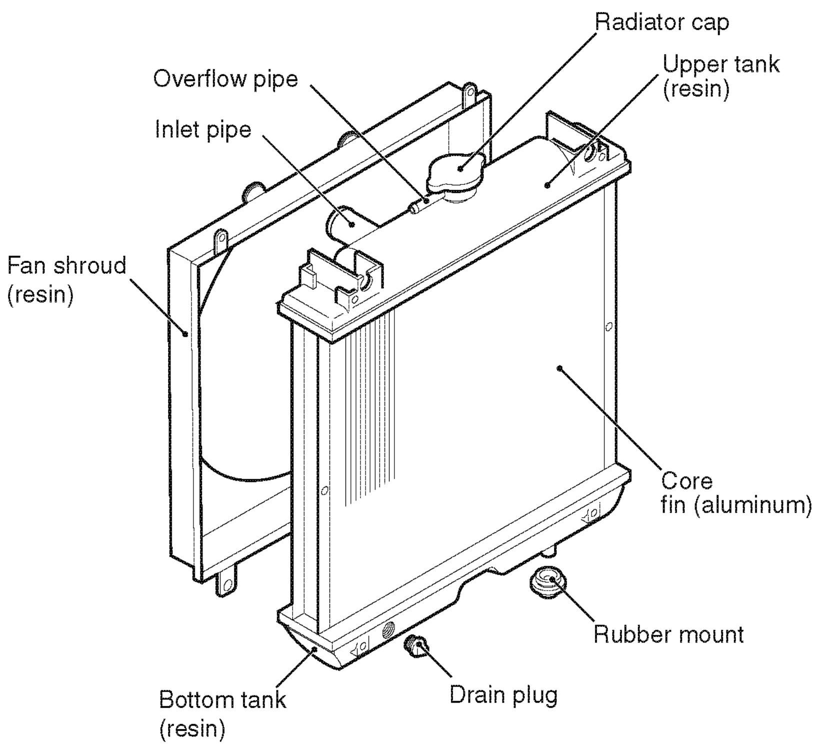


Figure 9-3

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

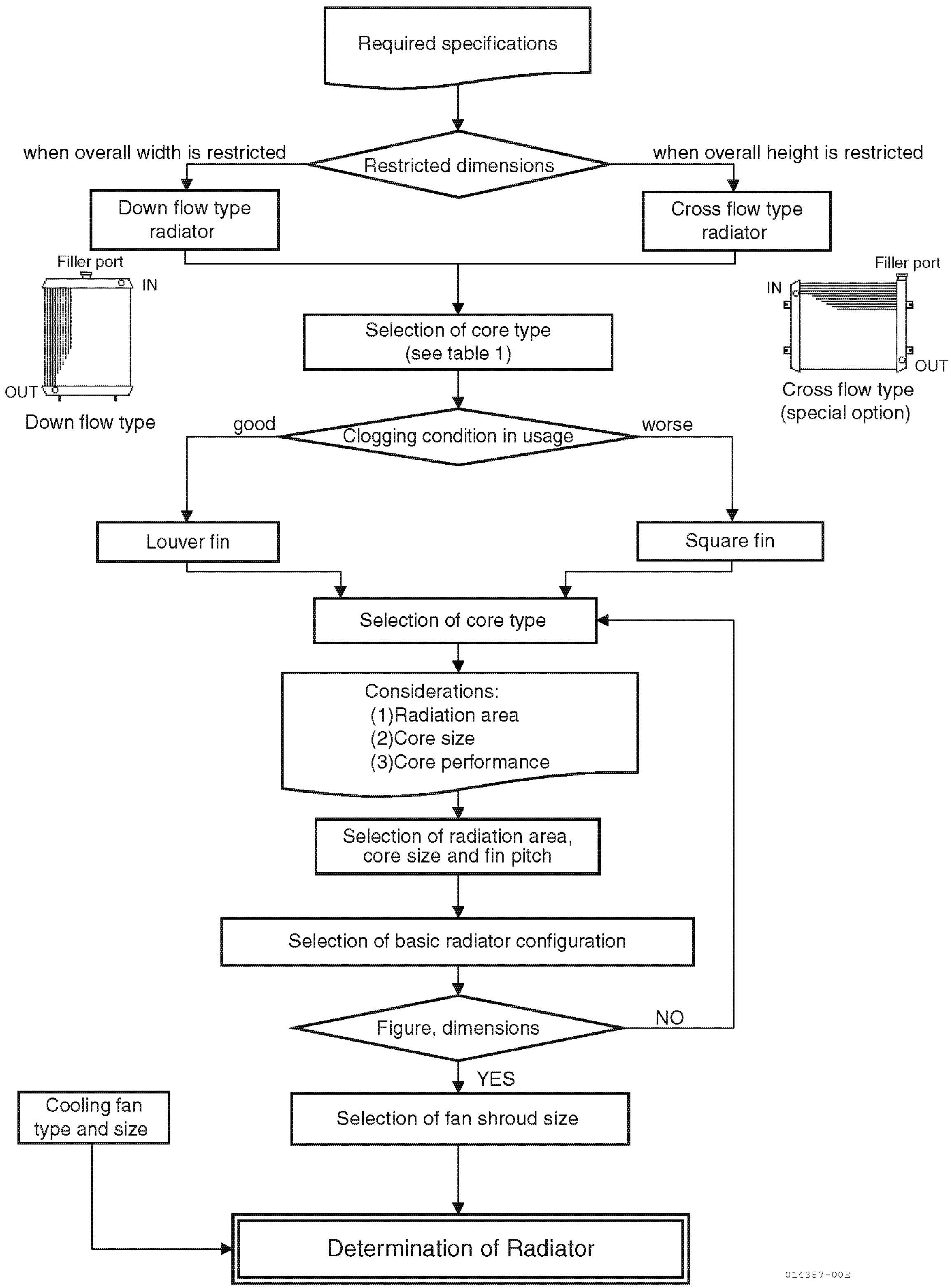
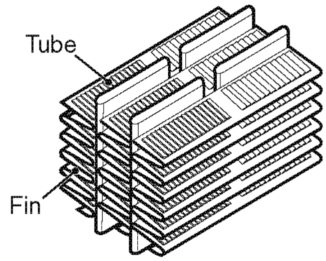
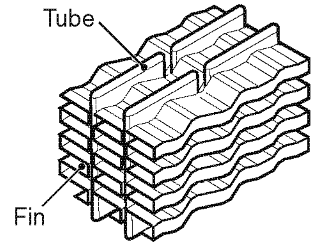
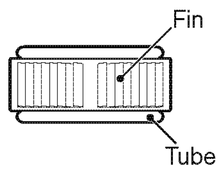
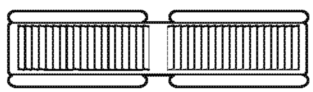
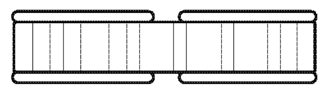


Figure 9-4

<table>
<tr><th></th><th>Louver fin</th><th>Square fin
(special option)</th></tr>
<tr><td>Corrugated fin figure</td><td></td><td></td></tr>
<tr><td rowspan="2">Core configuration</td><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

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

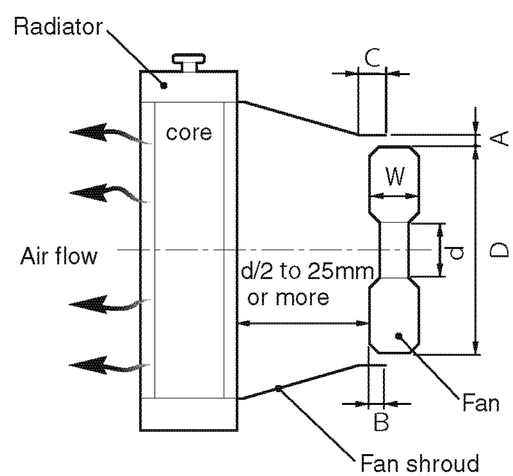


Figure 9-5

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

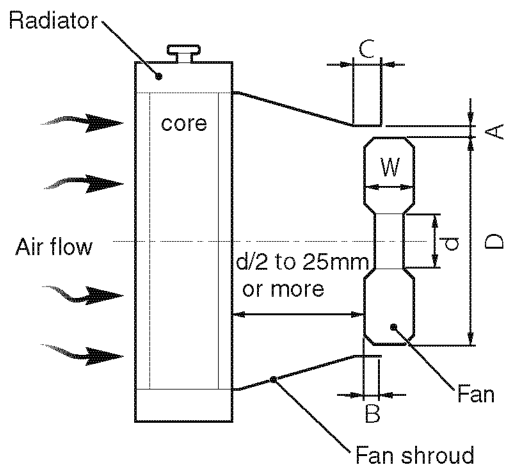


Figure 9-6

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 *Matching Test Procedure 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 (122°F) temperature difference between water and air.

<table>
<tr><th colspan="13">Nominal heat rejection rate unit: kcal/h (kW)</th></tr>
<tr><th rowspan="2">Model</th><th>Specification</th><th colspan="2">CL</th><th colspan="7">VM</th><th colspan="2">CH</th></tr>
<tr><th>min^{-1}</th><th>1500</th><th>1800</th><th>2000</th><th>2200</th><th>2400</th><th>2500</th><th>2600</th><th>2800</th><th>3000</th><th>3000</th><th>3600</th></tr>
<tr><td colspan="2">2TNV70</td><td></td><td></td><td colspan="9">20,300 (23.6)</td></tr>
<tr><td colspan="2">3TNV70</td><td colspan="9">20,300 (23.6)</td><td colspan="2">24,600 (28.6)</td></tr>
<tr><td colspan="2">3TNV76</td><td colspan="9">20,300 (23.6)</td><td colspan="2">24,600 (28.6)</td></tr>
<tr><td colspan="2">3TNV82A</td><td colspan="9">20,300 (23.6)</td><td></td><td></td></tr>
<tr><td colspan="2">3TNV84</td><td colspan="2">20,300 (23.6)</td><td colspan="7">24,600 (28.6)</td><td></td><td></td></tr>
<tr><td colspan="2">3TNV88</td><td colspan="2">20,300 (23.6)</td><td colspan="7">24,600 (28.6)</td><td></td><td></td></tr>
<tr><td colspan="2">3TNV84T</td><td colspan="2">30,700 (35.7)</td><td colspan="6">30,700 (35.7)</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">4TNV84</td><td colspan="2">30,700 (35.7)</td><td colspan="7">37,500 (43.6)</td><td></td><td></td></tr>
<tr><td colspan="2">4TNV88</td><td colspan="2">30,700 (35.7)</td><td colspan="7">37,500 (43.6)</td><td></td><td></td></tr>
<tr><td colspan="2">4TNV84T</td><td colspan="2">37,500 (35.7)</td><td colspan="7">44,500 (51.7)</td><td></td><td></td></tr>
<tr><td colspan="2">4TNV94L</td><td colspan="6">51,800 (60.2)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">4TNV98</td><td colspan="6">51,800 (60.2)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">4TNV98T</td><td colspan="6">51,800 (60.2)</td><td></td><td></td><td></td><td></td><td></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/s2 (6G) 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.

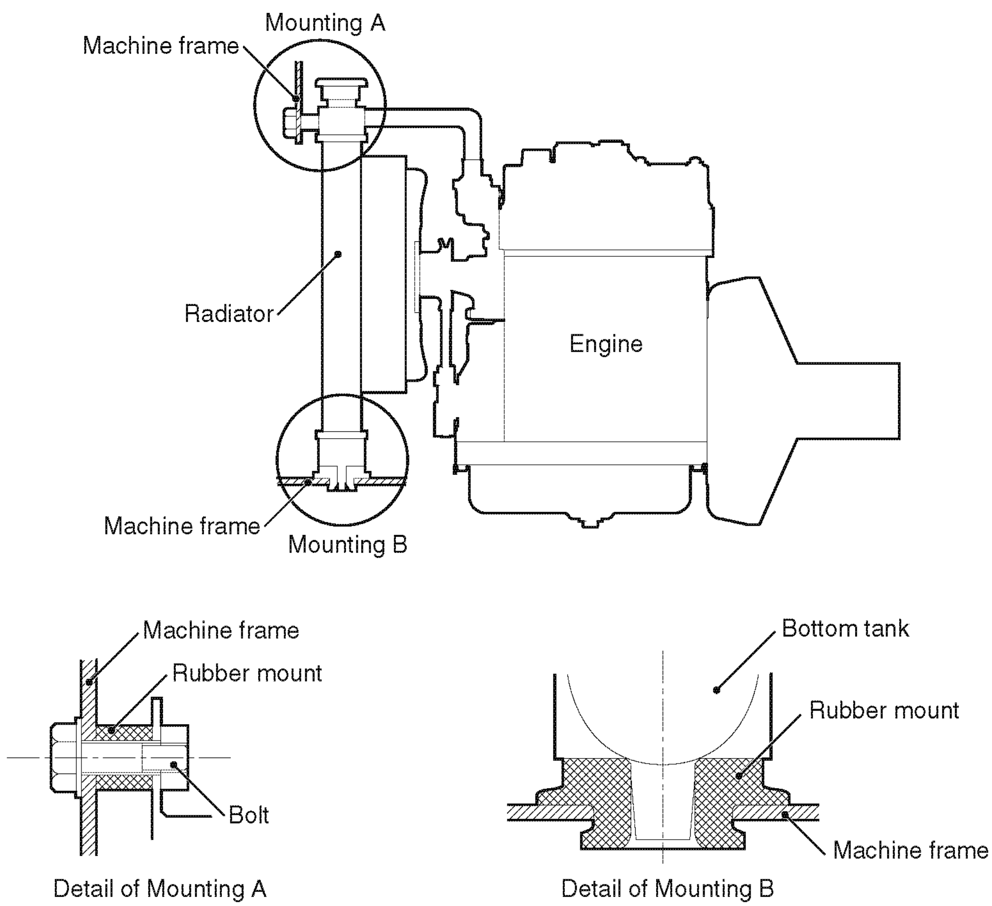


Figure 9-7

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 (shown by the arrow in **(Figure 9-7)**).
- 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)**.

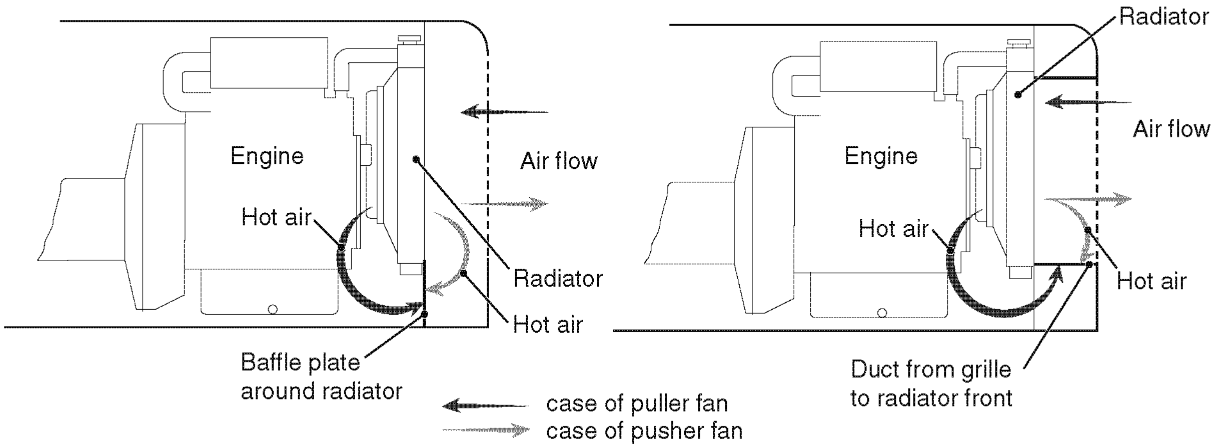


Figure 9-8

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, see *Cooling System Recovery Tank on page 9-22*.
- 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.

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 (2 kgf/cm^2) or more
Heat resistance	393 K 120°C (248°F) or more
Tensile strength	8820 kPa (90 kgf/cm^2) 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.

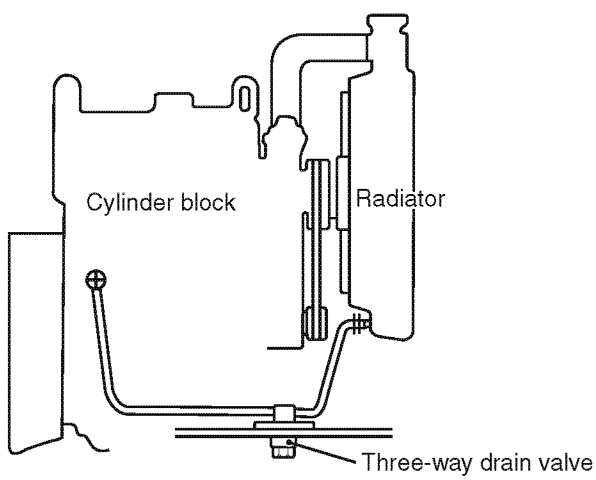


Figure 9-9

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.

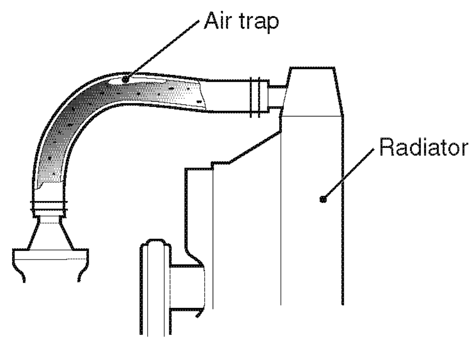


Figure 9-10

Always install an engine coolant temperature indicator. See *Engine Coolant Temperature Switch on page 9-21.*

Hose Clamps

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

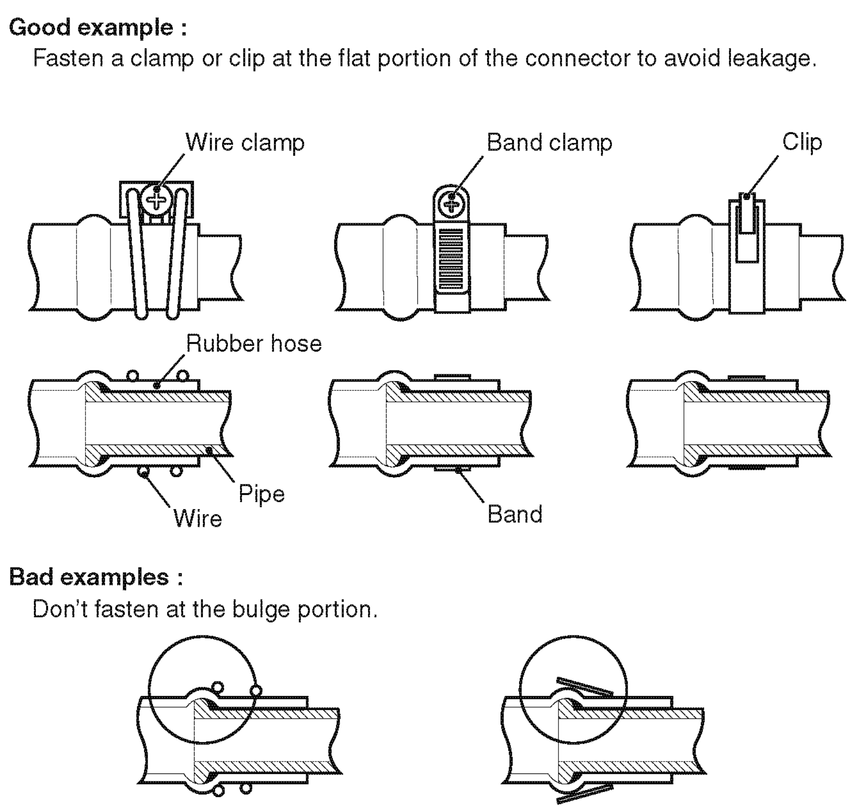


Figure 9-11

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:

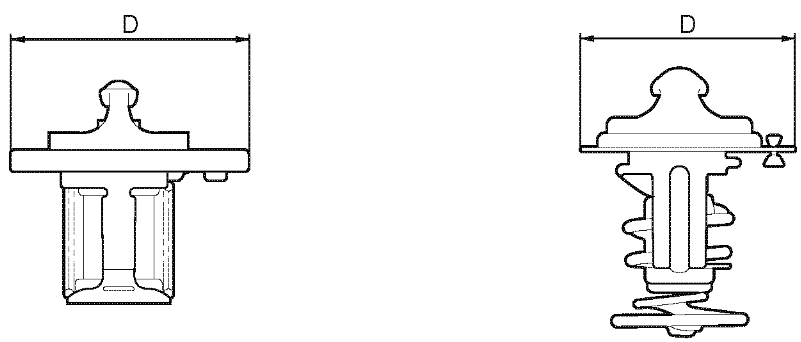
- After engine coolant is poured into the radiator, run the engine for a short period of time to remove air from the cooling system.
- The engine coolant level should be just below the engine coolant filler port on the radiator. If necessary, fill it again. Run engine long enough to open thermostat. 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**		
	2TNV70 3TNV70 3TNV76	3TNV82A 3TNV84(T) 3TNV88 4TNV84(T) 4TNV88	4TNV94L 4TNV98(T)	2TNV70 3TNV70 3TNV76	3TNV82A 3TNV84(T) 3TNV88 4TNV84(T) 4TNV88	4TNV94L 4TNV98
Part code	119717-49800	129155-49800	121850-49810	119718-49800	129574-49800	121850-49800
Thermostat type	Wax pellet type					
Valve opening temperature	71°C ± 1.5°C (160° ± 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	ϕ44 mm		ϕ54 mm	ϕ44 mm		ϕ54 mm
ID color	Blue			Red	Brown	None
Type	A	B		A	B	



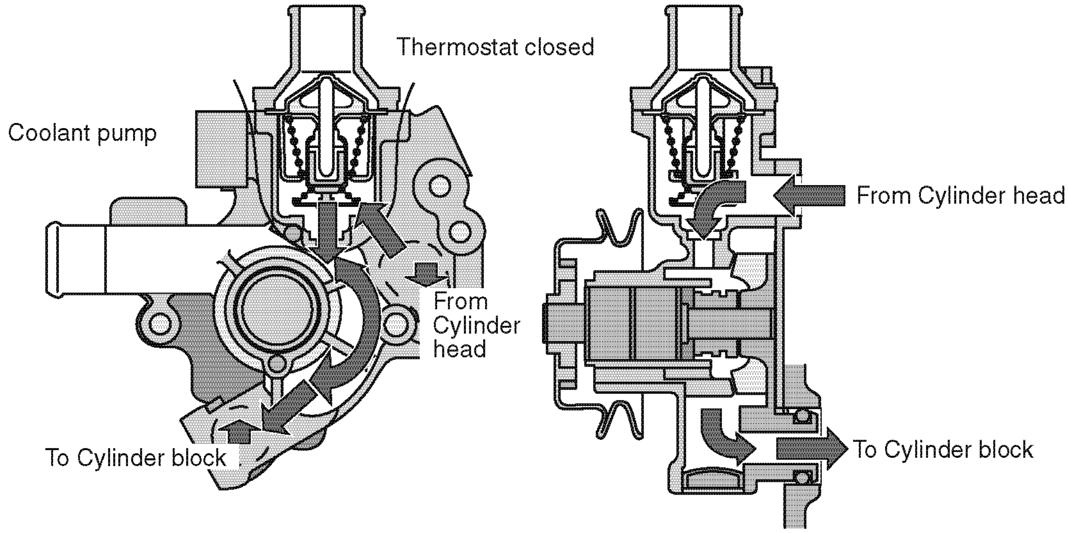
A type

B type

Figure 9-12

Operation of Thermostat and Flow of Coolant

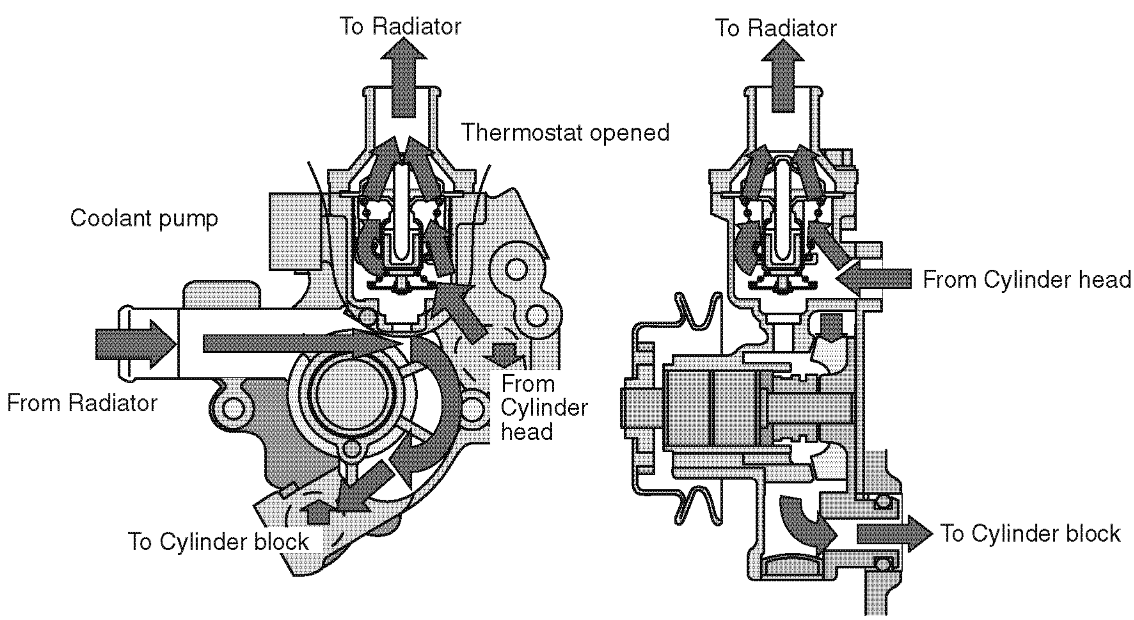
Under cold conditions



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

Figure 9-13

Under warm conditions



Engine coolant goes into the radiator when the thermostat is opened.

Figure 9-14

ENGINE COOLANT TEMPERATURE SWITCH

An abnormal increase in engine coolant temperature may cause serious engine damage. An engine coolant temperature switch is installed as standard equipment 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.

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 VDC–3.4 W or below
ID color		Gray

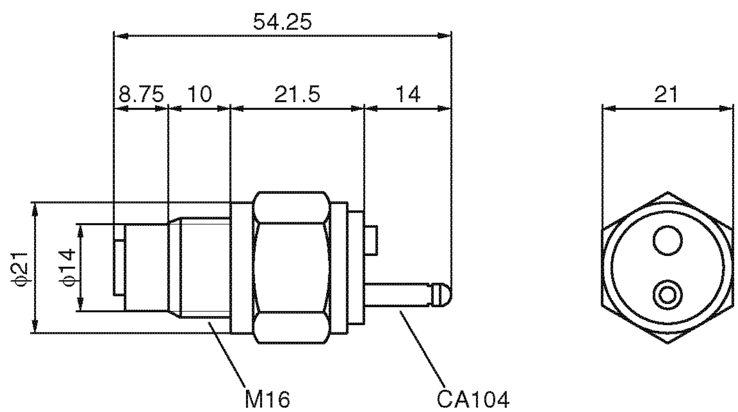


Figure 9-15

Example of wiring diagram

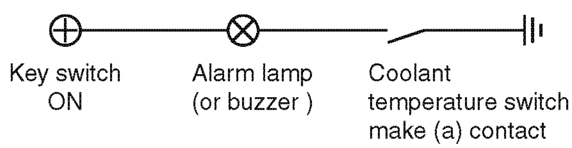


Figure 9-16

Note: 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.

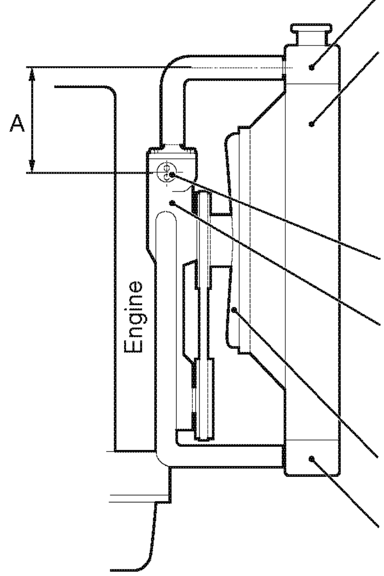


Figure 9-17

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.

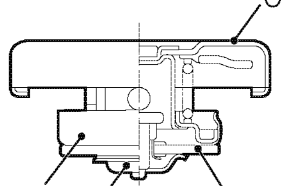


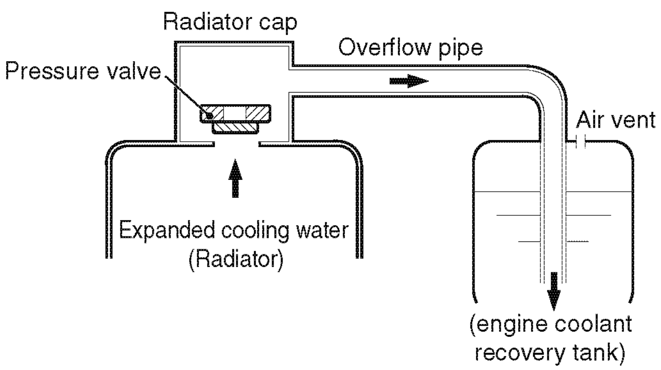
Figure 9-18

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

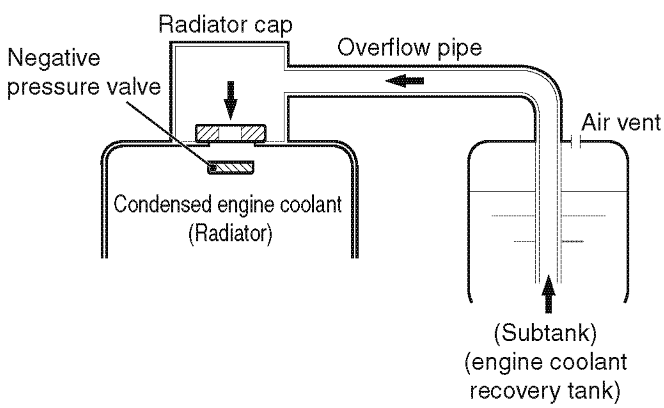
When engine coolant temperature increases it expands which causes the cooling system pressure to increase. When the cooling system pressure reaches 88 kPa (0.9 kg/cm^2) or more the pressure valve in the radiator cap opens and engine coolant flows through the overflow hose and into the engine coolant 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.

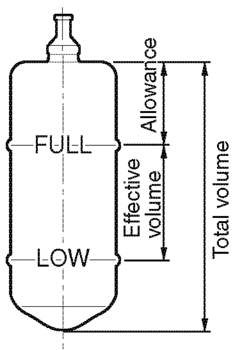


Figure 9-20

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.

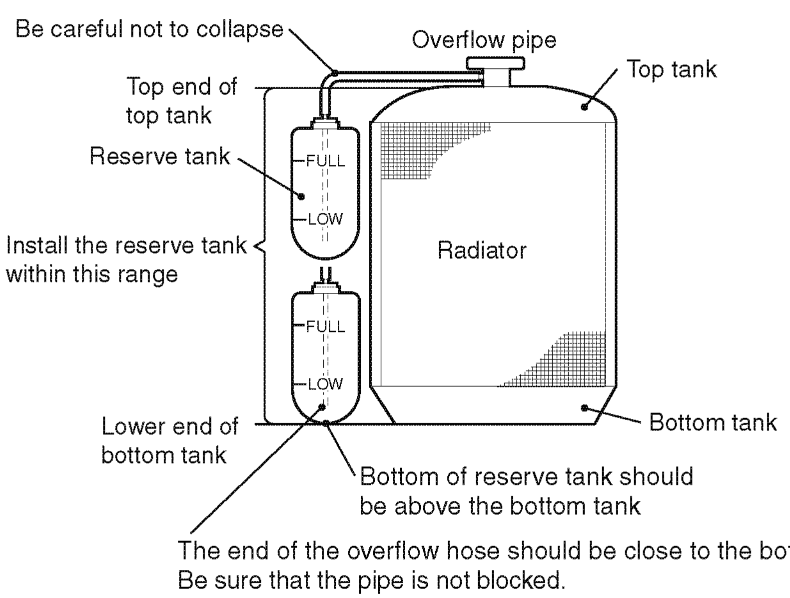


Figure 9-21

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:

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

Where,

q	:	Heat rejection to engine coolant	kJ/h(kcal/h)
f	:	Heat rejection ratio to engine coolant	
b	:	Specific fuel consumption	g/kW • h
P_o	:	Engine output	kW
H_u	:	Lower heat value of diesel fuel 4.3116×10^4	kJ/kg (10300 kcal/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

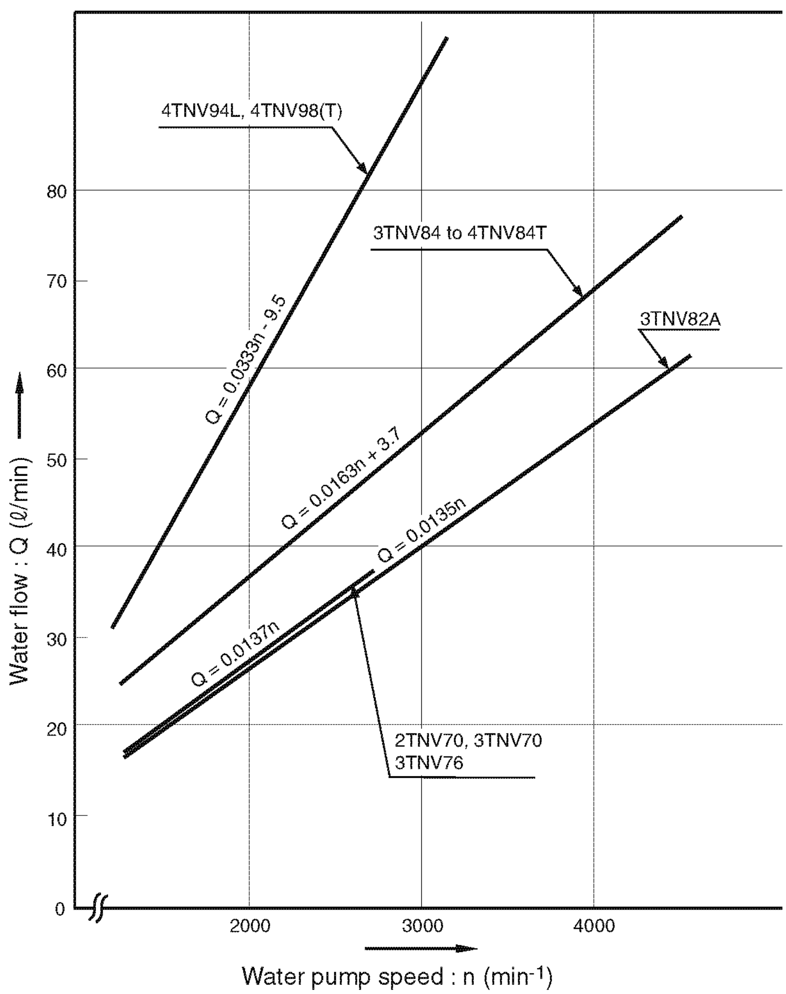
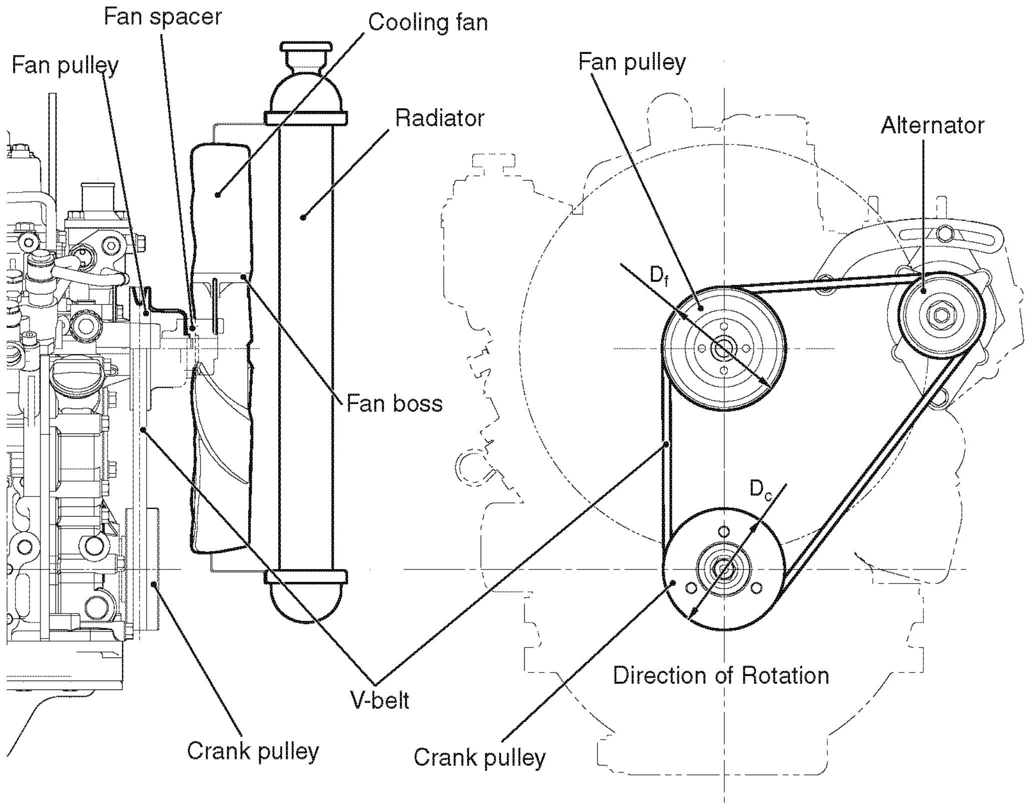


Figure 9-22

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.

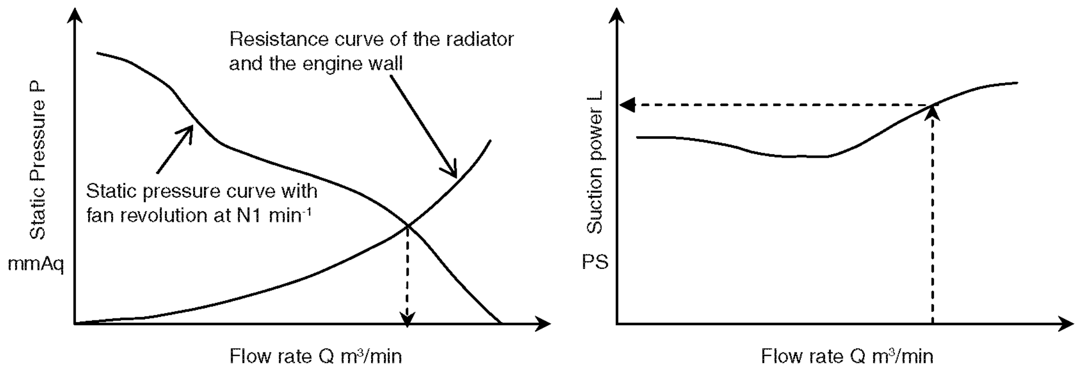


Figure 9-24

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)**.

Note: If the V-pulley ratio or the fan type is changed, the net engine output will be affected (See *Specifications on page 3-5*).

The standard fan diameter for each engine is shown in the table below. Specifications must be determined for each application.

Fan Dia.	2TNV70	3TNV70	3TNV76 3TNV82A	3TNV84 3TNV88	4TNV84 4TNV88	4TNV94L 4TNV98
ϕ 290	✔					
ϕ 300		✔				
ϕ 335			✔			
ϕ 360				✔		
ϕ 380					✔	
ϕ 430						✔

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 70m/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

The fan spacer reduces cooling air flow resistance caused by the engine block. Recommended spacer sizes are shown in the table below.

Engine model	Size of spacer (Pusher/Puller fan) (mm)
2TNV70, 3TNV70, 3TNV76	18
3TNV82A, 3TNV84/88, 4TNV84/88	25
4TNV94L, 4TNV98	40

This table is also used to adjust the location of the fan, as described in *Radiator Position on page 9-11.* Use the table as a reference when selecting a spacer from the *Yanmar TNV Option Menu Parts List, D-i.*

Contact Yanmar before using a spacer that is longer than recommended in the above table. The spacer and fan are installed on the extended line of the bearing axis that is fixed to the engine coolant pump axis. A longer spacer may decrease the natural vibration frequency of the axial system setting up resonant vibration within the normal speed range, causing damage to the bearing.

V-pulley

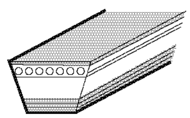
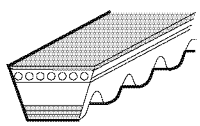
The cooling fan is driven by the crankshaft V-pulley, fan belt and a fan V-pulley. Cooling fan speed is controlled by the ratio between the crankshaft V-pulley and fan V-pulley. The ratio is D_c/D_f, with the crankshaft V-pulley outer diameter being D_c and the fan V-pulley outer diameter being D_f. (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.

See *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 low-edge 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*.

Ambient temperature and durability

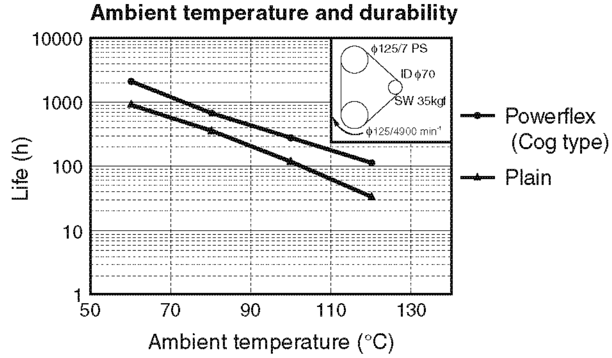


Figure 9-25

Note: 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.

The V-belt should be replaced after 1,000 hours of operation.

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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.

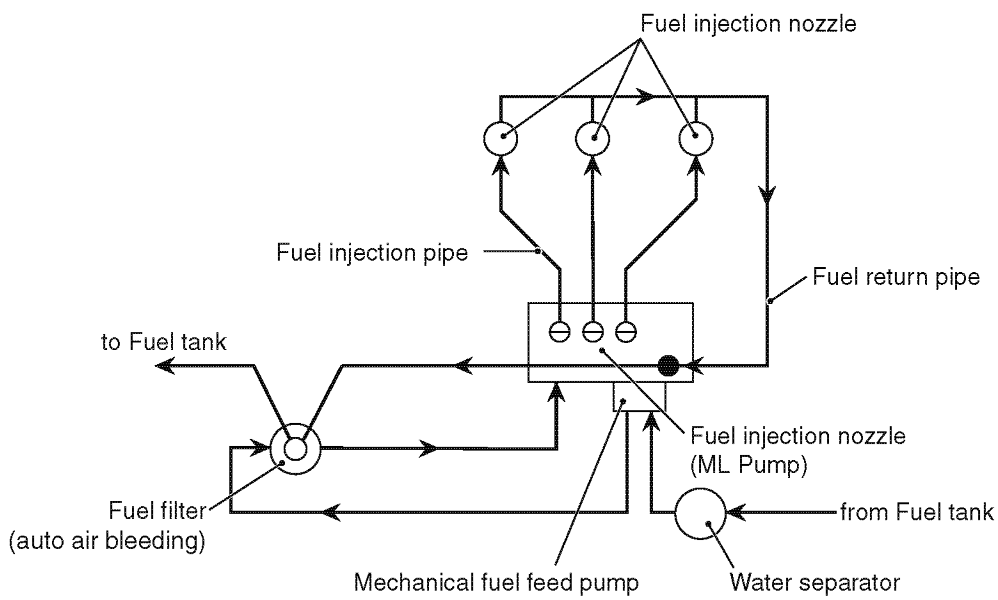
Fuel Inlet Label

Unless otherwise specified, Yanmar will also provide a supplemental fuel inlet label with each certified engine for installation on the equipment.
Permanently attach this label to the equipment near the fuel inlet.

DIESEL FUEL SYSTEM DIAGRAM

The following diagrams show standard diesel fuel system configurations.

Fuel System (IDI Engine/Equipped with Mechanical Fuel Feed Pump)



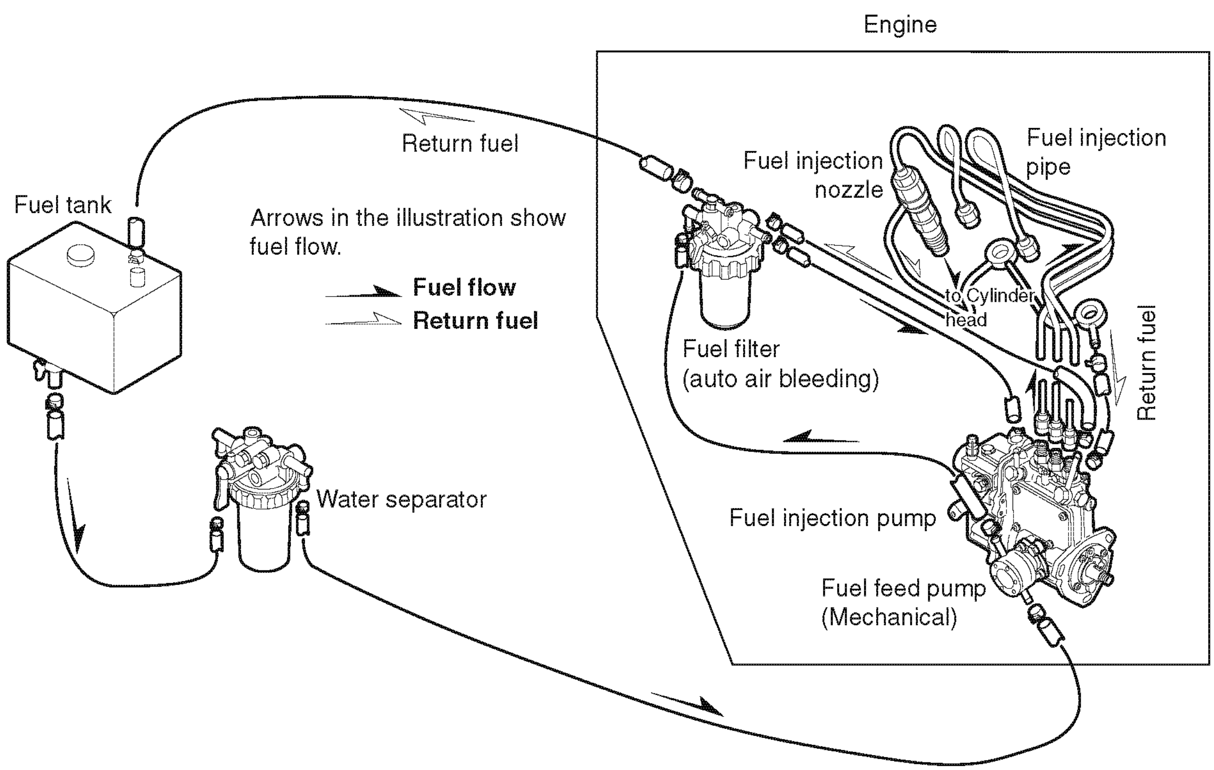
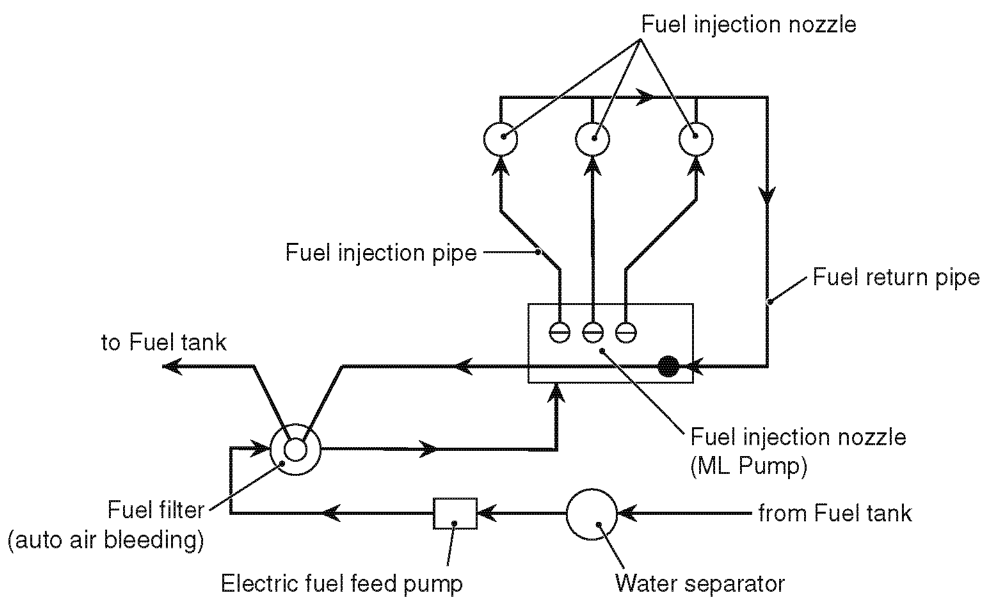


Figure 10-1

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



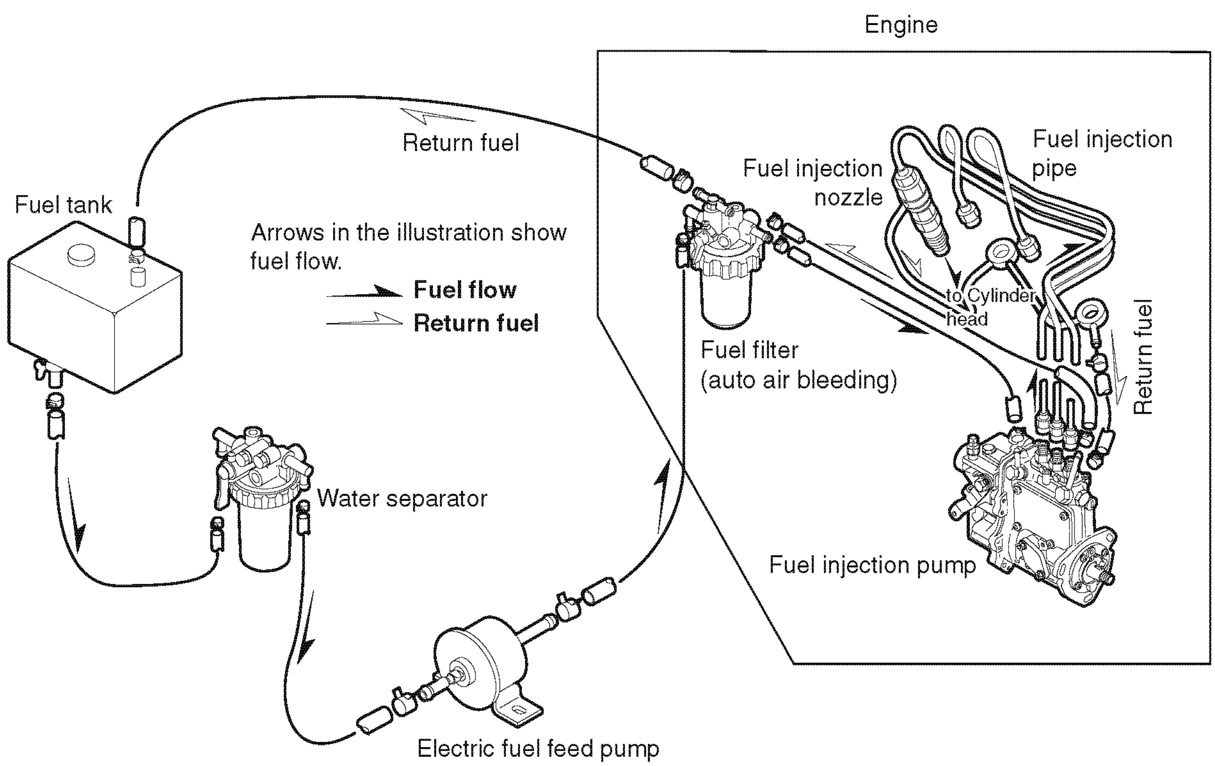


Figure 10-2

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

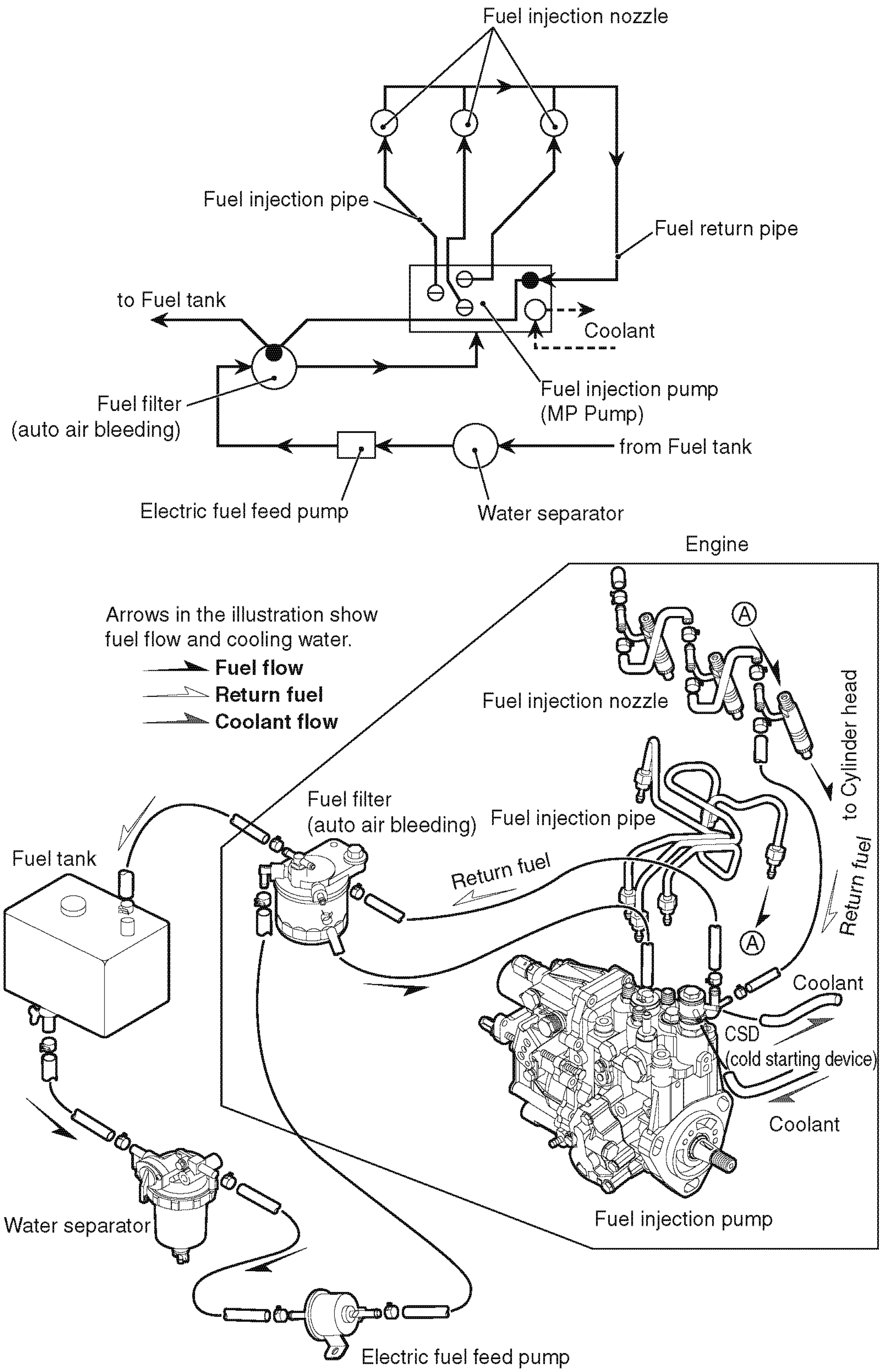


Figure 10-3

STANDARD DIESEL FUEL LINE LAYOUT

There are two typical diesel fuel line layouts for TNV engines. Fuel line layout shown in **(Figure 10-4)** is for IDI engines and **(Figure 10-5)** is for DI engines.

Layout for IDI Engines with ML Type Diesel Fuel Injection Pump

Diesel Fuel Line Layout for IDI Engines

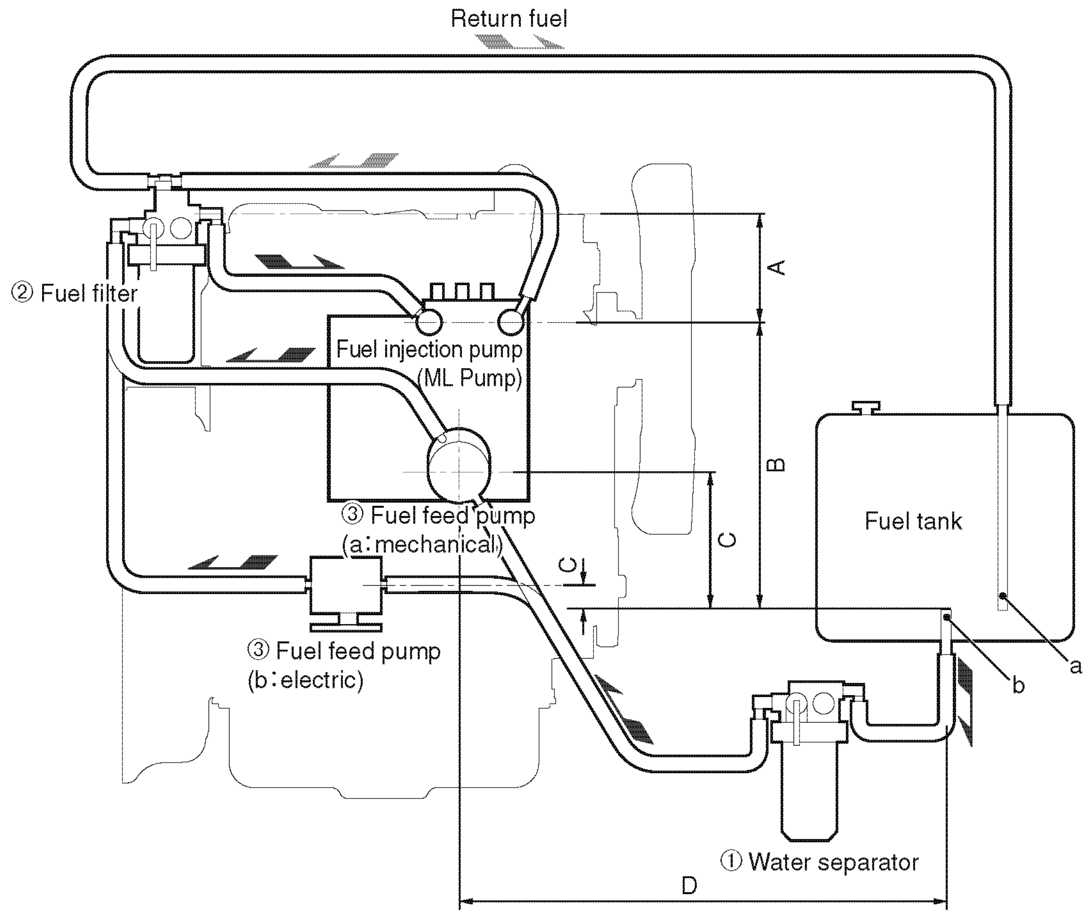


Figure 10-4

Note: 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

Diesel Fuel System Part Names and Functions for IDI Engines

No.	Part name	Function
(1)	Diesel fuel prefilter / water separator	A diesel fuel filter / water separator is mandatory for TNV engines to separate water from diesel fuel with a 100 mesh element and to prevent water from getting into the fuel injection pump and causing damage. 100 mesh or 25 to 50 μm is required for the element. When replacing or cleaning the diesel fuel filter / water separator element or diesel fuel filter, use the valve on the diesel fuel filter / water separator to shut off the fuel supply. (same as TNE engine)
(2)	Diesel fuel final filter	Has 8 μm mesh paper element inside. (same as TNE engine) There is a valve on the inlet of the diesel fuel filter for air bleeding
(3)	Diesel fuel pump	Sends diesel fuel to the diesel fuel injection pump from the fuel tank. Diesel fuel pumps are either mechanical or electrical.
	(a) Mechanical	Has a diaphragm and is installed on the diesel fuel injection pump. (same as TNE engine)
	(b) Electric	Has a solenoid and is installed outside the engine. (same as TNE engine)

Layout Dimension for IDI Engines

Position	Standard value	Content
A	50 ~ 150 mm	From diesel fuel filter outlet to diesel fuel injection pump inlet For air bleeding, diesel fuel filter outlet position should be higher than the diesel fuel injection pump inlet position.
B	≤1000 mm	Total head of diesel fuel pump (from fuel tank outlet to injection pump inlet)
C	(a) Mechanical feed pump: ≤500 mm (b) Electric feed pump: ≤400 mm	Suction head in dry condition (from fuel outlet of tank to feed pump inlet)
D	≤2000 mm	Suppression of the suction side resistance of the fuel feed pump (from diesel fuel tank outlet to diesel feed pump inlet)

Parts Specification for IDI Engines

Engine model	2TNV70 ~ 3TNV76	
Diesel fuel pump	(a) Mechanical type	:129100-52100
	(b) Electric type	:119225-52102 (standard) 129612-52100 (with water proof coupler)
Diesel fuel / water separator	129335-55700 (diesel fuel inlet downward) 121257-55700 (diesel fuel inlet upward) Filter mesh: 100 mesh (with valve)	

Fuel Filter for IDI Engines

Filter body:	119833-55620 (diesel fuel outlet downward) 119740-55600 (diesel fuel outlet sideways)
Filter element :	119810-55650
Filter mesh :	8 µm
Filtration size:	432 cm^2
For poor quality fuel :	Filter mesh: 5 µm

Contact Yanmar with questions

Layout for DI Engines with MP2 or MP4 Type Fuel Injection Pump

Fuel Line Layout for DI Engines.

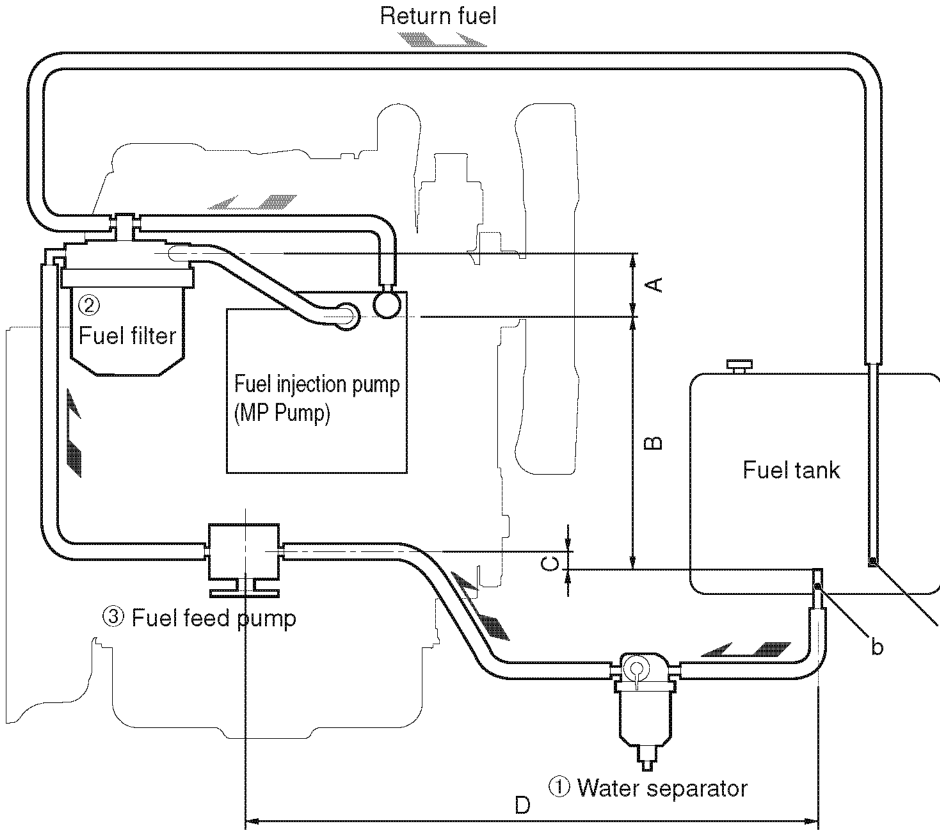


Figure 10-5

Note: 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 Engines

No.	Part name	Function
(1)	Diesel Fuel Filter / Water separator	Same as IDI engine.
(2)	Diesel fuel filter	Has 5 μm mesh paper element inside. Capacity to resist pressure is 7 kg/ cm^2. There is a valve on the inlet of the fuel filter for air bleeding.
(3)	Diesel fuel pump	Sends fuel to the fuel injection pump from fuel tank.
	Electric	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.

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

Fuel Line Layout (DI engines)

Position	Standard value	Content
A	50 ~ 150 mm	From fuel filter outlet to fuel injection pump inlet. For air bleeding, fuel filter outlet position should be higher than the fuel injection pump inlet position.
B	≤ 1000 mm	Total head of diesel fuel pump (from diesel fuel tank outlet to injection 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 feed pump inlet)

Parts Specification for Engine

Engine model	3TNV82A ~ 4TNV98	
Diesel fuel pump	Electric type:	119225-52102 (standard), 129612-52100 (with water proof coupler)
Diesel fuel filter / water separator	Standard : Filter mesh: Water reservoir:	129242-55700 (fuel inlet & outlet horizontal) 100 mesh (with valve) 150 cc
Diesel fuel filter	Bracket: Filter: Filter mesh: Filtration size:	129004-55612 (with automatic air bleeding hole ϕ0.7) 119802-55800 5 μm 2000 cm^2
Engine model	4TNV98T	
Diesel fuel pump	Same as 3TNV82A ~ 4TNV98	
Diesel fuel filter / water separator	Same as 3TNV82A ~ 4TNV98	
Fuel filter	Bracket: Filter: Filter mesh: Filtration size:	123907-55610 123907-55800 5 μm 5000 cm^2

For poor quality fuel

3TNV82A to 4TNV98	Filter Filter mesh Filtration size	129004-55800 1 μm 1650 cm^2	129907-55800 1 μm 4000 cm^2
4TNV98T	Filter Filter mesh Filtration size	129907-55800 1 μm 4000 cm^2	

DIESEL FUEL

Quality and composition of diesel fuel is very important. Poor fuel reduces engine performance and durability. Use the recommended diesel fuel or equivalent as listed below.

Recommended Diesel Fuel

Diesel fuel should comply with the following specifications.

1. Compliance with each national standard or international standards.
   For more specific details about the fuel standards, refer to the specification table of each country.
2. The following requirements also need to be fulfilled.
   - Cetane number should equal 45 or higher.
   - Sulfur content of the diesel fuel should not exceed 0.5% by volume and preferably be below 0.05%.
   - Water and sediment in the diesel fuel should not exceed 0.05% by volume.
   - Ash should not exceed 0.01% by mass. Al, Na and Mg should be below 10 mass ppm.
   - 10% carbon residue content of the fuel; it should not exceed 0.35% by volume and preferably be below 0.1%.
   - 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, residual fuels.

NEVER mix kerosene with diesel fuel.

NEVER use residual fuels that cause diesel fuel filter clogging and carbon deposits on the nozzles.

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:

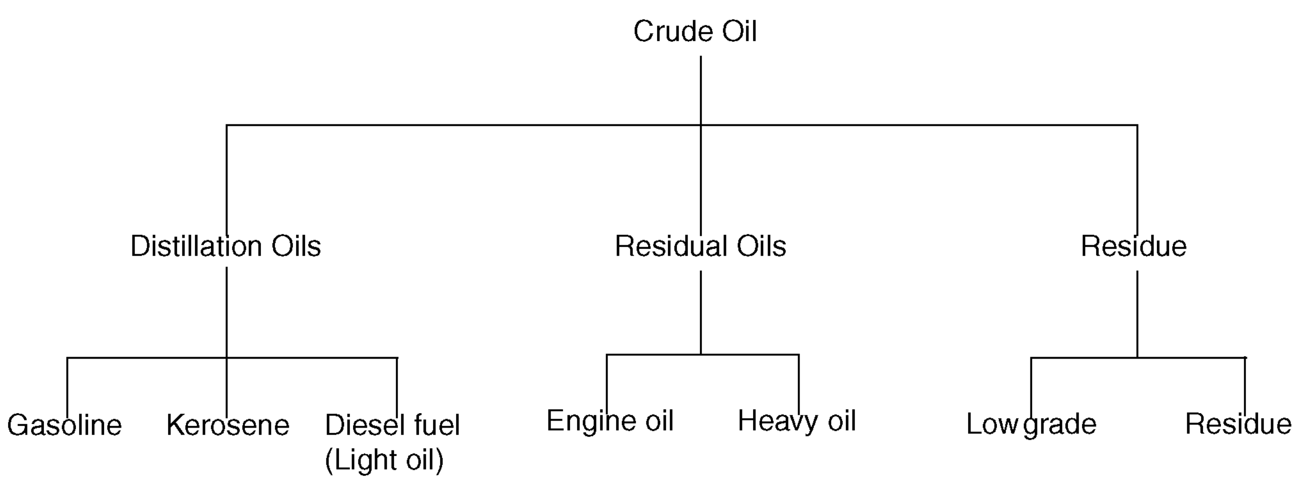


Figure 10-6

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 (For details, refer to the specification table of each country)

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 (59°F). Specific gravity falls by about 0.0007 for every 1°C (1.8°F) 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 (122 to 140°F) 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.

Note: Viscosity is represented by Saybolt or Redwood specifications. The JIS has a kinematic viscosity of 50°C (122°F) for heavy oil and 30°C (86°F) for light oil. Internationally, it is common to show the specification by Redwood (RW) at 40°C (104°F). The unit is the Stokes. Usually, 1/100 of a Stokes, i.e., centistokes (cSt) is used. JIS specifies 20 cSt or below for Heavy Oil A and more than 2.5 cSt for light oil. Viscosity of 2.5 to 5.0 cSt at 30°C (86°F) is recommended.

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, and exhaust pipe. Higher sulfur content results in higher particulate emission. The lower the sulfur content, the better. Sulfur content of below 0.5% (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 diesel fuel injection pump and the nozzles. 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.

U.S.A, ASIA and Pacific Rim Countries - National Specifications For Diesel Fuel

(Source: (1) PETROTECH, Vol.20, No.6&7 (2) PARAMINS, WORLD WIDE WINTER DIESEL FUEL QUALITY SURVEY) Oct. 2003

Country	Standard	Grade	Aromatics contents vol%	Cetane number	Cetane index	Cloud point °C	Pour point °C	CFPP (*1) °C	Density at 15°C kg/m³		Flash point °C (PM)(*5)	Kinematic viscosity (mm²/sec)				Ash content mass%	Water content vol%	Particulates mg/l	Copper corrosion 3h at 50°C	Carbon residue (10%btms) mass%	Sulfur mass%	Sedi-ment mass%	Distillation temp. (°C)						
												at 20°C		at 40°C									IBP	10%	50%	65%	85%	90%	95%
			max.	min.	min.	max.	max.	max.	min.	max.	min.	min.	max.	min.	max.	max.	max.	max.	max.	max.	max.	max.	min.	min.	max.	min.	max.	max.	max.
KOREA	KS-M-2610	No.1 Summer			50		–10				40			1.4	2.5	0.01				0.15	0.2							330	
		No.1 Winter			50		–25				40			1.4	2.5	0.01				0.15	0.2							330	
		No.2 Summer			45		–5				40			2	5.8	0.01				0.2	0.2							360	
		No.2 Winter			45		–18				40			2	5.8	0.01				0.2	0.2							360	
THAILAND	TSI	Type1		47	47		10		810	870	52			1.8	4.1	0.01	0.05		1	0.05	1.0							357	
		Type2		47	47		10		810	870	52			1.8	4.1	0.01	0.05		1	0.05	0.5							357	
CHINA	GB 252	No. 0		50	50		0				60	3	8			0.003	0.03		1	0.3 (CCR (*3))	0.5				300			355	365
		No.10		50	50		–10				60	3	8			0.003	0.03		1	0.2 (CCR)	0.5				300			350	360
INDIA	IS-1460	HSO		42							32 (Abel)			2	7.5	0.01	0.05		1(100°C)	0.2 (RCR (*4))	1.0	0.05							
		LDO		42										2.5	16	0.02	0.25		2(100°C)	1.5 (RCR)	1.8	0.1							
INDONESIA	MIGAS			45	48		18.3				65.5			1.6	5.8	0.01	0.05		1(100°C)	0.1 (CCR)	0.5	0.01							
MALAYSIA	MS123			45	47	47	15				60			2	5.8	0.01	0.05		1(100°C)	0.2 (CCR)	0.5	0.01							
PAKISTAN		Summer		45	45	5	0		820	870	66			1.6	7.5	0.01	0.1		1(100°C)	0.1 (CCR)	1.0	0.01							
		Winter		45	45	–1	–6		820	870	66			1.6	5.5	0.01	0.1		1(100°C)	0.1 (CCR)	1.0	0.01							
PHILIPPINES	PNS20			40	45	20		17			62			1.7	6		0.1			1.0 (CCR)	0.8								
TAIWAN	CNSK5024				46		–4				50			1.7	4.1	0.01	0.05		1(100°C)	0.1	0.3								
AUSTRALIA	AS1987			45					820	870	61.5			1.9	5.5	0.01	0.05		2(100°C)	0.2 or 0.16	0.5	0.01							
NEW ZEALAND					47						63			1.9	4.5		0.05			0.2	0.3								
BAHRAIN					50	2	–3		830	870	60						0.05			0.2	1.0							357	
U.A.R. (the United Arab Republic)					50	15		12	820	870	65					0.01	0.05		1(100°C)	0.2	1.0						357		
BRAZIL Federative Republic of Brazil)	DNC (09/96)				45			5	820	880				1.6	6	0.02	0.05 (water & sediment)		2										
JAPAN Note: Cetane No. is available for cetane index.	JIS K2204	Special No.1			50		+5				50	2.7min. (at 30°C)								0.1	0.005 (after 2004)								
		No.1			50		–2.5	–1			50	2.7min. (at 30°C)								0.1									
		No.2			45		–7.5	–5			50	2.5min. (at 30°C)								0.1								350	
		No.3			45		–20	–12			45	2.0min. (at 30°C)								0.1								330	
		Special No.3			45		–30	–19			45	1.7min. (at 30°C)								0.1								330	
U S A Note: For LS No.1 & 2, Cetane index is available for cetane No.	ASTM D 975-94	LS No. 1-D	35	40	40	6°C below ambient temp. (*2)	–	–	–	–	38			1.3	2.4	0.01	0.05		NO.3	0.15 (RCR)	(1) 0.05 (after Oct.1995)							288	
		LS No. 2-D	35	40	40		–	–	–	–	52			1.9	4.1	0.01	0.05		NO.3	0.35 (RCR)	(2) 0.0015 (after 2006)							338	
		No. 1-D	–	40	–		–	–	–	–	38			1.3	2.4	0.01	0.05		NO.3	0.15 (RCR)	(1) 0.50 (after Oct. 1995)							288	
		No. 2-D	–	40	–	–	–20	–12	–	–	52			1.9	4.1	0.01	0.05		NO.3	0.35 (RCR)	(2) 0.05 (after 2007)							338	
		No. 4-D	–	30	–	–	–30	–19	–	–	55			5.5	24.0	0.1	0.50		–	–	(3) 0.0015 (after 2010)							–	

Note:
*1) FPP: The Filter Plugging Point temperature should be equal to or below the lowest expected fuel temperature.
*2) The cloud point should be 6°C below the lowest expected fuel temperature to prevent clogging of fuel filter by wax crystals.
*3) CCR (Conradoson method): Conradoson Carbon Residue (developed in U.S.A.)
*4) RCR (Ramsbottom method): Ramsbottom Carbon Residue (developed in EU.
*5) PM: Pensky-Martens closed cup method

European National Specifications For Diesel Fuel

(Source: (1) PETROTECH,Vol.20,No.6&7 (2) PARAMINS,WORLD WIDE WINTER DIESEL FUEL QUALITY SURVEY) Oct. 2003

Country	Standard (Institution d/m/y)	Grade	Cetane number	Cetane index	Cloud point °C	Pour point °C	CFPP (*1) °C	Density at 15°C kg/m^3	Flash point °C (PM)(*2)	Kinematic viscosity (mm^2/sec) at 20°C	Kinematic viscosity (mm^2/sec) at 40°C	Ash content mass%	Water content mg/kg	Particulates mg/l	Copper corrosion 3h at 50°C	Carbon residue (10%btms) mass%	Sulfur mass%	Distillation temp. °C IBP	10%	50%	65%	85%	90%	95%	Remarks
			min.	min.	max.	max.	max.		min.			max.	max.	max.	max.	max.	max.	min.	min.	max.	min.	max.	max.	max.	
AUSTRIA	O-Norm EN 590 (01/02/'94)	Winter	49	46	–		–20	820–860	55		2.0–4.5						0.05								
		Intermediate					–15														250	350	–	370	
		Summer					5																		
BELGIUM & LUXEMBURG	NBN	Winter	49	46	–	–	0	820–870	55		2.0–4.5						0.05				250	350		370	
		Intermediate					–5																		
		Summer					–15																		
DENMARK		CEN Diesel	49	46	–	–		820–860	55	–	2.0–4.5						0.05				250	350	–	370	
		Bus Diesel	50	47				820–855	–															325	
FINLAND	SF-EN590 Reformulated Diesel	C	49	46	–		–5	820–860	55		2.0–4.5													370	
		1	47	46	–16		–26	800–845	55		1.5–4.0								180					340	
		3	45	43	–28		–38	800–840	55		1.4–4.0								180					340	
		4	45	43	–34		–44	800–840	55		1.2–4.0								180					340	
		Summer	49	49	–5		–15	820–850	56		2.0–3.5													350	
		Winter	47	47	–29		–34	800–830	56		1.4–2.8													310	
FRANCE	EN 590:1993	Summer	49	46			0	820–860	55		2.0–4.5						0.05				250	350		370	AFNOR T60103 (equivalent to > 52 °C PM)
		Winter					–15																		
		Grand Froid					–20																		
GERMANY	DIN EN 590: 1993	Summer	49	46	–	–	0	820–860	55 (see notes)		2.0–4.5						0.05							370	EN 590 3/93
		Intermediate					–10																		
		Winter					–20																		
GREECE	EN 590: 1993	Summer	49	46	–	–	5	820–860	55	–	2.0–4.5						0.05							370	Greek Government Gazette 3336/94
		Winter					–5																		
IRELAND	IS EN 590: 1993	Summer	50	50	–	–	–	820–860	55	-	2.0–4.5						0.05							370	
		Winter			0		–12																		
ITALY	UNI-CUNA EN 590: 1993	Summer	49	46	–		0	820–860	55		2.0–4.5						0.05							370	
		Winter					–10																		
NETHERLANDS		Summer					–15										0.05							370	
		Intermediate					-5																		
		Winter					0																		
NORWAY	NS EN 590	Summer	49	46	0	–	–10	820–860	55	–	2.0–4.5													370	
		Winter			–15		–24																		
PORTUGAL	EN 590: 1993	Summer	49	46	–	–	0	820–860	55	–	2.0–4.5						0.05								
		Winter					–6																		
SPAIN		Summer	50	45	4	–	0	825–860	55	–	5.2 max						0.05							370	
		Winter			–1		–8				4.3 max														
SWEDEN	SIS 15 54 35 (13/03/'91)	Urban Diesel 1																							Further details of urban diesel grades. TD1 and TD2 will be found in Section n7.7.1.
		Summer	50	50	*0	–	–10	800–820	56	–	1.2–4.0						0.001	180						285	
		(TD1Grade)-Winter			–16		–26																		
		Urban Diesel 2																							
		Summer	47	47	*0	–	–10	800–820	56	–	1.2–4.0						0.005	180						295	
		(TD2 Grade)-Winter			–16		–26																		
		Normal Summer Diesel D 10	49	46	*0	–	–10	820–860	56	–	2.0–4.5						0.005				250	250		370	
		Winter Diesel 1 D 26	47	46	–16	–	–26	800–845	56	–	1.5–4.0								180					340	
		Winter Diesel 2 D 32	48	46	–22	–	–32	800–840	56	–	1.5–4.0								180					340	
		Winter Diesel 3 D 36	45	43	–38	–	–28	800–840	56	–	1.4–4.0								180					340	
SWITZERLAND	SN EN 590	Summer (01.05-30.09)	49	46	–	–	–10	820–860	55	–	2.0–4.5						0.05		180		250	350		370	
		All year	47	46	–	–	–20	820–845	55	–	2.0–4.0								180max.						
UK	EN 590: 1993 BS 869-A1or A2		49	46	–	–	–15	820–860	55	–	2.0–4.5						0.05				250	350		370	Alternative Standards Class A2: Off-Highway
CEN Standard (European Committee for Standardization/ Comite European de Normalisation)	European Committee Standardization EN 590: 1996	(1) for warm district: (CFPP; A~F)	49	46	–	–	–20 to +5	820–860	55	–	2.0–4.5	0.01	200	24	1	0.30	0.2 (after 1993) 0.1 (offroad, after 2007) 0.005 (offroad, after 2009) 0.05 (onroad, after 1996) 0.035 (onroad, after 2000) 0.005 (onroad, after 2005) 0.001 (onroad, after 2009)				250	350		370	
		(2) for extremely cold district: (CFPP: 0 to 4) Grade 0	47	46	–10		–20																		
		Grade 1	47	46	–16		–26																		
		Grade 2	46	46	–22		–32																		
		Grade 3	45	43	–28		–38																		
		Grade 4	45	43	–34		–44																		

Note:

*1) CFPP: The Filter Plugging Point temperature should be equal to or below the lowest expected fuel temperature.

*2) PM: Pensky-Martens closed cup method

Selection of Diesel Fuel

Select diesel fuel according to the application and the diesel fuel property list. Use the following to help identify poor quality diesel fuel.

Volatile Matter

Diesel fuel with a strong or unpleasant smell contains volatile matter and impurities.

Soot

Use the diesel fuel as a lamp oil. Good quality diesel fuel yields little soot.

Water

Soak paper in the diesel fuel and burn it. If there are cracking sounds, the diesel fuel contains water.

Impurities

Pour the diesel fuel into a glass tube, add the same amount of sulfuric acid and stir the tube. The presence of a black substance indicates impurities with a high content of brown coal and resins.

Acids

If litmus paper turns red, the diesel fuel contains acids.

Use Diesel Fuels Classified According to Ambient Temperature

Ambient temperature °C (°F)	Class of diesel fuel in JIS	Other diesel fuel
≤–5 (23)	No. 2	Equivalent to JIS
–5 to –20 (23 to –4)	No. 3	Equivalent to JIS
–20 to –30 (–4 to –22)	Special No. 3	Equivalent to JIS

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.

Sediments Inside the Crankcase

Sometimes incorrectly attributed to the engine oil quality, but 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:

Deposits in Combustion Chamber

Carbon deposits accumulate on the injection valve, exhaust valve, exhaust port, cylinder wall, piston and cylinder head vary as follows:

- Deposits decrease as the cetane number increases.
- Deposits increase as the volatile distillation temperature rises.
- Deposits increase as the viscosity rises.
- Deposits increase as the specific gravity increases.
- Deposits increase when the content of residual carbon is high.

Startability

- The higher the cetane number, the better the startability.
- Other properties have no direct relation to startability. The pour point should be considered according to the season.

Production of Smoke

- Smoke increases as diesel fuel volatility falls.
- Smoke increases with lower cetane numbers.
- Viscosity has no direct causal relation to the smoke but the production of smoke does rise as viscosity increases.
- Smoke production increases as residual carbon rises. When residual carbon content falls below 0.4%, smoke decreases remarkably.
- There is a correlation between smoke production and the amount of deposit. The amount of deposit increases as the smoke increases.

Exhaust Smell

Exhaust smell is produced by a mixture of partially combusted hydrocarbon and exhaust gas. The intermediate combustion product produced by the incomplete combustion of fuels forms various aldehydes that emit a powerful smell. The extent of exhaust smell varies with the extent of incomplete combustion. The cetane number, i.e., the combustibility, is the foremost factor in controlling the exhaust smell.

Summary of Diesel Fuel Properties and Engine Performance

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

1. General Description of Biodiesel

(a) Biodiesel is a renewable, oxygenated 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.

(b) 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.

(c) Disadvantages of Biodiesel:

Concentrations that are higher than 5% of biodiesel (higher than B5) 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.
- Due to its natural characteristic, biodiesel will decrease the engine output by approximately 2 percent (in case of B 20) comparing to conventional (petroleum-based) diesel fuel.
- The fuel consumption ratio will increase by approximately 3 percent (in case of B 20) comparing to conventional diesel fuel.

2. Approved Engines

All of the following engine series of Yanmar can be operated with biodiesel with concentrations up to B 20. In case of using biodiesel fuel up to B5 concentrations, no special preparations etc. have to be made and the original operating conditions and service intervals as stated in the operating manuals apply. In case of running below indicated engines with biodiesel concentrations above B 6 up to B 20, the required operating conditions (see below No. 4) have to be observed.

Other than the following listed engines cannot be run with biodiesel:

- 3TNM68, 3TNM72, 2TNV70, 3TNV70 and 3TNV76
  Tier 2 and Tier 4

- 3TNV82A, 3TNV84, 3TNV84T, 3TNV88, 4TNV84, 4TNV84T, 4TNV88, 4TNV94L, 4TNV98 and 4TNV98T
  Tier 2, Tier3 and/or interim Tier 4
- 4TNV106 and 4TNV106T
  Tier 2
- 4TNE92, 4TNE94L and 4TNE98 for forklift application
  Tier 2 and interim Tier 4

3. Approved Fuel

   In case of using biodiesel (only concentrations up to B20) 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.

(a) EN14214 (European standard) and/or ASTM D-6751 (American standard).

(b) All applicable engines can be operated with biodiesel fuel up to B20 (20% bio-fuel blend) as a maximum concentration.
(For your information: In Japan, the legally allowed maximum concentration for on-road applications is B 5.)

4. Conditions for the Operation with Biodiesel (B 6 through B 20)

   When operating your applicable Yanmar engine (No. 2) with biodiesel blends concentrated above B5, we seriously recommend observing the following operation, service and maintenance conditions:

(a) The original service interval of the below stated services as indicated in the respective Yanmar engine standard operation manual, the application manual and the service manual should be halved (please refer to your own manuals for the each service interval):
- Replacement interval of engine oil filter, engine oil and the fuel filter.
- Cleaning interval of the water separator
- Drain interval of the fuel tank.

(b) It is required to inspect, clean and adjust the fuel injector every 1000 operating hours.

(c) Replacement of the following parts before using the recommended biodiesel:

1) Fuel hose
2) Fuel feed pump (Diaphragm type)
3) If not already installed, a water separator needs to be built in
4) O-ring of fuel filter
5) O-ring of water separator

Please refer to the attached list of exchange parts for details.

(d) Please use only biodiesel fuel that is appropriate to the intended operation environment of the engines. This especially applies if the operating ambient temperature falls below 0 degree centigrade.

(e) Operation with biodiesel requires daily maintenance as follows:

1) Please daily check the engine oil level. If the oil level rises above the oil level of the previous day, the engine oil needs to be immediately replaced.
2) Please daily check the water level of the water separator. If the water level rises above the "max" indicator, an immediate drain of the water separator is required.

(f) Biodiesel blends up to B 20 can only be used for a limited time of up to 3 months of the date of biodiesel manufacture. Therefore biodiesel needs to be used at latest within 2 months from the time of filling the tank or within 3 months from the time of production by the fuel supplier, whichever comes first.

(g) Before a long-term storage without operating the engine, the biodiesel needs to be drained out completely and the engine has to be run for 5 hours with conventional diesel fuel as indicated in your operation manual.

KIT PARTS LIST FOR B20

		KIT-M368BGS-BI	KIT-V270BGS-BI	KIT-V370BGS-BI	KIT-V382BGS-BI	KIT-V384BGS-BI
		3TNM68	**2TNV70**	**3TNV70,76**	**3TNV82A**	**3TNV84(T),88**
		D19125-59250	**D19446-59250**	**D19746-59250**	**D29283-59250**	**D29283-59260**
FUEL OIL TANK - / - FUEL OIL TANK	No.	(1)	(1)	(1)	(1)	(1)
	Length	2000	2000	2000	2000	2000
	Part No.	129946-59050	129946-59050	129946-59050	129946-59050	129946-59050
	Part Name	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	2	2	2	2	2
FUEL FEED PUMP - FUEL OIL FILTER	No.	(2)	(2)	(3)	(4)	(4)
	Length	380	380	450	1000	1000
	Part No.	119546-59030	119546-59030	119546-59020	129946-59040	129946-59040
	Part Name	CW-T CMP	CW-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	1	1	1	1	1
FUEL OIL FILTER - FUEL INJECTION PUMP	No.	(5)	(5)	(6)	(6)	(5)
	Length	220	220	270	270	220
	Part No.	129236-59000	129236-59000	119546-59200	119546-59200	129236-59000
	Part Name	CW-T CMP	CW-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	1	1	1	1	1
FUEL INJECTION PUMP - FUEL OIL FILTER	No.	(10)	(8)	(11)	(9)	(7)
	Length	400	320	450	350	300
	Part No.	129946-59220	119546-59210	119546-59220	119946-59200	129236-59010
	Part Name	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	1	1	1	1	1
CAP, FUEL INJECTION NOZZLE	Part No.				119593-59581 124060-77680	119593-59581 124060-77680
	Part Name	NO NEED	NO NEED	NO NEED	CAP CLIP	CAP CLIP
	Number				1 1	1 1
FUEL INJECTION NOZZLE -FUEL INJECTION NOZZLE	No.				(13)	(13)
	Length				115	115
	Part No.	NO NEED	NO NEED	NO NEED	129486-59581	129486-59581
	Part Name				FO-T CMP	FO-T CMP
	Number				2	2
FUEL INJECTION NOZZLE - FUEL INJECTION PUMP	No.	(16)	(16)	(16)	(17)	(17)
	Length	150	150	150	FORMED PIPE	FORMED PIPE
	Part No.	119546-59300	119546-59300	119546-59300	129636-59561	129636-59561
	Part Name	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	1	1	1	1	1
FUEL OIL FILTER		NEED TO CHANGE ONLY O-RING. P44: 24316-000440			NO NEED (BECAUSE OF CARTRIDGE TYPE)	
WATER SEPARATOR		NEED TO CHANGE ONLY O-RING. G75: 24326-000750 P16: 24316-000160 P7: 24316-000070 G65: 24326-000650 (NEED ONLY FOR TAIYO-GIKEN)				

		KIT-V484BGS-BI	KIT-V484TBGS-BI	KIT-V494GS-BI	KIT-V498ZGS-BI	KIT-V4106BGS-BI	KIT-E498BS-BI
		4TNV84,88	**4TNV84T**	**4TNV94L,98(T) Tier 2**	**4TNV98(T) Tier 3**	**4TNV106(T)**	**4TNE92/94L/98 Forklift**
		D29683-59250	**D29683-59260**	**D29946-59250**	**D29943-59250**	**D23946-59250**	**D29919-59250**
FUEL OIL TANK - / - FUEL OIL TANK	No.	(1)	(1)	(1)	(1)	(1)	(1)
	Length	2000	2000	2000	2000	2000	2000
	Part No.	129946-59050	129946-59050	129946-59050	129946-59050	129946-59050	129946-59050
	Part Name	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	2	2	2	2	2	2
FUEL FEED PUMP - FUEL OIL FILTER	No.	(4)	(4)	(4)	(4)	(4)	(4)
	Length	1000	1000	1000	1000	1000	1000
	Part No.	129946-59040	129946-59040	129946-59040	129946-59040	129946-59040	129946-59040
	Part Name	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	1	1	1	1	1	1
FUEL OIL FILTER - FUEL INJECTION PUMP	No.	(8)	(8)	(9)	(6)	(10)	(18)
	Length	320	320	350	270	400	660
	Part No.	119546-59210	119546-59210	119946-59200	119546-59200	129946-59220	129919-59000
	Part Name	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	1	1	1	1	1	1
FUEL INJECTION PUMP - FUEL OIL FILTER	No.	(11)	(11)	(11)	(9)	(12)	(12)
	Length	450	450	450	350	500	500
	Part No.	119546-59220	119546-59220	119546-59220	119946-59200	129946-59230	129946-59230
	Part Name	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	1	1	1	1	1	1
CAP, FUEL INJECTION NOZZLE	Part No.	119593-59581 124060-77680	NO NEED	NO NEED	NO NEED	NO NEED	NO NEED
	Part Name	CAP CLIP					
	Number	1 1					
FUEL INJECTION NOZZLE -FUEL INJECTION NOZZLE	No.	(13)	NO NEED	NO NEED	NO NEED	NO NEED	NO NEED
	Length	115					
	Part No.	129486-59581					
	Part Name	FO-T CMP					
	Number	3					
FUEL INJECTION NOZZLE - FUEL INJECTION PUMP	No.	(17)	(14)	(15)	(15)	(15)	(19)
	Length	FORMED PIPE	95	110	110	110	200
	Part No.	129636-59561	119946-59100	129946-59300	129946-59300	129946-59300	129919-59010
	Part Name	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP	FO-T CMP
	Number	1	1	1	1	1	1
FUEL OIL FILTER		NO NEED (BECAUSE OF CARTRIDGE TYPE)					NEED TO CHANGE ONLY O-RING. P34: 24316-000340 P7: 24316-000070
WATER SEPARATOR		NEED TO CHANGE ONLY O-RING. G75: 24326-000750 P16: 24316-000160 P7: 24316-000070 G65: 24326-000650 (NEED ONLY FOR TAIYO-GIKEN)					

	KIT-M368GS-FP
	D19125-93100
FUEL FEED PUMP	ELECTRIC FEED PUMP: 119225-52102 COVER ASSY, FEED PUMP: 129255-52000

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.

Any problem of components in the fuel injection system due to the use of JP-8 is not covered by warranty.

JP-4 fuel is not allowed for TNV or TNE engines.

ENGINE OIL FILTER SYSTEM

Sliding parts such as diesel fuel injection pump plungers, delivery valves 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 consists of a paper element type with a transparent plastic body or a cartridge type with a metal body. The type of filter used depends upon the type of engine.

Cautions for Installation

- Yanmar genuine parts should be used. Customer-installed fuel filters should have specifications equal to or better than Yanmar genuine parts.
- Install diesel fuel filters where the ambient temperature is 80°C (176°F) or below.
- Install diesel fuel filters where the maximum vibration level is below 8 G.
- 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. Contamination of the diesel fuel line causes most of the problems with sticky diesel fuel injector nozzles.

How to Check or Replace Diesel Fuel Filter

Maintenance on the diesel fuel filter should be done after the diesel fuel filter / water separator valve is CLOSED. Make sure the valve is OPEN before you start the engine.

Maintenance

This replacement interval will be 250 hours if you use a filter with mesh size of 1μm for poor quality fuel.

Replacement interval: 500 hours

Diesel Fuel Filter / Water Separator

A diesel fuel filter / water separator is mandatory for TNV (IDI & DI) 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. A diesel fuel filter / water separator efficiently removes water from the diesel fuel system.

The diesel fuel filter / water separator 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 the diesel fuel filter / water separator installed as a pre-filter. Installation of a diesel fuel filter / water separator 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.

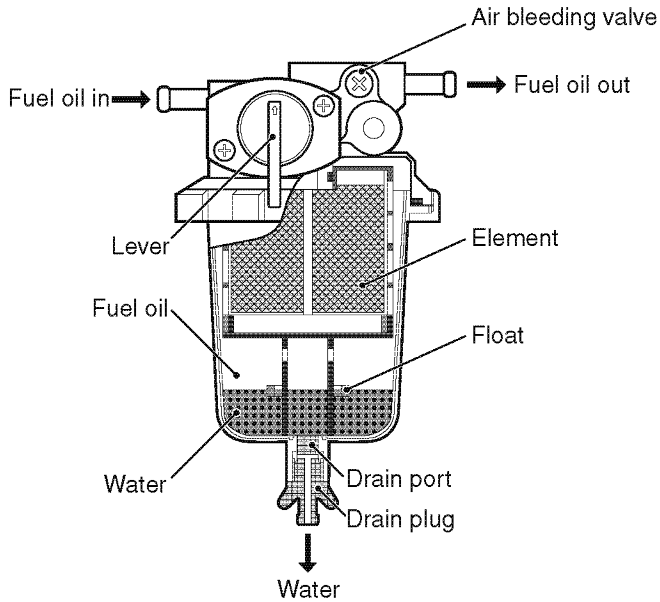


Figure 10-7

Cautions for Installation

- The diesel fuel filter / water separator should be installed as standard equipment.
- Select an element of 100 mesh or finer.
- Install the diesel fuel filter / water separator in a location where the ambient temperature is 80°C (176°F) or below.
- Make sure the maximum vibration level is below 8 G.
- Install the diesel fuel filter / water separator 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.
- Install it near the bottom of the diesel fuel tank for easy maintenance.
- Place the diesel fuel filter / water separator at the lowest position in the diesel fuel line.

Maintenance

- Check and drain water: 50 hours
- Cleaning: 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.

Structure of Diesel Fuel Tank

Avoiding air bubbles in the fuel line that leads into the injection 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 injection 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 air bubble formation.

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

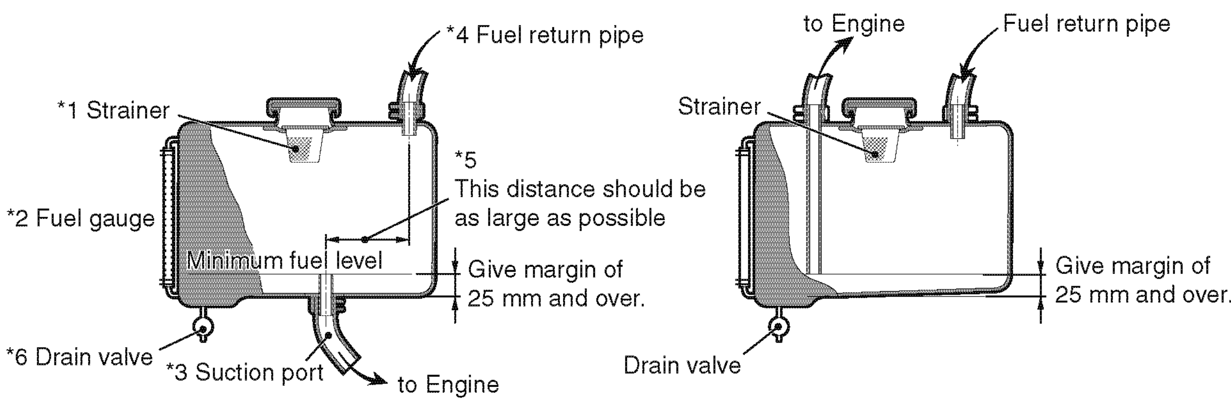


Figure 10-8

- When the fuel tank is mounted lower than the fuel injection pump, the fuel return line should be routed deep into 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.

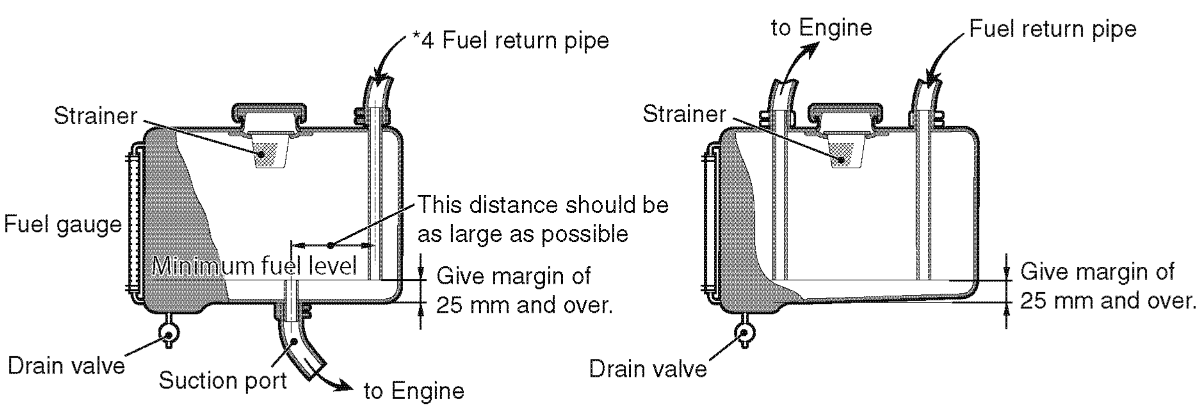


Figure 10-9

- 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 10-10** illustrates why the suction port should be located at the center of the tank:

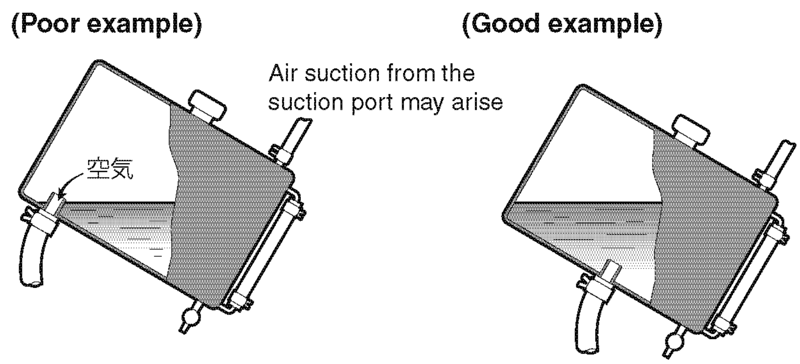


Figure 10-10

- 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

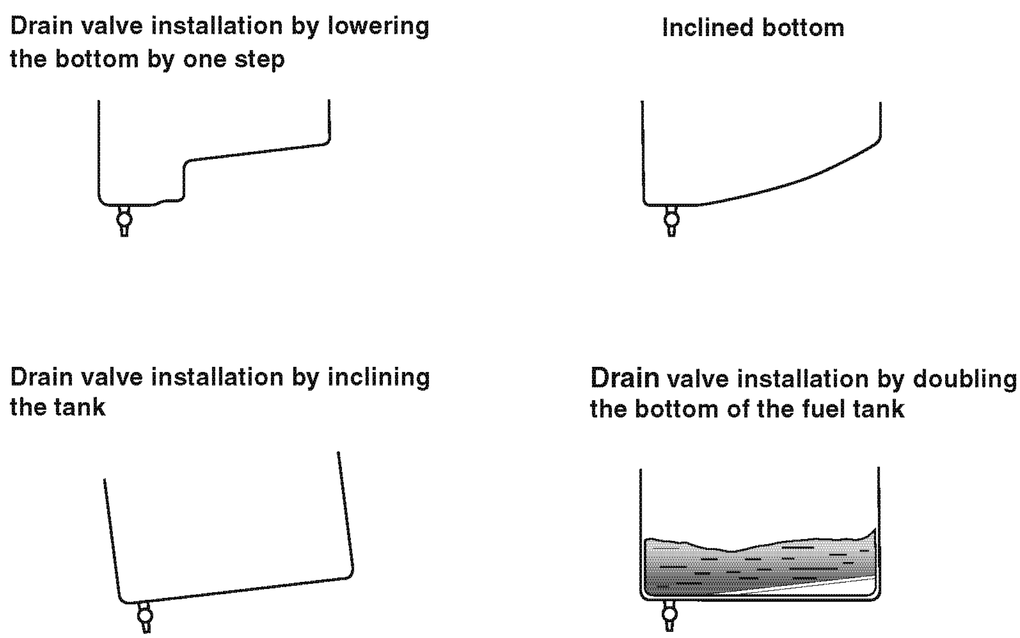


Figure 10-11

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 diesel fuel injection pump. The IDI series of TNV engines may use a mechanical or electric diesel fuel pump. The mechanical pump is installed on the side wall of the diesel fuel injection pump and is driven by the camshaft of the pump. An electric diesel fuel pump is used depending on the position of fuel tank.

If the fuel feeding performance of a mechanical pump is insufficient, or you need an easier way to bleed air from the diesel fuel system, or you need better startability, use an electric diesel fuel pump.

DI engines do not use a mechanical diesel fuel pump.

Types of diesel fuel pumps

- Fuel feed pump
  - Mechanical type — Diaphragm type (for IDI only)
  - Electric type — Solenoid type (for IDI & DI

Figure 10-12

Precautions for Installation

To install an electric diesel fuel pump (solenoid type)

- Remove the mechanical diesel fuel pump installed on the diesel fuel injection pump and close the opening port with a cover. (for IDI engine only)
- Install the electric diesel fuel pump in a dry place. The electric diesel fuel pump is not waterproof. Use a Yanmar genuine 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 50 mm or higher than the fuel inlet of the injection pump, a diesel fuel pump is not necessary.
- When installing an electric diesel fuel pump, install a diesel fuel filter / water separator (100 mesh or finer). This may be substituted with a Yanmar genuine diesel fuel filter / water separator.
- The water separator must be installed near the lower level of the fuel tank where maintenance (especially air-bleeding) can be performed easily.

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.

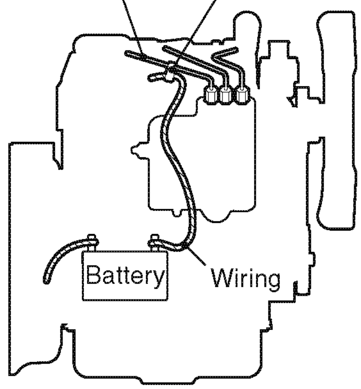


Figure 10-13

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.

