YANMAR

APPLICATION MANUAL

LV Series

L48V
L70V
L100V

LV series

APPLICATION MANUAL

L48V
L70V
L100V

YANMAR®

INDUSTRIAL
ENGINES

LV series
APPLICATION MANUAL

P/N: 0DLV0-U00100

INDUSTRIAL ENGINES

This *Application Manual* has been developed for the exclusive use of service and repair professionals such as Yanmar authorized Distributors and Yanmar authorized Dealers. It is written with these professionals in mind and may not contain the necessary detail or safety statements that may be required for a non-professional to perform the service or repair properly and / or safely. Please contact an authorized Yanmar repair or service professional before working on your Yanmar product.

Disclaimers:

All information, illustrations and specifications in this manual are based on the latest information available at the time of publishing. The illustrations used in this manual are intended as representative reference views only. Moreover, because of our continuous product improvement policy, we may modify information, illustrations, and / or specifications to explain and / or exemplify a product, service, or maintenance improvement. We reserve the right to make any change at any time.

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Section 1

INTRODUCTION

PREFACE

To achieve the highest performing miniaturized and light-weight diesel engines, Yanmar Diesel Engine Co., Ltd. developed the LV series air-cooled diesel engine using the most advanced technologies.

Yanmar offers seven models of the LV series diesel engines. Yanmar has succeeded in expanding displacement and increasing the power to make the LV series engines more flexible without affecting other performance characteristics. To further satisfy the needs of the market, the LV series diesel engines are designed to reduce noise level and improve stability and maintainability.

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Section 2

SAFETY

SAFETY STATEMENTS

Yanmar is concerned for your safety and your machine's condition. Safety statements are one of the primary ways to call your attention to the potential hazards associated with Yanmar LV Series engine operation. Follow the precautions listed throughout the manual before operation, during operation and during periodic maintenance procedures for your safety, the safety of others and to protect the performance of your engine. Keep the labels from becoming dirty or torn and replace them if they are lost or damaged. Also, if you need to replace a part that has a label attached to it, make sure you order the new part and label at the same time.

This safety alert symbol appears with most safety statements. It means attention, become alert, your safety is involved! Please read and abide by the message that follows the safety alert symbol.

⚠ DANGER

Danger (the word "DANGER" is in white letters with a red rectangle behind it) - indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. Danger is limited to the most extreme situations.

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⚠ WARNING

Warning (the word "WARNING" is in black letters with an orange rectangle behind it) – indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

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⚠ CAUTION

Caution (the word "CAUTION" is in black letters with a yellow rectangle behind it) – indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

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CAUTION

Caution without the safety alert symbol indicates a potentially hazardous situation that can cause damage to the machine, personal property and / or the environment or cause the machine to operate improperly.

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⚠ DANGER

EXPLOSION HAZARD!

- ALWAYS keep the area around the battery well-ventilated. While the engine is running or the battery is charging, hydrogen gas is produced which can be easily ignited.
- ALWAYS keep sparks, open flame and any other form of ignition away while the engine is running or battery is charging.
- Failure to comply will result in death or serious injury.

0000003en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- ALWAYS put an approved container under any opening to catch the fuel when removing any fuel system component to perform maintenance (such as changing the fuel filter).
- NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.
- ALWAYS wipe up any spills immediately.
- ALWAYS wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Only use the key switch to start the engine.
- NEVER jump-start the engine. Sparks caused by shorting the battery to the starter terminals may cause a fire or explosion.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- ALWAYS fill the fuel tank only with specified diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.
- NEVER refuel with the engine running.
- ALWAYS wipe up all spills immediately.
- ALWAYS keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.
- NEVER overfill the fuel tank.
- Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.
- Failure to comply will result in death or serious injury.

0000005en

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- ALWAYS put diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.
- NEVER place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.
- Failure to comply will result in death or serious injury.

0000014en

⚠ DANGER

EXPLOSION HAZARD!

- NEVER check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.
- If the electrolyte is frozen, slowly warm the battery before you recharge it.
- Failure to comply will result in death or serious injury.

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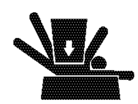
⚠ DANGER



CRUSH HAZARD!

- When you need to transport an engine for repair, have a helper assist you to attach it to a hoist and load it on a truck.
- NEVER stand under a hoisted engine. If the hoist mechanism fails, the engine will fall on you, causing death or serious injury.
- Failure to comply will result in death or serious injury.

0000008en

WARNING

SEVER HAZARD!

- Keep hands and other body parts away from moving / rotating parts such as the cooling fan / flywheel.
- Wear tight-fitting clothing and keep your hair short or tie it back while the engine is running.
- Remove all jewelry before you operate or service the machine.
- NEVER start the engine in gear. Sudden movement of the engine and / or machine could cause death or serious personal injury.
- NEVER operate the engine without the guards in place.
- Before you start the engine make sure that all bystanders are clear of the area.
- Keep children and pets away while the engine is operating.
- Check before starting the engine that any tools or shop rags used during maintenance have been removed from the area.
- Failure to comply could result in death or serious injury.

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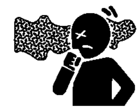
WARNING



EXHAUST HAZARD!

- NEVER operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.
- NEVER block windows, vents, or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.
- Make sure that all connections are tightened to specifications after repair is made to the exhaust system.
- Failure to comply could result in death or serious injury.

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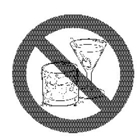
WARNING



ALCOHOL AND DRUG HAZARD!

- NEVER operate the engine while you are under the influence of alcohol or drugs.
- NEVER operate the engine when you are feeling ill.
- Failure to comply could result in death or serious injury.

0000004en

⚠ WARNING

EXPOSURE HAZARD!

- ALWAYS wear personal protective equipment such as gloves, work shoes, eye and hearing protection as required by the task at hand.
- NEVER wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing when you are working near moving / rotating parts such as the cooling fan, flywheel or PTO shaft.
- ALWAYS tie back long hair when you are working near moving / rotating parts such as a cooling fan, flywheel, or PTO shaft.
- NEVER operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the alert signals.
- Failure to comply could result in death or serious injury.

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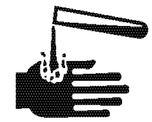
⚠ WARNING



BURN HAZARD!

- Batteries contain sulfuric acid. NEVER allow battery fluid to come in contact with clothing, skin or eyes. Severe burns could result. ALWAYS wear safety goggles and protective clothing when servicing the battery. If battery fluid contacts the eyes and / or skin, immediately flush the affected area with a large amount of clean water and obtain prompt medical treatment.
- Failure to comply could result in death or serious injury.

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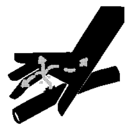
WARNING



HIGH-PRESSURE HAZARD!

- Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.
- NEVER check for a fuel leak with your hands. ALWAYS use a piece of wood or cardboard. Have your authorized Yanmar industrial engine dealer or distributor repair the damage.
- Failure to comply could result in death or serious injury.

0000008en

WARNING

SHOCK HAZARD!

- ALWAYS turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.
- Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.
- Failure to comply could result in death or serious injury.

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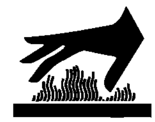
WARNING



BURN HAZARD!

- ALWAYS stay clear of the hot engine oil to avoid being burned.
- ALWAYS wear eye protection.
- Failure to comply could result in serious injury.

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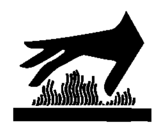
WARNING



BURN HAZARD!

- NEVER touch hot engine surfaces such as the muffler, exhaust pipe, turbocharger (if equipped) and engine block during operation and shortly after you shut the engine down. These surfaces are extremely hot while the engine is operating and could seriously burn you.
- Failure to comply could result in death or serious injury.

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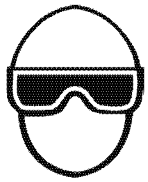
⚠ CAUTION



FLYING OBJECT HAZARD!

- ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.
- Failure to comply may result in minor or moderate injury.

0000003en

CAUTION

- ALWAYS use only the diesel fuels recommended by Yanmar for the best engine performance, to prevent engine damage and to comply with EPA / ARB warranty requirements.
- ALWAYS use clean diesel fuel.
- NEVER remove the primary strainer (if equipped) from the fuel tank filler port. If removed, dirt and debris could get into the fuel system causing it to clog.

0000004en

CAUTION

NEVER attempt to adjust the low or high idle speed limit screw. This may impair the safety and performance of the machine and shorten its life. If adjustment is ever required, contact your authorized Yanmar industrial engine dealer or distributor.

0000045en

CAUTION

If any problem is noted during the visual check, ALWAYS take the necessary corrective action before you operate the engine.

0000021en

CAUTION

NEVER hold the key in the START position for longer than 15 seconds or the starter motor will overheat.

0000007en

CAUTION

The illustrations and descriptions of optional equipment in this manual, such as the operator's console, are for a typical engine installation. Refer to the documentation supplied by the optional equipment manufacturer for specific operation and maintenance instructions.

0000018en

CAUTION

ALWAYS stop the engine immediately if any indicator illuminates during engine operation. Determine the cause and repair the problem before you continue to operate the engine.

0000029en

CAUTION

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

- Avoid operating in extremely dusty conditions.
- Avoid operating in the presence of chemical gases or fumes.
- Avoid operating in a corrosive atmosphere such as salt water spray.
- NEVER install the engine in a floodplain unless proper precautions are taken to avoid being subject to a flood.
- NEVER expose the engine to the rain.

0000003en

CAUTION

NEVER allow the recoil handle to snap back against the engine. Return the handle to the starting position gently to prevent damage to the starter.

0000066en

CAUTION

Observe the following environmental operating conditions to maintain engine performance and avoid premature engine wear:

- NEVER run the engine if the ambient temperature is above +104°F (+40°C) or below +14°F (-10°C).
  - If the ambient temperature exceeds +104°F (+40°C) the engine may overheat and cause the engine oil to break down.
  - If the ambient temperature falls below +14°F (-10°C) rubber components such as gaskets and seals will harden causing premature engine wear and damage.
  - Contact your authorized Yanmar industrial engine dealer or distributor if the engine will be operated in either temperature extreme.
- Contact your authorized Yanmar industrial engine dealer or distributor if you need to operate the engine at high altitudes. At high altitudes the engine will lose power, run rough and produce exhaust gases that exceed the design specifications.

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CAUTION

- ALWAYS use only the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.
- ALWAYS prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.
- NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.
- NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

0000005en

CAUTION

- NEVER overfill the engine with engine oil.
- ALWAYS keep the oil level between the upper and lower lines on the oil cap / dipstick.

0000015en

CAUTION

For maximum engine life, Yanmar recommends that when shutting the engine down, allow the engine to idle, without load, for five minutes. This will allow the engine components that operate at high temperatures, such as the turbocharger (if equipped) and exhaust system, to cool slightly before the engine itself is shut down.

0000008en

CAUTION

NEVER use an engine starting aid such as ether. Engine damage will result.

0000009en

CAUTION

Make sure the engine is installed on a level surface. If a continuously running engine is installed at an angle greater than 20° (in any direction) or if an engine runs for short periods of time (less than three minutes) at an angle greater than 25° in any direction, engine oil may enter the combustion chamber causing excessive engine speed and generate white smoke. This may cause serious engine damage.

0000010enTNE

CAUTION

- NEVER attempt to modify the engine's design or safety features such as defeating the engine speed limit control or the fuel injection quantity control.
- Failure to comply may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may affect the warranty coverage of your engine.

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CAUTION

New Engine Break-in:

- **On the initial engine start-up, allow the engine to idle for approximately 15 minutes while you check for proper engine oil pressure, diesel fuel leaks, engine oil leaks, coolant leaks, and for proper operation of the indicators and / or gauges.**
- **During the first hour of operation, vary the engine speed and the load on the engine. Short periods of maximum engine speed and load are desirable. Avoid prolonged operation at minimum or maximum engine speeds and loads for the next four to five hours.**
- **During the break-in period, carefully observe the engine oil pressure and engine temperature.**
- **During the break-in period, check the engine oil and coolant levels frequently.**

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CAUTION

NEVER engage the starter motor while the engine is running. This may damage the starter motor pinion and / or ring gear.

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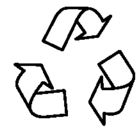
CAUTION



- **ALWAYS be environmentally responsible.**
- **Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.**
- **NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.**
- **Failure to follow these procedures may seriously harm the environment.**

0000013en

CAUTION

ALWAYS protect the air cleaner, turbocharger (if equipped) and electric components from damage when you use steam or high-pressure water to clean the engine.

0000014en

CAUTION

- **When the engine is operated in dusty conditions, clean the air cleaner element more frequently.**
- **NEVER operate the engine with the air cleaner element(s) removed. This may allow foreign material to enter the engine and damage it.**

0000026en

CAUTION

If the engine continues to run after you position the engine speed control to the STOP position, turn the fuel cock to the CLOSED position.

0000069en

CAUTION

The maximum air intake restriction shall be:

- L48V: 0.10 psi (0.69 kPa; 70 mmAq) or less
- L70V: 0.20 psi (1.37 kPa; 140 mmAq) or less
- L100V: 0.21 psi (1.47 kPa; 150 mmAq) or less.

Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

0000046enLV

CAUTION

Tips while starting engine with recoil starter:

- Pulling out the recoil starter handle too hard or fast will damage the equipment.
- ALWAYS pull recoil starter handle all the way out or the engine will not start.
- NEVER allow the recoil starter handle to snap back against the engine. Return the handle to the starting position gently to prevent damage to the recoil starter.

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Section 3

SPECIFICATIONS

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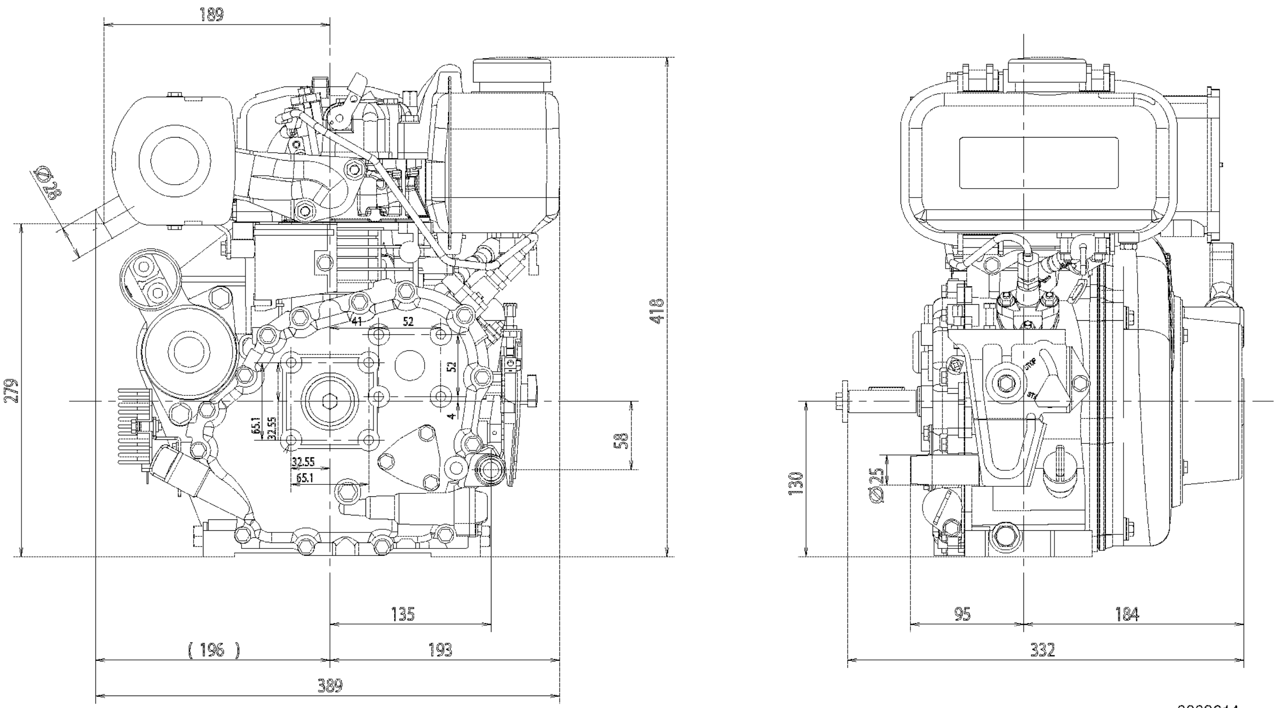
DIMENSIONAL DRAWINGS