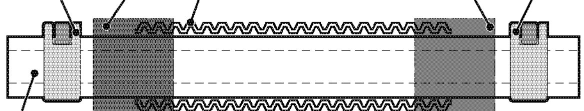


Figure 10-14

Fuel Hose Material (SAE J30R7)

	Inside	Outside
Material Recommendations	Nitrile butadiene rubber compound (NBR)	Chloroprene rubber compound (CR)
Thickness (mm)	1.4	0.9
Pressure-resistance	294 kPa (3 kgf/cm^2) or greater	
Temperature-resistance	80°C to –20°C (176°F to -4°F)	
Climate-resistance	Necessary (Ozone, moisture, engine oil, ultraviolet rays)	

* Vinyl hose is not used as a fuel hose because heat causes significant deformity.

Shape of Fuel Line

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

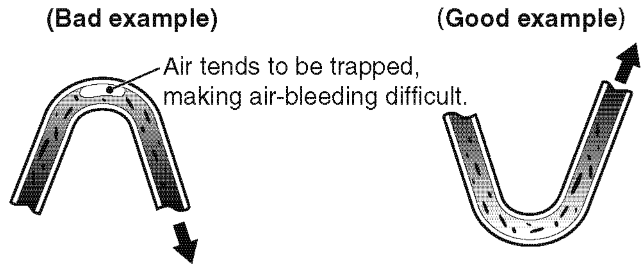


Figure 10-15

Fuel Line Layout

Refer to *Standard Diesel Fuel Line Layout on page 10-7*.

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. The procedure to bleed air from the diesel fuel system varies depending on whether or not the engine has an electric diesel fuel pump.

Engine with electric diesel fuel pump (solenoid type) for IDI & DI engine.

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.

Note: NEVER bleed air by using the starter motor.

Engine without electric diesel fuel pump (for IDI engine only).

1. Open the diesel fuel filter / water separator fuel cock.
2. Loosen the air vent valve on the top of the fuel filter 2 to 3 turns. Pump the priming pump knob up and down to feed diesel fuel. When diesel fuel runs clear with no air bubbles, tighten the air vent valve. The number of times you need to press the pump varies with the amount of air trapped in the diesel fuel line.
3. Pump the priming pump knob again. If the air is purged from the diesel fuel line, you will feel greater resistance.

Note: 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, fuel pump drive mechanism, fuel injection pump, 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 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 series engine lubricating system is shown in **Figure 11-1**:

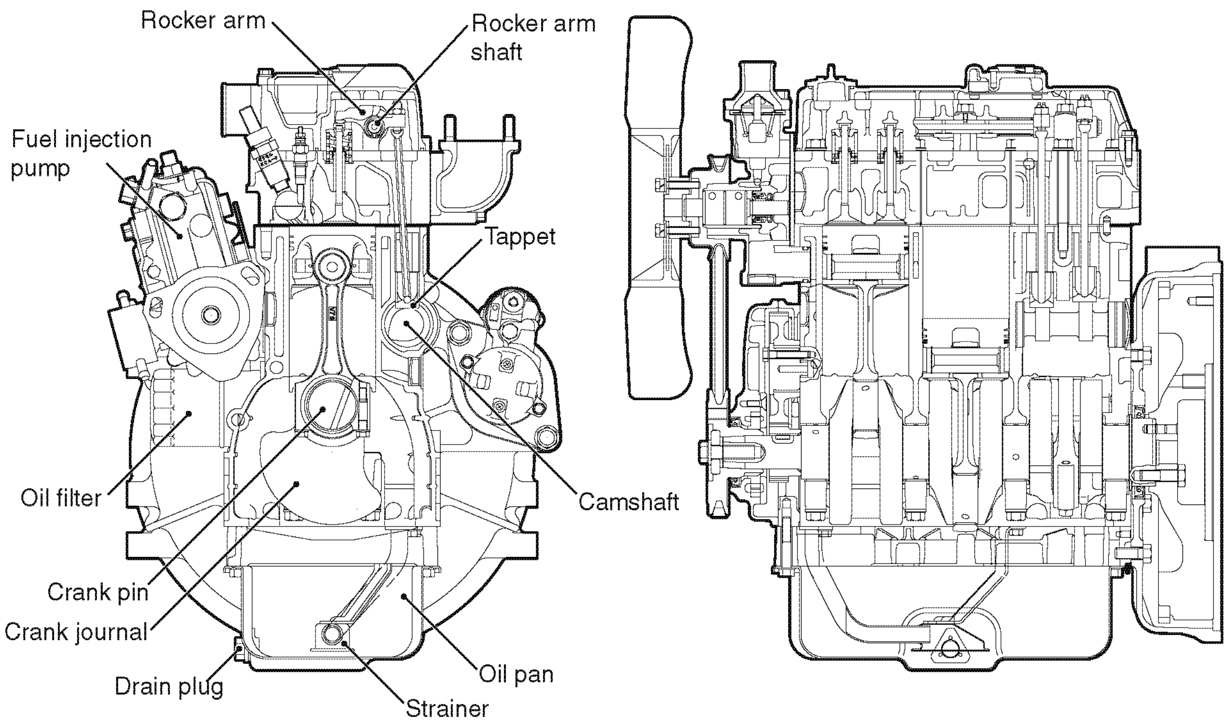


Figure 11-1

IDI (Indirect Injection) Engine

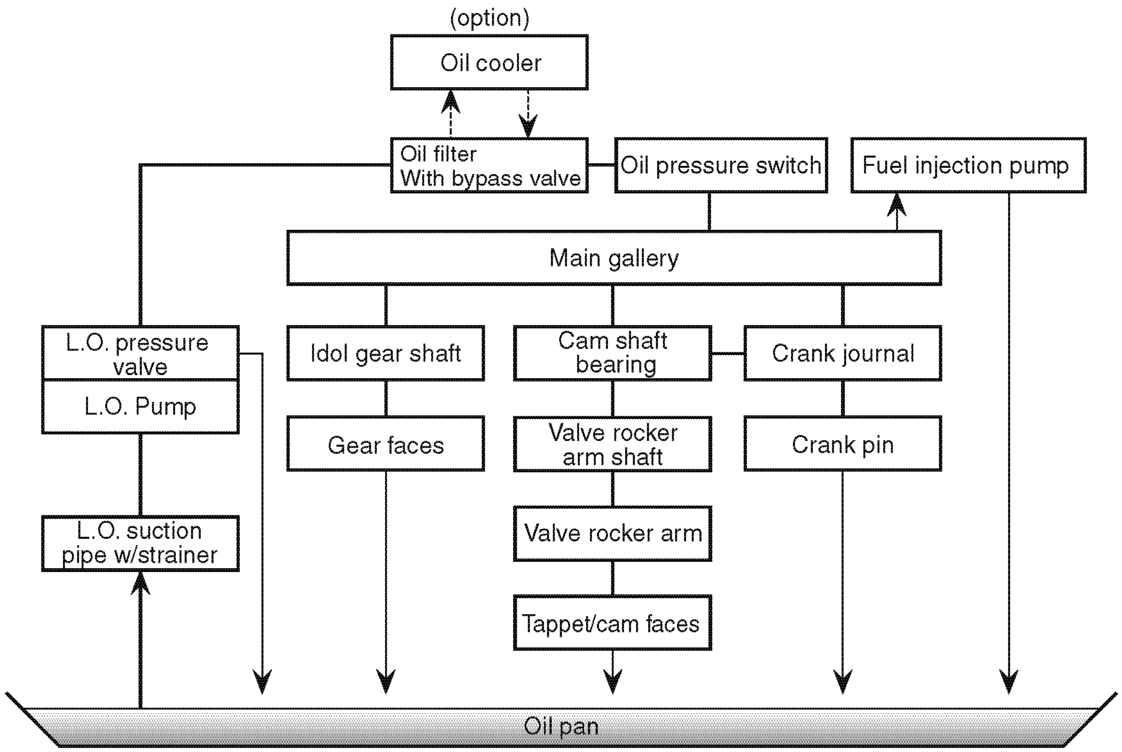


Figure 11-2

DI (Direct Injection) Engine

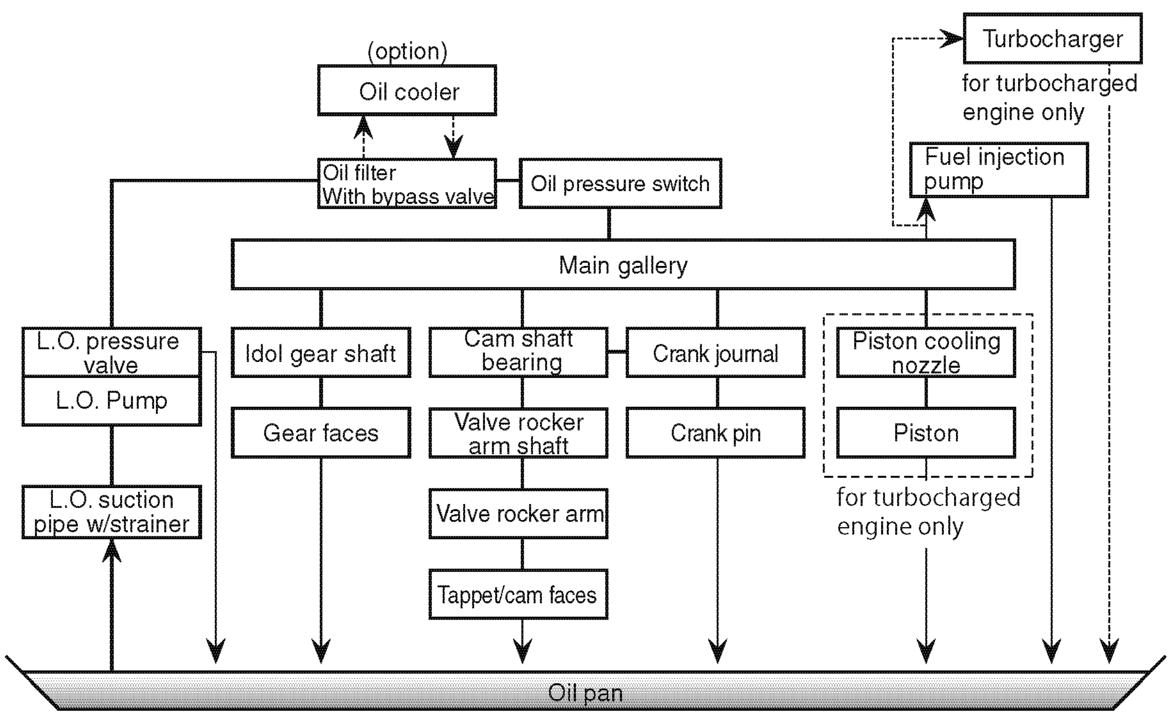


Figure 11-3

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

Engine oil should comply with the following specifications.

Classification

API classification		CD, CF, CF-4, CI-4
	TBN value:	≥9 (CD), ≥9 (CF), ≥7 (CF-4), ≥7 (CI-4)
ACEA classification		E-3, E-4, E-5
	TBN value:	≥10 (E-3), ≥10 (E-4), ≥10 (E-5)
JASO classification		DH-1
	TBN value:	≥10 (DH-1)

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

ACEA: E-1, E-2, B grade

Engine oil grade E-1 was developed for naturally aspirated diesel engines and for light duty applications.Engine oil grade E-2 was developed for naturally aspirated diesel engines.Engine oil grade B was only developed for light duty application (e.g., passenger car).

JASO: DH-2, DL-1

Engine oil grade DH-2 was developed for diesel engines fitted with a Diesel Particulate Filter (DPF) device.Engine oil grade DL-1 was developed for diesel engines fitted with a DPF device and it was only designed for light duty applications.

Current / Active U.S. Diesel Engine Oil Specifications						
Parameter [limit]	**API CF**	**API CF-2**	**API CF-4**	**API CG-4**	**API CH-4**	**MIL-PRF-2104G**
CRC L-38 Bearing Weight Loss (mg) [max] 1st Test/2 Test Avg./3 Test Avg.	43.7 /48.1 /50	43.7 /48.1 /50	50	43.1	NR	43.7 /48.1 /50
Viscosity (cSt) at 100 degree	NR	NR	NR	NR	NR	13.0
Oil viscosity (cSt) Above SAE J300 [min]	NR	NR	NR	0.5	NR	NR
Caterpillar 1K Weighted Demerits (WDK) [max] 1st Test/2 Test Avg./3 Test Avg.	NR	NR	332 /347 /353	NR	332 /347 /353	NR
Top Groove Fill (%) [max] 1st Test/2 Test Avg./3 Test Avg.	NR	NR	24 / 27 / 29	NR	24 / 27 / 29	NR
Top Land Heavy Carbon (%) [max] 1st Test/2 Test Avg./3 Test Avg.	NR	NR	4 / 5 / 5	NR	4 / 5 / 5	NR
Oil consumption (g/kW-h) [max] 1st Test/2 Test Avg./3 Test Avg.	NR	NR	0.27 / 0.27 / 0.27	NR	0.5 / 0.5 / 0.5	NR
Piston, Ring, Liner Distress, Stuck Rings	NR	NR	NONE	NR	NONE	NR
Caterpillar 1M-PC Weighted Demerits (WTD) [max]	240	100	NR	NR	NR	240
Top Groove Fill (%) [max]	70	NR	NR	NR	NR	70
Ring Side Clearance Loss (mm) [max]	0.013	NR	NR	NR	NR	0.013
Piston, Ring, Liner Distress. Stuck Rings	NR	NR	NR	NR	NR	NONE

Engine Oil Classification System for Commercial Diesel Engine Service "C" – Commercial Oils (Fleets, Contractors, Farmers, etc.)			
API Commercial Engine Service Categories	**Previous API Engine Service Categories**	**Related Military or Industry Designations**	**Engine Test Requirements**
CA	DG	MIL-L-2104A	CRC L-38; Caterpillar L-1:* (0.4% sulfur)
CB	DM	MIL-L-2104A, Supplement 1	CRC, L-38; Caterpillar L-1:* (0.4% sulfur)
CC	DM	MIL-L-2104B MIL-L-46152B	CRC L-38; Sequence IID; Caterpillar 1H2
CD	DS	MIL-L-45199B, Series 3 MIL-L-2104C/D/E	CRC L-38; Caterpillar 1G2*
CD-II	NONE	MIL-L-2104/D/E	CRC L-38; Caterpillar 1G2* Detroit Diesel 6V53T
CE	NONE	NONE	CRC L-38; Caterpillar 1G2* Cummins NTC-400*; MACK T-6; MACK T-7
CF-4	NONE	NONE	CRC L-38; Cummins NTC-400*; Mack T-6; MackT-7; Caterpillar 1K
CF-2	NONE	NONE	CRCL-38; Caterpillar 1M-PC Detroit Diesel 6V92TA
CF	NONE	NONE	CRCL-38; Caterpillar 1M-PC
CG-4	NONE	NONE	CRCL-38; Sequence IIIE; Roller Follower Wear; Mack T-8; Caterpillar 1N
CH-4	NONE	NONE	Sequence IIIE; Roller Follower Wear; Mack T-8E; Mack T-9; Cummins M11; Caterpillar 1P; Caterpillar 1K
CI-4	NONE	NONE	Caterpillar 1R; Cummins M11; Mack T-8E; Mack T-10; Roller Follower Wear; Caterpillar 1K or 1N; HEUI; Sequence IIIF

* The test is obsolete; engine parts, test fuel, or reference oils are no longer generally available, or the test is no longer monitored by the test developer or ASTM

Classification by Engine Oil Viscosity (SAE Viscosity Classification)

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

SAE Viscosity Classification SAE Viscosity Grades for Engine oils[a] – SAE J300 Dec 99 (document 2)					
Low-Temperature Viscosities			High-Temperature Viscosities		
SAE Viscosity Grade	Cranking[b] (cP) max at temperature °C	Pumping[c] (cP) max with no yield stress at temperature °C	Low Shear Rate Kinematic[d] (cSt) at 100°C		High Shear[e] Rate (cP) at 150°C min
			min	max	
0W	6200 at –35	60,000 at –40	3.8	–	–
5W	6600 at –30	60,000 at –35	3.8	–	–
10W	7000 at –25	60,000 at –30	4.1	–	–
15W	7000 at –20	60,000 at –25	5.6	–	–
20W	9500 at –15	60,000 at –20	5.6	–	–
25W	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, 200w-40, 25w-40, 40 grades)
50	–	–	16.3	<21.9	3.7
60	–	–	21.9	<26.3	3.7

[a] All values are critical specifications as defined by ASTM D 3244 (see text, *Section 3*).

[b] ASTM D 5293

[c] ASTM D 4684 (see also *Appendix B* and text *Section 4.1*): The presence of any yield stress detected by this method constitutes a failure regardless of viscosity.

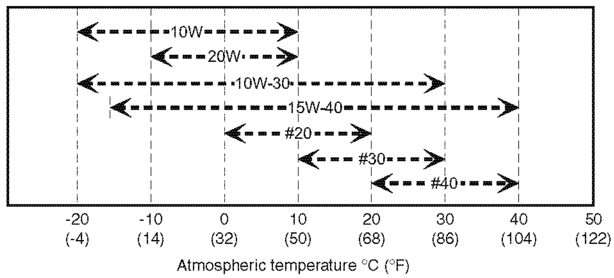
[d] ASTM D 445

[e] 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 engines.

Selection of viscosity (SAE Service grade)



15W-40/10W-30 can be used almost throughout the year.

Figure 11-4

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, the following chart shows the viscosity-temperature characteristics of Yanmar genuine engine oil. This chart uses kinematic viscosity at 40°C (104°F) and 100°C (212°F) 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

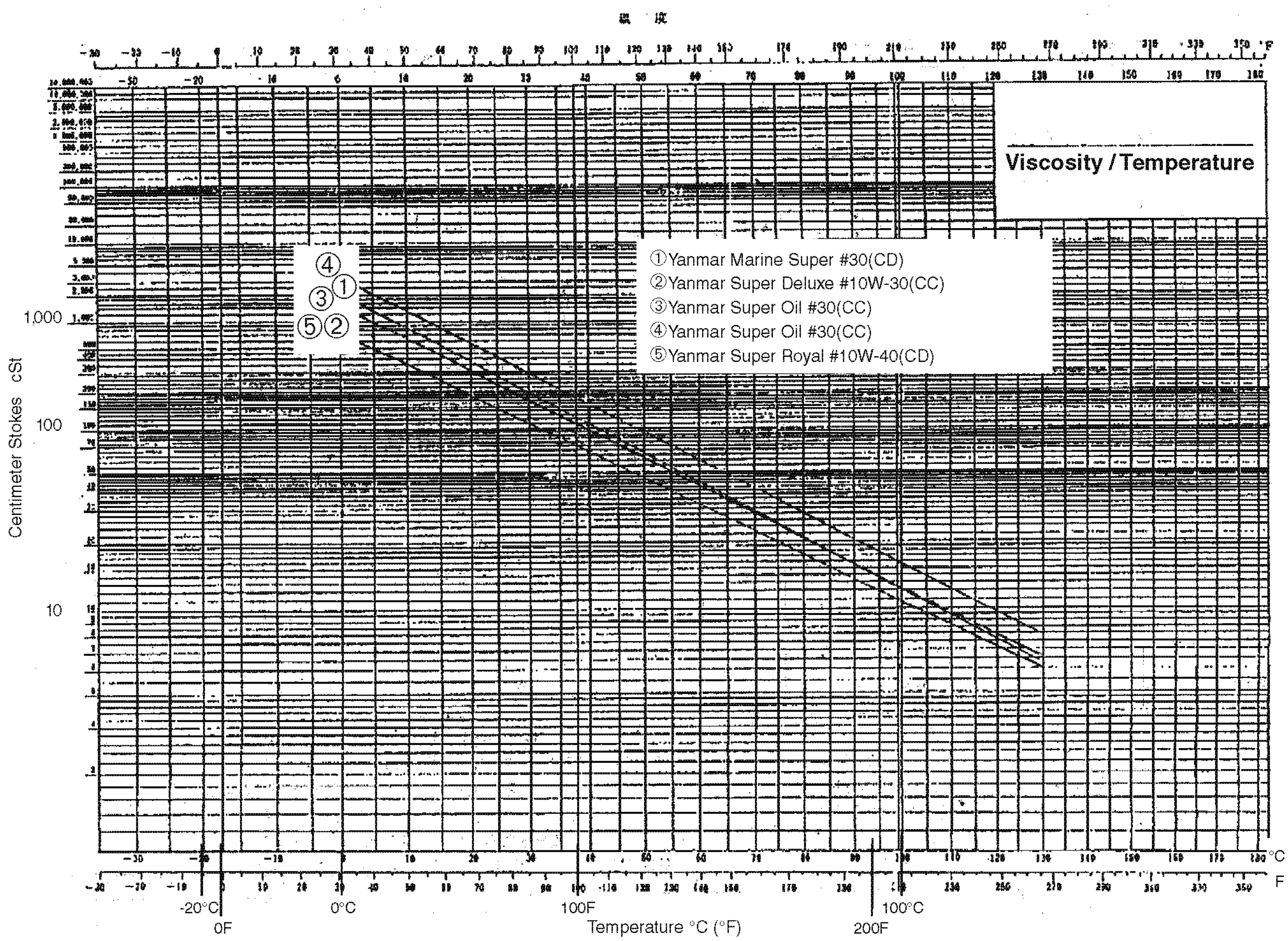


Figure 11-5

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%.

  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 water in the oil cannot be removed by the oil filter, replace the 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 (95°F) in gasoline engines and to 25°C (77°F) 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.

Criteria to replace the engine oil

Properties		Criteria
1. Increase/decrease of viscosity at 40°C (104°F)		25% increase/decrease of new engine oil
2. Total base value mg KOH/g		Over 2.0 (HCl method); Over 4.0 ($HClO_4$ method)
3.	Increase of insoluble substance	—
	Pentane insoluble content (mass)%	Below 2.0
	Insoluble resin (mass)%	Below 2.0
4. Water content (volume)%		Below 0.5
5. Flash point		Minimum 200°C (392°F)

Cautions for Replacing Engine Oil

In used engines, check the type of engine oil that was previously used before adding a new type of engine oil. The recent high-grade engine oils contain various additives.

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.

Oil temperature and engine oil replacement interval

Service classification	Allowable lubricating oil temperature	Engine oil replacement interval	Fuel used
CD, CF, CF-4, CI-4 E-3, E-4, E-5, DH-1	≥120°C (248°F)	Every 250 hours	Diesel fuel

In a closed engine compartment, provide air circulation near the oil pan (2m/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 oil suction pipe with strainer is installed between the oil pan and engine oil pump. A metallic strainer is attached to the end of the suction pipe to trap large foreign matter.

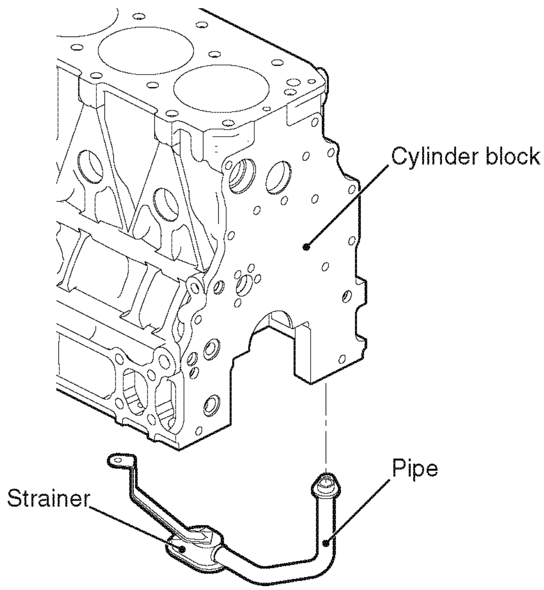


Figure 11-6

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 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.

Oil filter installed on TNV series engines				
Engine model	IDI		DI	
Type	STD	Large Capacity	STD	Large Capacity
Filtration area (cm^2)	690	810	1160	1630
Yanmar code	119305-35151	119660-35150	129150-35152	119005-35150

"STD (standard)" and "large capacity" types are available for TNV series engines.Large capacity type is applied when the engine is used in dusty/sandy areas (including China and Middle/Near East), or when long term maintenance is required by the specification (such as for refrigerator specific engines).

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 engines, refer to the *Yanmar TNV Option Menu*.

Oil Pump Structure

The TNV series engines use a trochoid engine oil pump.The pump is available in three configuration; type A, B, and C.Their exploded views are shown in **Figure 11-7, Figure 11-8 and Figure 11-9**.

3TNV82A-B	3TNV82A-Z
3TNV84T-Z	3TNV84T-B
3TNV88-B	3TNV88-Z
3TNV88-U	3TNV88-E
4TNV84T-Z	4TNV84T-B
4TNV88-B	4TNV88-Z
4TNV88-U	4TNV88-E

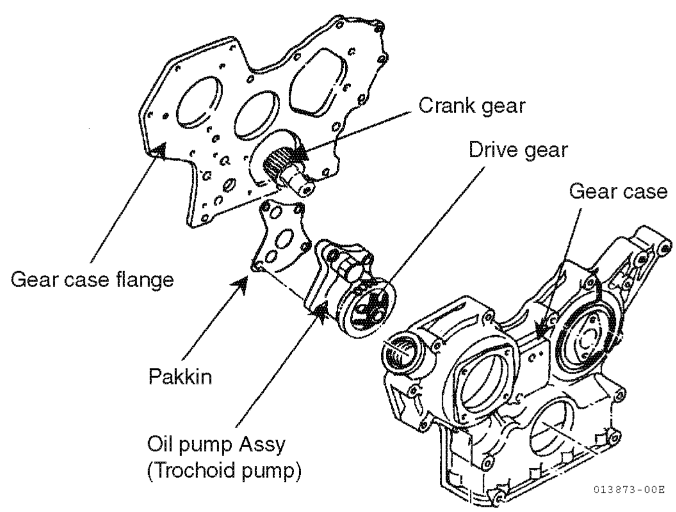


Figure 11-7

- Type A: Separated single typeDriven by the crank gear

2TNV70
3TNV70
3TNV76
3TNV82A
3TNV84
3TNV84T
3TNV88
4TNV84
4TNV84T
4TNV88

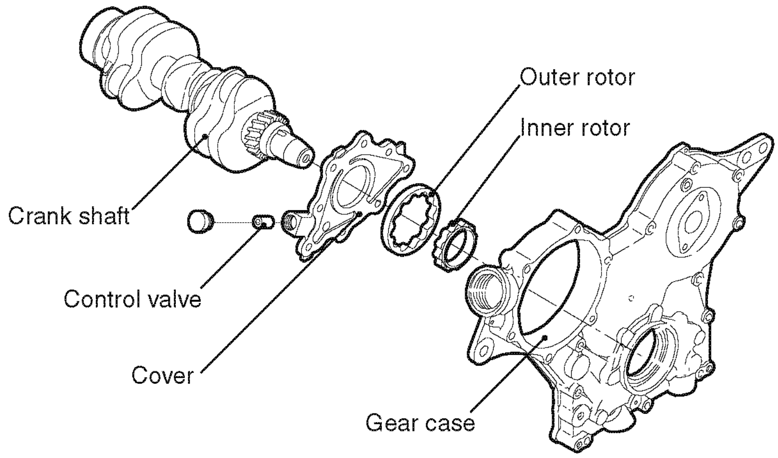


Figure 11-8

- Type B: Driven directly with an inner rotor attached to the crankshaft.This type produces lower mechanical noise because the pump drive gear is eliminated.
  Application: IDI and DI engines

4TNV98-Z
4TNV98-E
4TNV98T-Z
4TNV94L
4TNV98
4TNV98T

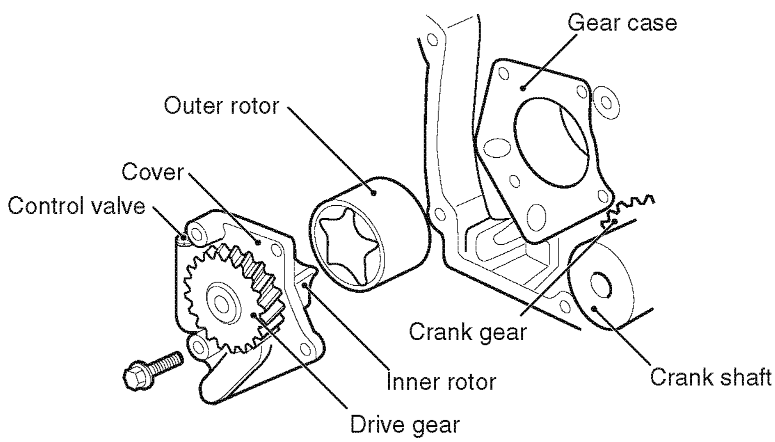


Figure 11-9

- Type C : Separate typeDriven by the crank gear
  Application: DI engines (94 and 98 series)

INCLINED PERFORMANCE

The TNV 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 pockets 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 series engine with deep oil pan (standard) is as follows:

Engine type	IDI	DI
Continuous operation	25° for all directions	30° for all directions
Instantaneous operation (within 3 min.)	30° for all directions	35° for all directions

* 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

Note: Keep the engine flat while supplying engine oil or coolant.

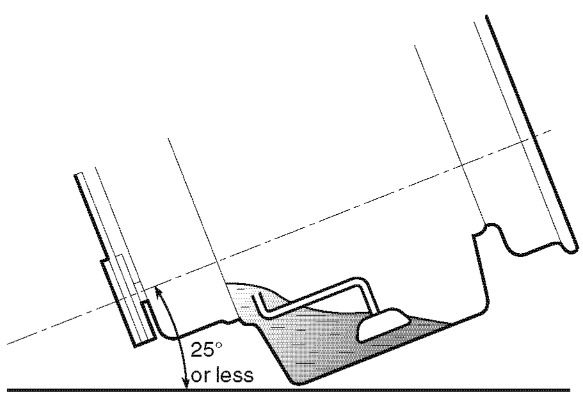


Figure 11-10

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 series engines (except for 3TNV84T/4TNV84T/4TNV98T with turbocharger) use intake circulating systems.This system is also used particularly for turbocharged engines which comply with next regulations such as EPA Interim Tier4 or Tier3.In a turbocharged engine, however, blow-by gas cannot be sucked into the intake manifold 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.

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.

Two breather systems are classified according to the structure.

Breather System Components

For all TNV engines ***except*** 4TNV94 and 98 and all turbocharged engines:

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

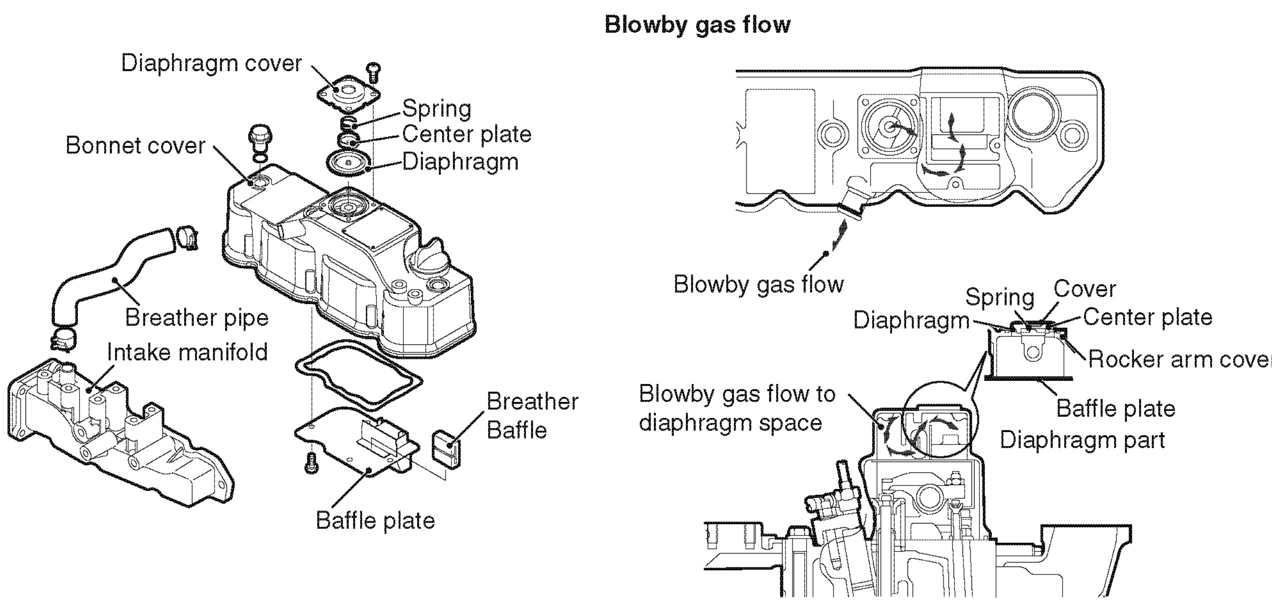
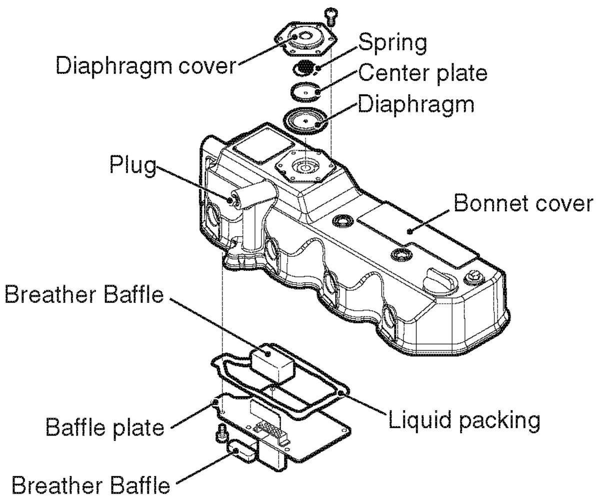


Figure 11-11

Breather System (pipeless type) Components

For engines of 4TNV94 and 98

Pipeless system that returns the blow-by gas to the intake manifold through a passage in the valve cover, without using pipe.



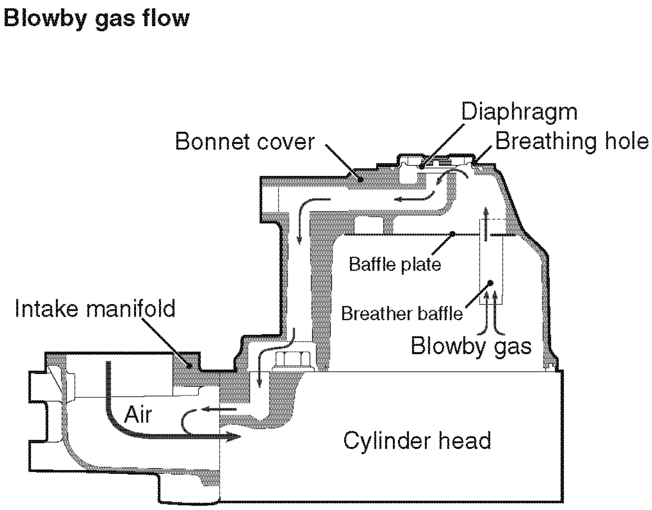


Figure 11-12

Breather System Components (Turbocharged Engines)

3TNV84T-Z, 3TNV84T-B, 4TNV84T-Z, 4TNV84T-B, 4TNV98T-Z 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 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 between the area just after the air cleaner to 300 mm away from the air cleaner.Route the hose as near as possible to avoid being affected by the intake restriction of the turbocharger.

- **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.This may cause the negative pressure to increase and the oil may be sucked by the TC side. Please be sure to route hoses without any pittings.

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

  Provide ϕ18 mm outer diameter for the return joint part and an aperture (ϕ3) 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:

Part name	Code No.	NOTE
Blow-by gas return joint ϕ36	129009-03050	
Blow-by gas return joint ϕ46	129509-03050	For 4TNV84T-Z/4TNV98T-Z

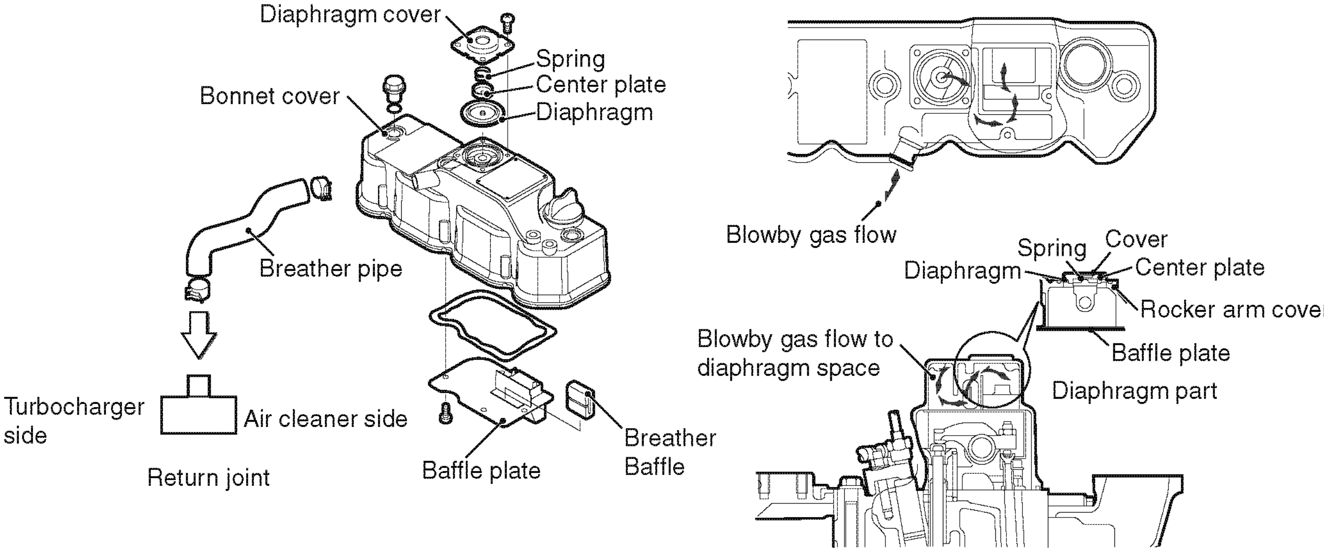
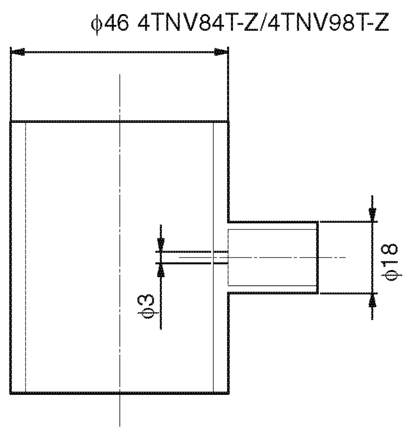
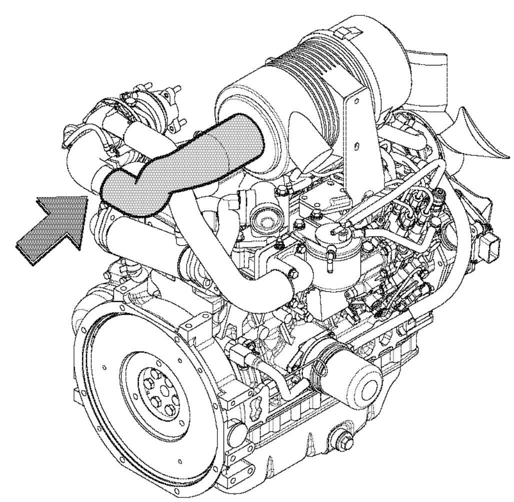


Figure 11-13



Return joint

Figure 11-14



Location of the breather system hoses

Figure 11-15

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.

Engine oil pressure switch mounted on the TNV series engine		
	Non-electronic control engines	**Electronic control engines**
Yanmar code No.	114250-39450	119761-39450
Actuation pressure of engine oil pressure switch	<49.0 ± 9.8 kPa (0.5 ± 0.1 kgf/cm^2)	
Contact capacity	12 VDC/0.4 A, 24 VDC / 0.2 A	

* M4 thread connection terminal type (121252-39450) is also available as an option.Refer to the Option Menu.

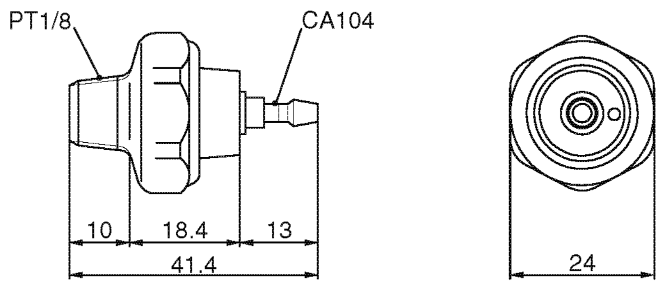


Figure 11-16

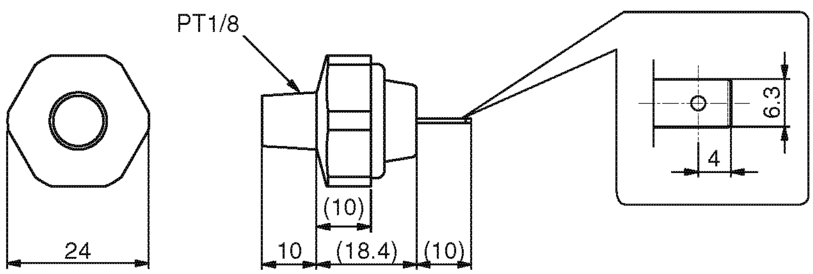


Figure 11-17

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.If engine operation is stopped using the stop lever without turning the key switch Off, the oil pressure drops to close the pressure switch contact and the indicator goes On again.

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.

An Example of Wiring Diagram

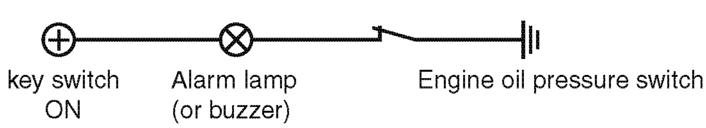


Figure 11-18

ENGINE OIL COOLER

The engine oil cooler is used on the following engines:

Turbocharged engines: 3TNV84T, 4TNV84T and 4TNV98T

Direct injection naturally aspirated engines: 3TNV82A to 4TNV88 with engine speeds at 2800 min^{-1} or greater.

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 series engines, the specifications of the engine oil cooler and their applicable engine models are as shown below.

Code No.		**119717-33010**	**129508-33010**	**123962-33010**	**Remarks**
Exchangeable heat amount	kW	3.0	4.0	5.8	
Core size	mm	ϕ 73 × 7 steps	ϕ 93 × 7 steps	ϕ 93 × 11 steps	
Oil side heat release area	m^2	0.074	0.117	0.242	
Water side heat release area	m^2	0.037	0.048	0.105	
Applicable engine models		(2TNV70) (3TNV70) (3TNV76)	3TNV84T 4TNV84T (3TNV82A) (3TNV84/88) (4TNV84/88)	4TNV98T (4TNV94L) (4TNV98)	Optional

Installation of Engine Oil Cooler

The 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.

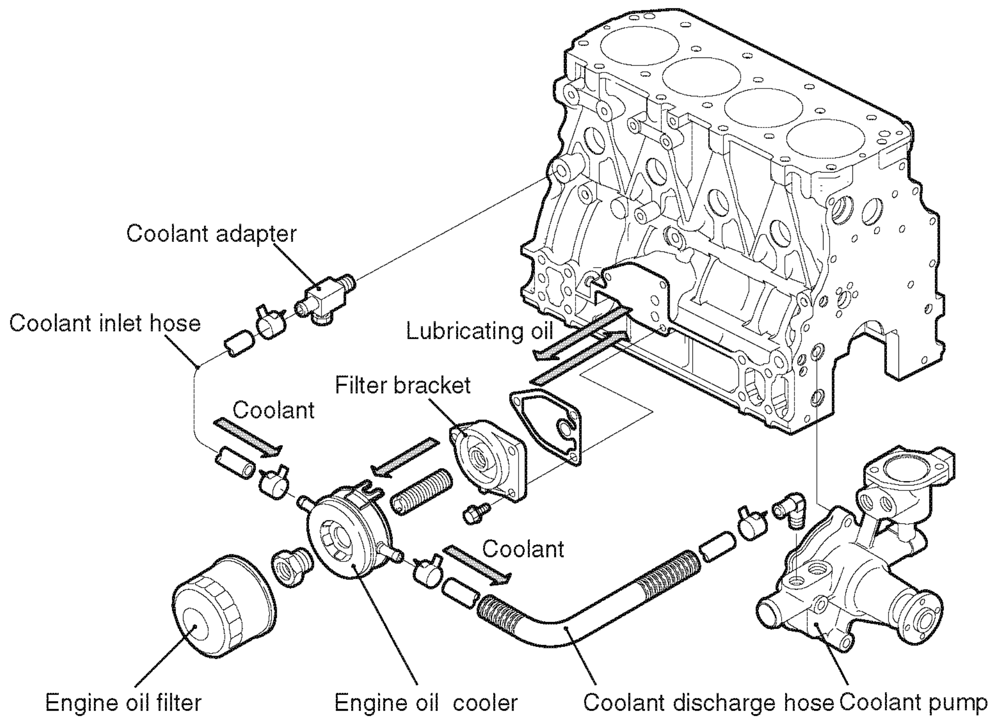


Figure 11-19

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.

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Section 12

MATCHING TEST PROCEDURE

Page

PURPOSE OF MATCHING TEST

All engine performance specifications are developed under standard atmospheric conditions as described in *Atmospheric Conditions and Engine Configuration Affect Engine Output on page 3-3.* Engines are installed in driven machines that are literally operated all over the world. It is expected that their operating environments will be totally different from standard atmospheric conditions.

It is important to know in advance if an engine and its driven machine can function without problems in a given operating environment.

As it is not practical to reproduce all operating conditions in a laboratory, the substitute performance verification method is a series of tests called the matching test. This 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 matching 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 matching test is divided into three parts: the heat balance test, the output matching test and installed state checking. If possible, the test, evaluation and improvements should be conducted simultaneously.

Refer to the separate publication *TNV Series Engine Installation Evaluation.*

ITEMS REQUIRED FOR TEST

Measurement instruments and tools needed for the test are dependent on the purpose and application of the driven machine. Below is a minimum list of measurement instruments to consider.

Measuring Instruments

	Measuring instrument	Comments
1	Barometer	Measure the atmospheric pressure during the test (or inquire at a local weather bureau).
2	Dry and wet-bulb thermometer	Measures the outside temperature and relative humidity. Take measurement in a shady, well-ventilated area that will be not influenced by the temperature of the subject machine.
3	Tachometer	High pressure fuel pipe clamping type (for IDI engine only), or non-contact type (optical reflection or magnetic pulse) to measure engine speed in the operating state. For instructions to install a magnetic pulse tachometer to a gear case, refer to *Engine Speed Measurement on page 12-12.* Special parts are available as Yanmar parts. Check the battery (if any) on the instrument before you use it.
4	Thermocouple	For exhaust temperature measuring: 800°C (1472°F) maximum temperature x 1 pc. For other temperature measuring: 500°C (932°F) maximum temperature x 5 pcs. Have extra thermocouples available in case of failure.
5	Six-channel digital thermometer	Thermometer for the above thermocouples to measure the temperature at different points. May need extension cords depending on the location of the subject machine. Check the battery (if any) on the instrument before you use it.
6	Vibration meter	Measures acceleration and amplitude in both directions. Make sure AC power supply is available on the test site. Take adhesive and metal fittings for mounting the pickup.
7	Stopwatch	Measures data measuring intervals and the speed of running vehicle.
8	Angle meter	Measures the hill climbing angle of a vehicle.
9	Anemometer	Measures radiator air flow rate.
10	Manometer	Checks intake and exhaust restriction, range 1.5 m min. H_2O.
11	Data logger	For mobile driven machines or automatic data recording.

Engine Parts

<table>
<tr><th></th><th>Engine parts</th><th colspan="7">Comments</th></tr>
<tr><td rowspan="4">1</td><td>Exhaust gasket</td><td colspan="7">Measures exhaust temperature.
Two gaskets required including one for repairing the test subject machine.
Use the following gaskets for standard exhaust manifold.</td></tr>
<tr><td>Engine model</td><td>2TNV70
3TNV70
3TNV76</td><td>3TNV82A
3TNV84
3TNV88</td><td>4TNV84
4TNV88</td><td>3TNV84T</td><td>4TNV84T</td><td>4TNV94L
4TNV98</td><td>4TNV98T</td></tr>
<tr><td>Code No.</td><td>119515
-13200</td><td>129004
-13200</td><td>129930
-13200</td><td>129403
-18091</td><td>129508
-18091</td><td>129930
-13201</td><td>123901
-18080</td></tr>
<tr><td>Bolt hole pitch (mm)</td><td>52 × 52</td><td>52 × 52</td><td>62 × 62</td><td>For T/C
(Special)</td><td>For T/C
(Special)</td><td>62 × 62</td><td>For T/C
(Special)</td></tr>
<tr><td rowspan="3">2</td><td>Fully blocked open thermostat</td><td colspan="7">Use for a heat balance test.
Mandatory when the engine coolant outlet port temperature is predicted to be under 85°C (185°F).
Parts for the fully blocked open thermostat testing are available for each engine model as shown in the table below.</td></tr>
<tr><td>Fully blocked open thermostat for testing</td><td colspan="2">119717-92100</td><td colspan="4">129155-92100</td><td>—</td></tr>
<tr><td></td><td colspan="7">No need to use a fully blocked open thermostat if the driven machine is tested under the target setting of the actual operating environmental temperature in a high constant temperature chamber.Use the standard thermostat unchanged.</td></tr>
<tr><td rowspan="4">3</td><td rowspan="2">Gasket</td><td colspan="7">For the thermostat cover.
For repair after replacing with the fully opened thermostat.
Two sets for repairing possible breakage during the test.</td></tr>
<tr><td>2TNV70
3TNV70
3TNV76</td><td colspan="2">3TNV82A
3TNV84
3TNV84T
3TNV88</td><td colspan="2">4TNV84
4TNV84T
4TNV88</td><td colspan="2">4TNV94L
4TNV98
4TNV98T</td></tr>
<tr><td>Thermostat
For cover</td><td>—</td><td colspan="2">129795-49551</td><td colspan="2">—</td><td colspan="2">129900-49540</td></tr>
<tr><td>Thermostat
For main unit</td><td>—</td><td colspan="2">129150-49811</td><td colspan="2">—</td><td colspan="2">121850-49550</td></tr>
</table>

Tools

	Tool	Tool carrying cautions, etc.
1	Phillips and straight-edge screwdrivers	For digital thermometer terminal and coolant hose band.
2	Wrench set	For bolts of the exhaust outlet port, thermostat cover, installed muffler, air cleaner, and for fixing the thermocouple.
3	T box wrench set	For the above mentioned work.
4	Instant glue	To fix metal fixtures of vibration measuring pick-up.
5	Double-stick tape	To mount vibration meter pick-up, in case the subject machine is a finished product to be sold.
6	Pliers	To mount high pressure pipe type tachometer pick-up.
7	Cutting pliers	For various works.
8	Tape measure	To measure the speed of the running vehicle.
9	Silicon sealant	To seal the hose connection when thermocouple is installed between hose and fitting, to prevent loss of coolant.
10	Needle file	To modify exhaust gaskets.
11	Inflating needle	For intake measurement.
12	Drill	To fit thermocouple if gasket location not possible.
13	Exhaust back pressure probe	
14	Circle compass knife	To slit rubber hoses for thermocouple or pressure tap.
15	Electrical tape (good quality)	For fixing thermocouples and leads.

Data Recording Paper

	Data recording forms	Comments
1	Sample machine data	Rated speed performance curve and load performance curve during operation with engine installed in driven machine.(Understanding load factor under the actual work conditions) Specific fuel consumption data of sample machines at shipment can also provide effective information when measuring/evaluating the fuel consumption of engines as a part of generator specifications or other purposes.
2	Test plan	Arrangements for the matching test.
3	Measured data recording sheet	See the separate publication, *TNV Series Engine Installation Evaluation*.
4	Installed state check sheet	See the separate publication, *TNV Series Engine Installation Evaluation.*
5	Memo pad	

Other

The following items may also be needed: ruler, camera, *TNV Operation Manual* and *TNV Service Manual*.

INSTRUCTIONS FOR MOUNTING MEASURING INSTRUMENTS

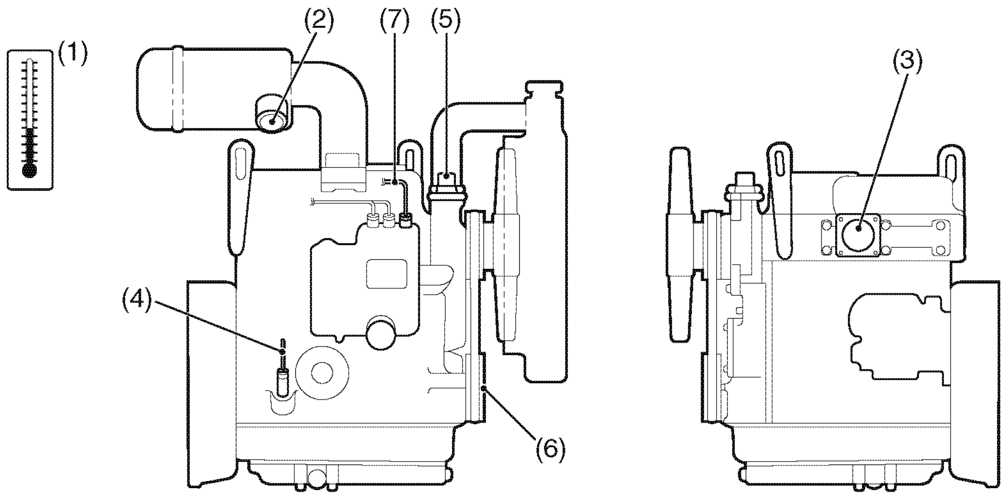


Figure 12-1

The heat balance test is the most important. The purpose of this test is to measure the temperature of various engine systems. If the measuring instrument is improperly mounted, incorrect temperature may be measured. Follow the instructions below for correct mounting of the measuring instruments.

Atmospheric Temperature (Dry and Wet-bulb Thermometer)

See **(Figure 12-1, (1))**:

- Measure in a well ventilated place that is not exposed to direct sunlight.
- Set the dry / wet bulb thermometer where it will not be influenced by the heat from the driven machine or engine.
- The atmospheric temperature will be the calculation basis for the temperature rise value of respective sections.
- Obtain the relative humidity from the temperature difference between the dry and wet bulbs.

Intake Air Temperature (Use a Thermocouple)

See **(Figure 12-1, (2))**:

- Bring the end of the thermocouple to the air cleaner inlet or at about 50 mm away from the intake extension hose end.
- Avoid the heat radiated from the exhaust system or other engine components.

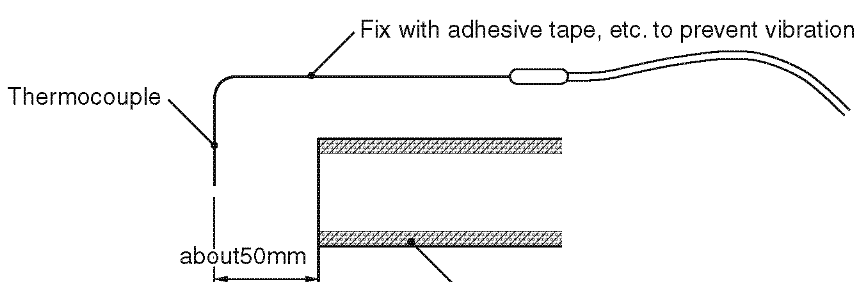


Figure 12-2

Measurement of Air Intake Restriction

See **(Figure 12-1, (3))**:

- Air intake restriction is measured between the air cleaner outlet and the beginning of the engine intake manifold.
- Typically, a negative pressure sensor is attached to the hose that runs between the air cleaner output and the intake manifold.
- Negative pressure is measured by a manometer that is connected to the sensor with a piece of hose.Be sure that there is no water in the air intake pipe.
- If the distance between the intake manifold and air cleaner is short, you can measure the negative pressure by connecting the sensor to the negative pressure indicator part.

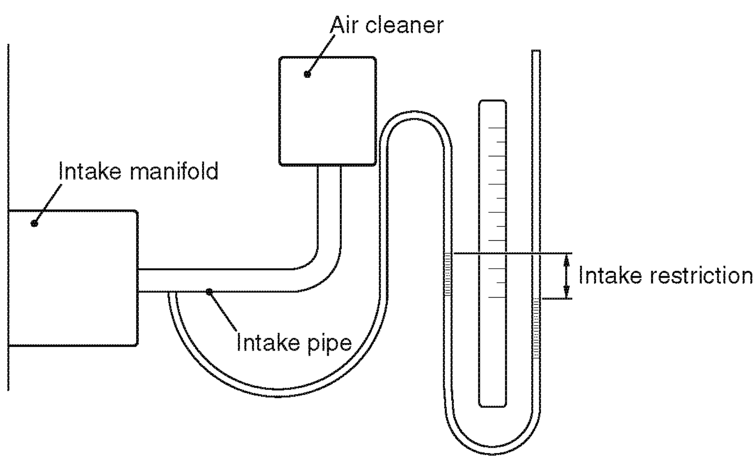


Figure 12-3

Exhaust Temperature: Thermocouple

See **(Figure 12-1, (4))**:

- Measure the exhaust temperature at the exhaust manifold outlet (or the outlet port of turbocharger).
- Insert the thermocouple by cutting a slot or groove in the gasket. If cut slot or groove is too wide, the exhaust gas may leak or the thermocouple location will not be maintained.
- Attach the flange to the exhaust pipe side so the end of the thermocouple is positioned at the center of the exhaust port.
- Make sure you keep the end of the thermocouple at the center of the exhaust port.

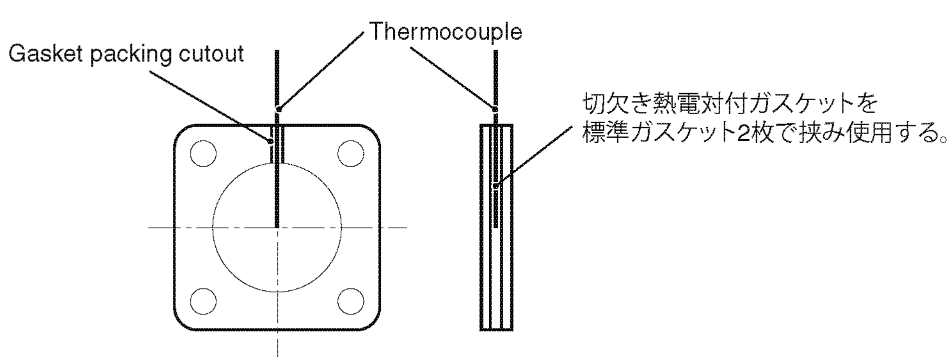


Figure 12-4

Measurement of Exhaust Back Pressure

See **(Figure 12-1, (5))**:

- Exhaust back pressure is measured by installing an adapter near the outlet of the engine exhaust manifold.
- The measurement adapter is normally connected to a manometer using a flexible hose.Since the adapter is exposed to heat from the exhaust gases, the vinyl hose may be damaged if the adapter is too short.To avoid this, use an 8 mm diameter copper pipe for the adapter.An extension pipe of about 1 meter will be needed for radiation of the heat.
- To isolate the extension pipe from engine vibration as much as possible, wind it into a spiral form.Make sure the manometer is filled with water before running the test.
- Fully equip the engine with exhaust system parts that will be used on the driven machine to create the equivalent maximum load.

NOTE:For electronic control engines with EGR, the differential pressure between air intake restriction and exhaust back pressure must be matched within the allowable value.

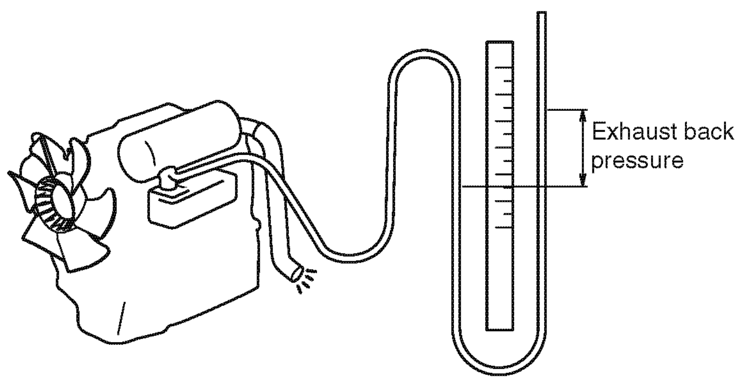


Figure 12-5

Engine Oil Temperature (Use a Thermocouple)

See **(Figure 12-1, (6))**:

- Measure the temperature of engine oil in the main gallery.When measuring in the main gallery, remove the oil pressure switch and prepare an adapter which is equipped with a thermocouple (with an R1/8 taper thread).
  If this adapter is not available, measure the temperature of engine oil in the oil pan according to the following procedures:
- Measure the temperature at the lower level (L) mark on the dipstick.
- Attach the thermocouple to the dipstick so that the end of the thermocouple is positioned at the lower level mark on the dipstick.
- Normally, it would be sufficient to wind the lead of the thermocouple around the dipstick. Make sure that the end of the thermocouple is not separated from the dipstick after assembly.

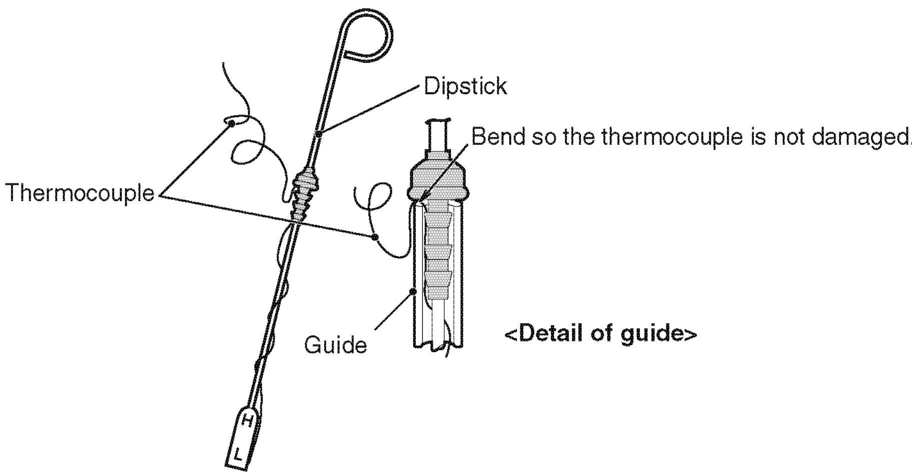


Figure 12-6

Coolant Temperature (Use a Thermocouple)

See **(Figure 12-1, (7))**:

- Drain the engine coolant to where no coolant leaks from the upper hose before removing it and mounting the thermocouple.
- If the temperature of the engine coolant outlet port is predicted to be equal to or below 85°C (158°F), a fully blocked open thermostat should be used.
  Use the standard thermostat unchanged if the driven machine is tested under the evaluating value for the actual operating environmental temperature in a high constant temperature chamber.
- When measuring the engine coolant temperature, remove the coolant temperature switch part of the thermostat case (or the coolant temperature sensor) and measure the temperature using an adapter, prepared for this purpose, which is equipped with a thermocouple (with a 16M thread) .
- If this adapter is not available, measure the engine coolant temperature at the engine outlet port or radiator inlet port.In that case, perform the measurement according to the following procedures:
- Insert the thermocouple at the end of the coolant hose nearest the hose clamp.
- Trace the outline of the hose clamp on the coolant hose.The leading end of the thermocouple will be inserted between the hose clamp wires to prevent coolant leakage as illustrated below.
- Mount the thermocouple away from the wind so it will not to be influenced by it.
- Before mounting the thermocouple, loosen the hose clamp and remove the coolant hose, then position the leading end of the thermocouple by aiming at the trace of the hose clamp you previously made.

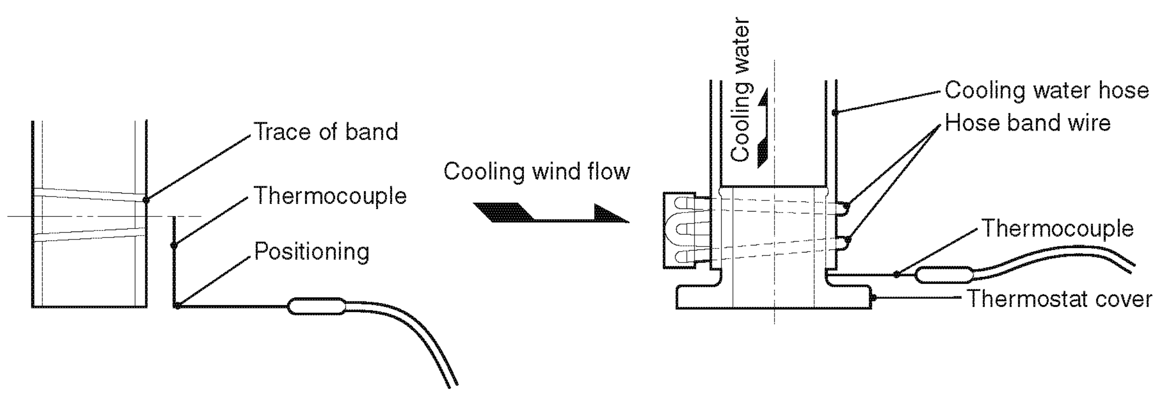


Figure 12-7

- If engine coolant leaks develop in the above setup, prick a hole on the coolant hose with an eyeleteer (stiletto) as diagonally as possible so the thermocouple can de inserted directly into the hose.
- Replace the hose after the test is complete.

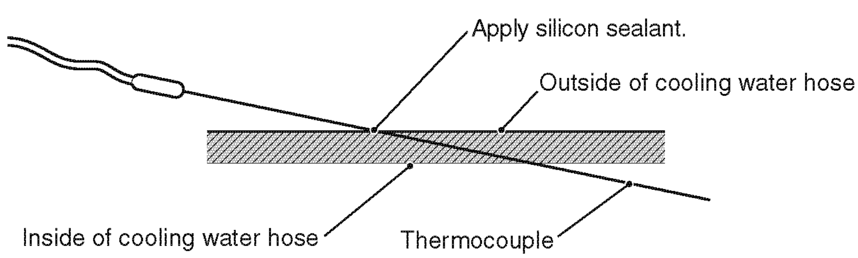


Figure 12-8

- The thermocouple can be inserted directly into the coolant and sealed with silicon sealant.

Engine Speed Measurement

See **(Figure 12-1, (8))**:

- A non-contact tachometer (optical reflection or magnetic pulse) is effective for measuring the engine speed of stationary and moving driven machine applications. The optical reflection tape is usually pasted on the crank pulley or flywheel for both engine types.
- How to measure engine speed (counting gear teeth)
  Since TNV engines, especially the direct injection system equipped with MP fuel pump, have a two-way delivery valve for controlling the pressure fluctuation of the fuel injection pump, their engine revolution speed cannot be measured the conventional way by measuring the vibration of the fuel injection high pressure lines.
  An alternative method like the one described below should be used.
  This method utilizes the fuel pump driving gear at the filler port of the gearcase as shown in **(Figure 12-9)**. The engine revolution speed is measured by counting the gear tooth pulse using the speed pick-up attached to the engine oil filler port through the adapter. The adapter and other necessary components are available from Yanmar as genuine accessories.

Adapter: 119802-99911

Lock ring: 119802-99921

Note that the number of teeth of the fuel injection pump driving gear varies among the models as described below.

2TNV70 – 3TNV76 models: 62 teeth

(For the above models, which are IDI system, the conventional method that utilizes the injection high pressure lines can be used for the measurement.)

3TNV82A – 4TNV88 models: 56 teeth

4TNV94L – 4TNV98T models: 64 teeth

Since the gap between the speed pick-up and the driving gear is a very important factor, set it according to the instructions packed with the pick-up device. It is recommended to select a speed pick-up that is a little longer than the specifications. **(Figure 12-10)** shows how to assemble the components.

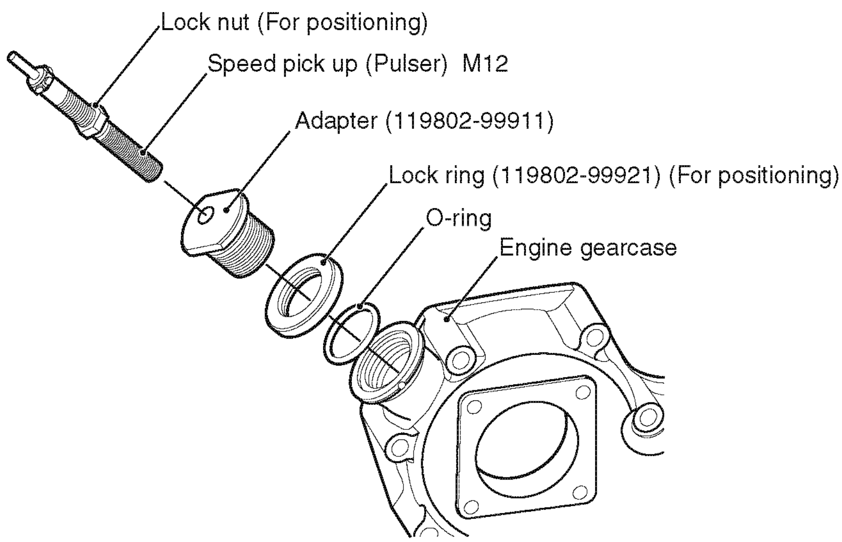


Figure 12-9

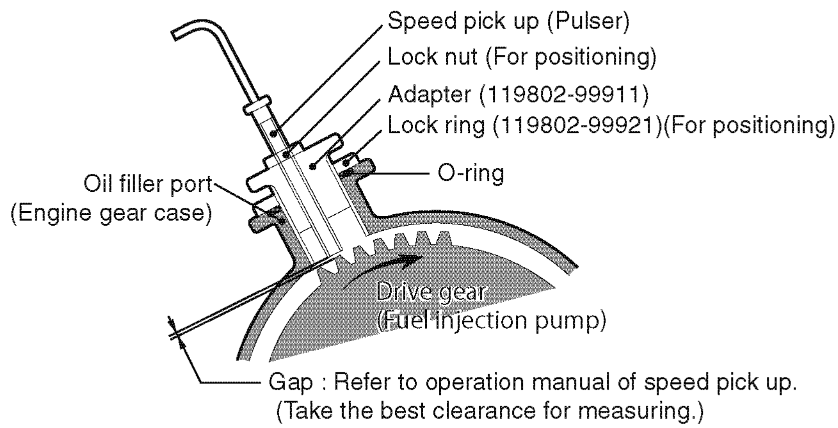


Figure 12-10

1. If you are using a high pressure pipe tachometer, mount the pick-up to the straight section of the high pressure pipe near the fuel injection valve. Use the pliers to firmly tighten it. (For IDI engine only)

Other Temperature Measurements (Use Thermocouple, etc.)

Measure the temperature of engine components as required:

1. Measure the temperature around electrical parts at any position 10-30 mm away from the engine body part.
    - Solenoid
    - Starter Motor
    - Alternator
    - Controller for electronic control
    - Governor for electronic control (actuator)
2. Fuel Temperature
    - Fuel temperature at injection pump inlet.
    - Fuel temperature at return fuel outlet.

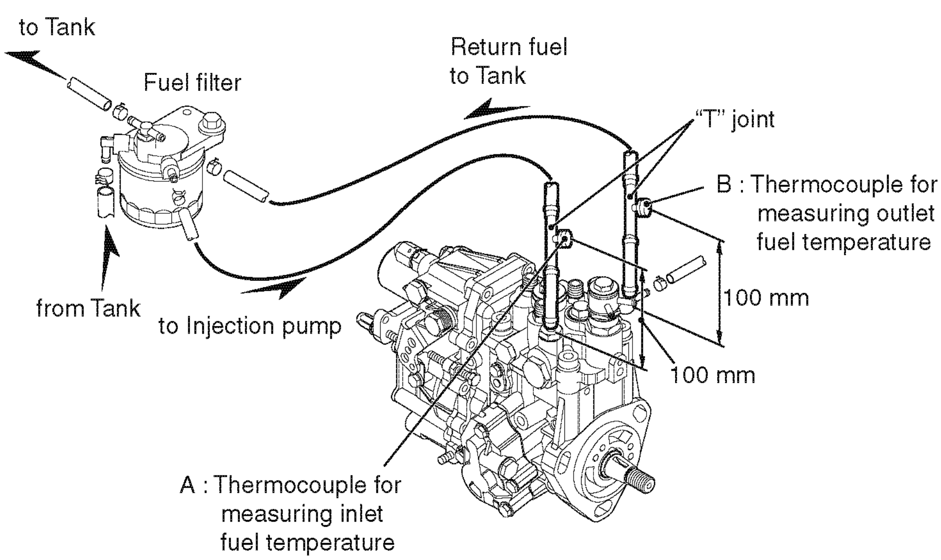


Figure 12-11

PREPARATION FOR MATCHING TEST OPERATION

After preparation for temperature and speed measurement as described in the preceding subsection, begin preparation for operating the driven machine.

Check the engine oil and coolant level and make sure that the test equipment is not in contact with any rotating parts.

If the driven machine has an engine compartment, open it before starting the engine. While the machine is warming up, check for leakage of oil, water, or diesel fuel from the thermocouple mounting or other areas of the engine. Close the engine compartment and add the load.

Operation with the machine loaded varies by the type of the driven machine. Even if it is designed for the same purpose, every driven machine application varies somewhat. Consult with the driven machine manufacturer and Yanmar to determine the correct setup before actually starting the matching test.

Both sides should verify the following items:

- Test is made under a load actually applied by the user.
- Test by following the work pattern designated by the driven machine manufacturer.
- Conduct the test under the maximum load capacity of the driven machine.

Often the matching test is performed at the manufacturer's laboratory or test site and in a different season from the intended use.

It is important is to establish and agree on the appropriate maximum load and duty cycle. This should be documented as part of the engine evaluation.

HEAT BALANCE TEST

Engine cooling performance is a critical component of the quality of the driven machine.

Conduct the loaded operation after making preparation as described in the preceding subsection. Sample the temperature data after all of the engine components are stabilized. Depending on the driven machine, and season, it will take 30 to 50 minutes for the temperature of all of the components to stabilize.

Data sampling may be started when engine oil temperature becomes stable (less than 1°C rise in 10 minutes). If the load changes, the coolant temperature and the exhaust temperature change sharply, but the engine oil temperature will remain comparatively stable.

TEST DATA INTERPRETATION AND CRITERIA

A number of things can be judged from the stable temperature data obtained from the test.

Although a final, comprehensive judgment is necessary, a guide for interpreting discrete temperature data and making a judgment is listed below.

Test Data Interpretation and Criteria

Measured temperature item		Allowable maximum temperature (criteria)	Improvement review item
1	Atmospheric temperature	• In evaluating the heat balance, atmospheric temperature shall be the maximum actual operating temperature of the driven machine. This temperature is determined depending on customer's specifications because the setting value may be different for each driven machine.If not specified by your customer, atmospheric temperature shall be 40°C (104°F) . • This will be the baseline you should use when you analyze the data for the engine components.	
2	Engine coolant temperature	• The allowable maximum coolant temperature shall be 105°C (221°F). This must be strictly adhered to regardless of the ambient temperature. (with radiator cap of 88 kPa (0.9 kgf/cm^2).) • If the coolant temperature reaches 105°C (221°F), see if the actual operating temperature of the driven machine is exceeded.If it is exceeded, see if the coolant temperature tracks with an atmospheric temperature rise (see *conversion rate*).If it cannot be explained by atmospheric conditions, try the Improvement Review suggestions. • The conversion rate between the atmospheric temperature rise and the engine coolant temperatures rise is 1:1.That means if the atmospheric temperature rises 1°C (1°F), the coolant temperature should also rise 1°C (1°F).	Engine compartment shape & openings (air outlet or inlet), recirculation of hot air, fan diameter and speed, radiator capacity, load capacity, duty cycle, exhaust outlet
3	Engine oil temperature	• The maximum engine oil temperature shall be 115°C (239°F). This must be strictly adhered to regardless of the atmospheric temperature. • Using the conversion rate, determine whether the converted engine oil temperature would be 120°C (248°F) when setting the atmospheric temperature to the actual operating temperature of the driven machine. • Using this conversion rate, you can also calculate/estimate the converted atmospheric temperature when setting the engine oil temperature to 120°C (248°F). • The conversion rate for the atmospheric temperature rise and the engine oil temperature rise shall be normally 0.8. • If the atmospheric temperature rises 1°C (1°F), the engine oil temperature would rise 0.8°C (0.8°F).	Engine compartment shape (air outlet and inlet), recirculation of hot air, air flow around the oil pan, review of the oil cooler, load capacity, duty cycle
4	Intake air temperature	• Set the development target for the allowable intake air temperature so it is no more than 5°C (41°F) above the atmospheric temperature. • If the intake air temperature cannot be lowered to 10°C (50°F) above the atmospheric temperature, even after you add or relocate the intake air hose, review the driven machine capacity since the engine output will be affected by atmospheric temperature.	Engine compartment shape (air outlet and inlet), recirculation of hot air, air cleaner position, intake air hose position, load capacity
5	Temperature inside engine compartment	• Set the development target for the allowable engine compartment temperature so it is no more than 10°C (50°F) above the atmospheric temperature. • As this is difficult to achieve using a puller fan, improve air flow so the diesel fuel temperature and electrical parts ambient temperature meet the specifications.	Engine compartment shape (air outlet and inlet), recirculation of hot air, fan type, panel position
6	Diesel fuel temperature	• Diesel fuel temperature should be a maximum of 80°C (176°F) to protect rubber materials in the pump. • Engine output will start to drop as the diesel fuel temperature rises above 40°C (104°F). It is recommended that you maintain a temperature below 60°C (140°F) at the fuel inlet port of fuel injection pump. • If the diesel fuel temperature rises higher than 60°C (140°F), the engine output will be adversely affected. • The temperature conversion rate shall be 1.0.	Engine compartment shape (air outlet and inlet), recirculation of hot air, fan type, panel position

Measured temperature item		Allowable maximum temperature (criteria)	Improvement review item
7	Temperature around electrical parts	• Set the development target value for ambient temperature around electrical parts (such as starter motors, alternators, solenoids, and relays) to 80°C (176°F) or below regardless of the atmospheric temperature.Also for the electronic control engines, the ambient temperature around the governor as well as the controller must be set to 80°C (176°F) or below.Even if the ambient temperature is under 80°C, do not allow the air to stagnate. • Ambient temperature above 80°C (176°F) may cause degradation of electrical parts and components.	Engine compartment shape (air outlet and inlet), recirculation of hot air, fan type, panel position
8	Exhaust temperature	For exhaust temperature, see *Output Matching Test on page 12-19*.	

Heat Balance Evaluation

This subsection describes how to evaluate heat balance by examining temperature data collected from the matching test.

Suppose that the final stable temperatures obtained from operation under load are as follows:

			Calculation Example
T_a	: Ambient temperature	°C (°F)	19°C (66.2°F)
T_w	: Coolant engine outlet port temperature	°C (°F)	87°C (188.6°F)
T_o	: Engine oil temperature	°C (°F)	101°C (213.8°F)
T_x	: Intake air temperature	°C (°F)	34°C (93.2°F)

The following temperatures are also necessary for the heat balance evaluation:

T_{mw}	: Allowable maximum temperature of coolant	105°C (221°F) (radiator cap: 0.9 kgf/cm^2)
T_{mo}	: Allowable maximum engine oil temperature	115°C (239°F)
T_{cw}	: Coolant use limit atmospheric temperature	°C (°F)
T_{co}	: Engine oil use limit atmospheric temperature	°C (°F)
T_{dif}	: Intake air temperature rise value (T_x - T_a)	°C (°F)

Coolant Use Limit Atmospheric Temperature Estimation

Calculation Example

This calculation estimates the coolant use limit atmospheric temperature T_{cw} when the maximum allowable coolant temperature (T_{mw} = 105°C [221°F]), the atmospheric temperature T_a and the coolant temperature T**w** are known.

Calculate the estimated T_{cw} as follows:

$$T_{cw} = (T_{mw} - T_w) + T_a$$

T_a	:	Ambient temperature	19°C (66.2°F)
T_w	:	Coolant engine outlet port temperature	87°C (188.6°F)
T_{mw}	:	Allowable maximum temperature of coolant	105°C (221°F) (radiator cap: 0.9 kgf/cm^2)
T_{cw}	:	Coolant use limit atmospheric temperature	°C (°F)

$$\begin{aligned} T_{cw} &= (T_{mw} - T_w) + T_a \\ &= (105 - 87) + 19 \\ &= 37°C\ (98.6°F) \end{aligned}$$

It is necessary to evaluate the coolant use limit atmospheric temperature T_{cw} by considering the environment in which the driven machine is operated.

For example, if this driven machine was to be used in Japan, the coolant use limit atmospheric temperature T_{cw} would generally be set at 40°C (104°F).

In the present example, T_{cw} = 37°C (98.6°F), the heat balance would not be met.

To make T_{cw} = 40°C (104°F) or higher, you need to lower the engine coolant temperature by the following amount:

(Target T_{cw} - Test result T_{cw}) x 1
= (40°C [104°F] - 37°C [98.6°F]) x 1
= 3.0°C (37.4°F)

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

Engine Oil Temperature Evaluation

Calculation Example

This calculation estimates the engine oil use limit atmospheric temperature T_{co} when the maximum allowable oil temperature [T_{mo} = 115°C (239°F), the atmospheric temperature T_a and the engine oil temperature T_o are known.

Calculate the estimated T_{co} as follows:

$$T_{co} = (T_{mo} - T_o)/0.8 + T_a$$

T_a	:	Ambient temperature	19°C (66.2°F)
T_o	:	Engine oil temperature	101°C (213.8°F)
T_{mo}	:	Allowable maximum engine oil temperature	115°C (239°F)
T_{co}	:	Engine oil use limit atmospheric temperature	°C (°F)

$$T_{co} = (T_{mo} - T_o)/0.8 + T_a$$

$$= (115°C\ [239°F] - 101°C\ [213.8°F])/0.8 + 19°C\ (66.2°F)$$

$$= 36.5°C\ (97.7°F)$$

Evaluate the engine oil use limit atmospheric temperature T_{co} by considering the environment in which the driven machine is operated.

In the present calculation example, T_{co} = 36.5°C (97.7°F).

For example, if this driven machine is to be used throughout the year in Japan, the limit atmospheric temperature T_{co} is generally set at 40°C (104°F).

T_{co} = 36.5°C (97.7°F) in the present calculation example does not meet the required heat balance.

To make T_{co} = 40°C (104°F) or more, you need to lower the engine oil temperature by the following amount:

$$(\text{Target } T_{co} - \text{Test result } T_{co}) \times 0.8$$

$$= (40°C\ [104°F] - 36.5°C\ [97.7°F) \times 0.8$$

$$= 2.8°C\ (37.04°F)(\text{Calculation example})$$

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

Intake Air Temperature Evaluation

This evaluation compares the engine intake air temperature T_x to the ambient temperature T_a. Suppose the intake air temperature rise value is T_{dif}, then the calculation is as follows:

$$T_{dif} = T_x - T_a$$

T_a	:	Ambient temperature	19°C (66.2°F)
T_x	:	Intake air temperature	34°C (93.2°F)
T_{dif}	:	Intake air temperature rise value (T_x - T_a)	°C (°F)

$$T_{dif} = T_x - T_a$$

$$= 34°C\ (93.2°F) - 19°C\ (66.2°F)$$

$$= 15°C\ (59°F)$$

The unit for T_{dif} in the calculation example shown above is °C.

If the intake air temperature rises, engine output is reduced.

It is best to supply air that is as close as possible to the ambient temperature.

In the prototype of the driven machine, examine air cleaner position and intake air hose direction, targeting T_{dif} at 5°C (41°F) or below.

Depending on the results of the output matching (see *Output Matching Test on page 12-19*), there is no major effect on engine output if T_{dif} is below 10°C (50°F). In the calculation example above, T_{dif} is 15°C (59°F), therefore it is necessary to change the position of the air cleaner or intake air hose.

Temperature Evaluation of Various Other Components

Evaluation of the coolant, engine oil and intake air temperatures are important in the heat balance test.

To evaluate the temperature of other engine components, refer to *Test Data Interpretation and Criteria on page 12-15*.

OUTPUT MATCHING TEST

Mismatching of engine output to the driven machine load may lower engine speed during operation and produce insufficient power. It is necessary to match engine output and load during the early stages of development. Using an actual machine to evaluate this is referred to as the output matching test.

ENGINE PERFORMANCE

Engine performance is generally represented by the output curve and torque curve as shown below. Performance is controlled by the fuel injection pump and the governor. The output, speed and maximum torque requirements vary among driven machine applications. Engines with various specifications are available so that the characteristic requirements of the driven machines are satisfied.

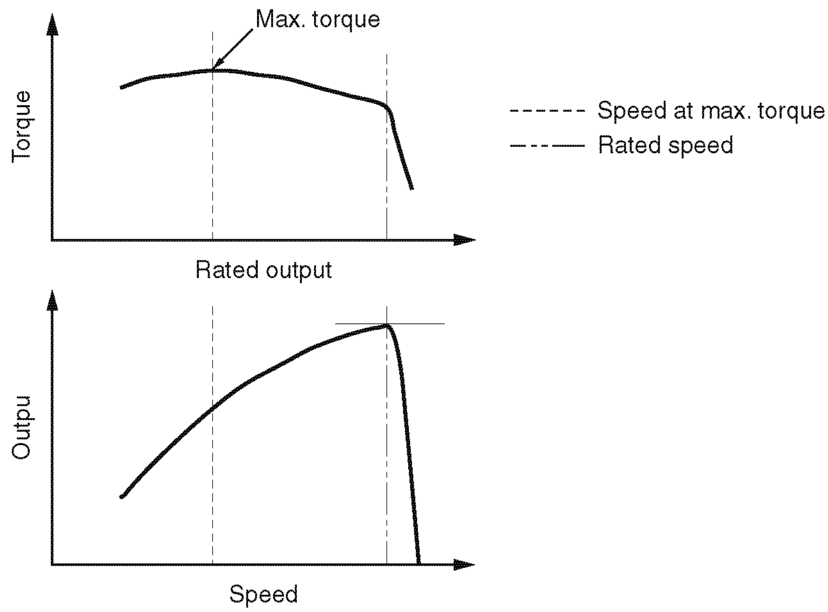


Figure 12-12

Engine performance is only guaranteed under the following conditions and within the range of tolerance.

Engine performance is affected by the following conditions. The amount of change in performance is discussed in the next section.

- Output setting under ISO standard atmospheric conditions

Ambient temperature	25°C (77°F)
Relative humidity	30%
Atmospheric pressure	100 kPa (750 mmAq)

- Fuel temperature at output setting: 38 ±3°C (100.4 ±3°F)
- Fuel meeting JIS specifications (density, cetane number)
- Output setting tolerance: ±3%
- Torque setting tolerance: ±5%
- Engine output: Median of tolerance
- Maximum torque: Range value

EVALUATION OF OUTPUT MATCHING

Engine output and torque are guaranteed under the conditions shown in the previous section. Performance is significantly affected, however, by how the engine is installed and the ambient conditions. Performance is also significantly affected by the diesel fuel and intake air temperatures. **Figure 12-12** and **Figure 12-13** show the effect of temperature. Perform the output matching test in the development stage to verify that the machine functions as specified even though temperature changes occur.

During the output matching test, it is essential to measure the temperature of the fuel and intake air. This data is used to estimate the fuel and intake air temperature that will be experienced when the machine is operated under maximum ambient temperature conditions. This allows you to estimate how much the engine performance will change.

Output matching evaluates machine load and engine torque performance.

Engines used for the output matching test must have their performance measured at the plant beforehand. This engine is referred to as a sample engine.

For correction of the output based on the atmospheric conditions and altitude characteristics, see *Power Corrections on page 4-3 and Altitude Characteristics on page 4-13*.

EVALUATION OF OUTPUT MATCHING FOR GENERAL PURPOSE INDUSTRIAL MACHINES

General industrial machines are driven by variable medium speed (VM) and variable high speed (VH) engines. The matching test of the machine and engine output is performed using the following procedure.

Preparation for Matching Test

Before the test, complete the preparation and checks described below.

- Use a sample engine and make sure engine performance data is available.
- Obtain an engine tachometer, fuel thermometer, intake air thermometer and atmospheric thermometer. A barometer and hygrometer are also needed.
- During the test, the engine's speed control must be kept in the full speed position.
- The operation of the machine must conform to the machine manufacturer's standard.
- The loaded operation, temperature measurement and engine speed measurement must be performed after sufficiently warming up the engine.
- Preparation for operation must conform to the operation manual. Fuel level and engine oil levels must be at the upper limit of their respective dipsticks.

Preparation of Engine Performance Curve at Matching Test

To evaluate the load of the machine, estimate the engine performance during the matching test and prepare the performance curve.

- The ambient temperature during matching test is expressed with T_t.
- Find the output ratio from the fuel temperature and **(Figure 12-12)**. For example, when the fuel temperature T_{tf} is 55°C (131°F), the output ratio P_{rtf} is 97% (0.97).
- Find the output ratio from the intake air temperature and **(Figure 12-13)**. For example, when the intake air temperature T_{ta} is 45°C (113°F), the output ratio P_{rta} is 96% (0. 96).

- Total output ratio P_{rt} is given by the following formula:

  $P_{rt} = P_{rtf} \times P_{rta}$

  For the above example, $P_{rt} = 0.97 \times 0.96 = 0.9312$, or 93.1%.

- This means that the engine output has been reduced to 93.1% of the performance guaranteed in *Engine Performance on page 12-20*. This reduction of output occurred because both the fuel temperature and intake air temperature are higher than those for guaranteed performance.
- The plot data provided under standard conditions for the sample machine (solid line) are multiplied by the above total output ratio P_{rt} over the whole plot area **(Figure 12-14)**.
- The result is the performance curve indicated by the dotted line in **(Figure 12-14)**. This curve represents the engine performance under the ambient conditions of the matching test.

Deration for Fuel Temperature (38°C (100°F) = 100)

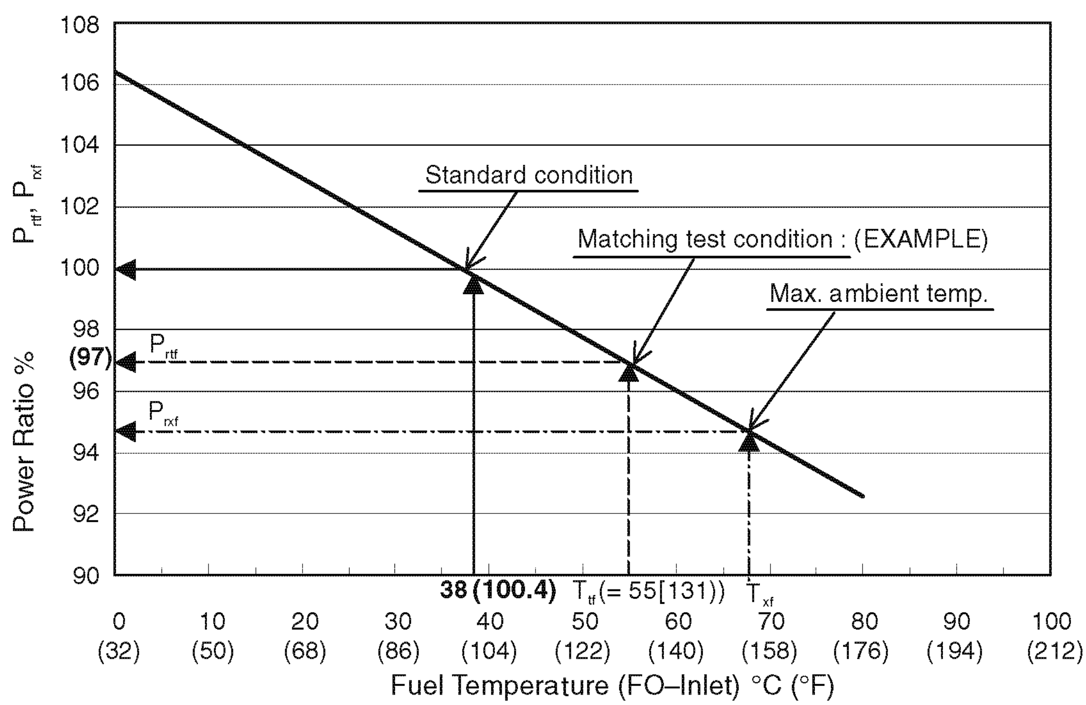


Figure 12-13

Deration for Inlet Air Temperature (25°C (77°F) = 100)

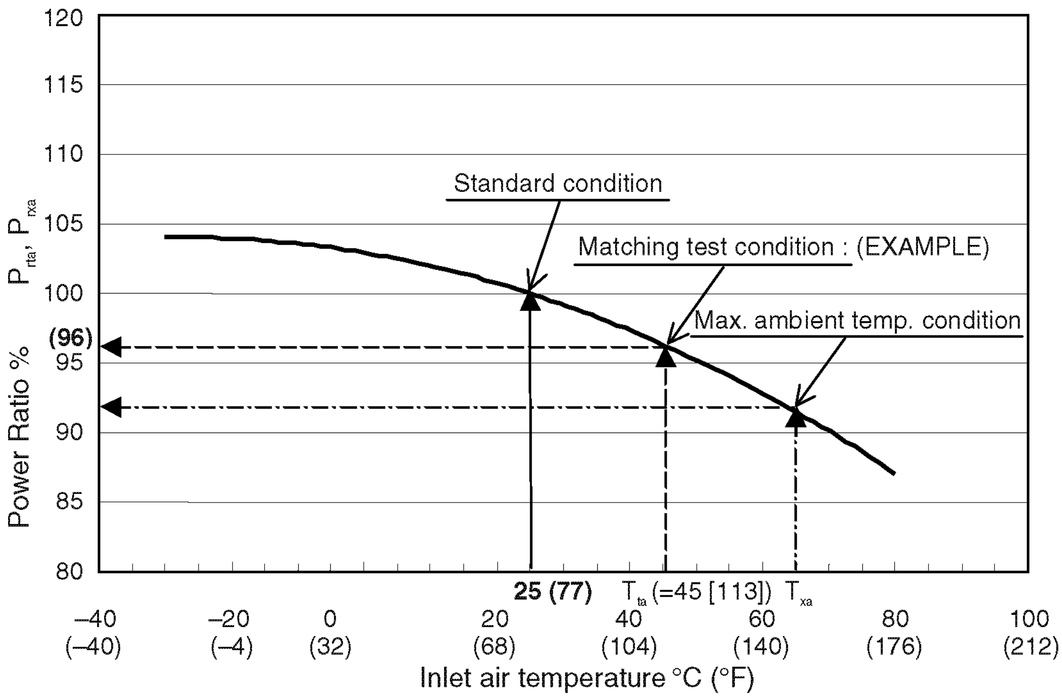


Figure 12-14

Evaluation of Machine Load

The machine load under individual operation pattern is estimated by using the following procedure.

- Plot the engine speed in each operation pattern on the performance curve.
- The intersection of the speed curve and the dotted performance curve indicates the load at the operation pattern.
- The largest load of all the operation patterns is the maximum machine load.
- The estimated machine load is deemed to be unaffected by the atmospheric conditions.
- Confirm with the machine manufacturer to ensure that the load is not affected by the atmospheric conditions.

Evaluation of Output Matching at the Maximum Ambient Temperature

In many cases, the ambient conditions under which machines are actually used are worse than the ambient conditions at the matching test. The method described here is to evaluate whether the engine performance matches the load of the machine at the maximum ambient temperature specified by the machine manufacturer.

Preparation of Engine Performance Curve at the Maximum Ambient Temperature.

First, estimate the engine performance at the maximum ambient temperature and prepare the performance curve by using the following procedure.

- The maximum ambient temperature specified by the machine manufacturer is expressed with T_x.
- The ambient temperature at the matching test is T_t. The fuel temperature and intake air temperature at this time are expressed with T_{tf} and T_{ta}, respectively.
- The fuel temperature T_{xf} and intake air temperature T_{xa} at the maximum ambient temperature T_x are given by the following formulas, respectively:

  $T_{xf} = T_{tf} + (T_x - T_t)$

  $T_{xa} = T_{ta} + (T_x - T_t)$
- Plot these T_{xf} and T_{xa} on **(Figure 12-13)** and **(Figure 12-14)**, respectively.
- The output ratio P_{rxf} at fuel temperature T_{xf} is expressed with α, and the output ratio P_{rxa} at intake air temperature T_{xa} is β.
- Then, the total output ratio P_{rx} at the maximum ambient temperature T_x is given by the following formula.
- $P_{rx} = \alpha \times \beta$
- The plot data provided beforehand for obtaining the performance curve (solid line) by the measurement using the sample engine are multiplied by the above total output ratio P_{rx} over the whole plot area **(Figure 12-15)**.
- The result is the performance curve shown in **(Figure 12-15)** with a dot-and-dash line. This line shows the engine performance at the maximum ambient temperature T_x specified by the machine manufacturer.

Evaluation of Output Matching at the Maximum Ambient Temperature

The machine load has already been measured at the output matching test (*Evaluation of Output Matching for General Purpose Industrial Machines on page 12-21*.

Plot this load on the performance curve shown with dot-and-dash line on **(Figure 12-15)**, and perform the following examination.

Evaluation of output matching at the normal operation of the machine

- Normal operation of the machine refers to the situation where the engine runs in the range from high idle to rated speed when loaded, or the one that is performed longest.
- Check whether the machine load measured in the output matching test is lower than the rated output obtained from the estimated performance curve (dot-and-dash line) at the maximum ambient temperature.
- If the machine load is equal to or higher than the rated output at the maximum ambient temperature, the engine has been used at the rated speed or lower. This is considered the overloaded operation. (The operation in this speed range is evaluated in Step 2. This operation is not deemed the usual one.)
- In case of overloaded operation, it is necessary to reexamine the capacity of machine or selection of engine.
- If it is difficult to prepare the rated output curve (dot-and-dash line) or to estimate it during operation at the maximum ambient temperature, use the following method for evaluation.
- Check whether the machine load is equal to or less than 90% of the rated output obtained from the performance curve (dotted line) at the output matching test. If it is on the 90% level or above, it may be considered as overloaded operation.

Evaluation of output matching at the rare operation of the machine (shown with * in (Figure 12-15))

- The rare operation refers to operations that are performed at the engine's rated speed or lower. Note that the operation is different from the one described in step 1 with regard to the time.
- In this speed range, the torque characteristics of the engine affect the workability of the machine.
- Check whether the allowable speed reduction at the maximum ambient temperature is within the allowable limit of the machine manufacturer standard.
- It is necessary to have an agreement between the machine manufacturer and engine manufacturer beforehand because reduction of speed affects the workability.

The allowable speed reduction from the rated speed is generally in the range from 200 ~ 300 min^{-1}.

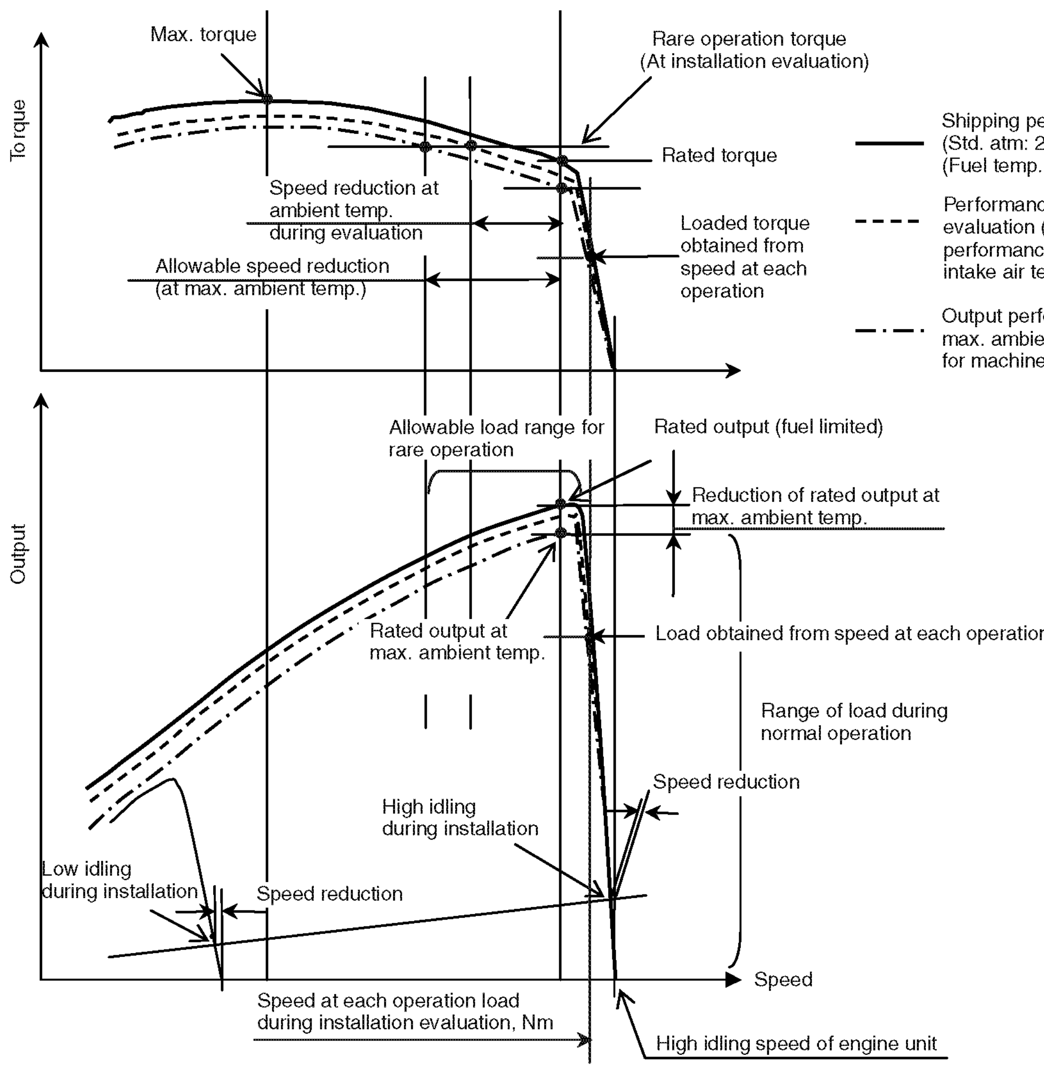


Figure 12-15

EVALUATION NOTES

Be careful of the following when handling the data.

- **Note on the evaluation of engine output and engine torque**

  When performing the evaluation of the load matching of the machine by using engine performance curve (dot-and-dash line) in maximum ambient temperature, note that the tolerance of the engine output is ±3% and that of torque is ±5%. Check whether the performance curve (solid line) of the sample engine, is set on the upper or lower limit of the tolerance.

- **Note on fuel temperature**

  The allowable limit of fuel temperature is 80°C (176°F). When it is estimated that the fuel temperature T_{xf} in *Evaluation of Output Matching for General Purpose Industrial Machines on page 12-21* exceeds 80°C (176°F), consider taking the sixth action described in *Test Data Interpretation and Criteria on page 12-15*. However, if the engine output is set at 38°C (100.4°F), power correction according to **(Figure 12-12)** should be necessary.

- **Note on intake air temperature**

  When the rise of the intake air temperature ($T_{ta} – T_t$) exceeds 10°C (50°F), consider taking the fourth action described in *Test Data Interpretation and Criteria on page 12-15*.

EVALUATION OF OUTPUT MATCHING OF GENERATOR

Engines classified as constant low speed (CL) or constant high speed (CH) are used to drive generators.Refer to *Engine Classification on page 2-3* for details.The procedure for testing output matching between the generator and the engine and the method for estimating the load of the generator are the same as those described in *Evaluation of Output Matching for General Purpose Industrial Machines on page 12-21*.

However, the method of output matching evaluation described for variable speed engines is different from the one for constant speed engines.Note that the meaning of the rated output for the generator is different from the one for the engine.For the meaning of rated output, refer to *Engine Output for Generator Use on page 3-3*.

EVALUATION OF OUTPUT MATCHING AT THE MAXIMUM AMBIENT TEMPERATURE

The load of the machine has already been measured at the output matching test *Evaluation of Machine Load on page 12-23*. Plot the load on the performance curve shown with dot-and-dash line in **(Figure 12-16)** to perform the following examination.

Evaluation of output matching at the rated output of generator

- Check whether the load at the rated output of generator that is measured at the output matching test is equal to or less than the engine's continuous rating obtained from the estimated performance curve (dot-and-dash line) at the maximum ambient temperature shown in **(Figure 12-16)**.

  If the load is over the rating, the engine is considered overloaded. In this case, reexamine the capacity of the generator or the engine selection.

- Or, use the following formula to make the judgment.

  The load at the rated output of generator ≤ Total output ratio P_{rx} x engine's continuous rating (specified value)

Evaluation of output matching at the output 110% of the generator's rated output

- Check whether the load at the output 110% of the generator's rated output that is measured in the output matching test is equal to or less than the engine's rated output that is obtained from the estimated performance curve (dot--and-dash line) at the maximum ambient temperature which is shown in **(Figure 12-16)**.
  If the load is over the rating the engine is considered overloaded.In this case, reexamine the capacity of the generator or the engine selection.
- Or, use the following formula to make determination.
  The load at the output 110% of the generator's rated output $\leq$ Total output ratio P_{rx} x engine's rated output (specified value)

ENGINES COMPATIBLE WITH BOTH 50 HZ AND 60 HZ

For engines that are compatible with both 50 Hz and 60 Hz perform the output matching test at 50 Hz and 60 Hz, respectively.