L48V



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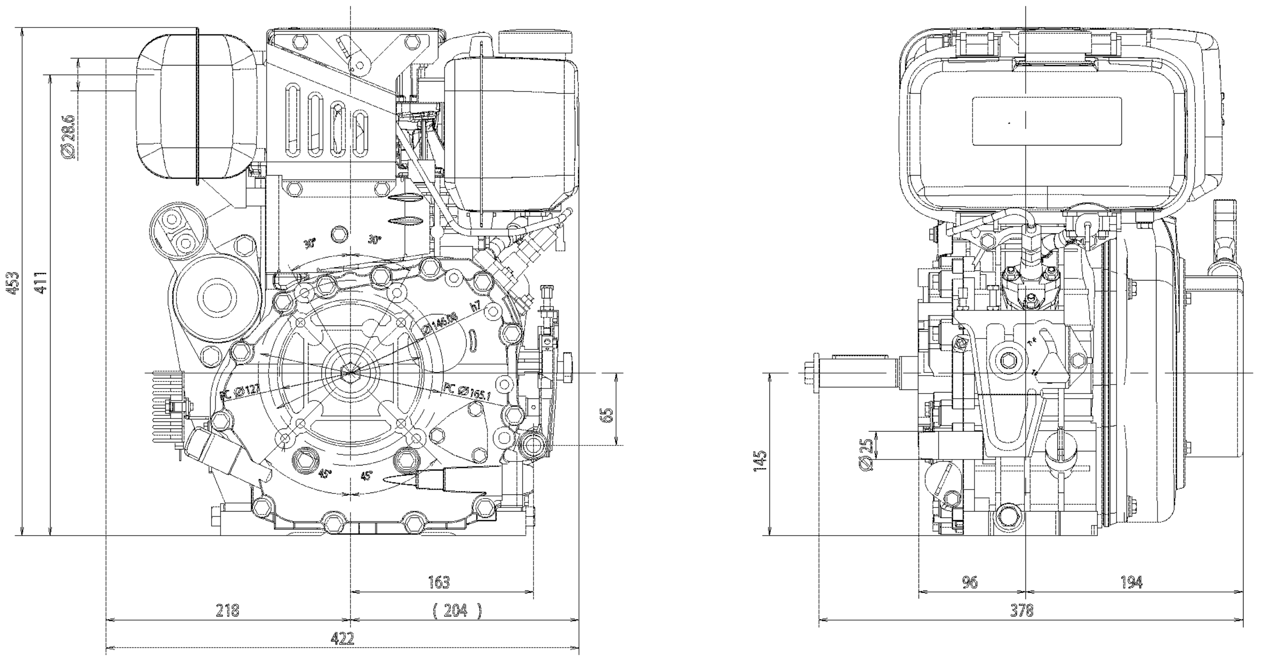
L70V



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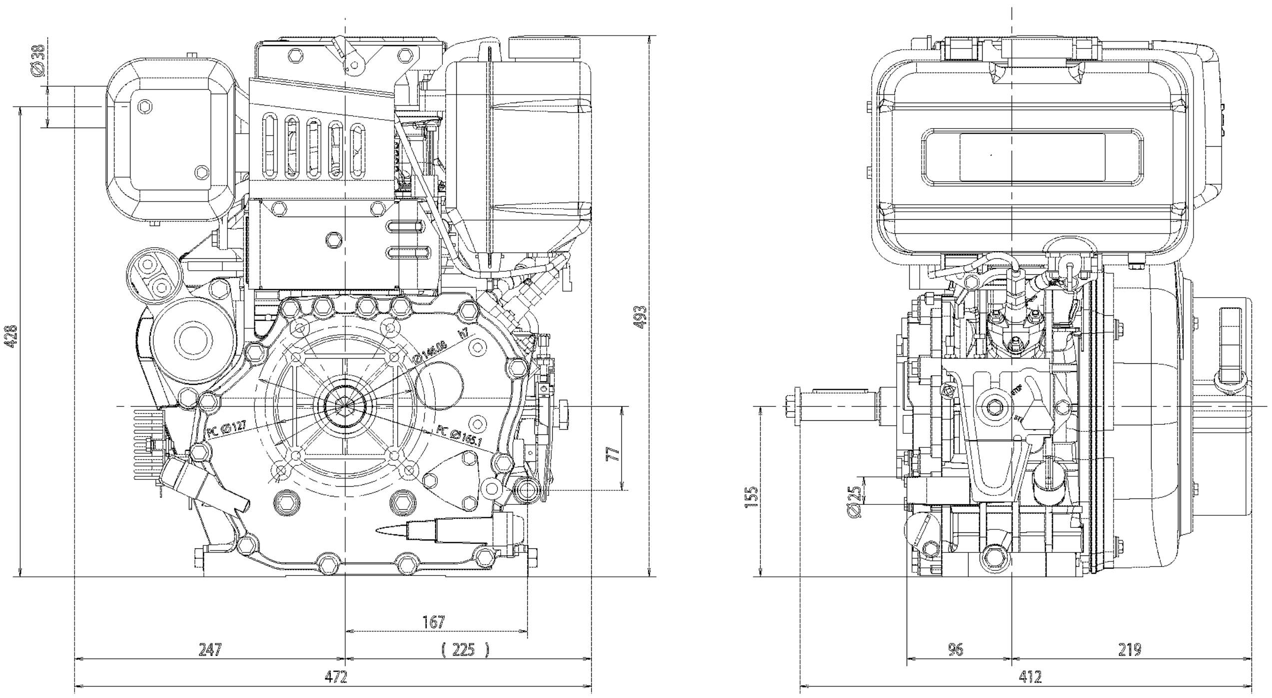
L100V