MAXIMUM OUTPUT OF GENERATOR

Generally, the maximum output of the generator is set to 110% of the rated output of generator. Some generator manufacturers set the maximum output to other percentages such as 105% or 107%. In this case, check whether the load at the rated output of generator (100% of generator output) that is measured at the output matching test is equal to or less than the engine's continuous rating.

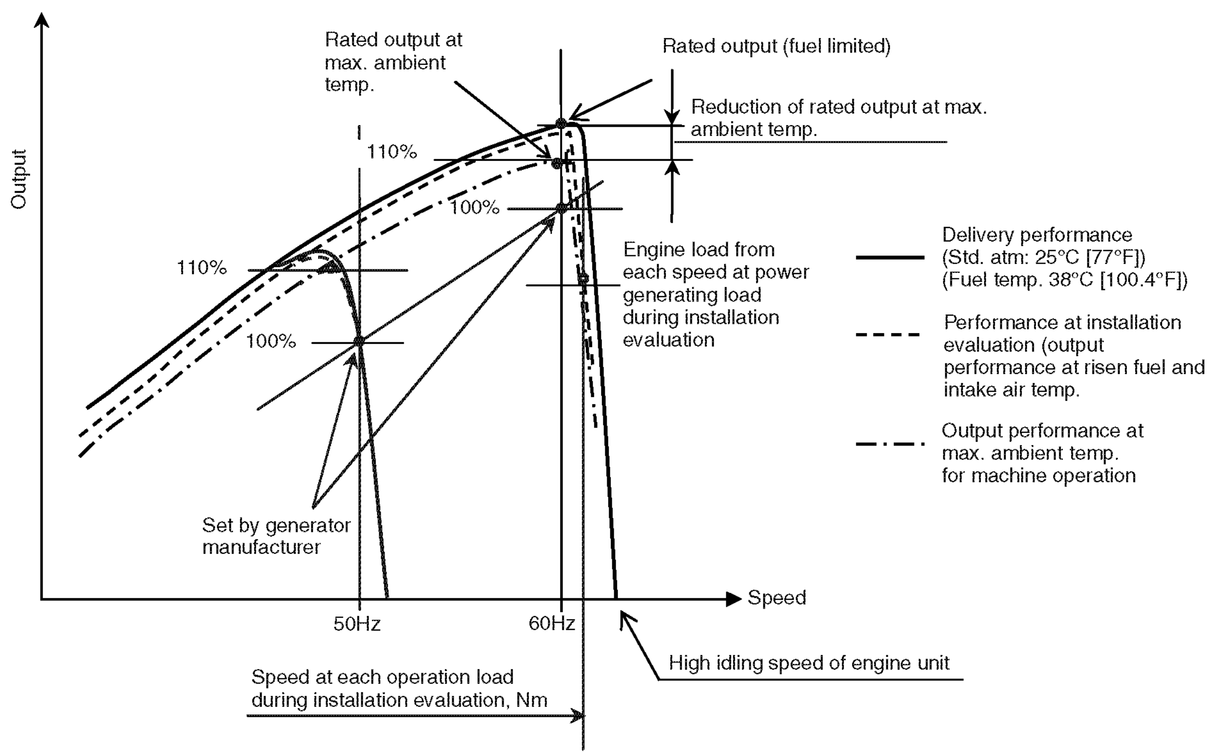


Figure 12-16

VIBRATION MEASUREMENT

Any resonance which occurs in the operating range of an engine will adversely affect the engine and the durability of engine parts.Verify that there is no resonance at each measuring point for the engine operating range.

If any resonance occurs, and the resonance level exceeds the allowable value, it is necessary to improve the vibration by reselecting rubber isolators or any other methods.

Major points to measure the vibration acceleration in longitudinal/lateral directions and vibration amplitude are:

1. Mounting part for engine feet
2. Silencer and bracket (tail pipe)
3. Air cleaner and bracket
4. Starter Motor
5. Alternator
6. Solenoid (* actuator and controller for electronic control engines)

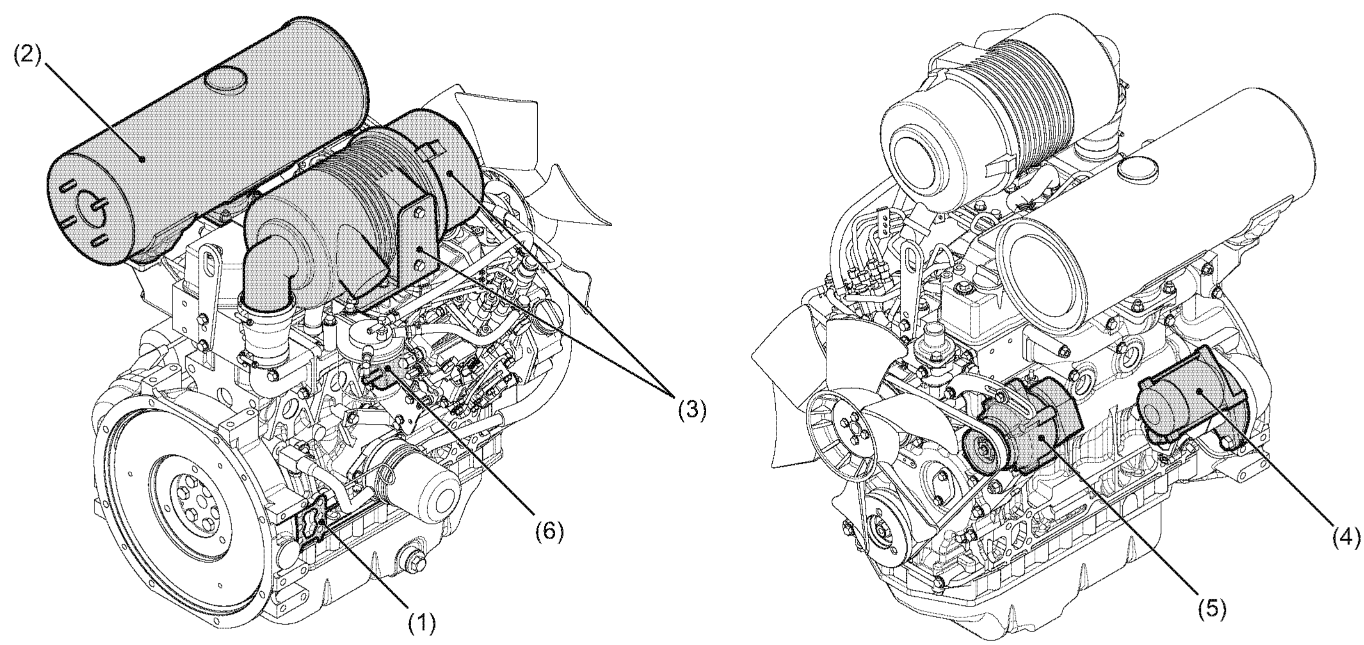


Figure 12-17

INSTALLATION STATE CHECK

This means you should check engine after it is installed in the driven machine for:

- Serviceability
- Interference of fuel system and cooling system parts with driven machine structure
- Interference of electrical wiring harnesses with driven machine structure

Make sure these checks are made before the driven machine goes into production.

The check points will vary depending on driven machine application. An example of a check sheet is provided in *TNV Series Engine Installation Evaluation*.

Section 13

ELECTRICAL SYSTEM

Page

The battery, generator, alternator supply power to the engine starting / stopping system and the electrical components including 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 (See *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. (See *Battery on page 13-31*.)

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. (See *Battery Cable Selection on page 13-37*.)

Use Starter Motor Cables with Appropriate Capacity for the Load

The overall wiring resistance between the starter motor and key switch, power relay or safety 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. (See *Starter Solenoid Cable Selection on page 13-39*.)

Use the Safety Relay in the Starter Motor Circuit

The principal cause of starter motor malfunction is continuing to energize the motor after engine is running (overrun phenomenon). Overrunning the starter motor may burn the armature coil and damage the clutch. Overrunning may be caused by operator error or defective return of the key switch.

The safety relay is a device for avoiding overrun. Users who wish to install the safety relay themselves should consult Yanmar beforehand.

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 using an electric or manual fuel pump in accordance with the TNV Operation Manual.

Note: 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 or being doused with a bucket of water (level R2 conforming to JIS D 0203). NEVER submerge the unit in water and avoid direct high pressure cleaning.

Note: 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 (See *Charging System on page 13-27*)

NEVER Use the Charging Output Voltage for Control

The starting speed of the engine is not in direct proportion to the charging output voltage. NEVER use the charging output voltage for any control purposes. Using the charging output voltage of the alternator to provide power for the starter motor safety relay control signal will lead to malfunction of the starter motor.

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. Manufacturers do not manage the rising output characteristic from the L-terminal and stability and accuracy cannot be guaranteed. Yanmar does not warrant failure of electrical components when the output from the L-terminal is used.

Be Careful with Battery Indicator Operation

When the alternator reaches its specified revolution speed (specified voltage), it begins to charge the battery and the battery indicator comes On. If the battery is not capable of maintaining a charge, the battery may actually be discharged even though the alternator is functioning normally. The battery indicator does not verify that the battery is charging but verifies normal function of the alternator. The charging system still functions normally even if the battery indicator is not working.

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. (See *Control of Battery Indicator on page 13-30*)

Note: 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.

Note: Instruct the driven machine user to use the specified V-belt.

Protect the Generator / Alternator From Water

NEVER submerge the generator / alternator in water or clean it by using high pressure water, which can cause water to enter the brush area and lead to defective charging.

Note: Instruct the driven machine user of the not to submerge the unit 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. Consult Yanmar before using the alternator in such an environment.

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. The P-terminal can be used only for a Yanmar safety relay and specified tachometer.

If a driven machine manufacturer uses their own safety relay system, Yanmar will not warrant starter motors that are burned due to overrun because reliability of the machine manufacturer's system cannot be verified.

Regulator (See *Regulator on page 13-30*)

Keep the Battery Voltage at Normal Level

Using a booster to crank the engine when the battery is over-discharged (8 V or less) can cause abnormally high voltage and destroy other electrical components. The over-discharged battery (8 V or less) should be recharged by using a dedicated battery charger.

Note: Instruct the driven machine user to use a battery or charging system that is at full charge (normal voltage), not a high voltage booster.

NEVER Disconnect the Battery Cable During Engine Operation

Disconnecting the battery cable or removing the battery during engine operation may cause the regulator to malfunction causing high voltage, ranging from 24 to 43 V (at dynamo speed of 5000 min^{-1}), to be output continuously. This can destroy the regulator and other electrical components.

Note: 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 regulator's SCR diode and could cause the wire harness to burn. 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.

Note: Instruct the driven machine user not to reverse the battery cable connections.

Observe the Following Requirements When Selecting the Location for Installation of the Separate Current Limiter

- NEVER install the unit on the engine block.
- Install the unit in a well-ventilated place where the ambient temperature is 65°C (149°F) or less.
- Layout the unit so that the cooling air flows along the cooling fins of the current limiter.
- NEVER connect the ground of other electrical components directly to the body of the current limiter to avoid ripple voltage.

Stop Solenoid (See *Stop Solenoid on page 13-24*)

Keep the Minimum Voltage at Solenoid Pull-in Coil Terminal

If the wiring resistance of the solenoid pull-in coil is very large, the amount of pull-in force will be reduced causing problems when you start the engine. The wiring resistance of the pull-in coil should be equal to or less than 0.07 Ω. When calculating the wiring resistance, the resistance should be assumed as 0.01Ω for one connector and 0Ω for one connected part using a screw.

Use a Standard Timer and a Relay

A one-second timer and a relay are required to control the pull-in coil of the solenoid. To ensure that these components have a high level of reliability and to protect the solenoid from burning, use a Yanmar standard timer and relay. Yanmar does not warranty the solenoid if a Yanmar standard timer and relay are not used.

Use a Diode on the Wire to the Holding Coil Terminal

To inhibit surge voltage, put a diode on the wire to the holding coil terminal. Use a Yanmar standard diode or component equivalent to 600 V - 1.1 A. Be sure to use the correct polarity when you connect the diode.

Consult Yanmar Before Deviating from the Wiring Diagram Provided by Yanmar

Be Careful of Operation at High Temperature

The solenoid is resistant to a maximum ambient temperature of 80°C (176°F) or maximum surface temperature of 100°C (212°F). When the solenoid is placed near hot components, such the exhaust system, place a heat shield between them to protect the solenoid.

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.

Structure of Conventional Type Starting Motor

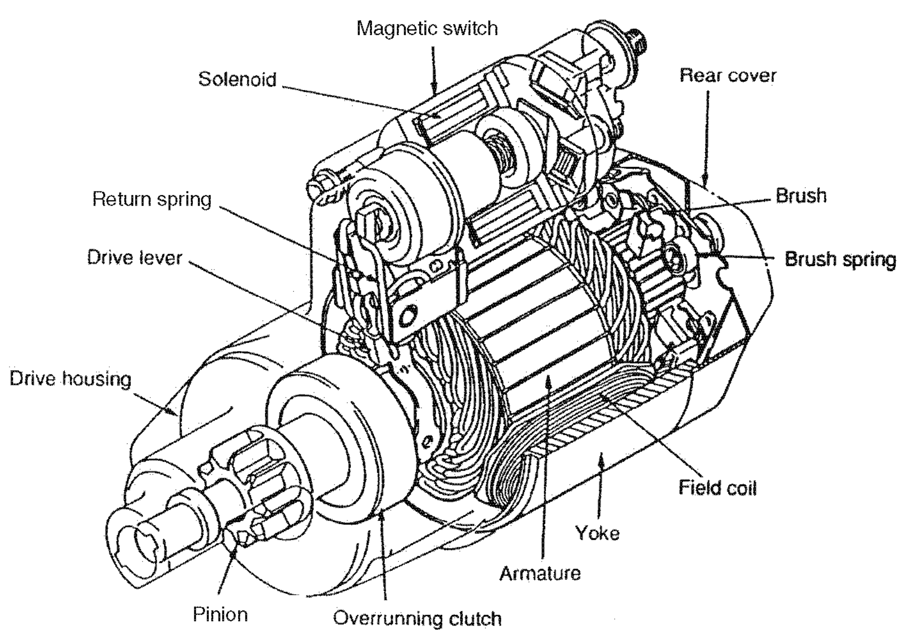


Figure 13-1

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.

Structure of Gear Reduction Starter Motor

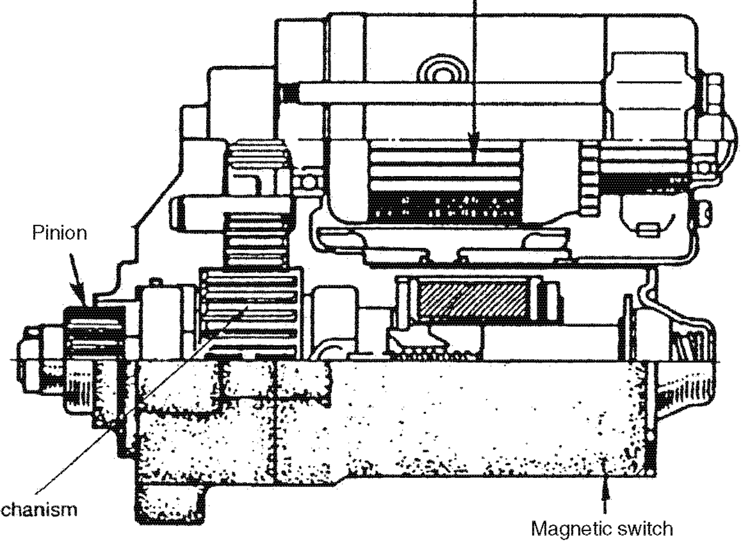


Figure 13-2

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. See *Wiring on page 13-36* 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

Installation of a safety relay is recommended to prevent the starter motor from overrunning (over speed and / or excessive duration of energization) due to operator error. The safety relay automatically cuts off the starter motor circuit during engine start operation when the motor reaches the prescribed speed. During engine operation, it prevents pinion gear engagement due to operator error.

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, see *Outline and Precautions on page 13-6*.

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.

Magnetic Switch

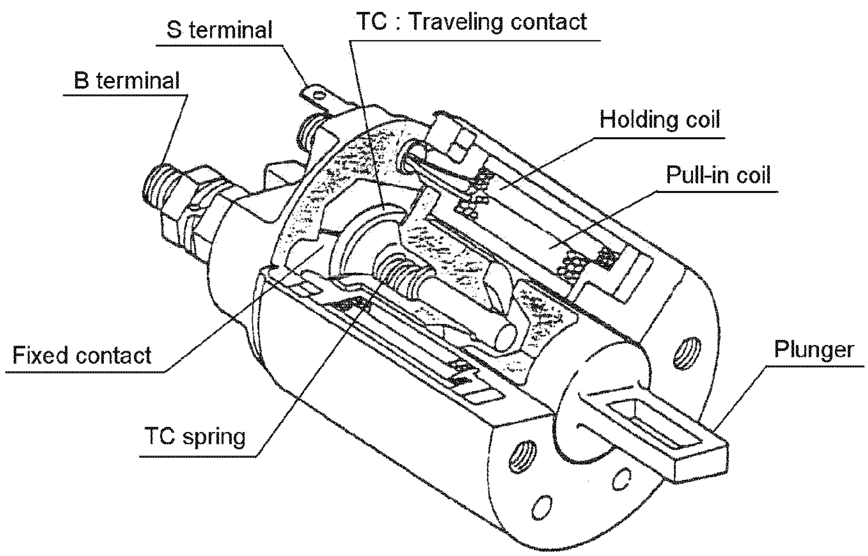


Figure 13-3

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.

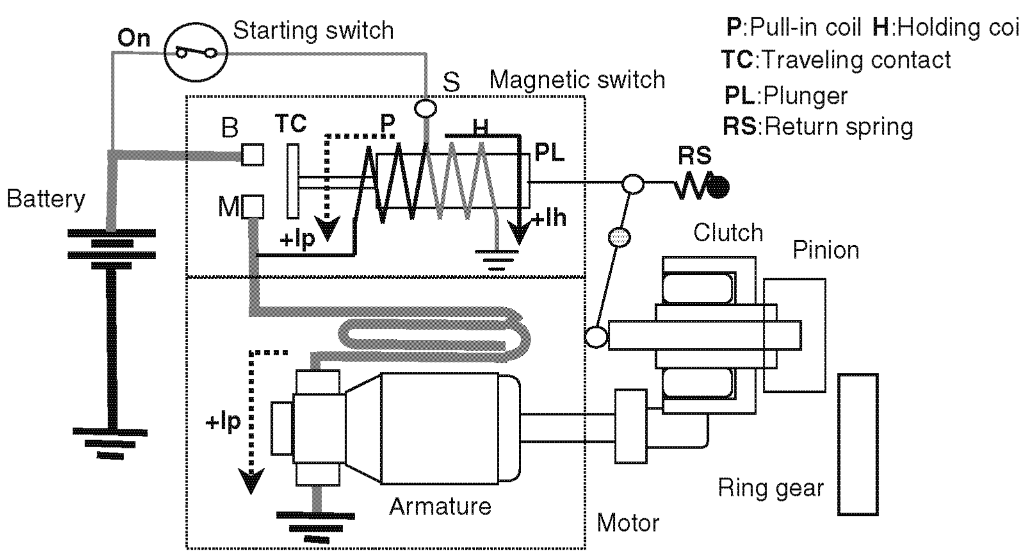


Figure 13-4

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 and holding coil H ($+I_p$ and $+I_h$ respectively), 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**.

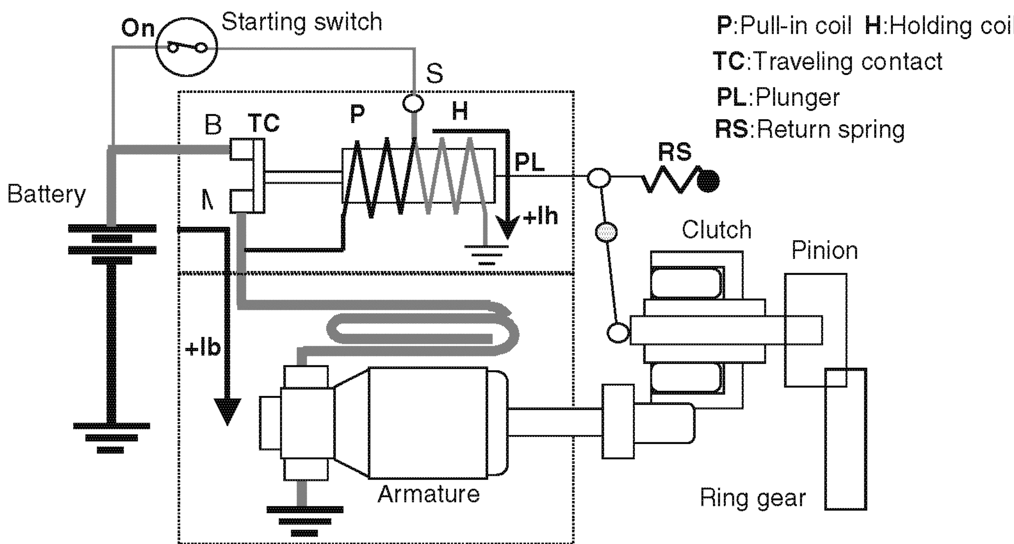


Figure 13-5

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. See *Determination of Cable Size and Length on page 13-38*.

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.

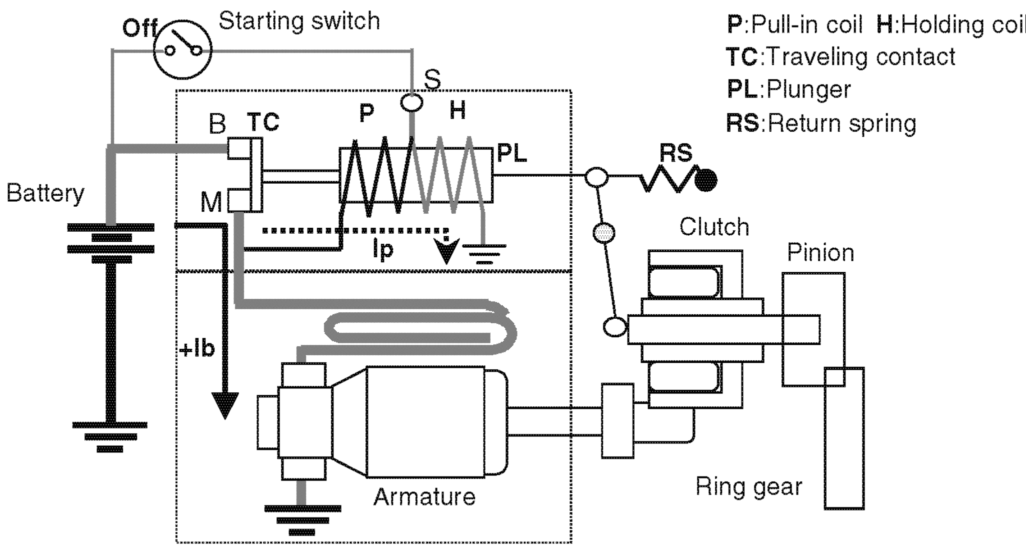


Figure 13-6

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. The terms overcranking and overrunning are defined in *Safety Relay on page 13-18*.
- 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.

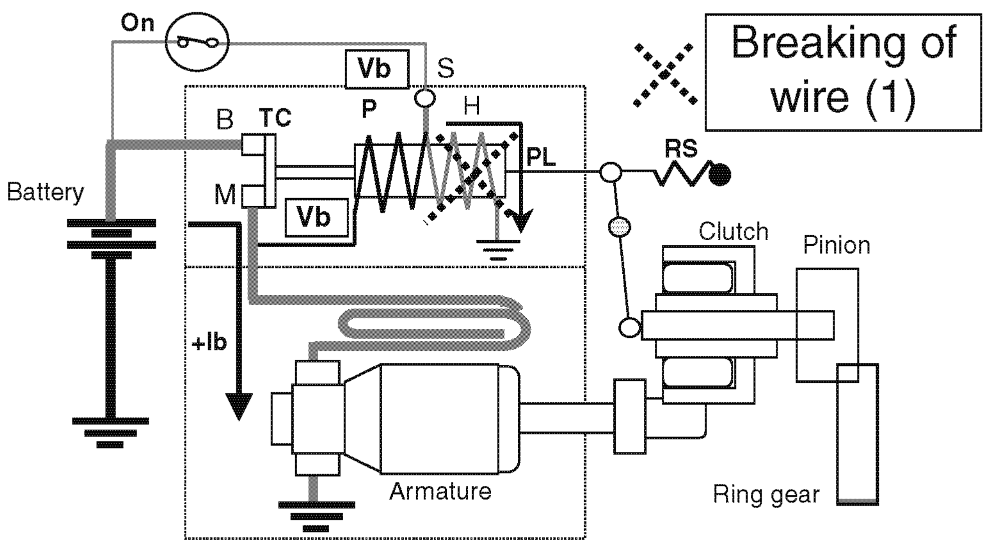


Figure 13-7

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.

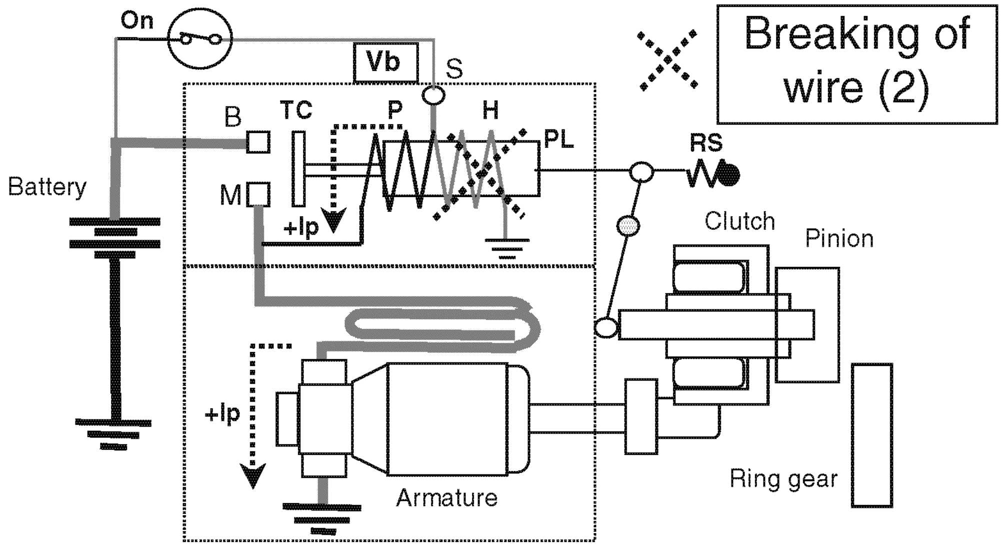


Figure 13-8

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.

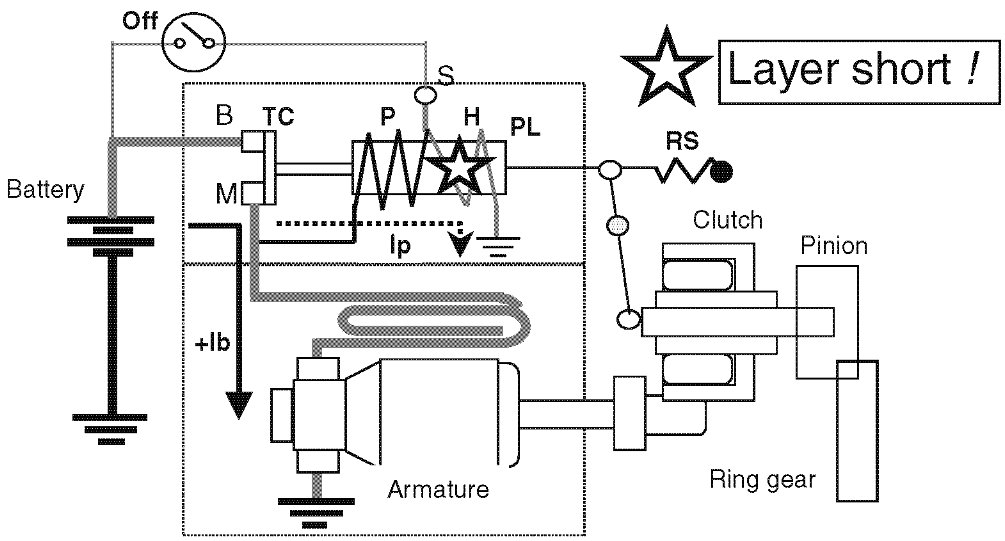


Figure 13-9

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.

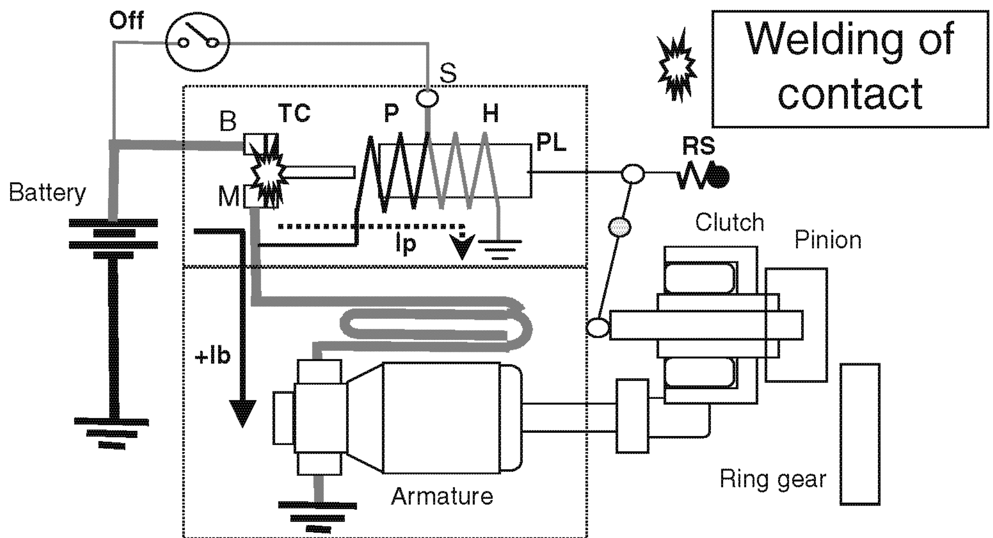


Figure 13-10

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)**.

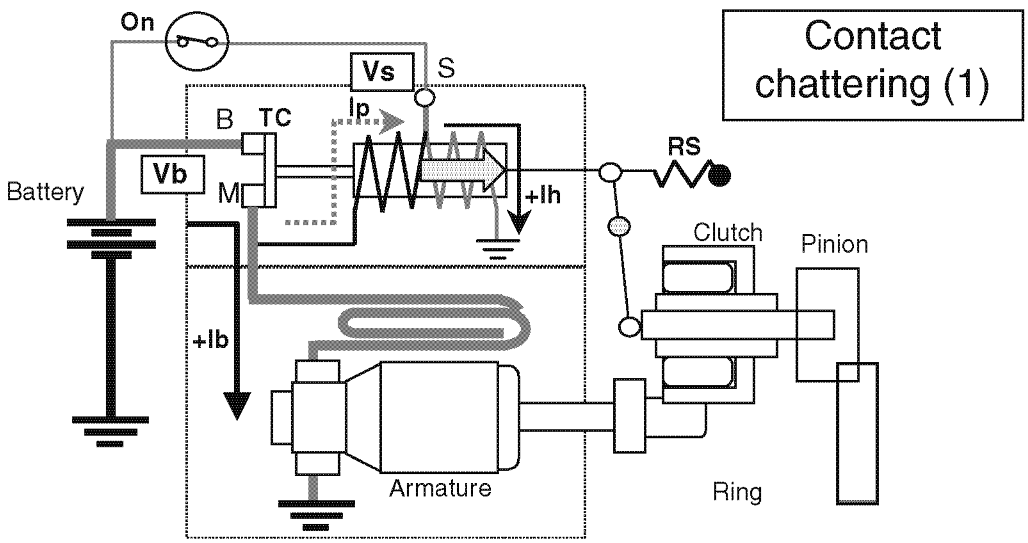


Figure 13-11

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.

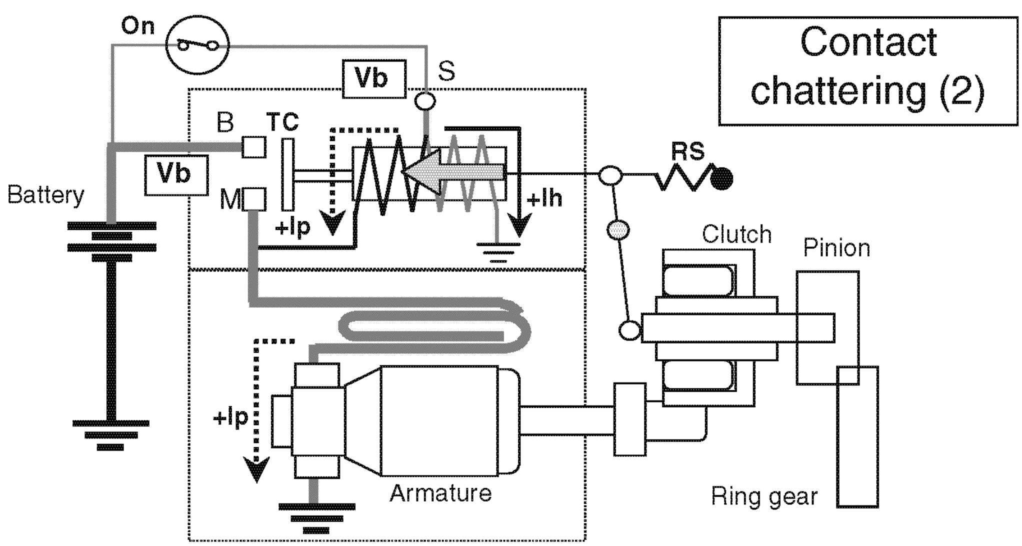


Figure 13-12

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, see *Starter Solenoid Cable Selection on page 13-39*.

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.

SAFETY RELAY

All of the general-purpose engines use a starter motor for cranking. Starter motors often experience burning or breakdown. It has been found that the starter motor itself seldom causes problems. Most problems are caused by incorrect handling and operation.

Most of the problems are from burning of the magnetic switch coils or armature coil, or damage to the pinion or pinion clutch. The immediate cause of the problems varies and may be complex. In any event, energizing the starter motor too long unnecessarily or energizing it unknowingly while the engine is running can cause the components to burn or break.

The safety relay has been employed as a device to prevent problems with the starter motor.

Function of the Safety Relay

The safety relay automatically de-energizes the starter motor when an engine starts to run and exceeds a pre-defined speed. The safety relay can prevent problems as described below.

Prevents Burning of the Magnetic Switch Coil or Armature Coil

The safety relay automatically de-energizes the starter motor once the engine has started even if imperfect return of the key switch or other cause occurs that may keep energizing the unit if the relay is not used. Thus, this function prevents the coils of the starter motor from burning.

When a starter motor is energized after the engine has started, it is called overrunning. The safety relay is able to prevent overrunning and can prevent the burning of the starter motor coils.

Prevents Damage to the Pinion or Pinion Clutch

When the starter motor is overrunning, the pinion and the pinion clutch turn at very high speed while they are engaged with the ring gear of the engine. This causes the sliding part of the pinion to generate heat and discoloration and can lead to clutch damage. It can also lead to generation of heat on the commutator and then damage that part.

Since the safety relay de-energizes the starter motor once the engine has started, the pinion is retracted and problems with the pinion can be prevented.

Prevents Engagement While Engine is Running

If the starter motor is turned on accidentally while the engine is running, the pinion flies out and strikes against the engine ring gear. Since the ring gear is rotating at a very high speed the pinion or pinion clutch can be damaged.

The safety relay can prevent the pinion from engaging while the engine is running.

The Safety Relay Does Not Prevent All Starter Motor Failures

Overcranking

To make the safety relay function, the engine has to run at a pre-defined speed at least once. The speed that an engine has to exceed to make the safety relay work varies among engine types and / or according to engine specifications, which is generally in the 750 to 1100 min^{-1} range.

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 safety relay cannot prevent burning of the starter motor caused by the 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 the overcranking, it is important to thoroughly instruct users to bleed air manually or with an 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.

Low Idle Starting

Some combinations of the safety relay and the crankshaft V-pulley may make the safety relay engine speed cutoff higher than the engine low idle setting. If the engine is started at low idle, the safety relay will not function properly.

Before cranking, be sure to set the engine speed control to medium or higher speed. Operate the engine in accordance with the procedures described in the *TNV Operation Manual*.

Safety Relay Operation Principle

The safety relay operates when the engine exceeds a specified engine speed. Engine speed is determined at the output of the charging system. The safety relay system is limited to three types because the charging system varies among the manufactures; Denso, Hitachi, and Kokusan Denki.

Denso or Hitachi Alternators

Denso and Hitachi alternators have a terminal dedicated to the safety relay, which is called the P terminal. This terminal outputs a pulse signal. The pulse count is proportional to the alternator speed (which is proportional to the engine speed).

The safety relay detects the pulse count and performs voltage conversion in the circuit in proportion to the alternator speed. When the magnitude of the converted voltage becomes the value that corresponds to the pulse count of the engine speed, 750 to 1100 min^{-1} (depending on the engine specification), the safety relay shuts off the starter circuit to turn off the starter motor.

The pulse count output from the Denso P terminal is different from the Hitachi P terminal output even though both alternator speeds are the same. This is due to the difference in the number of alternator poles. It is necessary to provide two types of safety relays that use the pulse detection system.

NEVER connect any electrical device except the safety relay and specified tachometer to this P terminal.

Kokusan Denki's Dynamo

The AC voltage generated by the dynamo is converted to DC by the current limiter. The DC voltage, before the voltage regulator, is proportional to the dynamo's speed (or engine speed). As the dynamo speed increases and the DC voltage reaches a certain point, a voltage of 12 V appears at the terminal dedicated to the safety relay (brown lead of the current limiter).

The voltage of 12 V energizes a separate safety relay (b-contact power relay). The safety relay (b-contact power relay) that is energized shuts off the starter circuit to turn off the starter motor.

The maximum allowable output current of the dedicated terminal (brown lead) is 12 VDC/0.15A.

Safety Relay Selection

There are currently three types of safety relays, Hitachi, NGK, and Kokusan Denki.

These are not interchangeable. The safety relay that is compatible with the charging system of the engine must be used. For the combination of an alternator or dynamo and the safety relay, see *H-d: Dynamo & Alternator* in the *Yanmar TNV Option Menu.*

NGK Safety Relay

NGK safety relays are used with engines equipped with Denso alternators (Part No.: 119802-77200). The alternator with the P terminal should be used.

The safety relay shuts off the starter circuit when the alternator's speed exceeds 1350 ± 210 min^{-1} (at ambient temperature). For example, when the pulley ratio of the alternator pulley to the crankshaft pulley is 0.6, the starter motor is turned off automatically when the engine speed reaches 810 ± 126 min^{-1}. After this, accidental operation of the key switch will not energize the starter motor.

After engagement, the safety relay drops out when the alternator speed becomes 650 ± 150 min^{-1} or less (at ambient temperature). For example, when the pulley ratio is 0.6, the engine speed becomes 390 ± 90 min^{-1} or less at this time. Since the low idle speed of normal engines is at least around 800 min-1, the safety relay continues to function in all engine speed ranges after it has functioned one time.

External Dimensions

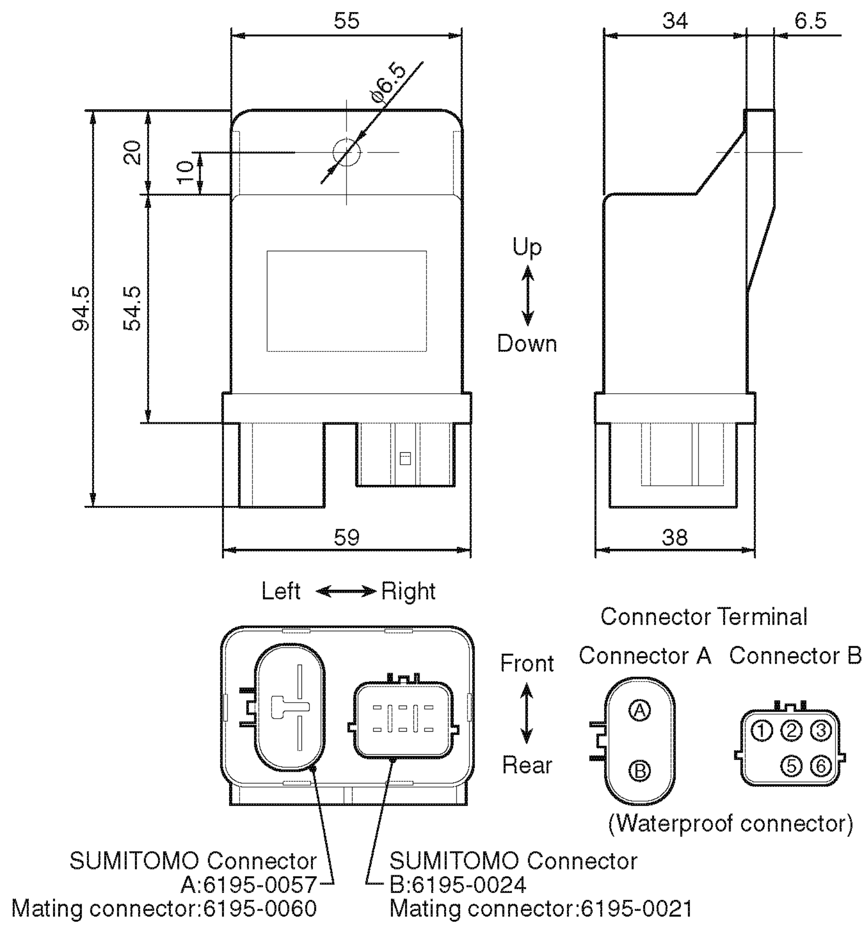


Figure 13-13

Wiring Diagram

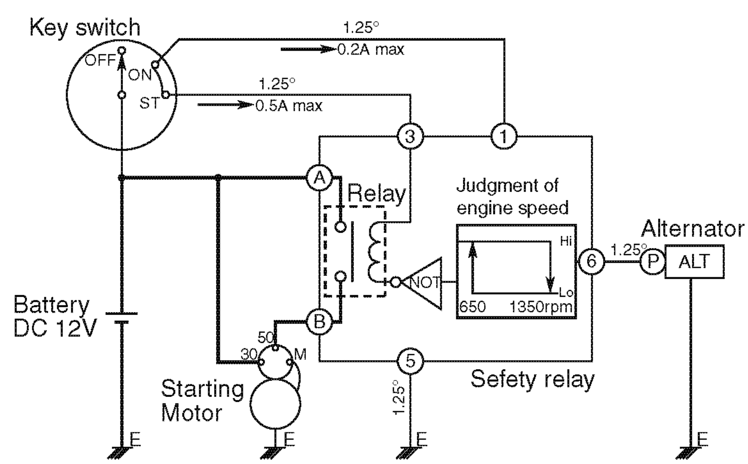


Figure 14-14

Hitachi Safety Relay

Use a Hitachi safety relay with engines that have an Hitachi alternator (Part No. 129136-77200). The alternator should have a P terminal. However, this safety relay is only compatible with Hitachi alternators that are 12V/60A or over. It is not compatible with other alternators.

The safety relay shuts off the starter circuit when the alternator's speed exceeds 1400 ± 120 min^{-1} (at ambient temperature). For example, when the pulley ratio of the alternator pulley to the crankshaft pulley is 0.6, the starter motor is turned off automatically when the engine speed reaches 840 ± 72 min^{-1}. After this, accidental operation of the key switch will not energize the starter motor.

After engagement, the safety relay drops out when the alternator speed becomes 498 min^{-1} or less (at ambient temperature). For example, when the pulley ratio is 0.6, the engine speed becomes 299 min^{-1} or less. Since the low idle speed of normal engines is at least around 800 min^{-1}, the safety relay continues to function in all engine speed ranges after it has functioned one time.

External Dimensions

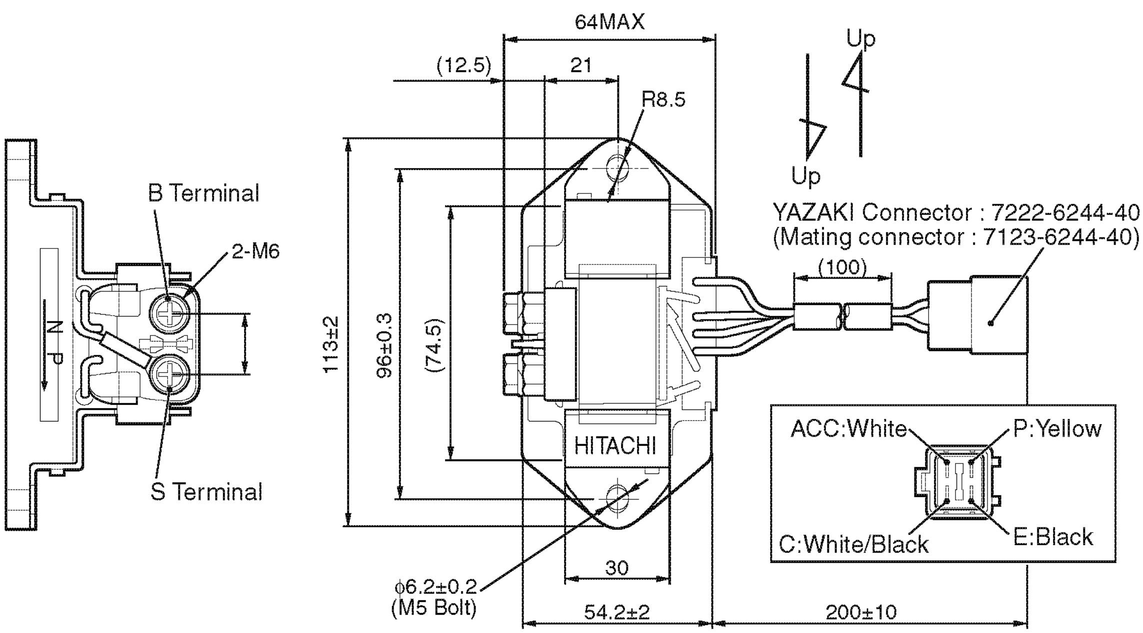


Figure 13-15

Wiring Diagram

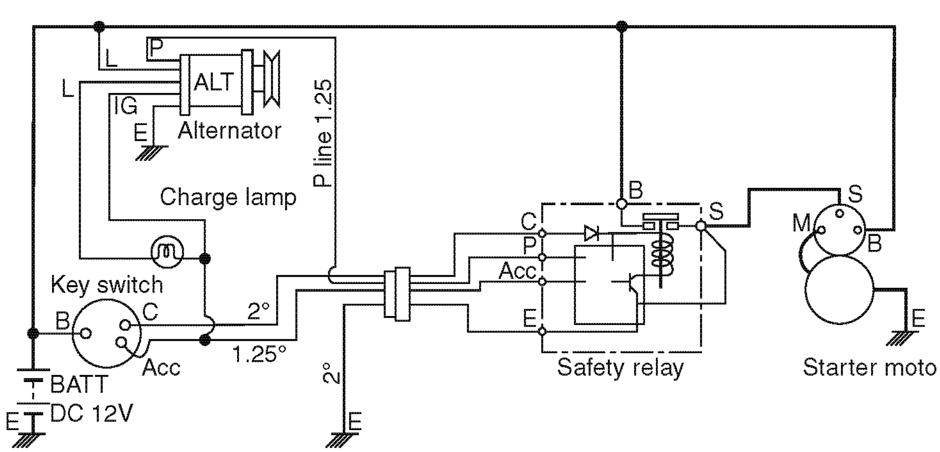


Figure 13-16

Kokusan Denki Safety Relay

Use a Kokusan Denki safety relay with an engine equipped with a Kokusan Denki dynamo (Part No.: 119247-77100).

The regulator for the safety relay is used. For the combination of these components, see *H-e: Current Limiter* in the *Yanmar TNV Option Menu*.

The safety relay shuts off the starter circuit when alternator speed exceeds 1975 ± 140 min^{-1}. For example, when the pulley ratio of the alternator pulley to the crank pulley is 0.6, the starter motor is turned off automatically at the moment the engine speed reaches 1191 ± 84 min^{-1}. After this, accidental operation of the key switch will not energize the starter motor.

After stopping the starter motor, the safety relay stops when the key switch is used to turn off the power. When an engine has stopped for any reason with the key switch in the ON position, the key switch cannot be used for energizing the starter motor without first returning it to OFF.

External Dimensions

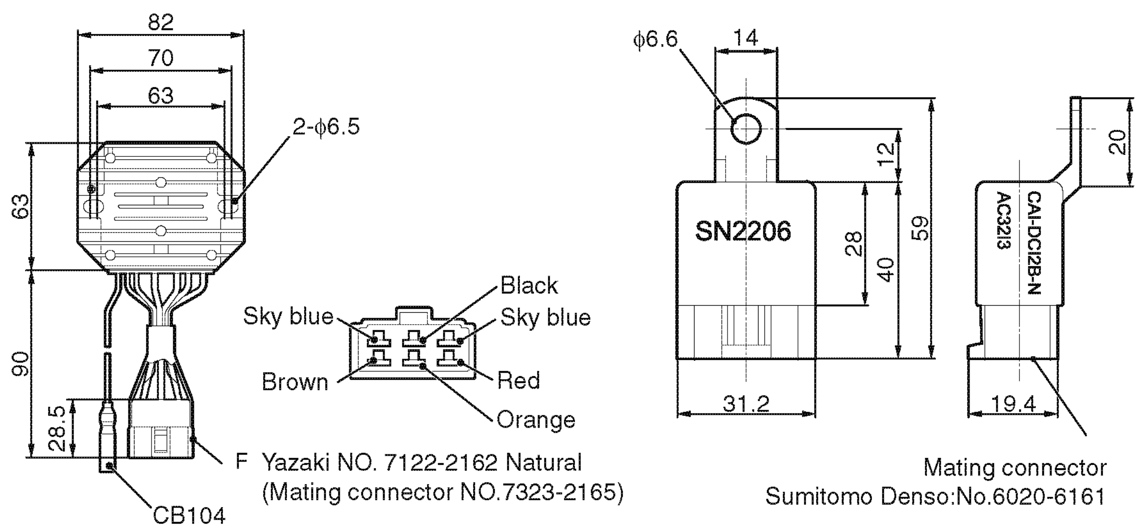


Figure 13-17

Wiring Diagram

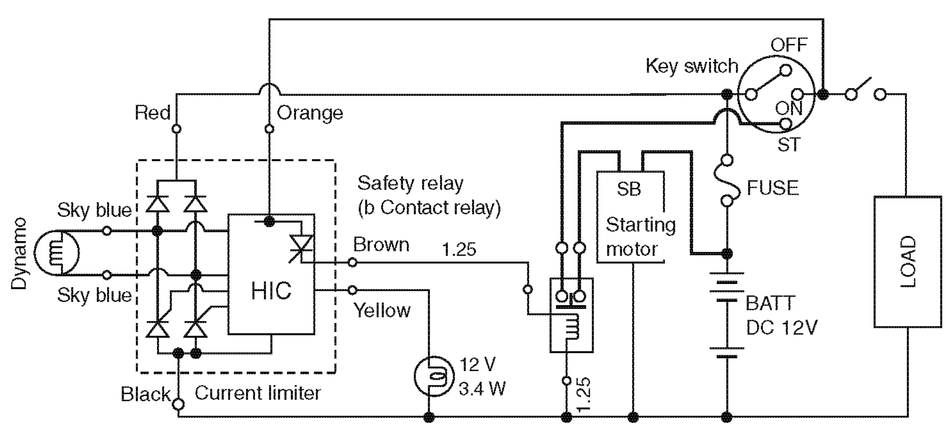


Figure 13-18

Safety Relays Obtained by the Customer

The safety relays are sometimes obtained by the manufacturer of driven machines.

The reliability of the unit's electronic circuit is essential for proper functioning of the safety relay. Matching with the charging system is also important. The reliability of the safety relay system is supported by the electronic circuit reliability test, test for matching with the charging system, and actual performance of the component.

If the system does not function well, Yanmar can investigate the whole system, examine the operations, and improve the system, unless the problem stems from a wire harness that was obtained by the customer.

However, if the safety relay system was obtained by the manufacturer of the driven machines, Yanmar cannot examine and improve the circuit, even though failure of the system is suspected.

Yanmar does not cover a starter motor under warranty if the failure of the starter motor is caused by the improper function of a safety relay obtained by the manufacturer of the driven machines.

Recommendation for Using a Safety Relay

Yanmar recommends that the manufacturer of the driven machines use a safety relay described above to prevent the coils from burning and damaging the starter motor.

STOP SOLENOID

To stop the operation of a diesel engine, it is necessary to shut off the fuel supply to the injection nozzles. A manual system that connects a wire cable to the stop lever or an electrical system that uses a stop solenoid can be used.

TNV series engines use a stop solenoid which is described below.

Solenoid Types

To stop an engine by using a stop solenoid, either of the following two methods may be used.

- De-energizing the solenoid to stop the engine
- Energizing the solenoid to stop the engine

TNV engines use the first method. The solenoid is energized when the engine is running. Turning the key switch to the OFF position, de-energizes the solenoid to stop the engine. The solenoid that is used in the system is called an “energize to run” solenoid. The run-on solenoid system functions to automatically stop the engine if the power supply system malfunctions. Many industrial use engines use this system.

If you are using the second method, no current is supplied to the solenoid while the engine is running. To stop the engine, this method energizes the solenoid for a certain period. This system is used in applications power supply malfunction cannot cause the engine to stop. Many marine engine applications use this system.

The following sections describe the energize to run solenoid that is standard on TNV engines.

Features of the Stop Solenoid

The run-on solenoid system is controlled by a timer and a power relay. A diode is also needed to protect the circuit. The functions of individual components are described in the following sections.

Stop Solenoid

This solenoid is also referred to as a three-wire solenoid. This component includes two types of coils; a pull-in coil and a holding coil. It has three wires, a positive lead for each coil and a grounding lead that is common to both coils. **(Figure 13-19)** shows the structure of the solenoid.

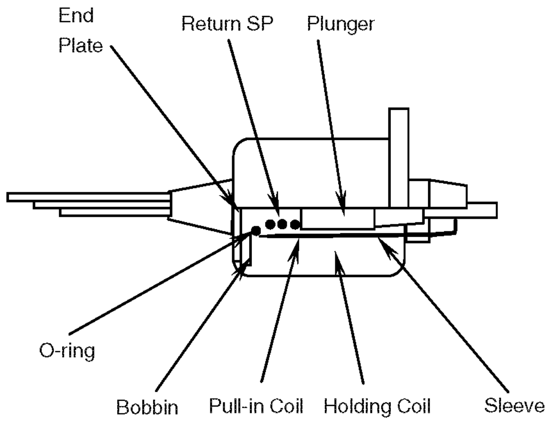


Figure 13-19

Pulling in the plunger requires a large amount of current to be applied to the pull-in coil. This is a common requirement for all types of solenoids. The magnetic force that is produced is called a pull-in force, and the current that is applied to generate the pull-in force is called pull-in current. The component that provides this function is the pull-in coil. After the plunger is pulled-in, the magnetic force that is needed to hold the plunger in is smaller. The magnetic force needed in this process is called the holding force, and the current that produces the holding force is called the holding current. The component that provides this function is the holding coil.

Operation of a TNV Stop Solenoid

(Figure 13-20) shows a TNV engine with a governor that is equipped with a stop solenoid. Turning the key switch to the ON position energizes the pull-in coil to draw in the plunger. The plunger and governor components are not linked. The rack that controls fuel injection is placed in the free state so the fuel injection system is ready for engine operation when you crank the starter motor.

Turning the key switch to the OFF position eliminates the magnetic force in the hold coil, causing the return spring to push the plunger out. Then, the plunger returns the rack to the fuel stop position through the governor lever and the engine stops.

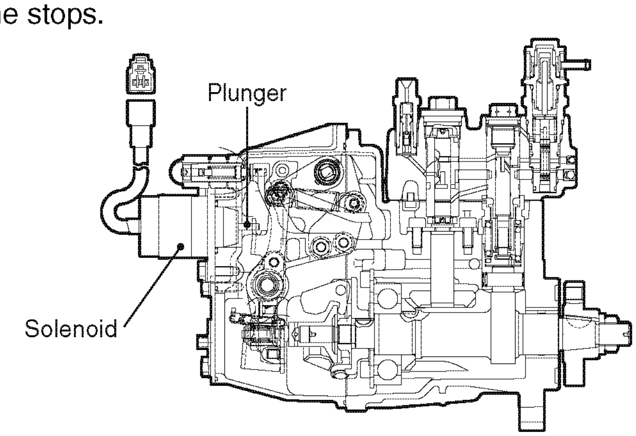


Figure 13-20

Control of the Stop Solenoid

The pull-in current and holding current for TNV stop solenoids is 36.5 A and 0.49 A, respectively. Turning the key switch to the ON position energizes the pull-in coil and the plunger pulls-in. The pull-in coil produces heat, however, and may be burned if the coil is energized with 36.5 A continuously. After the solenoid has pulled the plunger, it is necessary to de-energize the pull-in coil and switch to the holding coil.

The timer and the power relay automatically switch the current from the pull-in coil to the holding coil. The functions of these components and the diode that protects them are described below. (See the *wiring diagram*.)

Timer

While the allowable energization period of the pull-in coil is 30 seconds, actual pull-in time is less than 0.1 second. To protect the pull-in coil from burning, even if it is operated abnormally, such as repeated operation by the customer, this timer is designed to energize the coil for only one second. Since the unit uses an electronic circuit, the large current flow used to energize the pull-in coil cannot be used to power the timer. Therefore, the pull-in coil is energized through a separate relay.

Relay

The 0.3 A current output from the timer energizes the exciting coil of the relay. The 0.3 A signal only lasts one second, during which the pull-in coil is energized.

Be sure to use Yanmar's standard timer and relay. If another combination of timer and relay is used, the relay contacts may chatter. This is caused when the characteristics of the timer do not match the specifications required by the relay's contacts. If the contacts chatter, they may fuse together, causing continuous energization of the pull-in coil and eventually the pull-in coil will burn out.

Diode

When turning off the solenoid, surge voltage may be produced by the magnetic force of the holding coil, which can damage other electronic components connected to the same circuit. Put a diode in the wiring that is connected to the terminal of the holding coil to absorb this surge. Use Yanmar's standard diode or the component equivalent to 600 V - 1.1 A. Use the wiring diagram to make sure the polarity is correct when you connect the diode.

CHARGING SYSTEM

In general, alternators and generators are belt driven, deriving their motive force from the engine. They both charge the battery and supply power to the electric load. They both generate AC power and convert it to DC (the generator requires a separately installed circuit limiter to do the conversion). TNV series engines can use either a generator (dynamo) or alternator. This section compares the attributes of generators and alternators.

Features of a Generator (Dynamo)

The dynamo is a type of magneto generator using a permanent magnet as the field. The alternating current output by the dynamo is rectified into direct current by a separately installed current limiter.

Dynamo Structure

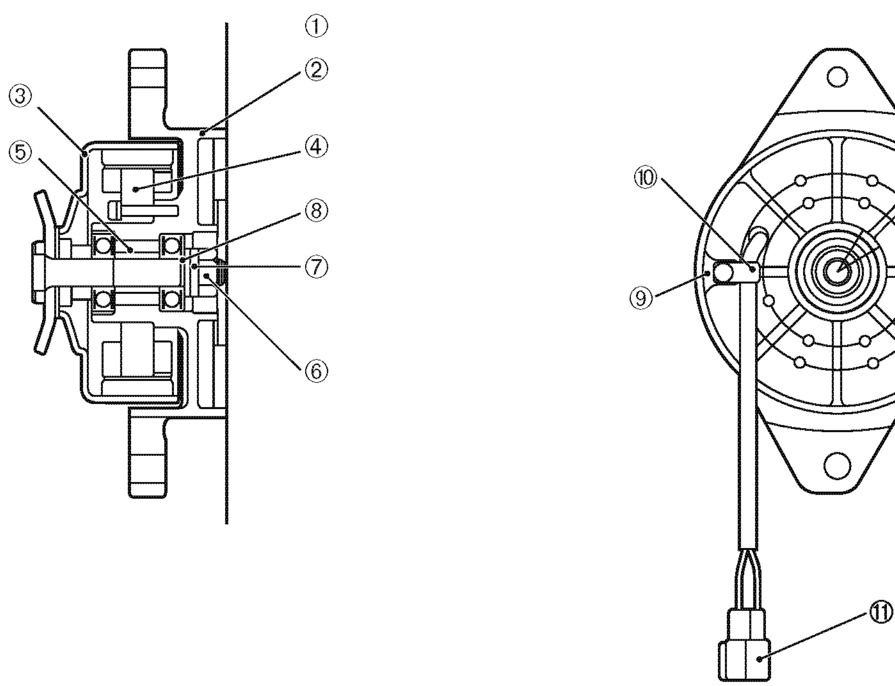


Figure 13-21

1. Plate complete
2. Plate
3. FW complete
4. Stator
5. Collar
6. Hexagon nut
7. Spring washer
8. Plain Washer
9. Washer set screw
10. Clamp
11. Coupler

Features of an Alternator

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

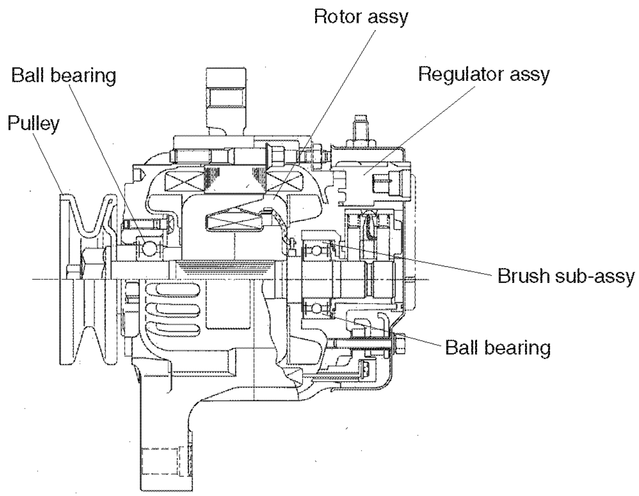


Figure 13-22

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, see the separate *Yanmar TNV Option Menu*.

Nominal output	Dynamo	Alternator
12 V, 15 A	O	-
12 V, 20 A	O	-
12 V, 40 A	-	O
12 V, 55 A	-	O

Output Characteristics

Dynamo output characteristics

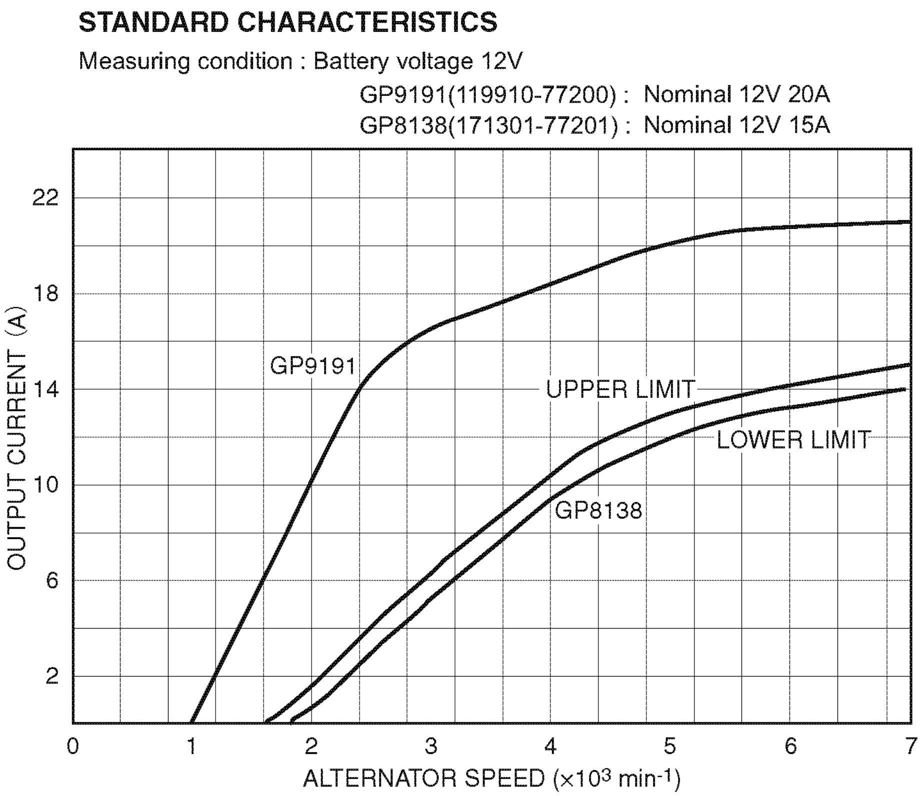


Figure 13-23

Alternator output characteristics

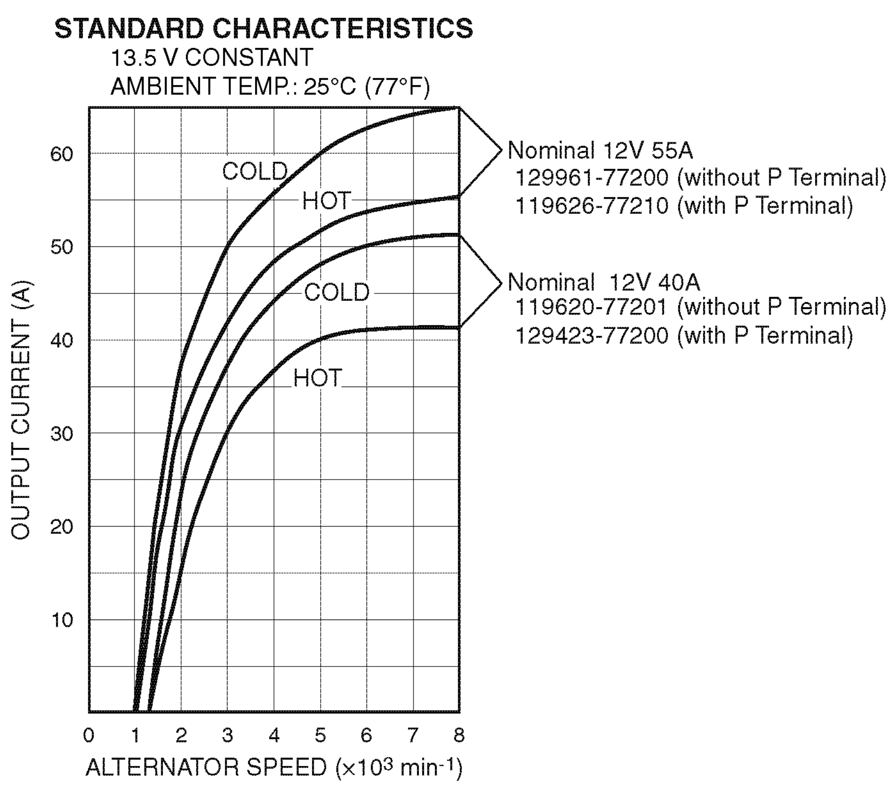


Figure 13-24

REGULATOR

The electric output from the generator or alternator 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.”

In the case of the dynamo, the regulator is not built into the body, but is provided separately. Yanmar calls this type of regulator a “current limiter.”

The “alternator with built-in IC regulator” and “current limiter” have different circuits for converting the AC to DC, but both of them output DC current.

CONTROL OF BATTERY INDICATOR

A major difference between the IC regulator system and the current limiter system exists in the control of the battery indicator. When the power is turned On, both systems apply voltage to the battery indicator to light it.

In the IC regulator system, 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.

For the current limiter system, when the engine is running and a specified engine speed (specified charging voltage) is attained, the current to the indicator is shutoff.

When the engine speed exceeds the speed specified, but it is so low (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 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) x 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, see *Battery Types on page 13-31*.
- 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 x 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 x 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

No.	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 (77±2°F)
	Cold cranking current (CCA)	Measure of engine starting performance in terms of discharge current (A) of an automobile battery at 18°C (64.4°F) 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 5301-1999.

Types of batteries in general use

Type	Capacity 5-hour rate (5HR)	High rate discharge characteristic at 258K (-15°C)				Life		Charge acceptability	(Reference) Standard capability	
		Discharge current	Duration	Voltage after 5 sec.	Voltage after 30 sec.	Heavy-load life	Light-load life		Reserve	Cold cranking current 255K (-18°C)
	(Ah)	(A)	(min)	(V)	(V)	(cycle)	(cycle)	(A)	(min)	(A)
28B17L	24	150	2.3	9.0	-	250	900	3.0	38	246
34B17L	27		3.0	9.2		200	1000	3.3	47	279
34B19L						225	1100		49	272
38B20L	28		3.5	9.5		250	1300	3.5	52	332
46B24L	36		4.2			300	1500	4.5	71	325
55B24L		300	2.0	8.6			1800		79	433
50D20L	40	150	4.0	9.6		285	2200	5.0	78	306
55D23L	48	300	1.9	8		315	3100	6.0	99	356
65D23L	52		2.5	8.5	8.4	320	3400	6.5	111	420
75D23L			2.9	8.9	-		3800		118	520
75D26L			2.9		8.8	330			123	490
80D26L	55		3.5	9.2	9.1				133	582
95D31L	64		4.3	-	9.3	375	4700	8.0	159	622
115E41L	88	500	2.6		8.3	485	-	11	212	651
130E41L	92		3.0		8.8				229	799
115F51	96		2.6		8.2			12	228	638
145F51	112		3.4		8.8	600		14	269	780
145G51	120		3.6		8.6			15	294	754
165G51	136		4.8		9.0	785		17	343	983
195G51	140		5.4		9.5	700			362	1146
190H52	160		5.6		9.0	785		20	421	924
245H52	176		7.8		9.9	800		22	460	1532

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 (68°F) (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 3TNV84-SA 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

$$q = S_a \times \frac{t}{3600}$$

$$= 215 \times \frac{20}{3600}$$

$$= 1.19\,\mathrm{Ah}$$

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 37.8A. 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

$$H_c = \frac{q}{A_c \times \beta}$$

$$= \frac{1.19}{37.8 \times 0.8}$$

$$= 0.04\ \mathrm{h}$$

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.

1. Use wires with the most suitable size and length to ensure required current and voltage is available.
2. Wires should be as short as possible, without sharp bends, and with sufficient strength.
3. Insulate the wires completely.
4. Use connectors or screws to secure the wire to the terminal. Connections should be made firmly to avoid looseness and short-circuiting.
5. Avoid placing wiring in contact with oil, hot components, or rotating components. Use protectors, such as covers or shields, if necessary.
6. When running wiring through an opening, protect the wire with a grommet or equivalent device.
7. 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.
8. Consider using waterproof connectors if the operating environment warrants it.
9. Electrical ground connections:
   - Prepare the areas where the grounding wire will be attached (such as removing paint) **(Figure 13-25)**.
   - 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.

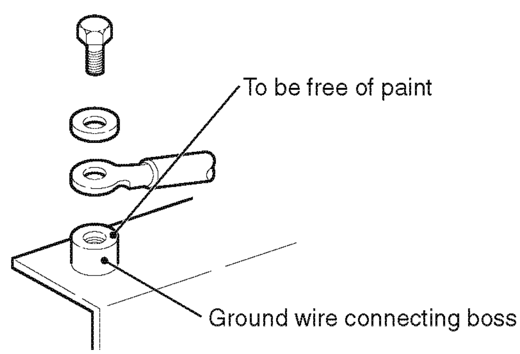


Figure 13-25

10. To prevent connecting the battery cables to the wrong terminals, determine their “length” and “battery location” properly.
11. 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 (4G).
12. 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.

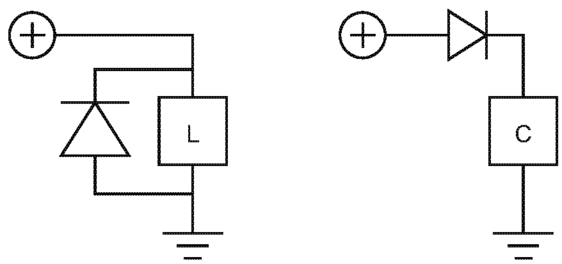


Figure 13-26

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

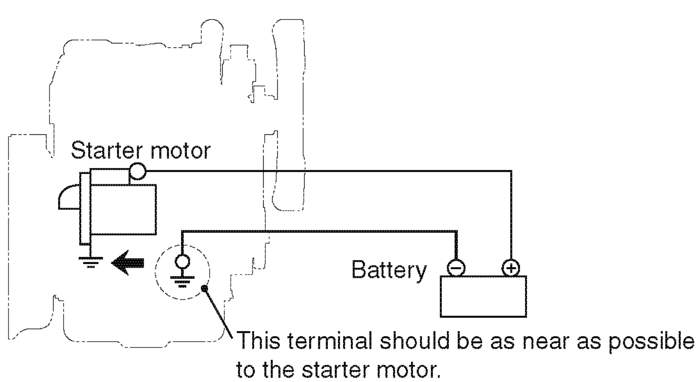
Battery cable size

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)

<table>
<tr><th>Schematic diagram</th><th>Overall length of cable (L)</th></tr>
<tr><td>
</td><td>$L = L_1 + L_2$</td></tr>
</table>

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.

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 0.0002Ω if the resistance is unknown)
ρ	:	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?

- $\alpha = 0\ \Omega$ because the battery switch is not used.

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)
ρ	:	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.

$$L = (R - \alpha)/r$$

$$= (0.002 - 0)/0.000887$$

$$= 2.3 \text{ m}$$

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.

Allowable resistance of the starting motor circuit of a Hitachi starting motor: R_S (terminal S)

Voltage	Starting motor output	Starting motor circuit allowable resistance at 20°C	Remarks
12 V	0.8 to 3.0 kW	≤ 0.050 Ω	
24 V	3.5 kW	≤ 0.050 Ω	
	4.0 kW	≤ 0.010 Ω	Use a starter relay.

Allowable resistance of the starting motor circuit of a Denso starting motor:
R_S (terminal 50)

Voltage	Starting motor output	Starting motor circuit allowable resistance at 20°C	Remarks
12 V	1.0 to 2.0 kW	≤ 0.050 Ω	
	2.5 kW (R2.5)	≤ 0.035 Ω	Use a starter relay.
	4.8 kW (R4.8)	≤ 0.035 Ω	Use a starter relay.

Allowable resistance of the starting motor circuit of a Sawafuji Electric starting motor:
R_S (terminal S)

Voltage	Starting motor output	Starting motor circuit allowable resistance at 20°C	Remarks
24 V	4.0 kW	≤ 0.039 Ω	Use a starter relay.
	5.2 kW	≤ 0.039 Ω	Use a starter relay.

Note: Use a starter motor relay when the wiring resistance exceeds the starter motor circuit allowable resistance, such as when you use a remote operator's console. When the current required by the starter solenoid exceeds the contact capacity of the key switch a starter motor relay should be used.

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.

Starter motor cable length L = L1 (or L1') + L2

General Starting Motor Circuit

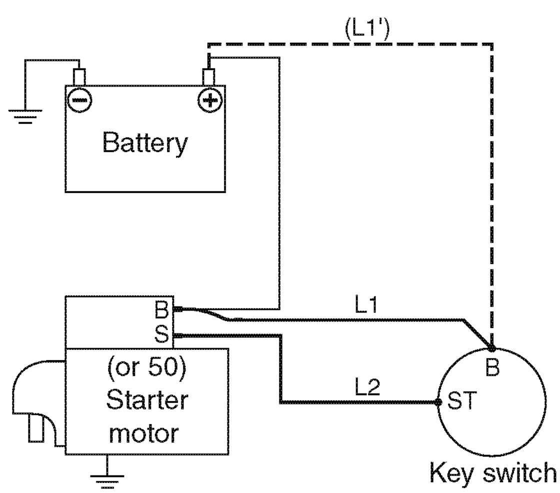


Figure 13-27

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.

Starter motor cable length L = L1 (or L1') + L2

Starting Motor Circuit That Uses a Starting Motor Relay

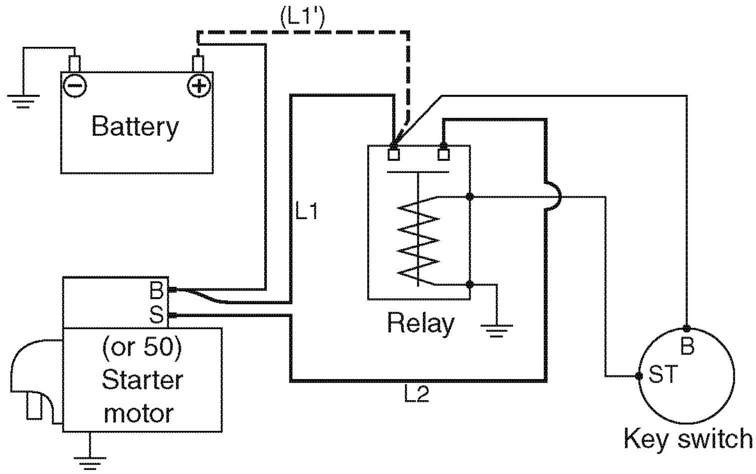


Figure 13-28

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 13-41*), the resistance of the terminals (*How to estimate the cable connection terminal resistance on page 13-41)* and the ambient temperature (*Ambient temperature and allowable current for determination of cable size on page 13-42)*.

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 1.8 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

$$L = (R_s - R_t)/r$$

$$= (0.050 - 0.010)/0.00881$$

$$= 4.5\ \text{m}$$

This means that the total length of the supply and return wires of Hitachi's 1.8 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.

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, see *Charging System on page 13-27*.

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.

Hitachi Starter Motor

No.	Part Code	Type of switch	Output (V-kW)	Instantaneous current / holding current (A)
1	119225-77011	Conventional, coil	12 - 0.8	52/19
2	119631-77011	Conventional, magnet	12 - 0.9	52/19
3	129052-77010	Coaxial, (reduction)	12 - 1.2	52/19
4	129608-77010	The same as above	12 - 1.4	52/19
5	171008-77010	The same as above	12 - 1.4	66/20
6	129400-77012	The same as above	12 - 2.0	66/20
7	129900-77012	The same as above	12 - 2.3	66/27
8	121254-77012	The same as above	12 - 2.5	75/20
9	129940-77010	The same as above	12 - 3.0	52/19
10	129900-77030	The same as above	24 - 3.5	-/19

Denso starting motor

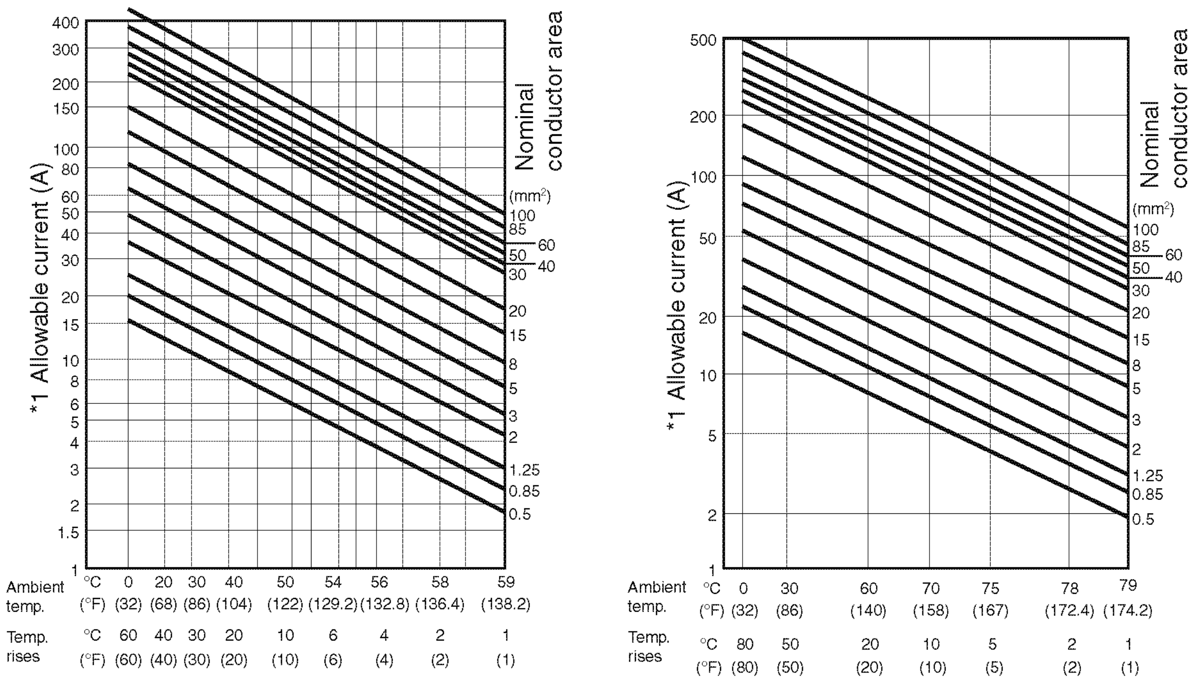
No.	Part Code	Type of switch	Output (V-kW)	Instantaneous holding current (A)
1	119225-77010	P1.0	12 - 1.0	44/13
2	119515-77010	P1.0	12 - 1.0	44/13
3	119853-77010	P1.1	12 - 1.1	44/13
4	119717-77010	P1.1	12 - 1.1	44/13
5	129129-77010	RA1.2	12 - 1.2	51/14
6	119740-77020	RA1.4	12 - 1.4	51/14
7	129407-77010	RA1.4	12 - 1.4	51/14
8	129429-77011	RA2.0	12 - 2.0	51/14

Selecting Cables for General Electrical Components

For a general electrical component, select a cable of sufficient size and length so that the voltage drop does not exceed 5%. The cable must also have sufficient mechanical strength.

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 (140°F) and 80°C (176°F), 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 (140°F)

Allowable current for AV cables rated for a maximum ambient temperature of 80°C (176°F)

Figure 13-29

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.

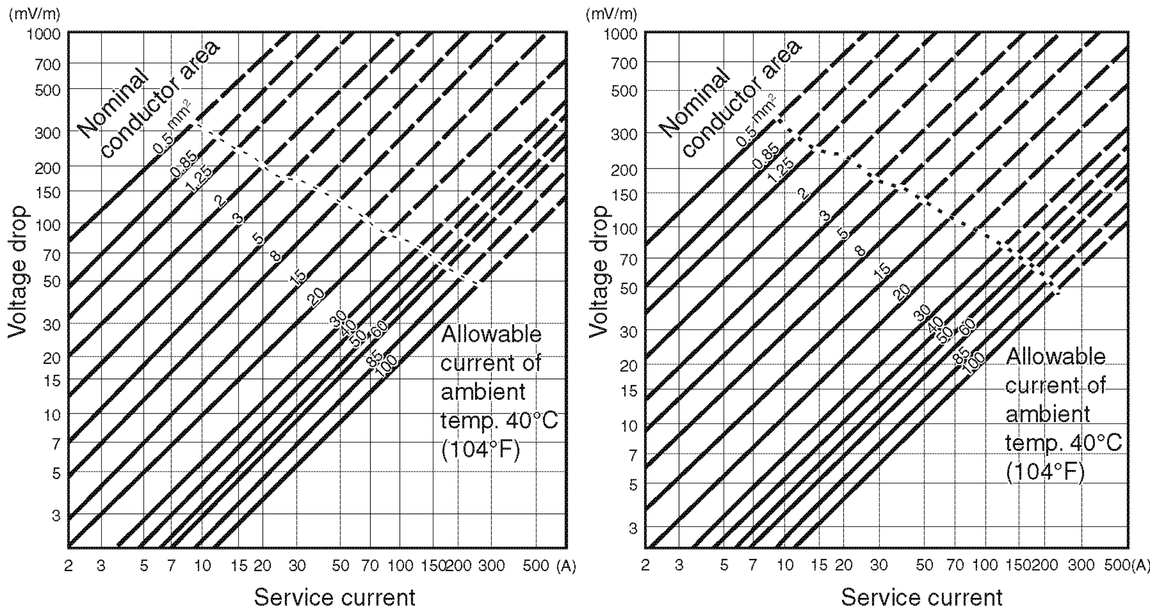
Read the tables **(Figure 13-29)** as follows:

When the maximum ambient temperature rating for an AV cable is 60°C (140°F) and the nominal cross-sectional area is 0.5 mm^2 and the ambient temperature is 50°C (122°F), the value of the allowable current is 6A. This allowable current will raise the cable temperature by 10°C (10°F).

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 13-29)** 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 (140°F)

Allowable current and voltage drop for AV cables rated for a maximum ambient temperature of 80°C (176°F)

Figure 13-30

How to read the figure above: When the allowable maximum temperature for an AV cable is 60°C (140°F) **(Figure 13-30)**, 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.

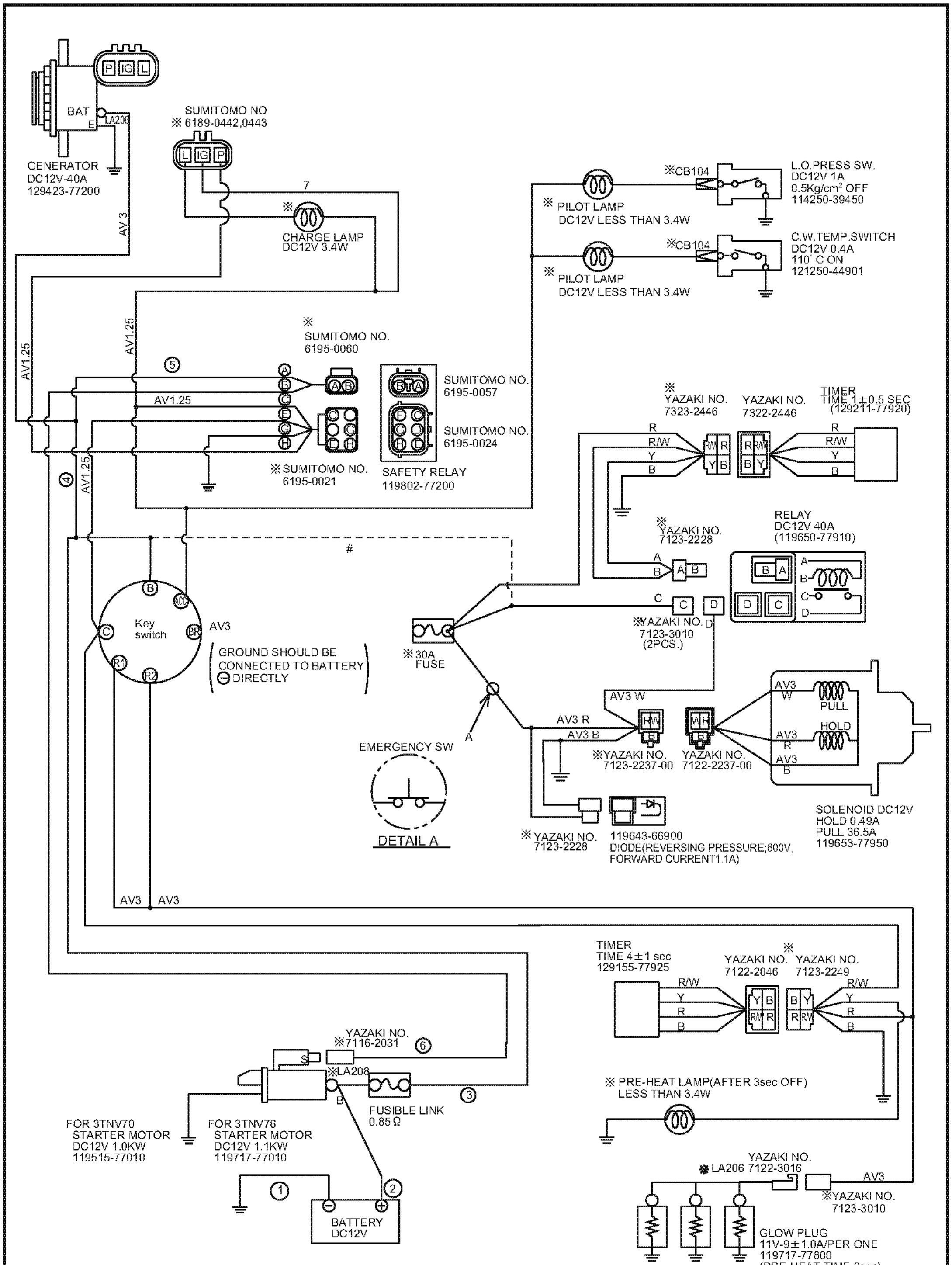
Cable Heat Resistance Comparison

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 (248°F) / 120 hours	100°C (212°F) / 48 hours	120°C (248°F) / 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.

Wiring Diagram for IDI Engine

Model: 3TNV70, 3TNV76



	B	R1	R2	ACC	C	BR
PRE-HEATING	O	O		O		
OFF	O					
ON	O			O		O
START	O		O	O	O	O

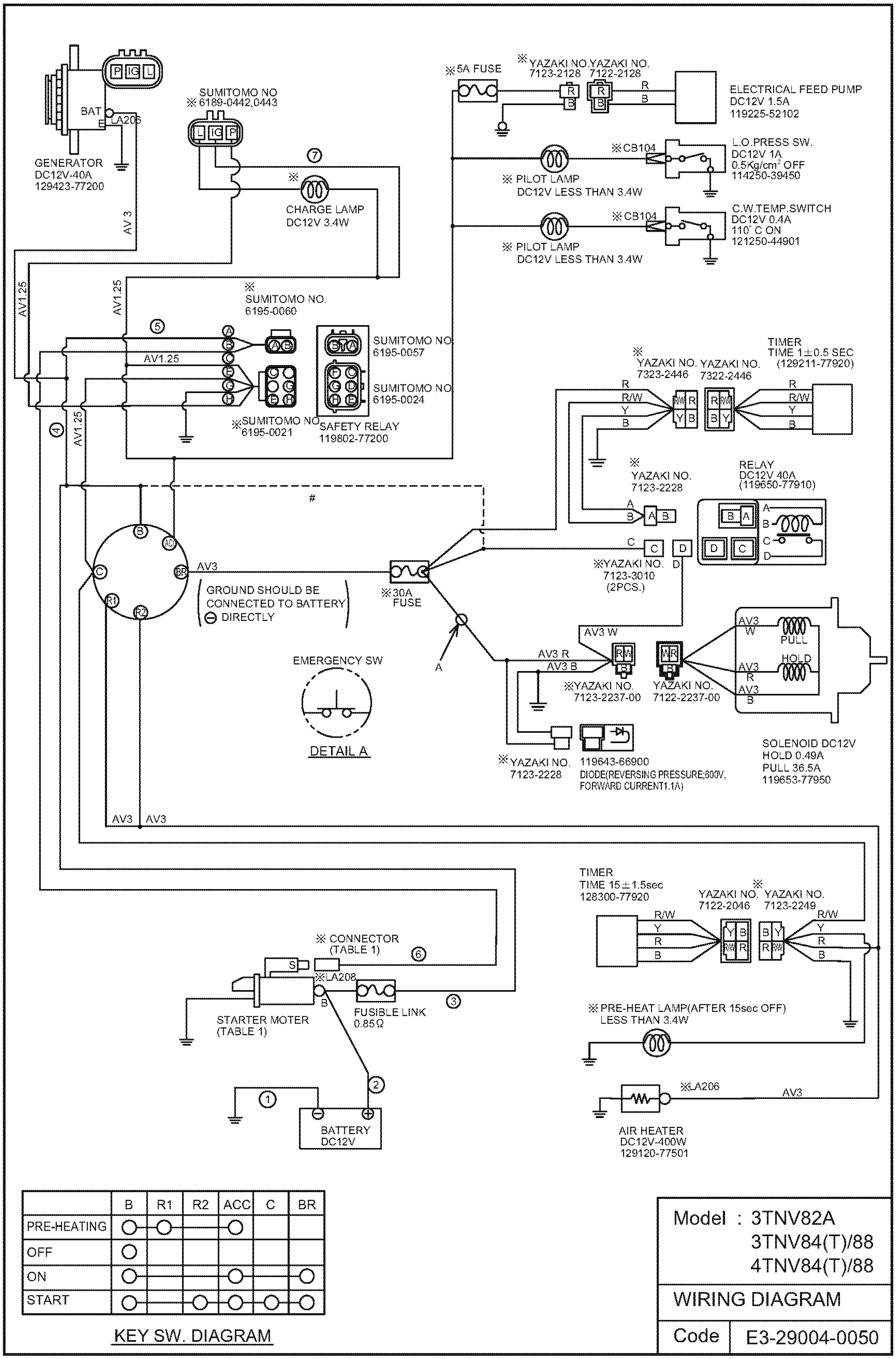
KEY SW. DIAGRAM

Model : 3TNV70/76	
WIRING DIAGRAM	
Code	E3-19717-0080

Figure 13-31

Wiring Diagram for DI Engine

Model: 3TNV82A, 3TNV84(T), 3TNV88, 4TNV84(T), 4TNV88



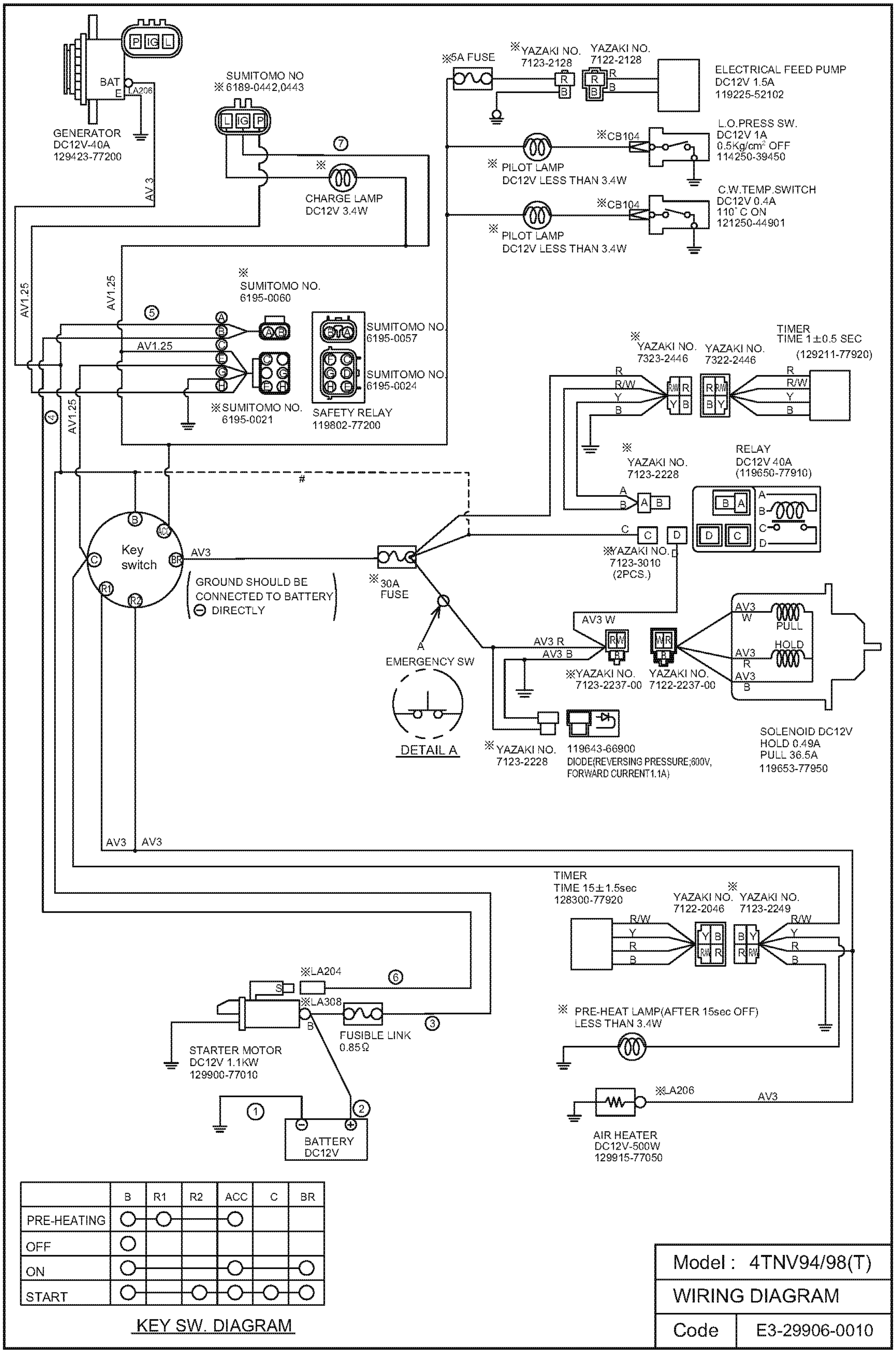
	B	R1	R2	ACC	C	BR
PRE-HEATING	O	O		O		
OFF	O					
ON	O			O		O
START	O		O	O	O	O

KEY SW. DIAGRAM

Figure 13-32

Wiring Diagram for DI Engine

Model: 4TNV94L, 4TNV98T



	B	R1	R2	ACC	C	BR
PRE-HEATING	O	O		O		
OFF	O					
ON	O			O		O
START	O		O	O	O	O

Figure 13-33

Notes for Manufacturing Wire Harness

Notes for main cables

- Starter motor wiring must observe the following precautions to avoid starter motor damage.
  - (a) Total electric resistance of battery cable (①+②) should be calculated according to *Battery Cable Selection on page 13-37*.

    Reference: AV15 : ≤ 1.4 m, AV20 : ≤ 2.2 m
    AV30 : ≤ 3.8 m, AV40 : ≤ 4.6 m

  - (b) Total electric resistance of wiring for starter motor should be calculated according to *Starter Solenoid Cable Selection on page 13-39*.

    Reference for terminal resistance:
    15/1000 Ω per coupler
    0 Ω per screw setting

  - (c) 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.
  - (a) Battery should be firmly secured and immovable using a mounting bracket.
  - (b) Battery cable length should be adjusted properly and clamped. NEVER reverse battery cable connections.
  - (c) 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."

Notes for engine stop solenoid

- Allowable resistance of solenoid circuit should be less than 0.07 Ω to guarantee lowest allowable voltage (9 V) to operate solenoid (pull-in coil).

  Terminal resistance: 15/1000 Ω per coupler
  0 Ω per screw setting
  Solenoid connector resistance need not be counted

  Reference: AV15 (0.0088 Ω/m) : ≤ 8.0 m.....Without terminal resistance
  AV30 (0.0056 Ω/m) : ≤ 12.5 m...Same as above

  When solenoid circuit resistance maximum is reached, use a relay. See the dotted lines marked with "#" in the wiring diagrams.

- High temperature parts, such as exhaust pipe, should not contact the solenoid to avoid reducing the pull-in power, and overheating the inner coil (allowable ambient temperature: -30 to 100°C [-22 to 212°F]).
- Install a fuse to protect the harness against problems, such as a short circuit or continuous operation of the pull-in coil.
- The power supply cable for the stop solenoid may not be used to power the alternator exciter circuit. (Otherwise, the solenoid may not stop the engine due to the power supply from the alternator “L” terminal.)
- For a watertight connection, all connectors should be secured using connector clamps to prevent the wire leads from breaking.
- When you need to provide an emergency stop switch, see *detail “A”* in the wiring diagrams.

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. These are out of the scope of Yanmar's verification process, but we have listed our recommendations.

1. 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.
2. 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.
3. Prevent damage from vibration. Standard interval between wire clamps is 250 mm.
4. Prevent fires:

   ① The wire harness should not be attached to the fuel system, lubrication system or exhaust system.

   ② NEVER run the wire harness through areas that could be exposed to spilled fuel from refueling or air bleeding.
5. Prevent damage from contact with other components. The wire harness should be installed away from rotating or vibrating parts.
6. Prevent incorrect wire connection. Use a different color for each terminal in a multi-terminal connector.

Section 14

ELECTRONIC CONTROL SYSTEM

Page

The control system uses a Yanmar proprietary electronic control governor (hereinafter referred to as "eco governor"). It is a second-generation eco governor (hereinafter referred to as "2G eco governor") meeting the EPA Phase 3 regulations through the EGR (Exhaust Gas Recirculation) control.NV3 engines and turbocharged engines are equipped with 2G eco governors as standard.Some of the NV2 engines also have option settings. Please consult with Yanmar for further details.

The engine controller (hereinafter referred to as "E-ECU") controls the engine speed and output The engine speed is output by controlling the rack position of the fuel injection pump based on the target speed instructions that are input from acceleration sensors, etc.

The EGR valve complies with exhaust gas regulations by controlling the valve opening based on the engine speed and the engine load factor.

2G eco governors can control the engine speed and output based on various conditions such as the engine's acceleration/deceleration conditions, cooling water temperature, external switch, or CAN communication, which provides convenience for application availability that mechanical governors cannot deliver.

The following sections describe the system and application functions of 2G eco governors. Options of the E-ECU require to be configured by Yanmar beforehand. Please contact Yanmar for further details.

Note: **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

2G eco 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 misapplications, 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.

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 (P.14-8)** thoroughly and comply with the operating requirements and precautions of each device.
When you design the wiring harness, comply with the precautions in **Harness (P.14-27)**.
You must also perform installation evaluations (specified by Yanmar) of the E-ECU and other electrical components and evaluate/improve the installed driven machine to satisfy operating requirements of each device.
The engine cannot be started due to an initialization at first power on. For more information, refer to **E-ECU Power on Checks after Factory Shipment (P.14-18)**.
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 (with the flashing fault indicator lamp). 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 with the fault indicator lamp flashing.
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 fuel injection pump needs to be moved to the new E-ECU from the old one (see **Structure of the Control Functions (P.14-31)** for details). An E-ECU without authorized injection amount adjustment data of the fuel injection pump cannot guarantee the engine performance.
Yanmar genuine engine diagnosis tool (hereinafter referred to as "YID" (Yanmar Diagnostic Tool)) should be used to perform maintenance of the injection amount adjustment data of the fuel injection pump that is recorded on the E-ECU. For the maintenance procedures, refer to the YDT's manual.
Never perform any misapplications that are not specified by Yanmar 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 high pressure cleaning for the ECU. (Replacing the ECU, rewriting or altering the E-ECU data, leaving failure conditions, or removing a sensor or actuator, etc.)

Fuel Injection Pump

You must perform installation evaluations of the fuel injection pump as specified by Yanmar and evaluate/ improve the installed driven machine to satisfy its operating requirements.

Note: Special caution should be taken about the temperature and vibration. As with other electrical components, the fuel injection pump must be used in an environment where the ambient temperature does not exceed 80°C. Measurements and adjustments of the vibration should be performed at the engine mount. Please note that the hunting or broken wiring harness may be caused if the vibration displacement exceeds the specified value. Do not use high pressure cleaning for the actuator or speed sensors.

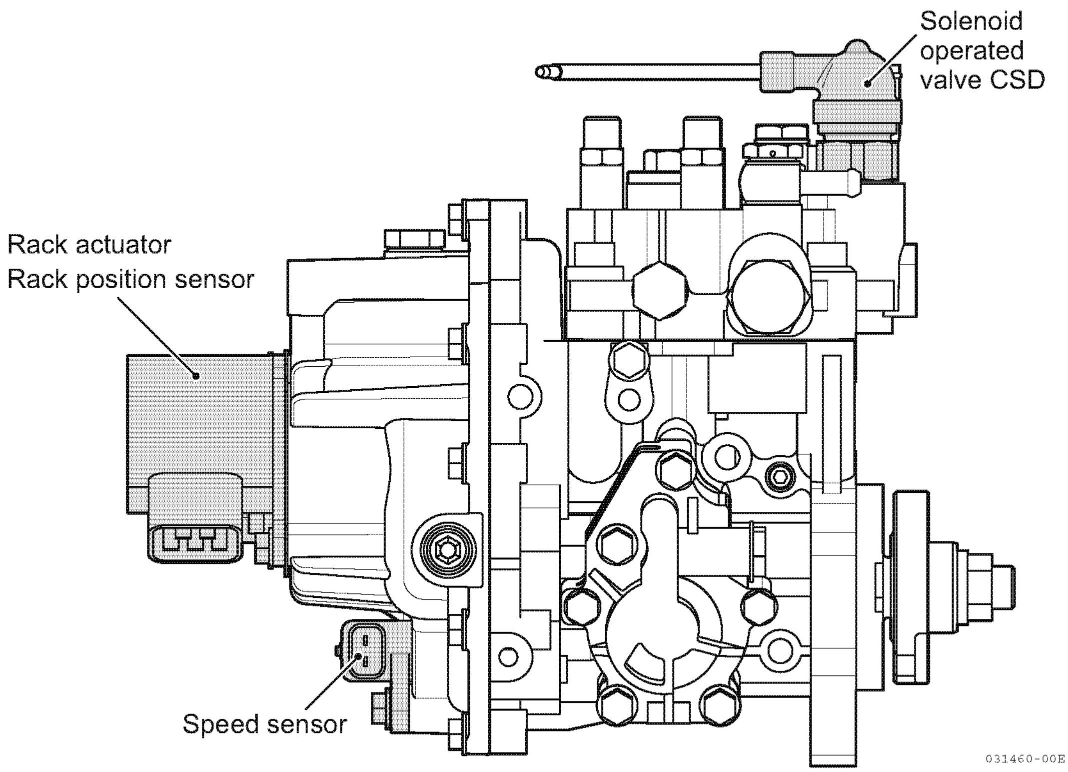


Figure 14-1 **MP Type Fuel Injection Pump for Eco Governors**

Power supply to the rack position sensor should be supplied from the AVB (E43) terminal of the E-ECU. Otherwise, a failure of the rack position sensor may occur due to surge voltage, etc.
Individual injection amount adjustment data is required for each fuel injection pump. Each fuel injection pump is shipped with its injection amount data. Make sure to update the injection amount adjustment data recorded on the E-ECU when you replace the fuel injection pump. The engine performance cannot be guaranteed for an E-ECU whose data has not been updated.
Yanmar genuine YDT should be used to perform maintenance of the injection amount adjustment data of the fuel injection pump that is recorded on the E-ECU. For the maintenance procedures, refer to the YDT's manual.