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SPECIFICATION CHARTS

Engine Model		L48V		L70V	L100V
Type		4-stroke, Vertical Cylinder, Air-Cooled Diesel Engine			
Combustion System		Direct Injection			
No. of Cylinders		1			
Bore × Stroke		70 × 57 mm (2.76 x 2.24 in.)		78 × 67 mm (3.07 x 2.64 in.)	86 × 75 mm (3.39 x 2.95 in.)
Displacement		0.219 L (13.4 cu. in.)		0.320 L (19.5 cu. in.)	0.435 L (26.5 cu. in.)
Compression Ratio		20.6		21.1	21.2
Continuous Rated Output	RPM (min^{-1})	3600	3450	3600	3600
	up SAE	4.0	3.8	5.8	8.3
	kW	3.0	2.8	4.3	6.2
	PS	4.1	3.8	5.9	8.4
Max. Rated Output (Net)	RPM (min^{-1})	3600	3450	3600	3600
	up SAE	4.4	4.2	6.4	9.1
	kW	3.3	3.1	4.8	6.8
	PS	4.5	4.2	6.5	9.3
High Idling	RPM (min^{-1})	3800 ± 30	3650 ± 30	3800 ± 30	3800 ± 30
Fuel Injection Timing	BTDC by FIC (A)	17.5°		16°	15.5°
PTO Position		Crankshaft			
Direction of Rotation		Counterclockwise viewed from PTO Side			
Fuel Injection Pump		BOSCH-type, with upper lead plunger			
Fuel Injection Nozzle		P-size, VCO			
Valve Opening Pressure		200 kgf/cm^2 (19.6 MPa)			
Fuel Selection		Diesel fuel BS2869 A1 or equivalent			
Fuel Filter		Paper Element, Fuel Tank Built-in Type			
Governor		All Speed Type, Mechanical			
Balancer Shaft		Single Shaft			
Engine Weight (Dry)	With Electric Start	32.0 kg (70.5 lb.)		41.0 kg (90.4 lb.)	53.5 kg (118 lb.)
	Without Electric Start	27.0 kg (59.5 lb.)		36.0 kg (79.4 lb.)	48.5 kg (107 lb.)
Cooling System		Forced Air by Flywheel Fan			
Lubricating System		Forced Lubrication with Trochoid Pump Splash Lubrication for Valve Rocker Arm Chamber			
Oil Selection		SAE 10W30, API Grade CD, CF, CF-4 or CI-4			
Oil Filter		Resin, 60 Mesh			
Permissible Angle of Inclination		20° (momentary 30°)			
Air Cleaner		Wet-Type Element Filter		Dry-Type Paper Element Filter	

Muffler		Expansion Silencer with Cover		
Starting System		Electric Start / Recoil Start		
Dimensions (L x W x H)		332 x 384 x 417 mm (13.1 x 15.1 x 16.4 in.)	378 x 422 x 453 mm (14.9 x 16.6 x 17.8 in.)	412 x 471 x 494 mm (16.2 x 18.5 x 19.4 in.)
Engine Oil Pan Capacity	Dipstick Upper Limit	0.8 L (0.85 qt.)	1.05 L (1.11 qt.)	1.6 L (1.7 qt.)
	Dipstick Lower Limit	0.55 L (0.58 qt.)	0.65 L (0.69 qt.)	1.0 L (1.06 qt.)
Fuel Tank Capacity (Recommended)		1.9 L (2.0 qt.)	2.7 L (2.85 qt.)	4.7 L (5.0 qt.)

Battery Capacity							
Battery Capacity (Recommended)		100 CCA	135 CCA	170 CCA	200 CCA	225 CCA	250 CCA
		18 Ah	24 Ah	30 Ah	35 Ah	40 Ah	45 Ah
Ambient Temp. usage by model	L48V	-10°C (14°F) or higher	-30°C (-22°F) or higher				
	L70V		-10°C (14°F) or higher		-30°C (-22°F) or higher		
	L100V				-10°C (14°F) or higher		-20°C (-4°F) or higher

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Section 4

APPLICATION STANDARD

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

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

APPLICATION STANDARD

No.	Item	Application Standard			Remarks
1	Engine type	(DI) Direct injection system engines			
2	Output/RPM	Output rpm		*See Engine Output on page 4-6.*	Output table
		Output setting conditions	Ambient temperature	25°C (77°F)	Same as in JIS and ISO
			Atmospheric pressure	100 kPa (750 mmHg)	
			Relative humidity	30%	
		Output power correction		*See Power Corrections on page 5-3*.	
3	Special operating environment	Precautions against dusty conditions		*See Special Operating Environment on page 4-4.*	
		Precautions for outdoor installation			
		Precautions against sea air and snow melting agents			
		Precautions against cold environment			
		Precautions against hot environment			
4	Fuel oil	Fuel oil	Ambient temperature °C (°F)	Equivalent fuel	*See Diesel Fuel on page 12-7* for fuel specifications.
		Diesel fuel	≥ -5 (23)	JIS No. 2	
			15 to -20 (59 to -4)	JIS No. 3	
			<-20 (<-4)	JIS special No. 3	
		Kerosene	Not allowed		
		Heavy oil	Not allowed		
		JP-4	Not allowed		
		JP-8, JP-5	Not allowed		
5	Engine oil	*See Engine Oil on page 13-4.*			The initial maintenance of the lubricating oil and filter should be done at 50 hours of service.
		Lubricating oil class	Lubricating oil replacement interval (hr)	Lubricating oil filter replacement interval (hr)	
		CD or higher	After first 50 hours then every 200 hours.	Clean after first 50 hours then every 200 hours. No need to replace if not damaged.	
		Allowable temperature at oil pan		≤115°C (239°F)	At the specified maximum ambient temperature.
6	Power take-off (PTO)	*See PTO System on page 16-1*.			

No.	Item	Application Standard			Remarks
7	Low-temperature startability	*See Cold Starting Systems on page 9-3.*			
8	Allowable inclination angle	Continuous operation	Longitudinal/lateral	≤20° / ≤20°	*See Gradients on page 13-6.*
		Instantaneous operation (within 3 minutes	Longitudinal/lateral	≤30° / ≤30°	
9	Allowable exhaust back pressure	*See Allowable Air Intake Restriction and Exhaust Back Pressures on page 4-6.*			
	Allowable air restriction at intake manifold	*See Allowable Air Intake Restriction and Exhaust Back Pressures on page 4-6.*			

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	Use a double element (safety element) to prevent dust from entering the engine.
	Starting motor	Dust-proof type starter motor may be required for preventing entry of sand and dust.

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 of engine		Only operate engine on a flat, well-ventilated area.

(*) 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	
	Muffler mounting bolts	
	Stop lever return spring	
	Regulator spring	
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 Cold Starting Systems on page 9-3* for startability.
	Starting motor		
-30°C to -40°C (-22°F to -40°F) (Not recommended for LV engine)		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.	

Precautions Against Hot Environment

Environmental temperature	Part	Countermeasure
Above 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.

Other Precautions

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

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

Engine Model	Allowable Air Intake Restriction ≤ kPa (mmAq)	
	Initial upper limit	Upper limit for air cleaner replacement
L48V	0.39 (40)	0.88 (70)
L70V	1.08 (110)	1.37 (140)
L100V	1.18 (120)	1.47 (150)

Allowable Exhaust Back Pressure

Engine Model	Allowable Exhaust Back Pressure ≤ kPa (mmAq)
	Upper limit for exhaust system cleaning
L48V	3.72 (380)
L70V	4.12 (420)
L100V	4.31 (440)

EPA Emission Control Regulations Nonroad Diesel Engines (Requirements for the Driven Machine Manufacturers)

This regulation applies to nonroad 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 (Environmental Protection Agency) regulations. The following is a brief description of the responsibilities introduced by the regulation.

Driven machine manufacturers should contact Yanmar for details.

Engine Output

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. The driven machine manufacturer must inform Yanmar of the additional power of the cooling fan, hydraulic pump, or other auxiliary equipment, which are provided by the manufacturer.

Yanmar may determine and re-adjust the *Net Power* based on the gross power.

Installation Evaluation

To ensure the exhaust emissions conform to the regulation, Yanmar must study the required engine specifications such as rated output, intake air restriction, and exhaust backpressure. *Engine Installation Evaluation* sheets are available to confirm engine specifications.

Engine Maintenance

When the equipment manufacturers prepare their own warranty card, owner's manual, and service manual for the applicable engines, they must describe all items required by the EPA regulations in their manuals using the same statements as Yanmar. Standard maintenance items and intervals are indicated in the technical documents such as the warranty statement, operation manual and service manual.

In their manuals, equipment manufacturer's maintenance intervals must be identical to Yanmar. The standard maintenance items should also conform to the foregoing regulation outlined in the EPA's Code of Federal Regulations. Emission related parts mentioned in the regulation must comply with the requirements.

For details, please refer to the *LV Operation Manual* and *LV Service Manual*.

Tamper Resistance

Dealers who are authorized by Yanmar to 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 adjustment by the ultimate 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 brand 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 continually updating 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 final report shall also be submitted to the appropriate authorities.

Yanmar requires the end purchaser's information: name, address and machine model to proceed with the recall program.

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Section 5

CORRECTING OBSERVED POWER

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CORRECTING OBSERVED POWER

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

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.

1. 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.

Power Corrections

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

1. Use the power correction formula (A) in *Correction Formula (A) on page 5-4* when atmospheric conditions are judged to be relatively close to standard conditions:

Standard atmospheric conditions:	25°C (77°F) 100 kPa (750 mmHg) 30%
Engine intake air temperature:	20 to 30°C (68 to 86°F)
Dry intake air pressure (may simply be regarded as atmospheric pressure):	96.8 to 101.3 kPa (740 to 760 mmHg) (at 1200 m (3937 ft.) or less in altitude)
Correction factor k:	0.9 to 1.1 [See Obtain Correction Factor k calculation in *Correction Formula (A) on page 5-4*.]

2. Use the power calculation formula (B) in *Correction Formula (B) on page 5-5* when atmospheric conditions are much different from standard 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.

   (a) For a naturally aspirated engine

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

Subscript $_r$ represents the value under standard conditions, and $_x$ the value under actual test conditions.

P_r	:	Standard atmospheric pressure	100 kPa (750 mmHg)
Φ_r	:	Relative humidity under standard conditions	0.30 (30%)
T_r	:	Intake air temperature under standard conditions	298 K (25°C [77°F])
P_{sr}	:	Saturation vapor pressure under standard conditions	3.172 kPa (23.80 mmHg) (See *Relationships Between Atmospheric Temperature and Saturation Vapor Pressure on page 5-9.*)
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) (See *Relationships Between Atmospheric Temperature and Saturation Vapor Pressure on page 5-9.*)

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 and absolute temperature K is as follows:

K = 273 + °C

2. Obtain correction factor k.

   $k = f_a$

Proceed with the calculation if the value of k satisfies the condition 0.9 < k < 1.1. Otherwise, follow **Correction Formula (B)** for power correction *See Correction Formula (B) on page 5-5.*

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

   $P = P_0 / k$

Where,

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

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.

   (a) For naturally aspirated engine

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

Subscripts $_r$ and $_x$ represent the values under standard conditions and actual test conditions, respectively.

P_r	:	Standard atmospheric pressure	100kPa (750 mmHg)
Φ_r	:	Relative humidity under standard conditions	0.30 (30%)
T_r	:	Intake air temperature under standard conditions	298K (25°C [77°F])
P_{sr}	:	Saturation vapor pressure under standard conditions	3.172 kPa (23.80 mmHg) (*See Relationships Between Atmospheric Temperature and Saturation Vapor Pressure on page 5-9.*)
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) (*See Relationships Between Atmospheric Temperature and Saturation Vapor Pressure on page 5-9.*)

2. Obtain correction factor α as follows:

$$\alpha = K - 0.7\ (1 - K)\ (1 / \eta - 1)$$
$$= K - 0.175\ (1 - K)$$

   Where:

   η = 0.8 (machine efficiency)

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

$$P = \alpha\ P_0$$

   Where:

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

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 (328 ft.) in altitude

This percentage should be added to the calculation result of power correction in *Power Corrections on page 5-3*. 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.

ATMOSPHERIC PRESSURE

Use this calculation to determine the 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

Use this calculation to determine the change in altitude.

$$Tx = Tr - 0.0065h$$

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)

ATMOSPHERIC RELATIONSHIPS

Relationships Between Altitude and Atmospheric Pressure

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	98.9 (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)	4200	60.1 (450.79)
1600	83.5 (626.30)	4400	58.5 (438.79)
1800	81.5 (611.30)	4600	56.9 (426.79)
2000	79.5 (596.30)	4800	55.3 (414.79)
2200	77.6 (582.05)	5000	54.1 (405.78)
2400	75.6 (567.05)		

How to Obtain Relative Humidity with 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)

Relationships 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 5-3*. 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 (3937 ft.)

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 of altitude is summarized below.

Note: The temperature is assumed to change as the operating altitude increases:

Altitude (m)		0	1000
Reduction of rated output (%)	Naturally aspirated engines	0%	13%

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
Minimum starting temperature	K	253	253	258
	°C (°F)	–20 (-4)	–20 (-4)	–15 (5)

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:

1. Use of diesel fuel with higher cetane number: 52 or greater
2. Energization of air heater after starting: 5 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 5-10* 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.

Heat Load and Carbon Build Up

Increased heat load due to rise of exhaust temperature. Engines can have a durability problem at altitudes higher than the operable altitude.

Altitude (m)		0	1000
Rise of exhaust temperature at rated output	Direct injection system	0%	10%

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

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Section 6

ENGINE PERFORMANCE

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ENGINE OUTPUT

Atmospheric Conditions and Engine Configuration Affect Engine Output

Atmospheric conditions and engine configuration affect the rated output of an LV engine. LV 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 5-3*:

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

Engine configuration also affects engine output. The engine output specified in *Dimensional Drawings on page 3-3* assumes a "standard" engine configuration. A standard configuration means that a standard engine cover, muffler and air cleaner are installed. Optional equipment is available from Yanmar. If your application uses optional equipment, please tell your Yanmar application engineer so engine output can be determined.

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". Most driven machines 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.

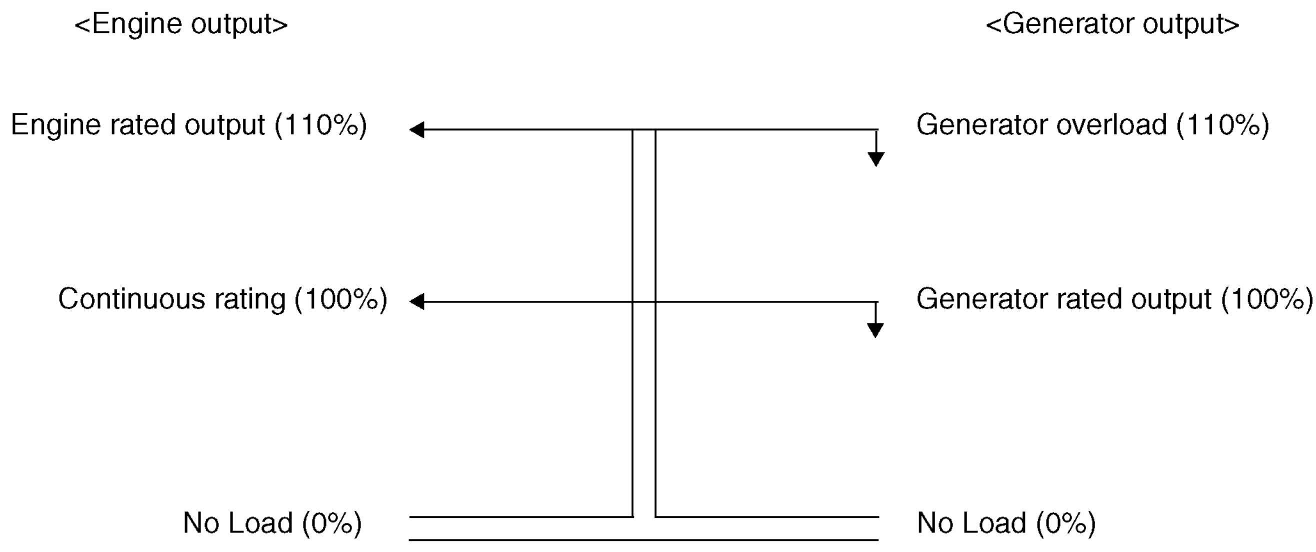
Some driven machines require the maximum output for a long period because of a fixed revolution range. In this case, select an engine so 90% of its rated output equals the continuous output requirement of the driven machine.