EGR Valve

You must perform installation evaluations (specified by Yanmar) of the EGR valve and evaluate/improve the installed driven machine to satisfy its operating requirements. The EGR flow volume fluctuates due to the pressure difference between the intake and exhaust flow. Adjust the intake and exhaust pressure in accordance with the range specified by Yanmar.

Note: In particular, the EGR Valve must be used in an environment where the ambient temperature does not exceed 80°C as with other electrical components. Measurements and adjustments of the vibration should be performed at the engine mount. Do not use high pressure cleaning for the EGR valve.

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.

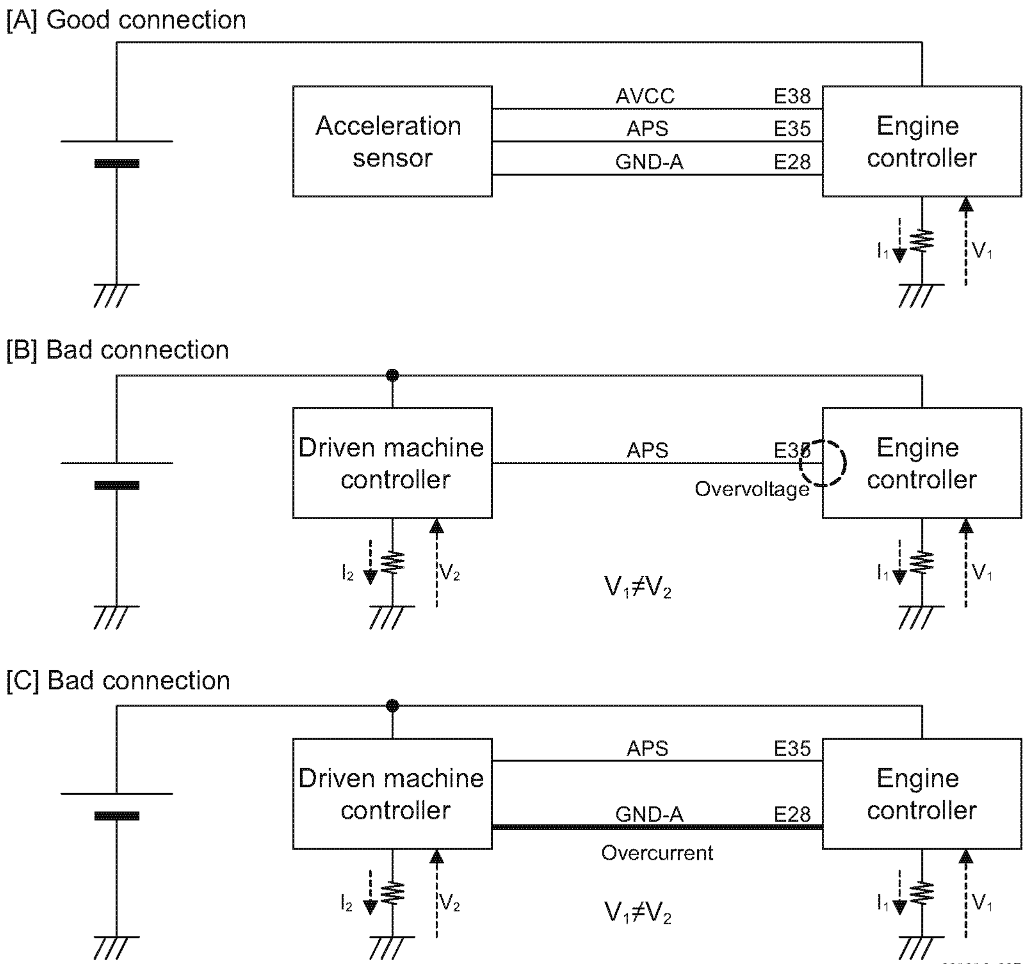


Figure 14-2 **Examples of Improper Acceleration Sensor Wiring**

When you use a Yanmar genuine acceleration sensor, you must read **Acceleration sensor (P.14-94)** 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.

YDT (Yanmar Diagnostic Tool)

To connect Yanmar genuine YDT, you must install the connector shown in **Figure 14-3** to a location that is easy to see on this device.

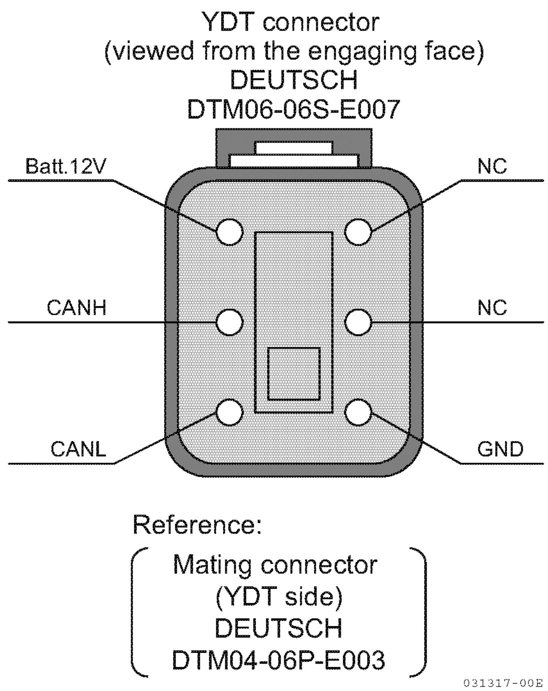
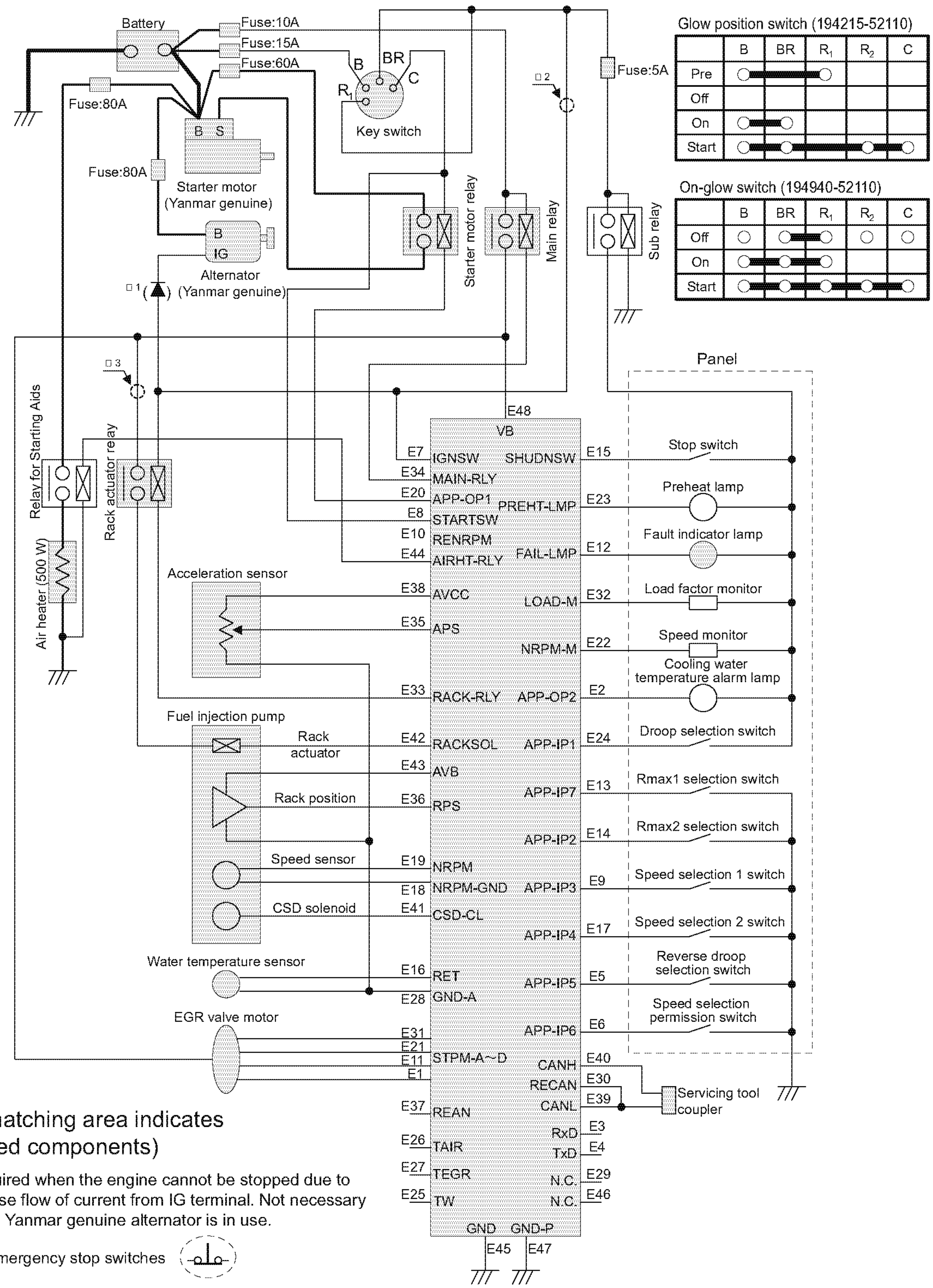


Figure 14-3 **YDT Connector**

CONTROL SYSTEM

System Overview

The standard electrical wiring diagram of 2G eco governors is shown in **Figure 14-4**.



(The hatching area indicates required components)

*1: Required when the engine cannot be stopped due to reverse flow of current from IG terminal. Not necessary when Yanmar genuine alternator is in use.

*2, *3: Emergency stop switches

Figure 14-4 **Standard Electrical Wiring Diagram of the Eco Governor System**

The following section describes the necessity of each component shown in **Figure 14-4**.

1. Roles of a Main Relay
   - Reducing the circuit length
     By not wiring via the key switch, a main relay prevents the circuit length between the battery and the VB terminal of the E-ECU becoming too long.
   - Recording the history
     It records the engine history when the key is turned OFF by means of the power supply self-hold function of the E-ECU (for example, failure history or operating hours).
   - Protection against a reverse connection
     It prevents application of reverse voltage to a device, such as the E-ECU or rack actuator, in the event of a reversed battery terminal connection by means of a diode that is built in an exciting coil.
2. Roles of a Rack Actuator Relay
   - Manual engine shutdown
     The rack actuator relay shuts off the rack actuator power supply when the key is turned OFF regardless of the state of the previously described power supply self-hold function of the main relay to ensure an engine shutdown.
   - Abnormal over speed shutdown
     It shuts down the rack actuator power supply to stop the engine when abnormal over speed is detected.
   - Protection against a reverse connection
     As with the main relay, it prevents application of reverse voltage to the E-ECU in the event of a reversed battery terminal connection by means of a diode that is built in an exciting coil.
3. Roles of a Sub Relay
   - Separating the circuits
     It prevents a situation in which the engine cannot be operated due to a failure of the panel electrical circuit by separating the panel electrical circuit from the engine electrical circuit that is essential for engine operations.
   - Leak current protection
     It prevents a situation in which leak current from the panel load flows to the IGNSW terminal of the E-ECU when the key is turned OFF.
   - Protection against a reverse connection
     As with the main relay, it prevents application of reverse voltage to the panel input terminal of the E-ECU in the event of a reversed battery terminal connection by means of a diode that is built in an exciting coil.
4. Roles of a Starting Aid 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 (either an air heater or glow plug) 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 (either an air heater or glow plug) including the on-glow, after-heat, and simultaneous energizing controls.
   - Available for both with and without a glow position
     Both a key switch with a glow position and a key switch without it (on-glow use key switch) can be used in the standard electrical wiring diagram shown in **Figure 14-4**.

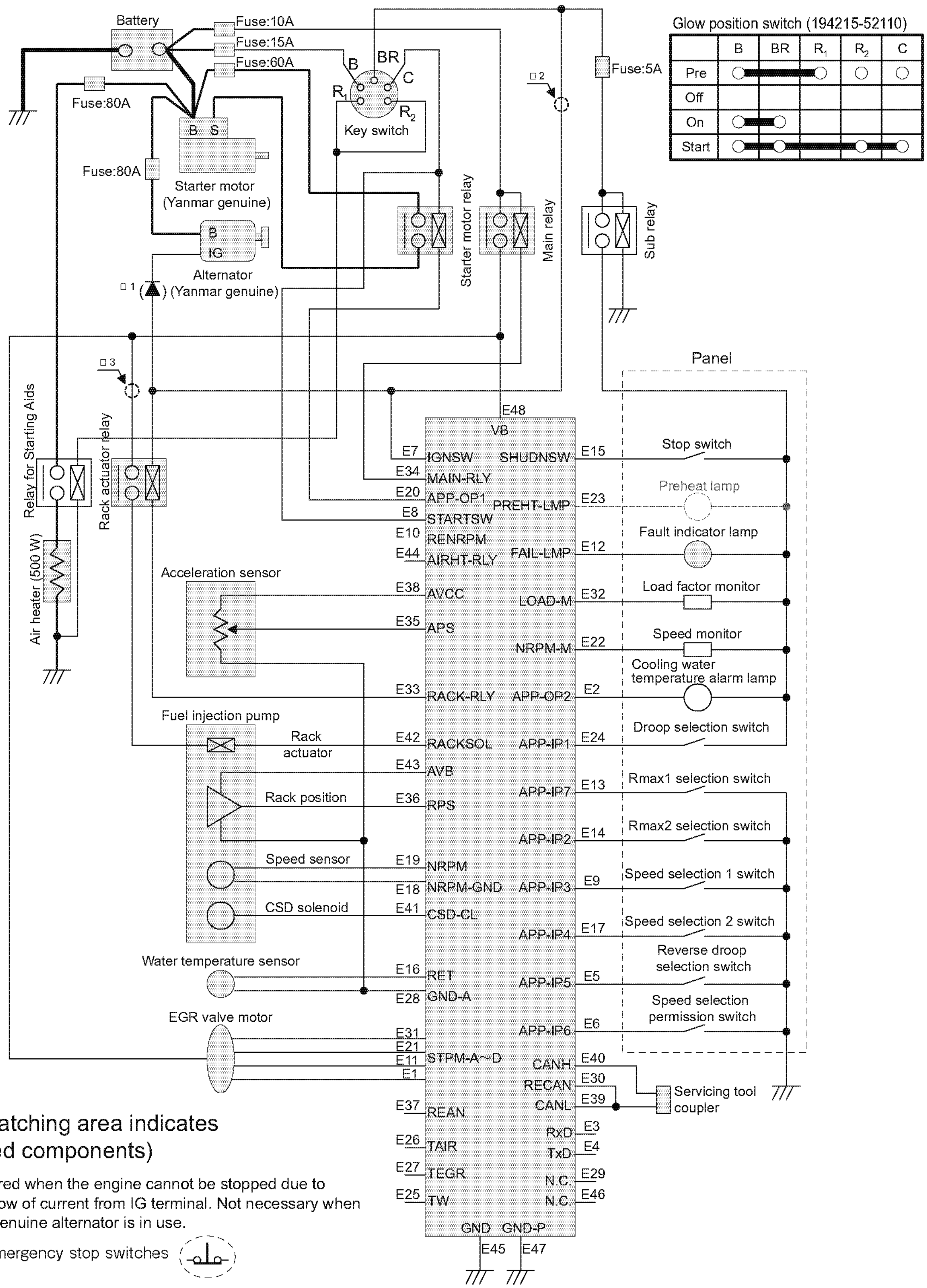
5. Roles of a Starter Relay
   - Starter motor restraint
     It performs restraint of the starter motor action to prevent the engine from being started during a rack self diagnosis (for about 0.5 second) when turning the key ON.
   - Starter motor protection
     As with a safety relay, it prevents 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.
6. Role of a Fault indicator lamp
   - Initial diagnosis
     It is used for an initial diagnosis to notify the energization state to the E-ECU or defects occurring in the eco governor system to the operator.
7. Roles of YDT
   - Confirming the control/history information
     YDT 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 fuel injection pump and E-ECU
     YDT is used to perform maintenance of the program, map, and adjustment values in the E-ECU. This is required when replacing a fuel injection pump or E-ECU on the market.
8. Roles of an Acceleration Sensor
   - Target speed setting
     An eco governor does not have a governor lever like a mechanical governor. Instead, an acceleration sensor is required to set the target speed of the engine. 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.
9. Roles of a Water Temperature Sensor
   - CSD/EGR control
     It is used for the CSD control to enable cold start and for the EGR control to deliver exhaust gas reduction. 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 (APP-OP2 terminal) illuminate or limit engine operation actions. For this reason, TNV engines with the eco governor specification are not configured to have traditional water temperature switches (121250-44901).
10. Role of a Panel Switch and Lamp
    - Option function activation
      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.

11. 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 (diode with the *1 symbol in **Figure 14-4**) 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).

Note: **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.

If no starting aid is performed on the E-ECU:

Figure 14-5 shows a reference electrical wiring diagram in which no starting aid control is performed on the E-ECU. In this case, pre-heat lamp and after-heat controls cannot be performed. Option settings of the ECU are required if you use the wiring below. Please consult with Yanmar.



(The hatching area indicates required components)

*1: Required when the engine cannot be stopped due to reverse flow of current from IG terminal. Not necessary when Yanmar genuine alternator is in use.

*2, *3: Emergency stop switches

Figure 14-5 **Reference Electrical Wiring Diagram of the Eco Governor System (If no starting aid is performed on the E-ECU)**

Timing of the E-ECU

Figure 14-6 shows the timing in relation to the E-ECU control initiation and termination when you turn the key switch of the 2G eco governor control system ON or OFF.

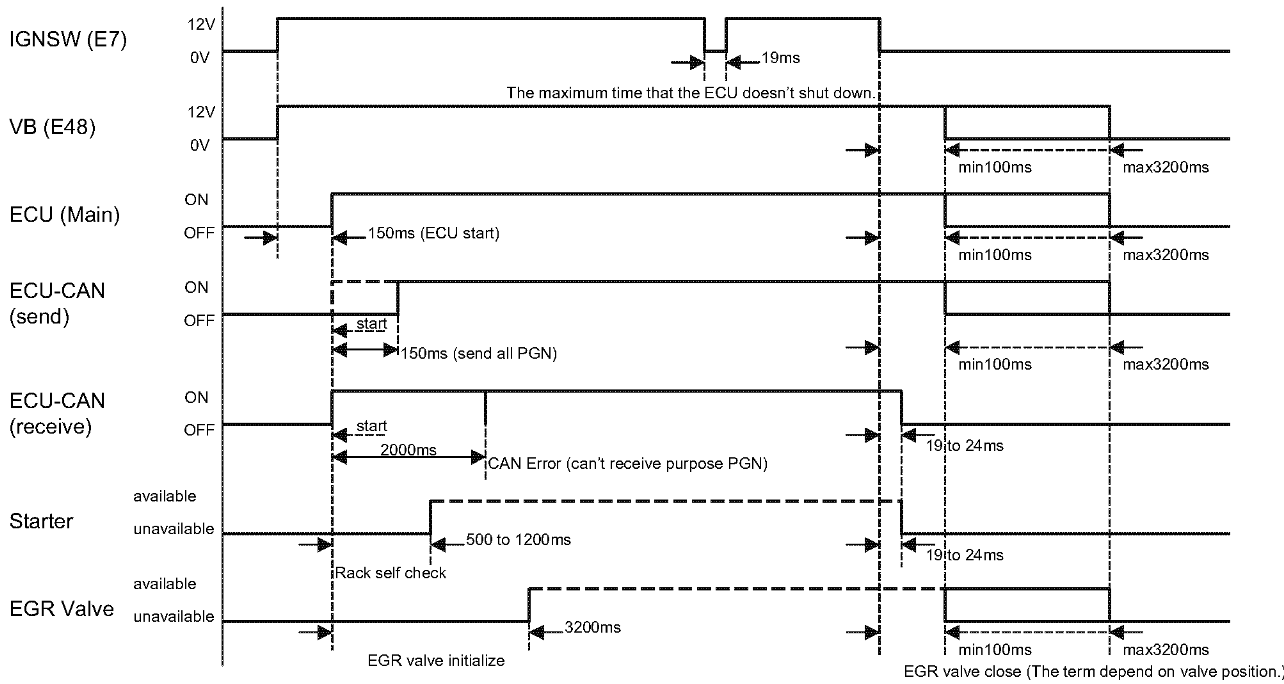


Figure 14-6 **Control Timing of the E-ECU**

E-ECU

External Dimensions

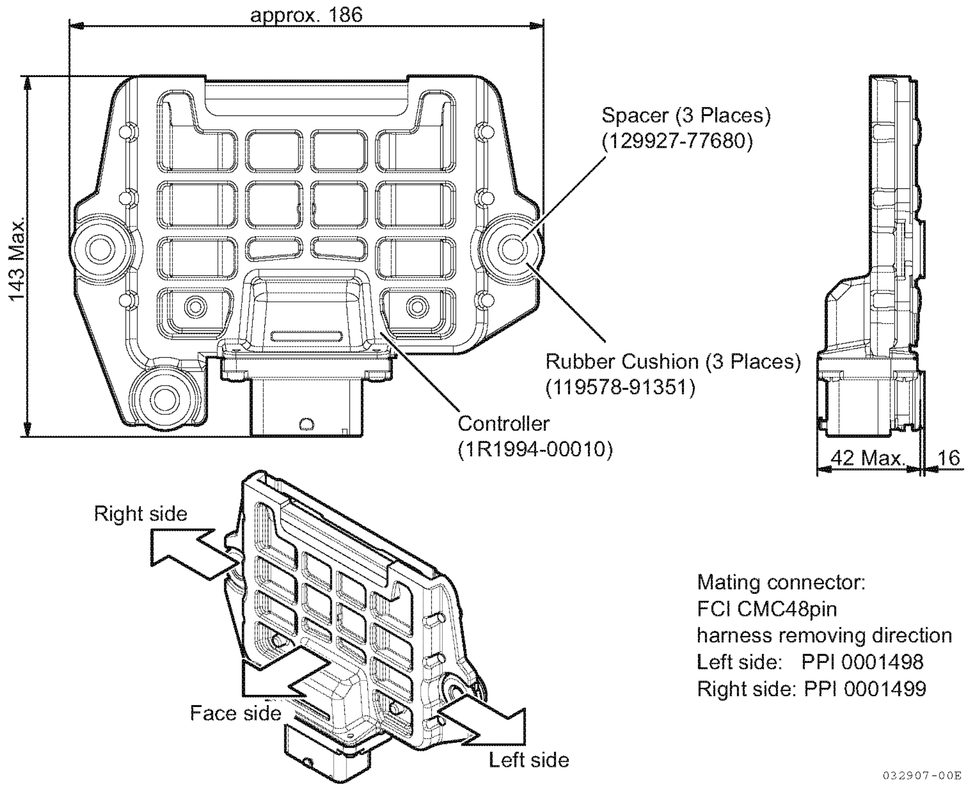


Figure 14-7 **E-ECU External Dimensions**

Notes for Grommet and Collar Usage

A Yanmar specified grommet (119578-91351) and collar (129927-77680) are installed to your E-ECU. Use only the grommet and collar specified by Yanmar. Otherwise, a failure of the E-ECU may be caused by vibration of the engine or driven machine.

Notes for the Circuit Symbols

The pin numbers of the E-ECU are shown in **Figure 14-8**. 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 "E".

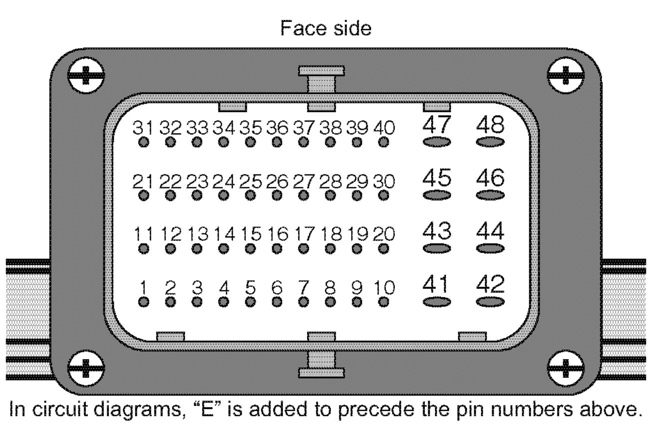


Figure 14-8 **Pin Numbers of the E-ECU Connector**

Operating Requirements

The operating requirements of the E-ECU are shown in **Table 14-1**.

Table 14-1 E-ECU Specifications

Item		Operating Requirements
Rating	Rated voltage	12V DC
	Operating Ambient Temperature Range	-30°C - 80 °C
	Storage Ambient Temperature Range	-40°C - 110 °C
Basic Performance	Available Voltage Range	10.0V - 16.0V DC
	Minimum Operating Voltage	6.0V DC or greater
Vibration	Vibration Severity Class	Install in a place meeting Class 45 or lower
	Overall values (5-1000Hz) of acceleration, velocity, and displacement in the ECU installation position shall satisfy the requirements indicated on the right.	Acceleration 70.4 m/s^2 (rms) or lower
		Velocity 44.6 mm/s (rms) or lower
		Displacement 0.283 mm (rms) or lower 0.800 mm (p-p) or lower
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)

[Other Precautions]

- Water resistance - The E-ECU must be installed in a location that will not be exposed directly to steam or high pressure cleaning.
  The E-ECU must be installed with the connecter part faces downward from the horizontal plane of the driven machine. Otherwise, water can be trapped in the connector part and corrosion of the connector pins may be caused.
- Weather resistance - The E-ECU must be installed in a well-ventilated location where will not be exposed to direct sunlight.
- Instantaneous power interruption - Do not connect or disconnect the connector of the E-ECU for about 6 seconds after turning ON or OFF the power supply.
- Static electricity - 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.
- Corrosion - 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.
- Defective contact - 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.
- Impact resistance - Do not use the E-ECU after dropping it.
- Salt water resistance - 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 be corroded and that a failure may be caused. You must take a precaution, such as covering the E-ECU, to prevent damage caused by salt.

Current Consumption

Notes about the Alternator Capacity

Current consumption of 4.6 [A] in actual measurement is required for devices related to engine controls including the ECU, rack actuator, EGR valve, CSD, main relay, rack actuator relay, starter motor relay, starting aid relay, lamps, and switches. Among these devices, cold starting devices such as CSD require current consumption approximately 1 [A], alternator capacity of 5 [A] or greater must be selected for applications where cold starting occurs frequently. For other applications, alternator capacity of 4 [A] or greater must be selected as a guide for the charging current.

Minimum Operating Voltage

Notes about the Battery Voltage

The minimum operating voltage of the E-ECU is 6.0V DC. If the E-ECU power supply voltage reaches below 6.0V, the E-ECU stops its operation. Once the power supply voltage is regained, the E-ECU is restarted from the initial condition.
For example, if the battery voltage is below 6.0V while overpassing a compression stroke upon cranking, such as at cold start, you may not be able to start the engine. You must check the battery voltage and E-ECU power supply voltage.
The conditions of the E-ECU power supply voltage at engine start are shown in **Figure 14-9**.

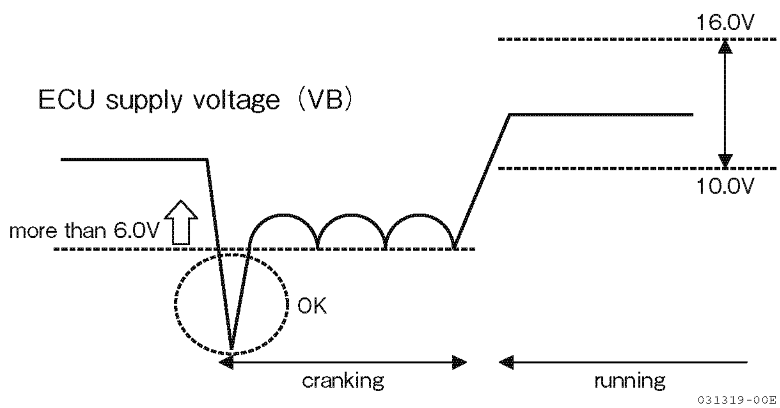


Figure 14-9 **E-ECU Power Supply Voltage Conditions at Engine Start**

Minimum Detectable Speed

The minimum detectable speed of the engine that can be detected by the E-ECU and fuel injection pump (speed sensor) is set to a value lower than the minimum cranking speed (average speed = approx. 75min^{-1}) that is required to start the engine. However, the E-ECU may indicate a speed sensor abnormality if the starting engine speed drops below the minimum detectable speed, such as when the engine starting load is extremely increased, due to a very low temperature, etc., or when the battery capacity is decreased due to deterioration or discharge. In such a case, a measure must be taken such as reducing the engine starting load or increasing the starter motor starting current.

Start/Stop Times and Energizing Duration

The E-ECU stores data such as the operation history to the internal EEPROM every time after turning OFF the power supply if the power supply self-hold function, which is described later, is enabled. If this function is disabled, the data is stored at regular intervals. Therefore, the design life of the E-ECU is determined by the guaranteed number of write times to the EEPROM that is specified by the EEPROM manufacturer.
If the power supply self-hold function is enabled, this number corresponds to about 100,000 times of operations to turn the key ON. If the power supply self-hold function is disabled, this number corresponds to about 10,000 hours of duration in which the key is turned ON.
An EEPROM is a kind of memory which can hold the data recorded (written) during the E-ECU was running even after turning off the E-ECU power supply. However, its number of write times is limited.

Safety Functions

The E-ECU is equipped with the following safety functions.

- Watchdog timer
  A function, called the watchdog timer, monitors whether or not the program process of the engine control microprocessor is working normally. *If any abnormality is detected from the microprocessor program, the watchdog timer restarts the microprocessor to help recover the program process.
- Duplex system for over speed detection
  Another detection circuit, other than the engine control microprocessor, also monitors the engine speed. If engine over speed is detected, this detection circuit turns OFF the rack actuator relay to force the engine to shut down (the standard setting for the speed of the over speed detection is set to the high idle speed plus 600min^{-1}).
- Dump surge protection
  The power supply input terminal (VB terminal) of the E-ECU contains a dump surge absorption zener diode. Since the rack actuator and the rack position sensor need to be protected using the dump surge absorption zener diode of the E-ECU, make sure that the power supplies of these components are branched from a point that is as near as possible to the VB terminal of the E-ECU.

Notes for Reversed Battery Terminal Connections

- Without protection
  The E-ECU or a rack position sensor will be damaged by a reversed battery terminal connection.
- Protection with a relay
  In order to protect the E-ECU or rack position sensor against a reversed battery terminal connection, you must use a main relay and sub relay equipped with a reverse connection preventive diode (198461-52950) to prevent application to of reverse voltage to terminals of the E-ECU or rack position actuator, as shown in the standard wiring diagram (Japanese: E3-29927-0031, English: E3-29927-0041).

E-ECU Power on Checks after Factory Shipment

The E-ECU is configured to clear data on the internal EEPROM, such as the failure history, at first power-up after its factory shipment. For this readon, you must perform the following power-up checks when you turn on the power:

First power on:
The initialization is complete if the fault indicator lamp is illuminated. You cannot continue to start the engine at this point. You must turn OFF the power supply (turn the key to OFF).
If the fault indicator lamp is not illuminated, it is assumed that the harness or E-ECU has a problem.
For more information, refer to the troubleshooting section.

Second power on and later:
The operation is normal if the fault indicator lamp is illuminated for 2 seconds and then turned off.
If the fault indicator lamp is not illuminated or if it flashes, it is assumed that the harness or E-ECU has a problem. For more information, refer to the troubleshooting section.

Input/Output Circuit

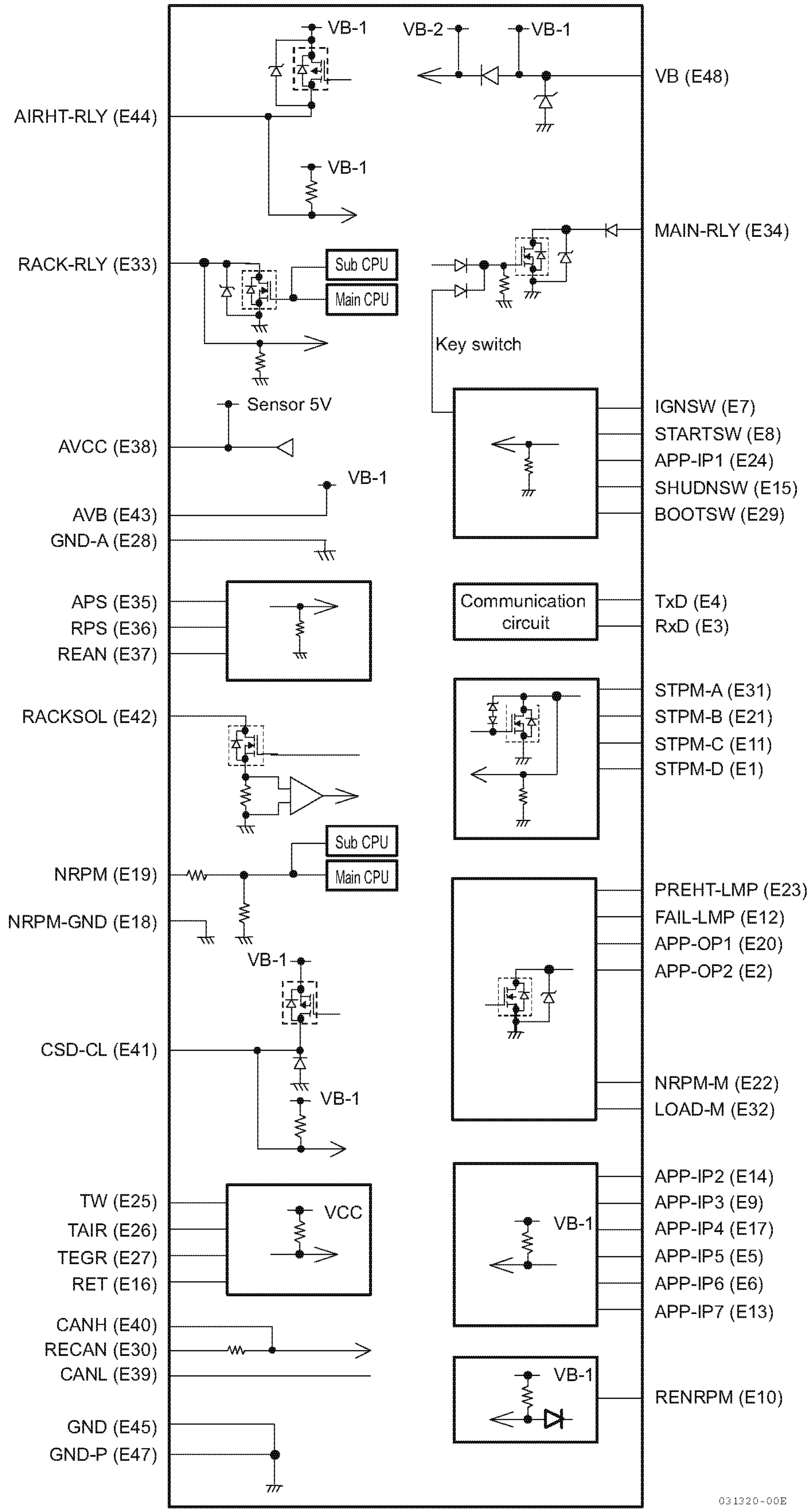


Figure 14-10 **E-ECU Input/Output Equivalent Circuit Diagram**

Input/Output Specifications

Table 14-2 E-ECU Terminal Specifications

Item	Classification	Terminal Name	Symbol	Number	Terminal Specification
Input	Analog	Accelerator position sensor	APS	E35	Recommended load: potentiometer (5kΩ) Range: 0 - 5V Accuracy: 512 ± 13 (@2.5V) Input resistance: 200kΩ
		Rack position sensor	RPS	E36	Load designation: rack position sensor Range: 0 - 5V Post-adjustment accuracy: 716 ± 2 (@3.5V, 25 - 30°C) Input resistance: 100kΩ
		Cooling water temperature (Not used)	TW	E25	Load designation: thermistor Range: -30 - 120°C Post-adjustment accuracy: ± 3°C (@0°C, 5.88kΩ) Output resistance: 1.5kΩ
		Intake air temperature (Not used)	TAIR	E26	Load designation: thermistor Range: -30 - 120°C Accuracy: ± 5°C (@20°C, 2.45kΩ) Output resistance: 1.5kΩ
		EGR temperature (Not used)	TEGR	E27	Load designation: thermistor (not configured) Range: 0 - 200°C Accuracy: ± 5°C (@100°C, 1.10kΩ) Output resistance: 1.5kΩ
		Spare temperature (Cooling water temperature)	RET	E16	Load designation: thermistor (129927-44900) Range: -30 - 120°C Accuracy: ± 2°C (@20°C, 2.45kΩ) ± 2°C (@110°C, 0.1417kΩ) Output resistance: 1.5kΩ
		Backup analog (Option)	REAN	E37	Recommended load: spare acceleration sensor Range: 0 - 5V Accuracy: 512 ± 13 (@2.5V) Input resistance: 100kΩ
	Contact	Engine start recognition	STARTSW	E8	Circuit: High Side Pull-down resistance: 1.2kΩ (10mA@12V)
		Engine emergency shutdown	SHUDNSW	E15	Circuit: High Side Pull-down resistance: 1.2kΩ (10mA@12V)
		Key switch	IGNSW	E7	Circuit: High Side Pull-down resistance: 1.2kΩ (10mA@12V)
		Application open input 1	APP-IP1	E24	Circuit: High Side Pull-down resistance: 1.2kΩ (10mA@12V)
		Application open input 2	APP-IP2	E14	Circuit: Low Side Pull-up resistance: 1.2kΩ (10mA@12V)
		Application open input 3	APP-IP3	E9	Circuit: Low Side Pull-up resistance: 1.2kΩ (10mA@12V)
		Application open input 4	APP-IP4	E17	Circuit: Low Side Pull-up resistance: 1.2kΩ (10mA@12V)
		Application open input 5	APP-IP5	E5	Circuit: Low Side Pull-up resistance: 1.2kΩ (10mA@12V)
		Application open input 6	APP-IP6	E6	Circuit: Low Side Pull-up resistance: 1.2kΩ (10mA@12V)
		Application open input 7	APP-IP7	E13	Circuit: Low Side Pull-up resistance: 1.2kΩ (10mA@12V)

Table 14-2 E-ECU Terminal Specifications

Item	Classification	Terminal Name	Symbol	Number	Terminal Specification
Input	Pulse	Speed input (-)	NRPM-GND	E18	Load designation: electromagnetic pick-up (158557-61720) Range: 10Hz, 0.4Vp-p - 400Hz, 60Vp-p
		Speed input (+)	NRPM	E19	
		Spare speed sensor	RENRPM	E10	Circuit: Low Side Pull-up resistance: 1.2kΩ (10mA@12V)
Output	Contact	Rack actuator	RACKSOL	E42	Circuit: High Side, PWM port Output: 6.0A or lower (@12V)
		Main relay	MAIN-RLY	E34	Circuit: High Side Output: 200mA or lower (@12V)
		Rack actuator relay	RACK-RLY	E33	Circuit: High Side Output: 200mA or lower (@12V)
		Air heater relay	AIRHT-RLY	E44	Circuit: Low Side Output: 1.2A or lower (@12V)
		CSD solenoid operated valve coil	CSD-CL	E41	Circuit: Low Side Output: 2.41A or lower (@12V)
		Fault indicator lamp	FAIL-LMP	E12	Circuit: High Side Output: 300mA or lower (@12V) Lamp load: 12V/3.4W or lower Inrush current: 12V/3A-10 ms or lower
		Pre-heat lamp	PREHT-LMP	E23	Circuit: High Side Output: 300mA or lower (@12V) Lamp load: 12V/3.4W or lower Inrush current: 12V/3A-10 ms or lower
		Application open output 1	APP-OP1	E20	Circuit: High Side Output: 300mA or lower (@12V) Lamp load: 12V/3.4W or lower Inrush current: 12V/3A-10 ms or lower Relay load: 40Ω or above, 200mH or lower
		Application open output 2	APP-OP2	E2	Circuit: High Side Output: 300mA or lower (@12V) Lamp load: 12V/3.4W or lower Inrush current: 12V/3A-10 ms or lower Relay load: 40Ω or above, 200mH or lower
	Pulse	Speed Monitoring	NRPM-M	E22	Circuit: High Side, directly connected to speed input Output: 200mA or lower (@12V) ON voltage: 1.5V or lower OFF voltage: load power supply voltage Output withstand voltage: 200V
		Load factor monitor	LOAD-M	E32	Circuit: High Side, PWM port Output: 200mA (@12V) ON voltage: 1.5V or lower OFF voltage: load power supply voltage Output withstand voltage: 200V
		Step motor A phase	STPM-A	E31	Circuit: High Side Output: 1.0A or lower (@12V)
		Step motor B phase	STPM-B	E21	Circuit: High Side Output: 1.0A or lower (@12V)
		Step motor C phase	STPM-C	E11	Circuit: High Side Output: 1.0A or lower (@12V)
		Step motor D phase	STPM-D	E1	Circuit: High Side Output: 1.0A or lower (@12V)

Table 14-2 E-ECU Terminal Specifications

Item	Classification	Terminal Name	Symbol	Number	Terminal Specification
Commu-nication	Network	CANL	CANL	E39	ISO11898 (Ver2.0B), 250/500 kbps
		CANH	CANH	E40	
		CAN termination	RECAN	E30	CAN Terminator: 120Ω E30 connected to CANL (E39)
	Serial	RxD1	RxD	E3	TTL level (Not available)
		TxD1	TxD	E4	
Power supply	For output	Sensor 5V	AVCC	E38	Voltage: Vcc ± 0.02V (Vcc = 5.0 ± 0.1V) Output: 25mA or lower
		Sensor GND	GND-A	E28	
		Sensor 12V	AVB	E43	Voltage: internally connected to VB Dump surge protection
	For input	Power supply 12V	VB	E48	Connected to main relay
		Power supply GND	GND	E45	Connected to (-) battery terminal
		Power GND	GND-P	E47	
Other	Other	Boot mode	BOOTSW	E29	Not available
		-	-	E46	

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.
- The serial communication terminals (E3, E4) are not available.
- If necessary, joint E30 with E39 to activate the CAN terminator. (See **Harness (P.14-27)** for details.)
- E25, E26, E27, E29, and E46 are unused terminals. No wiring is necessary.

Electrical Components

Table 14-3 Electrical Component List of the Eco Governor System

Component	Function	Setting*1	Compatibility*2
E-ECU (Engine model dependent)	Engine control	◉*3	No
Fuel injection pump (Engine model dependent)	• Fuel injection control (Rack actuator, rack position sensor) • Engine speed detection (speed sensor) • Cold starting aid (CSD solenoid operated valve solenoid)	◉	No
Water temperature sensor (129927-44900)	Engine control (Use only for engine control)	◉*3	No
EGR valve (≧ 37kW) (129927-13900)	Emission support	◉	No
Alternator (e.g., 129423-77200)	• Battery charge • Charge alarm/indication (ECU connection is option)	◉	Yes
starter motor (e.g., 129900-77010)	Engine startup	◉	Yes
Starting aid (e.g., air heater) (e.g., 129915-77050)	Cold start	◉	No
Acceleration sensor (129938-77800)	• Target engine speed instructions • Optional for generator specification	○*5 *3	Yes
Main relay (198461-52950)	Power supply self-hold and reverse battery terminal connection protection	◉*3	No
Rack actuator relay (198461-52950)	• Over speed prevention • Emergency stop	◉*3	Yes
Starter motor relay (129927-77920)*4	• Starter motor restraint • Connector: Yazaki 7223-6146-30 (recommended) Bracket for the above connector: 129927-77910	◉	Yes
Fault indicator lamp (124732-77720)	• E-ECU action indication (illuminates for 2s at power-on) • E-ECU abnormality indication (flashes under abnormal conditions)	○*6	Yes
Sub relay (198461-52950)	Panel power supply and reverse battery terminal connection protection	△	Yes
Starting aid relay (e.g., 129927-77920)*4	• On-glow control, etc. • Connector: Yazaki 7223-6146-30 (recommended) Bracket for the above connector: 129927-77910	○	Yes
Pre-heat lamp (No setting)	On-glow and pre-heat indications	△	Yes
Oil temperature 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)	◉	No
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	Yes
Diesel fuel filter/Water separator (w/sensor) (e.g., 129245-55700)	Diesel fuel filter/water separator alarm/indication (acts under abnormal conditions)	◉Customer selectable if sensor equipped	Yes
Harness (129927-91040, 129927-91050)	• Electrical component connection • YDT connection (German DTM connector)	○*7	Yes
Key switch (194215-52110)	• For glow position control • On-glow use is option	○	Yes
Diesel fuel pump (119225-52102)	• Fuel supply • Automatic air bleeding	◉	No

*1: The electrical components of the eco governor system are configured as follows:
◉: Standard component
O: Recommended option component (hatching)
△: Option component (hatching)

*2: The compatibility columns indicate compatibility between Yanmar genuine components and general-purpose components.
No: Yanmar genuine components should be used. Otherwise, the engine performance cannot be guaranteed.
Yes: Components with which general-purpose components can be used (hatching).
However, the component specifications provided by Yanmar should be satisfied.

*3: Indicates the electrical components that are specific to eco governors (not required for mechanical governors).

*4: Yanmar genuine starting aid relays and starter motor relays do not have mounting brackets.
Brackets 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: Make sure that the fault indicator lamp is installed at a position that can easily be seen by the operator.

*7: We do not offer custom development of harnesses.

The electrical components configured for mechanical governors, shown in **Table 14-4**, are not required for eco governors.

Table 14-4 Electrical Components Not Required for Eco Governors

Component	Product Number	Note
Water temperature switch	e.g., 121250-44901	Replaced by cooling water temperature rise alarm
Safety relay	e.g., 119802-77200	-
Stop solenoid	e.g., 119653-77950	-
Timer	129211-77920	Stop solenoid (for 1s)
Relay	119650-77910	-
Diode	119643-66900	-
Timer	128300-77920	Pre-heat lamp (for 15s, similar to glow use)
QHS controller	129457-77900	Eco governors require starting aid relay (similar to glow use)

Notes for the Electrical Specifications Required for General-Purpose Components

If eco-electrical components are configured by the customer (i.e., if Yanmar genuine components are not used), those components must meet the requirements in **Table 14-5**, 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 14-5 Electrical Specifications Required for General-Purpose Components

Component	Required Electrical Specifications	
Acceleration sensor input	• Sensor output voltage: 0 - 5V (standard setting: 0.7V (min. speed) to 3.0V (max. speed)) • Sensor's recommended available range is from 10% to 80% (input voltage: 0.5 - 4.0V). *The E-ECU detects sensor abnormalities when sensor input voltage is ≦ 0.2V or ≧ 4.6V. • For resistor type potentiometers: ≧ 2.0kΩ (5.0kΩ is recommended) • For Hall type position sensors: current consumption ≧ 10mA (5V)	
Rack actuator relay Sub relay	Contact Rated voltage Rated load current Coil current Coil inductance Electrical open/close lifetime	Normally open ("a" contact) 12V DC 12V DC/20A or above - continuous 12V DC/200mA or lower 200mH or lower 100,000 times or more
	Other performance should meet the installation environment requirements.	
Starter motor relay	Contact Rated voltage Rated load current Instantaneous load current Coil current Coil inductance Action delay time Electrical open/close lifetime	Normally open ("a" contact) 12V DC 12V DC/40A or above - 30s 12V DC/100A or above 12V DC/300mA or lower 200mH or lower 20 ms or lower 100,000 times or more
	Other performance should meet the installation environment requirements.	
Starting aid relay	Contact Rated voltage Rated load current Coil current Coil inductance Electrical open/close lifetime	Normally open ("a" contact) 12V DC 400W: 12V DC/40A or above - 30min (@30°C) 500W: 12V DC/50A or above - 4min (@30°C) 800W: 12V DC/80A or above - 4min (@30°C) 1000W: 12V DC/90A or above - 4min (@30°C) 12V DC/1.0A or lower 200mH or lower 100,000 times or more
	Other performance should meet the installation environment requirements.	
Fault indicator lamp Pre-heat lamp	Lamp load Inrush current	12V-3.4W or lower 12V/3A-10 ms or lower
Harness	Requirements of the separately provided standard wiring diagram should be satisfied. (E3-29927-0031, E3-29927-0041)	
Air cleaner (sensor SW) Diesel fuel filter/Water separator (sensor SW)	Contact E-ECU connected:	Normally open ("a" contact) Maximum current ≧ 20mA Minimum current ≦ 10mA
Key switch	No circuit instantaneous interruption to the ON terminal power supply should occur when the key is turned from ON to START.	

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 14-6 Requirements for Customer-Configured Electrical Components

Component	ECU Connection Terminal No.	Requirements	
Spare speed sensor	RENRPM (E10)	Output Rated voltage Maximum current	Open corrector type 12V DC 20mA or above
Shutdown switch	SHUDNSW (E15)	Contact Maximum current Minimum current	Normally open ("a" contact): standard Normally close ("b" contact): option 12V DC/20mA or above 12V DC/10mA or lower
Load factor monitor	LOAD-M (E32)	Resistance load Maximum current ON voltage OFF voltage	Pulled up to 12V power supply 12V DC/200mA or above 1.5V or lower Power supply voltage
Speed Monitor	NRPM-M (E22)		
Cooling water temperature alarm lamp (Eco mode lamp) (Speed change indicator lamp)	APP-OP2 (E2)	Lamp load Inrush current	12V DC-3.4W or above 12V DC/3A-10ms or lower
Block heater relay		Contact Rated voltage Rated load current Coil current Coil inductance Electrical open/close lifetime Other performance should meet the installation environment requirements. If a block heater is connected to commercial power supply, pressure resistance and insulation resistance of the relay contact should meet the related regulatory standards.	Normally open ("a" contact) 12V DC For 100V: 115V AC/4A or above - continuous For 200V: 210V AC/2A or above - continuous 12V DC/300mA or lower 200mH or lower 100,000 times or more
Droop Selection SW Starter motor permission SW	APP-IP1 (E24)	Contact Maximum current Minimum current	Normally open ("a" contact): standard Normally close ("b" contact): option 12V DC/20mA or above 12V DC/10mA or lower
Rmax1 SW	APP-IP7 (E13)		
Rmax2 SW	APP-IP2 (E14)		
Speed selection 1 SW	APP-IP3 (E9)		
Speed selection 2 SW Spare Starter motor permission SW	APP-IP4 (E17)		
Reverse droop selection SW	APP-IP5 (E5)		
Speed selection permission SW	APP-IP6 (E6)		

HARNESS

For the standard wiring and standard harness diagrams, refer to the material E3-29927-0031 (English: E3-29927-0041). The engine performance has been confirmed by Yanmar using this standard harness. Therefore, if the harness is prepared by the customer, the harness design must be performed according to the standard wiring and standard harness diagrams.
Yanmar can supply a harness (E-ECU side: 129927-91041, power supply side: 129927-91051) that is equivalent to the one shown in the standard harness diagram, however, we do not supply a harness customized for each customer.

Harness Conditions

Be sure to comply with the following notes: Otherwise, the engine performance may be affected and a malfunction or failure may be caused. For the battery and starter motor wiring and the charging system, refer to "13.Electrical System". For the wiring and harness of the eco governor system, refer to the material E3-29927-0031 (Japanese) and material E3-29927-0041 (English).

[ECU Wiring]

Power Supply Wires

1. 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.
2. Length of the main relay wire
   The main relay power supply should be connected directly to the battery (+) terminal and the wire line length should be within 4m. Otherwise, operations such as an ECU reset at cold start may be affected.
3. Length of the E-ECU power supply wire
   The total wire line length to the E-ECU power supply should be within 5m.
4. Impedance of the power supply wires
   Prevent common impedance between the E-ECU power supply circuit and power supply circuit of high-current devices such as the starter motor and air heater.Otherwise, an E-ECU reset is likely to occur at cold start.
5. Length of the GND wire
   The wire diameter of the GND wire should be 2.0 mm^2. Otherwise, it may be impossible to start the engine at low temperatures.

Other Wires

6. Length of the rack actuator wire
   The total wire length of the rack actuator wire should be within 10m.
7. Branches of the power supply wire
   The power supply side circuits of the rack actuator relay and EGR valve should be branched in a location as close to the E-ECU-VB terminal as possible.
8. Protection against a reverse connection
   For the main relay and sub relay, the E-ECU and rack position sensor against a reverse connection of the battery terminals, insert a reverse connection action preventive diode to the main and sub relays, or use the Yanmar-specified relay (198461-52950) for the protection purpose. Otherwise, the E-ECU is damaged when the battery is connected in reverse.
9. Speed sensor and CAN communication wires
   Use a twisted pair wire for the speed sensor. Use a shielded twisted pair wire for the CAN communication. Otherwise, a malfunction due to noise is likely to occur.
10. CAN terminator
    If you use a CAN terminator that is built into the E-ECU, the length of the E30-E39 joint circuit should be as short as possible.

Load

11. Circuit separation
    No load from other than the engine parts such as the E-ECU (E48), rack actuator, or EGR valve, should be connected to the main relay. Extension load power supplies to devices such as the external switch of the E-ECU or indicator lamps should be supplied from a separate circuit. This prevents the engine from becoming out of control due to troubles in the extension load circuit and avoids malfunctions due to such as current leakage to the E-ECU from the extension load.
12. Key switch power supply
    No load other than the one shown in **Figure 14-4** should be connected to the E-ECU IGNSW (E7) terminal. Current leakage may prevent the engine from cutting off the E-ECU power supply.
13. Lamp load
    The lamp load that can be connected to the E-ECU should be up to 12V/3.4W.
14. Contact current
    The minimum contact current that is connected to the E-ECU should be selected to be equal to or less than 10mA.
15. Lamp attachment position
    Make sure that the fault indicator lamp is attached to a position that can easily be seen by the operator.
16. Water temperature sensor
    No other load should be connected to the water temperature sensor of the E-ECU. Otherwise, the CSD or EGR control may not function properly, which can affect the cold startability and engine durability.
17. 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 0.1A or more contact current flows or use a pressure switch with a low contact current specification (for example, 124298-39450).
18. 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.

Starting Aid Wiring

1. Length of the starting aid wire
   The total wire line length to the starting aid device (either an air heater or glow plug) should be within 6m.

Key Switch

1. 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.

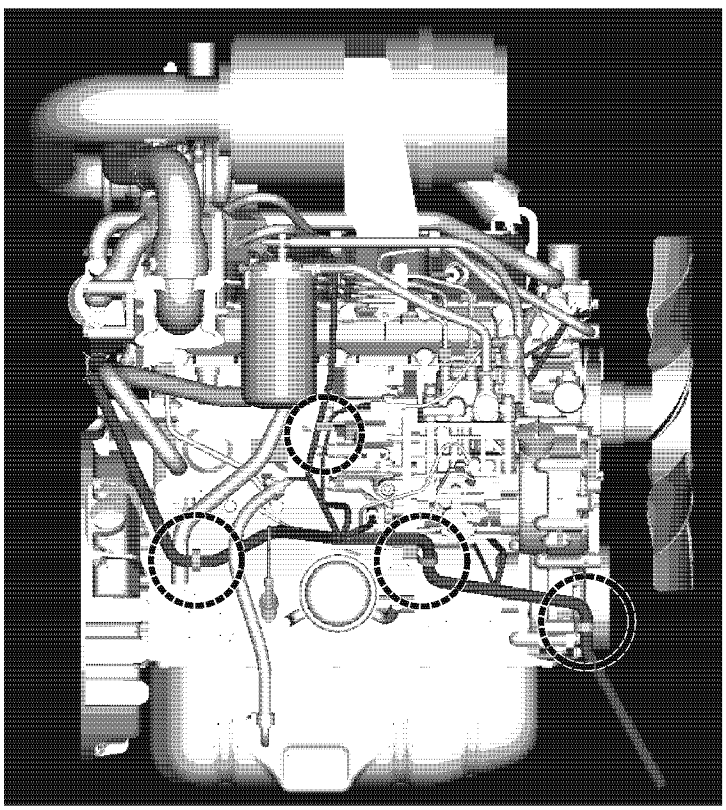
General

1. 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.
2. Heat resistance
   You must use wires with heat resistance that fits the ambient temperature of the environment in which the engine will be used.
3. Mating precaution
   When mating connectors, use caution to avoid entry of water into the couplers.

4. Clamping precaution
   You must clamp the harness at appropriate positions so that it will not be shaken by vibration.
5. Clamping precaution
   You must clamp the harness making enough allowance to prevent any tension.
6. Joint parts
   It is recommended to make the joint parts waterproof using joint couplers, butyl tape, etc.
7. Surges on a misuse
   Make sure that no surge current or voltage is caused under a normal operation or expected misuse.
8. 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 1ms) is caused under a normal operation or expected misuse.
9. Measurement probes
   Do not force a measurement probe, such as those of a tester, into a female coupler.

How to Clamp the Harness

The figure below shows an example of clamping the Yanmar standard harness onto the engine.



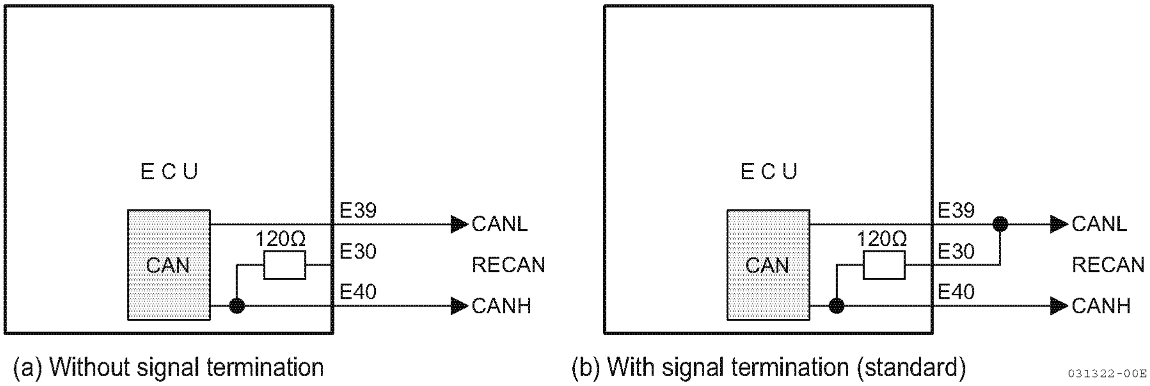
Clamp the harness at least at the four points indicated above.

031321-00E

Figure 14-11 **Harness Clamp Example**

CAN Bus Termination

Since the E-ECU has a built-in 120Ω CAN terminator, the CAN signal can be terminated by jointing the RECAN terminal (E30) and CANL terminal (E39) with the E-ECU harness, as shown in **Figure 14-12** (b).



(a) Without signal termination

(b) With signal termination (standard)

Figure 14-12 **CAN Terminator Setting**

If no device uses the CAN bus other than the E-ECU:

➡ Since a CAN terminator is required for a YDT connection, you must use the wiring shown in **Figure 14-12** (b).

If any device uses the CAN bus other than the E-ECU:

➡ Set up the harness to fit the device to be used.

Table 14-7 CAN Terminator Setting

		CAN Terminator Setting
If none (if there is no other CAN bus-dependant device)		Follow **Figure 14-12** (b)
If any (if there is any CAN bus-dependant device)	With a terminator (another device)	Follow **Figure 14-12** (a)
	Without a terminator (another device)	Follow **Figure 14-12** (b)

CONTROL FUNCTIONS

Structure of the Control Functions

The engine controller (E-ECU) software can be roughly divided into functions as shown in **Figure 14-13**.

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 engine control portion
5. Application function : The interface portion with the device

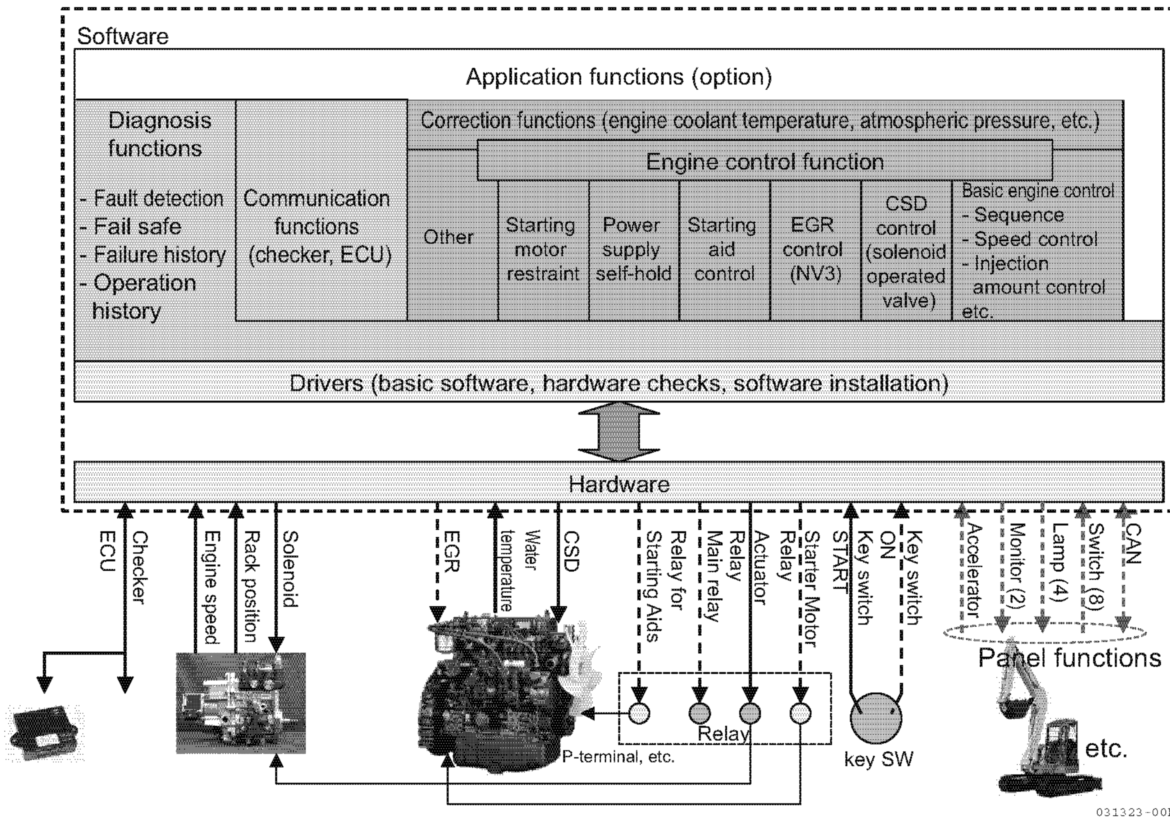


Figure 14-13 Structure of the E-ECU Software

The engine controller (E-ECU) software is also divided and managed in terms of its structure as follows.

1. Control program : Engine control logic
2. Model specific control map : Setting values for torque characteristics, options, etc.
3. Specific information : Correction values for the injection amount, output, etc., serial number, and shipment date

Management Categories

The control program and model specific control map are managed as controller Assy. components for each of the individual engine models. Specific information is managed as CS information that is adjusted for each of the fuel injection pumps and a single engine. **Figure 14-14** shows the internal data structure of the ECU.

Control Program

It is a common program that is independent of the individual engine models and it cannot be customized for each customer.

Model Specific Control Map

It consists of the base (unmodifiable) portion that determines the engine performance (for example, the torque characteristics) and the option setting portion to customize the E-ECU application functions for each customer.

Specific Information

It includes the adjustment values for each of the fuel injection pumps and per a single engine.

Replacing the E-ECU

The same specific information as in the previous E-ECU needs to be written to the new E-ECU.

Replacing the Fuel Injection Pump

Adjustment values for the new pump need to be written to the E-ECU.
*The maintenance of the specific information in the market is performed in the EEPROM area. When your specific information is written to the EEPROM, the map is automatically switched from the Flash memory area to the EEPROM area (EEPROM: Electrically Erasable Programmable Read-Only Memory).

Flash Memory

This is a kind of semiconductor memories. Any written program or data will not be lost even if the E-ECU power supply is turned off. This is a re-writable memory (for about 100 times).

Difference (EEPROM/Flash Memories)

You can write data to the EEPROM even while the engine is running. However, you cannot write data to the Flash memory while the engine is running. A special device is required to write data to the Flash memory.

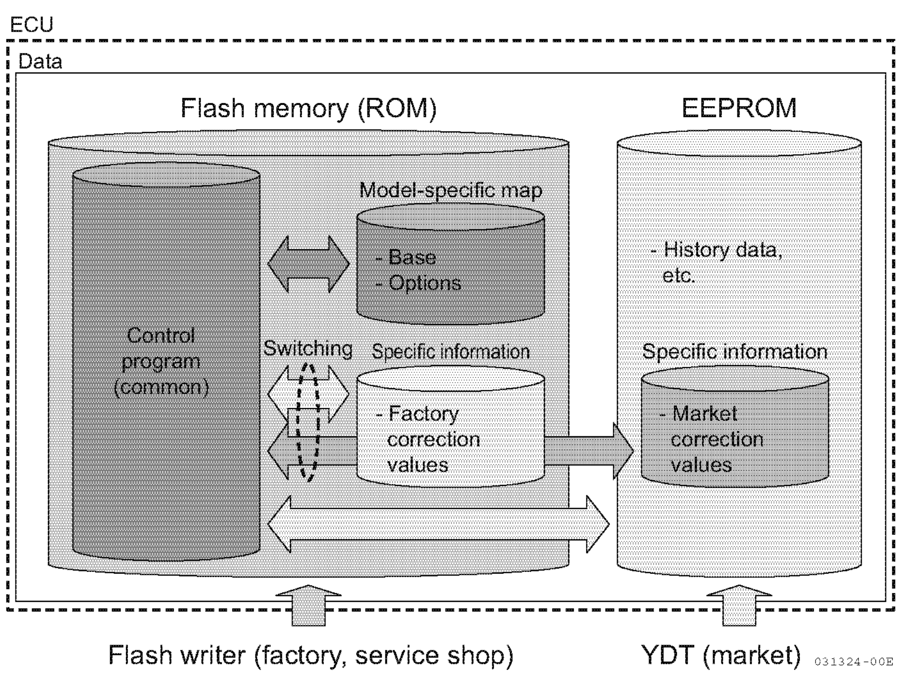


Figure 14-14 **Structure of the E-ECU Data**

General Control

Speed Sensor Inputs

As shown in **Figure 14-15**, the eco governor detect the engine speed from the twelve pieces of pulsars attached to the camshaft of the fuel injection pump.
Supposing that the pulse frequency detected from the pulsars is expressed as fp [Hz], the engine speed, Nrpm [min^{-1}], is expressed by the following formula (see **Figure 14-15** a)):

$$\text{Nrpm}\ [\text{min}^{-1}] = (\text{fp} \times 2/12) \times 60 = 10 \times \text{fp}\ [\text{Hz}]$$

An engine speed involves cyclic variability due to compressions and explosions. Therefore, for these pulsars mentioned above, 3 (= 12/4) pieces of pulses and 4 (= 12/3) pieces of pulses, for a four-cylinder engine and three-cylinder engine respectively, correspond to cyclic variability by a single cylinder.
In order to perform stable speed detection suppressing the effect due to the cyclic variability of the engine speed, the eco governor perform an averaging process on cyclic variability by a single cylinder (see **Figure 14-15** b)).

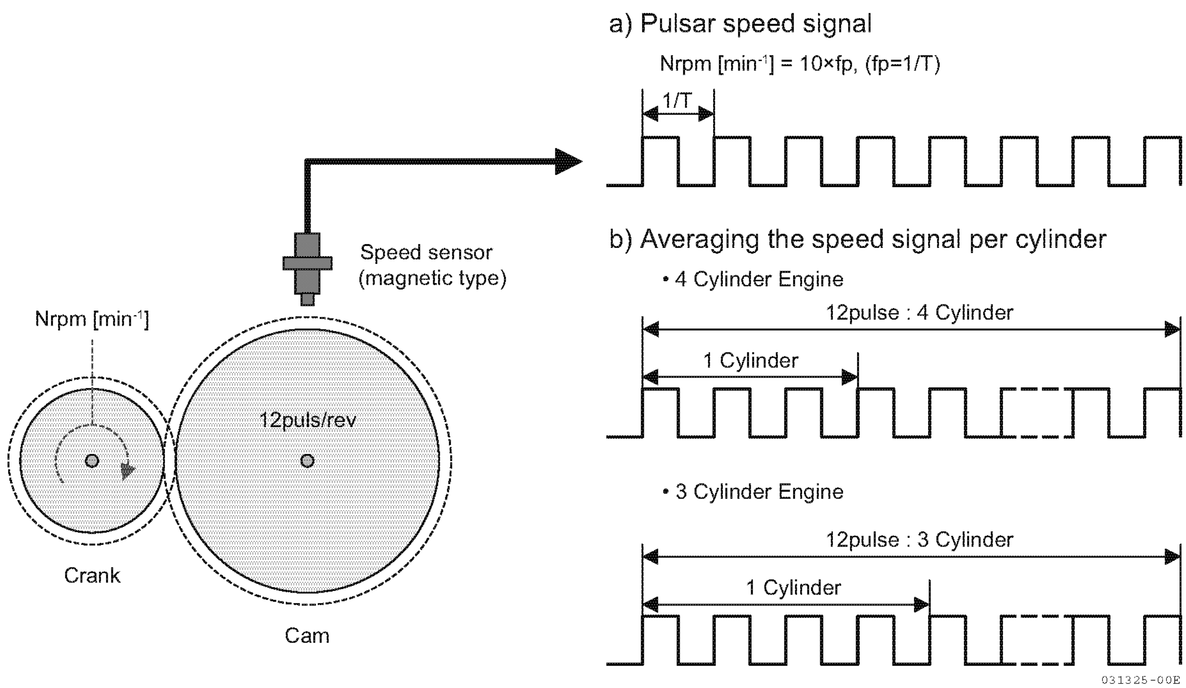


Figure 14-15 **Engine Speed Detection Method**

Rack Position Sensor Inputs

The eco governor controls the fuel injection amount by controlling the rack position of the fuel injection pump. Rack positions are converted to voltages by the rack position sensor and they are read by the AD converter through the RPS terminal of the E-ECU. As shown in **Figure 14-16**, voltage values ranging from 0 to 5V, that are read by the AD converter, are expressed by AD values ranging from 0 to 1023.
All of the eco governor's calculations, including the maximum rack position, lowest rack position, or load factor, are performed based on these AD values.

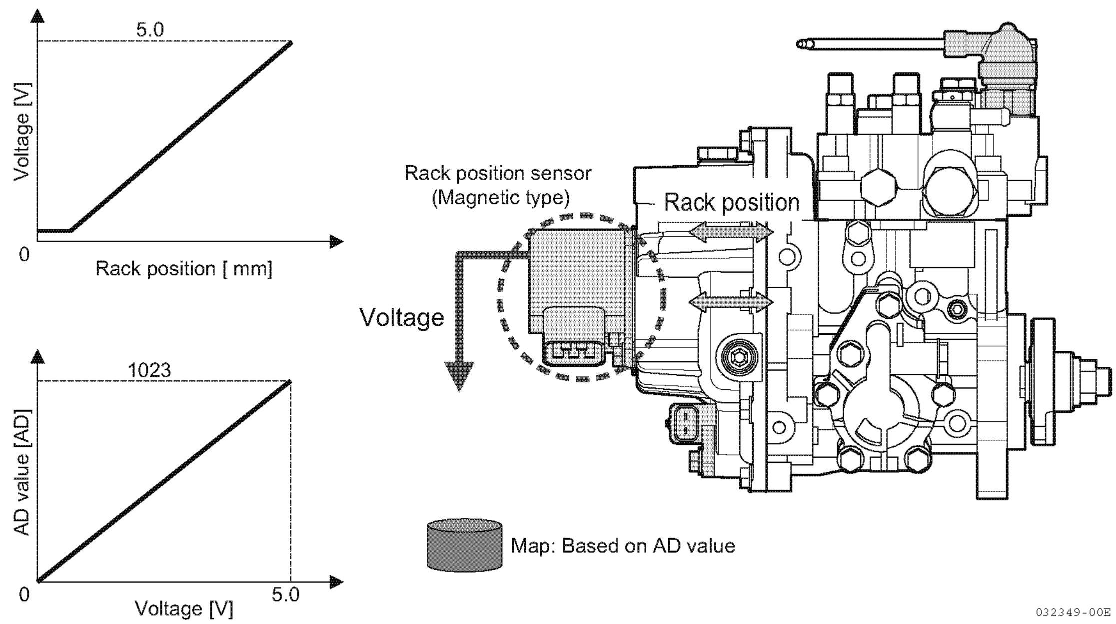


Figure 14-16 **Rack Position Detection**

Water temperature sensor Inputs

The input characteristics of the cooling water temperature sensor is shown in **Figure 14-17**. As with the rack position sensor, input voltages ranging from 0 to 5V are converted to AD values ranging from 0 to 1023. You can see that the thermistor resistance value to changes in the temperature will decrease as the temperature decreases.

The accuracy of the cooling water temperature sensor (129927-44900), newly introduced for 2G eco governors, is ± 3°C (at 0°C), ± 2°C (at 20°C), and ± 2°C (at 110°C). For 2G eco governors, 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.

Note: Use only the Yanmar genuine water temperature sensor for the RET terminal (E16-E28) 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.

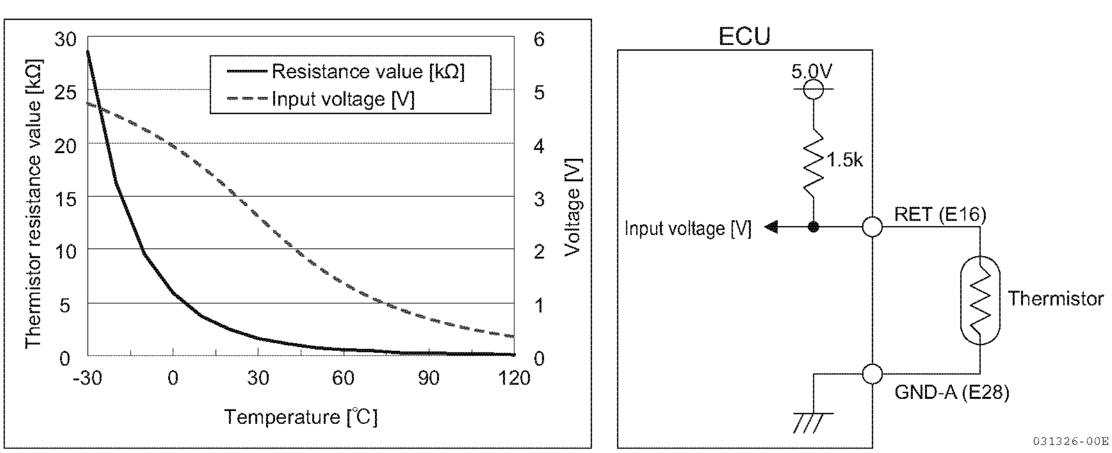


Figure 14-17 **Characteristics of the water temperature sensor**

Acceleration Sensor Inputs

The eco governor calculates the target engine speed based on input values from either analog input voltages or the CAN communication (The "actual engine speed" and the "target engine speed" do not always match because they are determined by the relationship between the maximum engine torque and the load torque).

Input voltages of the acceleration sensor, as shown in **Figure 14-18**, are converted from a low idle speed to a high idle speed (standard settings: 0.7V ➡ low idle speed, 3.0V ➡ high idle speed). The modifiable range of input voltages is described later. Optionally, you can also reverse the input voltage bias that is corresponding to the range from the low idle speed to the high idle speed.

For the settings of the acceleration sensor including the CAN communication, refer to **Application functions (P.14-47)**.

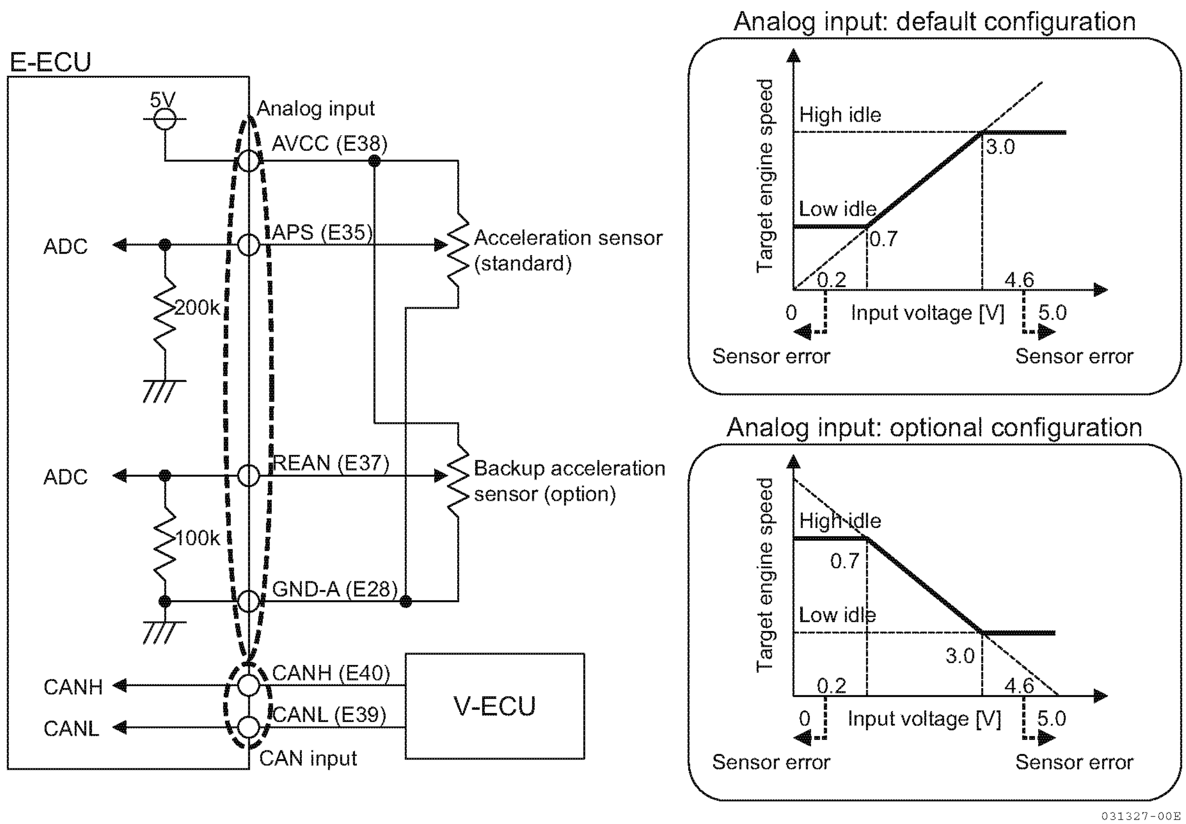


Figure 14-18 **Acceleration Sensor Inputs**

Input Voltage Settings

The E-ECU has detection errors on electric circuits and software hysteresis characteristics for input voltages from the acceleration sensor. The total of these values is ± 0.125V. If the acceleration voltage is used with the standard setting (0.7 - 3.0V), the voltage from the acceleration sensor must be at least within the range shown in **Figure 14-19**.

Note: The E-ECU detects an abnormality of the acceleration sensor when the input voltage from the acceleration sensor becomes equal to or less than 0.2V or equal to or greater than 4.6V.

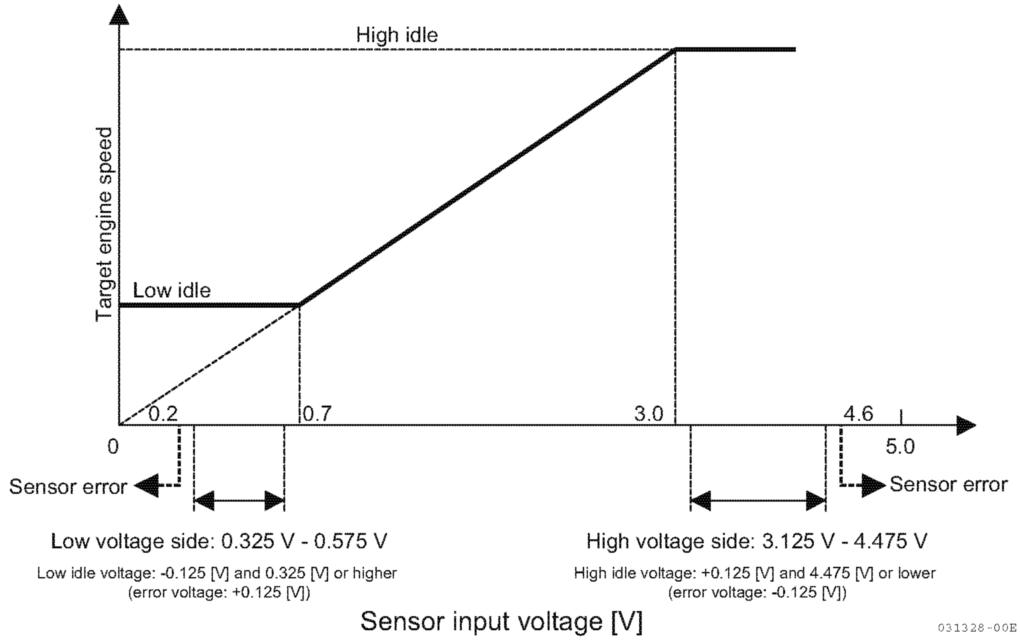


Figure 14-19 **Required Accuracy of the Acceleration Sensor**

Contact Input

Contact input of the E-ECU include high-side input and low-side input as shown in **Figure 14-20**. Both the sink and source current of the contact input of the E-ECU are designed to produce Typ.10mA. For the specifications of the contact input circuit on the E-ECU, refer to **Figure 14-10** and **Table 14-2**.

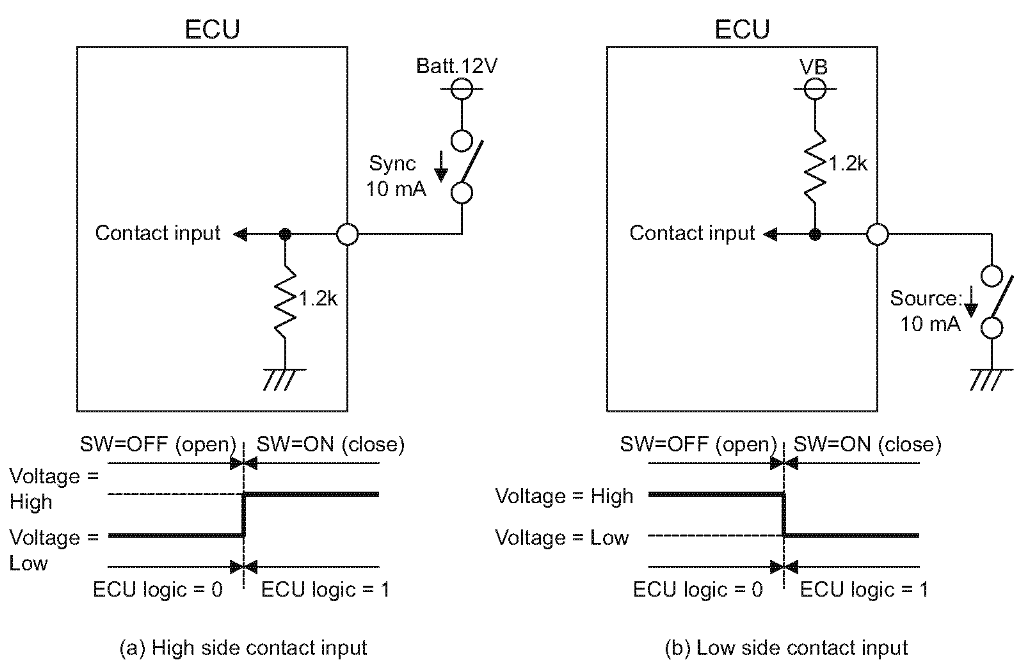


Figure 14-20 **Contact Input Circuits and Input Logic**

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 14-21 shows the difference of the input terminal voltage level by the SW types of a high-side contact input.
For NO : Switch ON ➡ High level (the input terminal voltage)
For NC : Switch ON ➡ Low level (the input terminal voltage)

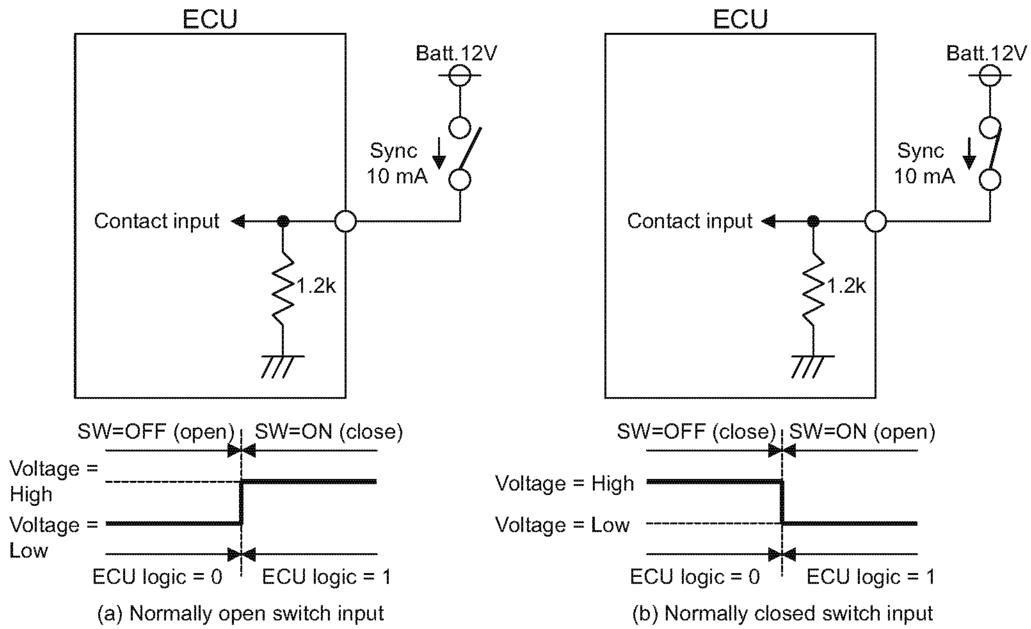


Figure 14-21 **High-Side Contact Input (Switch Type)**

Low-Side Contact Input

Figure 14-22 shows the difference of the input terminal voltage level by the SW types of a low-side contact input.
For NO : Switch ON ➡ Low level (input terminal voltage)
For NC : Switch ON ➡ High level (input terminal voltage)

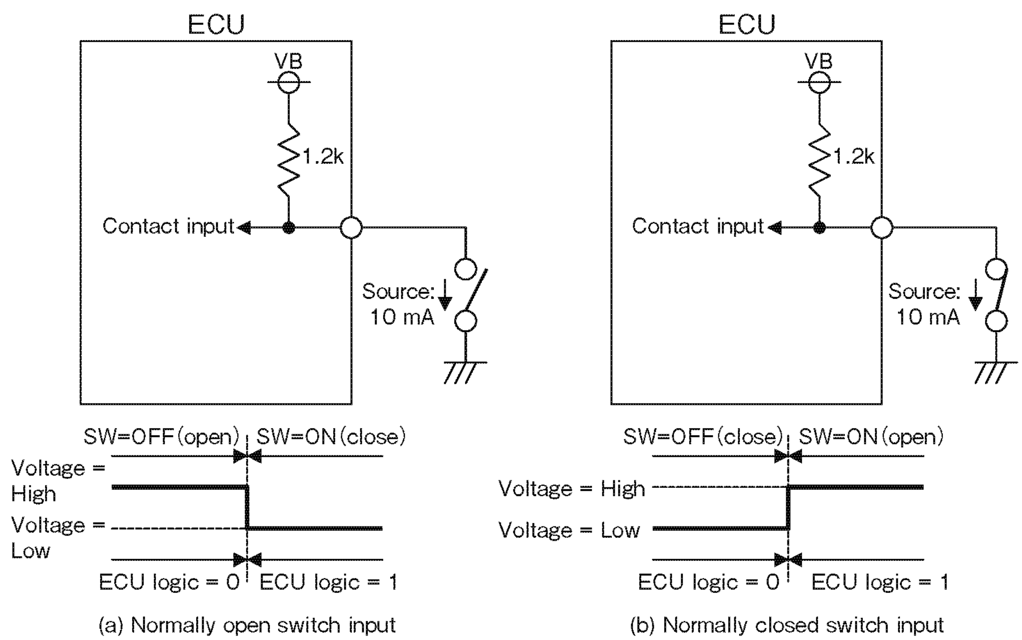


Figure 14-22 **Switch Types for a Low-Side Contact Input**

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 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 to use a Normally Open type switch or Normally Close type switch for the E-ECU with the mapflag settings. The ECU terminal function settings: **Table 14-25** shows the list of the contact input terminals where you can choose switch types.

Contact Output

Contact output of the E-ECU include high-side output and low-side output as shown in **Figure 14-23**.
For more information about the eco governor's E-ECU contact output including the sink/source current or allowable current values, refer to **Figure 14-10** and **Table 14-2**.
*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)

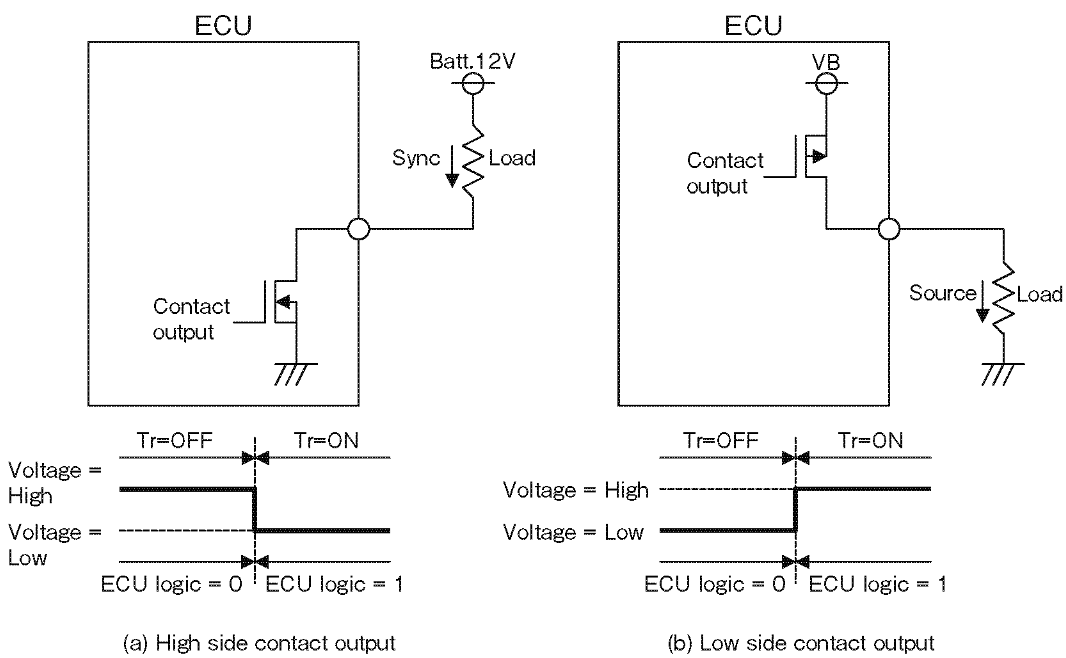


Figure 14-23 **Contact Output Circuits and Output Logic**

Rack Actuator Output

The rack actuator output is a high-side output as shown in **Figure 14-24**.
The E-ECU shorten or lengthen "The time length to set the output transistor ON" in order to decrease or increase "the current flowing to the solenoid of the rack actuator". Since the rack position of the fuel injection pump changes based on the amount of the current that flows to the rack actuator, the E-ECU can control the rack position.
This method to control the current by changing the ON time of a transistor is called the PWM control. (PWM: Pulse Width Modulation)

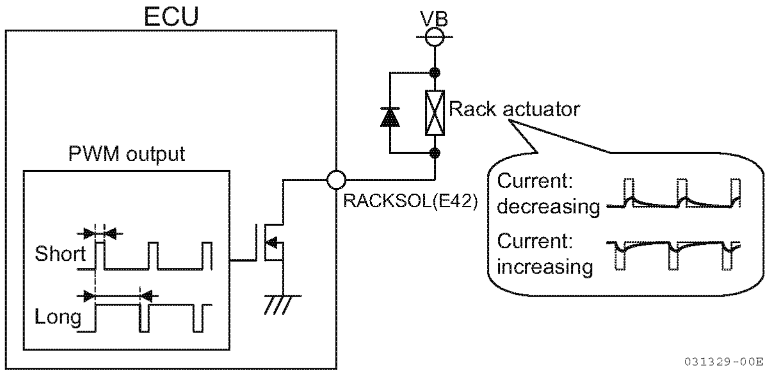


Figure 14-24 **Rack Actuator Output**

EGR Valve output

The EGR valve output is a high-side output as shown in **Figure 14-25**.
The EGR valve is driven by a step motor. The step motor uses the two-phase excitation method as its drive method and it requires a holding current even while the valve is stopped. Two-phase excitation means that two phase solenoids are energized at the same time, while a holding current means that solenoids are energized all the time.
The E-ECU opens and closes the valve by turning ON and OFF the output transistors that drive the step motor's solenoids of each phase in turn as shown in **Figure 14-25**.
The EGR valve becomes fully closed at the 0 (zero) step and becomes fully opened at the 54 step.

Note: The motor part of the EGR valve is hot even after stopping the engine. Be careful not to burn your skin.
*Heat of approximately 24W (12W x 2 phases)

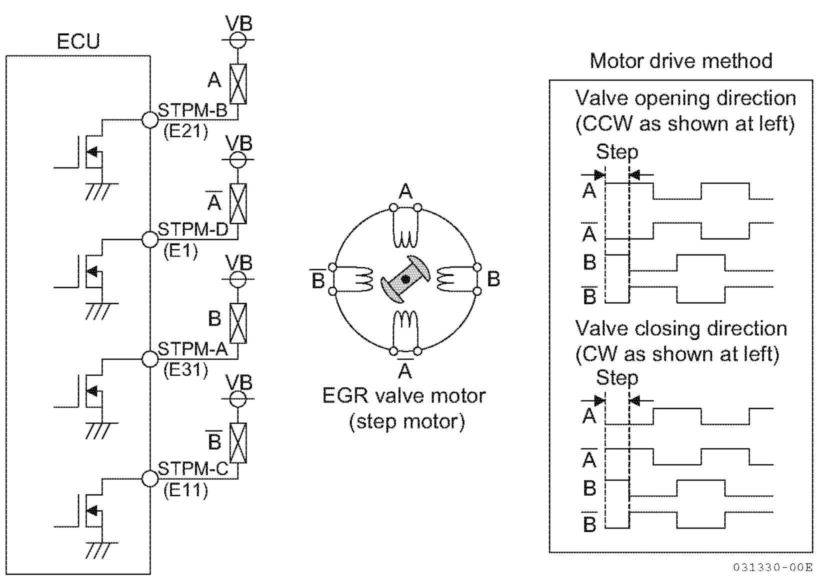


Figure 14-25 **EGR Valve Drive Method**

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

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.

CAN Communication Input

The power supply self-hold function can be performed using a CAN communication input.
For more information, refer to the CAN communication specification.

Wiring for the Self-Hold Function

For the power supply self-hold function, wiring of the E-ECU requires wiring between the main relay and the rack actuator, as shown in the standard electric wiring diagram in **Figure 14-4**.

Note: If you do not provide the self-hold wiring, the EGR valve cannot fully move back to the end and a large amount of black smoke may be emitted for an instant when the engine is started.

Starting Control

Rack Self Diagnosis

The engine starting sequence is shown in the figure at right. The E-ECU performs a rack self diagnosis immediately after the power supply is turned ON. This rack self diagnosis checks only the rack operation without starting the engine. Therefore, the starter motor action must be restrained in order not to start the engine during a rack self diagnosis.

On-Glow Control

Next, if the on-glow control is configured (standard), the energizing time to the starting aid 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.

Starting Rack Position Control

If the key switch is turned to the START position or the engine speed reaches equal to or greater than 240min^{-1}, the starting rack position control is initiated. This will control the rack to move to the preset position.

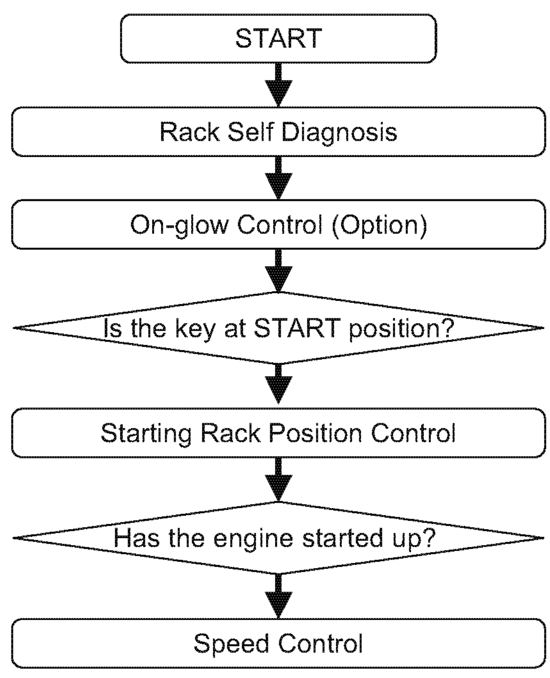


Figure 14-26 **Starting Sequence**

Transition to the speed control

If the engine speed reaches equal to or greater than 600min^{-1} (which varies depending on the engine model), the controller transitions from the starting rack position control to the speed control. The rack position is controlled through the speed control so that the engine speed is kept at the speed instructed by the accelerator.

Stop Actions

The engine stops when the engine speed reaches equal to or greater than 240min^{-1} or the key switch is turned OFF.

Torque Curve and Regulation

In general, the engine's torque curve is configured as shown in **Figure 14-27** and **Figure 14-28**. These figures are shown only for describing the concept. Please note that the details are different depending on the engine model. In addition, 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 for the eco governor:

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 120min^{-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).

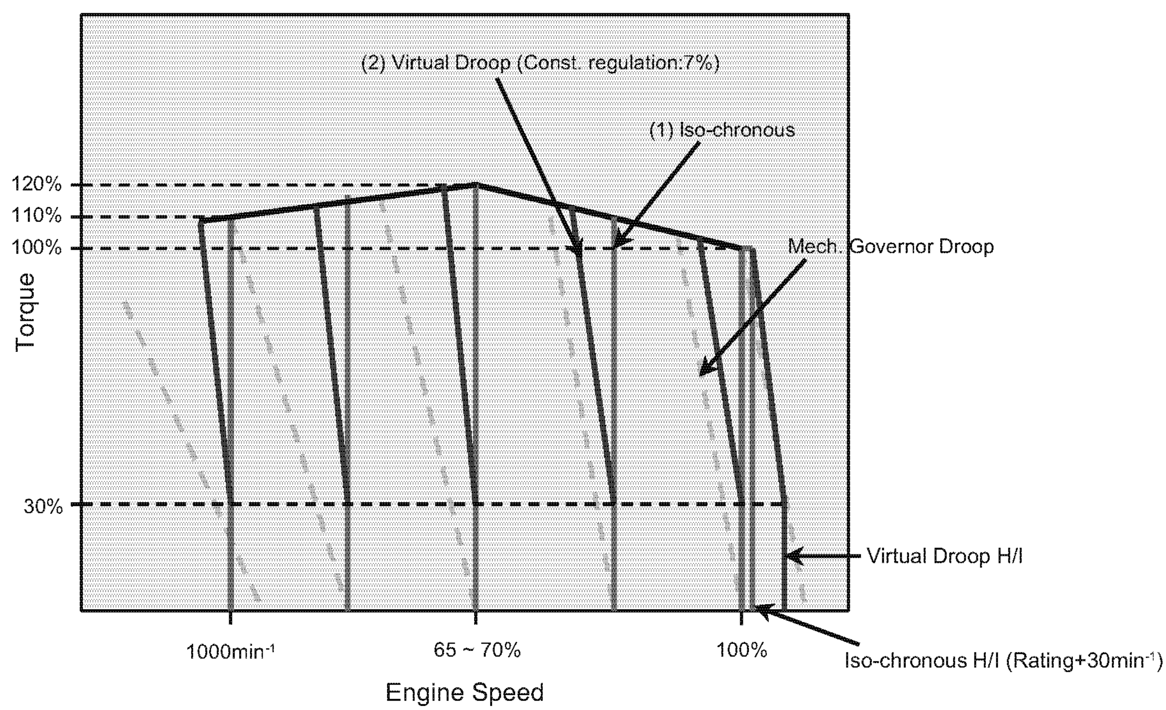


Figure 14-27 **(Example) 4TNV98-E, 4TNV98-Z (Conceptual Figure of the Standard Torque Curve)**

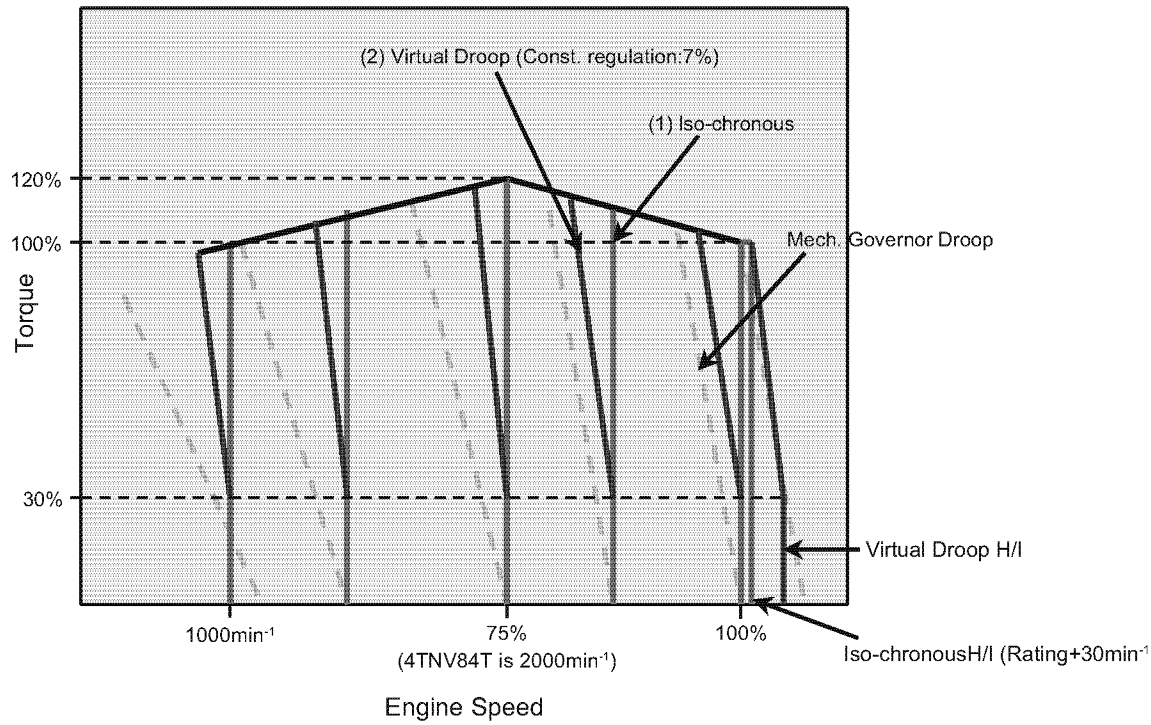


Figure 14-28 **(Example) 4TNV84T, 4TNV98T (Conceptual Figure of the Standard Torque Curve)**

The settings of the torque curve and regulation are the same for NV2 engines with the eco option specification and for those with the standard mechanical governor specification.

Switching the Regulation

The Iso-chronous and virtual droop settings can be switched using an external switch or CAN communication (even while the engine is running).
*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.

Wiring Diagram

Figure 14-29 shows the wiring diagram for switching between the iso-chronous and virtual droop settings with an external switch.

Note: We do not accept any requests to change the torque curve.

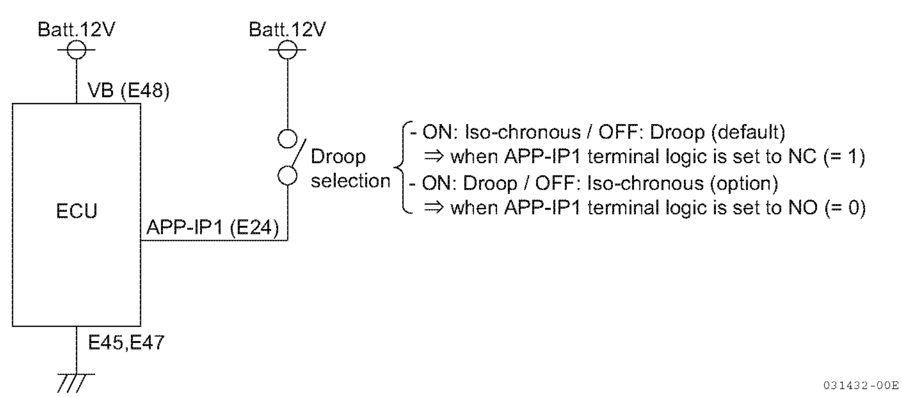


Figure 14-29 **Wiring Diagram (Switching the Iso-chronous and Virtual Droop Settings)**

Speed Control

The target engine speed is determined by the input from the acceleration sensor or CAN communication with the flow as shown in **Figure 14-30**. Summaries for each item and descriptions of the option setting items are documented later.

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 (see page **14-48** for details).

Speed Selection Function

The target speed from the acceleration sensors are changed depending on the condition of the external switches; APP-IP3, APP-IP4, and APP-IP6 (see page **14-57** for details).

Idle up Function

The engine's low idle speed is increased depending on the cooling water temperature (see page **14-69** for details).

Blue/White Smoke Suppression Control

The engine's high idle speed is decreased depending on the cooling water temperature (see page **14-70** for details).

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.

Accelerator filter

The change amount of the target speeds are suppressed in order to reduce overshoots or undershoots of the engine speed (see page **14-71** for details).

Governing Control

The target speed of the virtual droop setting is calculated (see page **14-41** for details).

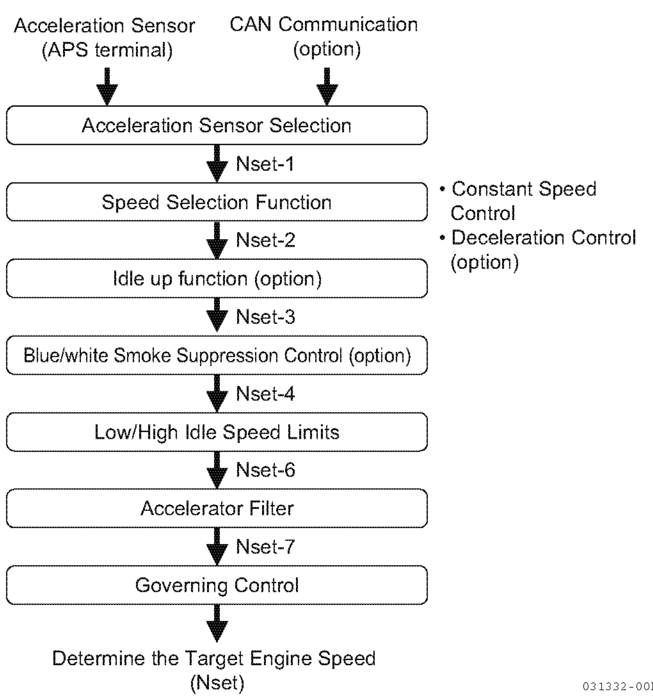


Figure 14-30 **Setting Flow for the Target Speed**

Figure 14-31 shows the engine speed control block diagram of the E-ECU.

[Speed Control]

The target rack position (REQRP) is calculated based on the deviation between the target engine speed (RES) and the actual engine speed (ES) through the PID control. At the same time, the controller limits the torque and performs a rack delay action for transient control, which is described later. The "actual engine speed" and the "target engine speed" do not always match because they are determined by the relationship between the maximum engine torque and the load torque.

[Rack Position Control]

The target current (RCV) is calculated based on the deviation between the target rack position (REQRP) and the actual rack position (ACTRP) through the PID control. The eco governor performs a diagnosis to see whether or not the system is running normally, by examining the engine, for example, if it always meets the "REQRP ≒ ACTRP" condition under steady state operation using YDT etc.

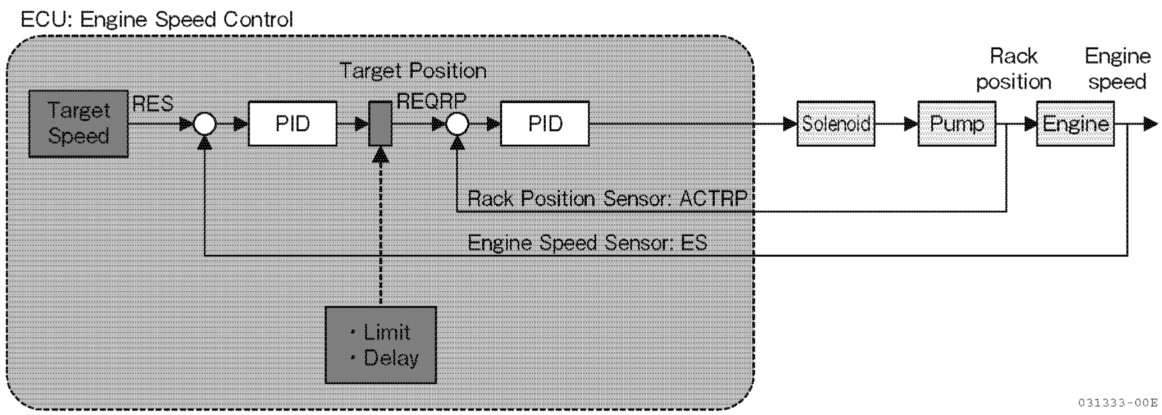


Figure 14-31 **Engine Speed Control Block Diagram**

EGR Control

The eco governor provides NOx reduction by installing an electronic control EGR valve to the engine models with rated outputs of 37kW or greater.
An EGR valve is driven by a step motor. An EGR valve adjusts the amount of circulating exhaust gas by controlling the valve opening (0 - 54 steps) that is pre-configured based on the engine speed and the engine load factor. In general, the relationship between the EGR valve's step number and the flow volume can be illustrated as shown in **Figure 14-32**.
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.

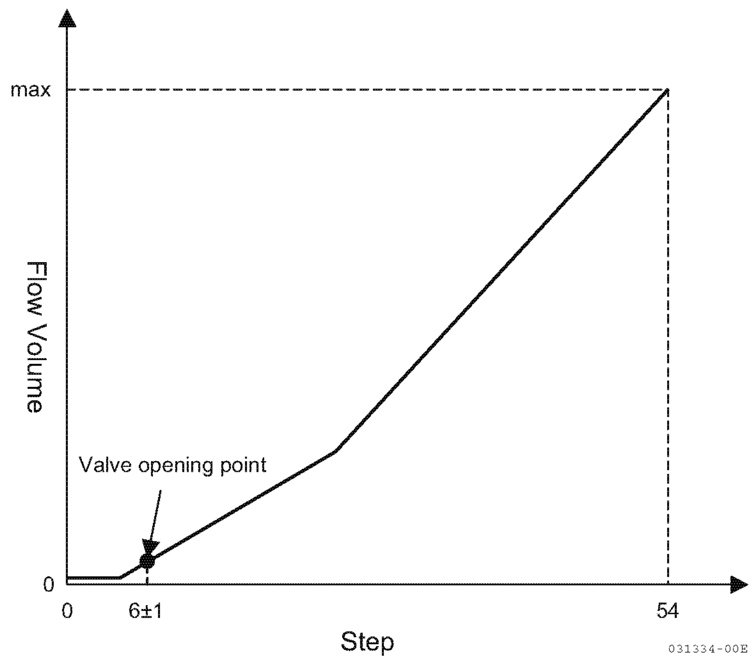


Figure 14-32 **EGR Valve Characteristics**

CSD Control

The CSD advances the fuel injection timing of the fuel injection pump (MP pump) in order to facilitate engine startability at low temperatures.
The eco governor uses an solenoid operated valve CSD which can open and close CSD by the solenoid.
The CSD operates when the cooling water temperature is 10°C or lower. Although the cooling water temperature that makes the CSD stop is different for each engine model, it will stop after up to 5 minutes have elapsed.
The eco governor increases the engine speed to 75min^{-1} and to 50min^{-1}, for NV3 engines and NV2 engines respectively, while the CSD is operating in order to confirm CSD operation. However, the high idle speed will never be exceeded even while the CSD is operating. The engine speed will automatically decrease to the normal speed after CSD operation is complete.
In addition, if the idle up function, which is described later, is used, the speed increase with the idle up function will be added, increasing the engine speed (see page **14-69** for details).
Table 14-8 is a summary of the CSD control behavior.

Table 14-8 CSD Control Behavior

	Operating Temperature	Stop Temperature	Max. Operating Time	Speed Increase at Operation
NV2 Engine	Below 10°C	Engine model dependent	5 minutes	50min^{-1}
NV3 Engine				75min^{-1}

Load Factor Monitoring (Load Factor Output)

As shown in **Figure 14-33**, the engine load is calculated as a percent load factor based on the value of the current rack position (Ract) in relation to the no-load (idle) rack position (Ridl), maximum rack position (Rmax), and minimum (injection-cutting) rack position.
The calculated load factor of the engine is output from the E-32 (Load-M) terminal of the E-ECU as PWM signals, while it is also output from the CAN communication.
Table 14-9 shows the relationship between load factors and PWM pulse widths of the signals that are output from the E-ECU terminal.
A negative load factor is output at transition such as a rapid decrease in engine speed or load rejection.

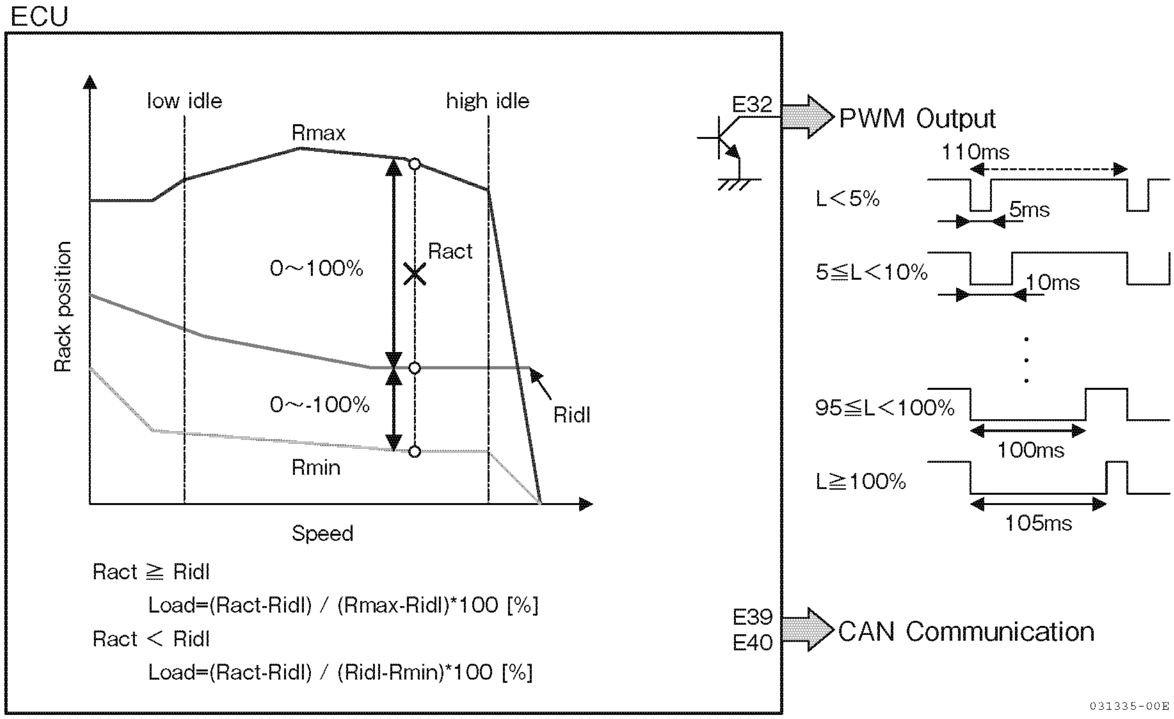


Figure 14-33 **Detection Method of the Load Factor**

Table 14-9 Relationship between Load Factors and PWM Pulse Widths

Load Factor [%]	PWM Width [ms]	Load Factor [%]	PWM Width [ms]	Load Factor [%]	PWM Width [ms]	Load Factor [%]	PWM Width [ms]
L <5	5	30 ≦ L<35	35	60 ≦ L<65	65	90 ≦ L<95	95
5 ≦ L<10	10	35 ≦ L<40	40	65 ≦ L<70	70	95 ≦ L<100	100
10 ≦ L<15	15	40 ≦ L<45	45	70 ≦ L<75	75	L ≧ 100	105
15 ≦ L<20	20	45 ≦ L<50	50	75 ≦ L<80	80		
20 ≦ L<25	25	50 ≦ L<55	55	80 ≦ L<85	85		
25 ≦ L<30	30	55 ≦ L<60	60	85 ≦ L<90	90		

Speed Monitoring (Speed Output)

The engine speed is output from the E22 (NRPM-M) terminal of the E-ECU as pulse signals, while it is also output from the CAN communication.
The relationship between a speed (N) and pulse frequency (fp) that is output from the E-ECU terminal is shown below.

$$N\ [\text{min}^{-1}] = 10 \times fp\ [\text{Hz}]$$

APPLICATION FUNCTIONS

Droop selection function (droop/iso-chronous control switching)

[Function]

This function allows you to switch between iso-chronous and droop control using an external switch, CAN communication, or menu settings.

[Application Menu]

b) 2-7 Droop Selection Input
➡ (0: Iso-chronous control always ON); The system always uses iso-chronous control regardless of the switch status.
➡1: APP-IP1 or CAN input (standard)
➡2: Droop control aways ON; the system always uses droop control regardless of the switch status.

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 [E24] 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, see **Figure 14-29**.

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 14-34**.

[Application Menu]

b) 2-8 Iso-chronous Control at Low Idle Speed ➡ 1: enabled (by standard ➡ 0: disabled).

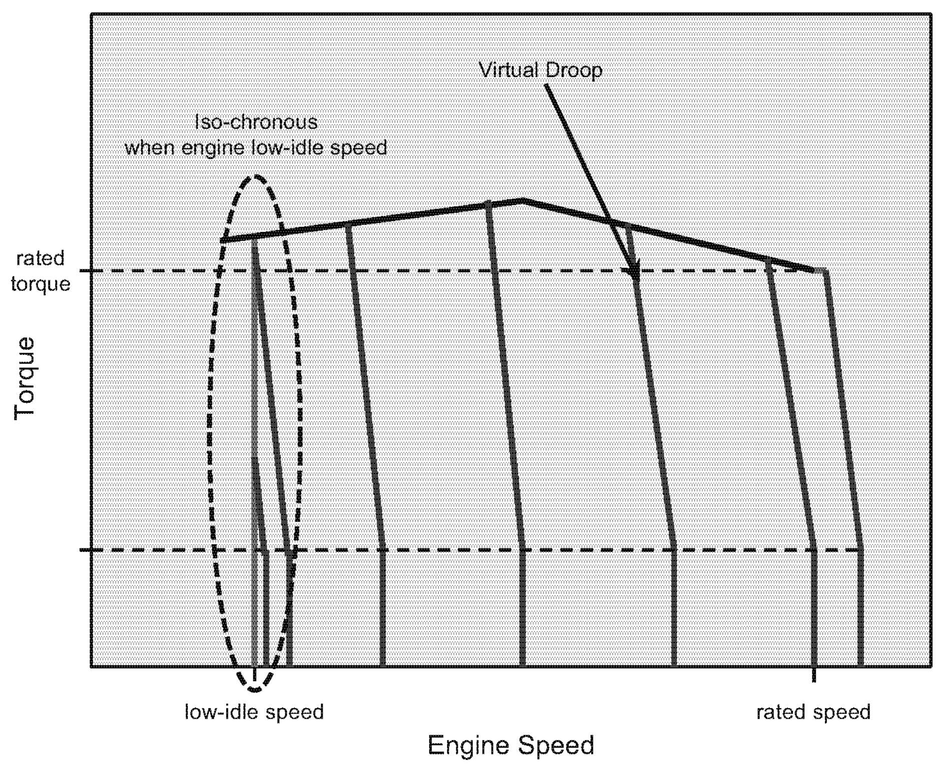


Figure 14-34 **Iso-chronous control at low idle speed**

Acceleration sensor selection

For an overview of the acceleration sensor, **Acceleration Sensor Inputs (P.14-35)**.

Configuring the acceleration input terminals

[Function]

The system supports three acceleration inputs: acceleration sensor (APS terminal), backup acceleration sensor (REAN terminal), and CAN communication. (See **Figure 14-18**).
You can enable/disable these sensor inputs in any combination by configuring the acceleration sensor setup flag.

[Application Menu]

Table 14-10 b) 2-1 Acceleration sensors setup flag

b) 2-1 Acceleration sensor Setup	Acceleration sensor APS (E35)	Backup acceleration sensor REAN (E37)	CAN input (E39, E40)	Preferential operation
0 (Generator standard)	×	×	×	Determined by the following contact inputs: • APP-IP6 (E6) • APP-IP3 (E9) • APP-IP4 (E17)
1 (Standard)	O	×	×	-
2	O	O	×	• The sensor with a higher speed is preferential. • The sensor operating normally is preferential.
3	×	×	O	-
4	O	×	O	• The CAN communication input is preferential.
5 (Reserved)	-	-	-	
6	O	O	×	• The sensor operated last (or, if the system is used for the first time, the main sensor) is preferential. • The sensor operating normally is preferential.

Standard setting (1) : The system operates in response to the acceleration sensor. (standard)
Map setting (0) : The system does not use the acceleration sensor and allows the engine speed to be changed in response to contact inputs. (generator)
Map setting (2) : The system uses the main and backup acceleration sensors and operates in response to one of them that has a higher speed setting.
If either of the sensors fails, the system operates in response to the other sensor operatring normally.
Map setting (3) : The system operates in response to the CAN communication.
Map setting (4) : The system operates in response to the CAN communication, however,if CAN fails, it operates in response to the acceleration sensor.
*An error occurs if this setting is selected and the acceleration sensor is not connected.
Map setting (5) : Do not use this setting under normal circumstances.
Map setting (6) : The system uses both the main and backup acceleration sensors and operates in response to one of them that was operated last.

Configuring the acceleration input terminal voltages

[Function]

You can configure each of the acceleration input terminal, acceleration sensor (APS) and backup acceleration sensor input terminal (REAN) with the input voltages equivalent of the low idle and high idle speeds, respectively.

[Application Menu]

Table 14-11

Menu	Terminal	Description	Standard value [V]
b) 2-2	APS (E35)	Voltage equivalent of the low idle speed	0.7
b) 2-3	APS (E35)	Voltage equivalent of the high idle speed	3.0
b) 2-4	REAN (E37)	Voltage equivalent of the low idle speed	0.7
b) 2-5	REAN (E37)	Voltage equivalent of the high idle speed	3.0

Note: The E-ECU has an error of ± 0.125V 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 = 0.575V (0.7 - 0.125V) to the high idle voltage = 3.125V (3.0 + 0.125V).

Configuring the input functions of the acceleration input terminals

[Function]

You can configure the input functions of the acceleration sensor input terminal (APS) and backup acceleration sensor input terminal (REAN). If you have chosen to disable both the acceleration sensor (APS) and backup acceleration sensor (REAN) using the acceleration sensor flag settings, be sure to disable the input function of each terminal by specifying 0 (disabled). If you configure the input function of each terminal by specifying a non-0 value, the system performs fault detection on the voltage input to the terminal as soon as the input voltage detection for the terminal is enabled.
When the input function of each terminal is set to 2, 3, or 4, you can connect a foot pedal compliant with SAE J1843, as detailed later on.

[Application Menu]

Table 14-12 Configuring the analog input function of each terminal (compliant with SAE J1843)

ECU terminal function setup flags		Type of the connected sensor
Acceleration sensor b) 3-18 APS (E35) Terminal Function Input Setup	Backup acceleration sensor b) 3-19 REAN (E37) Terminal Function Input Setup	
0 (Generator standard)	0 (Standard)	No sensor connected (fault detection disabled)
1 (Standard)	1	Standard acceleration sensor type
2	2	Foot pedal (SAE J1843 configuration) Analog + APP-IP2: NO & APP-IP7: NC
3	3	Foot pedal (SAE J1843 configuration) Analog + APP-IP2: NO
4	4	Foot pedal (SAE J1843 configuration) Analog + APP-IP7: NC
-	5	Reserved

Note: When the setup flag for the input function of the acceleration sensor is disabled (set to 0), the low idle speed is input as the target speed.

Configuring the acceleration sensor fault handling actions

[Function]

The system detects an acceleration sensor fault when it cannot receive a normal signal through the configured accelerator input.
You can configure the fault handling action for each of two cases: if a fault is detected while the engine is running and if a fault is detected with the key turned ON.
For the fault handling action against a fault detected while the engine is running, you can choose either action (1) or (2) described below.
For the fault handling action against a fault detected with he key turned ON, see **Configuring the ECU terminal functions (P.14-83)** and **Configuring the fault handling actions (P.14-85)**.

[Application Menu]

(1) a) 13-7 Acceleration sensor fault handling (1): (standard)
The engine runs at the same speed as immediately before the occurrence of the fault.

Note: 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.

(2) a) 13-7 Acceleration sensor fault handling (2): (option)
a) 13-5 The engine runs at the preset speed when an acceleration sensor fault is detected. The target engine speed changes to the preset speed at a rate of 100min^{-1}/second. (The preset speed, which standards to 1500min^{-1}, may be changed as needed.)

Note: 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.

Configuring the foot pedal

[Function]

When the input function of the APS (E35) or REAN (E37) terminal is set to 2, 3, or 4 as indicated in **Table 14-12**, you can connect a foot pedal compliant with SAE J1843. Note that only either one of the APS (E35) or REAN (E37) terminal can be connected with a foot pedal.
A foot pedal compliant with SAE J1843 is one designed so that the input voltage and switch contact state change depending on how deep the foot pedal is pressed as illustrated in **Figure 14-36**. The E-ECU detects a fault in the foot pedal by monitoring the input voltage and switch contact state.
There are 2 types of switch contacts: normally open (NO) and normally closed (NC). The E-ECU can be connected with either type.

[Application Menu]

Configuring the terminal functions

(1) When the ECU terminal function setup flag is set to 2,
the system monitors the state of both NO and NC switch contacts.
For the NO switch, configure the APP-IP2 terminal functions as follows:

- b) 3-5 APP-IP2 Terminal Logic Setup (0)
- b) 3-6 APP-IP2 Terminal Function Setup (4)

For the NC switch, configure the APP-IP7 terminal functions as follows:

- b) 3-3 APP-IP7 Terminal Logic Setup (1)
- b) 3-4 APP-IP7 Terminal Function Setup (4)

(2) When the ECU terminal function setup flag is set to 3, the system monitors the state of the NO switch contact only. For the NC switch, configure the APP-IP2 terminal functions as follows:

- b) 3-5 APP-IP2 Terminal Logic Setup (0)
- b) 3-6 APP-IP2 Terminal Function Setup (4)

(3) When the ECU terminal function setup flag is set to 4, the system monitors the state of the NC switch contact only. For the NC switch, configure the APP-IP7 terminal functions as follows:

- b) 3-3 APP-IP7 Terminal Logic Setup (1)
- b) 3-4 APP-IP7 Terminal Function Setup (4)

Configuring the acceleration input terminal voltages

If you have chosen to connect a foot pedal, you are recommended to set the voltages equivalent of the low and high idle speeds to 1.1V and 3.5V, respectively. Only either one of the APS (E35) or REAN (E37) terminal can be connected with a foot pedal.

Table 14-13

Menu	Terminal	Description	Standard value [V]
b) 2-2	APS (E35)	Voltage equivalent of the low idle speed	1.1
b) 2-3	APS (E35)	Voltage equivalent of the high idle speed	3.5
b) 2-4	REAN (E37)	Voltage equivalent of the low idle speed	1.1
b) 2-5	REAN (E37)	Voltage equivalent of the high idle speed	3.5

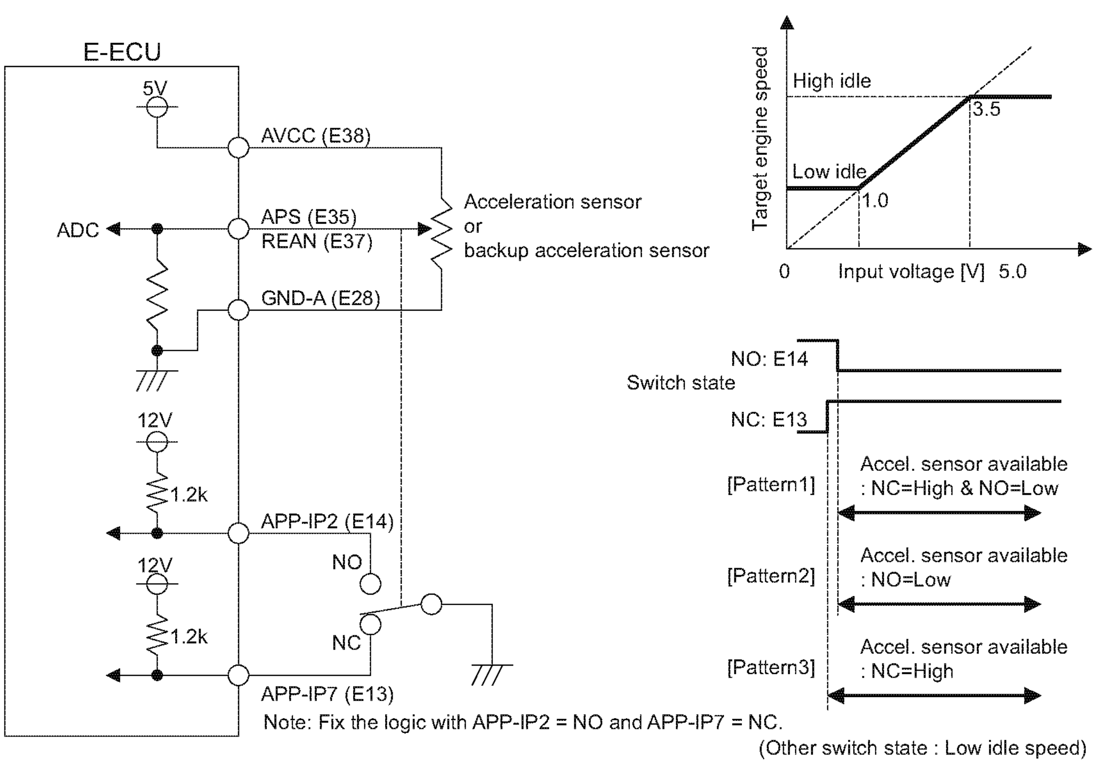


Figure 14-35 **Foot pedal operation**

[Description]

Figure 14-36 shows how the system detects a fault in the foot pedal. A sensor fault is detected in the following cases:

- Similar to the standard acceleration sensor, the system detects a sensor fault when the input voltage is below 0.2V or above 4.6V.
- When the input voltage is 1.1V or higher, the system detects a sensor fault when APP-IP2 changes from NO to High or APP-IP7 changes from NC to Low. (If the flag is set to 3 or 4, the detection depends on the state of the effective switch type.)
- When the input voltage is 0.65V or lower, the system detects a sensor fault when APP-IP2 changes from NO to Low or APP-IP7 changes from NC to High. (If the flag is set to 3 or 4, the detection depends on the state of the effective switch type.)

*The system handles a sensor fault by performing an action similar to that for the standard acceleration sensor.

Note:

- The E-ECU has an error of ± 0.125V in detected voltages shown below. Therefore, carefully note that switching of the pedal switch must occur somewhere between 0.775V (0.650 + 0.125) and 0.975V (1.1- 0.125).
- If you have chosen to connect a foot pedal, a sensor fault is reset when you turn OFF the power to the E-ECU by setting the key to the OFF position.
  (*When you are using the standard acceleration sensor, a sensor fault is reset when the normal sensor signal is restored.)

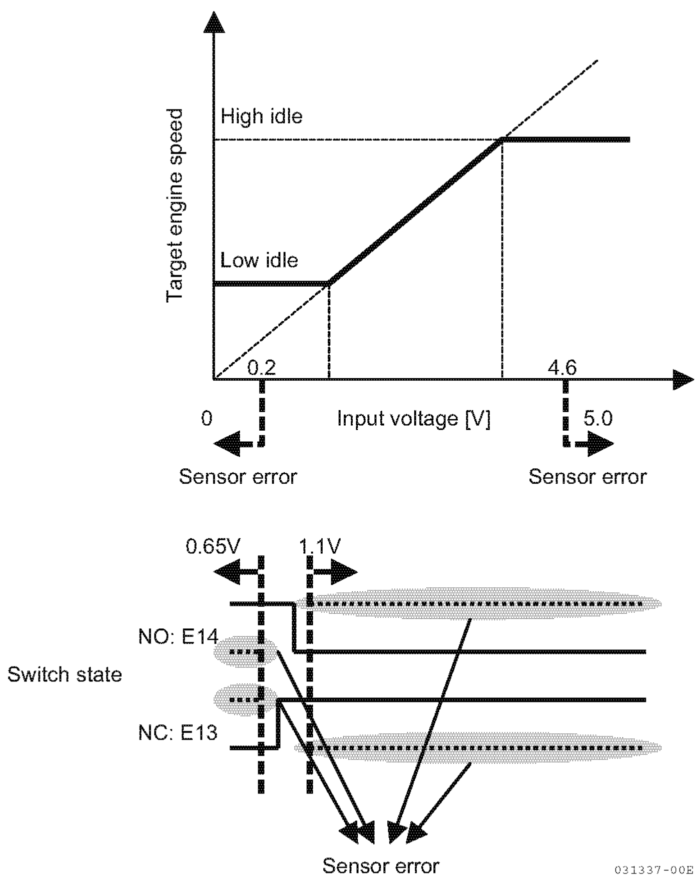


Figure 14-36 **Foot pedal fault detection**

Starting aid control

You can control the starting aid devices (air heater/glow plug) by configuring the following control functions based on the starting aid relay:

(1) Disconnection detection (standard)

[Function]

You can configure the E-ECU to detect a disconnection or short circuit in the starting aid relay. (standard)

[Application Menu]

b) 2-16 Starting Aid Relay Fault Detection Function ➡ 1: enabled (standard), 0: disabled.

(2) On-glow control (standard)

[Function]

When the key switch is set to the ON position, the system automatically energizes the starting aid 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 time in on-glow control differs between two starting aids: the air heater and glow plug. **Figure 14-37** shows how the preheat time is set up for the air heater and glow plug, respectively.

[Application Menu]

b) 2-17 Starting Aid Control Function: On-Glow ➡ 1: enabled (standard), 0: disabled.

(3) Simultaneous energizing control (standard)

[Function]

The starting aid 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.)
If the E-ECU power supply terminal voltage falls to 6.5V or lower during simultaneous energizing, the system cuts off the power to the starting aid 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 6.0V or lower.)

[Application Menu]

b) 2-18 Starting Aid Control Function: Simultaneous Energizing ➡ 1: enabled (standard), 0: disabled.
Do not disable the simultaneous energizing control function under normal circumstances.

(4) After-heat control (option)

[Function]

After the engine has started up, the system energizes the starting aid relay either for a maximum of 80 seconds or as long as the cooling water temperature is 10°C or below. The time until the blue/white smoke goes out can be reduced by using this function. (This function is equivalent to that provided by the QHS controller 129457-77900, however, uses different temperature and time settings. The QGS controller 119650-77900 does not perform after-glow control.)
*The after-heat control is disabled by standard because it is battery-intense.
Carefully consider the battery charge/discharge cycles before you choose to use this function.

[Application Menu]

b) 2-19 Starting Aid Control Function: After-Heat ➡ 0: disabled (standard), 1: enabled.

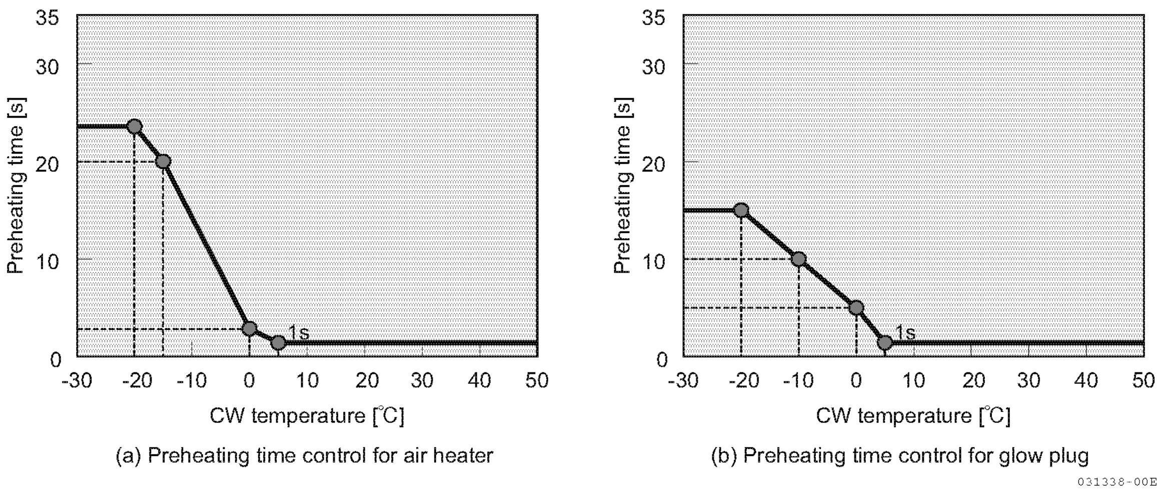


Figure 14-37 **On-glow control preheat time**

Note: 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

[Function]

During the time between when the key is set to the ON position and when the engine starts up, the eco governor system performs rack self diagnosis to ensure that the fuel injection pump rack operates properly. During the rack self diagnosis, the system restrains the starter motor to prevent the engine from starting up. This starter motor restraint control is performed by connecting the starter relay to the E-ECU as shown in **Figure 14-38**. ("Starter motor restraint" means restraining the starter motor from rotating.)
You can identify the reason for starter motor restraint by connecting a YDT and checking the restraint reason flag.) (See **Table 14-35**.)

[Application Menu]

Do not disable the function "b) 2-12 Permit/Restrain Starter Motor".
In addition to the starter motor restraint function during rack self diagnosis, the E-ECU has the following additional functions:

(1) Safety relay function (standard)
When the engine speed rises to or above 675min^{-1} (or the speed specific to the model), the system turns OFF the starter motor and disables it until the engine speed falls to or lower 325min^{-1}.
(This functions is equivalent to that provided by 119802-77200 assuming that the safety relay to pulley ratio is 2.0.)

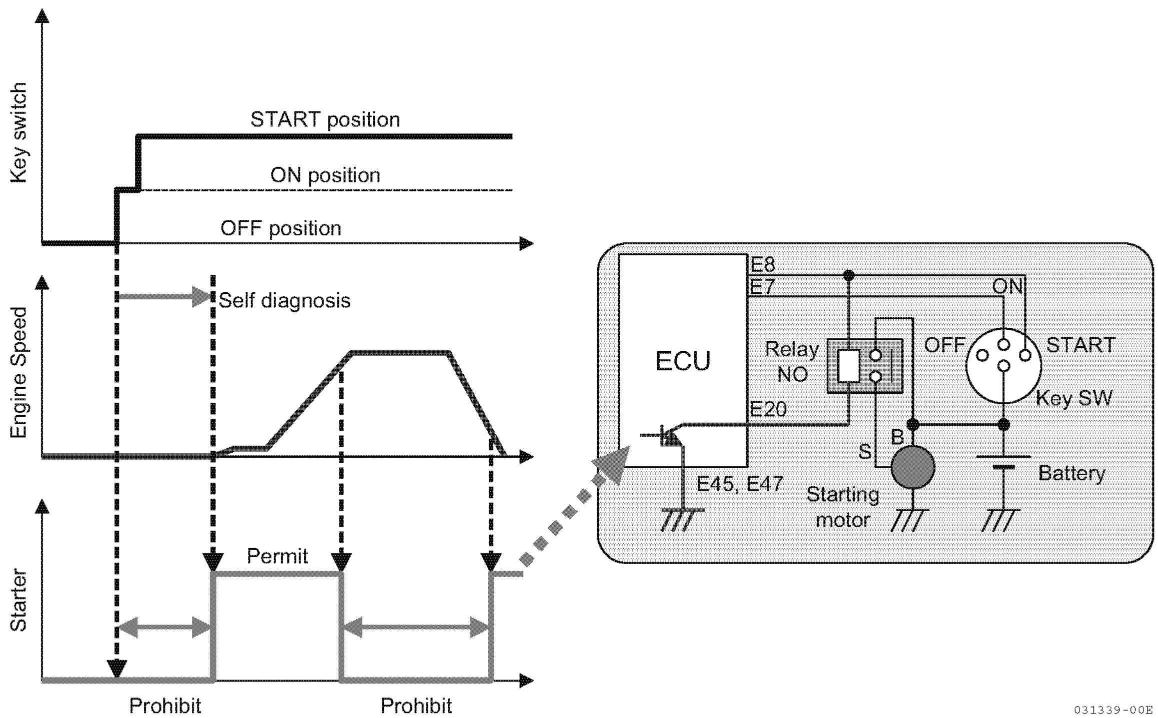


Figure 14-38 **Timing chart of starter motor restraint control**

(2) 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]

b) 2-15 Starter Motor Energization Time Control Function ➡ 0: disabled (standard), 1: enabled.

(3) 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-IP4) or sync type (APP-IP1) as shown in **Figure 14-39**. You can permit the starter motor to operate as described below.
When you use the APP-IP1 contact input (E24), you cannot use the Droop Selection function.
When you use the APP-IP4 contact input (E17), you cannot use the Speed Selection 2 function.
Alternatively, you can perform starter motor restraint control via the CAN communication, instead of a contact input.

[Application Menu]

Enable the external switch control function:
b) 2-13 External Switch Control Function ➡ 0: disabled (standard), 1: enabled.
Configure the terminal to which to connect the external switch:
b) 3-2 APP-IP1 Terminal (E24) Function Input Setup ➡ 2: Permit/Restrain Starter Motor
b) 3-10 APP-IP4 Terminal (E17)Function Input Setup ➡ 4: Permit/Restrain Starter Motor

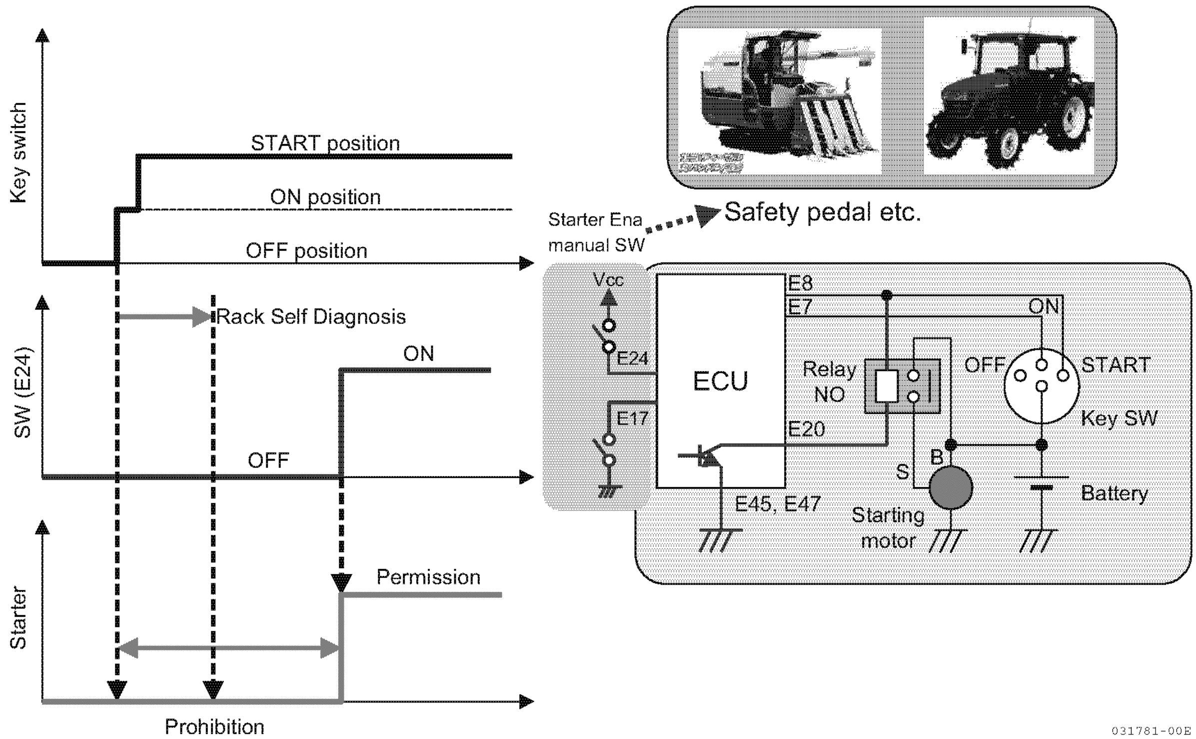


Figure 14-39 **Using an external switch to permit the starter motor to operate**

You can also use functions (1) and (2) described above to implement a remote (automatic) start/stop system. Details shown in **Figure 14-40**. This example uses the Engine Start Recognition (E8) signal from an external control device instead of the key switch.

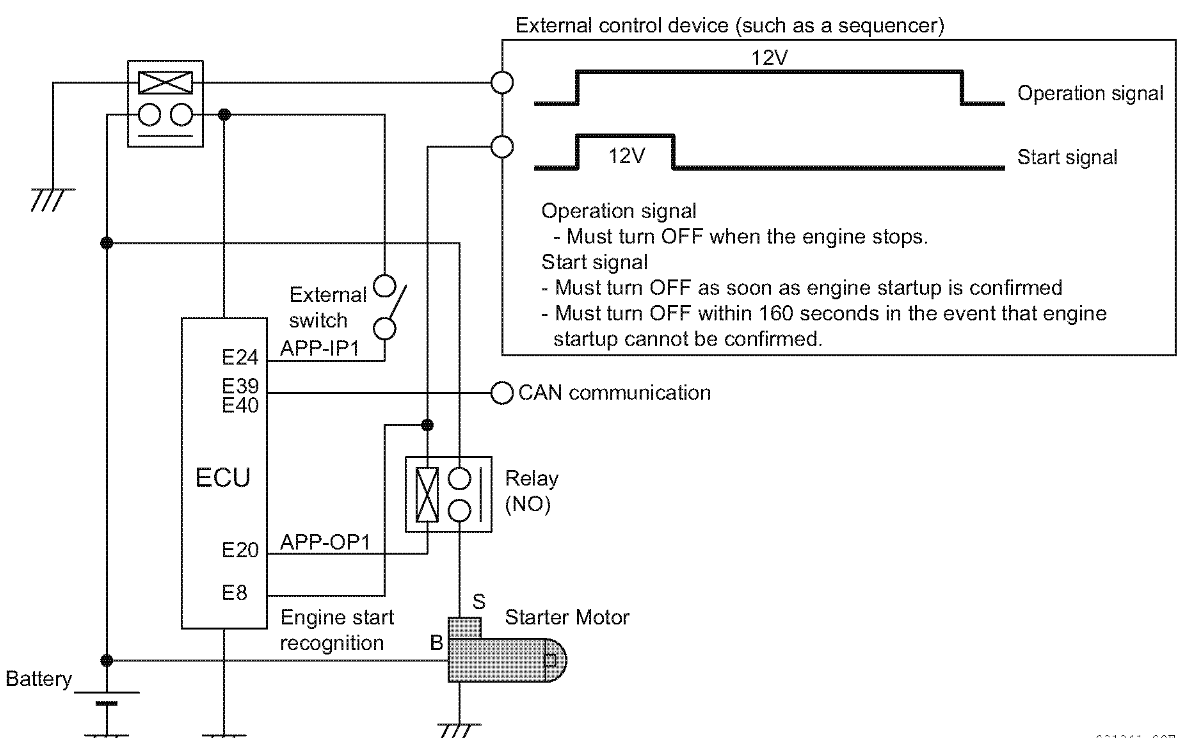


Figure 14-40 **Wiring diagram of a remote (automatic) start/stop system**

The run signal turns ON when the engine starts and turns OFF when the engine stops.

Note: 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.
*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.

Table 14-14 shows the relationships between the external switch status and engine speed for each of constant speed control, deceleration control, and auto deceleration control. The respective control functions will be described in detail later on.

Table 14-14 Control functions for changing the engine speed using an external switch

b) 2-21 Speed Selection function	External switch			Engine speed
	Speed selection permission SW (APP-IP6: E6)	Speed selection 1 SW (APP-IP3: E9)	Speed selection 2 SW (APP-IP4: E17)	
(1) Constant speed control 0 or 1 (standard: 0) 0: toggle type 1: momentary type	Prohibited (OFF)	-	-	Acceleration sensor signal
	Permitted (ON)	OFF	OFF	Constant speed 2: 1500min^{-1} *1
		OFF	ON	Low idle
		ON	OFF	Constant speed 1: 1800min^{-1} *2
		ON	ON	High idle
(2) Deceleration control 2 or 3 (option) 2: toggle type 3: 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 rate1: 85% deceleration*4
		ON	ON	Acceleration sensor signal
(3) Auto deceleration control 5 (option) 5: toggle type	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: 1800min^{-1} *2
		ON	ON	Acceleration sensor signal

*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.

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 (1) constant speed 1 (standard: 1800min^{-1}), (2) constant speed 2 (standard: 1500min^{-1}), (3) low idle speed, or (4) high idle speed by turning ON/OFF the speed selection 1 switch (APP-IP3: E9) and speed selection 2 switch (APP-IP4: E17).
(See **Table 14-14**.)
The values of constant speeds 1 and 2 can be changed (option).

[Application Menu]

b) 2-21 Speed Selection Function Setup ➡ 0: Constant speed control: toggle type (standard)
➡ 1: Constant speed control: momentary type
b) 2-24 Constant Speed 1 [min^{-1}] ➡ Can be changed to any value (standard value is 1800).
b) 2-25 Constant Speed 2 [min^{-1}] ➡ Can be changed to any value (standard value is 1500).
b) 3-13 APP-IP6 Terminal (E6) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-14 APP-IP6 Terminal (E6) Function Input Setup ➡ 1: speed selection permitted

(The following applies when using the lamp while constant speed control is in effect)
b) 3-17 APP-OP2 Terminal (E2) Function Input Setup ➡ 2: Speed change indicator lamp output (lit when speed selection is permitted)

(The following applies when using the low idle or high idle speed)
b) 3-7 APP-IP3 Terminal (E9) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-8 APP-IP3 Terminal (E9) Function Input Setup ➡ 1: Speed selection 1
b) 3-9 APP-IP4 Terminal (E17) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-10 APP-IP4 Terminal (E17) Function Input Setup ➡ 1: Speed selection 2

[Description]

Figure 14-41 and **Figure 14-42** show how to make wiring connections for constant speed control. Do not connect the indicator lamp power supply to the IGNSW (E7) terminal. Doing so could cause the leak current from the APP-IP terminal to enter the IGNSW terminal, possibly resulting in inability to turn OFF the E-ECU power supply.
*You can optionally connect the indicator lamp to the APP-OP2 (E2) terminal, but doing so will make unavailable the cooling water temperature warning and block heater control functions. (See **Table 14-24**.)

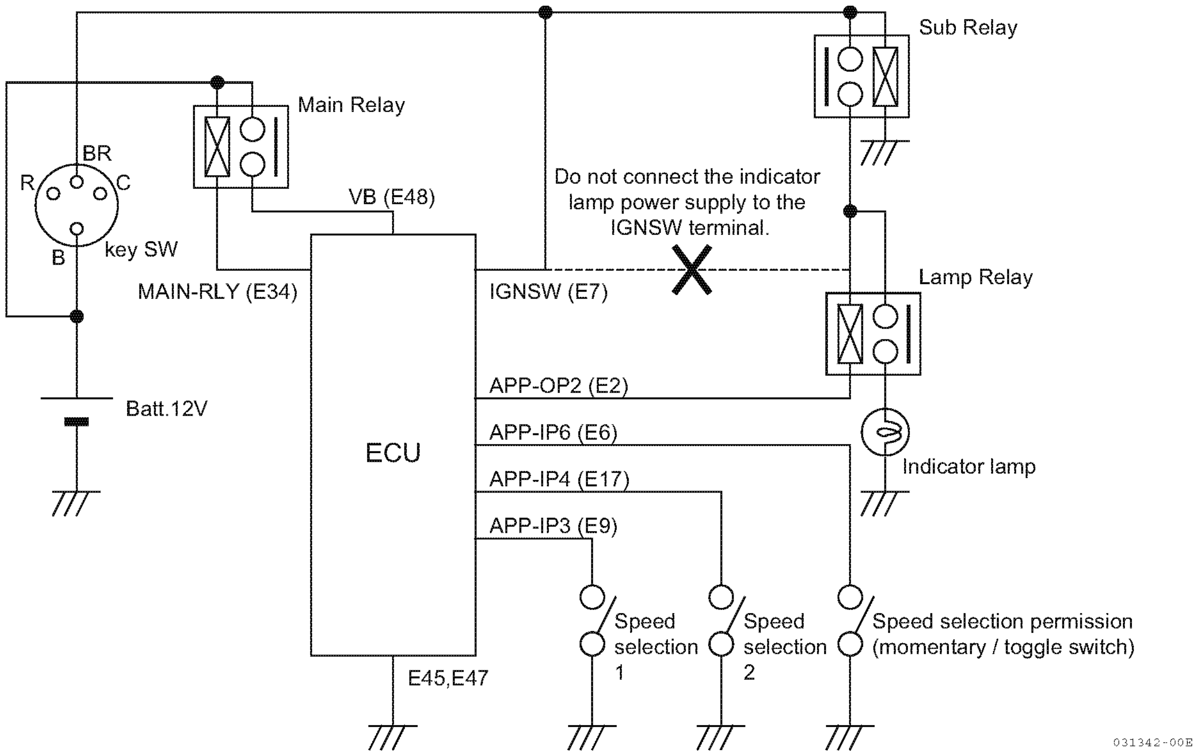


Figure 14-41 **Wiring diagram for constant speed control**

Figure 14-42 provides an operation timing chart for the constant speed control mode. For the speed selection permission switch (APP-IP6: E6), you can choose either toggle or momentary type.

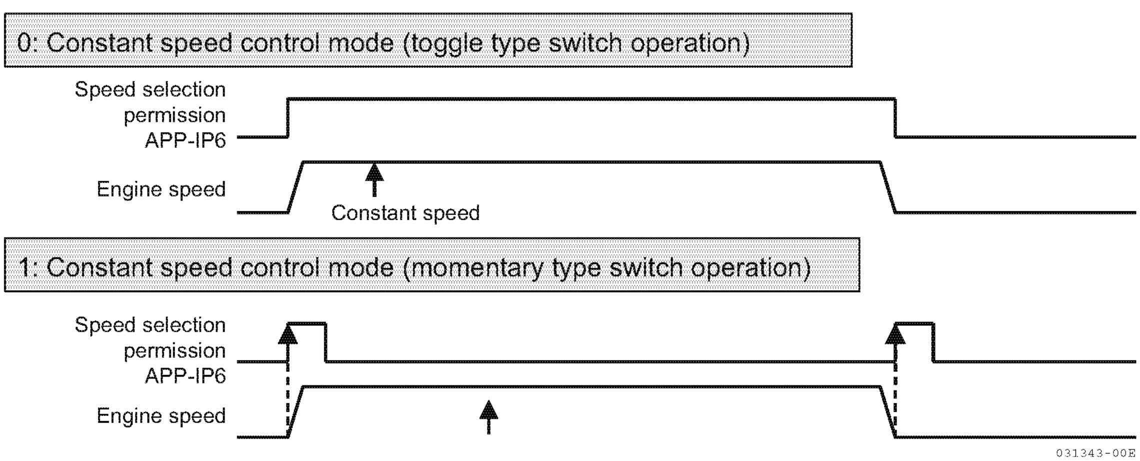


Figure 14-42 **Operation timing chart for the constant speed control mode**

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]

Speed selection using the switch

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: E9). (Speed selection 2 switch (APP-IP4: E17) must be turned off. See **Table 14-14**.)

Changing the settings

You can optionally change the deceleration rate and deceleration start speed (standard: 1500min^{-1}) for each of deceleration rates 1 and 2.

[Application Menu]

b) 2-21 Speed Selection Function Setup ➡ 2: Deceleration control: toggle type
➡ 3: Deceleration control: momentary type
b) 2-26 Deceleration Start Speed [min^{-1}] ➡ Can be changed to any value (standard value is 1500).
b) 2-27 Deceleration Rate 1 [%] ➡ Can be changed to any value (standard value is 85).
b) 2-28 Deceleration Rate 2 [%] ➡ Can be changed to any value (standard value is 70).
b) 3-13 APP-IP6 Terminal (E6) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-14 APP-IP6 Terminal (E6) Function Input Setup ➡ 1: speed selection permitted

(The following applies when using the lamp while deceleration control is in effect)
b) 3-17 APP-OP2 Terminal (E2) Function Input Setup 2 ➡ Speed change indicator lamp output (lit when speed selection is permitted)

(The following applies when switching to the acceleration sensor signal)
b) 3-7 APP-IP3 Terminal (E9) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-8 APP-IP3 Terminal (E9) Function Input Setup ➡ 1: Speed selection 1
b) 3-9 APP-IP4 Terminal (E17) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-10 APP-IP4 Terminal (E17) Function Input Setup ➡ 1: Speed selection 2

[Description]

Figure 14-43 shows how to make wiring connections for deceleration control. Similarly to constant speed control, do not connect the indicator lamp power supply to the IGNSW (E7) terminal. Doing so could cause the leak current from the APP-IP terminal to enter the IGNSW terminal, possibly resulting in inability to turn OFF the E-ECU power supply.
Similarly to constant speed control, you can optionally connect the indicator lamp to the APP-OP2 (E2) terminal, but doing so will make unavailable the cooling water temperature warning and block heater control functions. (See **Table 14-24**.)

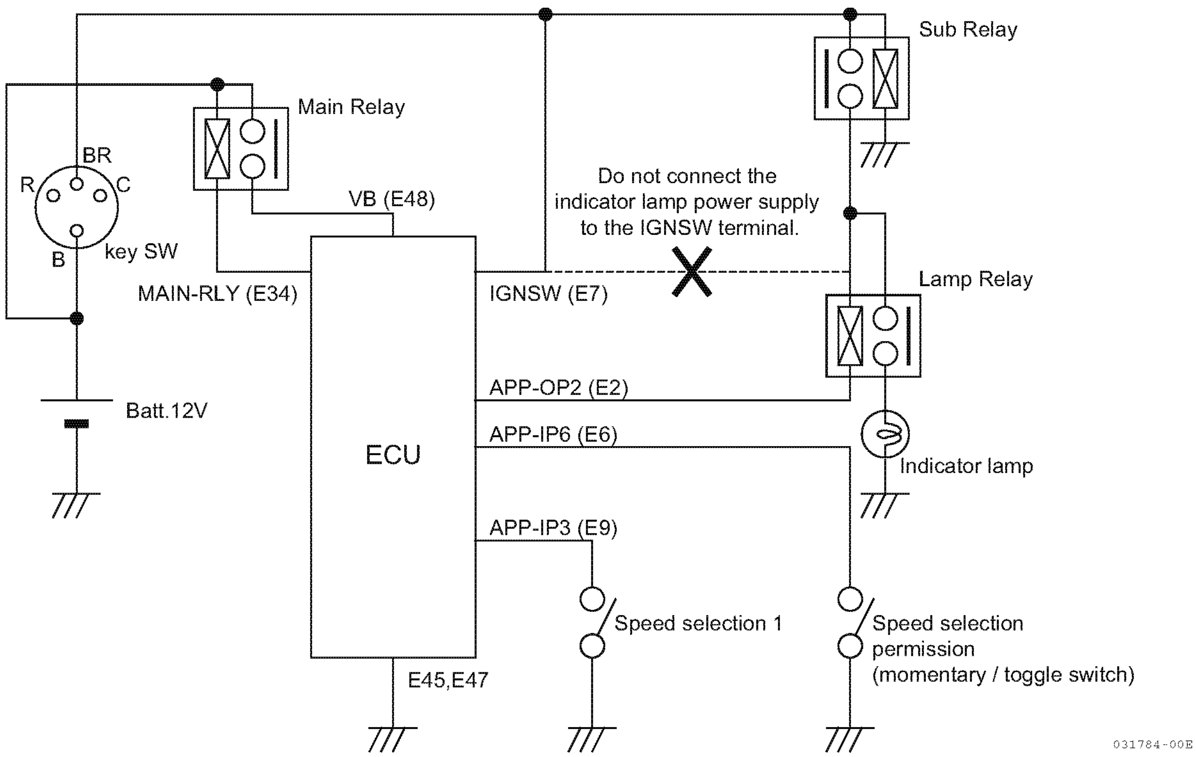


Figure 14-43 **Wiring diagram for deceleration control**

Figure 14-44 provides an operation timing chart for the deceleration control mode. For the speed selection permission switch (E6), you can choose either toggle or momentary type.

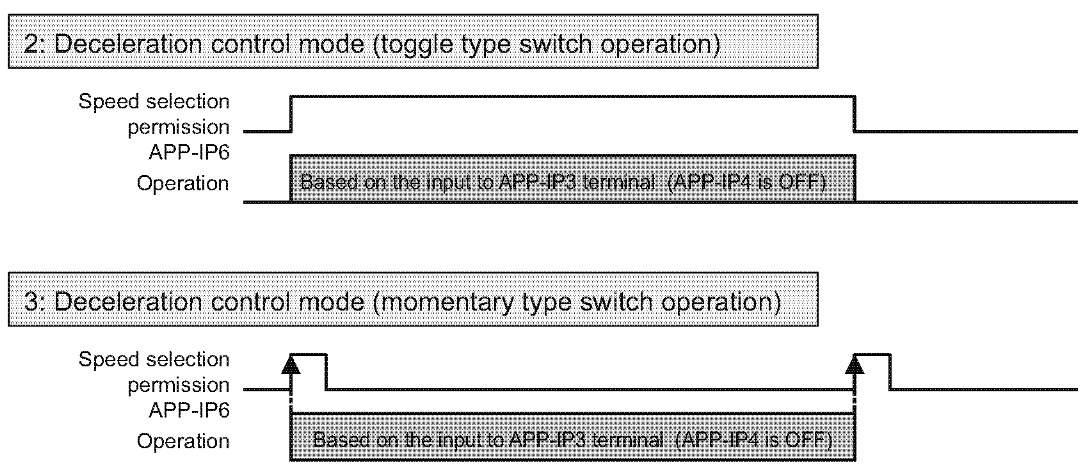


Figure 14-44 **Operation timing chart for the deceleration control mode**

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 14-45**, 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 (see **Table 14-14**) 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-OP2) does not turn ON even when deceleration control is in effect.

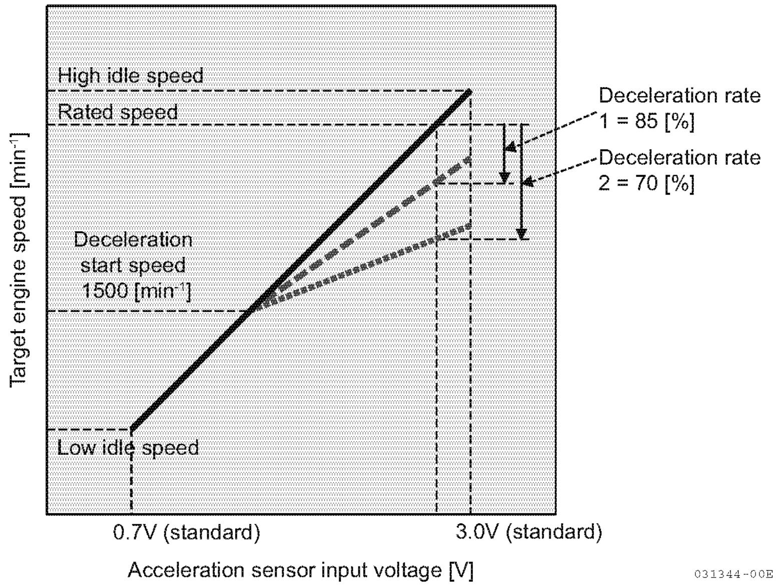


Figure 14-45 **Behavior of deceleration control**

Auto deceleration control

[Function]

To minimize fuel consumption, the system reduces the engine speed to a specific low speed.

[Application Menu]

b) 2-21 Speed Selection Function Setup ➡ 5: Auto deceleration control: toggle type
b) 2-22 Auto deceleration wait time [s] ➡ Can be changed to any value (standard value is 4).
b) 2-23 Auto deceleration accelerator disconnection ➡ 0: disabled (standard), 1: enabled.
b) 3-13 APP-IP6 Terminal (E6) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-14 APP-IP6 Terminal (E6) Function Input Setup ➡ 1: speed selection permitted

(The following applies when using the lamp while auto deceleration control is in effect)
b) 3-17 APP-OP2 Terminal (E2) Function Input Setup ➡ 2: Speed change indicator lamp output (lit when speed selection is permitted)

(The following applies when using constant speed 1)
b) 2-24 Constant Speed 1 [min^{-1}] ➡ Can be changed to any value (standard value is 1800).
b) 3-7 APP-IP3 Terminal (E9) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-8 APP-IP3 Terminal (E9) Function Input Setup ➡ 1: Speed selection 1

(The following applies when using the hydraulic oil pressure switch: switching to the speed corresponding to the acceleration sensor signal)
b) 3-9 APP-IP4 Terminal (E17) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-10 APP-IP4 Terminal (E17) Function Input Setup ➡ 1: Speed selection 2

[Description]

Figure 14-46 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. (Auto deceleration)

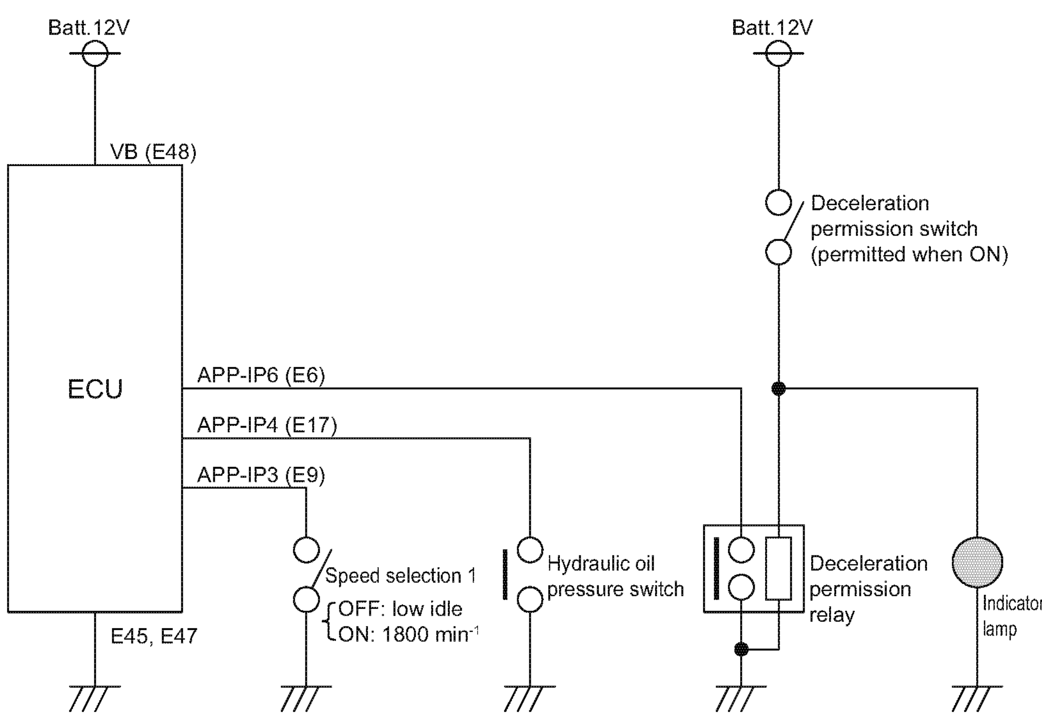


Figure 14-46 **Wiring diagram for auto deceleration (example: toggle type)**

Figure 14-47 provides an operation timing chart for the auto deceleration control mode.

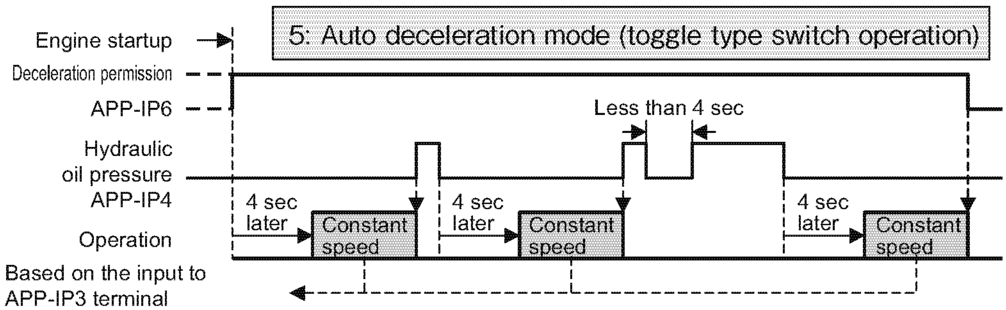


Figure 14-47 **Operation timing chart for the auto deceleration control mode**

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 (1800min^{-1} standard) or (2) low idle speed using the speed selection 1 switch (APP-IP3). (See **Table 14-14**.)

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 14-48**, 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)

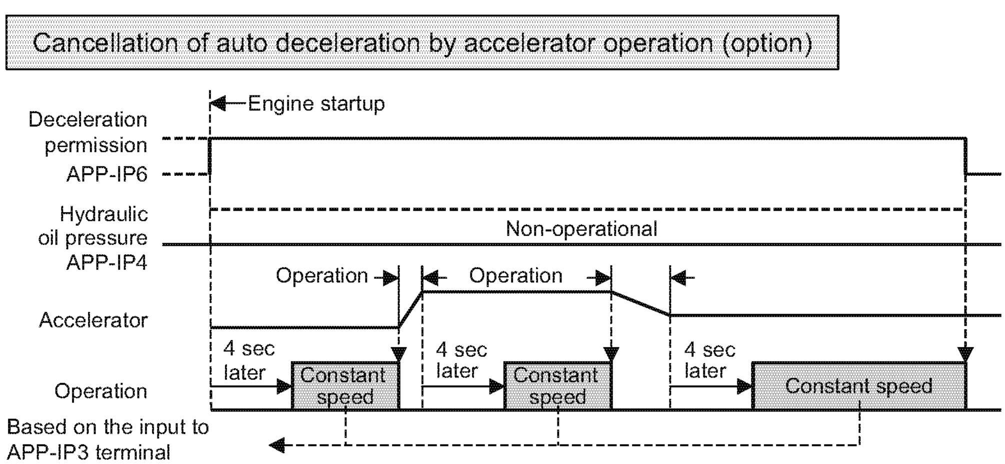


Figure 14-48 **Cancellation of auto deceleration by accelerator operation**

High idle speed limit function

[Function]

You can temporarily lower the high idle speed using an external switch input.
By connecting the high idle limit switch to the APP-IP5 (E5) terminal, you can limit the maximum target speed determined by acceleration sensor operations. Also, by connecting the high idle selection switch to the APP-IP7 (E13) 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 14-15

High idle limit switch APP-IP5 (E5)	High idle selection switch APP-IP7 (E13)	Speed Limit (standard setting)	
		Droop [min^{-1}]	Iso-chronous [min^{-1}]
OFF	-	Acceleration sensor signal	
ON	OFF: limit 1	1900	1900
	ON: limit 2	1700	1700

[Application Menu]

Configuring the terminal functions

b) 3-11 APP-IP5 Terminal (E5) Function Logic Setup ➡ 0: NO (standard) or 1: NC
b) 3-12 APP-IP5 Terminal (E5) Function Input Setup ➡ 4: High idle limit
b) 3-3 APP-IP7Terminal (E13) Function Logic Setup ➡ 0: NO (standard) or 1: NC
b) 3-4 APP-IP7 Terminal (E13) Function Input Setup ➡ 3: High idle selection

Configuring high idle limit 1

b) 2-34 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

a) 10-1 Droop Limit 1 [min^{-1}] ➡ Can be changed to any value (standard value is 1900).
a) 10-2 Iso-chronous Limit 1 [min^{-1}] ➡ Can be changed to any value (standard value is 1900).

Configuring high idle limit 2

b) 2-35 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

a) 10-3 Droop Limit 1 [min^{-1}] ➡ Can be changed to any value (standard value is).
a) 10-4 Iso-chronous Limit 1 [min^{-1}] ➡ Can be changed to any value (standard value is 1700).

[Description]

Figure 14-49 shows how to make wiring connections for high idle speed limit control.
The switches you connect to APP-IP5 and APP-IP7 may be either NO (Normally Open) or NC (Normally Closed). **Table 14-15** 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.

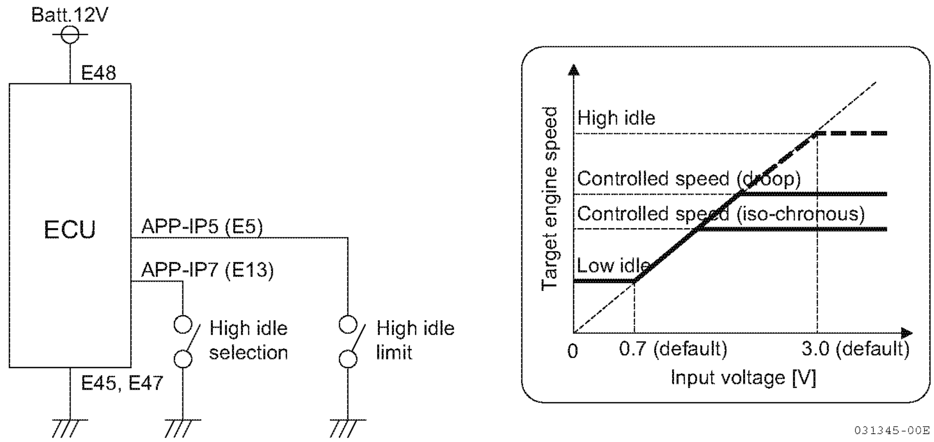


Figure 14-49 **High idle speed limit function**

Engine stop function

You can stop the engine in a number of ways as described in this section (including the key switch, SHUDN-SW [shutdown switch], APP-IP7, and so on).
When the engine stops but the power is not turned off, you can use YDT to identify the reason for engine stop. (See **Table 14-35**.)
*If the engine stops due to some other reason than an overload or out-of-fuel condition, you can use these functions to identify the reason.

[Application Menu]

b) 3-15 SHUDN-SW (E15) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-3 APP-IP7 Terminal (E13) Function Logic Setup ➡ 0: NO switch or 1: NC switch
b) 3-4 APP-IP7 Terminal (E13) Function Input Setup ➡ 2: engine stop 2 (standard)
b) 4-1 Cooling Temperature Water High Alarm Handling ➡ 6: engine stop (standard differs depending on the model)
➡ 7: time-delayed engine stop
b) 4-8 Oil Pressure Low Fault Handling ➡ 6: engine stop (standard differs depending on the model)
➡ 7: time-delayed engine stop
b) 4-10 Air Cleaner Clog Handling ➡ 6: engine stop (standard differs depending on the model)
➡ 7: time-delayed engine stop
b) 4-11 Diesel Fuel Filter/Water Separator Alarm Handling ➡ 6: engine stop (standard differs depending on the model)
➡ 7: time-delayed engine stop
b) 4-12 Backup Speed Sensor Running ➡ 6: engine stop (standard differs depending on the model)
➡ 7: time-delayed engine stop
a) 13-4 Engine Stop Delay Time [s] ➡ Can be changed to any value (standard value is 30).
(The system stops the engine when the Engine Stop Delay Time elapses after the ECU has detected a fault.)
a) 10-4 Iso-chronous Limit 2 [min^{-1}] ➡ Can be changed to any value (standard value is 1700).

[Using the key switch to stop the engine]

You can stop the engine by setting the key switch to the OFF position to cut off the power to the E-ECU and rack actuator. (In this case, you do not have to use the stop solenoid.)

[Using the SHUDN-SW terminal to stop the engine]

When the SHUDN-SW (E15) terminal is connected with the engine stop switch (hereinafter referred to as the "stop switch"), you can stop the engine by turning ON the stop switch. For how to connect the stop switch, see **Figure 14-50**. The normally open configuration is used as standard, which means that you can run the engine without the switch connected. Alternatively, you can configure the stop switch as normally closed.

Notes on restarting the engine

Once you have turned ON the stop switch, you must turn OFF the key switch before you can restart the engine. Also note that the starter motor does not work as long as the stop switch is ON.
For the effect of engine stop using the SHUDNSW terminal, see **Table 14-16**.

Advantages of normally closed configuration

When it is configured as normally closed, the engine is stopped and protected against a harness disconnection or short-circuit, as shown in **Figure 14-51**. The normally closed configuration allows you to use the SHUDN-SW terminal as a connection port for an immobilizer key or the like.

Note: **Precautions to take before using the normally closed configuration**
Carefully note that, once you have configured the engine stop switch as normally closed, the engine cannot run when the switch circuit is not connected.

[Using the APP-IP7 terminal to stop the engine]

When the APP-IP7 (E13) terminal is connected with the engine stop 2 switch (hereinafter referred to as the "stop 2 switch"), you can stop the engine by turning ON the stop 2 switch. For how to connect the stop 2 switch, see **Figure 14-50**. The normally open configuration is used as standard, which means that you can run the engine without the switch connected. Alternatively, you can configure the stop 2 switch as normally closed.

Notes on restarting the engine

Once you have turned ON the stop switch, you must turn OFF the key switch before you can restart the engine. Also note that the starter motor does not work as long as the stop switch is ON.

Advantages

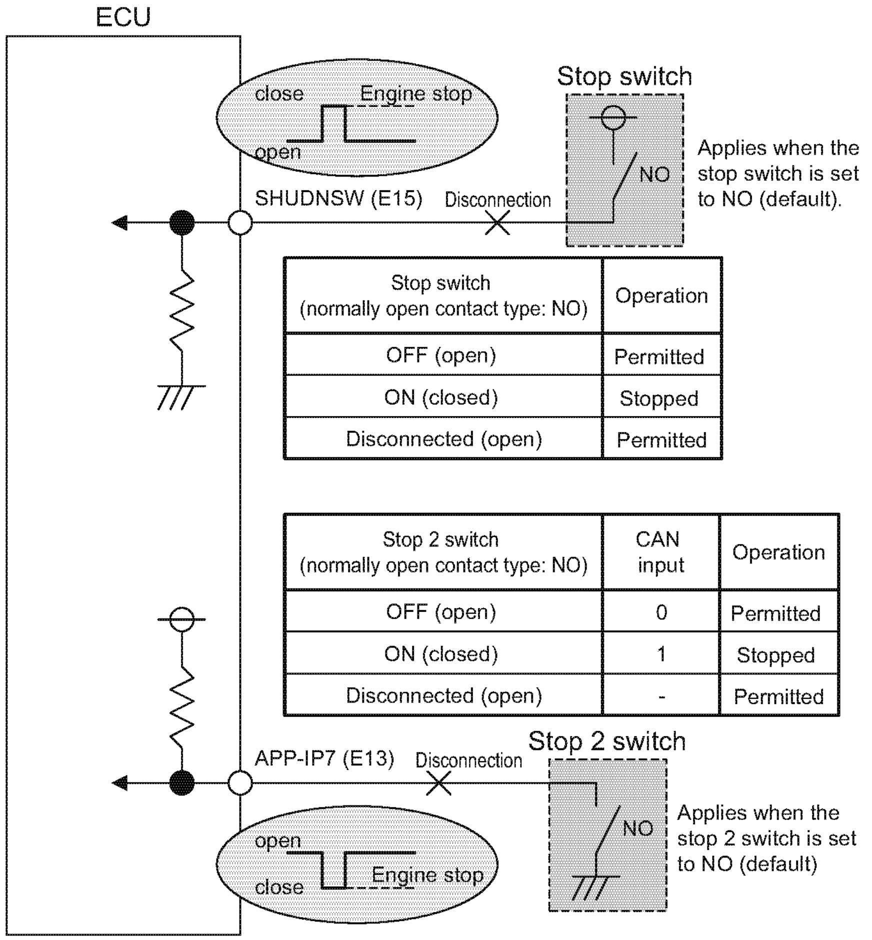
This function can be utilized for a safety function that stops the engine, for example, when the driven machine's cover is opened. You can also input signals via the CAN communication instead of the APP-IP7 terminal.
For the effect of engine stop using the APP-IP7 terminal, see **Table 14-16**.

[Fault detected by the E-ECU]

The engine may stop due to a fault detected by the E-ECU. For more information, see the description of the fault detection function.

Table 14-16 Comparison of the engine stop functions

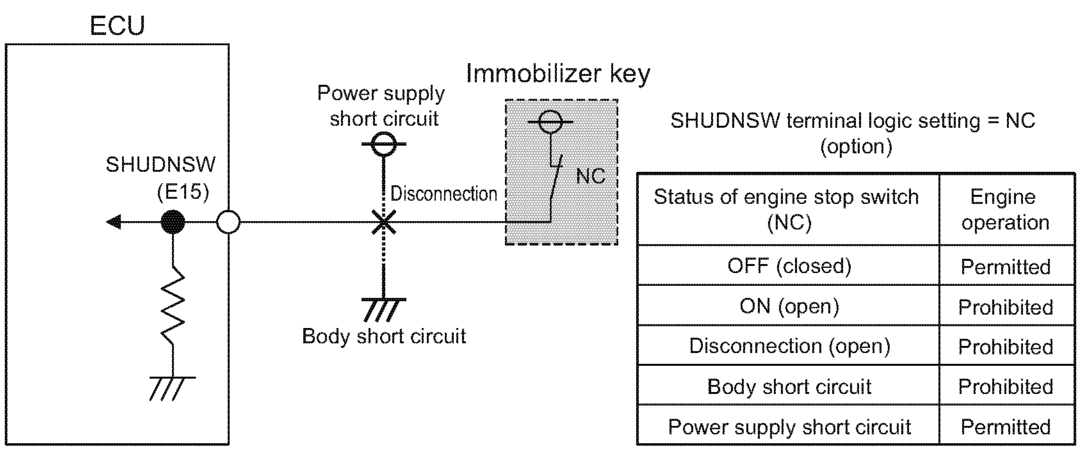
Terminal	Switch		CAN input stop	Behavior during engine stop			
	Circuit	Momentary		Rack actuator relay	Rack	Starter Motor	Reset when:
SHUDNSW	High side	OK	NG	OFF	Stopped	Restrained	Key is turned OFF
APP-IP7	Low side	OK	OK	OFF	Stopped	Restrained	Key is turned OFF



Stop switch (normally open contact type: NO)	Operation
OFF (open)	Permitted
ON (closed)	Stopped
Disconnected (open)	Permitted

Stop 2 switch (normally open contact type: NO)	CAN input	Operation
OFF (open)	0	Permitted
ON (closed)	1	Stopped
Disconnected (open)	-	Permitted

Figure 14-50 **An example of stopping the engine using an external switch**



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

Figure 14-51 **An example of connecting an immobilizer**

Emergency stop function

You can stop the engine by inserting the emergency stop switch at the point marked as *2 or *3 in **Figure 14-4**.

Table 14-17 Comparison of the emergency stop functions

Switch insertion location	Advantages	Disadvantages
Point *2 in **Figure 14-4** (recommended) Upstream of the key switch	• No entries are written to the fault history of the E-ECU. • The engine can be stopped even if the rack actuator relay contact is stuck. (The E-ECU cuts off the rack actuator output.)	• The engine cannot be stopped without relying on the E-ECU. (If the rack actuator relay contact is stuck.)
Point *3 in **Figure 14-4** Upstream of the rack actuator relay	• The engine can be stopped without relying on the rack actuator relay. • The engine can be stopped without relying on the E-ECU.	• Entries are written to the fault history of the E-ECU. (Rack actuator fault) • The total cable length of the rack actuator must not exceed 10m.

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 (see **Figure 14-52**).
*Recommended only for models that use a low idle speed of 1000min^{-1} or lower.

[Application Menu settings]

b) 2-32 Idle Up Function ➡ 1: enabled, 0: disabled (standard differs depending on the model)
For an engine that normally uses a low idle speed of 800min^{-1}, set the minimum speed to 1000min^{-1} or higher in order to make more stable the engine speed at cooling water temperatures of 10°C or lower (see **Figure 14-53**).
The speed increases in addition to the speed increase that occurs during CSD operation as described earlier, as given by the following formula:
Minimum speed = low idle speed + idle up speed increase + speed increase during CSD operation

Example: When cooling water temperature is 10°C, the target speed of a NV3 engine that normally uses a low idle speed of 800min^{-1} will be 1075min^{-1} (800 + 200 + 75).

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 1000min^{-1}.
As described above, using the idle up function causes the engine speed to rise by 275min^{-1} (standard) for an NV3 engine or by 250min^{-1} (standard) for an NV2 engine, at cooling water temperatures of 10°C or lower.

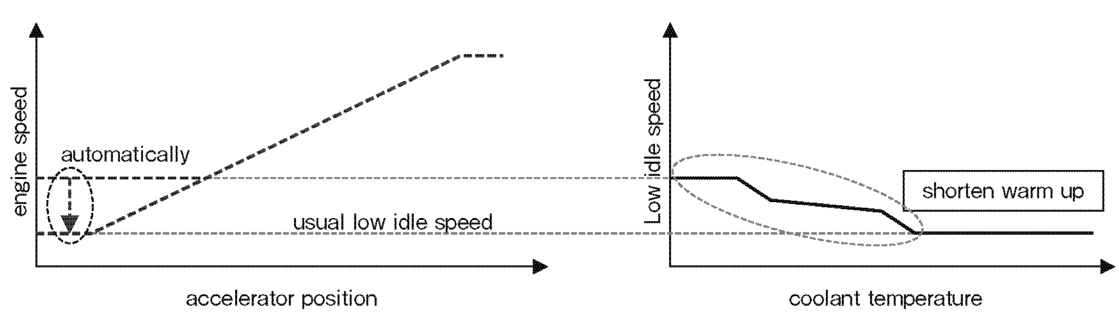


Figure 14-52 **Low idle speed control at low temperatures**

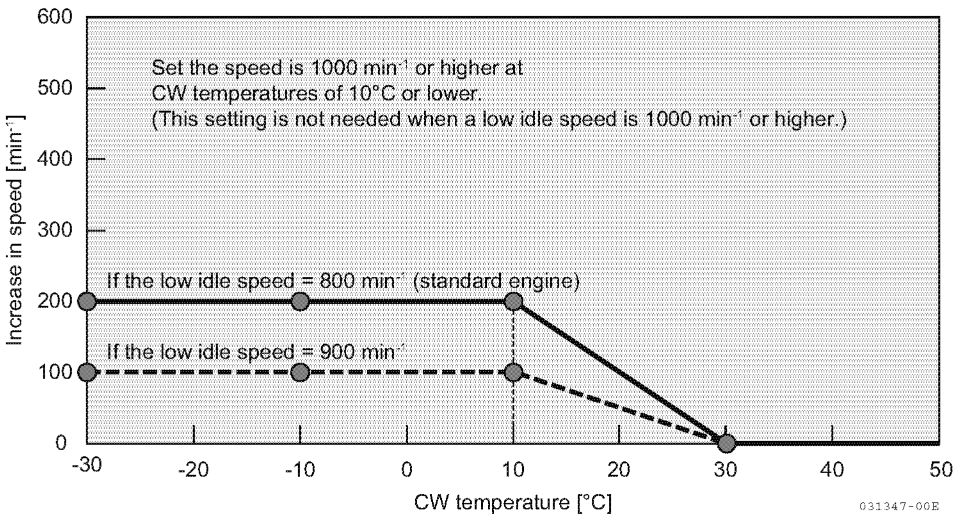


Figure 14-53 **Standard settings for the idle up function (low idle speed = 800min^{-1})**

You can shorten the warm-up time at low temperatures by optionally configuring the function as shown in **Figure 14-54**. You can change how much the idle up function increases the low idle speed this way. (option)

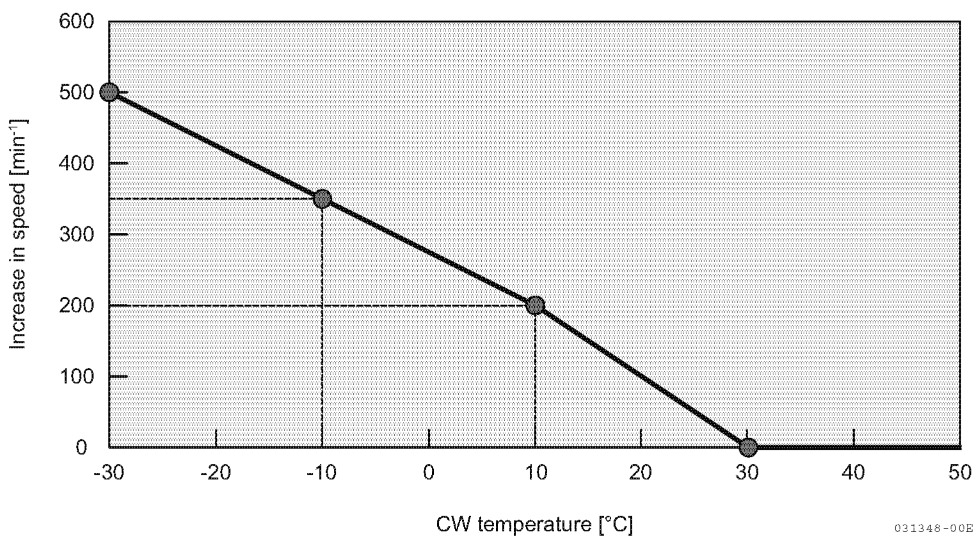


Figure 14-54 **Low idle speed increased by the idle up function**

Blue/white smoke suppression control (low-temperature high idle down 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 (see **Figure 14-55**).

[Application Menu settings]

b) 2-33 Blue/White Smoke Suppression Control ➡ 1: enabled or 0: disabled (standard)
For an engine with a rated speed of 2300min^{-1} or higher, you can shorten the time required for the blue/white smoke goes out at cooling water temperatures of 30°C or lower by reducing the high idle speed by approximately 150min^{-1}.
*The blue/white smoke suppression control function is disabled as standard.

Cancellation conditions

This control is cancelled when, at cooling water temperatures of 30°C or higher, the engine speed is reduced to or lower the blue/white smoke suppression speed by operating the accelerator. If the control is cancelled at a speed higher than the blue/white smoke suppression speed, the engine speed will not automatically increase.

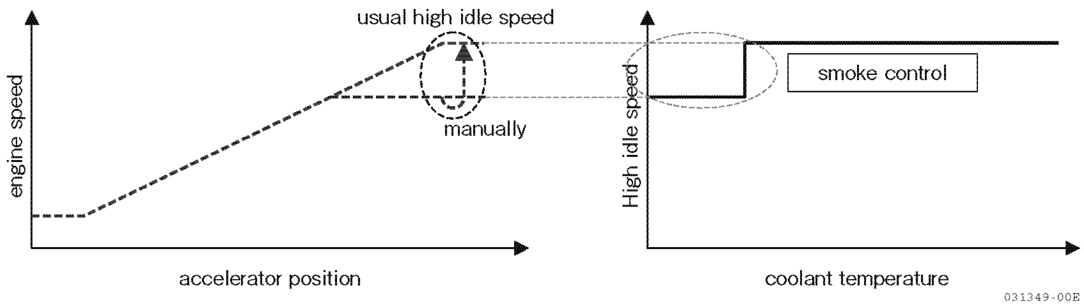


Figure 14-55 **High idle speed control at low temperatures**

Accelerator 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 14-56 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.
  - ➡ ×: The response during acceleration/deceleration is sacrificed.
- When the change of the target engine speed is advanced:
  - ➡ ×: Overshooting/undershooting of the engine speed may occur.
  - ➡ O: The response during acceleration/deceleration is improved.

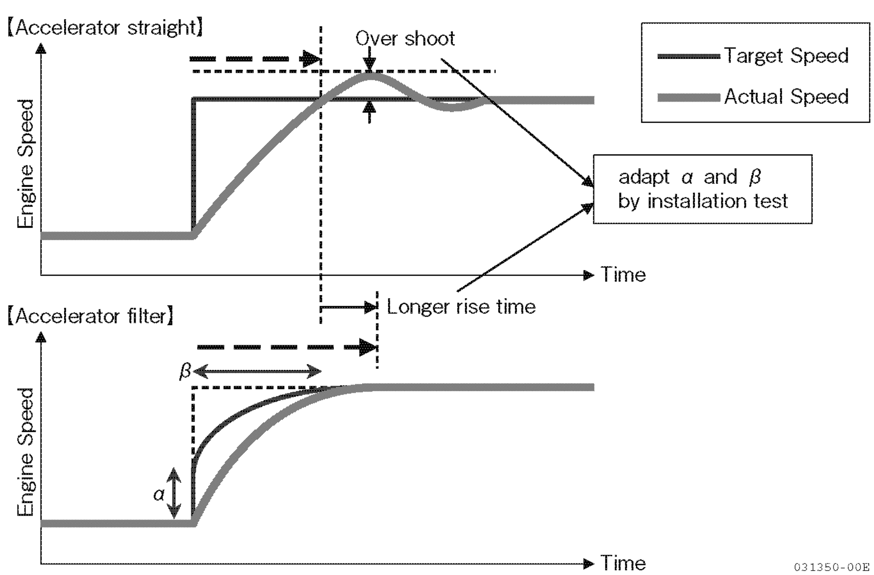


Figure 14-56 **Behavior of the accelerator filter**

Block heater control

[Function]

You can improve engine startability at low temperatures by connecting an external relay to the block heater. In addition, the relay can be controlled to turn ON/OFF depending on the cooling water temperature.

[Application Menu settings]

b) 3-17 APP-OP2 Terminal (E2) Function Setup ➡ 1: block heater relay output
(standard setting) ➡ 3: cooling water temperature alarm lamp output

Control behavior: When the power to the E-ECU is turned ON, an external block heater relay (customer-provided) is used to control the block heater to turn ON/OFF depending on the cooling water temperature.

Cooling water temperature of 15°C or lower ➡ Relay ON
Cooling water temperature of 50 °C or higher ➡ Relay OFF

Notes on setting: The block heater control function cannot be used at the same time as the cooling water temperature alarm display or speed change indicator lamp is used. (See **Table 14-24**.)

Figure 14-57 provides an example of circuit connections.

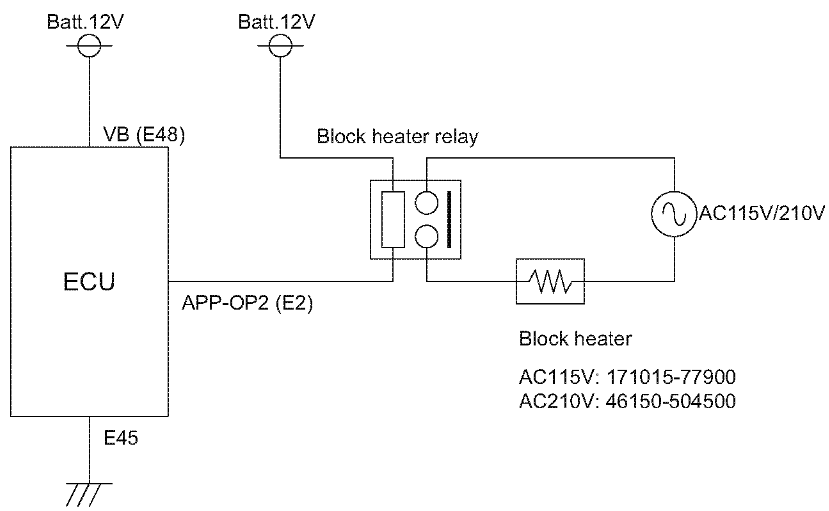


Figure 14-57 **Wiring diagram for block heater control**

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 14-58**, 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.

[Application Menu settings]

b) 2-43 Cooling Water Temperature High Alarm Setup ➡ 1: enabled (standard) or 0: disabled
b) 3-17 APP-OP2 Terminal (E2) Function Setup ➡ 3: cooling water temperature alarm lamp output (standard)
b) 4-1 Cooling Water Temperature High Alarm Handling ➡ 0: No restriction on operation (standard differs depending on the model)

b) 3-5 APP-IP2 Terminal (E14) Logic Setup ➡ 0: NO switch (standard) or 1: NC switch
b) 3-6 APP-IP2 Terminal (E14) Function Input Setup ➡ 2: oil pressure switch (standard: 1 - backup)
b) 4-8 Oil Pressure Low Fault Handling ➡ 0: No restriction on operation (standard differs depending on the model)

b) 3-11 APP-IP5 Terminal (E5) Logic Setup ➡ 0: NO switch (standard) or 1: NC switch
b) 3-12 APP-IP5 Terminal (E5) Function Input Setup ➡ 2: air cleaner sensor (standard: 1 - backup)
b) 4-10 Air Cleaner Clog Handling ➡ 0: No restriction on operation (standard)

b) 3-13 APP-IP6 Terminal (E6) Logic Setup ➡ 0: NO switch (standard) or 1: NC switch
b) 3-14 APP-IP6 Terminal (E6) Function Input Setup ➡ 2: diesel fuel filter/water separator (standard: 1 - speed selection permitted)
b) 4-11 Diesel Fuel Filter/Water Separator Alarm Handling ➡ 0: No restriction on operation (standard differs depending on the model)

b) 4-13 Error Occurrence Time Selection ➡ 0: total engine operating hours or 1: total ECU energized hours
➡ 2: CAN communication receiving hours
b) 3-7 APP-IP3 Terminal (E9) Logic Setup ➡ 0: NO switch (standard) or NC switch
b) 3-8 APP-IP3 Terminal (E9) Function Input Setup ➡ 2: charge alarm (standard: 1 - speed selection 1)

Terminal setup

Before the E-ECU can accept the respective sensor signals, you have to change the settings for the following terminals of the E-ECU: APP-IP2, APP-IP3, APP-IP5, and APP-IP6. These are optional settings and certain applications may become unavailable when sensor connections are enabled. For more information, see **Table 14-24**.

Lamp display

As shown in **Figure 14-58**, you can connect an indicator lamp to each engine fault detection sensor. In this case, avoid connecting the indicator lamp power supply to the IGNSW (E7) terminal, as instructed in **Figure 14-58**. Doing so could cause the leak current from the APP-IP terminal to enter the IGNSW terminal, possibly resulting in inability to turn OFF the E-ECU power supply.

Note: **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.

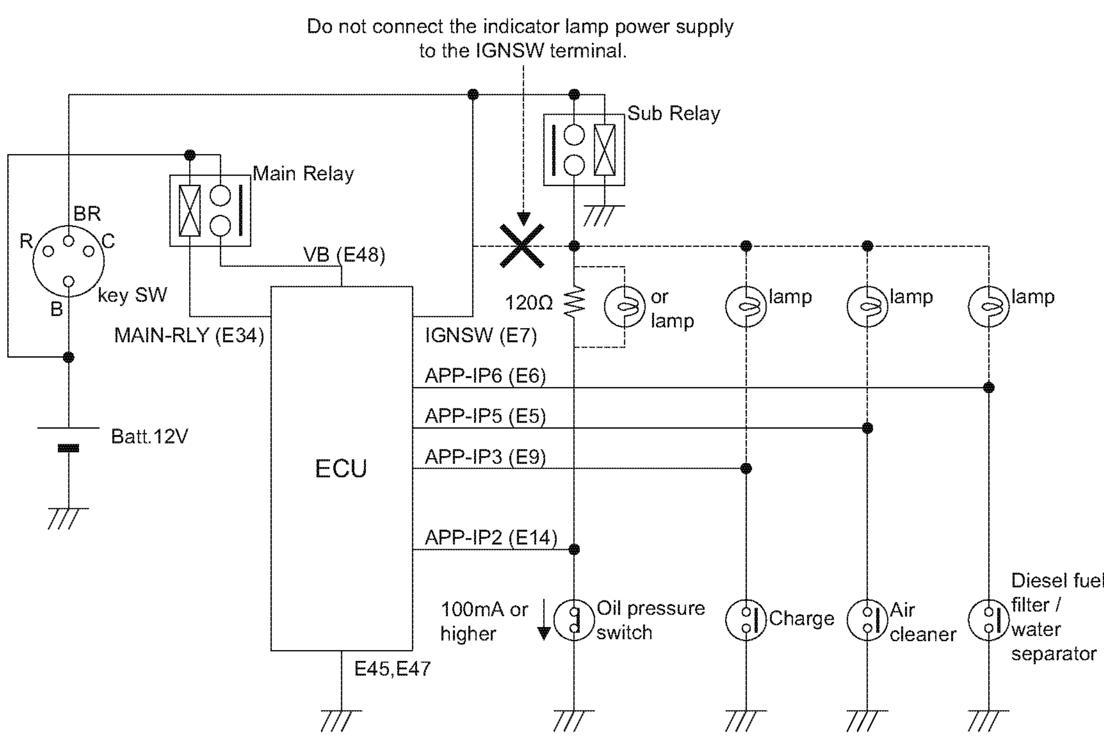


Figure 14-58 **Connecting engine fault detection sensors**

Fault detection function of the E-ECU

Definition of terms used in the table: **Table 14-18** provides a list of various error items covered by self diagnosis performed by E-ECU.

The setting column of the table uses the terms "Standard", "Default", and "Optional" in the following meanings:

Standard : Fault detection is permanently enabled for this item and cannot be disabled.
Default : Fault detection is by default enabled for this item but can be disabled.
Optional : Fault detection is by default disabled for this item but can be enabled.

Table 14-18 Fault detection list

No	Error item	Detection condition	Fault handling actions	Reset condition	Setting	Number of lamp flashes
1	Cooling Water Temperature Sensor Fault	Detected when the sensor voltage rises to or above 4.8V or drops to or lower 0.2V.	• The engine continues to run on condition that the cooling water temperature is 30°C (with the EGR valves disabled). • The engine operation is subject to the same restrictions as for EGR Valve Fault.	key: OFF	Standard	4
2	Acceleration sensor Fault	Detected when the sensor voltage rises to or above 4.6V or drops to or lower 0.2V.	[Engines not equipped with a backup acceleration sensor: standard] • The engine continues to run at the same speed as immediately before the fault (standard). • The engine runs at 1500min^{-1} * [Engines equipped with a backup acceleration sensor: option] The system fails over to the backup acceleration sensor: no restrictions. Backup Acceleration sensor Fault: • The engine continues to run at the same speed as immediately before the fault (standard). • The engine runs at 1500min^{-1} *	Reset upon restoration of normal condition.	Default	5
3	Speed Sensor Fault	Detected when the Engine Start Recognition (E8) signal is ON and the system cannot detect the engine speed. Detected when the engine speed instantaneously drops by specified amount or more.	[Engines not equipped with a backup speed sensor: standard] The engine stops. [Engines equipped with a backup speed sensor: option] • The system fails over to the backup speed sensor (with the speed limited to 1800min^{-1} * • Backup Speed Sensor Fault: The engine stops.	key: OFF	Standard	6

Table 14-18 Fault detection list

No	Error item	Detection condition	Fault handling actions	Reset condition	Setting	Number of lamp flashes
4	Rack Position Sensor Fault	Detected when the rack position sensor voltage exceeds the upper limit during rack self diagnosis.	The engine continues to run at restricted output and speed (i.e., the engine runs under speed control, but rack control is not performed).	key: OFF	Standard	7
		Detected when the relationship between the rack position and rack actuator output exceeds the upper limit.				
		Detected when the relationship between the rack position and rack actuator output falls below the lower limit.				
5	Rack Actuator Fault	Detected when a specific rack operation fails during rack self diagnosis.	The engine stops.	key: OFF	Standard	8
		When the rack actuator output exceeds the upper limit.				
		When the rack actuator output falls below the lower limit.				
		Detected when the engine speed rapidly increases despite the minimum rack actuator output.				
5	Rack Actuator Fault	Detected when the engine stalls during run after the detection of Rack Position Sensor Fault.	The engine stops.	key: OFF	Standard	8
6	Overspeed Fault	Detected when the engine speed rises to or above the high idle speed plus 600min^{-1}.	The engine is stopped by an independent circuit.	key: OFF	Standard	9
7	Backup Speed Sensor Fault	Detected when the Engine Start Recognition (E8) signal is ON and the system cannot detect the engine speed.	• The engine continues to run using the main speed sensor. • Main Speed Sensor Fault: The engine stops.	key: OFF	Optional	1-1 (○ - △) ○ ➡ 1.5s △ ➡ 0.5s
		Detected when the engine speed instantaneously drops by specified amount or more.				

Table 14-18 Fault detection list

No	Error item	Detection condition	Fault handling actions	Reset condition	Setting	Number of lamp flashes
8	CAN Communication Fault	Detected when the system cannot receive CAN communication packets.	• The system retains the same values as immediately before the fault. • The system fails over to the backup sensor. • This fault is not indicated when the power supply voltage is 10.5V or lower or while the engine is being started up.	Reset upon restoration of normal condition.	Optional	1-2
9	EGR Valve Fault (For 37kW or higher engines only)	Detected when the port is turned OFF but Low state is detected. Detected when the port is turned ON but High state is detected.	The engine continues to run with the output and speed limited to 92% and 1800min^{-1}, respectively.	key: OFF	Standard	1-3
10	CSD Solenoid operated Valve Fault	Detected when the port is turned OFF but High state is detected. Detected when the port is turned ON but Low state is detected.	The engine continues to run with the CSD turned OFF.	key: OFF	Standard	1-4
11	Starting Aid Relay Fault	Detected when the port is turned OFF but High state is detected. Detected when the port is turned ON but Low state is detected.	The engine continues to run with the starting aid relay turned OFF.	key: OFF	Optional	1-5
12	Main Relay Fault	Detected when the power to the ECU fails to turn OFF when the main relay is turned OFF.	The engine runs as normal.	Held until restoration of normal condition.	Default	1-6
13	Rack Actuator Relay Fault	Detected when the port is turned OFF but Low state is detected. Detected when the port is turned ON but High state is detected.	The engine stops.	key: OFF	Standard	1-7
14	Backup Acceleration sensor Fault	Detected when the sensor voltage rises to or above 4.6V or drops to or lower 0.2V.	The engine continues to run using the main acceleration sensor. Main Acceleration sensor Fault: • The engine continues to run at the same speed as immediately before the fault (standard). • The engine runs at 1500min^{-1} *	Reset upon restoration of normal condition.	Optional	1-8
15	Reserved	-	-	-	-	1-9
16	Oil Pressure Switch Fault	Detected when the oil pressure switch fails to turn ON during engine stop.	The engine runs as normal*.	key: OFF	Optional	2-1
17	Charge Switch Fault	Detected when the charge switch fails to turn ON during engine stop.	The engine runs as normal.	key: OFF	Optional	2-2

Table 14-18 Fault detection list

No	Error item	Detection condition	Fault handling actions	Reset condition	Setting	Number of lamp flashes
18	Power Supply Voltage Fault	Detected when the ECU power supply voltage is 10.0V or lower.	The engine runs as normal.	Reset upon restoration of normal condition.	Standard	2-3
		Detected when the ECU power supply voltage is 16.0V or higher.				
19	Sensor 5V Fault	Detected when the monitoring voltage is approx. 0V.	The engine runs as normal.	key: OFF	Standard	2-4
		Detected when the monitoring voltage is 4.5V or lower.				
		Detected when the monitoring voltage is 5.5V or higher.				
20	ECU Temperature High Alarm	Detected when the ECU temperature is 105°C* or higher. Reset when the ECU temperature is 100°C* or lower. (Can be changed optionally)	The engine runs as normal*.	Reset upon restoration of normal condition.	Optional	2-5
21	Oil Pressure Low Fault	Detected when the oil pressure switch fails to turn OFF during engine run.	The engine runs as normal*.	Reset upon restoration of normal condition.	Optional	3-1
22	Charge Alarm	Detected when the charge switch fails to turn OFF during engine run.	The engine runs as normal.	key: OFF	Optional	3-2
23	Reserved	-	-	-	-	3-3
24	Air Cleaner Clog Alarm	Detected when the air cleaner switch is turned ON.	The engine runs as normal*.	key: OFF	Optional	3-4
25	Diesel Fuel Filter/ Water Separator Alarm	Detected when the diesel fuel filter/water separator switch is turned ON.	The engine runs as normal*.	key: OFF	Optional	3-5
26	Cooling Water Temperature High Alarm	Detected when the cooling water temperature remains 110°C* or higher for 60 seconds. Reset when the cooling water temperature is 105°C* or lower.	The engine runs as normal*.	Reset upon restoration of normal condition.	Default	3-6
27	ECU Fault [ROM Fault]	Detected when Flash ROM checksum error occurs.	The engine stops.	key: OFF	Standard	4-1

Table 14-18 Fault detection list

No	Error item	Detection condition	Fault handling actions	Reset condition	Setting	Number of lamp flashes
28	ECU Fault [EEPROM Fault]	Detected when reads/ writes fail.	The engine runs as normal.	key: OFF	Standard	4-1
		Detected when a checksum error occurs.				
29	ECU Fault [Sub CPU fault]	Detected when the system fails to communicate with the sub CPU.	The engine runs as normal.	key: OFF	Standard	4-1
30	ECU Fault [Invalid map format]	Detected when the map format is invalid.	The engine stops.	key: OFF	Standard	4-1
31	ECU Fault [ECU Temperature Sensor Fault]	Detected when the sensor voltage rises to or above 4.6Vor drops to or lower 1.0V.	The engine runs as normal.	Reset upon restoration of normal condition.	Standard	4-1

*: These settings can be optionally changed.

Engine stop reasons without error indication

See the list of reasons for engine stop and starter motor restraint in **Table 14-35**.

Fault indicator lamp

Upon detecting one of the faults listed in the previous table, the E-ECU displays what fault has occurred along with brief description while flashing 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.)

Examples of flash patterns

Figure 14-59 shows how the fault indicator lamp flashes. For example, the fault indicator lamp flashes 5 times when Acceleration sensor Fault is detected after you have turned on the power and it flashes once and then 3 times when EGR Valve Fault is detected, as shown in **Figure 14-59**. When two or more faults are detected at the same time, the fault indicator lamp indicates one after another fault in the ascending order of the number of flashes, and then cycles through those flash patterns.