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:

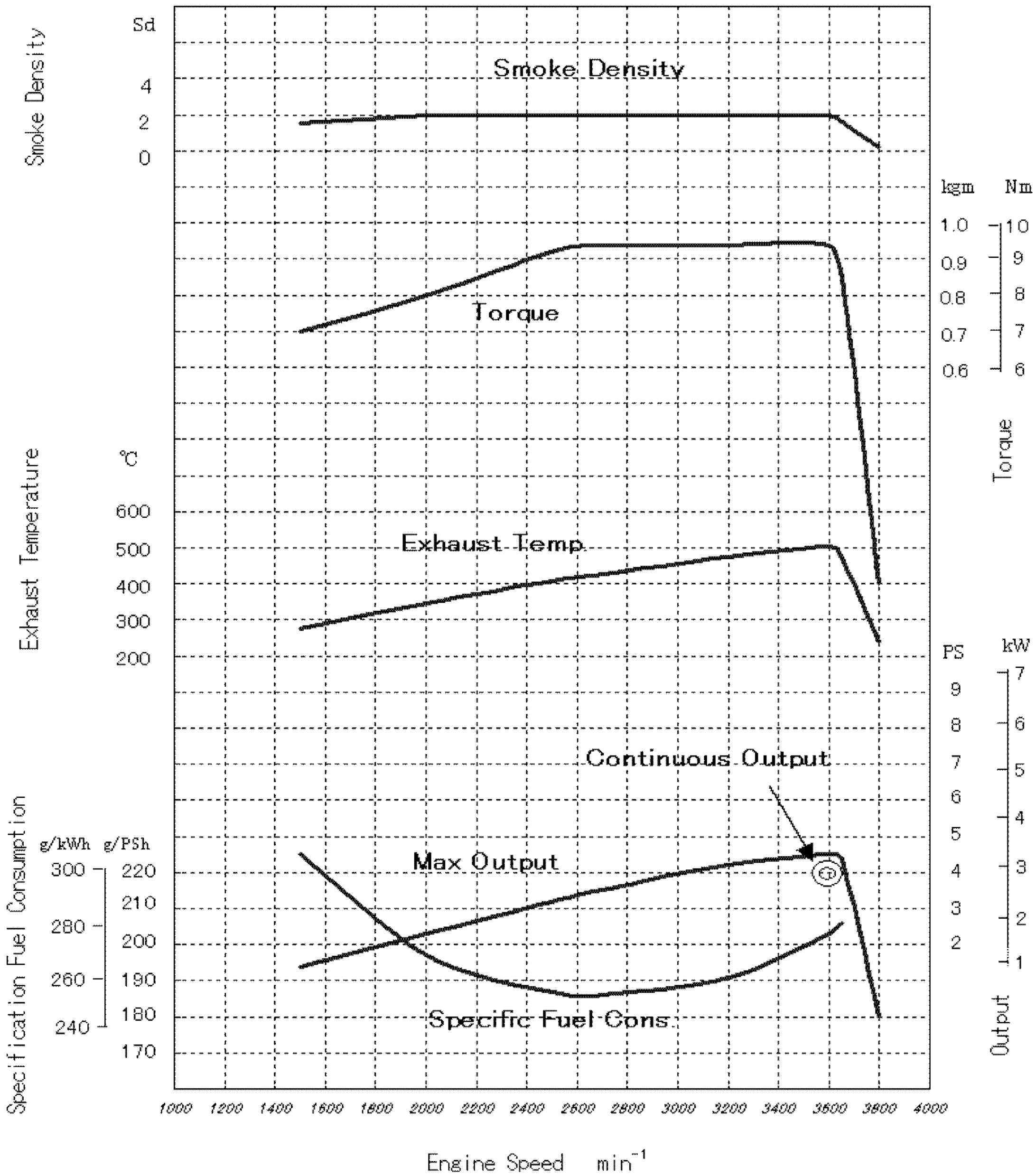


Though the rated output is a term common to the engine and generator, the meaning is completely different. Use caution when selecting the engine or determining the generator capacity.

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.

Performance Charts

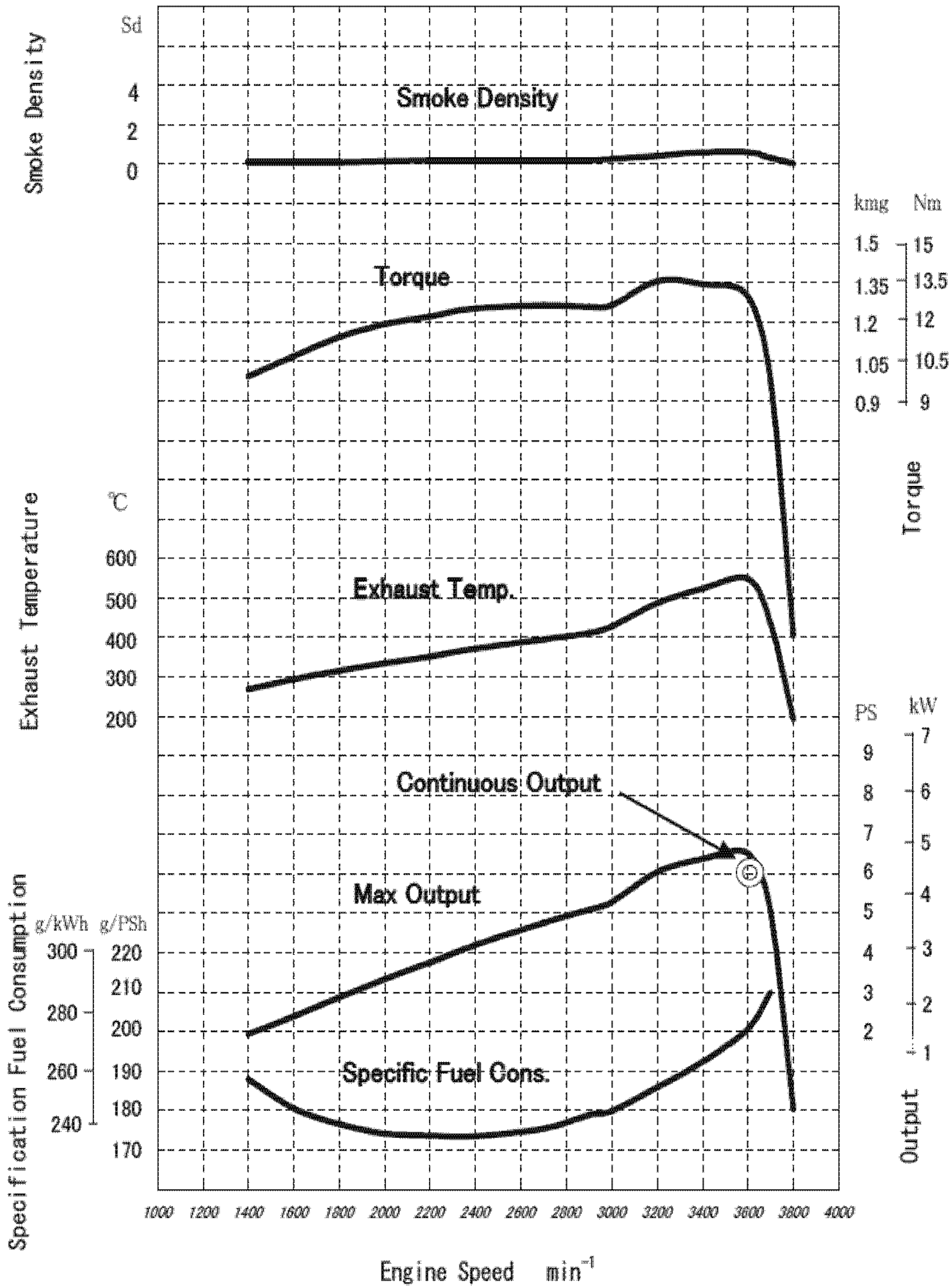
L48V



Notes : This performance is under the following condition.
After 30hrs. initial running
Atmospheric conditions : Temperature 298K(25°C)
Pressure 100kPa(750mmHg)
Humidity 30%