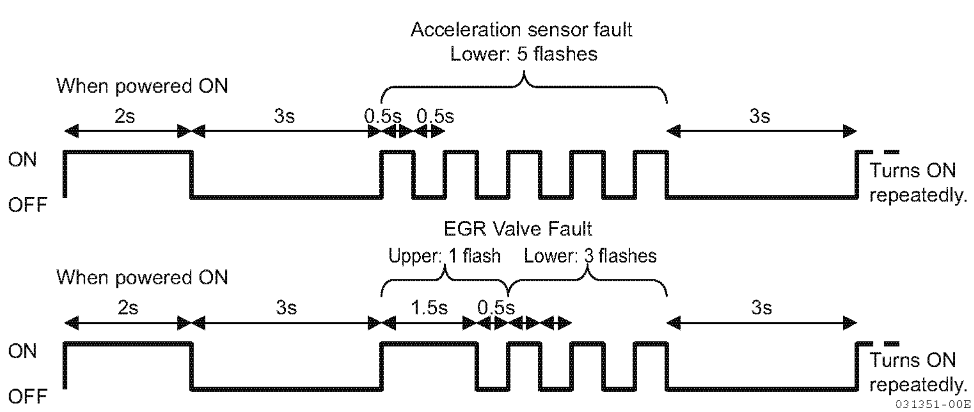


Figure 14-59 **How the fault indicator lamp flashes**

Obtaining detailed fault information

By connecting Yanmar genuine YDT as shown in **Figure 14-60**, 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 14-19 List of fault occurrence timestamps

Flag	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 YDT.

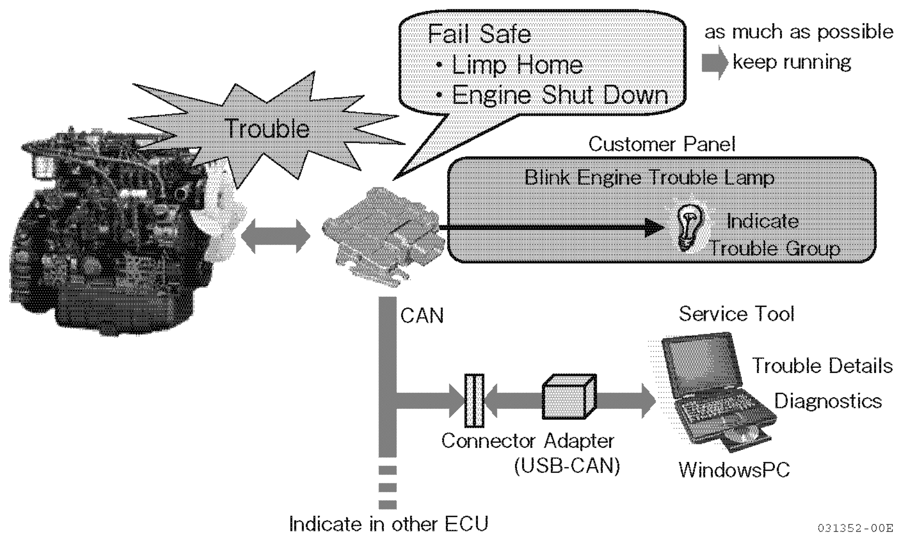


Figure 14-60 **Diagnosing the eco governor**

CAN communication function

The E-ECU is complete with a single CAN communication port that can be used for either communications with YDT 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. (See **Figure 14-61**.)

Communications protocols supported by the E-ECU include ISO15765 & KWP2000 for YDT and SAE J1939 for inter-ECU communications.

By using YDT, you can monitor, diagnose, and configure the engine. For more information, refer to the manual of YDT.

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 settings]

Before sending control commands such as target engine speed instructions to the E-ECU through the CAN communication, you have to configure the following:

b) 1 Application Function Setup ➡ 1: standard CAN (standard is 0: standard contact)

[Description]

Information commands from the E-ECU are sent regardless of whether or not the above application function settings have been configured.

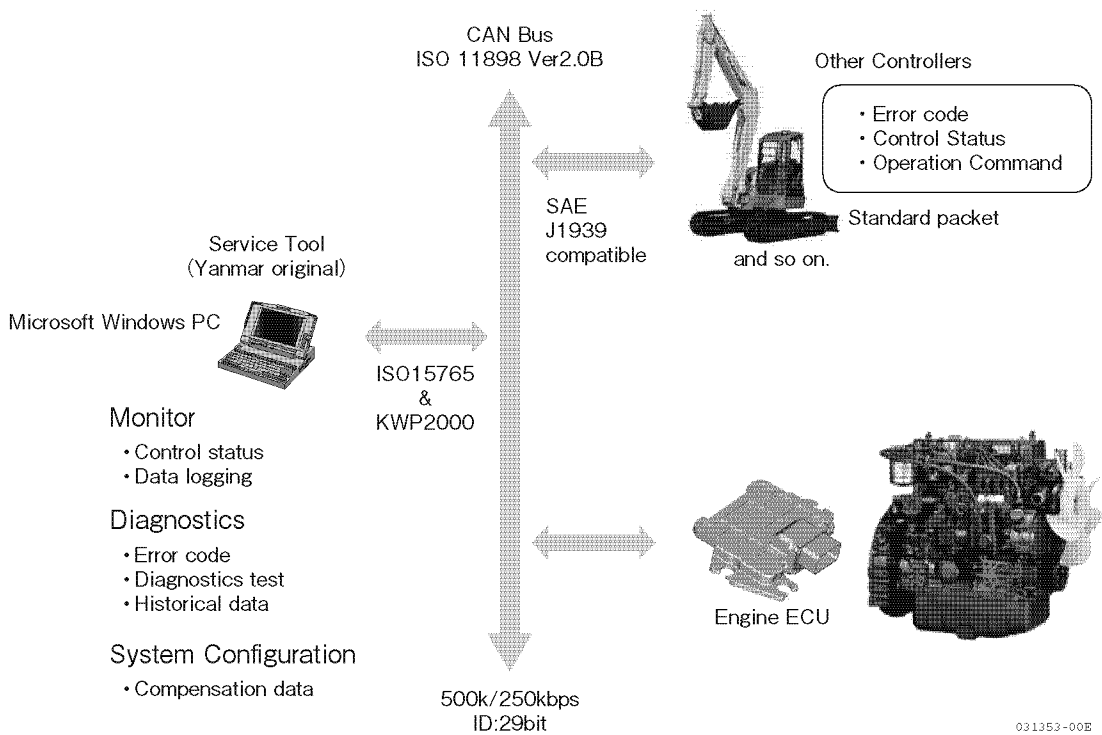


Figure 14-61 **CAN communication overview**

Precautions in the use of CAN communication

When using the settings described in **Table 14-20**, make sure that the J1939 PGN signals specified in this table are transmitted.
Without these signals transmitted, a CAN communication error will result.
*For more information, see **"15. On-vehicle Communication CAN Specifications"**.

Table 14-20

<table>
<tr><th>Item</th><th>Setting (model specific control map)</th><th>PGN: transmitted data</th><th>Cycle length [ms]</th></tr>
<tr><td>b) 2-1 Acceleration sensor</td><td>3. CAN communication
4. CAN communication + APS terminal
5. CAN communication + APP-IP3 terminal</td><td>PGN = 0 (TSC1)
If, in addition, TSC1 control mode is 0:
PGN = 65282 (Y_ECR1)</td><td>10</td></tr>
<tr><td>b) 4-13 Error Occurrence Time Selection</td><td>2: CAN communication receiving hours</td><td>PGN = 65255 (VH)</td><td>1000</td></tr>
<tr><td>b) 2-7 Droop Selection Input</td><td>1: APP-IP1 or CAN input</td><td rowspan="2">PGN = 65255 (VH)</td><td rowspan="2">1000</td></tr>
<tr><td>b) 3-2 APP-IP1 Terminal (E24) Function Input Setup</td><td>2 - 4: CAN (Droop selection)</td></tr>
<tr><td>b) 2-12 Permit/Restrain Starter Motor</td><td>1: Enabled - NO - Relay
2: Enabled - NC - Relay</td><td rowspan="2" colspan="2">If in addition you use "b) 2-14 CAN Communication Based Restraint Switching Function", configure using the following PGN:</td></tr>
<tr><td>b) 2-13 External Switch Control Function</td><td>1: Enabled</td></tr>
<tr><td rowspan="2">b) 2-14 CAN Communication Based Restraint Switching Function</td><td>0: based on Y_EC (PGN 65308)</td><td>PGN = 65308 (Y_EC)</td><td>100</td></tr>
<tr><td>1: based on Y_ECR1 (PGN 65282)</td><td>PGN = 65282 (Y_ECR1)</td><td>10</td></tr>
<tr><td>b) 3-4 APP-IP7 Terminal (E13) Function Input Setup</td><td>1 - 5: CAN (when stopping the engine)</td><td>PGN = 65309 (Y_STP)</td><td>Request</td></tr>
<tr><td colspan="4">*You can stop the engine using CAN communication, however, the engine will stop also when the signal indicated above is received from the driven machine ECU.</td></tr>
<tr><td>b) 2-34 High Idle Limit 1</td><td>1 - 3: Enabled</td><td rowspan="4">PGN = 65308 (Y_EC)</td><td rowspan="4">100</td></tr>
<tr><td>b) 3-12 APP-IP5 Terminal (E5) Function Input Setup</td><td>1, 2, 3, 5: CAN (high idle limit)</td></tr>
<tr><td>b) 2-35 High Idle Limit 2</td><td>1 - 3: Enabled</td></tr>
<tr><td>b) 3-4 APP-IP7 Terminal (E13) Function Input Setup</td><td>1, 2, 4, 5: CAN (high idle selection)</td></tr>
<tr><td>b) 2-21 Speed Selection Function Setup</td><td>0 - 5: Enabled (constant speed, deceleration, auto deceleration, etc.)</td><td rowspan="4">PGN = 65310 (Y_RSS)</td><td rowspan="4">10</td></tr>
<tr><td>b) 3-8 APP-IP3 Terminal (E9) Function Input Setup</td><td>2 - 5: CAN</td></tr>
<tr><td>b) 3-10 APP-IP4 Terminal (E17) Function Input Setup</td><td>2 - 5: CAN</td></tr>
<tr><td>b) 3-14 APP-IP6 Terminal (E6) Function Input Setup</td><td>2 - 4: CAN</td></tr>
</table>

OverRide Control Mode of TSC1 can be configured by (a) specifying the target speed or (b) specifying the accelerator pedal position. The following subsections provide examples of configuring OverRide Control Mode by each method:

(a) Specifying the target speed
Configure TSC1 (PGN = 0) as shown in **Table 14-21** and send it to the E-ECU.

TSC1 (PGN = 0, ID = 0x0C0000)**

Table 14-21

<table>
<tr><th>Data Byte</th><th colspan="2">Description</th><th>SPN</th><th>Recommended</th><th>Remarks</th></tr>
<tr><td rowspan="4">1</td><td>LSB</td><td>Override Control Mode</td><td>695</td><td>01B</td><td>“Requested Speed” is available</td></tr>
<tr><td></td><td>Requested Speed Control Condition</td><td>696</td><td>11B</td><td>Not available</td></tr>
<tr><td></td><td>Override Control Mode Priority</td><td>897</td><td>00B</td><td>Not available</td></tr>
<tr><td>MSB</td><td>Not defined</td><td>-</td><td>00B</td><td></td></tr>
<tr><td>2</td><td colspan="2">LSB of “Requested Speed”</td><td rowspan="2">898</td><td>80h (example)</td><td rowspan="2">When 2000min^{-1} is requested.
2000/0.125 = 16000 = 3E80h</td></tr>
<tr><td>3</td><td colspan="2">MSB of “Requested Speed”</td><td>3Eh (example)</td></tr>
<tr><td>4</td><td colspan="2">Requested Torque</td><td>518</td><td>00h</td><td>Not available</td></tr>
<tr><td>5</td><td colspan="2">Not defined</td><td>-</td><td>00h</td><td></td></tr>
<tr><td>6</td><td colspan="2">Not defined</td><td>-</td><td>00h</td><td></td></tr>
<tr><td>7</td><td colspan="2">Not defined</td><td>-</td><td>00h</td><td></td></tr>
<tr><td>8</td><td colspan="2">Not defined</td><td>-</td><td>00h</td><td></td></tr>
</table>

Cf1) continuous 10 ms period
Cf2) " ** " of ID except 00 and 01

(b) Specifying the accelerator pedal position
Configure TSC1 (PGN = 0) as shown in **Table 14-22** and **Table 14-23**, then send it to the E-ECU.

TSC1 (PGN = 0, ID = 0x0C0000)**

Table 14-22

<table>
<tr><th>Data Byte</th><th colspan="2">Description</th><th>SPN</th><th>Recommended</th><th>Remarks</th></tr>
<tr><td rowspan="4">1</td><td>LSB</td><td>Override Control Mode</td><td>695</td><td>00B</td><td>"Accelerator pedal position" is available</td></tr>
<tr><td></td><td>Requested Speed Control Condition</td><td>696</td><td>11B</td><td>Not available</td></tr>
<tr><td></td><td>Override Control Mode Priority</td><td>897</td><td>00B</td><td>Not available</td></tr>
<tr><td>MSB</td><td>Not defined</td><td>-</td><td>00B</td><td></td></tr>
<tr><td>2</td><td colspan="2">LSB of “Requested Speed”</td><td rowspan="2">898</td><td>00h</td><td rowspan="2">Not use</td></tr>
<tr><td>3</td><td colspan="2">MSB of “Requested Speed”</td><td>00h</td></tr>
<tr><td>4</td><td colspan="2">Requested Torque</td><td>518</td><td>00h</td><td>Not available</td></tr>
<tr><td>5</td><td colspan="2">Not defined</td><td>-</td><td>00h</td><td></td></tr>
<tr><td>6</td><td colspan="2">Not defined</td><td>-</td><td>00h</td><td></td></tr>
<tr><td>7</td><td colspan="2">Not defined</td><td>-</td><td>00h</td><td></td></tr>
<tr><td>8</td><td colspan="2">Not defined</td><td>-</td><td>00h</td><td></td></tr>
</table>

Cf1) continuous 10 ms period
Cf2) " ** " of ID except 00 and 01

Y_ECR1 (PGN = 65282, ID = 0x0CFF02**)

Table 14-23

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	Not defined		-	00h	
6	Not defined		-	00h	
7	Not defined		-	00h	
8	Not defined		-	00h	

Cf1) continuous 10 ms period
Cf2) " ** " of ID except 00 and 01

Configuring the ECU terminal functions

Each of the contact input/output terminals of the E-ECU listed in **Table 14-24** is assigned multiple functions, one of which is enabled at a time. You can change which function is enabled using map settings. *Functions can be assigned through CAN communication.
For more information on changing the settings, consult Yanmar.

Table 14-24 List of E-ECU contact input/output terminals that are assigned multiple functions

Terminal No.	Terminal name	Map settings				
		0	1	2	3	4
E24	APP-IP1	No function	Droop Selection*	Starter Motor Permission 1	Starter Motor Permission 1	Reserved
E14	APP-IP2	No function	Reserved*	Oil pressure switch	Reserved	Foot Pedal NO
E9	APP-IP3	No function	Speed Selection 1*	Charge	Reserved	Reserved
E17	APP-IP4	No function	Speed Selection 2*	Reserved	Reserved	Starter Motor Permission 2
E5	APP-IP5	No function	Reserved	Air Cleaner*	Reserved	High Idle Limit
E6	APP-IP6	No function	Speed Selection Permission*.	Diesel Fuel Filter/ Water Separator	Reserved	Reserved
E13	APP-IP7	No function	Reserved	Engine Stop 2*	High Idle Selection	Foot Pedal NC
E20	APP-OP1	Starter Motor Relay*	Reserved	Prohibited	Prohibited	Prohibited
E2	APP-OP2	Reserved	Block Heater Relay	Speed Change Indicator Lamp	Cooling Water Temperature Alarm Lamp*	Prohibited

* Enabled by standard

You can configure each of the contact input terminals listed in **Table 14-25** as one of the two types: Normally Closed (NC) and Normally Open (NO).

Table 14-25 List of contact input terminals that can be configured as either NC or NO

Terminal No.	Terminal name	Function enabled by standard	Input logic selected by standard
E24	APP-IP1	Droop selection	Normally Closed
E14	APP-IP2	Reserved	Normally Open
E9	APP-IP3	Speed Selection 1	Normally Open
E17	APP-IP4	Speed Selection 2	Normally Open
E5	APP-IP5	Air Cleaner	Normally Open
E6	APP-IP6	Speed Selection Permission	Normally Open
E13	APP-IP7	Engine Stop 2	Normally Open
E15	SHUDNSW	Engine Stop	Normally Open

Functions assigned to the E-ECU terminals listed in **Table 14-26** must be configured through map settings depending on how they are connected with the external devices:

Table 14-26 ECU terminals that need the configuration of assigned functions

Terminal No.	Terminal name	Connected device	Application Menu settings
E35	APS	Acceleration sensor	0: No acceleration sensor (generator standard) 1: Analog sensor (standard) 2: Foot pedal + APP-IP2/APP-IP7 switches 3: Foot pedal + APP-IP2 switch 4: Foot pedal + APP-IP7 switch (For more information, see the description of the acceleration sensor.)
E10	RENRPM	Backup speed sensor	0: Not equipped with backup speed sensor (standard) 1: Equipped with backup speed sensor
E44	AIRHT-RLY	Starting aid relay	0: Fault detection disabled for starting aid relay 1: Fault detection enabled for starting aid relay (standard)
E34	MAIN-RLY	Main relay	Power supply self-hold function 0: Disabled 1: Enabled (standard)
E37	REAN	Backup analog	0: No acceleration sensor (standard) 1: Analog sensor 2: Foot pedal + APP-IP2/APP-IP7 switches 3: Foot pedal + APP-IP2 switch 4: Foot pedal + APP-IP7 switch (For more information, see the description of the acceleration sensor.)
E16	RET	Backup temperature sensor	1: High accuracy cooling water temperature sensor (standard)

Among the terminals listed in **Table 14-26**, E16 is used as the standard cooling water temperature sensor input.

Configuring the fault handling actions

For the alarms/faults listed in **Table 14-28**, you can change the handling actions (operation modes) depending on the specifics of the driven machine on which the engine is mounted.
Table 14-27 provides a list of map flag settings that control the fault handling actions:

Table 14-27 Map settings for fault handling actions

Flag setting	Fault handling action (restriction)	
	Speed restriction	Output restriction
6	Engine Stop	
5	$1800 min^{-1}$	92%
4	$1500 min^{-1}$	92%
3	No restriction	92%
2	$1800 min^{-1}$	No restriction
1	$1500 min^{-1}$	No restriction
0	No restriction	No restriction

Table 14-28 shows standard fault handling action flags for the respective alarms/faults:

Table 14-28 List of standard fault handling action flags for alarms/faults

No. *2	Item	Fault handling action flag applied by standard
2	Acceleration sensor Fault Handling Action*1	1
7	Action during Backup Speed Sensor Operation	2
9	EGR Valve Fault Handling Action	5 (cannot be changed)
20	ECU Temperature High Alarm Handling Action	0
21	Oil Pressure Low Fault Handling Action	0
23	Reserved	-
24	Air Cleaner Clog Alarm Handling Action	0
25	Diesel Fuel Filter/Water Separator Alarm Handling Action	0
26	Cooling Water Temperature High Alarm Handling Action	0

*1: For more information on Acceleration sensor Fault Handling Action, see **Acceleration sensor selection (P.14-48)**. You can configure the speed limit dedicated to acceleration sensor fault handling since the speed limit applied when an acceleration sensor fault has occurred is different than for another faults.

*2: These numbers correspond to those indicated in **Table 14-18**.

Whether each alarm/fault is detected is determined by the flag settings listed in **Table 14-29**.

Table 14-29 List of flags that determine whether to detect each alarm/fault

No. *1	Item	Detection condition
2	Acceleration sensor Fault	Depends on the APS Terminal Function Setup Flag.
7	Backup Speed Sensor Fault	Depends on the RENRPM Terminal Function Setup Flag.
8	CAN Communication Fault	Depends on the Application Function Setup Flag.
11	Starting Aid Relay Fault	Depends on the Starting Aid Relay Fault Detection Function Setup Flag.
12	Main Relay Fault	Depends on the Power Supply Self-Hold Function Setup Flag.
14	Backup Acceleration sensor Fault	Depends on the REAN Terminal Function Setup Flag.
15	Reserved	-
16	Oil Pressure Switch Fault	Depends on the APP-IP2 Terminal Function Setup Flag.
17	Charge Switch Fault	Depends on the APP-IP3 Terminal Function Setup Flag.
20	ECU Temperature High Alarm	Depends on the ECU Temperature Alarm Setup Flag.
21	Oil Pressure Low Fault	Depends on the APP-IP2 Terminal Function Setup Flag.
22	Charge Alarm	Depends on the APP-IP3 Terminal Function Setup Flag.
23	Reserved	-
24	Air Cleaner Clog Alarm	Depends on the APP-IP5 Terminal Function Setup Flag.
25	Diesel Fuel Filter/Water Separator Alarm	Depends on the APP-IP6 Terminal Function Setup Flag.
26	Cooling Water Temperature High Alarm	Depends on the Cooling Water Temperature Alarm Setup Flag.

*1: These numbers correspond to those indicated in **Table 14-18**.

Lamp check function

When the power is turned ON (i.e., the key switch is set to the ON position, the E-ECU turns ON all lamp outputs to check the lamps for disconnection.If there is any lamp that does not turn ON when the key switch is set to the ON position, check the lamp.

Table 14-30 Eco governor lamp outputs

Lamp name	E-ECU terminal name	E-ECU terminal number
Fault indicator lamp	FAIL-LAMP	E12
Preheat lamp	PREHT-LAMP	E23
Cooling water temperature alarm lamp	APP-OP2	E2
Speed change indicator lamp		

Functional Overview of YDT

With the 2G eco governor, you can use YDT to monitor, diagnose, and configure the E-ECU. This section provides supplementary information for YDT. For more information, refer to the YDT manual.

Data monitoring and logging functions

Table 14-31 provides a list of data items that can be monitored/logged. The standard data you can monitor and log are that the 17 different freeze frame data items listed in the left half of **Table 14-31**. In addition to these 17 items, you can optionally select 8 items of the 19 items listed in the right half of **Table 14-31**. *Freeze frame data means data taken just before the occurrence of the fault.

Table 14-31 List of data items that can be monitored and logged

Freeze frame data (FFD)*1			Data items that can be optionally logged*2		
	Item	Code		Item	Code
1	Basic Target Engine Speed	RES	21	Acceleration sensor Position	APP
2	Final Target Engine Speed	ERSF	22	Camshaft Speed	CMRS
3	Actual Engine Speed	ES	23	Backup Engine Speed	AUXRSS
4	Target Rack Position	REQRP	24	Target EGR Opening Degree	REVCV
5	Actual Rack Position	ACTRP	25	Maximum Rack Position	RMAX
6	Actual EGR Opening Degree	AEVCV	26	Idle Rack Position	RIDLE
7	Cooling Water Temperature	ECT	27	Minimum Rack Position	RMIN
8	Gloss Engine Load Factor	ELRG	28	Net Engine Load Factor	%LOAD
9	Engine Start Recognition	ESSS	29	Speed Control P Gain	GCPG
10	Target Rack Current	RCV	30	Speed Control I Gain	GCIG
11	ECU Temperature	EET	31	Speed Control D Gain	GCDG
12	Battery Voltage	BV	32	Rack Current	RAC
13	Total Engine Operating Hours	ERH	33	Rack Position Control State	RCS
14	Contact Input 1	DIS1	34	Virtual Droop Correction Value	DCV
15	Contact Input 2	DIS2	35	Reverse Droop Correction Value	RDCV
16	Contact Output 1	DOS1	36	Engine Acceleration Flag	EAF
17	Contact Output 2	DOS2	37	Engine Deceleration Flag	EDF
18	-	-	38	Engine Stop Reason Flag	ESWS
19	-	-	39	Sensor 5V Voltage	SSV
20	-	-	40	-	-

*1: The 17 data items logged by the FFD function is also logged by the data logging function.

*2: The data logging function allows you to select and log 8 optional data items (listed in the right half above) in addition to the 17 items logged by the FFD function.

History functions

The E-ECU stores the history data items listed below in its internal EEPROM. These history data items can be viewed using Yanmar YDT. For more information, refer to the YDT instruction manual.

The history data stored in the EEPROM is maintained by the power supply self-hold function (which is enabled by standard) while the power to the E-ECU is OFF. The history data may be lost if the power supply self-hold function is disabled.

Table 14-32 List of history functions

Item	Content	Granularity of recorded data
Total ECU Energized Hours	Total hours during which the E-ECU has been energized.	Recorded in units of 1 second
Total Engine Operating Hours	Total hours during which the engine has run.	Recorded in units of 1 second
Total Engine Operating Hours under Alarm Condition ("Odometer" type)	Total hours during which the engine has run under specific error condition*1 (unresettable).	Recorded in units of 1 second
Total Engine Operating Hours under Alarm Condition ("Trip Meter" type)	Total hours during which the engine has run under specific error condition*1 (resettable).	Recorded in units of 1 second
Number of Engine Startups	How many times the engine has started up.	Counts of successful startups
Load Factor Profile	Averages the engine speed and engine load factor for a duration of 1 minute at intervals of 10 minutes, and records the frequencies at which the calculated averages match one of the cells of the separately provided frequency map*2 for engine speed versus load factor.	Recorded in units of 0.167 hour (Displayed in units of 0.2 hour)
Error History	Records the first occurrence time, last occurrence time, total occurrences, and FMI at the last occurrence for each error code. The occurrence times are based on the engine operating hours*3.	Number of occurrences: up to 127 First occurrence time: in units of 0.05 hour Last occurrence time: in units of 0.05 hour FMI at the last occurrence
Freeze Frame Data (FFD)	Records the data 1 second and 2 second before the error occurs. Errors logged*4 include 4 items. FFD data*5 includes 17 items.	For the most recent 10 occurrences (The oldest occurrence is lost when the number of occurrences exceeds 10.)
Engine Stop Reason	Records engine stop reasons*6 as well as total engine operating hours at the time of the occurrence.	For the most recent 50 occurrences
Starter Motor Restraint Reason	Records starter motor restraint reasons*7 as well as total engine operating hours at the time of the occurrence.	For the most recent 50 occurrences

*1: "Specific error condition" means Cooling Water High Alarm, EGR Fault, Oil Pressure Low Fault, or ECU Temperature High Alarm.

*2: The frequency map is shown in **Table 14-33**.

*3: By standard, this function uses "Total Energization Operating Hours", but you can optionally use "Total ECU Energized Hours" or "CAN Communication Hours" instead.

*4: For information on errors logged by the FFD function, see **Table 14-34**.

*5: For information on types of data contained in FFD , see **Table 14-31**.

*6: For information on engine stop reasons, see **Table 14-35**.

*7: For information on starter motor restraint reasons, see **Table 14-35**.

Table 14-33 Example: Use frequency map for engine speed versus load factor

Used hours [h]		Engine speed [min^{-1}]							
		Below 1000	Below 1200	Below 1500	Below 1800	Below 2000	Below 2300	Below 2500	2500 or above
Engine load factor [%]	Below 20%	0	0	0	0	0	0	0	0
	Below 40%	10	10	10	10	10	0	0	0
	Below 50%	10	100	100	100	10	0	0	0
	Below 60%	10	100	100	100	10	0	0	0
	Below 70%	10	100	100	100	10	0	0	0
	Below 80%	10	10	10	10	10	0	0	0
	Below 90%	0	0	0	0	0	0	0	0
	90% or above	0	0	0	0	0	0	0	0

Note: Calculates the use frequencies for each of the load factor and engine speed ranges based on the given used hours [h].
(The used hours are calculated based on how many times the result of averaging the engine speed and load factor for a duration of 1 minute at intervals of 10 minutes matches one of the cells.)

Table 14-34 List of errors logged by the FFD function

Error item	DTC code
Engine Overspeed Fault	P0219
Rack Position Sensor Fault	P1202, P1203
Rack Actuator Fault	P1211, P1212, P1213
Rack Actuator Relay Fault	P1222, P1223

Table 14-35 [Important] List of engine stop reasons and starter motor restraint reasons

Engine stop reason flag		Starter motor restraint reason flag	
Reason	Flag position	Reason	Flag position
Engine stall	bit0	Safety relay function activated	bit0
Key switch	bit1	Rack self diagnosis in progress	bit1
Engine stop switch (E15)	bit2	External switch (E24, E17)	bit2
Engine Stop 2 switch (E13)	bit3	Immobilizer (CAN message)	bit3
Speed sensor fault	bit4	Energization time control	Bit4
Rack actuator system fault	bit5	CAN message	bit5
E-ECU fault - ROM	bit6	Engine stop switch (E15, E13)	bit6
Engine overspeed	bit7	Key switch OFF	bit7
E-ECU fault - MAP	bit8	Rack self diagnosis failure	bit8
Engine fault handling action flag*	bit9	E-ECU fault	bit9
EEPROM initialization in progress	bit10	Engine overspeed Engine fault handling action flag*	bit10
E-ECU fault - EEPROM	bit11	Service maintenance in progress	bit11
CAN message	bit12	E-ECU fault - EEPROM	bit12
-	bit13	Rack actuator system fault	bit13
-	bit14	-	bit14
-	bit15	-	bit15

*: Applies when the engine is stopped due to the action flag setting of 6 as described in **Table 14-28**.

Tuning functions

Engine control by the E-ECU supports tuning of the engine mounted on a driven machine. This type of tuning is basically unnecessary; when Yanmar deems it necesary to perform such tuning to have the engine correctly match the driven machine, however, Yanmar performs such tuning.

This type of tuning is performed by modifying the EEPROM data area of each individual E-ECU through YDT. Therefore, it will be necessary to redesign the model-specific E-ECU control maps in order to apply the tuning results to mass produced engines.

Table 14-36 Overview of the tuning functions

Item		Content
1	Startup time high injection rate control	This tuning is intended for use in testing the engine by temporarily increasing the injection rate at startup time through YDT when engine startability is poor due to wear of the fuel injection pump plunger.
2	Accelerator filter change	This tuning is intended for use in testing the engine by changing the responsiveness to target engine speed when there is a problem with the engine speed control performance of the eco governor. For more information, see **Accelerator filter (P.14-71)**.
3	Simplified governor gain adjustment	This tuning is intended for use in testing the engine by changing the engine speed control gain when there is a problem with the engine speed control performance of the eco governor.
4	Rack position control adjustment	The engine vibration may affect the rack position control of the eco governor if the engine vibration isolator mount is not properly used.This tuning is intended for use in testing the engine by changing the rack position control gain when there is a problem with the engine speed control performance of the eco governor.

FUEL INJECTION PUMP

You must perform installation evaluations of the fuel injection pump as specified by Yanmar and evaluate/ improve the installed driven machine to satisfy its operating requirements.

[Caution]

Special caution should be taken about the temperature and vibration. As with other electrical components, the fuel injection pump must be used in an environment where the ambient temperature does not exceed 80°C. Measurements and adjustments of the vibration should be performed at the engine mount. Please note that the hunting or broken wiring harness may be caused if the vibration displacement exceeds the specified value.

When creating a harness, correctly identify the polarity of the rack actuator solenoid and speed sensor.

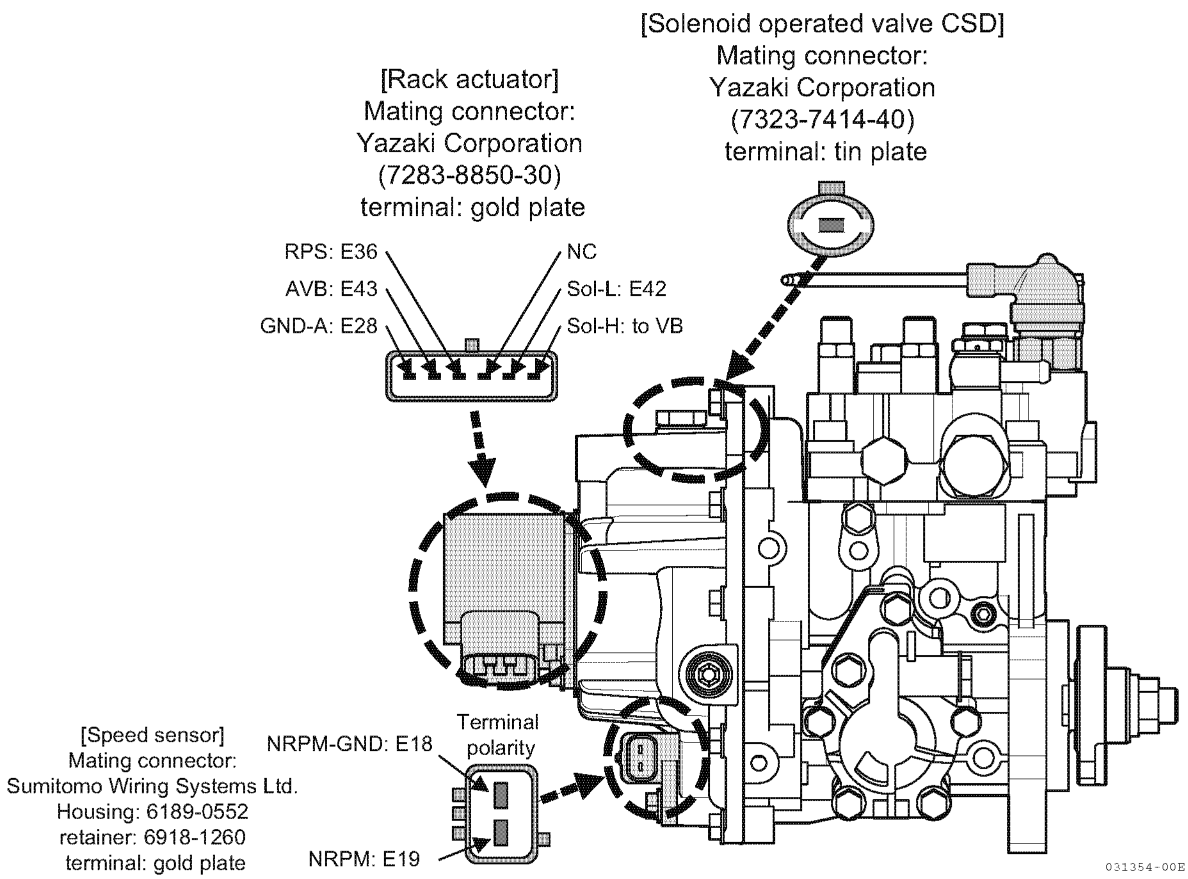


Figure 14-62 **Connectors compatible with the fuel injection pump**

COOLING WATER TEMPERATURE SENSOR

This is a thermistor temperature sensor used for eco governor control.

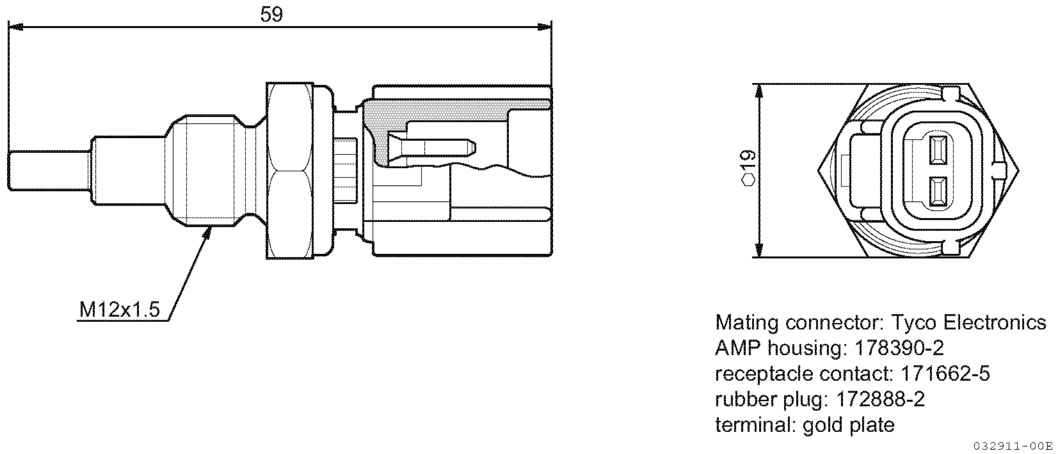


Figure 14-63 **Water temperature sensor (129927-44900)**

EGR VALVE

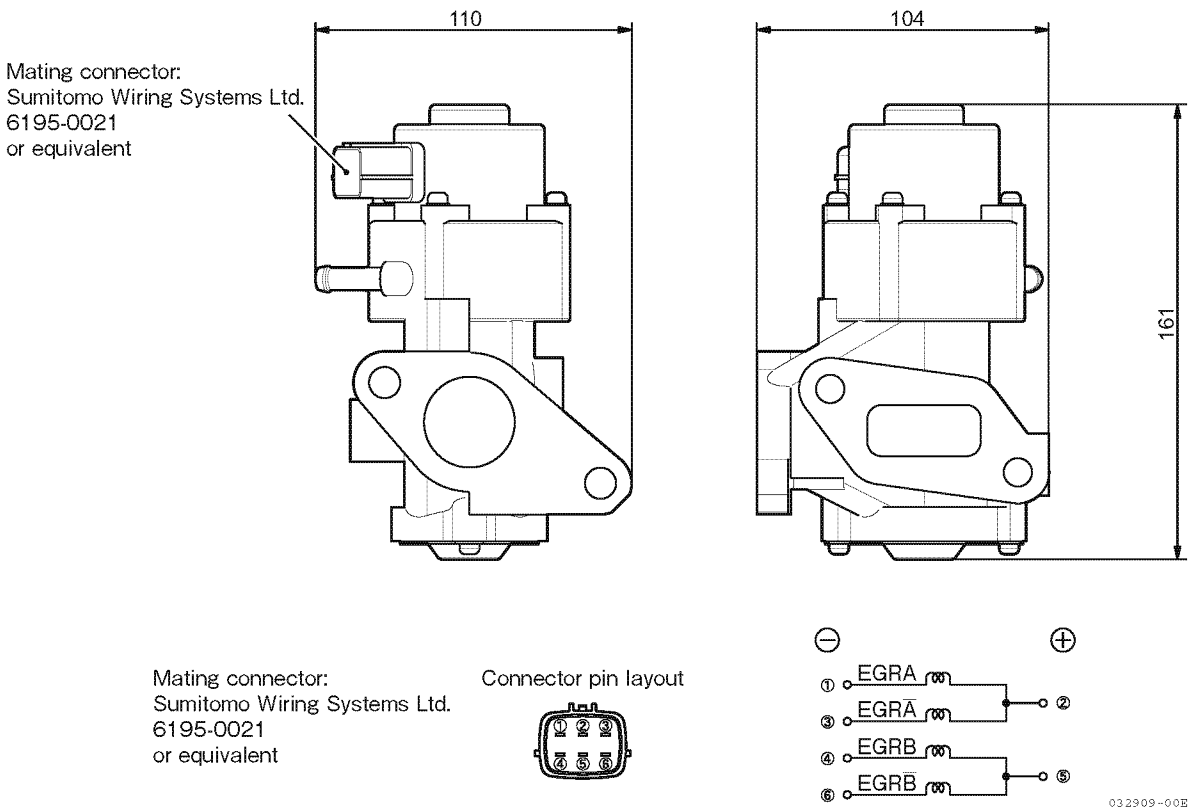


Figure 14-64 **EGR valve external dimensions**

ACCELERATION SENSOR

Instead of a mechanical pump type governor lever, an acceleration sensor is required for the eco governor to set the engine speed. The acceleration sensor you use may be Yanmar standard acceleration sensor shown in **Figure 14-65** or equivalent. For general requirements regarding the acceleration sensor, refer to **Figure 14-2**, **Table 14-5**, **Acceleration Sensor Inputs (P.14-35)**, and **Acceleration sensor selection (P.14-48)**.

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.

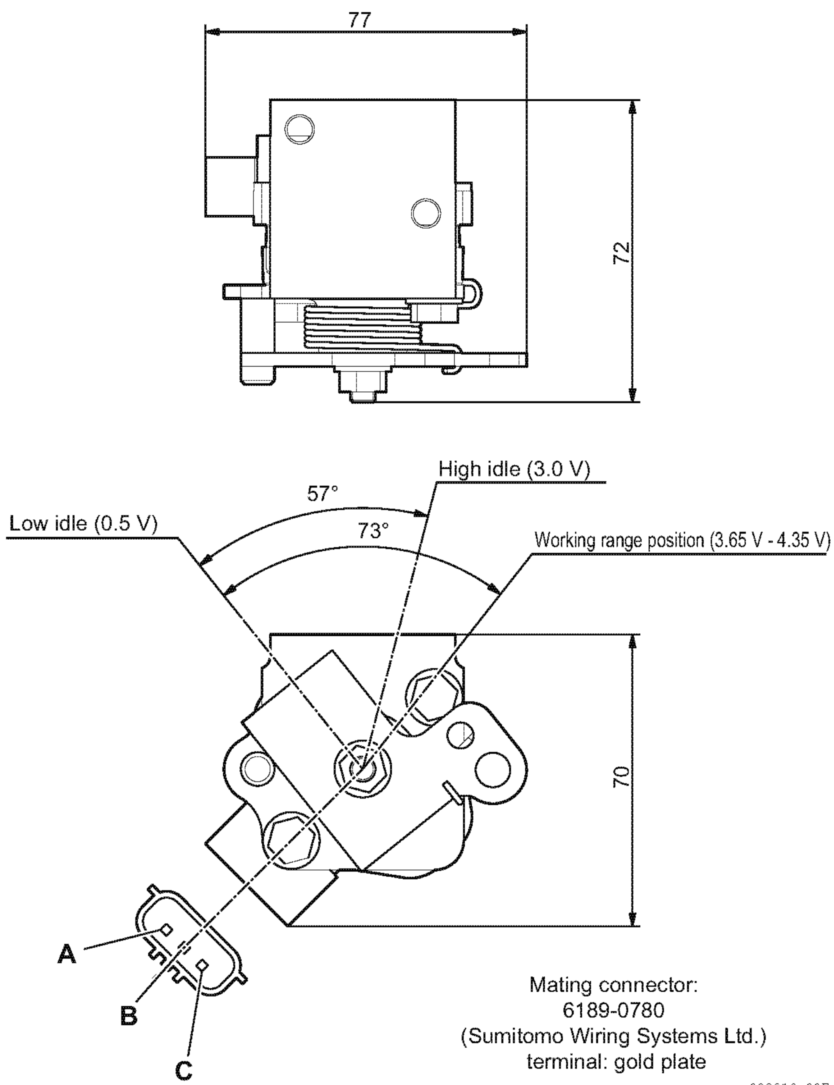


Figure 14-65 **Yanmar standard acceleration sensor (129938-77800)**

Terminal	Wire
A	GND GND-A (E28)
B	OUTPUT APS (E5)
C	INPUT AVCC (E38)

The operating conditions for Yanmar standard acceleration sensor (129938-77800), observe the guidelines described below:

(1) 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.

(2) 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.

(3) 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.

(4) Other

- Do not use the sensor if it has dropped or it is apparently broken.

Table 14-37 Acceleration sensor specifications

Rated voltage	5V DC ± 0.01V
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

MAIN RELAY

The main relay is used to supply the power to the E-ECU, rack actuator, EGR valve, and other components. It has a built-in diode that prevents the contact from operating when the polarity of an exciting coil is connected in reverse. For wiring connections, see the electrical wiring diagram in **Figure 14-4**.

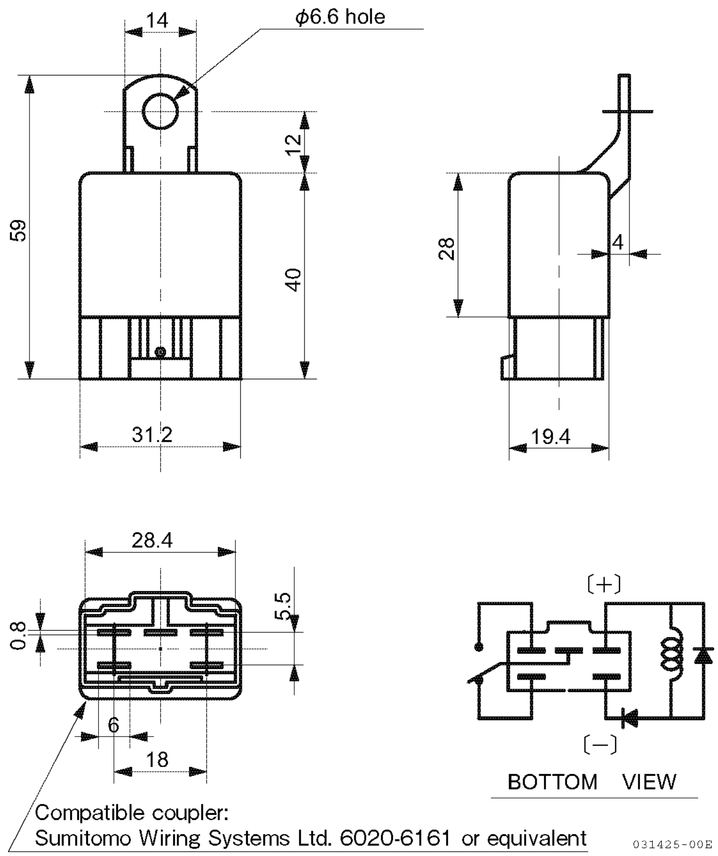


Figure 14-66 **CA relay**

Table 14-38 CA relay specifications

Yanmar code	198461-52950
Rated coil voltage	12V DC
Rated exciting current	150mA
Contact specifications	C contact
Rated contact voltage	12V DC
Rated contact current	20 A - continuous/100A - 0.1 s

RACK ACTUATOR RELAY

The rack actuator relay is used to supply the power to the rack actuator. The standard-equipped rack actuator relay is a relay identical to the main relay. It has a built-in diode that prevents the contact from operating when the polarity of an exciting coil is connected in reverse. For wiring connections, see the electrical wiring diagram in **Figure 14-4**.

SUB RELAY

The sub relay is used to supply the power to the fault indicator lamps on the panel, external switches, and so on. The standard-equipped sub relay is a relay identical to the main relay. It has a built-in diode that prevents the contact from operating when the polarity of an exciting coil is connected in reverse.
For wiring connections, see the electrical wiring diagram in **Figure 14-4**.

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, see the electrical wiring diagram in **Figure 14-4**.
The starter motor relay is compatible with the status of 12V DC/2.3kW (129900-77010, 129910-77022) or 12V DC/3.0kW (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). (See **Figure 14-68**.)

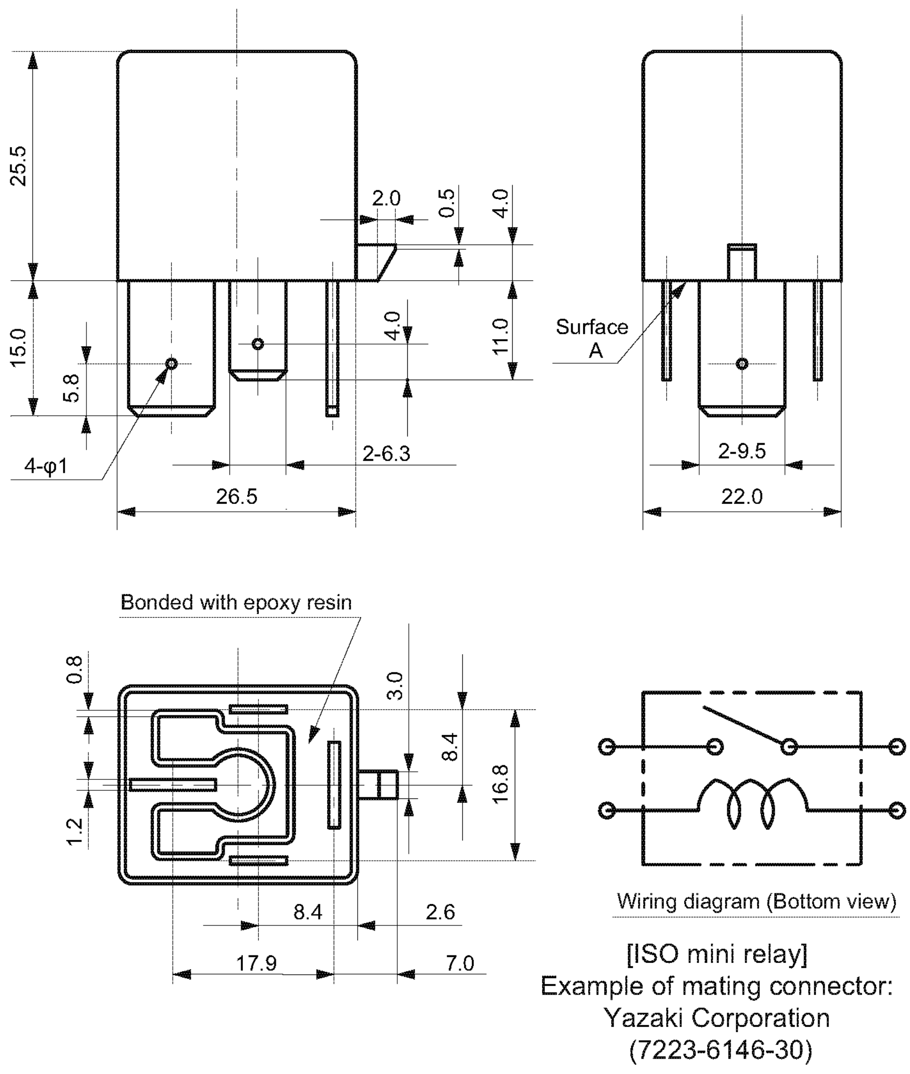


Figure 14-67 **ISO relay (70A)**

Table 14-39 ISO relay (70A) specifications

Yanmar code	129927-77920
Rated coil voltage	12V DC
Rated exciting current	117mA
Contact specifications	a-contact
Rated contact voltage	12V DC
Rated contact current	70 A
Operation delay time	15 ms or less
Reset delay time	15 ms or less

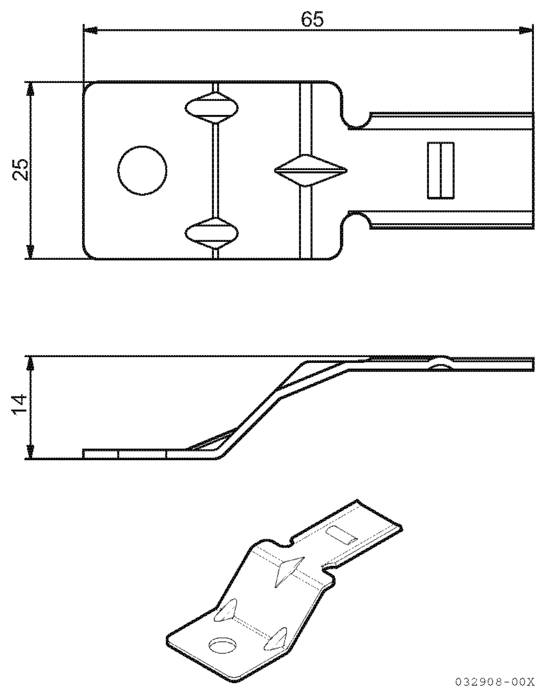


Figure 14-68 **ISO relay bracket (129927-77910)**

STARTING AID RELAY

The starting aid relay allows the E-ECU to control the current flowing into the air heater and glow plug. For wiring connections, see the electrical wiring diagram in **Figure 14-4**. The starting aid relay is available in three versions depending on the load capacity:

Relay for 400 W air heater (glow plug)

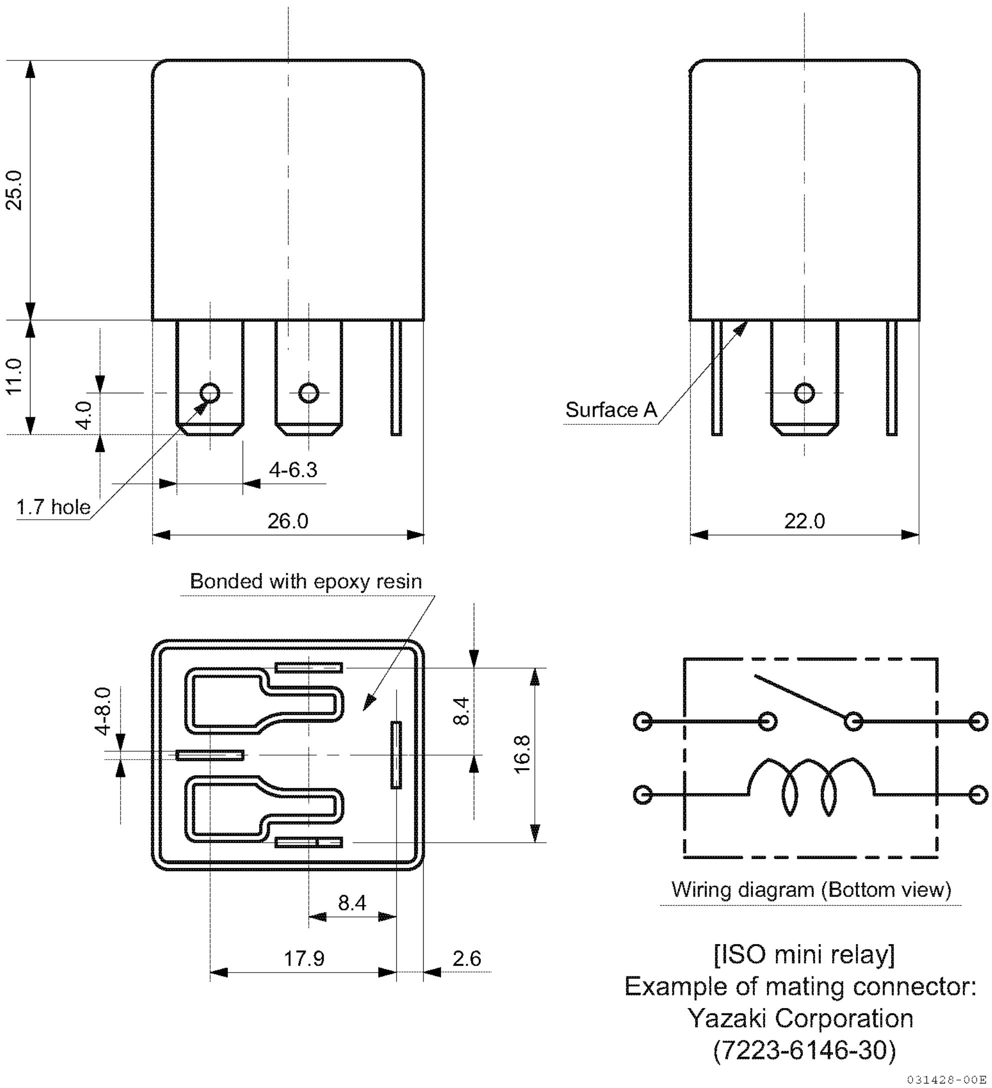


Figure 14-69 **ISO relay (40A)**

Table 14-40 ISO relay (40A) specifications

Yanmar code	129927-77930
Rated coil voltage	12V DC
Rated exciting current	117mA
Contact specifications	a-contact
Rated contact voltage	12V 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). (See **Figure 14-68**.)

Relay for 500W/800W air heater

Identical to the starter motor relay (129927-77920).

Relay for 1000W air heater

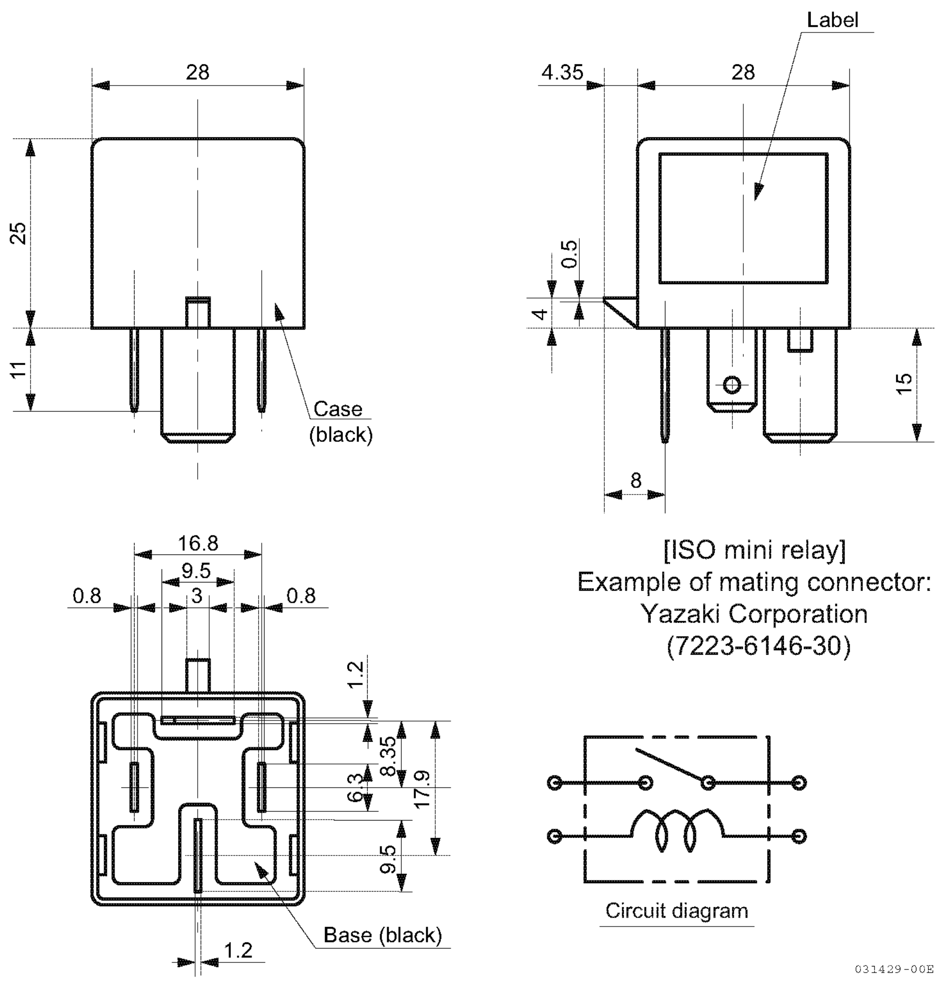


Figure 14-70 **ISO relay (90A)**

Table 14-41 ISO relay (90A) specifications

Yanmar code	129927-77900	
Rated coil voltage	12V DC	
Rated exciting current	200mA	
Contact specifications	a-contact	
Rated contact voltage	12V DC	24V DC
Rated contact current	Resistance load: 90A - 4minutes	Resistance load: 55A - 4minutes Inductive load: 19A - 30seconds

ECO GOVERNOR CHECK LIST

The contents of the check list are subject to change. Contact Yanmar for the availability of the latest check list.

Created on April 26, 2007

No	Item	Results		
		Design	Installation	Remarks
Design and verification of the control system				
1	Make sure that the alternator charge current is sufficient with respect to the total current consumption of the driven machine. An additional current of 4 to 5A is required to drive additional electric components (including the E-ECU, pump, CSD, EGR valve, E-ECU lamps, E-ECU relays, and so on) that have been added for the purpose of engine control.	OK / NG	-	
2	Make sure that the E-ECU connector is NOT oriented upward (tilted in the positive degree direction) from the horizontal plane (at 0 degree). Also, make sure that the outgoing harness is NOT oriented upward (tilted in the positive degree direction) from the horizontal plane (at 0 degree). Avoid installing the connector in any location or configuration where water may enter the ECU side coupler or the harness side coupler may get wet with water when the connector is unplugged. Failure to observe this could cause rusting of the connector terminals.	OK / NG (deg)	OK / NG (deg)	
3	Make sure that the E-ECU is installed in a location where it will not be exposed to weather or high pressure or steam cleaning water or it is sufficiently protected from such exposure. Failure to observe this could cause rusting of the connector terminals or contact failure.	OK / NG	OK / NG	
4	If there is a possibility of salt damage or chemical damage, make sure that the E-ECU is protected with a cover or the like against such damage. Failure to observe this could cause rusting of the aluminum surface of the E-ECU, possibly resulting in separation of the molding or some other failure.	OK / NG	OK / NG	
5	Make sure that the E-ECU is installed in a well-ventilated location where it will not be exposed to direct sunlight. Failure to observe this could cause discoloration or overheat due to sunlight, possibly resulting in a failure.	OK / NG	OK / NG	
6	Make sure that the E-ECU is installed in a location that meets the specified environmental requirements. For the environmental requirements, refer to the application manual.	-	OK / NG	
7	Make sure that the fault indicator lamps and other means to indicate faults/failures detected by the E-ECU are installed at a location readily visible to the operator. The engine performance is not guaranteed while the engine is running despite any engine failures/faults being detected by the E-ECU.	OK / NG	OK / NG	
8	Make sure that the connector for the engine diagnostic tool is installed at a location readily accessible to the service engineer. The connector for the engine diagnostic tool is indispensable for failure diagnosis and maintenance of the engine and E-ECU.	OK / NG	OK / NG	
9	Avoid installing Yanmar genuine acceleration sensor (129938-77800) directly on the engine or fuel injection pump. Failure to observe this could cause a failure due to vibrations.	-	OK / NG	
10	Make sure that the acceleration sensor is installed in a location that meets the specified environmental requirements. For the environmental requirements, refer to the application manual.	-	OK / NG	
11	Make sure that the engine type and production number indicated on the E-ECU label match those indicated on the engine identification plate. Yanmar ships engines and E-ECUs in specific combinations only. The engine performance is not guaranteed when used in any other combination.	-	OK / NG	

Created on April 26, 2007

No	Item	Results		
		Design	Installation	Remarks
12	Make sure that the power supply voltage to the E-ECU is always at least 6.0V. Evaluations should be performed under conditions where the battery voltage drops significantly, for example, by cranking the engine to start it up at a low temperature. Measurements should be taken at locations as close as possible to the VB terminal (E48) and GND terminal (E45) of the E-ECU. The engine may fail to start when the power supply voltage to the E-ECU falls below 6.0V.	-	OK / NG (V)	
Design and verification of the electrical components				
13	Make sure that fault indicator lamp and other lamp loads connected to the E-ECU do NOT exceed 12V/3.4W. The E-ECU may possibly fail if connected with a load beyond the rating.	OK / NG (W)	-	
14	Make sure that the switches used for contact input to the E-ECU have a minimum working current of 10mA or lower. Also, make sure that the switches used for contact input to the E-ECU have an allowable current of 10m A or higher. The E-ECU contact input current is 10mA at the rated voltage of 12V. Select switches compatible with the ratings. Failure to observe this could cause malfunction or failure of the E-ECU.	OK / NG (mA)	-	
15	Make sure that the cooling water temperature sensor connected to the E-ECU is Yanmar genuine sensor (129927-44900). Also, make sure that the RET terminal (E16) of the E-ECU is NOT connected with any other load than the E-ECU. DO NOT connect the cooling water temperature sensor intended for use with the E-ECU with any other load than the E-ECU. Failure to observe this could cause malfunction of the E-ECU.	OK / NG	-	
16	If an oil pressure switch (such as 119761-39450) is connected to the APP-IP2 terminal (E14) of the E-ECU, make sure that a proper load such as a resistor or lamp is connected so as to maintain the oil pressure switch contact current at 100mA or higher. A contact current of lower than 100mA could cause the oil pressure switch (119761-39450 or the like) to fail to make contact or otherwise malfunction due to contaminants in the lubricating oil. Also, make sure that a circuit independent of the IGNSW terminal (E7) of the E-ECU is used to supply the power to resistors, lamps, and any other loads connected to the oil pressure switch. Failure to observe this could cause current leak from the APP-IP2 terminal (E14), possibly resulting in inability to turn OFF the power to the E-ECU using the key switch. For more information, refer to the application manual.	OK / NG (mA)	-	
17	Make sure that the alternator IG terminal and the E-ECU are NOT power-supplied from the same terminal of the key switch. Depending on the alternator, generated current may flow in reverse from the IG terminal.If this is the case, turning OFF the key switch may fail to stop the engine. If it is unavoidable to power-supply both the alternator IG terminal and E-ECU from the same key switch terminal, be sure to verify whether the engine stops without fail. Insert a diode into the IG terminal as needed to prevent generated current from flowing in reverse from the IG terminal. For more information, refer to the application manual.	OK / NG	-	
18	Make sure that the E-ECU power supply circuit is NOT cut off at the moment when the key switch is returned from the START position to the ON position. Make sure that the E-ECU fault indicator lamps do NOT turn ON (for approximately 2 seconds) immediately after the starter motor is released. Depending on the key switch, the switch circuit may open when the key is somewhere between the START and ON positions. Carefully note that this phenomenon is likely to occur at low temperatures in particular. If this is the case, the engine may suffer from speed fluctuation or stall immediately after started. It is recommended to change the key switch. For more information, refer to the application manual.	OK / NG	OK / NG (ms)	

Created on April 26, 2007

No	Item	Results		
		Design	Installation	Remarks
19	If an E-ECU harness is used to joint the CANL terminal (E30) and RECAN terminal (E39) of the E-ECU, make sure that the E-ECU harness is designed to have a total wiring length of 500mm or shorter. If this joint line length is longer than 500mm, CAN communication errors may result. For more information, refer to the application manual.	Short/ Open	-	
20	Make sure that NONE of the E-ECU terminals are connected with any other electronic parts than specified by Yanmar or any electronic parts that do not fall within the standard range specified by Yanmar. For more information, refer to the application manual.	OK / NG	-	
21	Make sure that the GND terminals (E45, E47) of the E-ECU are earthed at a single point as close as possible to the battery minus terminal. If the GND terminals are too far from the battery minus terminal, failure to observe this could cause malfunction or failure of the E-ECU.	OK / NG	OK / NG	
22	Make sure that the eco governor power supply cables (to the E-ECU, rack actuator, etc.) are directly branched from the battery plus terminal. If the eco governor power supply cables are branched from the B terminal of the starter motor or from another high current circuit, the E-ECU power supply voltage may become difficult to maintain at 6.0V or higher when voltage drop has occurred. For more information, refer to the application manual.	OK / NG	-	
23	Make sure that the power supply circuits for E-ECU VB terminal power supply (E48) and the engine electrical components such as the rack actuator and EGR valve are fuse circuits independent of other electrical components. Failure to observe this could cause inability to start the engine when one of the other electrical components fails or cause the E-ECU to malfunction when there is leak current from one of the other electrical components. For more information, refer to the standard wiring diagram.	OK / NG (A)	-	
24	Make sure that the power supply circuits for E-ECU VB terminal power supply (E48), rack actuator and EGR valve have a fuse capacity of 10 A. Too much fuse capacity could cause overcurrent, possibly resulting in a fire. Also, a fuse with a small capacity is readily blown. For more information, refer to the standard wiring diagram.	OK / NG (A)	-	
25	Make sure that the E-ECU power supply circuit (connected with the main relay) has connections that allow power supply self-hold exactly as indicated in the standard wiring diagram. If power supply self-hold is not allowed, E-ECU data such as fault history or operation history may possibly be lost when the power is OFF. For more information, refer to the application manual.	OK / NG	-	
26	Make sure that the rack actuator relay is connected that the power to the rack actuator can be cut off directly by turning OFF the key switch. Failure to observe this could cause inability to stop the engine when the power supply self-hold function fails. For more information, refer to the application manual.	OK / NG	-	
27	Make sure that the power supply cables to the rack actuator (relay) and EGR valve branched in a location as close to the E-ECU VB terminal (E48) as possible (preferably within 220mm of the VB terminal). If the power supply cables to the rack actuator and EGR valve are branched at a point distant from the E-ECU VB terminal, conductive noise may result. For more information, refer to the application manual.	OK / NG (mm)	-	
28	Make sure that the starter motor relay is connected that it can be controlled via the E-ECU APP-OP1 terminal (E20). For safety reasons, Yanmar recommends a circuit configuration that prevents the engine from starting until rack self diagnosis successfully completes when the E-ECU is powered ON. For more information, refer to the application manual.	OK / NG	-	

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No	Item	Results		
		Design	Installation	Remarks
29	Make sure that the key switch start position signal is connected to the E-ECU STARTSW terminal (E8). The E-ECU will not turn ON the starter motor relay unless a 12V signal is input to the STARTSW terminal (E8),thus preventing the starter motor from operating.	OK / NG	-	
30	Make sure that the main and sub relays used are the Yanmar-specified relay (198461-52950) or a relay with a reverse connection protection diode inserted. Such a diode is required to protect the E-ECU against reverse connection of the battery cable.	OK / NG	-	
31	Make sure that the total wiring length of the E-ECU (the sum of the VB terminal wiring length and GND terminal wiring length) is within 5m. This maximum length is based on the engine performance verification performed at Yanmar.If the wiring length of the E-ECU is too long, failure to observe this could cause malfunction or failure of the E-ECU. For more information, refer to the standard wiring diagram.	OK / NG (m)	-	
32	Make sure that the total wiring length of the rack actuator circuit (the sum of the length from the rack actuator to the battery and the length from the rack actuator to the E-ECU) is within 12m. This maximum length is based on the engine performance verification performed at Yanmar.If the wiring length of the E-ECU is too long, failure to observe this could cause malfunction or failure of the E-ECU. For more information, refer to the standard wiring diagram.	OK / NG (m)	-	
33	Make sure that the circuit length from the rack position sensor to the E-ECU RPS terminal (E36) is within 5m. This maximum length is based on the engine performance verification performed at Yanmar. If the wiring length of the E-ECU is too long, failure to observe this could cause malfunction or failure of the E-ECU. For more information, refer to the standard wiring diagram.	OK / NG (m)	-	
34	Make sure that the wires used to connect the speed sensors (E18, E19) are twisted pair wires. Yanmar recommends a twist pitch of 100mm or smaller. If you do not use twisted pair wires, failure to observe this could cause malfunction or failure of the E-ECU due to noise. Also, correctly identify the polarity of the speed sensor. For more information, refer to the standard wiring diagram.	OK / NG	-	
35	Make sure that the wires for CAN communication (E39, E40) are twisted pair wires. Yanmar recommends a twist pitch of 100mm or smaller. If you do not use twisted pair wires, failure to observe this could cause CAN communication errors due to noise. For more information, refer to the standard wiring diagram.	OK / NG	-	
36	Make sure that all the fuses used are compatible with the required current for loads and the allowable current of the wires. Improper design could result in frequent blowing of fuses or a harness fire. For more information on designing fuse circuits, refer to the standard wiring diagram.	OK / NG	-	
37	Make sure that the wires used have a conductor sectional area and outside diameter compatible with the applicable standards used by the respective connector manufacturers. Improper selection of wires could result in waterproof failure or contact failure. For more information on selecting the wires, refer to the standard wiring diagram.	OK / NG	-	
38	Make sure that the wires uses have a heat resistance property suitable for the installation environment. Harnesses installed around the engine should preferably have a heat resistance temperature of 100°C or higher.	OK / NG (°C)	-	

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No	Item	Results		
		Design	Installation	Remarks
Installation of wiring harnesses				
39	Make sure that the harnesses are clamped at proper locations so that they will not be shaken by vibrations. Should the harnesses be shaken by vibrations, the conductors inside the wires may be disconnected or the wire coverings may be abraded and worn, resulting in corrosion of the conductors, disconnection, or short-circuiting. For information on the standard harnesses, refer to the application manual.	-	OK / NG	
40	Make sure that the harnesses are clamped with sufficient allowance to prevent any tension. Failure to observe this could cause disconnection.	-	OK / NG	
41	Make sure that the harnesses are installed where they will not interfere with edges or get pinched. Failure to observe this could cause disconnection or short-circuiting.	-	OK / NG	
42	Make sure that the harnesses are properly protected against water, chemicals, external forces, and heat. Protect the harnesses with a vinyl tube or corrugate tube as needed. Failure to observe this could cause disconnection or short-circuiting.	-	OK / NG	
43	Make sure that the harnesses are installed away from heat sources such as the exhaust system.	-	OK / NG	
44	Make sure that no water enters through non-waterproof terminals and joints. Non-waterproof parts are likely to allow water to enter the wire interior due to capillary action or pressure difference, possibly resulting in corroded or disconnected conductors. Apply waterproof treatment if water is likely to enter.	-	OK / NG	

ECU APPLICATION MENU

The contents of the application menu are subject to change. Contact Yanmar for the availability of the latest application menu.

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Item		Unit	Setting	Base engine	Driven machine specific standard				Customer spec
					Backhoes	Tractors	Loaders	Generators	
a) Engine Control Setup									
1	Engine Specifics								
	2 Manufacturer Code		Used by the failure diagnosis tool.	B828	B828	B828	B828	B828	
	3 Low Idle Speed	min^{-1}		-	-	-	-	-	
	6 Speed at Managed Torque	min^{-1}	Need not be configured (spare).	-	-	-	-	-	
10	High Idle Speed Limit								
	1 Droop Limit 1	min^{-1}		1900	1900	1900	1900	1900	
	2 Iso-chronous Limit 1	min^{-1}		1900	1900	1900	1900	1900	
	3 Droop Limit 2	min^{-1}		1700	1700	1700	1700	1700	
	4 Iso-chronous Limit 2	min^{-1}		1700	1700	1700	1700	1700	
13	Restrictions on Operation								
	1 Speed Limit A	min^{-1}		1500	1500	1500	1500	1500	
	4 Engine Stop Delay Time	s		30	30	30	30	30	
	5 Acceleration sensor Fault Speed A	min^{-1}		1500	1500	1500	1500	1500	
	7 Acceleration sensor Fault Handling		0: Acceleration sensor fault speed 1: Maintain the last value	1	1	1	1	1	
b) Application Function Setup									
1	Application Function Setup		0: Standard contact 1: Standard CAN	0	0	0	0	0	
2	ECU Control Function Setup								
	Acceleration sensor Input								
	1 Acceleration sensor Setup		0: No acceleration sensor 1: APS terminal 2: APS terminal + REAN terminal (whichever at higher speed or normal takes precedence) 3. CAN communication 4. CAN communication + APS terminal (CAS communication link takes precedence) 5: Reserved 6: APS terminal + REAN terminal (whichever operated last or normal takes precedence) 7: Check inputs with APS terminal + REAN terminal	1	1	1	1	0	
	2 Low Idle Speed Voltage at APS Terminal	V		0.7	0.7	0.7	0.7	0.7	
	3 High Idle Speed Voltage at APS Terminal	V		3.0	3.0	3.0	3.0	3.0	
	4 Low Idle Speed Voltage at REAN Terminal	V		0.7	0.7	0.7	0.7	0.7	
	5 High Idle Speed Voltage at REAN Terminal	V		3.0	3.0	3.0	3.0	3.0	
	7 Droop Selection Input		(0: Always use iso-chronous control) 1: APP-IP1 or CAN input 2: Always use droop control	1	1	1	1	1	
	8 Iso-chronous Control at Low Idle Speed		0: Disabled 1: Enabled	0	0	0	0	0	
	11 Power Supply Self-Hold Function		0: Disabled (without fault detection) 1: IGNSW terminal or CAN	1 (mandatory)	1	1	1	1	
	12 Starting Motor Permission/Restraint Function		0: Disabled 1: Enabled - NO - Relay 2: Enabled - NC - Relay (reserved)	1 (mandatory)	1	1	1	1	
	13 External Switch Control Function		0: Disabled 1: Enabled	0	0	0	0	0	
	14 CAN Communication Based Restraint Switching Function		0: based on Y_EC (PGN 65308) 1: based on Y_ECR1 (PGN 65282)	0	0	0	0	0	
	15 Starting Motor Energization Time Control Function		0: Disabled 1: Enabled	0	0	0	0	0	
	16 Starting Aid Relay Fault Detection Function		0: Disabled 1: Enabled	1	1	1	1	1	

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	Item	Unit	Setting	Base engine	Driven machine specific standard: Backhoes	Tractors	Loaders	Generators	Customer spec
2	17 Starting Aid Control Function: On-Glow		0: Disabled 1: Enabled (can be disabled using CAN communication command)	1	1	1	1	1	
	18 Starting Aid Control Function: Simultaneous Energizing		0: Disabled 1: Enabled (can be disabled using CAN communication command)	1 (mandatory)	1	1	1	1	
	19 Starting Aid Control Function: After Heat		0: Disabled 1: Enabled (can be disabled using CAN communication command)	0 (1: recommended)	0	0	0	0	
	20 CAN Communication Based Starting Aid Control Function		0: Disabled 1: Enabled	0	0	0	0	0	
	21 Speed Selection Function Setup		0: Constant speed control, APP-IP6 = toggle type switch 1: Constant speed control, APP-IP6 = momentary type switch 2: Deceleration control, APP-IP6 = toggle type switch 3: Deceleration control, APP-IP6 = momentary type switch 4: Reserved 5: Auto deceleration control, APP-IP6 = toggle type switch 6: Disabled	0	0	0	0	0	
	22 Auto Deceleration Wait Time	s		4	4	4	4	4	
	23 Auto Deceleration Accelerator Disconnection		0: Disabled 1: Enabled	0	0	0	0	0	
	Constant Speed Control								
	24 Constant Speed 1	min^{-1}		1800	1800	1800	1800	1800	
	25 Constant Speed 2	min^{-1}		1500	1500	1500	1500	1500	
	Deceleration Control								
	26 Deceleration Start Speed	min^{-1}		1500	1500	1500	1500	1500	
	27 Deceleration Rate 1	%		85	85	85	85	85	
	28 Deceleration Rate 2	%		70	70	70	70	70	
	30 CAN Immobilizer		0: Disabled 1: Enabled	0	0	0	0	0	
	32 Idle Up Function		0: Disabled 1: Enabled	1 (mandatory)	1	1	1	0	
	33 Blue/White Smoke Suppression Control (Low-Temperature High Idle Down Function)		0: Disabled 1: Enabled	0 (1: recommended)	0	0	0	0	
	34 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	0	0	0	0	0	
	35 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	0	0	0	0	0	
	43 Cooling Water Temperature High Alarm Setup		0: Disabled 1: Enabled	1	1	1	1	1	
3	ECU Terminal Function Setup								
	1 APP-IP1 Terminal (E24) Logic Setup		0: Input for NO switch 1: Input for NC switch	1	1	1	1	0	
	2 APP-IP1 Terminal (E24) Function Input Setup		Setting / Droop Selection / Starting Motor Permission/Restraint / Spare / Spare	1	1	1	1	1	
			0 / None / None / - / -						
			1 / APP-IP1 / CAN / - / -						
			2 / CAN / APP-IP1 / - / -						
			3 / CAN / APP-IP1/ CAN / - / -						
			4 / CAN / CAN / - / -						
	3 APP-IP7 Terminal (E13) Logic Setup		0: Input for NO switch 1: Input for NC switch	0	0	0	0	0	

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Item		Unit	Setting					Base engine	Driven machine specific standard				Customer spec
									Backhoes	Tractors	Loaders	Generators	
3	4 APP-IP7 Terminal (E13) Function Input Setup		Setting	Spare	Engine Stop 2	High Idle Selection	Foot Pedal switch - NC	2	2	2	2	2	
			0	None	None	None	None						
			1	APP-IP7	CAN	CAN	None						
			2	CAN	APP-IP7/ CAN	CAN	None						
			3	CAN	CAN	APP-IP7	None						
			4	CAN	CAN	CAN	APP-IP7						
			5	CAN	CAN	CAN	None						
	5 APP-IP2 Terminal (E14) Logic Setup		0: Input for NO switch 1: Input for NC switch					0	0	0	0	0	
	6 APP-IP2 Terminal (E14) Function Input Setup		Setting	Spare	Oil pressure switch	Spare	Foot Pedal switch - NO	1	1	1	1	1	
			0	None	None	None	None						
			1	APP-IP2	None	CAN	None						
			2	CAN	APP-IP2	CAN	None						
			3	CAN	None	APP-IP2	None						
			4	CAN	None	CAN	APP-IP2						
			5	CAN	None	CAN	None						
	7 APP-IP3 Terminal (E9) Logic Setup		0: Input for NO switch 1: Input for NC switch					0	0	0	0	0	
	8 APP-IP3 Terminal (E9) Function Input Setup		Setting	Speed Selection 1	Charge Alarm	Spare	Spare	1	1	1	1	1	
			0	None	None	None	None						
			1	APP-IP3	None	None	None						
			2	CAN	APP-IP3	None	None						
			3	CAN	None	APP-IP3	None						
			4	CAN	None	None	APP-IP3						
			5	CAN	None	None	None						
	9 APP-IP4 Terminal (E17) Logic Setup		0: Input for NO switch 1: Input for NC switch					0	0	0	0	0	
	10 APP-IP4 Terminal (E17) Function Input Setup		Setting	Speed Selection 2	Spare	Spare	Starter Motor permission/ restraint	1	1	1	1	1	
			0	None	None	None	None						
			1	APP-IP4	None	None	None						
			2	CAN	APP-IP4	None	None						
			3	CAN	None	APP-IP4	None						
			4	CAN	None	None	APP-IP4						
			5	CAN	None	None	None						
	11 APP-IP5 Terminal (E5) Logic Setup		0: Input for NO switch 1: Input for NC switch					0	0	0	0	0	
	12 APP-IP5 Terminal (E5) Function Input Setup		Setting	Spare	Air Cleaner Sensor	Spare	High Idle Limit	2	2	2	2	2	
			0	None	None	None	None						
			1	APP-IP5	None	CAN	CAN						
			2	CAN	APP-IP5	CAN	CAN						
			3	CAN	None	APP-IP5	CAN						
			4	CAN	None	CAN	APP-IP5						
			5	CAN	None	CAN	CAN						
	13 APP-IP6 Terminal (E6) Logic Setup		0: Input for NO switch 1: Input for NC switch					0	0	0	0	0	

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<table>
<tr><th rowspan="2"></th><th rowspan="2">Item</th><th rowspan="2">Unit</th><th rowspan="2" colspan="5">Setting</th><th rowspan="2">Base engine</th><th colspan="4">Driven machine specific standard</th><th rowspan="2">Customer spec</th></tr>
<tr><th>Backhoes</th><th>Tractors</th><th>Loaders</th><th>Generators</th></tr>
<tr><td rowspan="6">3</td><td rowspan="6">14 APP-IP6 Terminal (E6) Function Input Setup</td><td rowspan="6"></td><td>Setting</td><td>Speed Selection Permission</td><td>Diesel Fuel Filter/Water Separator</td><td>Spare</td><td>Spare</td><td rowspan="6">1</td><td rowspan="6">1</td><td rowspan="6">1</td><td rowspan="6">1</td><td rowspan="6">1</td><td></td></tr>
<tr><td>0</td><td>None</td><td>None</td><td>None</td><td>-</td><td></td></tr>
<tr><td>1</td><td>APP-IP6</td><td>None</td><td>CAN</td><td>-</td><td></td></tr>
<tr><td>2</td><td>CAN</td><td>APP-IP6</td><td>CAN</td><td>-</td><td></td></tr>
<tr><td>3</td><td>CAN</td><td>None</td><td>APP-IP6</td><td>-</td><td></td></tr>
<tr><td>4</td><td>CAN</td><td>None</td><td>CAN</td><td>-</td><td></td></tr>
<tr><td></td><td>15 SHUDNSW Terminal (E15) Logic Setup</td><td></td><td colspan="5">0: Input for NO switch
1: Input for NC switch</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td></td></tr>
<tr><td></td><td>16 APP-OP1 Terminal (E20) Function Setup</td><td></td><td colspan="5">0: Starter Motor Relay
1: Reserved
2: Reserved</td><td>0 (mandatory)</td><td>0</td><td>0</td><td>0</td><td>0</td><td></td></tr>
<tr><td></td><td>17 APP-OP2 Terminal (E2) Function Setup</td><td></td><td colspan="5">0: Reserved
1: Block heater relay output (connected with block heater)
2: Speed change indicator lamp output (lit when speed selection is permitted)
3: Cooling water temperature alarm lamp output</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td></td></tr>
<tr><td></td><td>18 APS Terminal (E35) Function Input Setup</td><td></td><td colspan="5">0: Disabled (without acceleration sensor fault detection)
1: Analog input
2: SAE foot pedal (synchronized with NO & NC switch)
3: SAE foot pedal (synchronized with NO switch)
4: SAE foot pedal (synchronized with NC switch)</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td></td></tr>
<tr><td></td><td>19 REAN Terminal (E37) Function Input Setup</td><td></td><td colspan="5">0: Disabled (without acceleration sensor fault detection)
1: Analog input
2: SAE foot pedal (synchronized with NO & NC switch)
3: SAE foot pedal (synchronized with NO switch)
4: SAE foot pedal (NC switch)
5: Reserved</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td></td></tr>
<tr><td></td><td>20 RENRPM Terminal (E10) Function Setup</td><td></td><td colspan="5">0: Backup speed sensor disabled
1: Backup speed sensor enabled
2: Speed sensor enabled (without backup speed sensor error detection)</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td></td></tr>
<tr><td>4</td><td>Fault Handling Actions</td><td></td><td colspan="5"></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>1 Cooling Water Temperature High Alarm Handling Action</td><td></td><td colspan="5">0: No restriction on operation
1: Speed Limit A
2: Speed limited to 1800min^{-1}
3: Output limited to 92%
4: Speed Limit A + output limit
5: Speed limited to 1800min^{-1} and output limited to 92%
6: Engine stop
7: Time-delayed engine stop</td><td>0</td><td>0</td><td>0</td><td>0</td><td>3</td><td></td></tr>
<tr><td></td><td>4 Acceleration sensor Fault Handling Action</td><td></td><td colspan="5">0: Low idle
1: Acceleration sensor Fault Speed A
2: 1800 min^{-1}
3: Engine stop
4: Engine stop
5: Engine stop
6: Engine stop
7: Time-delayed engine stop</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td></td></tr>
<tr><td></td><td>8 Oil Pressure Low Fault Handling Action</td><td></td><td colspan="5">0: No restriction on operation
1: Speed Limit A
2: Speed limited to 1800min^{-1}
3: Output limited to 92%
4: Speed Limit A + output limit
5: Speed limited to 1800min^{-1} and output limited to 92%
6: Engine stop
7: Time-delayed engine stop</td><td>0</td><td>0</td><td>0</td><td>0</td><td>6</td><td></td></tr>
<tr><td></td><td>10 Air Cleaner Clog Alarm Handling Action</td><td></td><td colspan="5">0: No restriction on operation
1: Speed Limit A
2: Speed limited to 1800min^{-1}
3: Output limited to 92%
4: Speed Limit A + output limit
5: Speed limited to 1800min^{-1} and output limited to 92%
6: Engine stop
7: Time-delayed engine stop</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td></td></tr>
</table>

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Item		Unit	Setting	Base engine	Driven machine specific standard				Customer spec
					Backhoes	Tractors	Loaders	Generators	
4	11 Diesel Fuel Filter/Water Separator Alarm Handling Action		0: No restriction on operation 1: Speed Limit A 2: Speed limited to 1800min^{-1} 3: Output limited to 92% 4: Speed Limit A + output limit 5: Speed limited to 1800min^{-1} and output limited to 92% 6: Engine stop 7: Time-delayed engine stop	0	0	0	0	0	
	12 Action during Backup Speed Sensor Operation		0: No restriction on operation 1: Speed Limit A 2: Speed limited to 1800min^{-1} 3: Output limited to 92% 4: Speed Limit A + output limit 5: Speed limited to 1800min^{-1} and output limited to 92% 6: Engine stop 7: Time-delayed engine stop	2	2	2	2	0	
	13 Error Occurrence Time Selection		0: Total engine operating hours 1: Total ECU energized hours 2: CAN communication receiving hours	0	0	0	0	0	
5	CAN Setup								
	1 Communication speed		0: 500 Kbps 1: 250 Kbps	1	1	1	1	1	
6	Other								

Section 15

ON-VEHICLE COMMUNICATION CAN SPECIFICATION

Page

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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.

(a) 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.

(b) Y-LINK allows sharing engine data with electronic monitor displays and vehicle management information system via J1939 data link.

(c) E-ECU can receive the operation messages from the vehicle control unit via J1939 data link.

(d) E-ECU transmits and performs diagnostic procedures from TESTER via ISO 15765 data link.

(e) Y-LINK allows transmitting customer requested change to the E-ECU from the external equipment via ISO 15765 data link.

This document dose not includes communication protocols of ISO 15765.

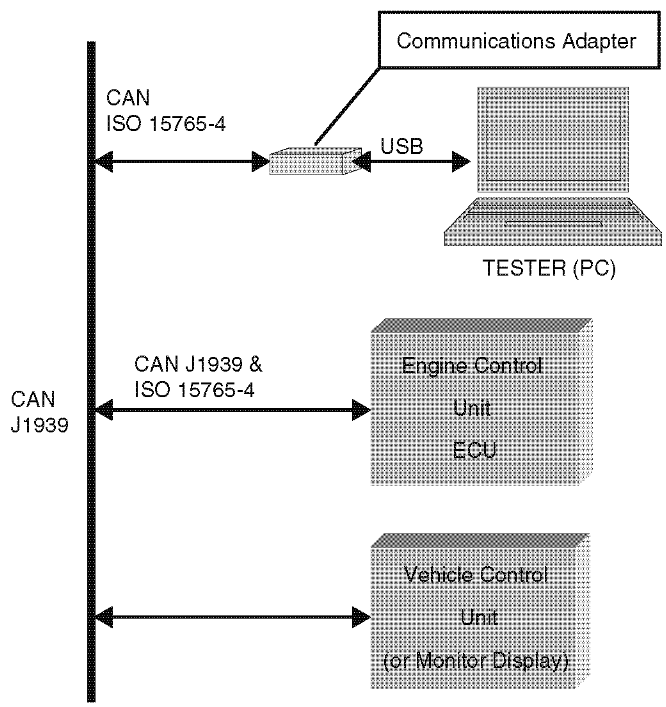


Fig. 15-1 **CAN-BUS Diagram**

COMMUNICATION PROTOCOLS

The following table shows a comparison between 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	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 • Single frame • Multi-packet BAM • Request/Acknowledge • Proprietary B	ISO11898, ISO15765-4
	Network (layer 3)		ISO15765-2, ISO15765-4	J1939-31	-	ISO15765-2, ISO15765-4
	Transport (layer 4)		-	-	-	-
	Session (layer 5)		ISO15765-4	-	-	ISO15765-4
	Presentation (layer 6)		-	-	-	-
	Application (layer 7)	Diagnostics	ISO15031-5	SAE J1939-73	SAE J1939-73(DM1~3)	ISO 14230-3
		Implement	-	-	-	ISO 15765-3
		Drivetrain	-	SAE J1939-71	SAE J1939-71	-
		Management	-	SAE J1939-81	-	-

Data Link Layer

The data link layer is based on SAE J1939-21 Revised April 2001.

Message/Frame Format

"CAN 2.0B" Extended Frame Format
Nominal bit rate: 250kbps (500kbps 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

29bit CAN normal fixed addressing

Address mapping (SA)

E-ECU can receive the message from other ECU with a given any source address. It is necessary to prevent duplication of source addresses. 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
For example		
	17 (11H)	Physical CAN identifier of Cruise Control Equipment
	39 (27H)	Management Computer #1
255 (0FFH)		Global (All-Any Node)

Communication Methods

- Single frame message : data length =< 8bytes
- Multi-packet Broadcast message : data length > 8bytes
  (Multi-packet RTS/CTS session is under development.)
- Multi-packet Broadcast message is used to send DTCs (Diagnostic Trouble Code) and component ID etc.

Table 15-3 indicates which service item is required which set of Request/Response procedure.

Table 15-3 Request and Response Requirements

No.	Item	Description	Data length	Request PGN 59904	Response	TP Used
1	J1939-71 Application Layer Send/Receive Message	Single frame message	≤8bytes	None	DA Global	NA
2	Active Diagnostic Trouble Code	Multi-packet message Global Destination	>8bytes	None	DA Global	BAM
3	Previously Active Diagnostic Trouble Code	On request Global, Multi-packet message Global Destination	>8bytes	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	On request, Acknowledgement	≤8bytes	DA Global	DA Global	NA
		On request Specific, Acknowledgement		DA Specific	DA Global	NA

*.TP=Transport Protocol , BAM=Broadcast Announce Message

Note: Specific destination request session is under development.

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

1. If the Request is sent to a global address, then the response is sent to a global address.
   (a) NOTE: A NACK is not permitted as a response to a global request.
2. If the Request is sent to a specific address, then the response is sent to a specific address.
   (a) NOTE: A NACK is required if the PGN is not supported.
   (b) If the data length is more than 8 bytes, the Transport Protocol RTS/CTS must be used for the response to a specific address.
   (c) Exceptions:
      i) PDU2 format PGNs with 8 bytes or less can only be sent to a global destination because there is no destination address field in the PDU2 Format.
      ii) The Address Claim PGN is sent to the global destination address even though the request for it may have been to a specific destination address (see J1939-81).(N/A)
      iii) The Acknowledgment PGN response uses a global destination address even though the PGN that causes Acknowledgment was sent to a specific destination address.

ON-VEHICLE COMMUNICATION CAN SPECIFICATION

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: 250kbps (500kbps is option)

CAN bit timing

Sample Point = 75%
tsync = 1tp, TSEG1 = (7+4)tp , TSEG2 = 4tp

RECEIVE and SEND MESSAGE CAN ID SUMMARY

(See Appendix A)

MESSAGE FORMAT

J1939-71 Application Layer

(See 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 <N/A>	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**	1136
5-6	2 bytes	Engine Differential Pressure<N/A>	411
7-8	2 bytes	Engine EGR Temperature<N/A>	412

pgn65247 - Electronic Engine Controller #3 - EEC3 -

Transmission Repetition Rate:		250 msec	
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 “*”	

pgn65262 - Engine Temperature #1 - ET1 -

Transmission Repetition Rate:	1000 ms
Data Length:	8 bytes
Data Page:	0
PDU Format:	254
PDU Specific:	238
Default Priority:	6
Parameter Group Number:	65262 (0x00FEEE)

Bit Start Position/Bytes	Length	SPN Description	SPN
1	1 byte	**Engine Coolant Temperature**	110
2	1 byte	Fuel Temperature<N/A>	174
3-4	2 bytes	Engine Oil Temperature 1 <N/A>	175
5-6	2 bytes	Turbo Oil Temperature<N/A>	176
7	1 byte	Engine Intercooler Temperature<N/A>	52
8	1 byte	Engine Intercooler Thermostat Opening<N/A>	1134

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<N/A>	171
6	1 byte	Air Inlet Temperature<N/A>	172
7-8	2 bytes	Road Surface Temperature<N/A>	79

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 -

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:See Figures PGN56320_D for examples of Anti-theft message transfers. Bit 1 is the right most bit in each byte.

pgn56576 - Anti-theft Request - ATR -

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:See 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>

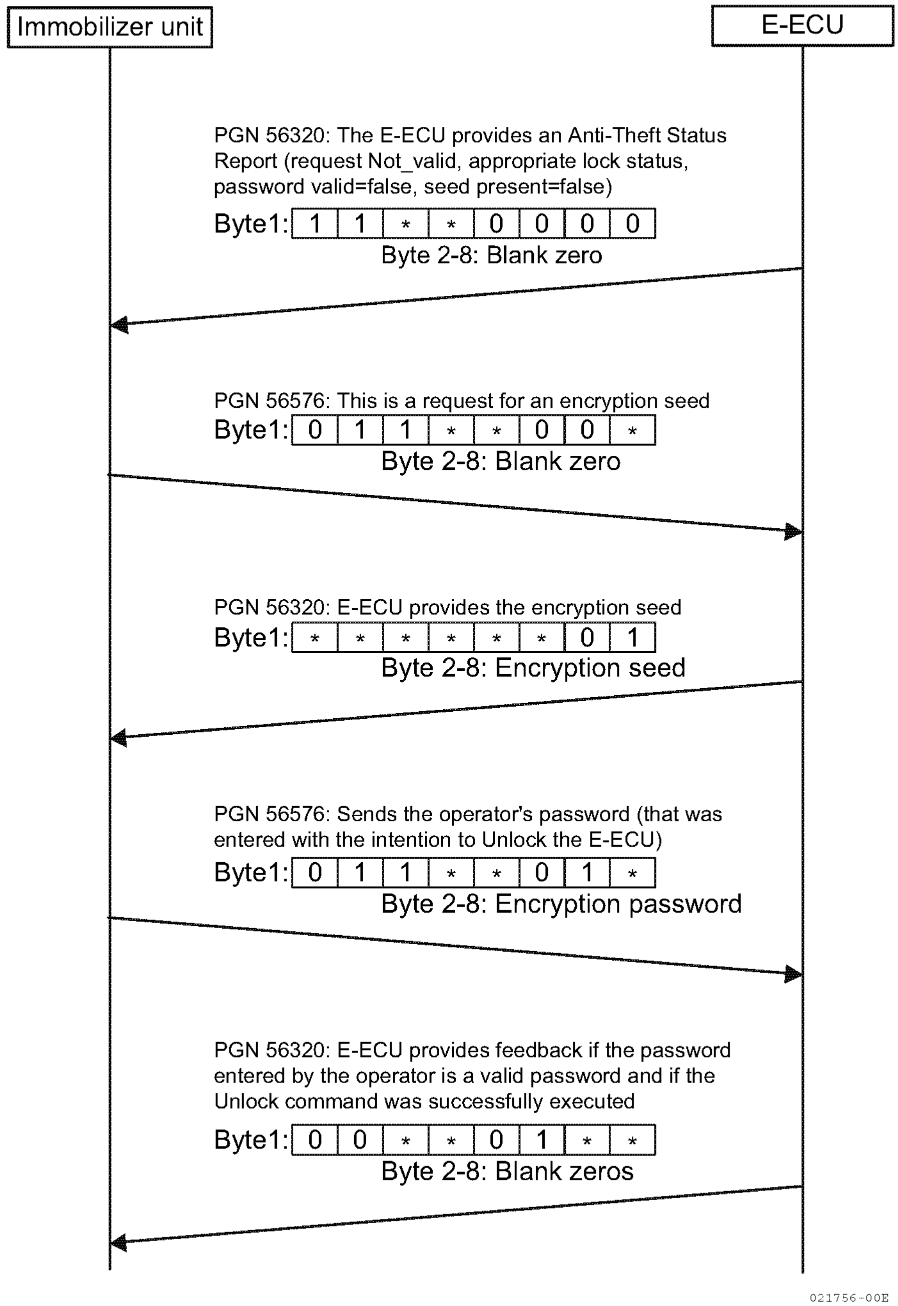


Fig. 15-2 **PGN56320 - Operator desires to unlock the E-ECU<R.1.1>**

J1939-21 Data Link Layer

(See 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 to 3	See definitions below
	4 to 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
	3-5	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	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
	3-5	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	6-8	Parameter Group Number of requested information (see 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
	3-5	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	6-8	Parameter Group Number of requested information (see 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
	3-5	Reserved for assignment by SAE, these bytes should be filled with 0xFF
	6-8	Parameter Group Number of requested information (see 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 to 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

* This priority is set to be equal to the priority of single packet transfer.

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 to 1785 (2 bytes), zero to 8 and 1786 to 65535 not allowed
Total Number of Packets:	2 to 255 (1 byte), zero not allowed
Maximum Number of Packets:	2 to 255 (1byte), zero through 1 are not allowed
Number of Packets that can be sent:	0 to 255 (1 byte)
Next Packet Number to be sent:	1 to 255 (1 byte), zero not allowed
Sequence Number:	1 to 255 (1 byte), zero not allowed

* This priority is set to be equal to the priority of single packet transfer.

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

J1939-73 Diagnostic Layer

(See Appendix B)

ACTIVE DIAGNOSTIC TROUBLE CODES (DM1)

Transmission Rate: A DM1 message is transmitted whenever a DTC becomes an active fault and at a normal update rate of only once per second thereafter. If a fault has been active for 1 second or longer, and then becomes inactive, a DM1 message shall be transmitted to reflect this state change. If a different DTC changes state within the 1 second update period, a new DM1 message is transmitted to reflect this new DTC. To prevent a high message rate due to intermittent faults that have a very high frequency, it is recommended that no more than one state change per DTC per second be transmitted. Thus a DTC that becomes active/ inactive twice within a 1 second interval, such as shown in Example Case 1, would have one message identifying the DTC becoming active, and one at the next periodic transmission identifying it being inactive. This message is sent only when there is an active DTC existing (lamp status are not zeros).

Note that this Parameter Group will require using the “multi-packet Transport” Parameter Group (reference SAE J1939-21) when more than one active DTC exists.

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	Reserved for SAE assignment Lamp Status <N/A> 0xFF
2.3	2 bits	Reserved for SAE assignment Lamp Status <N/A>
2.5	2 bits	Reserved for SAE assignment Lamp Status <N/A>
2.7	2 bits	Reserved for SAE assignment Lamp Status <N/A>
3	1byte	SPN, 8 least significant bits of SPN (most significant at bit 8)
4	1byte	SPN, second byte of SPN (most significant at bit 8)
5.6	3bits	SPN, 3 most significant bits (most significant at bit 8)
5.1	5bits	FMI (most significant at bit 5)
6.1	7bits	Occurrence Count
6.8	1bit	SPN Conversion Method

<table>
<tr><td rowspan="3">Version 4.
Recommended
Version</td><td colspan="32">DTC</td></tr>
<tr><td colspan="8">Byte 3
8 least significant bits of SPN
(bit 8 most significant)</td><td colspan="8">Byte 4
second byte of SPN
(bit 8 most significant)</td><td colspan="8">Byte 5
3 most significant bits of SPN and the FMI
(bit 8 SPN msb and bit 5 FMI msb)</td><td colspan="8">Byte 6</td></tr>
<tr><td colspan="19">SPN</td><td colspan="5">FMI</td><td>CM</td><td colspan="7">OC</td></tr>
<tr><td rowspan="2">J1939 Frame Format</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td></tr>
</table>

EXAMPLE1 : 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.

EXAMPLE2 : The following illustrates the message format for when a request of the DM1 is made and there are zero active faults.

Byte1 is Zero.
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
Byte2	bits 1-2	= 11
	bits 3-4	= 11
	bits 5-6	= 11
	bits 7-8	= 11
Byte3-6	SPN	=0
	FMI	=0
	OC	=0
	CM	=0
Byte 7		=255
Byte8		=255

EXAMPLE3 : Three cases are enumerated as follows to define the transmission rate requirements (Figure1.)

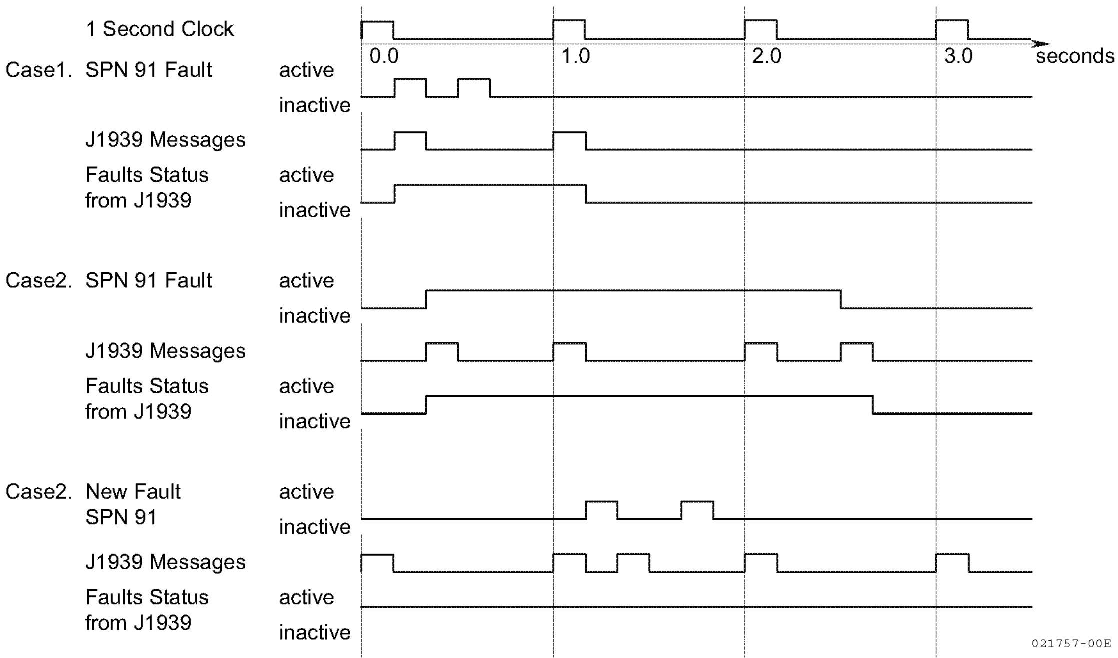


Fig. 15-3 **Defining the Transmission Rate Requirements**

Case 1 illustrates that not every transition of a fault (active to inactive or inactive to active) results in a SAE J1939 message being sent. In this case, there are no other faults active when the example SPN 91 fault occurs. The SPN 91 fault is the Accelerator Pedal Position parameter which has an update faster than once a second.
The “SAE J1939 Message” (DM1 message) will be sent every 1 second while this fault is active. The first SAE J1939 message is sent when the "SPN 91 fault" becomes active on the first occurrence and not when it goes inactive for the first occurrence or active/inactive for the second occurrence. The inactive state is sent once at the next normal 1-second update (T=1 second). The “SAE J1939 Message” (DM1) is required to be sent at the 1 second interval even though the fault is no longer active and the actual DM1 message will contain no active faults. This is done as the action to show the fault went away. The way this is done for this specific case (where there are no longer any active faults) is as shown in the preceding Example 2. If there were other active faults they would have been sent in this message.
If the second SPN 91 would have been a different SPN it would have been sent prior to the 1 second in a DM1 sent in between normal 1 second updates. The 1 second interval message would not contain this new SPN or SPN 91 assuming they both transitioned on and off before the 1 second message. Therefore, the 1 second DM1 message would still contain no faults.

Case 2 illustrates that the transition states can occur between the normal 1 second intervals. Therefore, a “SAE J1939 Message” is sent in between time equals 0 and time equals 1 to indicate that the SPN 91 fault has gone active. It is sent per the normal 1 second update at the 1 and 2 second points. It is sent at the time between 2 and 3 second to convey the transition to the inactive state. To do this the "J1939 Message" (DM1) is sent as shown in the preceding Example 2.

Case 3 shows the situation where there are already active faults in existence when SPN 91 becomes active.
Note that the transition of SPN 91 to active state is sent between the 1 and 2 second points. The message contains all active faults, not just the new one. The transition to the inactive state is sent during the normal 2second update. This message would contain all active faults and since SPN 91 went inactive it would not be in this message.

PREVIOUSLY ACTIVE DIAGNOSTIC TROUBLE CODES (DM2)

Transmission Rate:		On request using PGN 59904 See SAE J1939-21 A NACK is required if PG is not supported (see 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	Reserved for SAE assignment Lamp Status <N/A> 0xFF
2.3	2 bits	Reserved for SAE assignment Lamp Status <N/A>
2.5	2 bits	Reserved for SAE assignment Lamp Status <N/A>
2.7	2 bits	Reserved for SAE assignment Lamp Status <N/A>
3	1byte	SPN, 8 least significant bits of SPN (most significant at bit 8)
4	1byte	SPN, second byte of SPN (most significant at bit 8)
5.6	3bits	SPN, 3 most significant bits (most significant at bit 8)
5.1	5bits	FMI (most significant at bit 5)
6.1	7bits	Occurrence Count
6.8	1bit	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
Byte7		=255
Byte8		=255

DIAGNOSTIC DATA CLEAR/RESET OF PREVIOUSLY ACTIVE DTCS (DM3)

Transmission Rate:	On request using PGN 59904 See SAE J1939-21 A NACK is required if PG is not supported (see 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)

Note : If system voltage is below normal operational range for EEPROM Writing, E-ECU will respond with a NACK.

YANMAR Proprietary PGN

(See Appendix C)

CAN Communication Functionality

Shutdown

Shutdown request signal

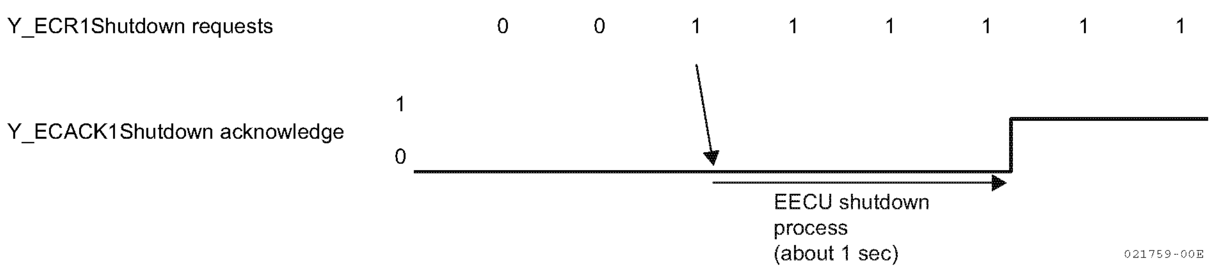
Description	PGN Number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direction	EECU	note
Y_ECR1	65282	NA	NA	10ms	2	3-4	Shutdown requests	V=>E	available	0:No shutdown request (normal state) 1:Shutdown request (EECU begins the shutdown processing.)
							PTO Switch		Not available	
							Parking brake switch		Not available	
					2	7-8	Power supply/ Key position		available	0,1:Auto preheat/ afterheat is disabled 2:Auto preheat/ afterheat is enabled 3:The starter is permitted.
							Accelerator pedal low idle switch		Not available	
							Water separator drain switch status		Not available	
					4	1-8	Accelerator pedal position		available	0-100%
							Vehicle speed		Not available	
							Trim ramp		Not available	
							Control or trim state		Not available	
							Control or trim mode		Not available	
							Control or trim data		Not available	

Shutdown acknowledgement signal

Description	PGN Number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direction	EECU	note
Y_ECACK1	65292	0	3	100ms	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 (Airheat Relay Error) 3:NA ("preheat" only, not include "afterheat" and "air heat at cranking")
					2	8	Shutdown acknowledge		available	0:Power off not allowed 1:Power off allowed (Finished shutdown)

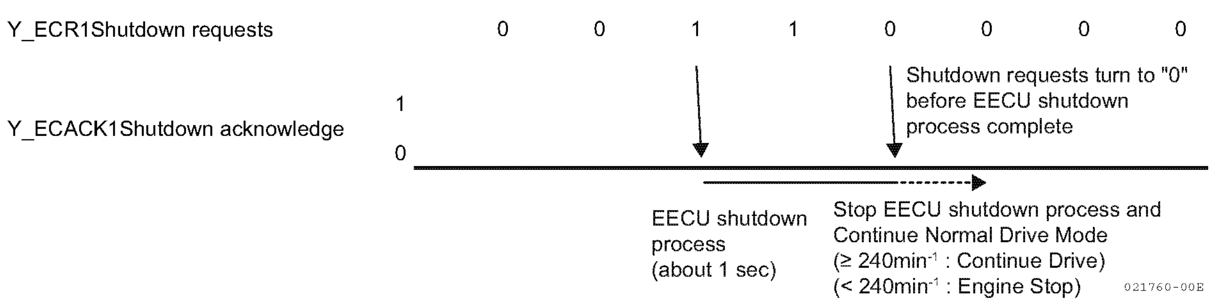
Shutdown process

1) Normal process



Shutdown acknowledgement turn to "1", only when EECU received shutdown requests and has finished shutdown process.

2) In case of cancellation of shutdown request on the shutdown process



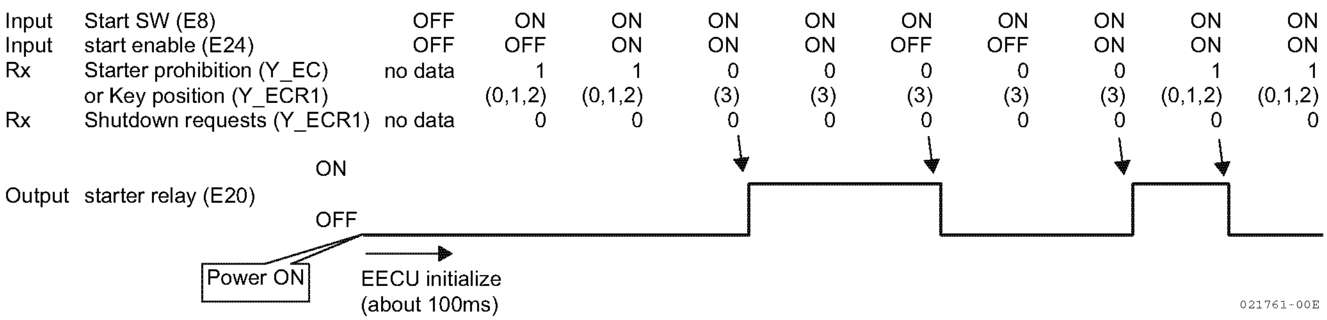
IF engine is stopped by failure (ex. Over speed condition), shutdown acknowledgement not turn to "1".

Start Lock

Starter prohibition request signal

Description	PGN Number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direc tion	EECU	note
Y_ECR1	65282	NA	NA	10ms	2	3-4	Shutdown requests	V=>E	available	0:No shutdown request (normal state) 1:Shutdown request (EECU begins the shutdown processing.)
							PTO Switch		Not available	
							Parking brake switch		Not available	
					2	7-8	Power supply/ Key position		available	0,1:Auto preheat/ afterheat is disabled 2:Auto preheat/ afterheat is enabled 3:The starter is permitted.
							Accelerator pedal low idle switch		Not available	
							Water separator drain switch status		Not available	
					4	1-8	Accelerator pedal position		available	0-100%
							Vehicle speed		Not available	
							Trim ramp		Not available	
							Control or trim state		Not available	
							Control or trim mode		Not available	
							Control or trim data		Not available	
Y_EC	65308	NA	NA	100ms	1	5	Starter prohibition	V=>E	available	0:Permission 1:Prohibition

Cranking Condition



Even after cranking, if Start enable becomes OFF or Shutdown request comes from VECU, EECU stop engine.

Y_ECR1		E8	E24	Y_EC (standard) (*2)	Y_ECR1 (option) (*2)	E20
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.

Air-Heat function

Preheat/afterheat enable/disable signal

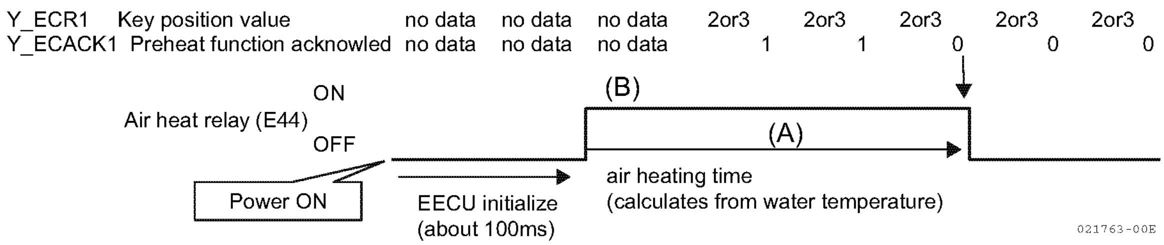
Description	PGN Number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direc tion	EECU	note
Y_ECR1	65282	NA	NA	10ms	2	3-4	Shutdown requests	V=>E	available	0:No shutdown request (normal state) 1:Shutdown request (EECU begins the shutdown processing.)
							PTO Switch		Not available	
							Parking brake switch		Not available	
					2	7-8	Power supply/ Key position		available	0,1:Auto preheat/ afterheat is disabled 2:Auto preheat/ afterheat is enabled 3:The starter is permitted.
							Accelerator pedal low idle switch		Not available	
							Water separator drain switch status		Not available	
					4	1-8	Accelerator pedal position		available	0-100%
							Vehicle speed		Not available	
							Trim ramp		Not available	
							Control or trim state		Not available	
							Control or trim mode		Not available	
							Control or trim data		Not available	

Preheat/afterheat acknowledgement signal

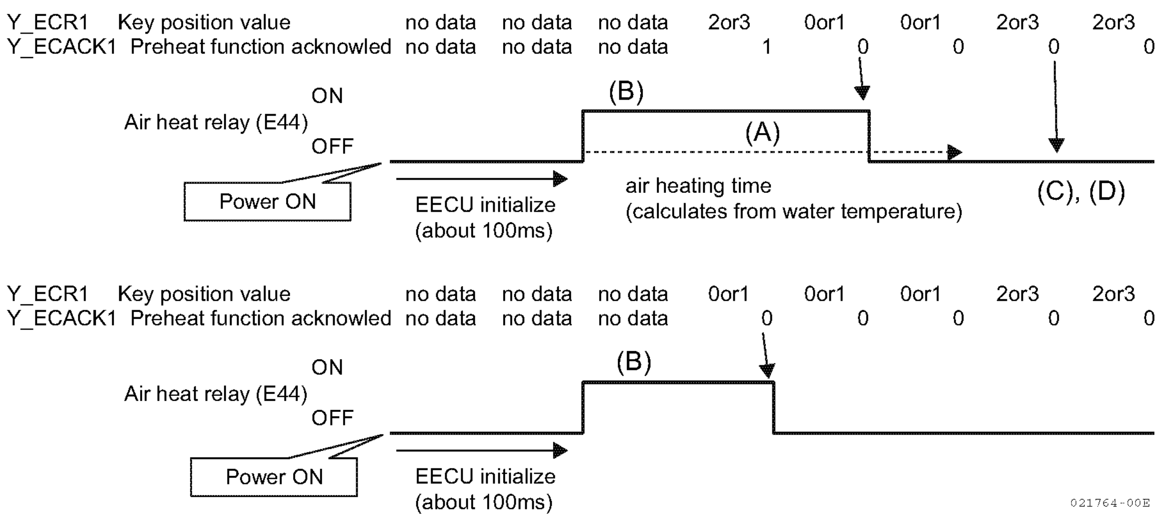
Description	PGN Number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direc tion	EECU	note
Y_ECACK1	65292	0	3	100ms	2	4-5	Preheat function acknowledge (State of preheat energizing)	E=>V	available	0:Not active (Preheat OFF) 1:Active (Preheat ON) 2:Error indicator (Airheat Relay Error) 3:NA ("preheat" only, not include "afterheat" and "air heat at cranking")
					2	8	Shutdown acknowledge		available	0:Power off not allowed 1:Power off allowed (Finished shutdown)

Air-heat function

1) Auto preheat /post heat



2) Disable auto preheat /post heat



Note:

(A) EECU calculates air-heating time from the water temperature, and controls air heater relay automatically.

(B) EECU automatically starts preheating after boot up process.

(C) Once VECU disables to preheat, auto post heat (include at cranking time) is disabled too.

(D) Once VECU disables to preheat, EECU doesn't start preheating even if VECU set enable bit in Y_ECR1 later. This condition is only canceled by power-on reset of EECU.

Engine Speed control

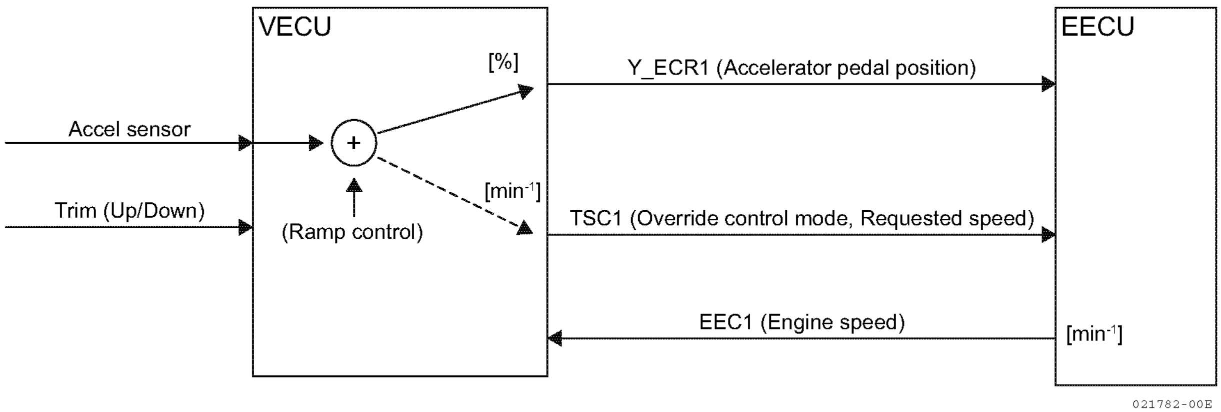
Speed control signal

Description	PGN Number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direc tion	EECU	note
Y_ECR1	65282	NA	NA	10ms	2	3-4	Shutdown requests	V=>E	available	0:No shutdown request (normal state) 1:Shutdown request (EECU begins the shutdown processing.)
							PTO Switch		Not available	
							Parking brake switch		Not available	
					2	7-8	Power supply/ Key position		available	0,1:Auto preheat/ afterheat is disabled 2:Auto preheat/ afterheat is enabled 3:The starter is permitted.
							Accelerator pedal low idle switch		Not available	
							Water separator drain switch status		Not available	
					4	1-8	Accelerator pedal position		available	0-100%
							Vehicle speed		Not available	
							Trim ramp		Not available	
							Control or trim state		Not available	
							Control or trim mode		Not available	
							Control or trim data		Not available	
TSC1	0	NA	3	10ms	1	1-2	Override Control Mode	V=>E	available	0:Override disable 1:Speed control 2,3:N/A (Override disable)
					2-3	1-16	Requested Speed	V=>E	available	A value of 0xFExx is sent as 'Error indicator' (At 0xFExx, EECU does the CAN (TSC1) error operation.)

Engine speed information signal

Description	PGN Number	SA	Priority	Transmission update period	Byte	Bit	Signal name	Direc tion	EECU	note
EEC1	61444	0	3	20ms	4-5	1-16	Engine Speed	E=>V	available	A value of 0xFExx is sent as 'Error indicator' ex.at rotation speed sensor error

Engine Speed control diagram



EECU controls the engine speed based on the value of "Accelerator pedal position" of Y_ECR1.

IF "Override control mode" equals to "Speed control mode", EECU controls the engine speed based on the value of "Requested speed" of TSC1.

Note:

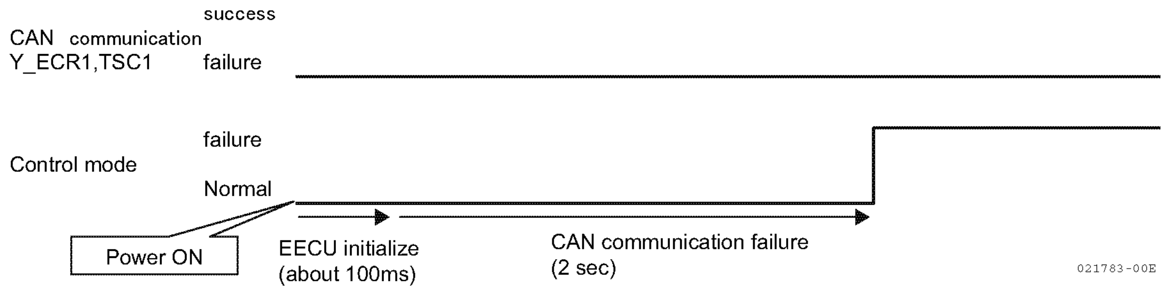
Exceptional conditions as below:

- Idle speed up
- Max/min speed limit
- Engine speed transition period
- EGR valve failure etc.

CAN communication failure

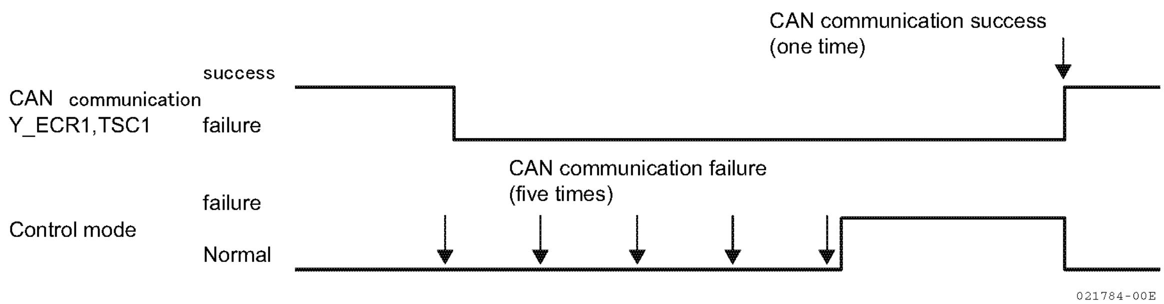
Detect CAN communication malfunction

1) At system start



When EECU cannot receive necessary information via CAN-BUS for two seconds* after power-on start, it considers that the CAN communication failure occurred.

2) After system start normally



When EECU cannot receive necessary information via CAN-BUS five times continuously, it is considers that the CAN communication failure occurred. (ex. period of five times: TSC1:10 x 5 ms, Y_ECR1:10 x 5 ms)

When EECU can receive necessary information via CAN-BUS for one time, it considers that the CAN communication has done normally.

Start lock at CAN communication failure mode

When EECU cannot receive Y_ECR1 or Starter Prohibition (65308) via CAN-BUS for two seconds* after power-on start, EECU will allow to start engine according to discrete input signals.

Y_ECR1		**E8**	**E24**	**Y_EC (standard)**	**Y_ECR1 (option)**	**E20**
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, EECU will select a speed control mode as bellow 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.1800min^{-1})	
			NG	-		CAN Error
NG	-	-	OK	OK		CAN Error
				N/A		CAN Error
			NG	-		CAN Error

EECU shutdown at CAN communication failure condition

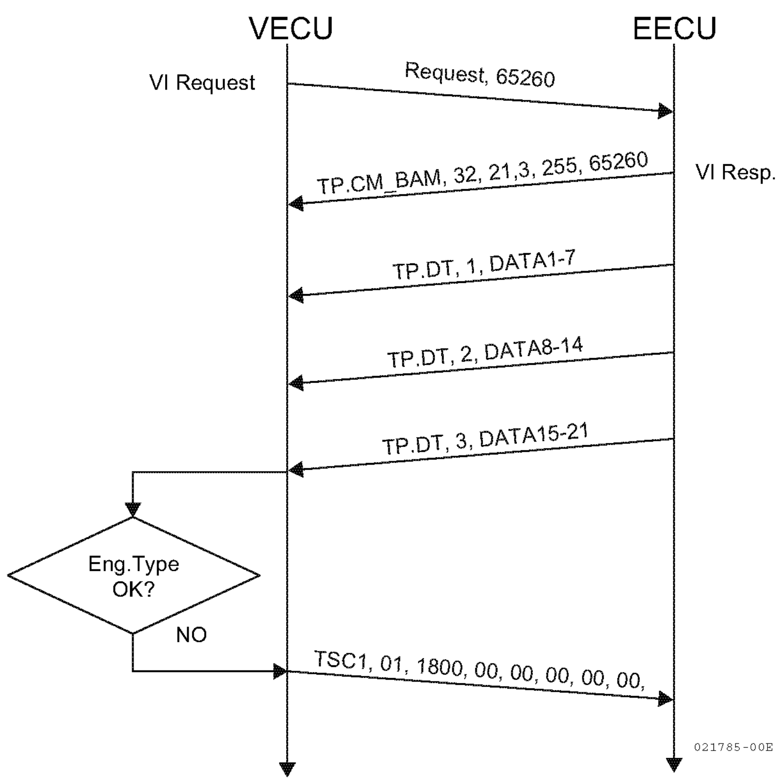
At CAN communication failure condition EECU doesn't execute the shutdown process, so log-data cannot be written in EEPROM (ex. Engine run time). There is a possibility that the new log-data is broken at power OFF, when EECU is writing the log-data in EEPROM temporarily.

There is no influence on driving the engine even if the new log-data has been broken.

Component ID Check

When EECU is replaced, it has no way to check the actual engine type. Therefore we recommend that VECU should check Component_ID of EECU. IF Component_ID is different from original one, VECU should turn to the derate_mode.

VECU can get vehicle manufacture specific component ID by VI Request, if VI has already written in EEPROM.



DIAGNOSTIC TROUBLE CODES (DTCS)

Listing of DTCs on E-ECU

(See 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	: 2G-ECO Governor Controller DTC Table

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
55808	18DAF****	Reserved for 15765 (Physical Addressed)	6	0	0	218	DA	SA	100ms	Variable	KWP2	R/S	Diagnostics on CAN (Physical Addressed)
56064	18DB****	Reserved for 15765 (Functional Addressed)	6	0	0	219	DA	SA	100ms	Variable	KWP1	R/S	Diagnostics on CAN (Functional Addressed)
0	0C0000**	Torque speed control	3	0	0	0	0	SA	10ms	8	TSC1	R	Override control mode, Requested speed
56320	1CDC0000	Anti-theft Status	7	0	0	0	DA	0	On request	8	ATS	S	Anti-theft Status
56576	1CDD00**	Anti-theft Request	7	0	0	0	DA	SA	As Needed	8	ATR	R	Anti-theft Request
61443	0CF00300	Electronic Engine Controller #2	3	0	0	240	3	0	50ms	8	EEC2	S	Accelerator pedal position, Load at current speed
61444	0CF00400	Electronic Engine Controller #1	3	0	0	240	4	0	20ms	8	EEC1	S	Actual engine %torque, Engine speed
65188	0CFEA400	Engine Temperature #2	3	0	0	254	164	0	1000ms	8	ET2	S	ECU temperature, EGR temperature
65247	0CFEDF00	Electronic Engine Controller #3	3	0	0	254	223	0	250ms	8	EEC3	S	Nominal friction %torque, Engine's desired speed
65253	18FEE500	Engine Hours, Revolutions	6	0	0	254	229	0	On request	8	HOURS	S	Total engine hours, Total engine revolution
65255	18FEE700	Vehicle Hours	6	0	0	254	231	SA	1000ms	8	VH	R	Total vehicle hours
65259	18FEEB00	Component Identification	6	0	0	254	235	0	On request	48	CI	S	ECU number, Engine serial number, Engine type,
65260	18FEEC00	Vehicle Identification	6	0	0	254	236	0	On request		VI	S	Vehicle Identification number
65262	18FEEE00	Engine Temperature #1	6	0	0	254	238	0	1000ms	8	ET1	S	Engine coolant temperature, fuel, oil,
65269	18FEF500	Ambient conditions	6	0	0	254	245	0	1000ms	8	AMB	S	Barometric pressure
65271	18FEF700	Vehicle Electrical Power	6	0	0	254	247	0	1000ms	8	VEP	S	Electrical potential
65282	0CFF02**	Engine control request 1	3	0	0	255	2	SA	10ms	8	Y_ECR1	R	Engine control request 1
65292	0CFF0C00	Engine control Acknowledge 1	3	0	0	255	12	0	100ms	8	Y_ECACK1	S	Engine control Acknowledge 1
65297	18FF1100	State of digital In/Out	6	0	0	255	17	0	100ms	8	Y_I/OS	S	Digital ports status
65298	18FF1200	Rack position control	6	0	0	255	18	0	20ms	8	Y_RPC	S	Actual rack position, Request rack position. Iset_raw
65300	18FF14**	Output Request	6	0	0	255	20	SA	On request	8	Y_OPR	R	Active Control Request
65301	18FF1500	Output Acknowledge	6	0	0	255	21	0	On request	8	Y_OPA	S	Active Control Answer
65302	18FF1600	Over load alarm command	6	0	0	255	22	0	On request	8	Y_OLS	R	Yanmar special PGN
65303	0CFF1700	Engine load	3	0	0	255	23	0	20ms	8	Y_LF	S	Engine percent load
65306	18FF1A00	Analog input	6	0	0	255	26	0	100ms	8	Y_AIN1	S	AD value (CW temp, Rack position, Accel sensor, Reserved analog)
65307	18FF1B00	Analog input2	6	0	0	255	27	0	100ms	8	Y_AIN2	S	AD value (Reserved temp, Intake temp, EGR temp)
65308	18FF1C**	Governor functions	6	0	0	255	28	SA	100ms	8	Y_EC	R	Droop/Isochrous, Reverse droop, Starter prevention
65309	0CFF1D**	Engine stop command	3	0	0	255	29	SA	On request	8	Y_STP	R	Engine stop
65310	18FF1E**	Speed selection functions	6	0	0	255	30	SA	10ms	8	Y_RSS	R	Constant speed, Constant deceleration
65311	18FF1F00	Engine control factor	6	0	0	255	31	0	20ms	8	Y_SRF	S	Engine stop factor, Starter prevention factor
65315	18FF2300	Lamp control	6	0	0	255	35	0	100ms	8	Y_TRS_S	S	Yanmar special PGN
65317	18FF2500	Diagnostic Trouble Code	6	0	0	0	37	0	On request	Variable	Y_TRS_DTC	S	Yanmar special PGN
65318	18FF2600	Engine speed specifications	6	0	0	255	38	0	250ms	8	Y_SRSI	S	Lo-idle speed, Hi-idle speed, Available max speed
65319	18FF2700	Engine control status	6	0	0	255	39	0	100ms	8	Y_ESI	S	Engine state information
59392	18E8FF00	Acknowledge/Negative Acknowledge	6	0	0	232	255	0	On request	8	Ack/Nack	S	Global Response
59904	18EAFF**	Request	6	0	0	234	255	SA	As Needed	3		R	Global Request
60160	1CEBFF00	TRANSPORT PROTOCOL-DATA TRANSFER	7*	0	0	235	255	0	As Required	8	TP.DT	S	
60416	1CECFF00	TRANSPORT PROTOCOL-CONNECTION MANAGEMENT	7*	0	0	236	255	0	As Required	8	TP.CM	S	Broadcast Announce Message Only
61184	18EF****	PROPRIETARY A (Development Tool)	6	0	0	239	DA	SA					Yanmar Proprietary
65226	18FECA00	Active Diagnostic Trouble Code	6	0	0	254	202	0	1000ms	Variable	DM1	S	Multi-packet Broadcast message
65227	18FECB00	Previously Active Diagnostic Trouble Code	6	0	0	254	203	0	On request	Variable	DM2	S	Multi-packet Broadcast message
65228		Diagnostic Data Clear/Reset of Previously Active DTCs				254	204		On request		DM3		Positive response = ACK

* This priority is set to be equal to the priority of single packet transfer.

APPENDIX B

PGN		Acronym											
0		TSC1											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
	1	1	2	Override Control Mode								695	
R				Override Disabled	00								"Accelerator pedal position" is enabled
R				Speed Control	01								"Requested Speed" is enabled
N/A				Torque Control	10								Ignored (Hold previous state)
N/A				Speed/Torque Limit	11								Ignored (Hold previous state)
N/A	1	3	2	Requested Speed Control Condition								696	Not available
N/A				Not available	11								
	1	5	2	Override Control Mode Priority								897	Not available
N/A				Highest	00								
N/A				High	01								
N/A				Medium	10								
N/A				Low	11								
N/A	1	7	2	not defined									
R	2	1	16	Requested Speed / Speed Limit		U16	0.125	0	0	8031.875	min^{-1}	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."
R				Error Indicator	FE**								
R				Not available	FF**								
N/A	4	1	8	Requested Torque / Torque Limit		U8	1	-125	-125	125	%	518	Not available
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
N/A	5	1	32	Not defined									

PGN		Acronym											
61443		EEC2											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
N/A	1	1	2	Accelerator Pedal Low Idle Switch								558	Not available
N/A				Accelerator pedal not in low idle condition	00								
N/A				Accelerator pedal in low idle condition	01								
N/A				Error Indicator	10								
S				Not available	11								
N/A	1	3	2	Accelerator Pedal Kickdown Switch								559	Not available
N/A				Kickdown passive	00								
N/A				Kickdown active	01								
N/A				Error Indicator	10								
S				Not available	11								
N/A	1	5	2	Road Speed Limit Status								1437	Not available
N/A				Active	00								
N/A				Not active	01								
N/A				Error Indicator	10								
S				Not available	11								
N/A	1	7	2	not defined									
S	2	1	8	Accelerator Pedal Position		U8	0.4	0	0	100	%	91	Droop mode hi-idle speed is 100%.
S				Error Indicator	FE								
S				Not available	FF								
S	3	1	8	Percent Load At Current Speed		U8	1	0	0	100	%	92	
S				Error Indicator	FE								When the load ratio cannot be calculated.
N/A				Not available	FF								
N/A	4	1	8	Remote Accelerator		U8	0.4	0	0	100	%	974	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
N/A	5	1	32	Not defined									

PGN		Acronym											
61444		EEC1											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
N/A	1	1	4	Engine/Retarder Torque Mode								899	Not available
N/A				Low idle governor/no request (default mode)	0000								
N/A				Accelerator pedal	0001								
N/A				Cruise control	0010								
N/A				PTO governor-N/A	0011								
N/A				Road speed governor	0100								
N/A				ASR control-N/A	0101								
N/A				Transmission control	0110								
N/A				ABS control-N/A	0111								
N/A				Torque limiting	1000								
N/A				High speed governor	1001								
N/A				Braking system-N/A	1010								
N/A				Remote Accelerator	1011								
N/A				not defined	1100								
N/A				not defined	1101								
N/A				Other	1110								
S				Not available	1111								
N/A	1	5	4	not defined									
N/A	2	1	8	Driver's Demand Engine - Percent Torque		U8	1	-125	-125	125	%	512	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
N/A	3	1	8	Actual Engine - Percent Torque		U8	1	-125	-125	125	%	513	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
S	4	1	16	Engine Speed		U16	0.125	0	0	8031.875	min^{-1}	190	
S				Error Indicator	FE**								
N/A				Not available	FF**								
N/A	6	1	8	Source Address of Controlling Device for Engine Control		U8	1	0	0	253		1483	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
	7	1	4	Engine Starter Mode								1675	
S				start not requested	0000								Available
S				starter active, gear not engaged	0001								Available
S				starter active, gear engaged	0010								Available
S				start finished	0011								Available
N/A				starter inhibited due to engine already running	0100								
N/A				starter inhibited due to engine not ready for start	0101								
N/A				starter inhibited due to driveline engaged	0110								
N/A				starter inhibited due to active immobilizer	0111								
N/A				starter inhibited due to starter over-temp	1000								
N/A				reserved	1001								
N/A				reserved	1010								
N/A				reserved	1011								
N/A				reserved	1100								
S				starter inhibited - reason unknown	1101								Detail is shown in PGN65311(Y_SRF).
N/A				error	1110								
N/A				Not available	1111								
N/A	7	5	4	Not defined									
N/A	8	1	8	Not defined									

PGN		Acronym											
65188		ET2											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
N/A	1	1	16	Engine Oil Temperature 2		U16	0.031	-273	-273	1735	deg C	1135	Not available
N/A				Error Indicator	FE**								
S				Not available	FF**								
S	3	1	16	Engine ECU Temperature		U16	0.031	-273	-273	1735	deg C	1136	
S				Error Indicator	FE**								
N/A				Not available	FF**								
N/A	5	1	16	Engine EGR Differential Pressure								411	Not available
N/A				Error Indicator	FE**								
S				Not available	FF**								
N/A	7	1	16	Engine EGR Temperature		U16	0.031	-273	-273	1735	deg C	412	Not available
N/A				Error Indicator	FE**								
S				Not available	FF**								

PGN		Acronym											
65247		EEC3											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
N/A	1	1	8	Nominal Friction - Percent Torque		U8	1	-125	-125	125	%	514	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
S	2	1	16	Engine's Desired Operating Speed		U16	0.125	0	0	8031.875	min^{-1}	515	
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
N/A	4	1	8	Engine's Desired Operating Speed Asymmetry Adjustment		U8	1	0	0	250		519	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
N/A	5	1	32	Not defined									

PGN		Acronym											
65253		HOURS											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	32	Total Engine Hours		U32	0.05	0	0	210,554,061	hr	247	Total engine running hours
N/A				Error Indicator	FE******								
N/A				Not available	FF******								
N/A	5	1	32	Total Engine Revolutions		U32	1,000	0	0	4,211,081,215,000	r	249	Not available
N/A				Error Indicator	FE******								
S				Not available	FF******								

PGN		Acronym											
65255		VH											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
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
N/A				Error Indicator	FE******								Ignored
N/A				Not available	FF******								Ignored
N/A	5	1	32	Total Power Takeoff Hours		U32	0.05	0	0	210,554,061	hr	248	
N/A				Error Indicator	FE******								
N/A				Not available	FF******								

PGN		Acronym											
65259		CI											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	40	Make "YDECO"		ASCII						586	
S	6	1	160	Engine Model Number (ASCII *20)		ASCII						587	Engine model name
S	26	1	8	Delimiter "*"		ASCII							
S	27	1	48	Engine Serial Number (ASCII *6)		ASCII						588	Engine serial number
S	33	1	8	Delimiter "*"		ASCII							
S	34	1	112	ECU Number (ASCII *14)		ASCII						233	ECU ASSY part number
S	48	1	8	Delimiter "*"		ASCII							

PGN	Acronym												
65260	VI												
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	256	Vehicle Identification Number (ASCII)		ASCII						237	Engine model name (engine decal)
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
S	1	1	8	Engine Coolant Temperature		U8	1	-40	-40	210	deg C	110	
S				Error Indicator	FE								
N/A				Not available	FF								
N/A	2	1	8	Fuel Temperature		U8	1	-40	-40	210	deg C	174	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
N/A	3	1	16	Engine Oil Temperature		U16	0.031	-273	-273	1735	deg C	175	Not available
N/A				Error Indicator	FE00								
S				Not available	FF00								
N/A	5	1	16	Turbo Oil Temperature		U16	0.031	-273	-273	1735	deg C	176	Not available
N/A				Error Indicator	FE00								
S				Not available	FF00								
N/A	7	1	8	Engine intercooler temperature		U8	1	-40	-40	210	deg C	52	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
N/A	8	1	8	Engine intercooler Thermostat Opening		U8	0.4	0	0	100	%	1134	Not available
N/A				Error Indicator	FE								
S				Not available	FF								

PGN	Acronym												
65269	AMB												
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	8	Barometric Pressure		U8	0.5	0	0	125	kPa	108	Reserved
S				Error Indicator	FE								
S				Not available	FF								
N/A	2	1	16	Cab Interior Temperature		U16	0.031	-273	-273	1735	deg C	170	Not available
N/A				Error Indicator	FE00								
S				Not available	FF00								
N/A	4	1	16	Ambient Air Temperature		U16	0.031	-273	-273	1735	deg C	171	Not available
N/A				Error Indicator	FE00								
S				Not available	FF00								
N/A	6	1	8	Air Inlet Temperature		U8	1	-40	-40	210	deg C	172	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
N/A	7	1	16	Road Surface Temperature		U16	0.031	-273	-273	1735	deg C	79	Not available
N/A				Error Indicator	FE00								
S				Not available	FF00								

PGN	Acronym												
65271	VEP												
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
N/A	1	1	8	Net Battery Current		U8	1	-125	-125	125	A	114	Not available
N/A				Error Indicator	FE								
S				Not available	FF								
N/A	2			Not defined									
N/A	3	1	16	Alternator Potential (Voltage)		U16	0.05	0	0	3212.75	V	167	Not available
N/A				Error Indicator	FE00								
S				Not available	FF00								
N/A	5	1	16	Electrical Potential (Voltage)		U16	0.05	0	0	3212.75	V	168	Not available
N/A				Error Indicator	FE00								
S				Not available	FF00								
S	7	1	16	Battery Potential (Voltage), Switched		U16	0.05	0	0	3212.75	V	158	ECU Voltage
N/A				Error Indicator	FE00								
N/A				Not available	FF00								

PGN		Acronym											
65226		DM1											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
N/A	1	1	2	Protect Lamp Status								987	a
S				Lamp Off	00								Machine failure
N/A				Lamp On	01								
S	1	3	2	Amber Warning Lamp Status								624	The trouble without engine stop
S				Lamp Off	00								
S				Lamp On	01								
S	1	5	2	Red Stop Lamp Status								623	The trouble with engine stop
S				Lamp Off	00								
S				Lamp On	01								
S	1	7	2	Malfunction Indicator Lamp Status								1213	The trouble influenced on exhaust gas without engine stop
S				Lamp Off	00								
S				Lamp On	01								
N/A	2			Reserved									
S	3	1	8	SPN, 8 least significant bits of SPN		U19	1	0	0	524286		1214	b
S	4	1	8	SPN, 8 second byte of SPN									Version 4 Format
S	5	6	3	SPN, 3 most significant bits									
S	5	1	5	FMI		U5	1	0	0	30		1215	c
N/A				Not available	3F								
S	6	1	7	Occurrence count		U7	1	0	0	126		1216	d
N/A				Not available	7F								
S	6	8	1	Conversion Method	0							1706	
S	7	1	8	Not defined (Set to 0FFH) : Single Frame/SPN-H : Multi-packet									b
S	8	1	8	Not defined (Set to 0FFH) : Single Frame/SPN-M : Multi-packet									
S	9			(SPN-L)+(FMI) : Multi-packet									c
S	10			(OC)									d
S	11			(SPN-H)									b
S	12			(SPN-M)									
S	13			(SPN-L)+(FMI)									c
S	14			(OC)									d

PGN		Acronym											
65227		DM2											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	2	Protect Lamp Status								987	a
S				Lamp Off	00								
S				Lamp On	01								
S	1	3	2	Amber Warning Lamp Status								624	
S				Lamp Off	00								
S				Lamp On	01								
S	1	5	2	Red Stop Lamp Status								623	
S				Lamp Off	00								
S				Lamp On	01								
S	1	7	2	Malfunction Indicator Lamp Status								1213	
S				Lamp Off	00								
S				Lamp On	01								
N/A	2			Reserved									
S	3	1	8	SPN, 8 least significant bits of SPN		U19	1	0	0	524286		1214	b
S	4	1	8	SPN, 8 second byte of SPN									Version 4 Format
S	5	6	3	SPN, 3 most significant bits									
S	5	1	5	FMI		U5	1	0	0	30		1215	c
N/A				Not available	3F								
S	6	1	7	Occurrence count		U7	1	0	0	126		1216	d
N/A				Not available	7F								
S	6	8	1	Conversion Method	0							1706	Version 4 Format
S	7	1	8	Not defined (Set to 0FFH) : Single Frame/SPN-H : Multi-packet									b
S	8	1	8	Not defined (Set to 0FFH) : Single Frame/SPN-M : Multi-packet									
S	9			(SPN-L)+(FMI) : Multi-packet									c
S	10			(OC)									d
S	11			(SPN-H)									b
S	12			(SPN-M)									
S	13			(SPN-L)+(FMI)									c
S	14			(OC)									d

PGN		Acronym											
59904		Requests											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
R	1	1	8	Least Significant Byte of PGN			1	0	0	131071		2540	
R	2	1	8	Byre 2 of PGN									
R	3	1	8	Most Significant Byte of PGN									

PGN		Acronym											
59392		Ack/Nack											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
	1	1	8	Control Byte			1	0	1	3		2541	
S				0: Positive Acknowledgment									
S				1: Negative Acknowledgment									
S				2: Access Denied (PGN supported but security access denied)									
S				3: Busy (PGN supported but ECU is busy and cannot respond now)									
N/A	2	1	8	Group Function					255	255		2542	
N/A	3	1	8	Not defined									
N/A	4	1	8	Not defined									
N/A	5	1	8	Not defined									
S	6	1	8	Least Significant Byte of PGN of Requested Information		U24	1	0	0	131071		2543	
S	7	1	8	Middle Byte 2 of PGN of Requested Information									
S	8	1	8	Most Significant Byte of PGN of Requested information									

PGN		Acronym											
60160		TP_DT											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	8	Sequence Number		U8	1	0	1	255			
S	2	1	16	Packetized Data (7 bytes)									Note the last packet of a multipacket Parameter Group may require less than 8 data bytes. The extra bytes should be filled with 0xFF

PGN		Acronym											
60416		TP_CM_ BAM											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	8	Control Byte - set to 32 for CM_BAM		U8	1	32	32	32		2556	
S	2	1	16	Total Message Size, number of byte		U16	1	0	9	1785		2567	
S	4	1	8	Total number of packets		U8	1	0	2	255		2568	
S	5	1	8	Not Defined									
S	6	1	8	Least Significant Byte of PGN		U24	1	0	0	131071		2569	
S	7	1	8	Byre 2 of PGN									
S	8	1	8	Most Significant Byte of PGN									

PGN		Acronym		Planning									
56320		ATS		(Not available)									
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	2	Anti-theft Encryption Seed Present Indicator								1194	
S				Random number is not present	00								
S				Random number is present	01								Seed send
S	1	3	2	Anti-theft Password Valid Indicator								1195	
S				Password is not a validated password	00								
S				Password is a validated password	01								Unlock
S	1	5	2	Anti-theft Component Status States								1196	
S				Unlocked	00								
S				Locked	01								
S				Blocked	10								
S				Not defined	11								
S	1	7	2	Anti-theft Modify Password States								1197	
S				Ok	00								Unlock
S				Full_of_Password	01								
S				Empty_of_Password	10								
S				Not_valid	11								
S	2	1	56	Anti-theft Random Number								1198	
S				MSB									Seed number
S				:									
				:									
				LSB									

PGN		Acronym		Planning									
56576		ATR		(Not available)									
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
R	1	1	1	Not defined									
R	1	2	2	Anti-theft Encryption Indicator States								1199	
R				Encryption_Seed_Request	00								Seed request
R				Encrypted_Code_present	01								Password send
R				Not defined	10								
R				Not_Available	11								
R	1	4	2	Anti-theft Desired Exit Mode States								1200	
R				Lock_Upon_Operator_Request	00								
R				Lock_When_Key_Off	01								
R				Not defined	10								
R				Not_Available	11								
R	1	6	3	Anti-theft Component Status States								1201	
R				Add_Password	000								
R				Delete_Password	001								
R				Change_Password	010								
R				Lock_or_Unlock	011								Seed request,
R				Check_Status	100								
R				Login	101								
R				Not defined	110								
R				Not defined	111								
R	2	1	56	Anti-theft Password Representation								1202	
R				MSB									Password number
R				:									
R				:									
R				LSB									

APPENDIX C

PGN		Acronym											
65282		Y_ECR1											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
N/A	1	1	8	not defined									
N/A	2	1	2	not defined									
	2	3	2	Shutdown requests									
R				No shutdown request	00								normal state
R				Shutdown request	01								Engine ECU begins the shutdown processing.
N/A				Error Indicator	10								Ignored
N/A				Not available	11								Ignored
N/A	2	5	2	not defined									
	2	7	2	Power supply/Key position									
R				Ignition key in off-position	00								Auto preheat/afterheat is disabled. / The starter is not permitted.
R				Ignition key in normal driving position	01								Auto preheat/afterheat is disabled. / The starter is not permitted.
R				Ignition key in preheat-position	10								Auto preheat/afterheat is enabled. /The starter is not permitted.
R				Ignition key in crank-position	11								The starter is permitted.
N/A	3	1	8	not defined									
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.
R				Error Indicator	FE								
R				Not available	FF								
N/A	5	1	32	not defined									

PGN		Acronym											
65292		Y_ECACK1											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
N/A	1	1	8	not defined									
N/A	2	1	3	not defined									
	2	4	2	Preheat function acknowledge									State of preheat energizing ("preheat" only, not include "afterheat" and "airheat at cranking")
S				Not active (Preheat OFF)	00								
S				Active (Preheat ON)	01								
S				Error indicator (Airheat Relay Error)	10								
N/A				Not available	11								
N/A		6	2	not defined									
	2	8	1	Power down enable									
S				Power off not allowed	0								
S				Power off allowed (Finished shutdown)	1								
N/A	3	1	48	not defined									

PGN		Acronym											
65297		Y_I/OS											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
	1	1	3	Digital input 1 status									External switch OFF (open)=0 / ON (close)=1
S		1	1	STARTSW(E8) Port	XX1								
S		2	1	SHUDNSW(E15) Port	X1X								
S		3	1	IGNSW(E7) Port	1XX								
N/A		4	5	not defined									
	2	1	7	Digital input 2 status									External switch OFF (open)=0 / ON (close)=1
S		1	1	APP-IP1(E24) Port	XXXXXX1								Droop selection / Starter permission
S		2	1	APP-IP2(E14) Port	XXXXX1X								Rmax2 / Oil pressure switch / Pedal switch NO
S		3	1	APP-IP3(E9) Port	XXXX1XX								Speed1 / Charge alarm
S		4	1	APP-IP4(E17) Port	XXX1XXX								Speed2
S		5	1	APP-IP5(E5) Port	XX1XXXX								Reverse droop / Air cleaner
S		6	1	APP-IP6(E6) Port	X1XXXXX								Speed selection / Water separator
S		7	1	APP-IP7(E13) Port	1XXXXXX								Rmax1 / Stop2 / Pedal switch NC
N/A		8	1	not defined									
	3	1	8	Digital output 1 status									Output port OFF=0 / ON=1
S		1	1	MAIN-RLY(E34) Port	XXXXXXX1								
S		2	1	RACK-RLY(E33) Port	XXXXXX1X								
S		3	1	AIRHT-RLY(E44) Port	XXXXX1XX								
S		4	1	CSD-CL(E41) Port	XXXX1XXX								
S		5	1	FAIL-LMP(E12) Port	XXX1XXXX								
S		6	1	PREHT-LMP(E23) Port	XX1XXXXX								
S		7	1	APP-OP1(E20) Port	X1XXXXXX								
S		8	1	APP-OP2(E2) Port	1XXXXXXX								
N/A	4	1	40	not defined									

PGN		Acronym											
65298		Y_RPC											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	16	ACTUAL RACK POSITION		U10	1	0	0	1023			
S				Error Indicator	FE**								Rack position sensor error
N/A				Not available	FF**								
S	3	1	16	REQUEST RACK POSITION		U10	1	0	0	1023			Target rack position
S				Error Indicator	FE**								Rack position sensor error
N/A				Not available	FF**								
S	5	1	16	Iset_raw		U10	1	0	0	6000			Target rack current
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
S	7	1	16	EGR STEP (actual)		U16	1	0	0	54			EGR step current value
S				Error Indicator	FE**								
S				Not available	FF**								

PGN		Acronym											
65300		Y_OPR											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
R	1	1	8	Command ID Code	4Fh	U8							Fixed Value. ASCII Code of "O" (Ignore other Value)
R	2	1	8	Function ID Code		U8							Select Active Control Object. (This Function is Valid only when Engine Speed=0 and Key switch OFF)
				APP-OP1	00h								Digital output
				Rack Actuator Relay	01h								Digital output
				Air Heat Relay	02h								Digital output
				Request Rack Position	25h								Analog output
				Failure Lamp	33h								Digital output
				Pre-Heat Lamp	34h								Digital output
				EGR Stepping Motor	35h								Analog output
				APP-OP2	36h								Digital output
				CSD Solenoid Valve	37h								Digital output
R	3	1	8	Port Select Data (Digital output Value)		U8							When "Function ID Code" is Digital output 0=OFF (open) / 1=ON (close) When "Function ID Code" is Analog output 0=0 output / 1=use "Port Output Data"
R	4	1	8	Port Output Data (Analog output Value)		U8	1	0	0	100	%		When "Function ID Code" is Digital output 0 (Fixed Value) When "Function ID Code" is Analog output output Value (0-100%)
N/A	5	1	32	not defined									

PGN		Acronym											
65301		Y_OPA											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	8	Command ID Code	4Fh	U8							Fixed Value. ASCII Code of "O"
S	2	1	8	Function ID Code		U8							Return received Value
S	3	1	8	ECU ID Code	00h	U8							Fixed Value (E-ECU)
S	4	1	8	Port Select Data (Digital output Value)		U8							Return received Value
S	5	1	8	Port Output Data (Analog output Value)		U8							Return received Value
S	6	1	16	Feed Back Data		U16	1	0	0	100	%		When "Function ID Code" is Request Rack Position Return Actual Rack Position (0-100%) When "Function ID Code" is EGR Stepping Motor Return EGR Valve Opening Value When "Function ID Code" is Digital output 0 (Fixed Value)
S				Error Indicator	FE**								When "Function ID Code" is Request Rack Position Rack Position Sensor Error When "Function ID Code" is EGR Stepping Motor EGR Stepping Motor Error, dump surge limit
S				Not available	FF**								When "Function ID Code" is EGR Stepping Motor and Select "No EGR"
S	8	1	8	Process Result		U8							0:Failure (output impossible) / 1:successful

PGN		Acronym		Yanmar special PGN									
65302		Y_OLS											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
R	1	1	16	Amount of speed down at overload detection		U16	0.125	0	0	8031.875	min^{-1}		
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
R	3	1	16	Amount of speed down at overload absolution		U16	0.125	0	0	8031.875	min^{-1}		
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
R	5	1	8	Load ratio at overload detection		U8	1	0	0	101	%		
N/A				Error Indicator	FE								
N/A				Not available	FF								
R	6	1	8	Load ratio at overload absolution		U8	1	0	0	101	%		
N/A				Error Indicator	FE								
N/A				Not available	FF								
R	7	1	8	Over load RPM down ratio (for Tractor)		U8	1	0	0	100	%		
N/A				Error Indicator	FE								
N/A				Not available	FF								
N/A	7	1	16	Not defined									

PGN		Acronym											
65303		Y_LF											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	8	Engine gross load ratio		U8	1	0	0	100	%		
S				Error Indicator	FE								When the load ratio cannot be calculated
N/A				Not available	FF								
S	2	1	8	Engine net load ratio		U8	1	0	0	100	%		Option
S				Error Indicator	FE								When the load ratio cannot be calculated
N/A				Not available	FF								
S	3	1	8	Load ration for UFO control		U8	1	0	0	100	%		Yanmar special function
S				Error Indicator	FE								When the load ratio cannot be calculated
N/A				Not available	FF								
S	4	1	8	Load ratio for load detection		U8	1	0	0	100	%		Yanmar special function
S				Error Indicator	FE								When the load ratio cannot be calculated
N/A				Not available	FF								
S	5	1	8	Engine net load ratio (Hold at acceleration)		U8	1	0	0	100	%		Yanmar special function
S				Error Indicator	FE								When the load ratio cannot be calculated
N/A				Not available	FF								
S	6	1	2	Overload alarm									Yanmar special function
S				OFF	00								Initial state
S				ON	01								
S				Error Indicator	10								When the load ratio cannot be calculated
S				Not available	11								When it cannot receive 'Y_OLS' command
N/A			6	Not defined									
N/A	7		16	Not defined									

PGN		Acronym											
65306		Y_AIN1											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	16	Coolant Temperature Sensor Voltage		U16	0	0	0	1,023			TW (E25) Port, Reserved
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
S	3	1	16	Rack Position Sensor Voltage		U16	0	0	0	1,023			RPS (E36) Port
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
S	5	1	16	Accel Position Sensor Voltage		U16	0	0	0	1,023			APS (E35) Port
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
S	7	1	16	Reserve Analog Sensor Voltage		U16	0	0	0	1,023			REAN (E37) Port, Option
N/A				Error Indicator	FE**								
N/A				Not available	FF**								

PGN		Acronym											
65307		Y_AIN2											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	16	Reserve Thermistor Sensor Voltage		U16	0	0	0	1,023			RET (E16) Port
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
S	3	1	16	Suction Temperature Sensor Voltage		U16	0	0	0	1,023			TAIR (E26) Port, Reserved
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
S	5	1	16	EGR Temperature Sensor Voltage		U16	0	0	0	1,023			TEGR (E27) Port, Reserved
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
S	7	1	16	Not defined		U16	0	0	0	1,023			
N/A				Error Indicator	FE**								
N/A				Not available	FF**								

PGN		Acronym											
65308		Y_EC											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
	1	1	2	Rmax selection									Yanmar special function CAN Bus state >Initial state : 0=OFF >Error state : keep last state
R		1	1	Rmax1	X1								0=OFF / 1=ON, Depend on APP-IP7 function setting
R		2	1	Rmax2	1X								0=OFF / 1=ON, Depend on APP-IP2 function setting
	1	3	2	Governor mode									CAN Bus state >Initial state : 0=OFF >Error state : keep last state
R		3	1	Droop mode	X1								0=OFF (Isochroous) / 1=ON(Droop), Depend on APP-IP1 function setting
R		4	1	Reverse droop mode	1X								0=OFF (Isochroous) / 1=ON (Reverse droop), Depend on APP-IP5 function setting
	1	5	1	Starter prevention									CAN Bus state >Initial state : 1=ON >Error state : 0=OFF
R		5		Starter permission	1								0=OFF(permission) / 1=ON (preven-tion), Depend on APP-IP1 function setting
	1	6	2	Hi-idle limit									Yanmar special function CAN Bus state >Initial state : 0=OFF >Error state : keep last state
R		6		Hi-idle limit	1								0=OFF / 1=ON, Depend on APP-IP5 function setting
R		7		Hi-idle limit speed	1								0=OFF / 1=ON, Depend on APP-IP7 function setting
N/A	1	8	1	Not defined									
N/A	2	1	56	Not defined									

PGN		Acronym											
65309		Y_STP											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
R	1	1	2	Engine Stop command									
R				Engine stop not requested	00								
R				Engine stop	01								
N/A				Error Indicator	10								Ignored
N/A				Not available	11								Ignored
N/A	1	3	6	not defined									
N/A	2	1	56	Not defined									

PGN		Acronym											
65310		Y_RSS											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
	1	1	5	Speed selection function									Constant speed, Constant deceleration CAN Bus state >Initial state : 0=OFF >Error state : keep last state
R		1	1	Speed1	XXXX1								0=OFF / 1=ON, Depend on APP-IP3 function setting
R		2	1	Speed2	XXX1X								0=OFF / 1=ON, Depend on APP-IP4 function setting
R		3	1	Implement (up)	XX1XX								0=OFF / 1=ON, Depend on APP-IP5 function setting, Only Yanmar internal
R		4	1	Implement (down)	X1XXX								0=OFF / 1=ON, Depend on APP-IP6 function setting, Only Yanmar internal
R		5	1	Speed selection enable	1XXXX								0=OFF / 1=ON, Depend on APP-IP6 function setting
N/A		6	3	Not defined									
R	2		16	Speed up function		U16	0.125	0	0	8031.875	min^{-1}	2211	Yanmar special function CAN Bus state >Initial state : 0=OFF >Error state : keep last state
N/A				Error Indicator	FE**								
N/A				Not available	FF**								
N/A	4	1	40	Not defined									

PGN		Acronym											
65311		Y_SRF											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	16	Starter Prevention factor									
S		1	1	Safety relay operation	1								prevention=1, permission=0
S		2	1	Under E-ECU initial operation	1								prevention=1, permission=0
S		3	1	External switch	1								prevention=1, permission=0
S		4	1	Immobilizer	1								prevention=1, permission=0
S		5	1	Starter over time (more than 30s)	1								prevention=1, permission=0
S		6	1	CAN Y_EC status	1								prevention=1, permission=0
S		7	1	Engine stop operation	1								prevention=1, permission=0
S		8	1	Key switch OFF	1								prevention=1, permission=0
S		9	1	Initial rack cheek error	1								prevention=1, permission=0
S		10	1	ECU error	1								prevention=1, permission=0
S		11	1	Engine over speed error	1								prevention=1, permission=0
S		12	1	Diagnostics tool operation	1								prevention=1, permission=0
N/A		13	1	reserved									0
N/A		14	1	reserved									0
N/A		15	1	reserved									0
N/A		16	1	reserved									0
S	3	1	16	Engine stop factor									
S		1	1	Engine stall	1								Engine stall=1, Other=0 When the engine speed become 240min^{-1} or less after engine starting once.
S		2	1	Key switch OFF	1								Key switch OFF=1, normal=0 IGNSW (E7) terminal is OFF (When self power control is enabled.)
S		3	1	Engine stop 1 SW	1								Engine stop by SHUDNSW=1, normal=0 Engine stop by SHUDNSW (E15) terminal.
S		4	1	Engine Stop 2 SW	1								Engine stop by APP-IP7 or CAN=1, normal=0 Engine stop by APP-IP7 (E13) terminal or CAN.
S		5	1	Speed sensor error	1								Speed sensor error=1, normal=0 Engine stop by speed sensor error.
S		6	1	Rack actuator or Rack actuator relay error	1								Rack actuator error=1, normal=0 Engine stop by rack actuator error or rack actuator relay error
S		7	1	ECU error (FLASHROM)	1								ECU error (FlashROM)=1, normal=0 Engine stop by FlashROM check sum error.
S		8	1	Engine over speed error	1								Over speed error=1, normal=0 Engine stop by over speed error.
S		9	1	ECU error (Map)	1								ECU error (MAP)=1, normal=0 Incompatibility of map version.
S		10	1	Other engine stop operation	1								Engine stop operation=1, normal=0 Engine stop by operational limitations.
S		11	1	ECU error (EEPROM)	1								ECU error (EEPROM)=1, normal=0 Engine stop by EEPROM check sum error.
S		12	1	reserved									0
N/A		13	1	reserved									0
N/A		14	1	reserved									0
N/A		15	1	reserved									0
N/A		16	1	reserved									0
S	5	1	8	Immobilizer status									
S		1	1	Blocked	1								Active=1(default)
S		2	1	Lock or Unlock	1								Active=1
S		3	1	Unlocked	1								Active=1
S		4	1	Locked	1								Active=1
S		5	1	N/A Immobilizer	1								Active=1
N/A		6	3	reserved									
N/A	6	1	24	Not defined									

PGN		Acronym		Yanmar special PGN									
65315		TRS_S											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	2	ECO-Mode Lamp									
S		1	1	High-speed ON	X1								0 : Lamp OFF / 1 : Lamp ON
S		2	1	Low-speed ON	1X								0 : Lamp OFF / 1 : Lamp ON
N/A	1	3	6	not defined									
N/A	2	1	56	Not defined									

PGN		Acronym		Yanmar special PGN									
65317		TRS_DTC											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	8	DTC Number		U8	1	0	1	20			
N/A				Error Indicator	FE								
S				Not available	FF								
S	2	1	8	SPN, 8 least significant bits of SPN		U19	1	0	0	524286		1214	
S	3	1	8	SPN, 8 second byte of SPN									
S	4	6	3	SPN, 3 most significant bits									
S	4	1	5	FMI		U5	1	0	0	30		1215	
N/A				Not available									
S	5	1	7	Occurrence count		U7	1	0	0	126		1216	
N/A				Not available									
S	5	8	1	Conversion Method	0							1706	
S	6	1	24	DTC Occurrence Time		U24	0.05	0	0	832,307	hr		
N/A				Error Indicator	FE****								
S				Not available	FF****								

PGN		Acronym											
65318		Y_SRSI											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	16	Low-idle speed		U16	0.125	0	0	8031.875	min^{-1}	188	depend on engine specification
S	3	1	16	Hi-idle speed (Under droop mode)		U16	0.125	0	0	8031.875	min^{-1}	532	depend on engine specification
S	5	1	16	Hi-idle speed (Under isochroous mode)		U16	0.125	0	0	8031.875	min^{-1}		depend on engine specification
S	7	1	16	Available maximum speed		U16	0.125	0	0	8031.875	min^{-1}		depend on control operation

PGN		Acronym											
65319		Y_ESI											
R/S	Byte	Bit	Len	Description	States	Type	Res.	Offset	Min	Max	Unit	SPN	Note
S	1	1	8	Engine control state		U8							The control state of the engine is shown. 0 : Stand by (INJ_ZERO) 1 : Engine starting (INJ_START) 2 : Engine running (NJ_REG) 3 : Engine error (INJ_ERROR) 4 : Engine stop operation (INJ_STOP) 5 : Rack initial check (INJ_PRE)
S	2		2	Derate mode									
S		1	1	Engine power derate	X1								Under derate=1, normal=0
S		2	1	Engine speed derate	1X								Under derate=1, normal=0
N/A		3	6	Not defined									
S	3		3	Optional control									
S		1	1	Idling speed up function	XX1								Under Low-idle speed up=1, normal=0
S		2	1	White smoke control function	X1X								Under High-idle speed down=1, normal=0
S		3	1	Speed up function	1XX								Under speed up=1, normal=0, Yanmar special function
N/A		4	5	Not defined									
S	4		3	Governor mode									
S		1	1	Isochroous	XX1								Isochroous mode=1
S		2	1	Droop	X1X								Droop mode=1
S		3	1	Reverse droop	1XX								Reverse droop mode=1
N/A		4	5	Not defined									
N/A	5	1	32	Not defined									

APPENDIX D

2G-ECO Governor Controller DTC Table

DTC				Description	J1939 Lamp Status			
Remark	J1939 Format							
	SPN (Hex)	SPN (DEC)	FMI		MIL	RSL	AWL	PL
	4BA	1210	4	Engine Fuel Rack Position Sensor : Shorted to low source			X	
			3	Engine Fuel Rack Position Sensor : Shorted to high source		X (Engine drive)	X (E-ECU start)	
	5B	91	4	Accelerator Pedal Position Sensor "A" : Shorted to low source			X	
			3	Accelerator Pedal Position Sensor "A" : Shorted to high source			X	
			2	Accelerator Pedal Position Sensor "A" : Intermittent fault				
			1	Accelerator Pedal Position Sensor "A" : Below normal operational range (SAE J1843)			X	
			0	Accelerator Pedal Position Sensor "A" : Above normal operational range (SAE J1843)			X	
			15	Accelerator Pedal Position Sensor "A" : Not available (SAE J1843)			X	
	1D	29	4	Accelerator Pedal Position Sensor "B" : Shorted to low source			X	
			3	Accelerator Pedal Position Sensor "B" : Shorted to high source			X	
			2	Accelerator Pedal Position Sensor "B" : Intermittent fault				
			1	Accelerator Pedal Position Sensor "B" : Below normal operational range (SAE J1843)			X	
			0	Accelerator Pedal Position Sensor "B" : Above normal operational range (SAE J1843)			X	
			8	Accelerator Pedal Position Sensor "B" : Communication fault			X	
			15	Accelerator Pedal Position Sensor "B" : Not available (SAE J1843)			X	
	6C	108	4	Barometric Pressure Sensor : Shorted to low source	X			
			3	Barometric Pressure Sensor : Shorted to high source	X			
			2	Barometric Pressure Sensor : Intermittent fault				
	470	1136	4	E-ECU Internal Temperature Sensor : Shorted to low source			X	
			3	E-ECU Internal Temperature Sensor : Shorted to high source			X	
			2	E-ECU Internal Temperature Sensor : Intermittent fault				
			0	E-ECU Internal Temperature : Too High				X
	6E	110	4	Engine Coolant Temperature Sensor : Shorted to low source			X	
			3	Engine Coolant Temperature Sensor : Shorted to high source			X	
			2	Engine Coolant Temperature Sensor : Intermittent fault				
			0	Engine Coolant Temperature : Too High				X
	437	1079	4	Sensor 5V : Shorted to low source			X	
			3	Sensor 5V : Shorted to high source			X	
			2	Sensor 5V : Intermittent fault				
	9E	158	1	System Voltage : Too Low				X
			0	System Voltage : Too High				X
	436	1078	4	Engine Fuel Injection Pump Speed Sensor : Shorted to low source		X (Both)	X (Ether)	
*	7F8A2	522402	4	Auxiliary Speed Sensor : Shorted to low source				
*	7F801	522241	4	Engine Fuel Rack Actuator Relay : Circuit fault A		X		
			3	Engine Fuel Rack Actuator Relay : Circuit fault B		X		
			7	(Reserved)				
			2	Engine Fuel Rack Actuator Relay : Intermittent fault				
*	7F803	522243	4	Air Heater Relay : Circuit fault A	X			
			3	Air Heater Relay : Circuit fault B	X			
			2	Air Heater Relay : Intermittent fault				

ON-VEHICLE COMMUNICATION CAN SPECIFICATION

DTC				Description	J1939 Lamp Status			
Remark	J1939 Format SPN (Hex)	SPN (DEC)	FMI		MIL	RSL	AWL	PL
*	7F802	522242	4	Cold Start Device : Circuit fault A	X			
			3	Cold Start Device : Circuit fault B	X			
			2	Cold Start Device : Intermittent fault				
*	7F80B	522251	4	EGR Stepping Motor "A" : Circuit fault A	X			
			3	EGR Stepping Motor "A" : Circuit fault B	X			
*	7F80C	522252	4	EGR Stepping Motor "B" : Circuit fault A	X			
			3	EGR Stepping Motor "B" : Circuit fault B	X			
*	7F80D	522253	4	EGR Stepping Motor "C" : Circuit fault A	X			
			3	EGR Stepping Motor "C" : Circuit fault B	X			
*	7F80E	522254	4	EGR Stepping Motor "D" : Circuit fault A	X			
			3	EGR Stepping Motor "D" : Circuit fault B	X			
	64	100	4	Oil Pressure Switch : Shorted to low source			X	
			1	Oil Pressure : Too Low				X
	A7	167	4	Battery Charge Switch : Shorted to low source			X	
			1	Charge warning				X
*	7F84A	522314	0	Engine Coolant Temperature : Abnormal temperature				X
*	7F853	522323	0	Air Cleaner : Mechanical Malfunction				X
*	7F859	522329	0	Oily Water Separator : Mechanical Malfunction				X
	BE	190	0	Engine speed : Over speed Condition		X		
	27E	638	4	Engine Fuel Rack Actuator : Shorted to low source		X		
			3	Engine Fuel Rack Actuator : Shorted to high source		X		
			7	Engine Fuel Rack Actuator : Mechanical Malfunction		X		
			2	Engine : Malfunction		X		
	27F	639	12	High Speed CAN Communication : Communication fault			X	
	276	630	2	E-ECU internal fault : EEPROM Check Sum Error (Data Set 2)		X		
			12	E-ECU internal fault : EEPROM ReadWrite fault			X	
	274	628	12	E-ECU internal fault : FlashROM Check Sum Error (Main Software)		X		
			2	E-ECU internal fault : FlashROM Check Sum Error (Data Set 1)		X		
			2	E-ECU internal fault : FlashROM Check Sum Error (Data Set 2)		X		
	5CD	1485	4	E-ECU Main Relay : Shorted to low source			X	
*	7F9E7	522727	12	E-ECU internal fault : Sub-CPU Error A			X	
			12	E-ECU internal fault : Sub-CPU Error B			X	
			12	E-ECU internal fault : Sub-CPU Error C			X	
*	7F9E8	522728	12	E-ECU internal fault : Engine Map Data Version Error		X		
*	7F9EA	522730	12	Immobilizer : CAN Communication fault			X	
			8	Immobilizer : Pulse Communication fault			X	
	4B2	1202	2	Immobilizer : System fault			X	

Remark : Yanmar original DTC

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.

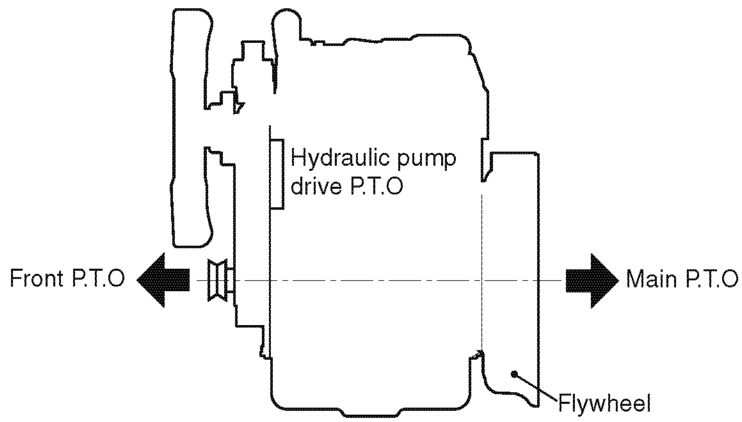


Figure 16-1

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)

Model	Allowable torque N·m (kgf·m)
2TNV70, 3TNV70	27 (2.8)
3TNV76	30 (3.1)
3TNV82A, 3TNV84, 3TNV88, 3TNV84T	43 (4.4)
4TNV84, 4TNV88, 4TNV84T	57 (5.9)
4TNV94L, 4TNV98, 4TNV98T	(Option) 63 (6.5)

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.

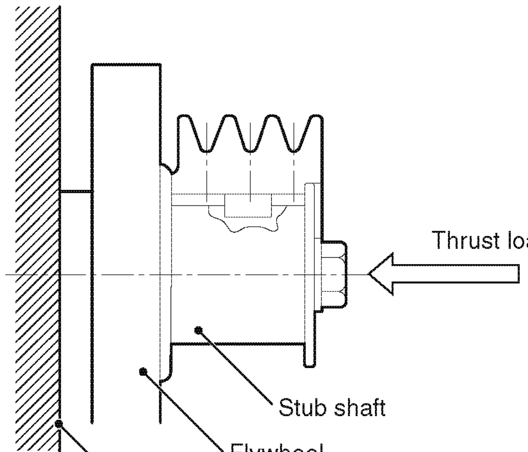


Figure 16-2

Allowable Thrust Load

Unit: N (kgf)

Engine model name	Static thrust load	Dynamic thrust load
2TNV70, 3TNV70	1568 (160)	784 (80)
3TNV76	1764 (180)	882 (90)
3TNV82A	2352 (240)	1176 (120)
3TNV84, 3TNV88, 3TNV84T	2842 (290)	1372 (140)
4TNV84, 4TNV88, 4TNV84T	2842 (290)	1372 (140)
4TNV94L, 4TNV98, 4TNV98T	3136 (320)	1568 (160)

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

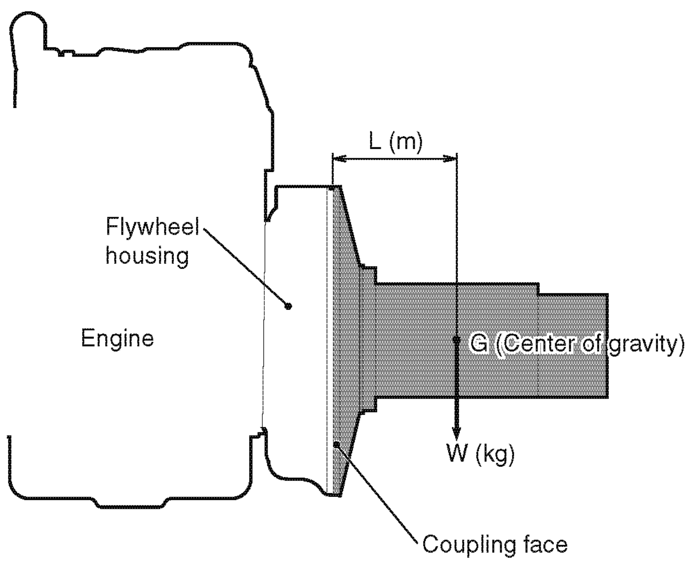


Figure 16-3

Engine model name	Max: Maximum bending moment at the coupling face of flywheel housing (N·m)	Housing type
2TNV70	490	SAE #6
3TNV70	980	SAE #5
3TNV76		
3TNV82A		
3TNV84(T)	1770	
3TNV88		
4TNV84(T)		
4TNV88		
4TNV94L	1960	SAE #4
4TNV98(T)		

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 (*TIR mm)	Face runout (*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

* 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.

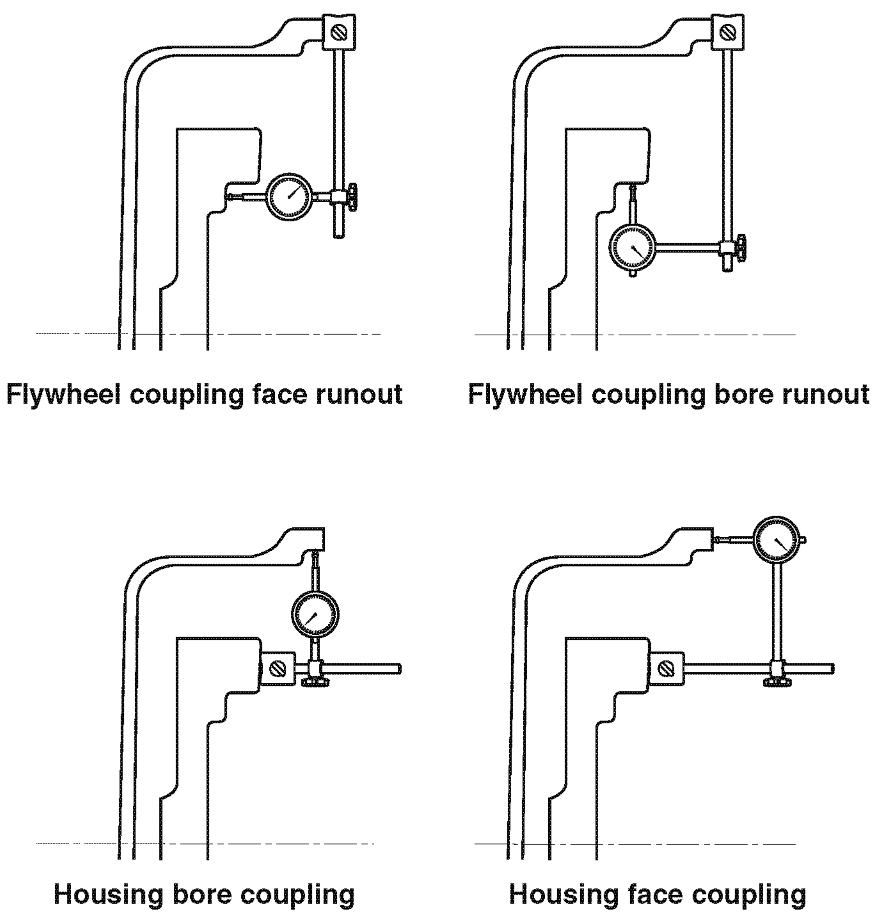


Figure 16-4

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

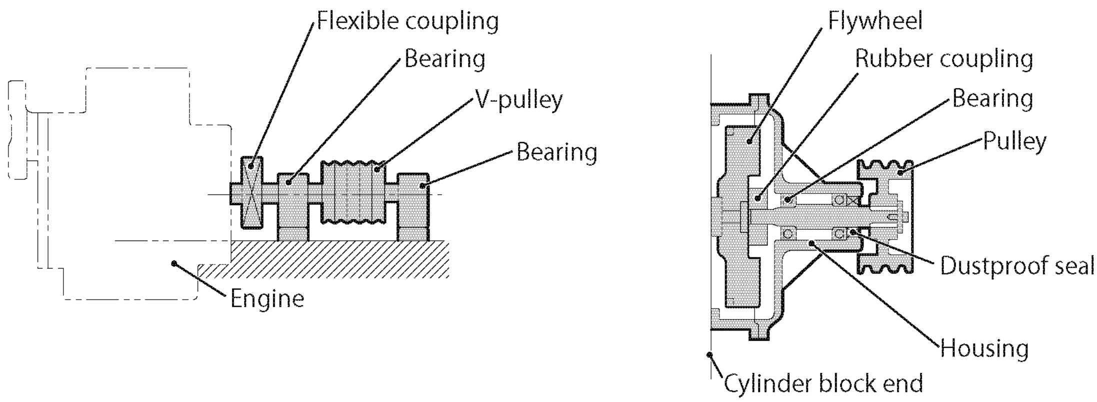


Figure 16-5

- If a side belt drive is required and an external bearing cannot be used because there is no room on the driven machine, see *How To Calculate the Side Load on page 16-9*, *Allowable Side Load for Main P.T.O. on page 16-26* and *Allowable Side Load for Front P.T.O. on page 16-31*. *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 16-26*. 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 16-31*. Belt manufacturers can be consulted for calculation assistance.
- Prepare the following data before starting the analysis:

  (a) Engine type

  (b) Required horsepower and speed for driven machine

  (c) Effective diameter of pulleys (on the engine side and driven machine side: D1, D2)

  (d) V-pulley overhang (L and ℓ)
  * When two or more belts are used, use the center of the V-pulley.

  (e) Types and numbers of belts used.

  (f) Relative positions of engine and driven machine (a, b)

  (g) Belt center-to-center distance (C)

How to calculate C

$$C = \sqrt{a^2 + b^2}$$

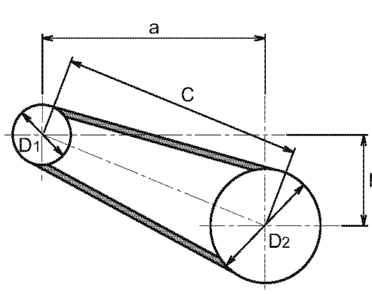
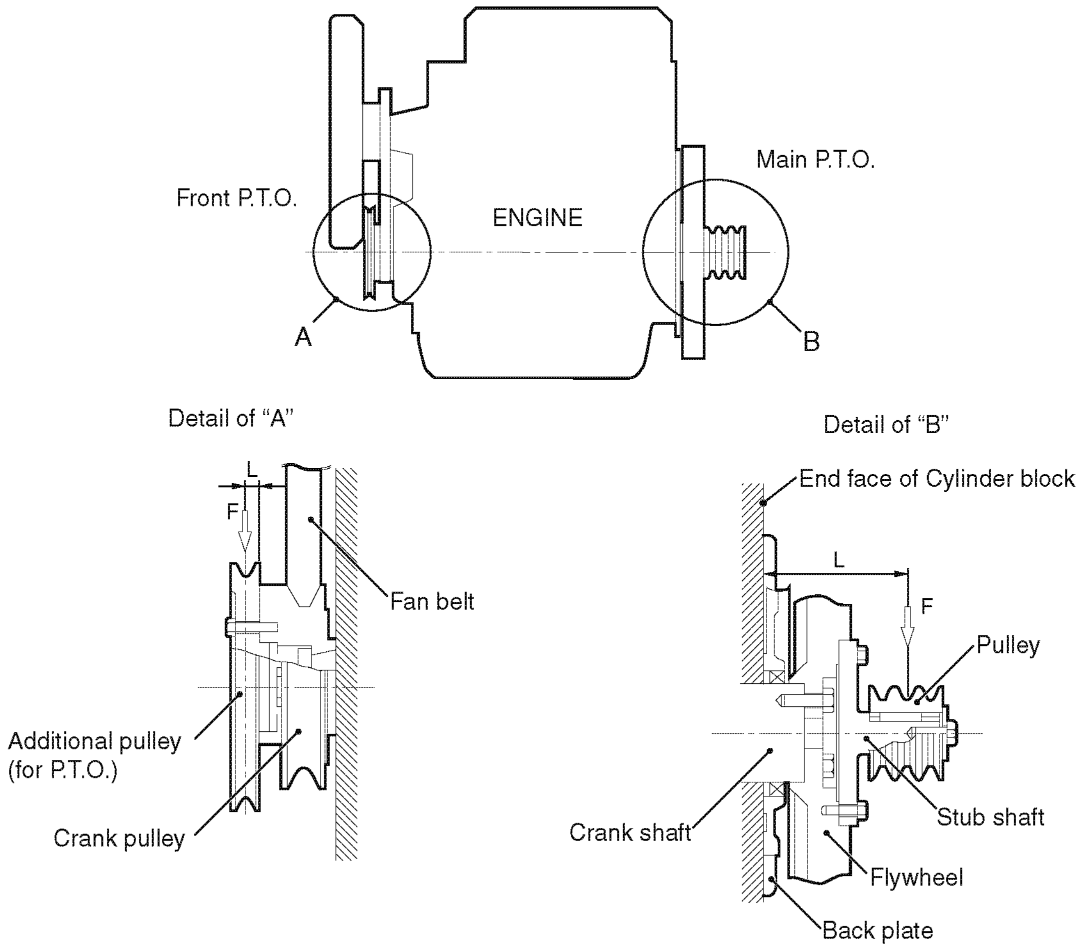


Figure 16-6



How to measure distance L

L is distance from fitting face(c) for additional pulley on the crank pulley to groove center of additional pulley.

How to measure distance L

Select a position at the center of 2 grooves farthest and nearest from the cylinder block end.

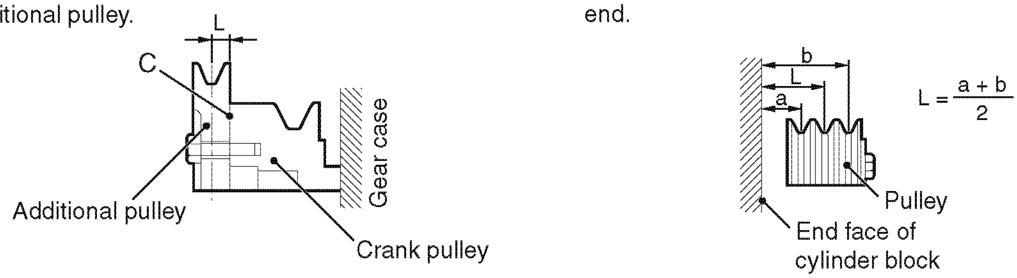


Figure 16-7

HOW TO CALCULATE THE SIDE LOAD

Example

A side belt drive is connected to the front P.T.O. of a 4NTV98 engine to provide power to a 9kW/1500 min^{-1} generator. Is the side belt load within the range specified for the 4NTV98 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

   2-1. Determine the "design power" exerted by V-belt based on the "required power".

   2-2. Determine the "type" of V-belt.

   2-3. Calculate the length of V-belt to determine the "nominal number".

   2-4. Determine the "transmission capacity" of V-belt.

   2-5. 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 (PN)

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.

$$\text{Required power } (P_N) = \frac{\text{Generator capacity}}{\text{Generator efficiency}} = \frac{9\text{ kW}}{0.82} = 11\text{ kW}$$

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	(See *Service factor (K_0) on page 16-21*)
K_i	: Idler correction factor	(See *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 (see *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.

$$P_d = P_N(K_0 + K_i) = 11.0(1.1 + 0)$$
$$= 12.1 \text{kW}$$

Determining Type of V-belt

Select a type of V-belt to be used from **(Figure 16-8)**.

V-belt Selection Table

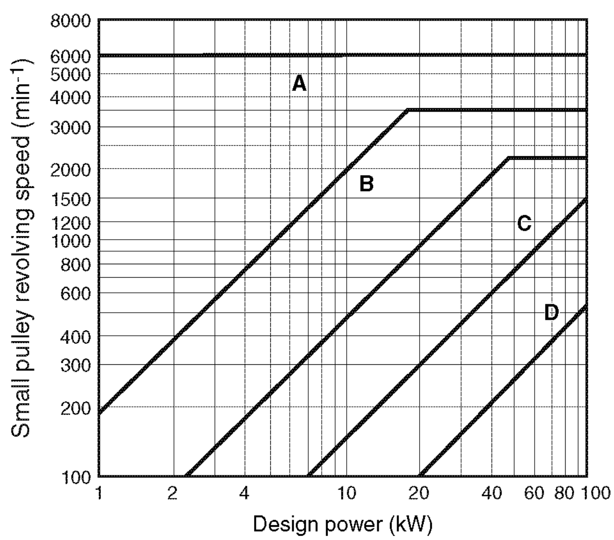


Figure 16-8

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

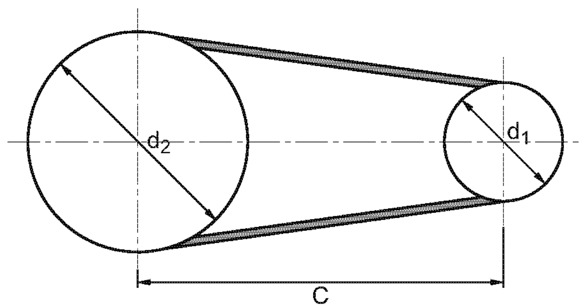


Figure 16-9

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 4TNV98. 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 d1 = 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:

$$\text{Large pulley pitch circle diameter } (d_2) = \frac{\text{Engine min}^{-1}}{\text{generator min}^{-1}} \times \text{small pulley pitch circle diameter } (d_1)$$

$$= \frac{2250}{1500} \times 140$$

$$= 210 \text{ mm}$$

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).

$$L = 2C + 1.57(d_1 + d_2) + \frac{(d_2 - d_1)^2}{4C}$$

$$= 2 \times 600 + 1.57(140 + 210) + \frac{(210 - 140)^2}{4 \times 600}$$

$$= 1751.5 \text{ mm}$$

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 16-23*). 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.)

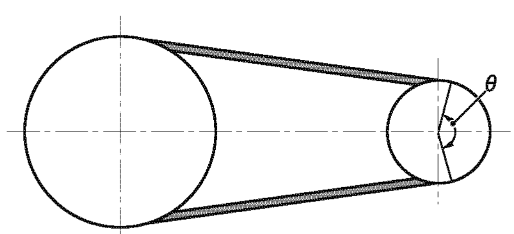


Figure 16-10

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	See *Constants (C_1, C_2, C_3) on page 16-24*
K_r	:	Correction factor by rotation ratio	See *Correction factor by rotation ratio (K_r) on page 16-25*
d_2/d_1	:	Rotation ratio	See *Correction factor by rotation ratio (K_r) on page 16-25*

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:

(a) d_1 = 140 mm

(b) n = 2250 x 10^{-3}

(c) The values of C_1, C_2 and C_3 are selected from *Constants (C_1, C_2, C_3) on page 16-24*. Since A type belt is used, these are as follows respectively; 3.1149 x 10^{-2}, 1.0399 and 1.1108 x 10^{-8}.

(d) The value of K_r is selected from *Correction factor by rotation ratio (K_r) on page 16-25*. 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

$$P = 140 \times 2250 \times 10^{-3}\left[3.1149 \times 10^{-2}(140 \times 2250 \times 10^{-3})^{-0.09} - \frac{1.0399}{140} \times 1.1108\right.$$

$$10^{-8}(140 \times 2250 \times 10^{-3})^2]1.0399 \times 2250 \times 10^{-3}\left(1 - \frac{1}{1.1036}\right)$$

$$= 315 \times [3.1149 \times 10^{-2} \times 315^{-0.09} - 8.2509 \times 10^{-11} \times 314^2] + 2.3398 \times 0.0939$$

$$= 315 \times [0.0186 - 0.000008] + 0.2197$$

$$= 6.0787 \text{ kW (per each A type V-belt)}$$

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 (Pc)

$$P_c = P \times K_L \times K_\theta$$

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	See *Length correction factor (K_L) on page 16-23*
K_θ	:	Contact angle correction factor	*Contact angle correction factor (K_θ) on page 16-24*

Before using *Length correction factor (K_L) on page 16-23*, complete the following calculation.

$$\frac{(d_2 - d_1)}{C}$$

For this example case, the calculation is developed as follows.

(a) The value of P, 6.0787 kW, was obtained from *Determining "Transmission Capacity" (P) of V-belt on page 16-12*

(b) Select the value of K_L from *Length correction factor (K_L) on page 16-23*.

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 16-23* is 1.00.

(c) Obtain K_θ from *Contact angle correction factor (K_θ) on page 16-24*.

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.

$$\begin{aligned} P_c &= P \times K_L \times K_\theta \\ &= 6.0787 \times 1.00 \times 0.99 \\ &= 6.0179\ \text{kW} \end{aligned}$$

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:

(a) The value of P_d, 12.1 kW, was obtained in *Design Power of V-belt (P_d) on page 16-10*.

(b) The value of P_c, 6.0179 kW, was obtained in *Corrected transmission capacity of V-belt per piece (Pc) 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_o) of V-belt

The initial tension that is required for transmission of power through the V-belt is calculated by using the following formula:

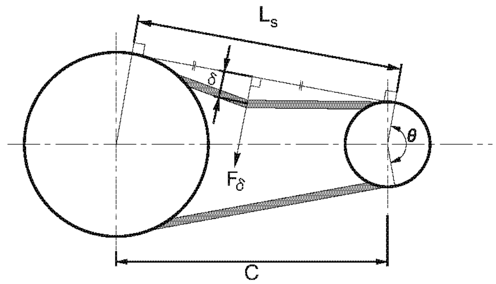


Figure 16-11

$$F_o = 0.9\left[500\left(\frac{2.5 - K_\theta}{K_\theta}\right)\frac{P_d}{Z \times \nu} + m \times \nu^2\right]$$

F_o	:	Initial tension 1 kgf = 9.80665 N	N
K_θ	:	Contact angle correction factor	See *Contact angle correction factor (K_θ) on page 16-24*
P_d	:	Design power	kW
Z	:	Number of V-belts	
ν	:	V-belt speed	m/s

$$\nu = \frac{\pi \times d_1 \times N}{1000 \times 60}$$

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 See *Applicable V-belt length limit (allowable difference) on page 16-25*

For this example, the calculation is developed as follows.

(a) The value of K_θ, 0.99 pieces, was obtained from *Determining “the Number of V-belts” (Z) on page 16-14*.

(b) The value of P_d, 12.1 kW, was obtained in *Design Power of V-belt (P_d) on page 16-10*.

(c) The value of Z, 3 pieces, was obtained in *Determining the number of V-belts (Z) on page 16-15*.

(d) The following parameters that are used for calculating the speed of V-belt (ν) 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*.

$$\nu = \frac{\pi \times d_1 \times N}{1000 \times 60} = \frac{3.14 \times 140 \times 2250}{1000 \times 60}$$

$$= 16.5 \text{ m/s}$$

(e) The value of m is obtained from *V-belt mass per unit length and constant (Y) on page 16-25*. 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.

$$F_o = 0.9\left[500\left(\frac{2.5 - K_\theta}{K_\theta}\right)\frac{Pd}{Z \bullet \nu} + m \bullet \nu^2\right]$$

$$= 0.9\left[500\left(\frac{2.5 - K_\theta}{K_\theta}\right)\frac{12.1}{3 \times 16.5} + 0.12 \times 16.5^2\right]$$

$$= 0.9\left[500\left(\frac{2.5 - 0.99}{0.99}\right)\frac{12.1}{3 \times 16.5} + 0.12 \times 16.5^2\right]$$

$$= 0.9(500 \times 1.525 \times 0.244 \times 32.67)$$

$$= 0.9(186.05 + 32.67)$$

$$= 197 \text{ N (20 kgf)}$$

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 See *Contact angle correction factor (K_θ) on page 16-24*

For this example case, the calculation is developed as follows.

(a) The value of Z, 3, was obtained in *Determining the number of V-belts (Z) on page 16-15*.

(b) The value of F_o, 197, was obtained from *Determining "Initial Tension" (F_o) of V-belt on page 16-16*.

(c) The value of θ, 174, is obtained from *Contact angle correction factor (K_θ) on page 16-24*. The value of K_θ, 0.99, is obtained from *Contact angle correction factor (K_θ)* on page *16-24*.

$$F_s = 1.5\left(2Z \times F_0 \sin\frac{\theta}{2}\right) = 1.5\left(2 \times 3 \times 197 \sin\frac{174}{\theta}\right)$$

$$= 1.5(2 \times 3 \times 197 \times 0.999)$$

$$= 1771 \text{ N (181 kgf)}$$

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	See *Contact angle correction factor (K_θ) on page 16-24*
P_d	:	Design power	kW
ν	:	V-belt speed	m/s
θ	:	Small V-pulley contact angle	degrees See *Contact angle correction factor (K_θ) on page 16-24*

$$F_d = 9.8\left(\frac{2.5 - K_\theta}{K_\theta}\right) \times \frac{102 \times P_d}{\nu}\sin\frac{\theta}{2}$$

For this example case, the calculation is developed as follows:

(a) The value of P_d, 12.1 kW, was obtained in *Design Power of V-belt (P_d) on page 16-10*.

(b) The value of ν, 16.5 m/s, was obtained from *Determining "Initial Tension" (F_o) of V-belt on page 16-16*.

(c) The value of θ, 174 is obtained from *Contact angle correction factor (K_θ) on page 16-24*. The value of K_θ, 0.99, is obtained from *Contact angle correction factor (K_θ) on page 16-24*.

$$F_d = 9.8\left(\frac{2.5 - K_\theta}{K_\theta}\right) \times \frac{102 \times P_d}{\nu}\sin\frac{\theta}{2}$$

$$= 9.8\left(\frac{2.5 - 0.99}{0.99}\right) \times \frac{102 \times 12.1}{16.5}\sin\frac{174}{2}$$

$$= 9.8 \times 1.525 \times 74.8 \times 0.999$$

$$= 1117 \text{ N } (114 \text{ kgf})$$

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. However, the reference line of the overhang varies among engines.

When examining this factor, be sure to refer to the drawing of pertinent engine shown in *Allowable Side Load for Front P.T.O. on page 16-31*.

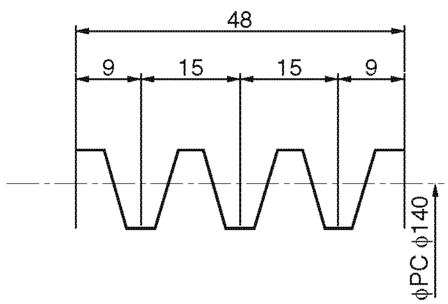


Figure 16-12

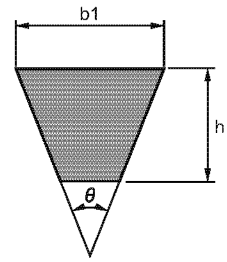
Examining Allowable Shaft Load

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 16-31* 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, that uses 4NTV98 engine, entering the overhang (L) of 20 mm and shaft load of 181 kgf (this value is used because the static shaft load is largest) 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	



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.

Note: 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.

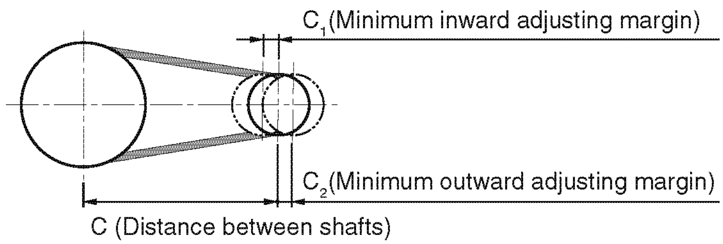


Figure 16-13

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="3">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>40</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

Length correction factor (K_L)

Nominal No.	Type			
	A	B	C	D
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				

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.

IDI Series

2TNV70, 3TNV70

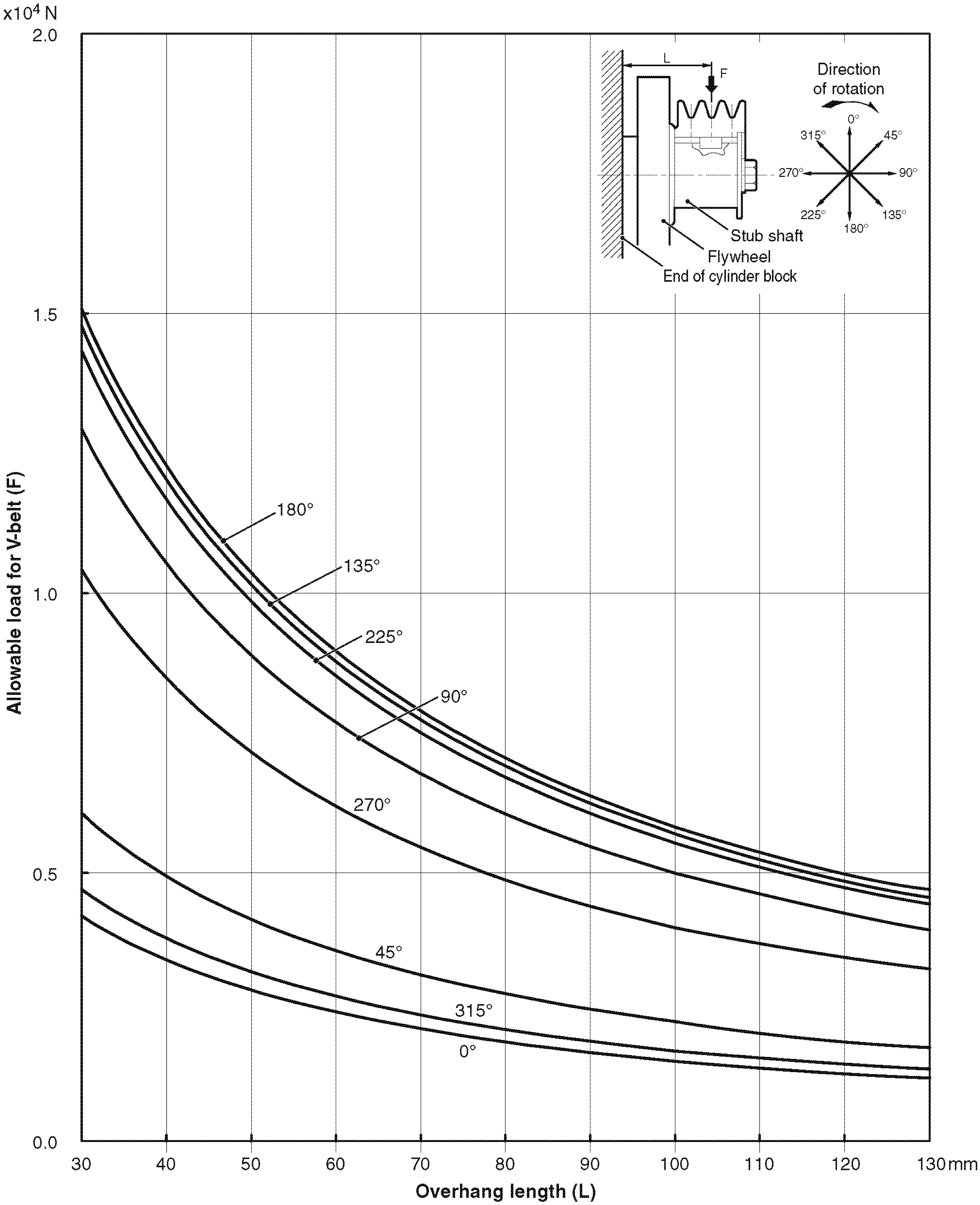


Figure 16-14

3TNV76

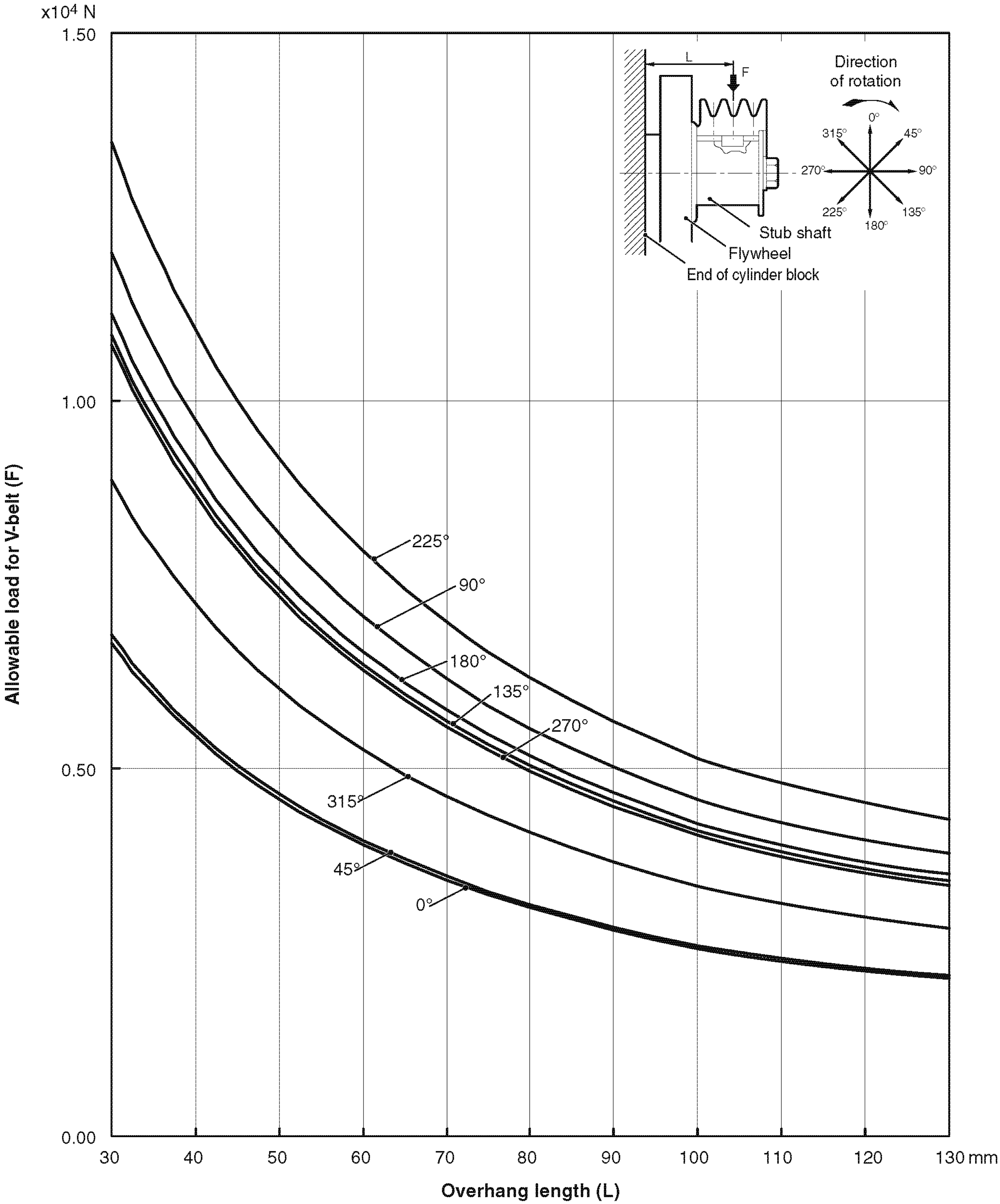


Figure 16-15

3TNV82A

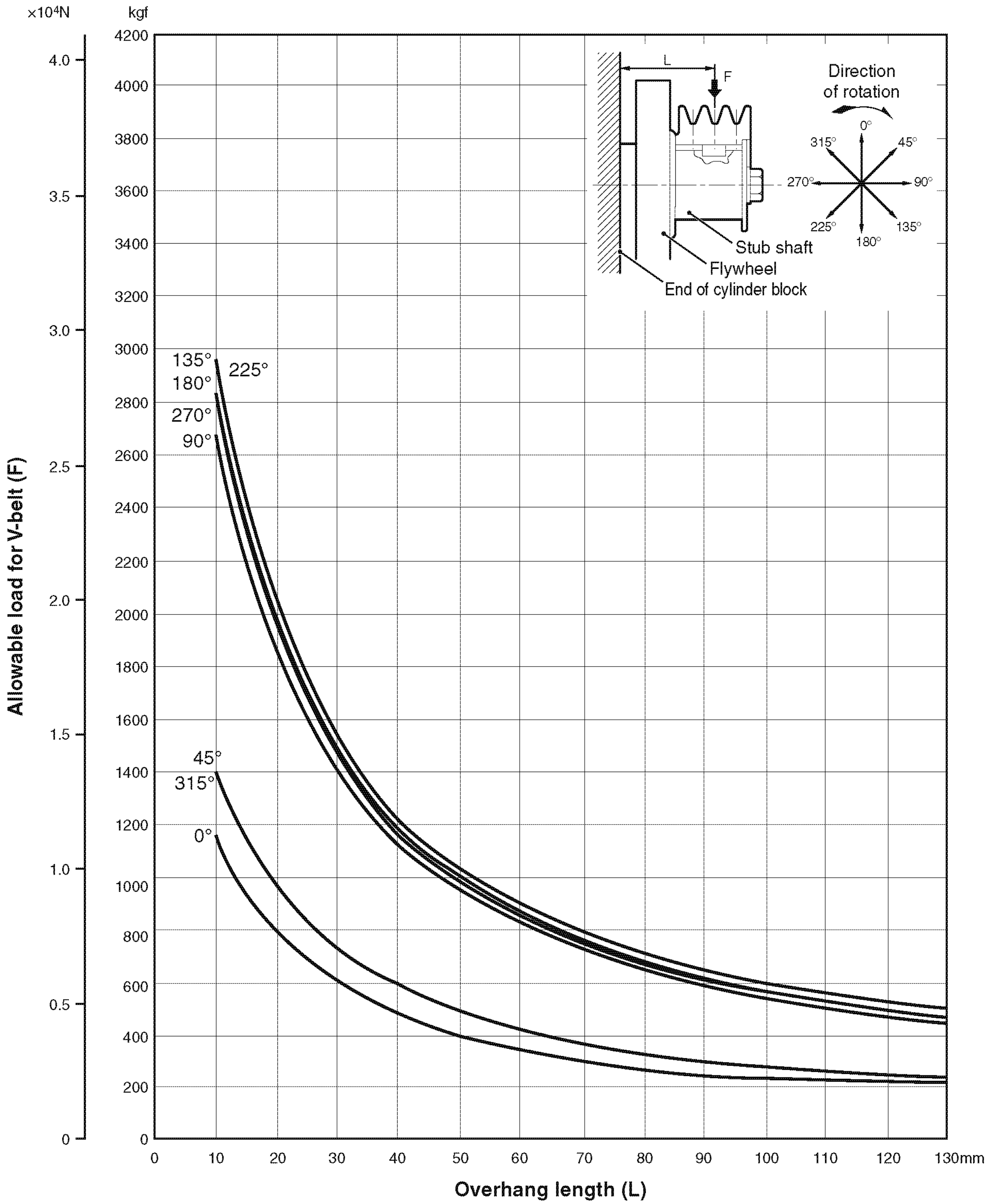


Figure 16-16

DI Series

3TNV84, 3TNV84T, 3TNV88, 4TNV84, 4TNV84T, 4TNV88

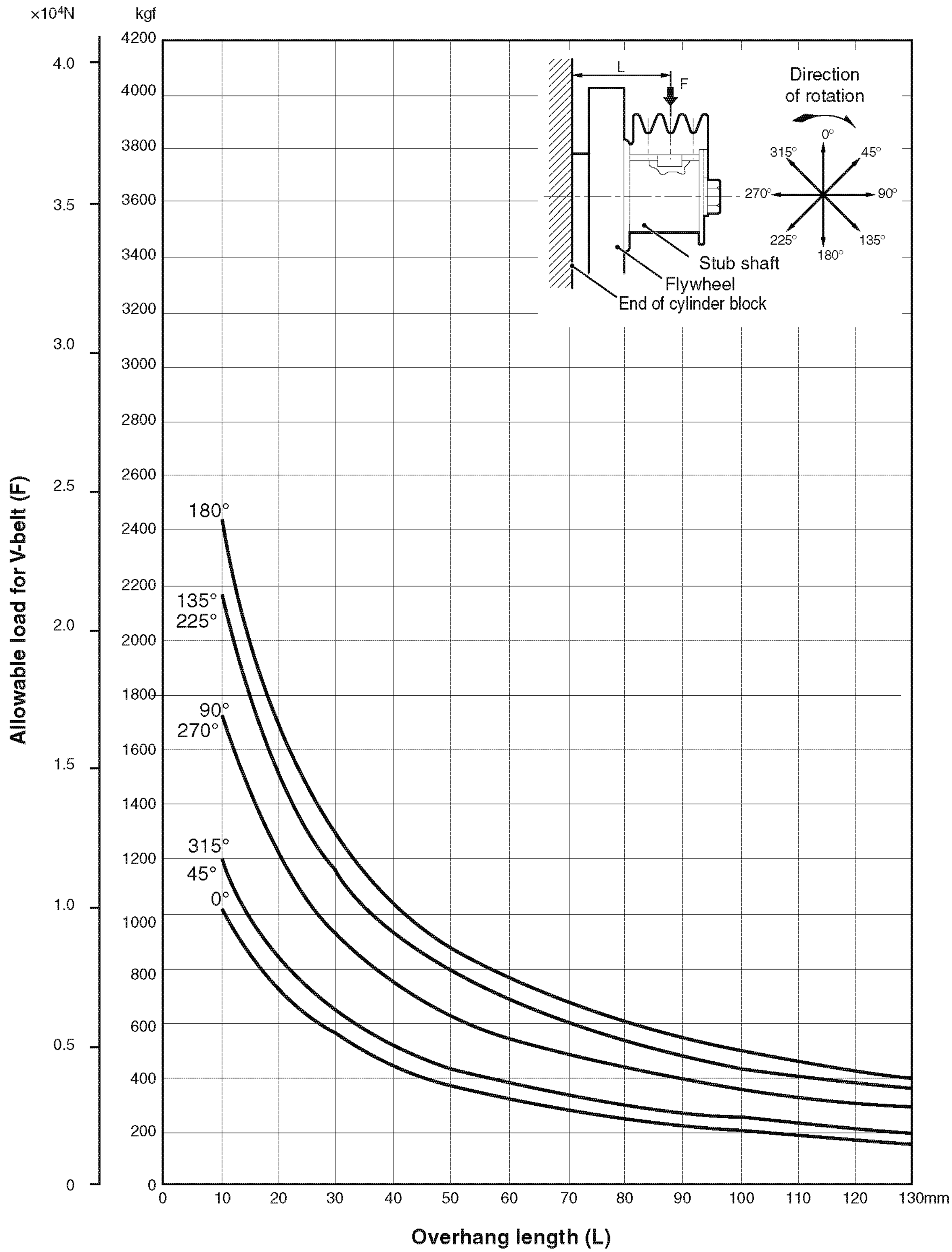


Figure 16-17

4TNV94L, 4TNV98, 4TNV98T

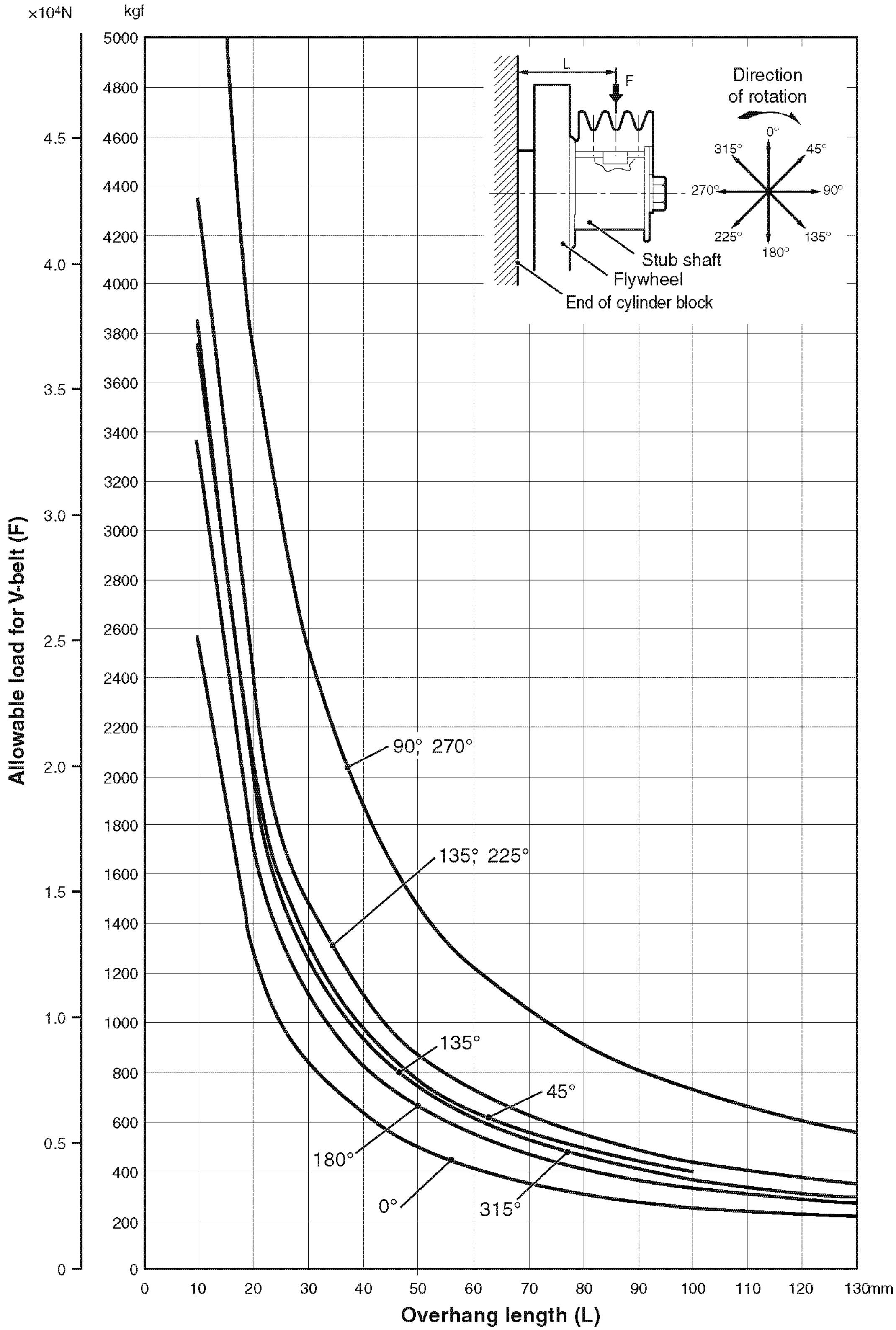


Figure 16-18

ALLOWABLE SIDE LOAD FOR FRONT P.T.O.