0006442

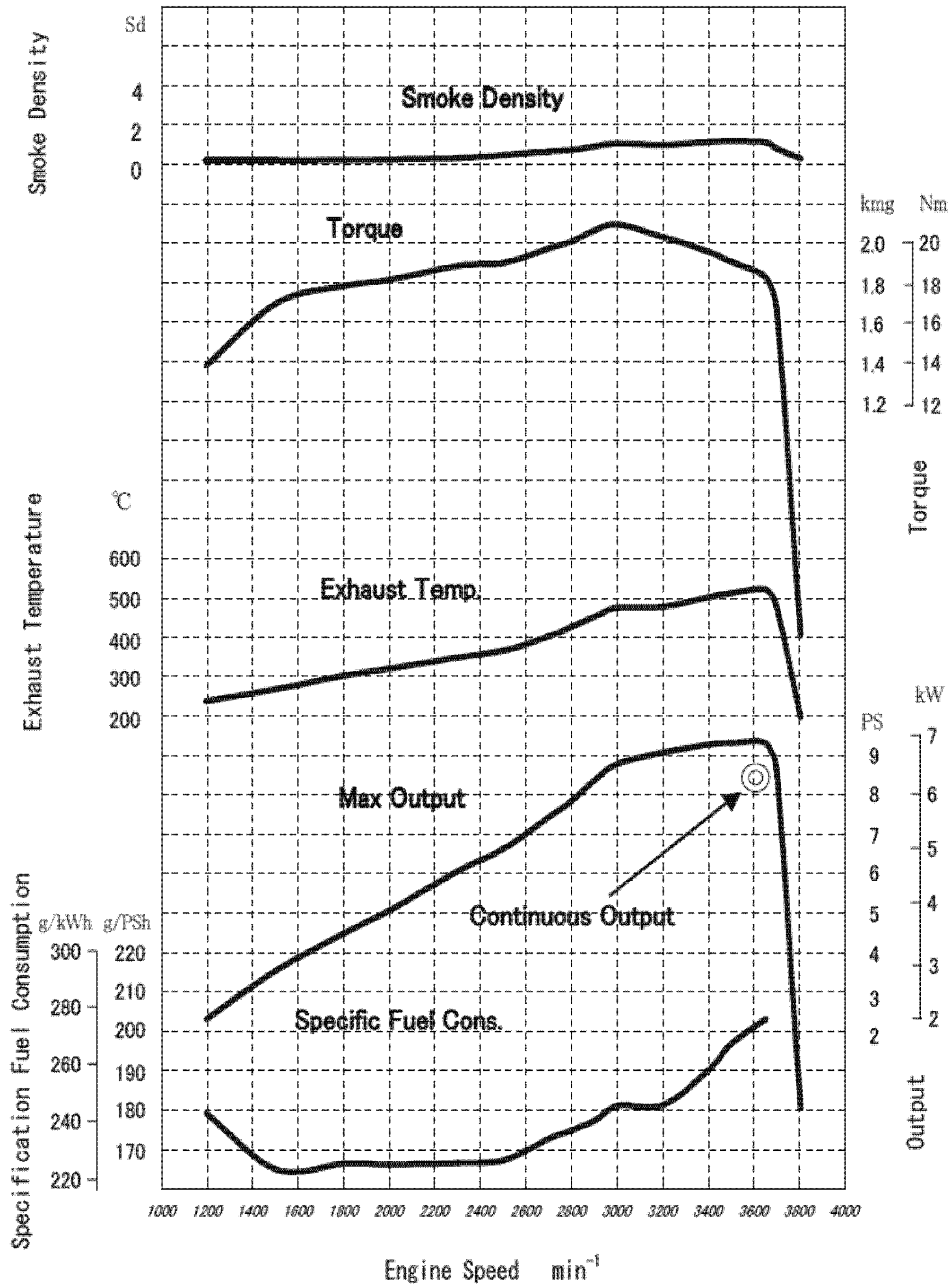
L70V



Notes : This performance is under the following condition.
After 30hrs. initial running
Atmospheric conditions : Temperature 298K (25℃)
Pressure 100kPa (750mmHg)
Humidity 30%

0003481

L100V

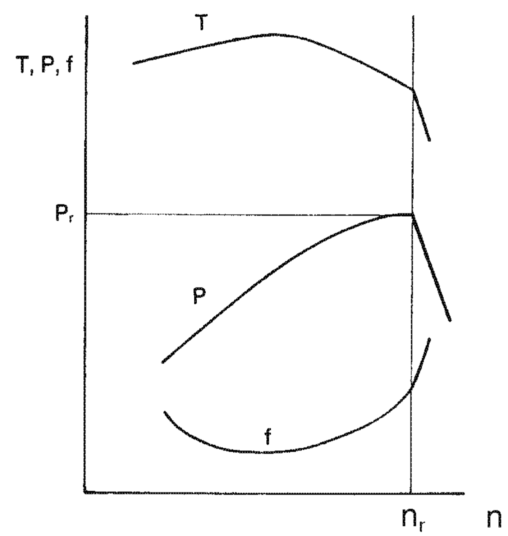


Notes : This performance is under the following condition.
After 30hrs. initial running
Atmospheric conditions : Temperature 298K(25℃)
Pressure 100kPa(750mmHg)
Humidity 30%

0003482

PERFORMANCE CURVES

Engine performance is generally expressed with three curves: output, specific fuel consumption and torque curves, as shown in **(Figure 6-1)**:



T: Torque (N·m or kgf·m)

P: Output (kW)

f: Specific fuel consumption (g/kWh)

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

Pr: Rated output (kW)

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

Figure 6-1

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

(Figure 6-2) 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.

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

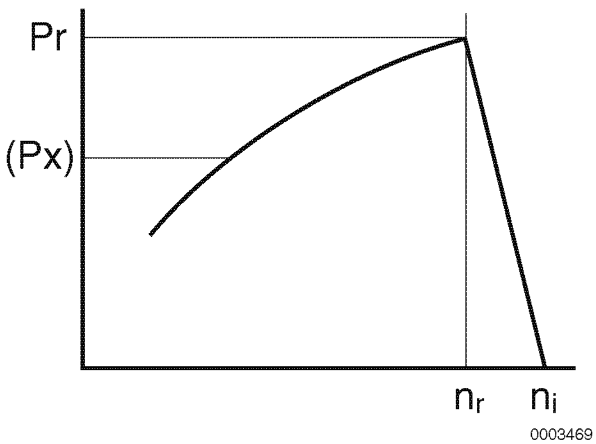


Figure 6-2

Generators are often driven continuously under load. The engine output to meet this demand is termed the "continuous rated output" **(Figure 6-3)**. 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.