IDI Series

2TNV70, 3TNV70

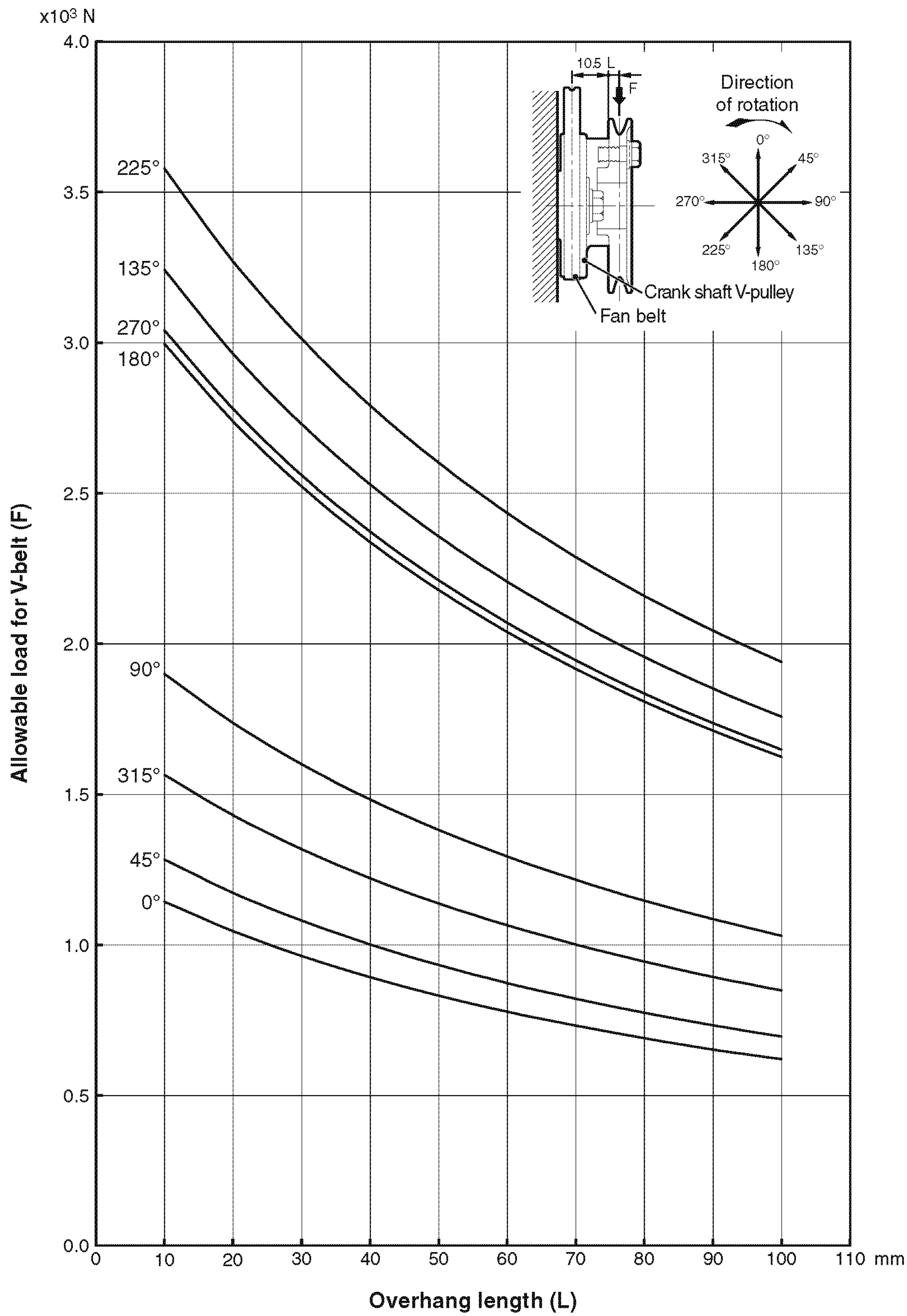


Figure 16-19

3TNV76

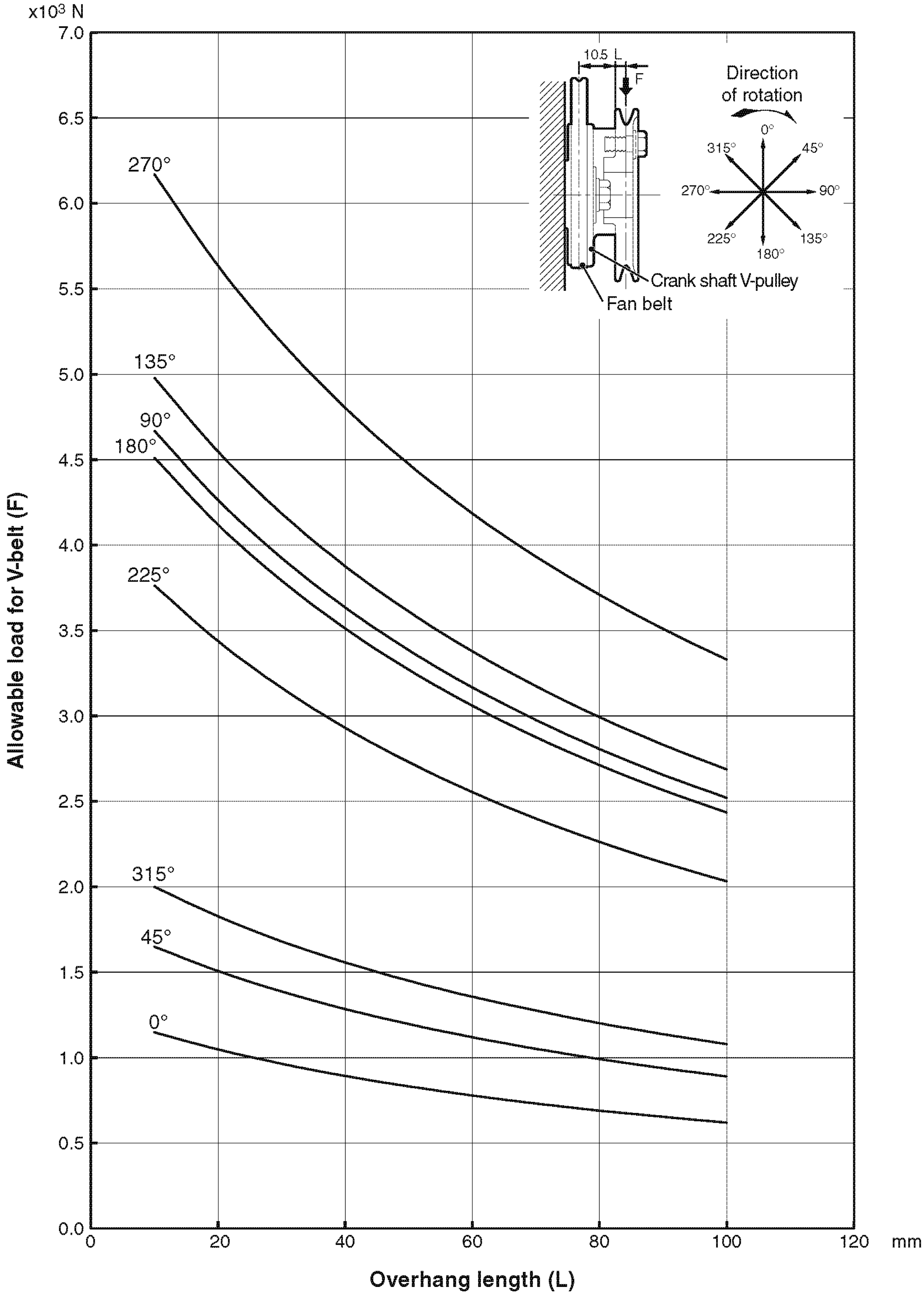


Figure 16-20

DI Series

3TNV82A

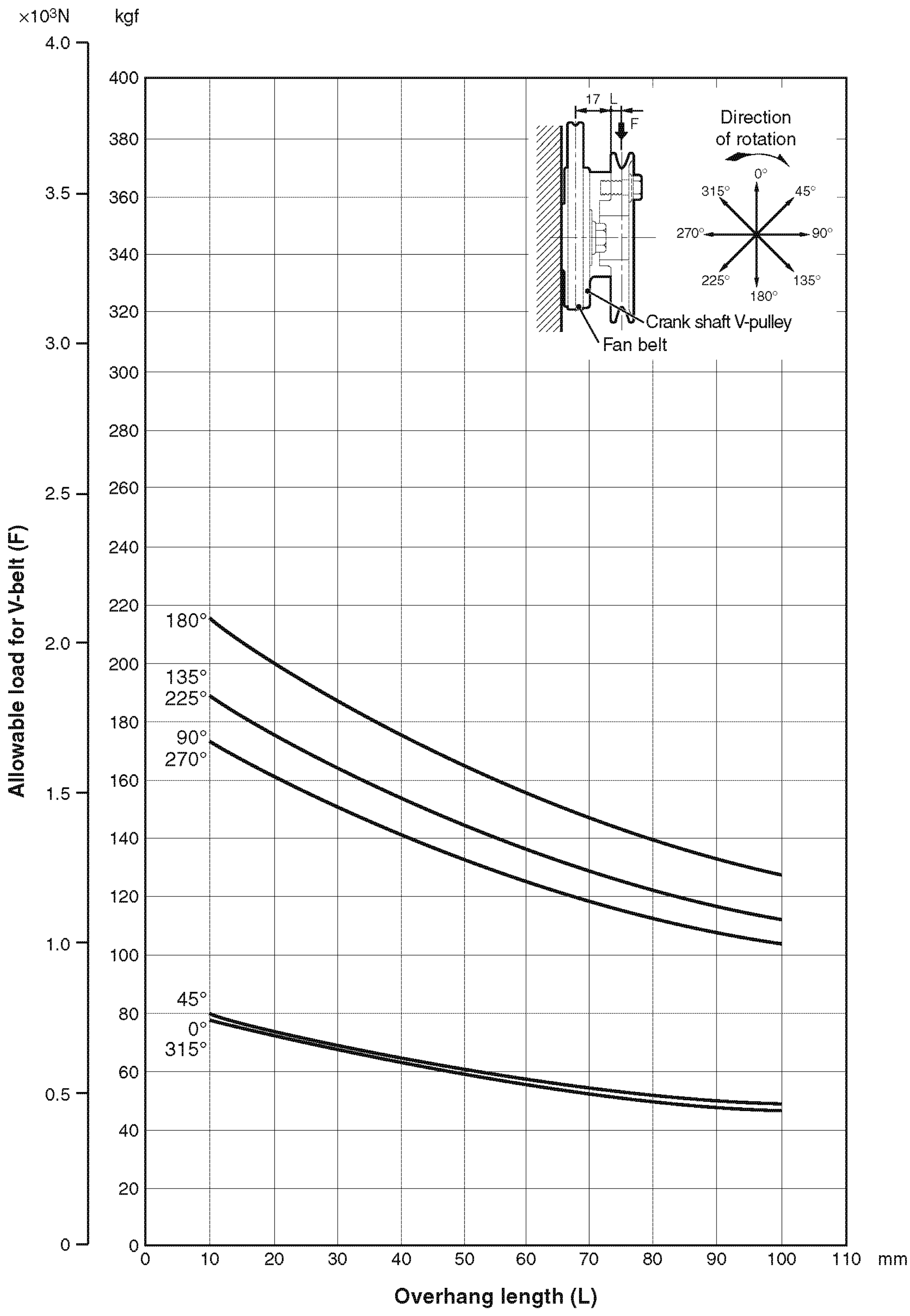


Figure 16-21

3TNV84(T), 3TNV88, 4TNV84(T), 4TNV88

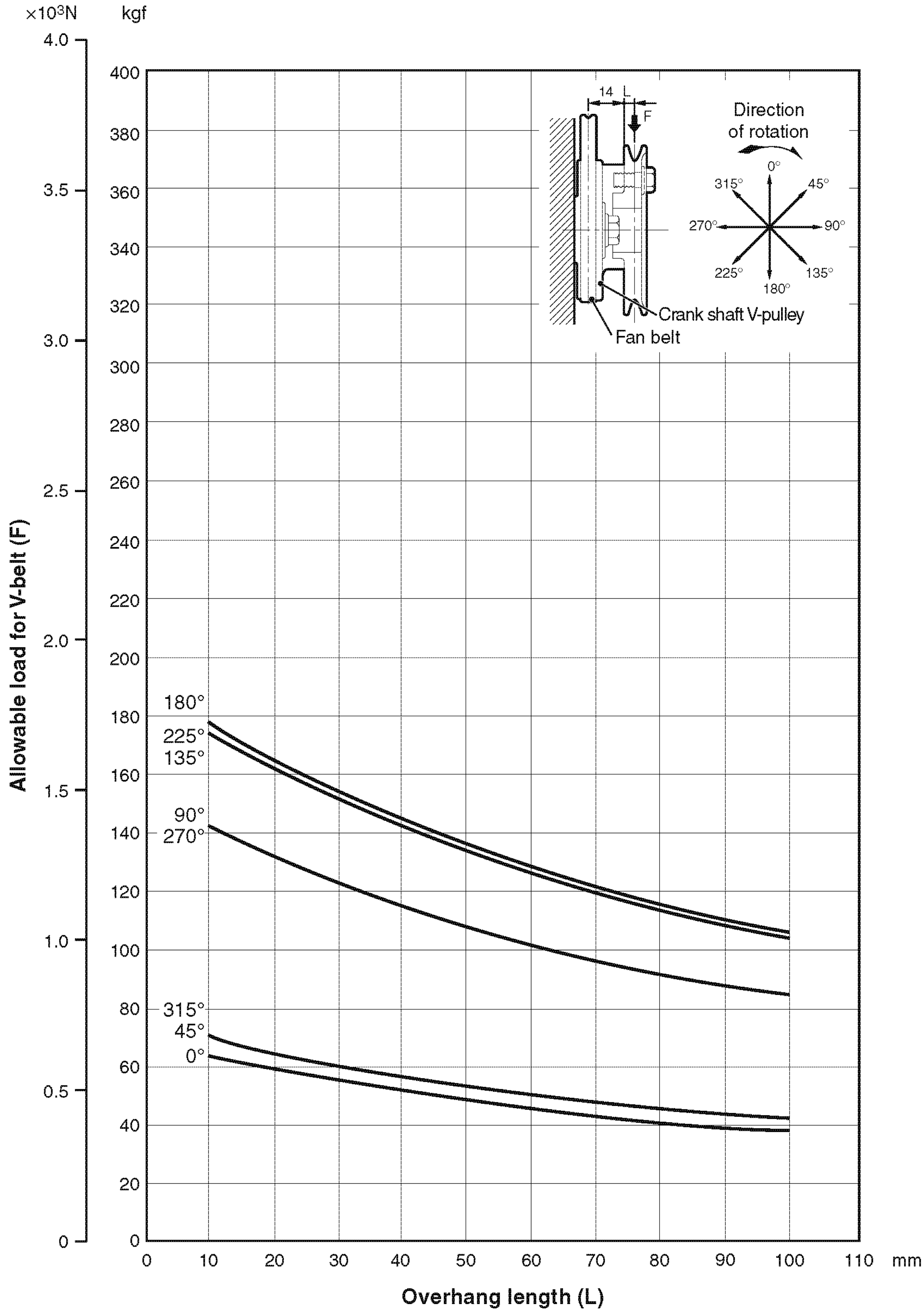


Figure 16-22

4TNV94L, 4TNV98(T)

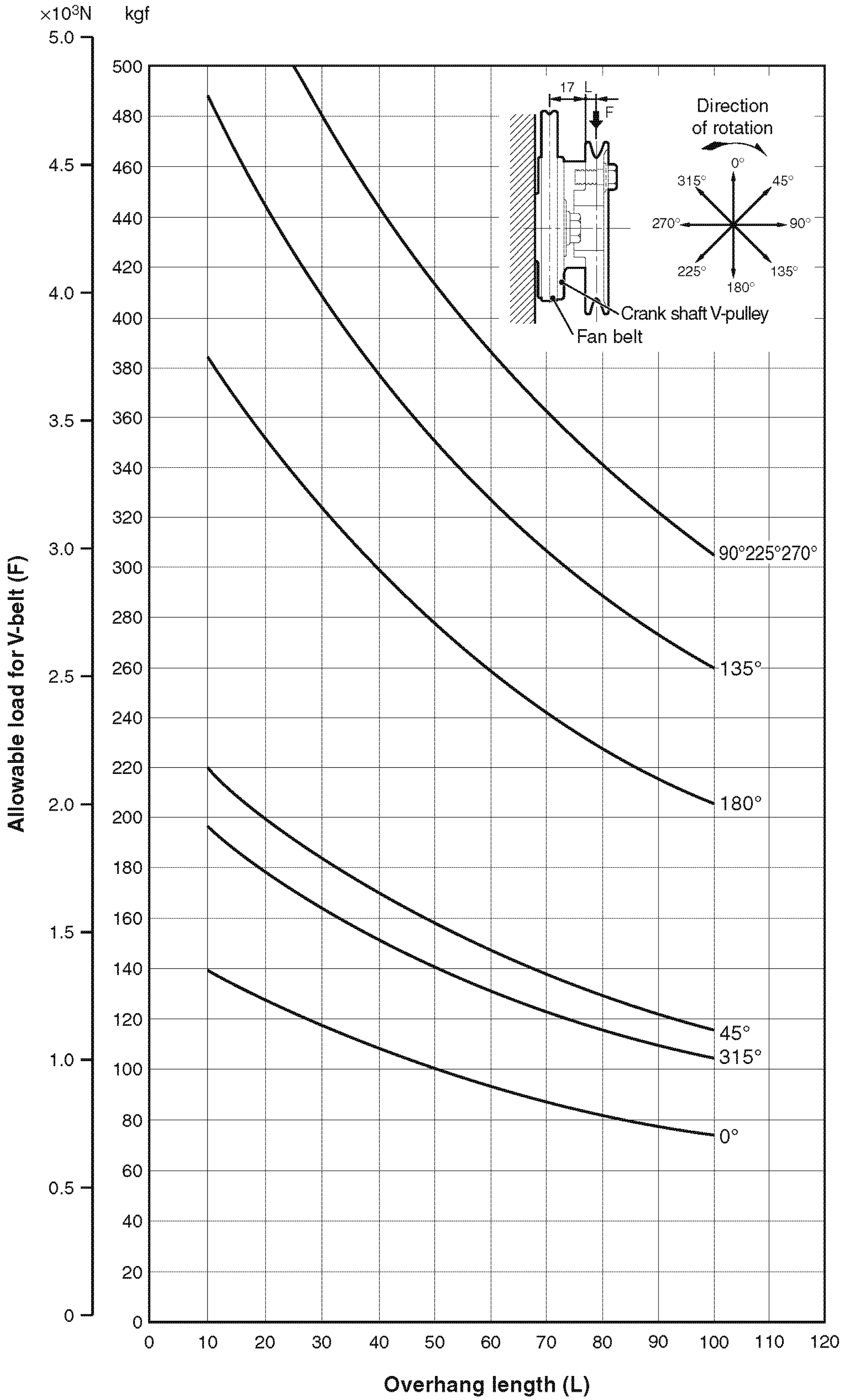


Figure 16-23

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 16-38*.

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.

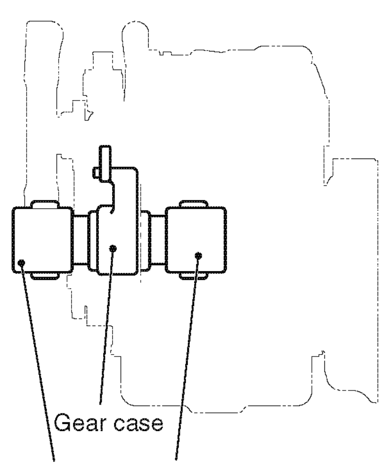


Figure 16-24

Gear Train

Code	Name		Number of teeth		
			2TNV70 3TNV70/76	3TNV82A/84(T) 4TNV84(T)/88	4TNV94L/98(T)
A	Crank gear	❒	31	28	32
B	Idle gear	❒	61	43	50
C	Fuel pump drive gear	❒	62	56	64
D	Cam gear	❒	62	56	64
E	Hydraulic pump drive gear	✔	37	31	26
F	Lubricating oil pump drive gear	❒	—	—	29
Gear ratio: A/E			0.838	0.903	1.231
Hydraulic pump position: W/H (mm)			138/80	162.3/65.979	178.5/107.5

❒: Standard part

✔: Option part

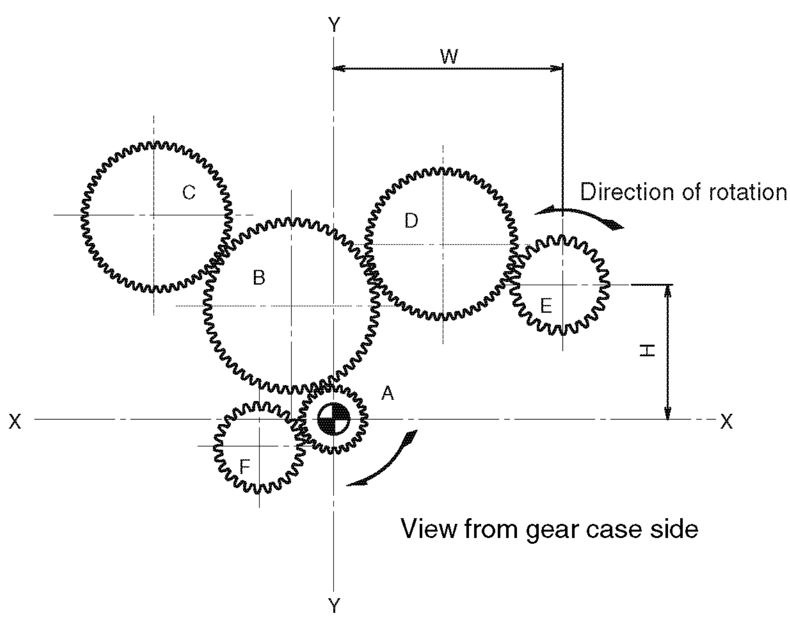


Figure 16-25

ALLOWABLE LOAD FOR HYDRAULIC PUMP DRIVE P.T.O.

IDI Series

2TNV70, 3TNV70, 3TNV76

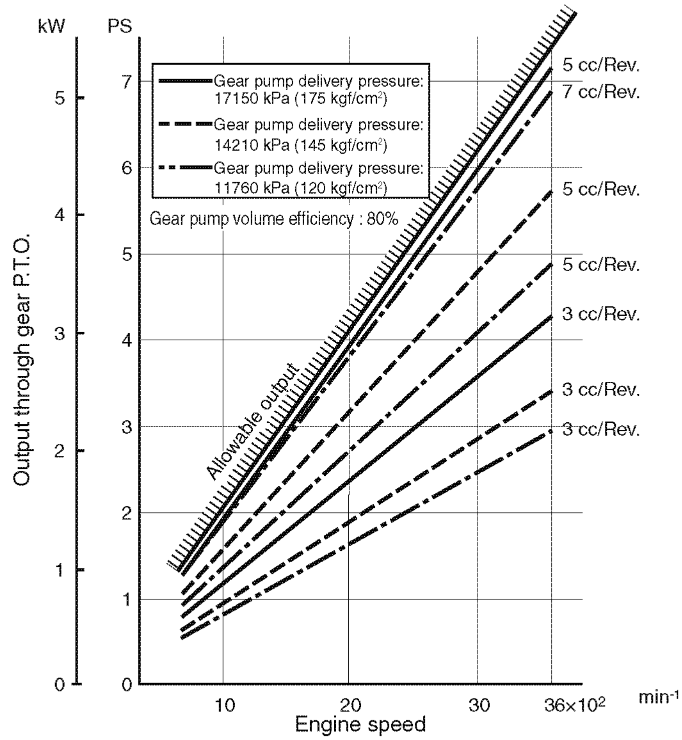


Figure 16-26

DI Series

3TNV82A, 3TNV84(T), 3TNV88

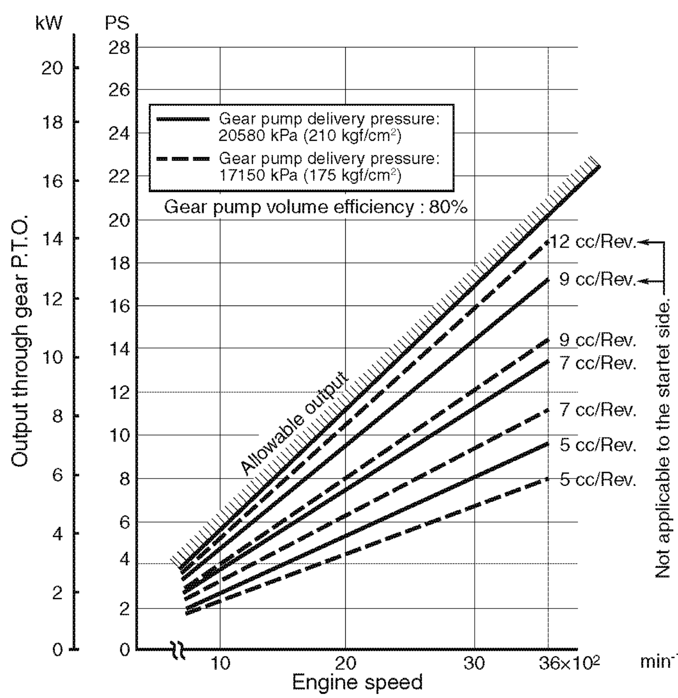


Figure 16-27

4TNV84(T), 4TNV88

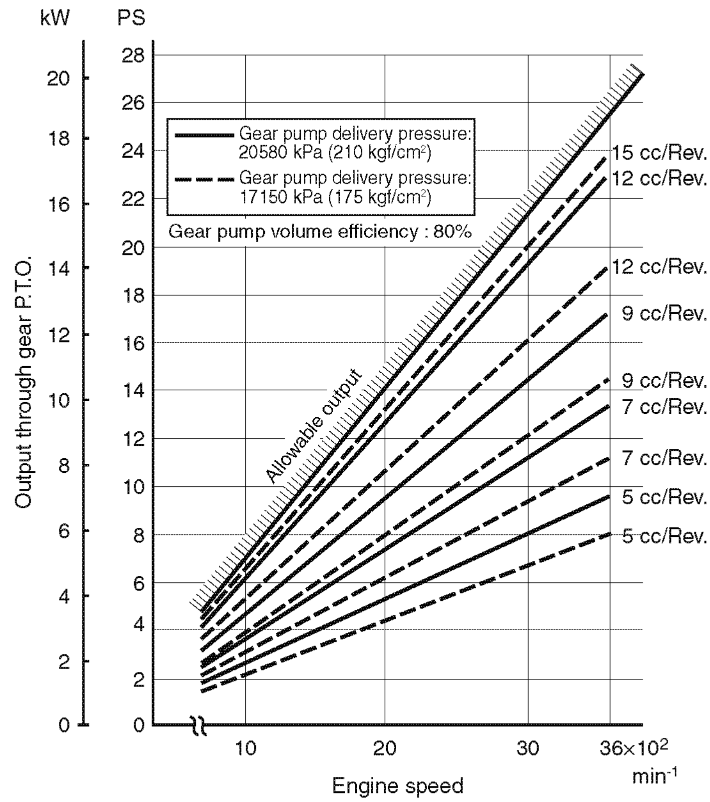
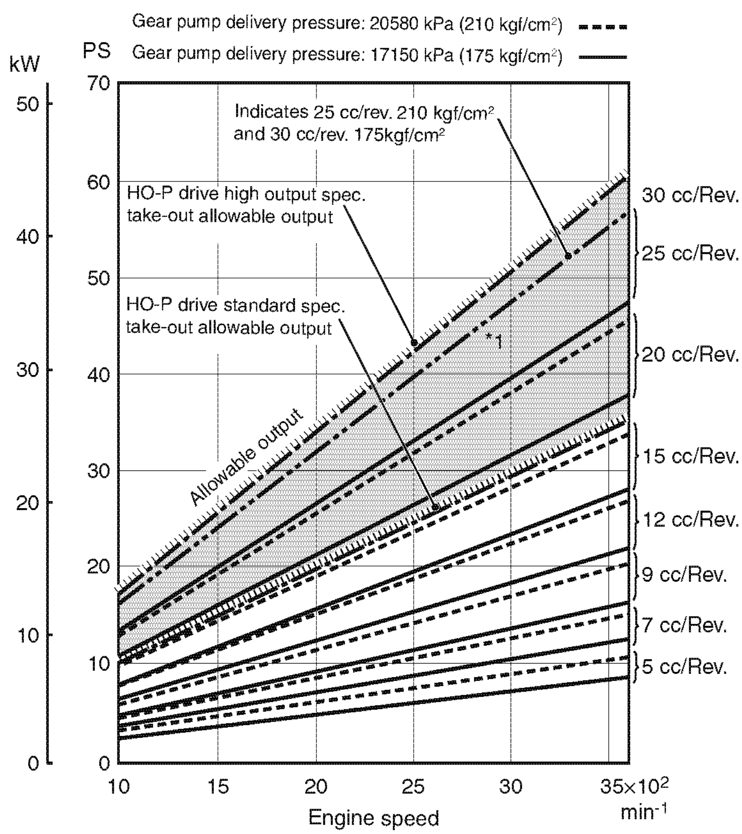


Figure 16-28

4TNV94L, 4TNV98(T)



*Note 1:
In the case of corresponding with a high output pump, it is required to change the drive gear to the special material product (the shaded range).

Figure 16-29

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Section 17

VIBRATION ISOLATION SYSTEM

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The internal combustion engine generates various types of vibration from its reciprocating parts and rotating parts. The vibration is minimized at the design stage of the engine but perfect elimination is theoretically impossible. Therefore, it is necessary to provide the engine with a vibration isolation system to minimize the vibration transmitted to the driven machine.

The diagram below shows a spring having a spring constant K mounted on a fixed wall on which a weight m is loaded. The total system is called a vibratory system. 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.

Now, if the weight m is fixed to the fixed wall, the excitation force F_0 is directly transmitted to the fixed wall. This may be undesirable for the fixed wall. To prevent this, a spring is provided between the weight m and the fixed wall. Then force F transmitted to the fixed wall can be reduced to less than the excitation force F_0 by appropriate selection of the spring constant K.

Vibration System

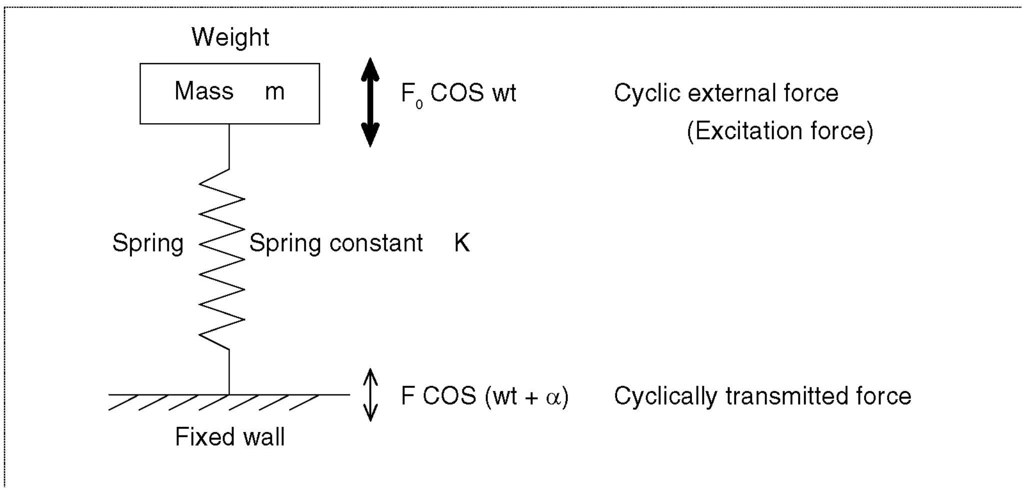


Figure 17-1

This spring structure is called the vibration control equipment. Generally, a rubber isolator is used for the spring system. When selecting an actual rubber isolator, use the total mass of the engine and driven machine unit for the weight of mass m, and substitute the fixed wall with the chassis or bench floor for examination. Therefore, the driven machine manufacturer must examine the machine as the vibratory system, while the engine manufacturer must arrange for such vibration isolation materials as unbalanced force and forced frequency data.

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.

PRINCIPLE OF VIBRATION ISOLATION

Principle of Vibration Isolation and Vibration Transmissibility

A rubber isolator is used for two purposes. One is for preventing vibration generated by machine operation from being transferred to the base **(Figure 17-2,** left side) and the other is for preventing the vibration in the base from being transferred to the machine (**(Figure 17-2,** right side).

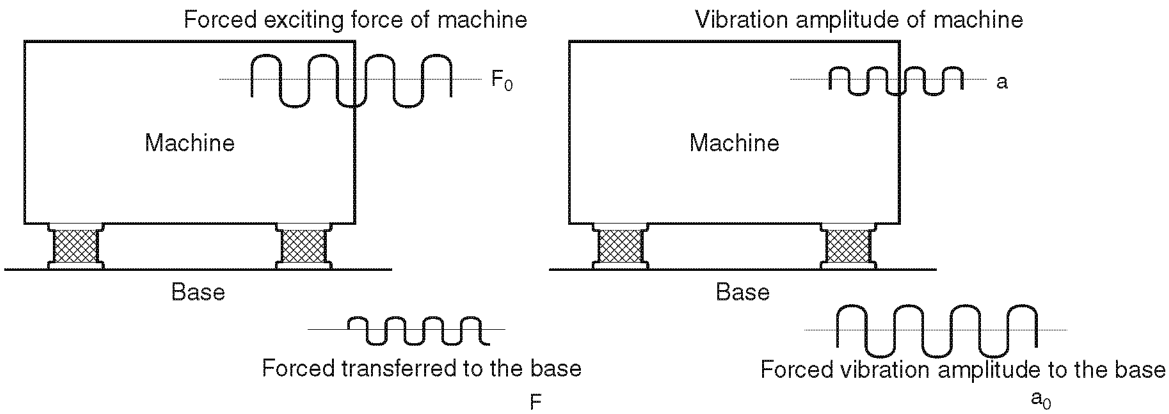


Figure 17-2

When a machine is provided with a vibro-isolating support, assume the excitation force of the machine as F_0 and the force transferred to the base as F. The ratio of transferred vibration is called the transmissibility and is expressed by the following equation:

$$\tau = \frac{F}{F_0} = \frac{a}{a_0} = \left| \frac{1}{1 - \left(\frac{n}{f}\right)^2} \right|$$

τ : Transmissibility

F_0 : Forced excitation force of machine

F : Force transferred to the base

a_0 : Forced excitation amplitude of the base

a : Amplitude transferred to the machine

n : Forced frequency generated from the machine

f : Natural frequency when vibro-isolating support is provided

The graphic representation of the equation above is the curves of vibration transmissibility shown in **(Figure 17-3)**.

Transmissibility Versus Frequency Ratio Curve

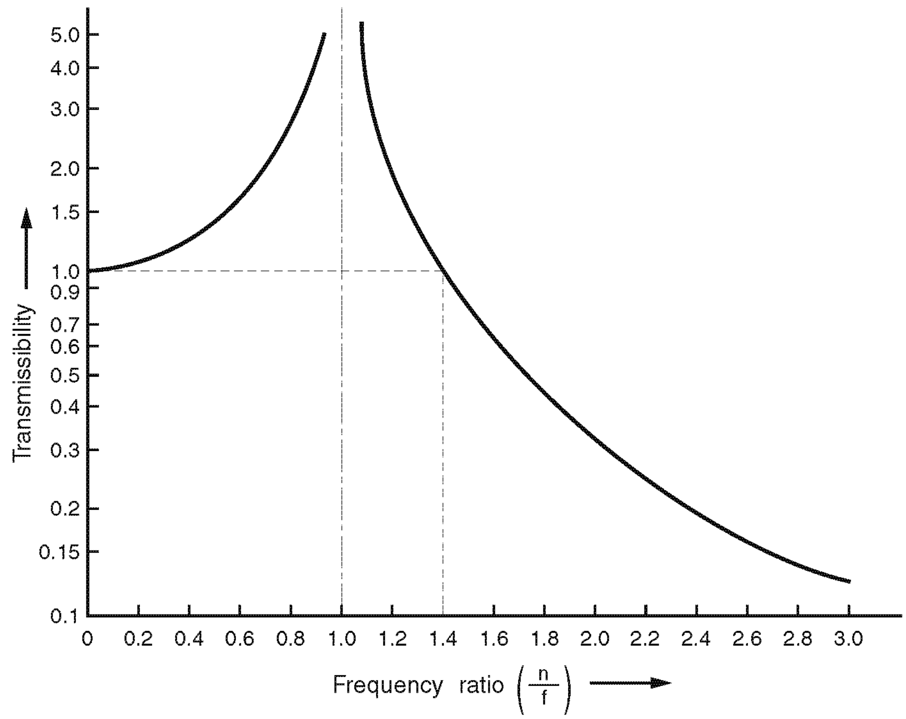


Figure 17-3

Frequency Ratio and Vibration Damping Effect

The vibration transmissibility is determined by the forced frequency (n) of machine and natural frequency (f) with vibro-isolating support.

Frequency ratio	Transmissibility	Vibration isolation effect
$\frac{n}{f} = 1$	$\tau \rightarrow \infty$	Resonance
$\frac{n}{f} = 1.4$	$\tau = 1$	No vibration isolation effect
$\frac{n}{f} > 1.4$	$\tau < 1$	Effective vibration isolation

Normally, select 2 to 3 for n/f.

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.

$$f = \frac{1}{2\pi}\sqrt{\frac{K \times g}{W}}$$

f	:	Natural frequency	Hz
K	:	Dynamic spring constant of rubber isolator (1.4 times the catalog value)	N/cm
g	:	Acceleration of gravity	980 cm/sec^2
W	:	Load on one piece of rubber isolator	

The graphic representation of the equation above is shown in **Figure 17-4**.

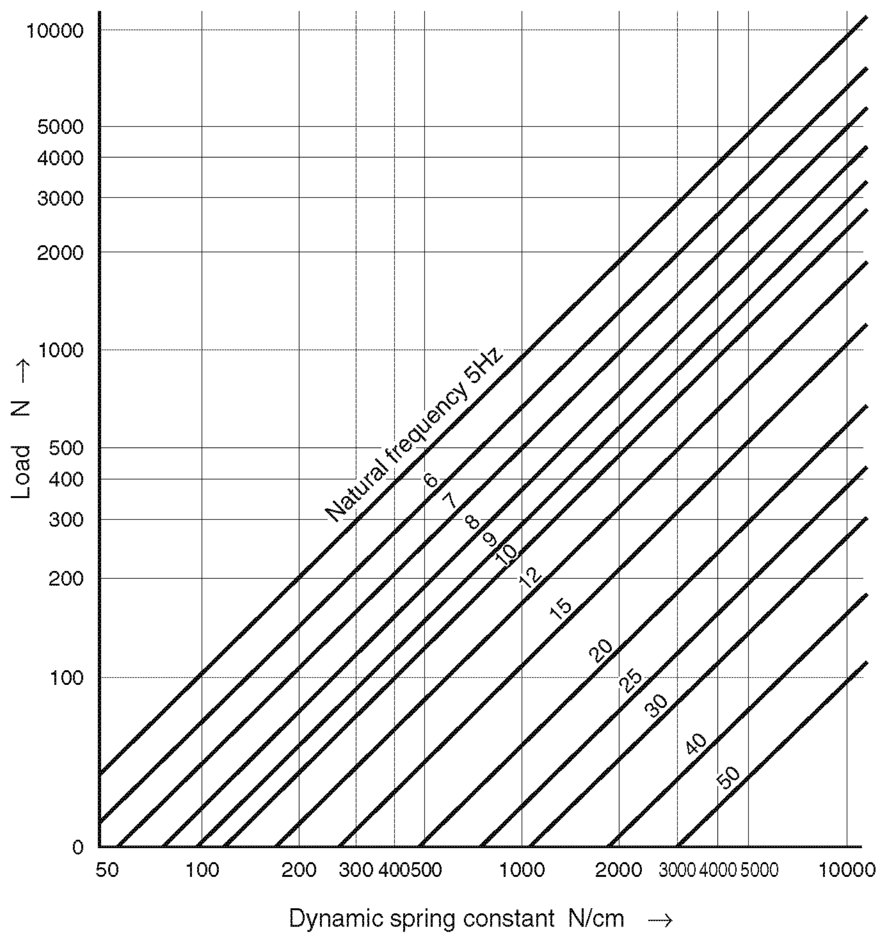


Figure 17-4

CALCULATION OF RUBBER ISOLATOR

Selection Procedures of Vibro-isolating Support

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*
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.

Examples of Selection

Design Specification

Machine	: Refrigerator		
Weight	: Engine	:	1,296 kg
	Refrigerator	:	980 kg
	Coupling and bed	:	800.5 kg
Engine speed	: Normal	:	1,600 min^{-1} (≈27 Hz)
	4-cylinder engine		
	*2nd order reciprocating excitation force (n≈53.3 Hz)		
Support point	: 8 points		

Calculation of Static Spring Constant

Support Load

Static load (W) at each support point is obtained from the following equation:

$$W = \frac{3076.5 \times 9.807}{8} \approx 3771\,\mathrm{N}$$

Determination of Natural Frequency

If a vibration transmissibility in the vicinity of 10% is targeted, n/f = 3 from the curve of vibration transmissibility, and the natural frequency (f) can be obtained from the following equation:

$$f = \frac{n}{3} = \frac{1600 \times 2}{3} = 1067\,\mathrm{cpm} \approx (17.8)\ \mathrm{Hz}$$

Calculation of Dynamic Spring Constant

Because the static load per point is 3771 N, the dynamic spring constant can be calculated from:

$$f = \frac{1}{2\pi}\sqrt{\frac{K \times g}{W}}\ \text{Hz}$$

$$K = (2\pi f)^2 \times \frac{W}{g}$$

$$= (2 \times 3.14 \times 17.8)^2 \times \frac{3771}{980} = 48083\ \text{N/cm}$$

Calculation of Static Spring Constant

From the following equation for static spring constant:

$$\text{Static spring constant} = \frac{\text{Dynamic spring constant}}{1.4}$$

$$K_s = \frac{K}{1.4} = \frac{48083}{1.4} = 34345\ \text{N/cm}$$

Selection of Rubber Isolator

The result of the above calculation:

Static load per support point of rubber isolator	: 3771 N
Static spring constant	: 34345 N/cm

Verification of Vibration Isolation Effect

Suppose that the following rubber vibration isolators are selected as closest to the above result:

Allowable load	: 7845N (800kg)
Static spring constant	: 31381 N/cm (3200 kg/cm)

Then,

- Natural frequency of the support system is obtained from the following equation:

$$f = \frac{1}{2\pi}\sqrt{\frac{K \times g}{W}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1.4 \times 31381 \times 980}{3771}} = 17.0\ \text{Hz}$$

- The vibration transfer ratio is obtained from the following equation:

$$\tau = \frac{1}{\left(\frac{n}{f}\right)^2 - 1} \times 100$$

$$= \frac{1}{\left(\frac{53.3}{17}\right)^2 - 1} \times 100 = 11\%$$

- Vibration isolation effect

$$100 - \tau = 100 - 11 = 89$$

Therefore, the vibration isolation effect is 89%.

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 rubber isolator types preceding or following the tested isolator to find the most effective rubber vibration isolator.

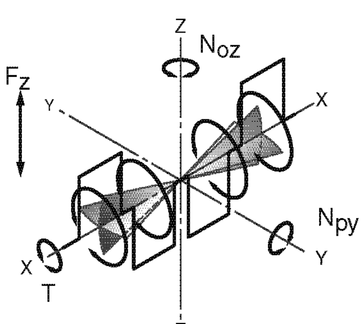
Vibration Improvement

As stated in the preceding section, if the test result of the rubber isolator produces a poor vibration isolating effect, conduct tests again using various types of commercially available rubber isolators. The rubber isolator should be selected considering the vibration characteristics of the engine.

The forced 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.

Degree and direction of exciting force to be avoided by vibration damping system

Exciting force / Number of cylinders	Torque alternation (lowest order)	Unbalance force: Inertia force by reciprocating mass		Inertia couple force by rotating mass	Inertia couple force by reciprocating mass	
		1st order	2nd order	1st order	1st order	2nd order
	T N·m	F_z N		N_{oz} N·m	N_{py} N·m	
1	1/2 order	O	O	--	--	--
2	1/2 order	--	O	O	O	--
3	1-1/2 order	--	--	O	O	O
4 (90° crank)	1/2 order	--	--	--	O	O
4 (180° crank)	2nd order	--	O	--	--	--
5	2-1/2 order	--	--	--	O	O
6	3rd order	--	--	--	--	--



T : Rolling
F_z : Vertical motion
N_{oz} : Yawing
N_{py} : Pitching

VIBRATION ISOLATION MATERIALS

If vibration fails to reach the target value as the result of tests using a rubber isolator of the calculated specifications, conduct tests again by using various types of rubber isolator to find a practical solution. In this case, select a rubber isolator by considering the engine vibration characteristics.

Engines differ in the size of unbalance force (excitation force), forced frequency and the direction of vibration with the number of cylinders. These vibration characteristics are outlined in a separate table for reference when trying to improve the vibration characteristics.

Generally, unbalance force and torque alternation are jointly called excitation force, and the materials concerning it always involve the term "order." This indicates the number of times an excitation force is generated during one rotation of an engine. For example, excitation force of 2nd order refers to the vibration that causes the excitation force to be generated two times during one engine rotation.

Specifically, when an engine is driven at 2600 min^{-1}, the excitation force of 2nd order is generated two times during each engine rotation, or 5200 times a minute. This is called the forced frequency, and is expressed in units of cpm and by the following formula:

$$n = h \times N$$

Where,

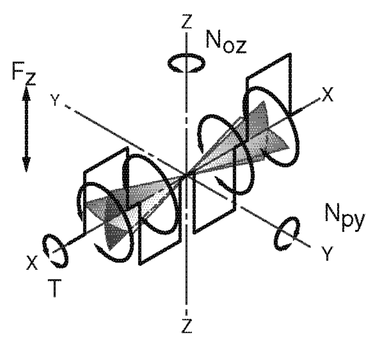
n	:	Forced frequency of ecitation force	cpm
h	:	Order of excitation force	
N	:	Engine speed	rpm

Excitation Force

Unbalance force

Engine model	1st order inertia force by reciprocating mass	2nd order inertia force by reciprocating mass	1st order couple force by rotating mass	1st order couple force by reciprocating mass	2nd order couple force by reciprocating mass
	F_z (N)[1]	F_z (N)[2]	N_{oz} (N·m)[1]	N_{py} (N·m)[1]	N_{py} (N·m)[2]
2TNV70	-	$15.034 \times 10^{-5} \times N^2$	$7.022 \times 10^{-6} \times N^2$	$18.368 \times 10^{-6} \times N^2$	-
3TNV70	-	-	$7.747 \times 10^{-6} \times N^2$	$31.833 \times 10^{-6} \times N^2$	$10.425 \times 10^{-6} \times N^2$
3TNV76	-	-	$15.701 \times 10^{-6} \times N^2$	$44.160 \times 10^{-6} \times N^2$	$14.838 \times 10^{-6} \times N^2$
3TNV82A	-	-	$13.406 \times 10^{-6} \times N^2$	$57.467 \times 10^{-6} \times N^2$	$18.927 \times 10^{-6} \times N^2$
3TNV84(T)	-	-	$22.928 \times 10^{-6} \times N^2$	$82.170 \times 10^{-6} \times N^2$	$25.233 \times 10^{-6} \times N^2$
3TNV88	-	-	$22.928 \times 10^{-6} \times N^2$	$89.967 \times 10^{-6} \times N^2$	$29.557 \times 10^{-6} \times N^2$
4TNV84(T)	-	$66.323 \times 10^{-5} \times N^2$	-	-	-
4TNV88	-	$72.609 \times 10^{-5} \times N^2$	-	-	-
4TNV94L	-	$12.474 \times 10^{-4} \times N^2$	-	-	-
4TNV98(T)	-	$13.033 \times 10^{-4} \times N^2$	-	-	-

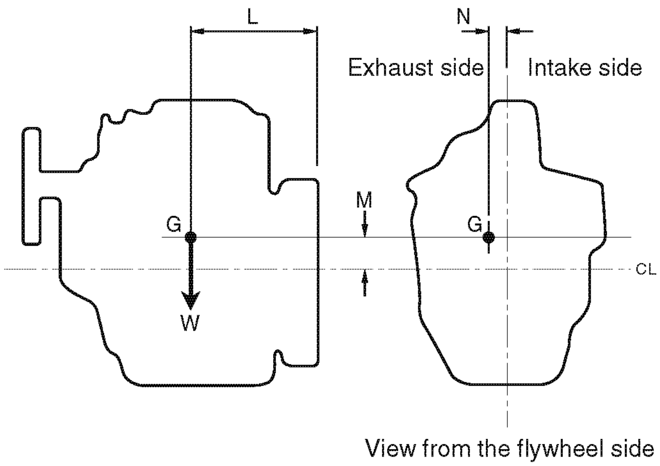
1 With unbalance moment to V-pulley and flywheel
2 Without unbalance moment to V-pulley and flywheel



Torque alternation by gas pressure:

Engine model	Torque alternation T (N·m)					
	1/2 order	1st order	1-1/2 order	2nd order	3rd order	4th order
2TNV70	-	92.2	-	78.5	50.0	30.4
3TNV70	-	-	134.4	-	75.5	-
3TNV76	-	-	175.5	-	98.1	-
3TNV82A	-	-	221.6	-	117.7	-
3TNV84	-	-	249.1	-	132.4	-
3TNV88	-	-	273.6	-	145.1	-
3TNV84T	-	-	293.2	-	139.3	-
4TNV84	-	-	-	293.2	-	107.9
4TNV88	-	-	-	321.7	-	117.7
4TNV84T	-	-	-	322.6	-	107.9
4TNV94L	-	-	-	449.1	-	164.8
4TNV98	-	-	-	520.7	-	179.5
4TNV98T	-	-	-	700.2	-	162.8

Engine Weight and Center of Gravity



G : Center of gravity
L : Distance from flywheel housing end
M : Distance from crankshaft center line
N : Distance from crankshaft center line
W : Weight (including cooling water and lubricating oil)

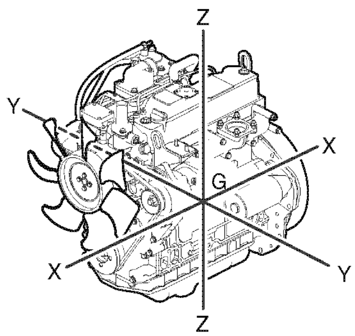
The data in the table below is based on the outlines of the standard dimensions shown in *3. Specifications*.

If the customer's required specifications are known, use them instead.

	L mm	**M mm**	**N mm**	**W kg**
2TNV70	151.3	64.9	4.3	84
3TNV70	192.5	77	5	98
3TNV76	158	53	10	112
3TNV82A	208	82	9.5	135
3TNV84	213	92	11	163
3TNV88	213	92	11	163
3TNV84T	213	92	11	168
4TNV84	266	92	4.6	190
4TNV88	266	92	4.6	190
4TNV84T	266	92	4.6	195
4TNV94L	282	124	27	244
4TNV98	282	124	27	244
4TNV98T	282.5	137.1	35	254

Note: F-F specs., (excluding radiator, air cleaner and muffler) including intake manifold, exhaust manifold and flywheel housing.

Engine Moment of Inertia



G : Center of gravity
I_x : X-axial moment
I_y : Y-axial moment
I_z : Z-axial moment

The data in the table below is based on the outlines of the standard dimensions shown in *3. Specifications*.

	Moment of inertia (N·cm-sec^2)			Wet weight (kg) *
	I_x	I_y	I_z	W
2TNV70	238.50	261.45	132.78	84
3TNV70	295.18	370.00	203.00	98
3TNV76	270.66	370.69	246.15	112
3TNV82A	311.26	412.86	301.95	135
3TNV84	463.37	596.84	426.49	163
3TNV88	463.37	596.84	426.49	163
3TNV84T	478.67	616.55	440.52	168
4TNV84	579.28	901.92	688.92	190
4TNV88	579.28	901.92	688.92	190
4TNV84T	593.50	925.65	707.06	195
4TNV94L	1258.2	1714.2	1235.6	244
4TNV98	1258.2	1714.2	1235.6	244
4TNV98T	1364.1	1821.1	1238.6	254

Note: Including cooling water and lubricating oil.

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Section 18

TORSIONAL VIBRATION

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A 4-cycle engine continuously generates output by igniting on every other revolution of the crankshaft. It changes the reciprocating motion of the pistons to the rotary motion of the crankshaft. Therefore, the crankshaft is constantly loaded with tension, bending, torsion or a combination of these. When a crankshaft is designed, the designer takes into consideration the forces that are applied when the engine is running to avoid breakage due to fatigue. If an excessive load is applied to the crankshaft while the engine is running, it may shorten the life of the crankshaft.

Consequently if a large stress is applied by the torsional motion, it may lead to breakage due to fatigue of the crankshaft and transmission shaft. If the additional stress poses no problem, the excessive amplitude may cause breakage due to fatigue of the transmission gear system. 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.

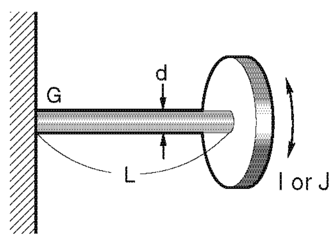


Figure 18-1

The disc vibrates in this way around its axis. This type of vibration is called torsional vibration. If damping, such as air resistance or internal resistance of the bar does not take place, the disc may continue to vibrate indefinitely.

In practice, because of damping, the vibration gradually diminishes until it stops. This type of vibration is called free vibration, and the number of vibrations per unit time (generally 1 minute) is called natural frequency (f_n).

Natural frequency always has a constant value when the moment of inertia of the disc (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) are determined. Natural frequency decreases as the moment of inertia of the disc increases or the elasticity of the bar decreases, and vice versa. Large inertial masses such as direct coupled A.C. alternators connected directly with the crankshaft need most careful examination.

Resonance Curve

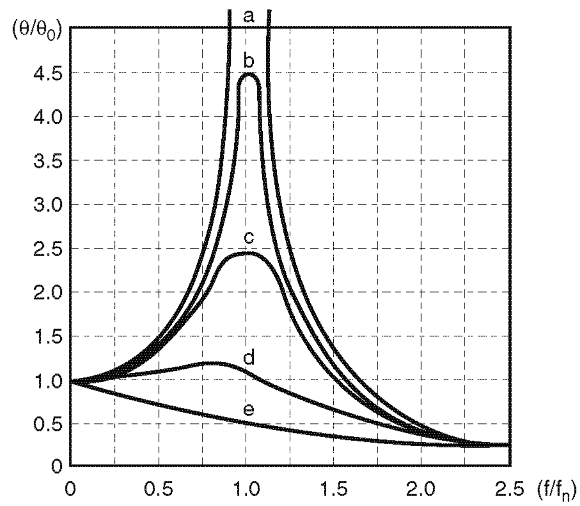


Figure 18-2

The free vibration as described previously is caused simply by twisting and releasing the disc. If the twisting force (exciting force) is periodically applied to the disc, the subsequent vibration is called forced vibration. If the frequency of the exciting force agrees with the natural frequency of the vibratory system, the bar twisting angle (amplitude) increases greatly. This state is called resonance. **(Figure 18-2)** shows how amplitude θ 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. Assume θ_0 is the bar twisting angle of torsion when exciting force is applied statically.

In the case of a vibratory system that has a small exciting force, θ/θ_0 becomes infinite at the resonance point f/f_n 1.0 if no damping exists **(Figure 18-2)**. 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 θ_0.

As damping increases to b, c, d and upward, the amplitude at the resonance point decreases. When it reaches position e, it does not enter the vibrating state because of excessive damping resistance, hence the resonance point vanishes.

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.

TORSIONAL VIBRATION OF MULTI-CYLINDER ENGINE

Equivalent Vibration System

What is Torsional Vibration? on page 18-3 describes the basic concept of the simplest so-called torsional vibration of one-degree-of-freedom system having a single disc. The free vibration form of a shaft having several discs attached is similarly determined.

If the multi-cylinder engine shaft system as shown in **(Figure 18-3), (A)** is replaced with an ideal form of vibratory system like **(B)** consisting of shaft of a uniform diameter and simple discs for the analysis, the vibratory system is now called an equivalent vibration system.

Shaft System of Multi-cylinder Engine

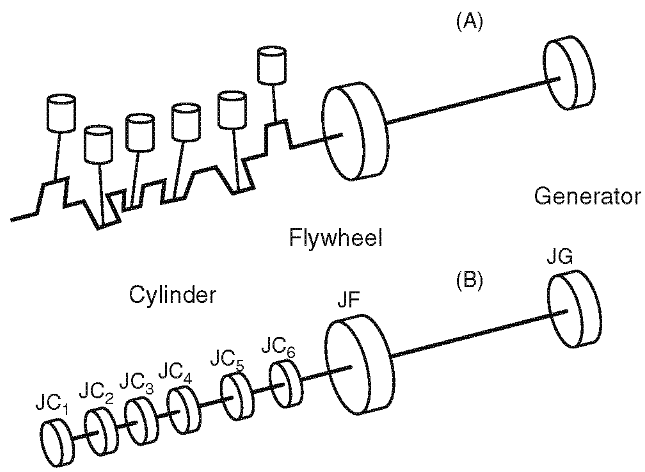


Figure 18-3

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).

Equivalent Vibration System and Elastic Curves

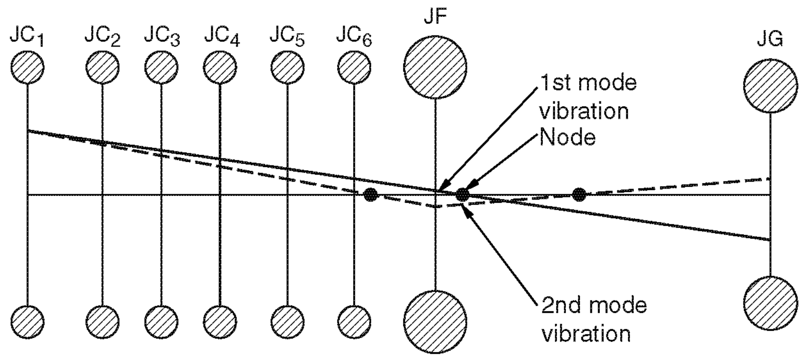


Figure 18-4

(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.

Harmonics of Torque

To this point, the free vibration of a multi-cylinder engine shaft system has been described. Let us assume a 4-cycle engine with its crankshaft revolving is being tested. Combustion is generated in one of the cylinders once in every two revolutions of the crankshaft. The pressure change is rewritten as the torque change of the crankshaft **(Figure 18-5)**. While this represents an a harmonic change, the crankshaft torque consists of harmonically changing torques as shown in **(Figure 18-6)**, that is, a group of harmonics. The 1st or 2nd order stated in **(Figure 18-6)** refers to the torque alternation that repeats one time or two times at every revolution of the crank. The higher the degree of the order, the weaker the strength of harmonics. Because of many harmonics, multi-cylinder engines involve awkward problems of torsional vibration.

Cylinder Pressure Change and Crank Torque Change

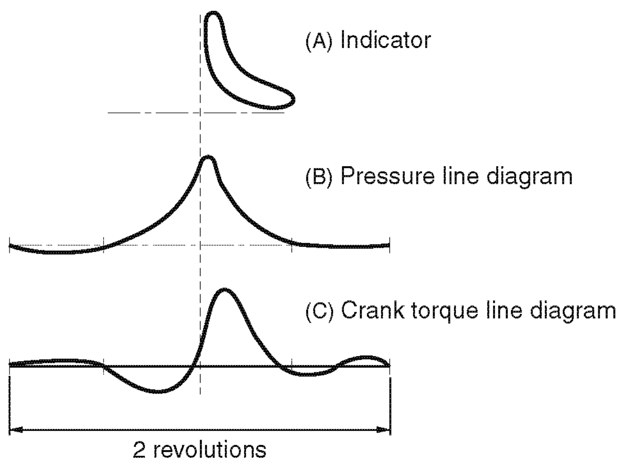


Figure **18-5**

Crank Torque Harmonics

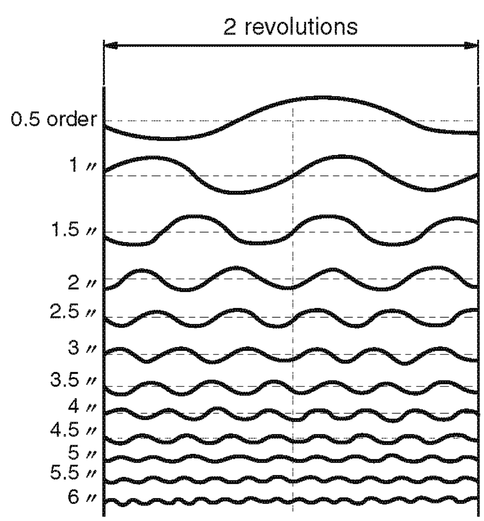


Figure 18-6

Forced Vibration of a Multi-cylinder Engine

As described in the preceding section, torque harmonics of respective degrees of order act on the engine crankshaft as the source of vibration. Therefore, if only one natural frequency of the vibratory system is present, a characteristic critical speed, resonates with the torque harmonics. The level of criticality in the critical speed is determined by the scale of work performed by the torque harmonics of the pertinent degree of order to vibration. Up to this point, descriptions of torque harmonics have been made for a single cylinder engine. In the case of a multi-cylinder engine, the level of criticality in the critical speed is determined by the size of total torque harmonics in consideration of the phases of respective cylinders of the pertinent degree of order.

As described above, there are a number of critical speeds, but their level of criticality is determined by the size of the torque harmonics. Therefore, it is not necessary to consider torque harmonics of a lower degree of order as objects of criticality. Consideration should be given to the degrees of order having the harmonics of a certain size or more.

Generally, with 4-cycle engines, torque harmonics of the degree of order equivalent to one half of the number of cylinders multiplied by an integer is called the major critical speed, which is an object of criticality.

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, there is a case where torque harmonics of other degrees of order t may become the object of criticality depending on the crank layout and / or firing order. The following table indicates the degrees of order for critical speed that cause practical problems, and that have to be avoided.

Number of cylinders (crank layout)	First mode vibration	Second mode vibration
2	No consideration required for practical application	
3	3, 4-½, 6	No consideration required
4 (180° crank)	4, 6, 8	No consideration required

ACTUAL PROCESSING FOR TORSIONAL VIBRATION

It is assumed that the reader understands the basics of torsional vibration for diesel engines described so far. This section describes how to process the torsional vibration for practical application. When planning a device using a diesel engine as the prime mover, it is important to ensure that no critical speed 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. To do this, it is customary to select an appropriate natural frequency of a vibratory system configured with the engine and the driven machine.

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

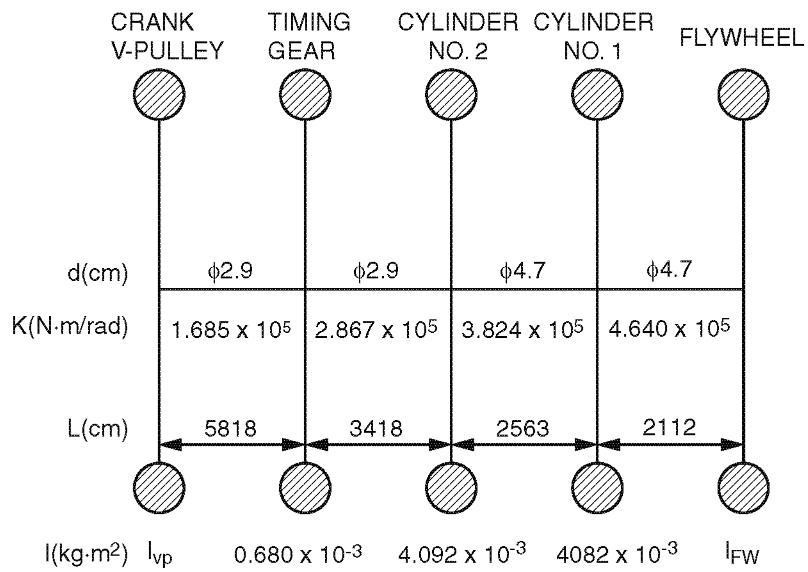
To avoid the risk of torsional vibration, it is necessary, as already described, to either avoid the critical speed by changing the natural frequency or to suppress the amplitude of vibration to a lower level.

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

IDI Series

2TNV70



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

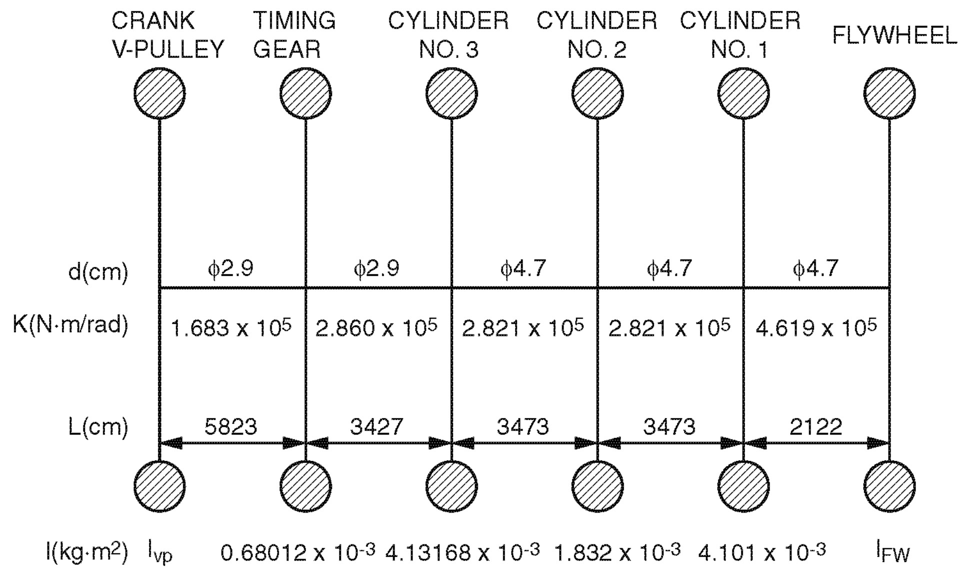
Crankshaft V-pulley moment of inertia

I_{VP}	Code No.	GD^2
0.720×10^{-3}	119717-21650 (ϕ110)	0.0029

Flywheel Moment of Inertia

I_{FW}	Code No.	GD^2
0.113	119415-21590	0.4500

3TNV70



I	:	Moment of inertia	$kg \cdot m^2$
K	:	Spring constant	$N \cdot m/rad$
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

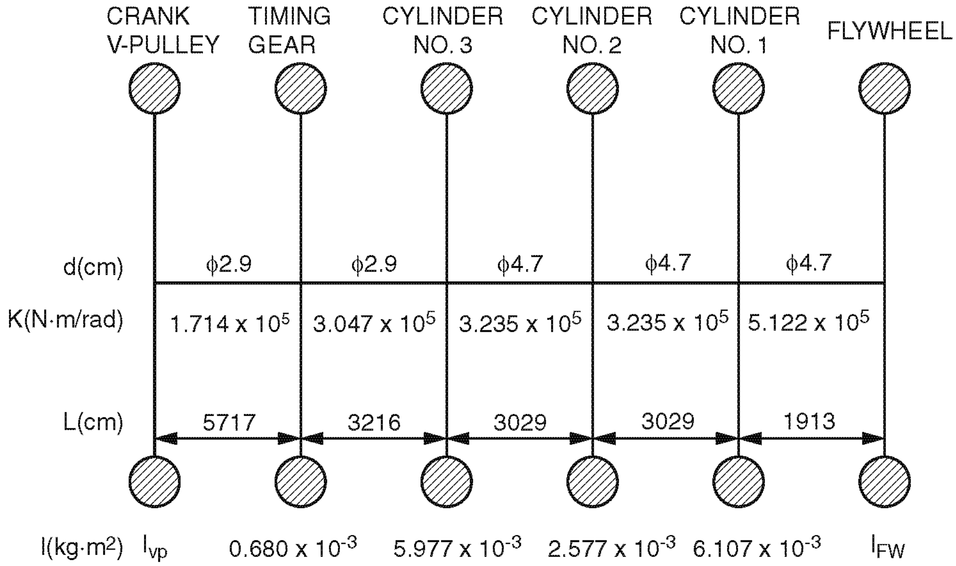
Crankshaft V-pulley moment of inertia

I_{VP}	Code No.	GD^2
0.7203×10^{-3}	119717-21650 (ϕ110)	0.0029

Flywheel Moment of Inertia

I_{FW}	Code No.	GD^2
0.1125	119515-21590	0.4500

3TNV76



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

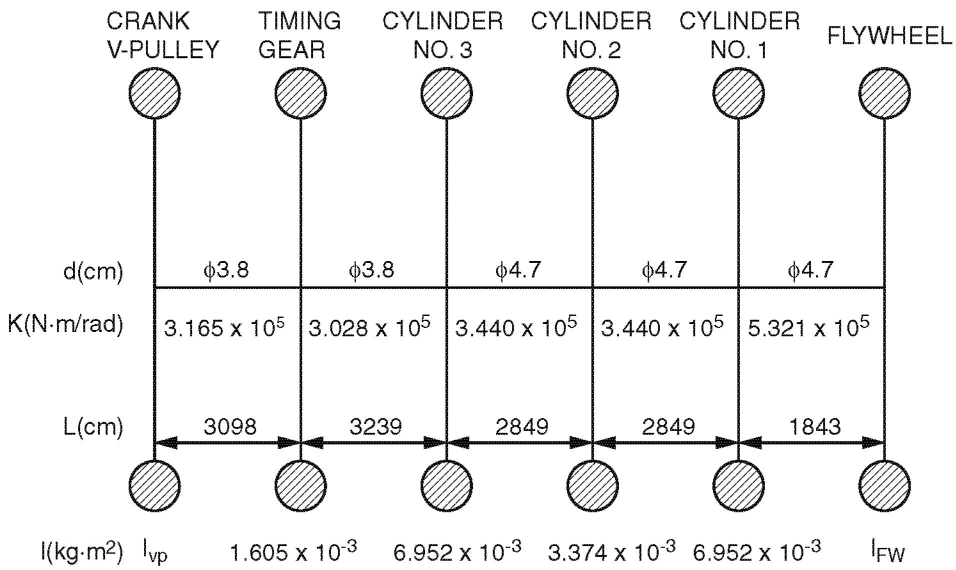
I_{VP}	Code No.	GD^2
0.7203×10^{-3}	119717-21650 (ϕ110)	0.0029

Flywheel Moment of Inertia

I_{FW}	Code No.	GD^2
0.234	119636-21580	0.9360

DI Series

3TNV82A



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

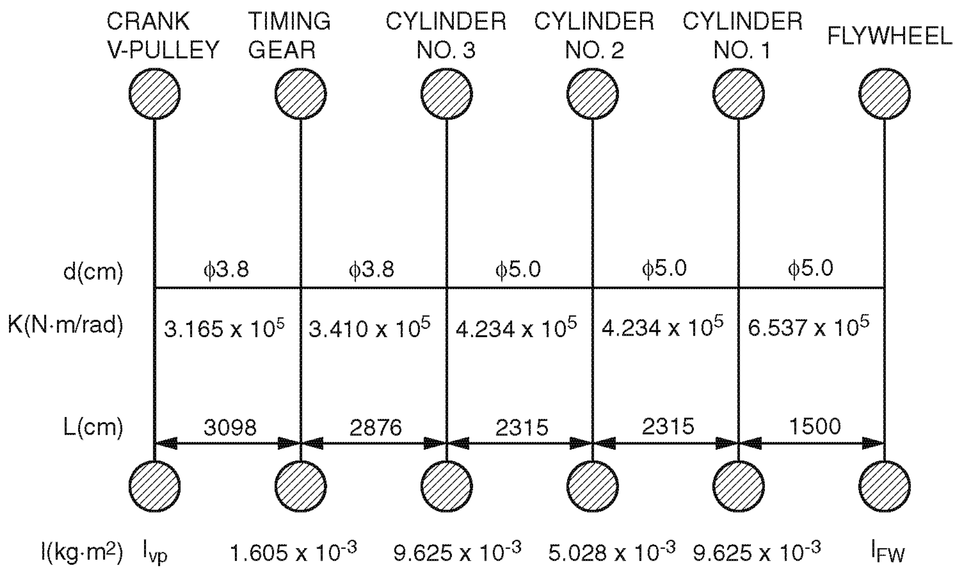
Crankshaft V-pulley moment of inertia

I_{VP}	Code No.	GD^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}	Code No.	GD^2
0.435	171420-21590 (CL)	1.7400
0.199	129403-21590 (VM)	0.7950
0.220	129489-21590 (VM)	0.8800
0.227	171420-21590 (CH)	0.9100
0.327	129188-21590 (SAE#5)	1.3100

3TNV84(T)



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

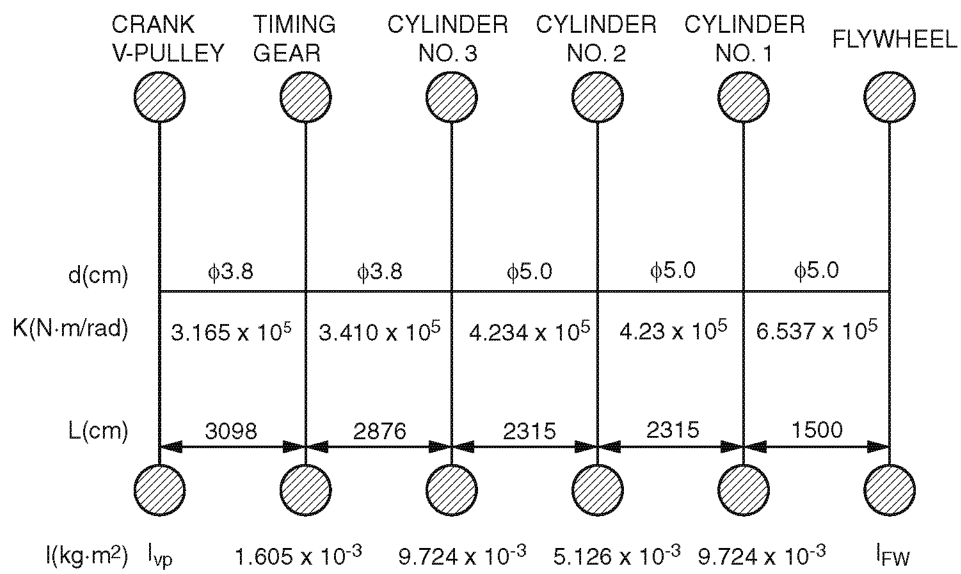
Crankshaft V-pulley moment of inertia

I_{VP}	Code No.	GD^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}	Code No.	GD^2
0.435	171340-21590 (CL)	1.7400
0.330	171350-21590 (VM)	1.3200
0.227	171340-21580 (CH)	0.9100
0.220	129128-21590 (VM)	0.8800
0.327	129188-21590	1.3100

3TNV88



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

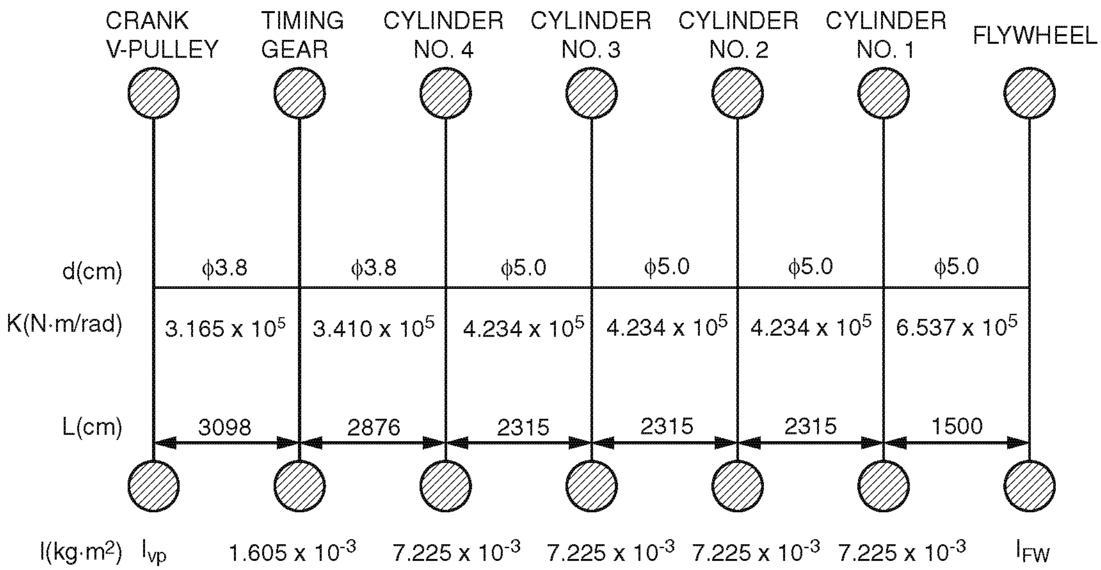
Crankshaft V-pulley moment of inertia

I_{VP}	Code No.	GD^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}	Code No.	GD^2
0.435	171340-21590 (CL)	1.7400
0.330	171350-21590 (VM)	1.3200
0.220	129128-21590 (VM)	0.8800
0.327	129188-21590	1.3100

4TNV84(T)



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

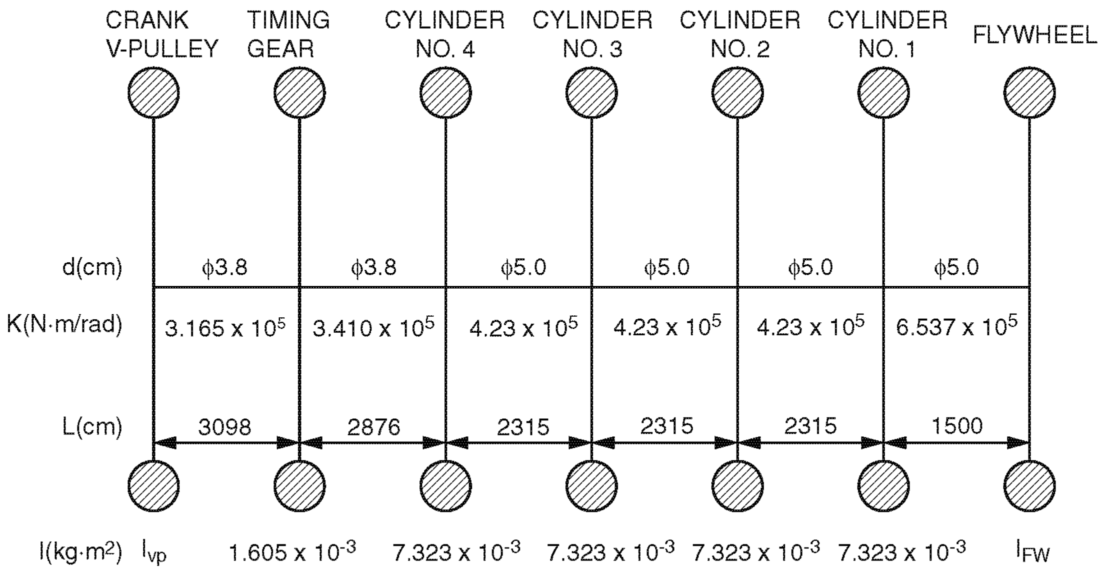
Crankshaft V-pulley moment of inertia

I_{VP}	Code No.	GD^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}	Code No.	GD^2
0.435	171420-21590 (CL)	1.7400
0.199	129403-21590 (VM)	0.7950
0.220	129489-21590 (VM)	0.8800
0.227	171420-21590 (CH)	0.9100
0.327	129188-21590 (SAE#5)	1.3100

4TNV88



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

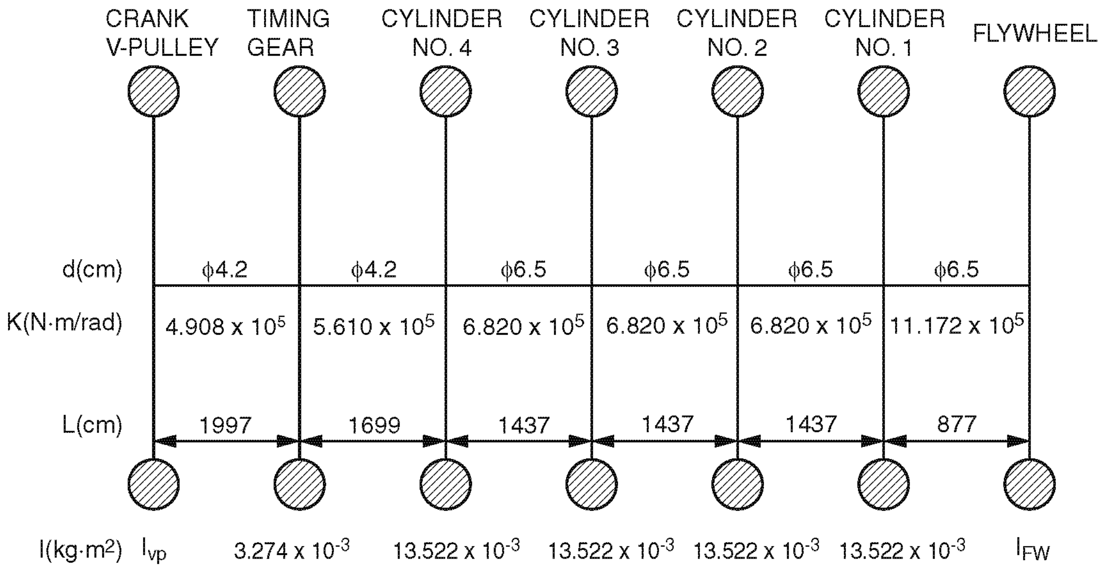
Crankshaft V-pulley moment of inertia

I_{VP}	Code No.	GD^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}	Code No.	GD^2
0.435	171420-21590 (CL)	1.7400
0.199	129403-21590 (VM)	0.7950
0.220	129489-21590 (VM)	0.8800
0.327	129188-21590 (SAE#5)	1.3100

4TNV94L



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

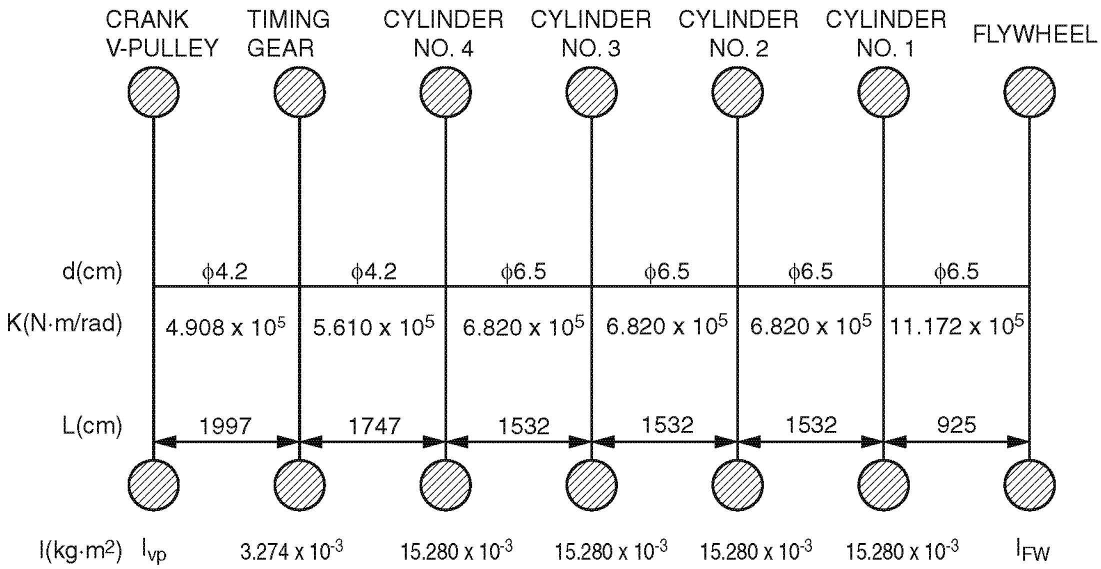
Crankshaft V-pulley moment of inertia

I_{VP}	Code No.	GD^2
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}	Code No.	GD^2
0.495	129902-21580 (CL)	1.98
0.293	129900-21580 (VM)	1.17
0.605	129955-21590	2.42
0.707	129920-21580	2.83

4TNV98(T)



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}	Code No.	GD^2
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}	Code No.	GD^2
0.495	129902-21580 (CL)	1.98
0.293	129900-21580 (VM)	1.17
0.605	129955-21590	2.42
0.707	129920-21580	2.83

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Section 19

REFERENCE MATERIALS

Page

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/cm²	=	98	kPa		1	kPa	=	0.0102	kgf/cm²
		=	0.098	MPa		1	MPa	=	10.2	kgf/cm²
750	mmHg	=	100	kPa		1	Pa	=	1	N/m²

Specific fuel and lubrication oil consumption

g/kW·h	g/hp·h	g/PS·h
1	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:

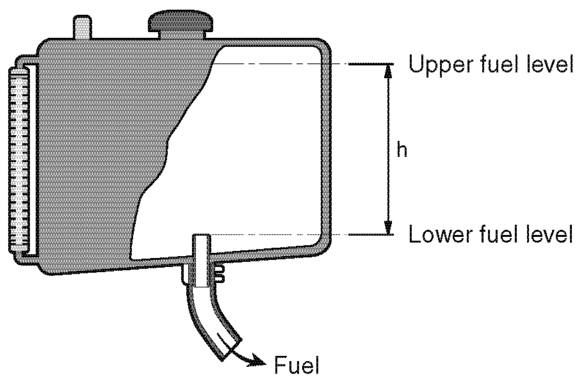
$$Q = \frac{b \times P_e}{1000 \times d}$$

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 3TNV84 series diesel engine, the continuous rating at 1800 rpm is 13.5 kW and the fuel consumption is 245 g/kW·h. For how many hours will a fuel tank having an effective capacity of 20L last at the continuous rating?

Fuel Consumption (ℓ/h)

$$B = \frac{b \times P_e}{d} \times 10^{-3}$$

$$= \frac{245 \times 13.5}{0.83} \times 10^{-3}$$

$$= 3.98 \text{ ℓ/h}$$

B	:	Fuel consumption	ℓ/h
b	:	Specific fuel consumption	245 g/kW·h
P_e	:	Rated output	13.5 kW
d	:	Specific gravity of fuel	Diesel fuel 0.83

Fuel Tank Holding Time (h)

$$t = \frac{V}{B}$$

$$= \frac{20}{3.98}$$

$$= 5\,h$$

t	:	Fuel tank holding time	h
V	:	Effective fuel capacity	20 ℓ
B	:	Fuel consumption	3.98 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 3TNV76 series diesel engine, the effective capacity of the standard oil pan in CH specifications is 2.1 ℓ.

When driven at the continuous rating of 17.7 kW for 3600 rpm, for how many hours will the oil pan last? The specific engine oil consumption is 0.2 g/kW·h.

Engine Oil Consumption (ℓ/h)

$$C = \frac{c \times P_e}{d} \times 10^{-3}$$

$$= \frac{0.2 \times 17.7}{0.89} \times 10^{-3}$$

$$= 3.98 \times 10^{-3} \ \ell/h$$

C	:	Engine oil consumption	ℓ/h
c	:	Specific engine oil consumption	0.2 g/kW·h
		Reference only: Specific engine oil consumption for TNV.	

Engine	IDI	DI
g/kW·h	0.28	0.34

P_e	:	Continuous rating	17.7 kW
d	:	Specific gravity of engine oil	0.89

Oil Pan Holding Time (ℓ/h)

$$t = \frac{V}{C}$$

$$= \frac{2.1}{3.98 \times 10^{-3}}$$

$$= 121 \ h$$

t	:	Oil pan holding time	h
V	:	Effective capacity of oil pan	2.1 ℓ
C	:	Engine oil consumption	3.98×10^{-3} ℓ/h

MEAN PISTON SPEED

Mean Piston Speed (m/s)

$$V_m = \frac{2S \bullet n}{60} \times 10^{-3}$$

V_m	:	Mean piston speed	m/s
S	:	Engine stroke	mm
n	:	Engine speed	rpm

Example

According to the specification sheet for the 3TNV84 series diesel engine, the piston stroke is 90 mm. What is the mean piston speed for 3000 rpm of engine speed in VM specifications.

$$V_m = \frac{2S \bullet n}{60} \times 10^{-3}$$

$$= \frac{2 \times 90 \times 3000}{60} \times 10^{-3}$$

$$= 9.0 \text{ m/s}$$

V_m	:	Mean piston speed	m/s
S	:	Engine stroke	90 mm
n	:	Engine speed	3000 rpm

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 3TNV76 series diesel engine, the cylinder bore is 76 mm, and the piston stroke is 82 mm. What is the total displacement of this engine?

$$V_{st} = \frac{\pi}{4} D^2 SN \times 10^{-3}$$

$$= \frac{\pi}{4} \times 76^2 \times 82 \times 3 \times 10^{-3}$$

$$= 1115 \text{ cc}$$

V_{st}	:	Total displacement	l
D	:	Bore	76 mm
S	:	Stroke	82 mm
N	:	Number of cylinders	3
p	:	Pi	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	Torque T_{tq} 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 — rpm

1kgf·m = 9.80665 N·m

Example
According to the specification sheet for the 4TNV84T series diesel engine, the rated output for a rated speed of 2400 rpm 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 — 33.5 kW
n : Engine speed — 2400 rpm

To obtain the rated torque in N·m:

$$T_{tq} = 9550 \times \frac{P_e}{n}$$

$$= 9550 \times \frac{33.5}{2400}$$

$$= 133 \text{ N·m}$$

To obtain the rated torque in kgf·m:

$$T_{tq} = 973.8 \times \frac{P_e}{n}$$

$$= 973.8 \times \frac{33.5}{2400}$$

$$= 13.6 \text{ kgf·m}$$

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	rpm

1kgf/cm^2 = 9.80665 x 10 kPa

> ***Example***
> According to the specification sheet for the 4TNV84T series diesel engine, the rated output for the rated speed of 2400 rpm is 33.5 kW. What is the net mean effective pressure? The total displacement of the engine is 1995 cc.

Since the unit is in kW, equation (a) is used.

P_e	: Output	33.5 kW
V_{st}	: Total displacement	1.995 ℓ
n	: Engine speed	2400 rpm

To obtain the net mean effective pressure in kPa:

$$P_{me} = \frac{120.0 \times P_e}{V_{st} \times n} \times 10^3$$

$$= \frac{120.0 \times 33.5}{1.995 \times 2400} \times 10^3$$

$$= 840 \text{ kPa}$$

To obtain the net mean effective pressure in kgf/cm^2:

$$P_{me} = \frac{1224 \times P_e}{V_{st} \times n}$$

$$= \frac{1224 \times 33.5}{1.995 \times 2400}$$

$$= 8.56 \text{ kgf/cm}^2$$

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	rpm
N	:	Number of engine cylinders	

> ***Example***
> According to the specifications sheet for the 4TNV98 series diesel engine, the rated output for the rated speed of 2500 rpm is 51.1 kW and the specific fuel consumption is 224 g/kWh. What is the injection quantity?

Q	:	Fuel injection quantity	g/1000 st
b	:	Specific fuel consumption	224 g/kWh
P_e	:	Output	51.1 kW
n	:	Engine speed	2500 rpm
N	:	Number of engine cylinders	4

$$Q = \frac{b \times P_e}{60 \times (n/2) \times N} \times 10^3$$

$$= \frac{224 \times 51.1}{60 \times (2500/2) \times 4} \times 10^3$$

$$= \frac{38.2}{1000} \frac{\text{g}}{\text{st}}$$

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	rpm
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 4TNV98 series diesel engine, the rated output for a rated speed of 1500 rpm is 34.6 kW. Based on the torsional vibration materials in *Torsional Vibration on page 18-1*, the inertia weight GD^2 of a flywheel is 1.98 kg·m^2 for CL specifications. What is cyclic irregularity for this combination?

To find the cyclic irregularity when output is in kW:

$$\delta = \frac{1}{\dfrac{n^3 \times GD^2}{K \times P_i} \times 0.7355}$$

$$= \frac{1}{\dfrac{1500^3 \times 1.98}{2.7 \times 10^6 \times 43.25} \times 0.7355}$$

$$= \frac{1}{42}$$

δ	:	Cyclic irregularity	
n	:	Engine speed	1500 rpm
GD^2	:	Inertia weight of flywheel	1.98 kg·m^2
K	:	Sass's constant (4-cylinder, 180° crank)	2.7 x 10^6
P_i	:	Indicated output of engine $P_i = P_e / 0.8$	43.25 kW (34.6 / 0.8)
P_e	:	Rated output of engine	34.6 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 x 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 x 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 x 10^2 kcal/h

> ***Example***
> The specific fuel consumption for the 4TNV98 series diesel engine for a rated output of 51.1 kW at the rated speed of 2500 rpm is 224 g/kWh. What is the thermal efficiency?

To find thermal efficiency when specific fuel consumption is in kW:

h	: Thermal efficiency	%
P_e	: Engine output	51.1 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 3TNV76 series diesel engine for the rated output of 14.9 kW at the rated speed of 2500 rpm is 279 g/kWh, and the exhaust temperature is 500°C. What is the exhaust loss?

ϕ_{ex}	:	Exhaust loss	%
V_{st}	:	Total displacement	1.232 ℓ
n	:	Engine speed	2500 rpm
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	279 g/kWh
P_e	:	Engine output	14.9kW

$$\phi_{ex} = 2.9126 \times 10^{-3} \times \frac{V_{st} \times n \times \eta_t \times c_p \times t_{ex}}{b \times P_e} \times 10^2$$

$$= 2.9126 \times 10^{-3} \times \frac{1.232 \times 2500 \times 0.85 \times 0.321 \times 500}{279 \times 14.9} \times 10^2$$

$$= 0.294 \times 10^2$$

$$= 29.4\ \%$$

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
r	:	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 3TNV76 series diesel engine for the rated output of 14.9 kW at the rated speed of 2500 rpm is 279 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
$(t_{wo}\text{-}t_{wi})$	:	Temperature difference of cooling water between the outlet and inlet of the engine	5°C
b	:	Specific fuel consumption	279 g/kWh
P_e	:	Engine output	14.9 kW

$$\phi_{cw} = 5.8252 \times \frac{Q_p \times (t_{wo} - t_{wi})}{b \times P_e} \times 10^2$$

$$= 5.8252 \times \frac{34 \times 5}{279 \times 14.9} \times 10^2$$

$$= 0.238 \times 10^2$$

$$= 24\%$$

Other Loss ϕ_o

$$\phi_o = 100 - (\eta + \phi_{ex} + \phi_{cw})$$

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	h

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.

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	rpm
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	rpm
η_v	: Volume efficiency	

Driving Horsepower (Required Horsepower)

Theoretical Driving Horsepower (Theoretical Required Horsepower)

		Discharge pressure P	
		kPa	kgf/cm^2
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/cm^2)

Q_t : Theoretical discharge — ℓ/min

1 kW = 1.0000 x 10^3 x N·m/s = 102.0 kgf·m/s

1 hp = 0.7457 x 10^3 x N·m/s = 76.04 kgf·m/s

1 PS = 0.7355 x 10^3 x 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	rpm

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

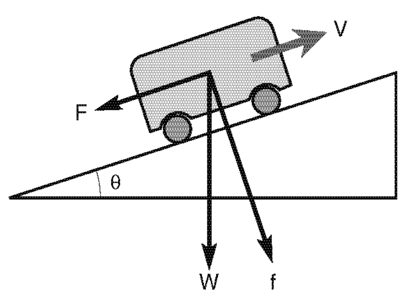
The required horsepower of a mobile driven machine can be divided into working, traveling and hill climbing horsepower.

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	$V \times W\sin\theta \times 10^{-3}$	$\dfrac{V \times W\sin\theta}{102.0}$
hp	$\dfrac{V \times W\sin\theta}{0.7457} \times 10^{-3}$	$\dfrac{V \times W\sin\theta}{76.04}$
PS	$\dfrac{V \times W\sin\theta}{0.7355} \times 10^{-3}$	$\dfrac{V \times W\sin\theta}{75}$

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

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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

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.

1. If you want to convert from A to B, you have to multiply A and C together. (B = A x C)
2. If you want to convert from A to D, you have to multiply A and E together. (D = A x E)

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