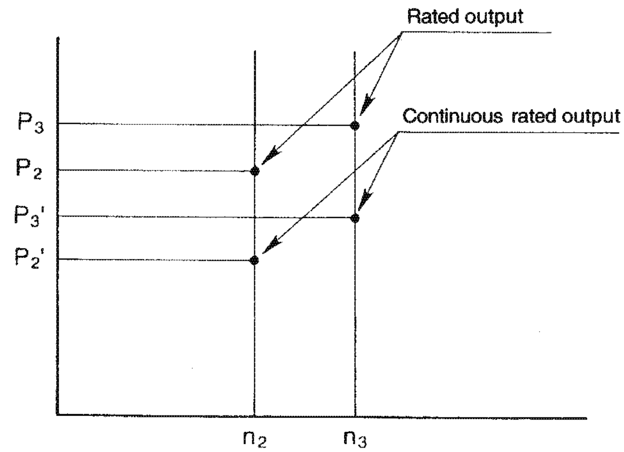


Figure 6-3

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

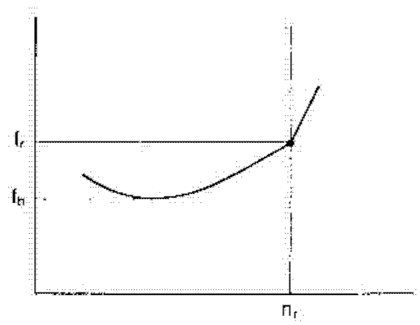


Figure 6-4

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 **(Figure 6-4)**.

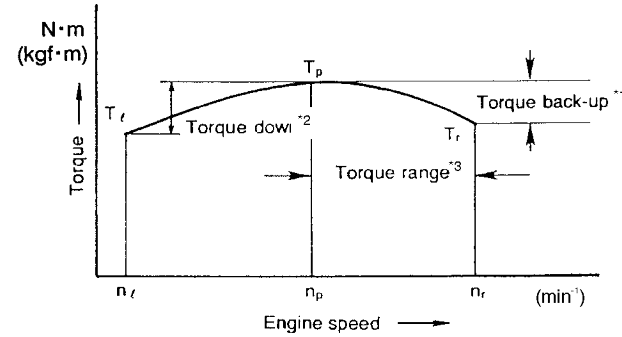
TORQUE CURVE: T

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 in **(Figure 6-5)**.



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}

Figure 6-5

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

Torque backup = Maximum torque (T_p) – torque at rated output (T_r)

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

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

Torque down = $T_p - T_L$

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

3. 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),

Speed Governing (Governor Regulation)

Speed governing systems are specified by International Organization for Standardization – International Standard (ISO-IS).

This International Standard (ISO 3046/IV) establishes a classification for the requirements and parameters of speed governing systems for reciprocating internal combustion engines.

Where necessary, individual requirements may be given for particular engine applications.

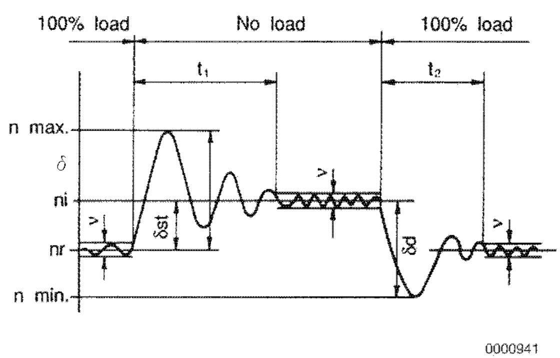


Figure 6-6

Where:

- υ : Steady state speed range, width variations of the engine speed under steady state conditions.
- δ_{st} : Speed difference between zero and declared power (100% load).
- δ_d : Transient speed difference in maximum deviation of speed after sudden load change from previous speed to steady state level.
- t : Recovery time, the time interval from the point where the speed departs from the steady state speed range after the load change until the speed returns to and remains within the steady state speed range.
- n : Engine speed (nr: speed under 100% load, ni: idling speed)

Speed Droop

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

Transient Speed Difference

$$\frac{\delta_d}{n_r} \times (100)\%$$

Shown below are the value of speed governing of the LV engine and the requirements of ISO 3046/IV for governing speed.

	Constant Speed	**General Speed**
Engine Speed	3000/3600 RPM	3000/3600 RPM
Transient Speed Difference (%)	10 or less	10 or less
Speed Droop	5 or less	5 or less
Recovery Time (sec)	5 or less	5 or less
Steady State Speed Band (rpm)	60 or less	60 or less

Governing Accuracy Class/Accuracy Requirement		**A1 / High Require-ments**	**A2 / Normal Require-ments**
Transient Speed Difference (%)		≤10	≤ 15
Speed Droop (%)		≤ 5	≤ 8
Recovery Time (sec)		≤8	≤15
Steady State Speed Band (%)	Relative Power ≥ 25%	≤0.8	≤1.0
	Relative Power < 25%	≤1.0	≤1.5
	Relative Power ≥ 50%	—	—

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Section 7

ENGINE MODEL SELECTION

Page

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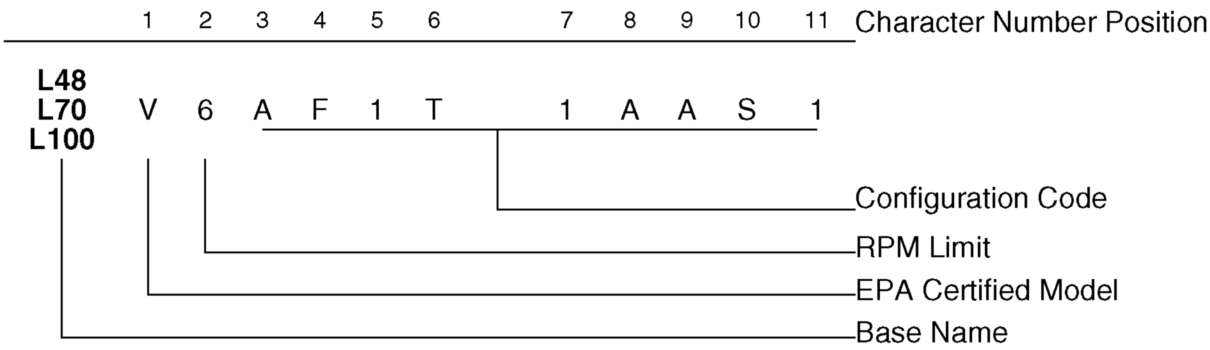
MODEL DESIGNATION



MATRIX FOR MODEL NAME

RPM Limit (Number Position 2)

RPM	L48	L70	L100
3600	6	6	6
3450	4	-	-
3300	-	-	-
3200	-	-	-
2500	-	-	-

RATED OUTPUT (NET & GROSS POWER) TABLE

Note: Gross outputs are theoretical, calculated from cooling fan formula. These are for reference only.

Engine Model			L48V	L70V	L100V
Combustion System			Direct Injection		
Number of cylinders = Bore x Stroke (mm x mm)			1 - 70 x 57	1 - 78 x 67	1 - 86 x 75
Displacement (cc)			219	320	435
Revolution speed (min^{-1})			NET POWER kW		
Industrial and Generator Use	Rated output	3600	3.3	4.8	6.8
		3450	3.1	-	-
	Cont. output	3600	3.0	4.3	6.2
		3450	2.7	-	-

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 LV 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.

Section 8

MATCHING TEST PROCEDURE

Page

PURPOSE OF MATCHING TEST APPLICATION REVIEW TEST

All engine performance specifications are developed under standard atmospheric conditions as described in *Atmospheric Conditions and Engine Configuration Affect Engine Output on page 6-3*. Engines are installed in driven machines that are 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.

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, or non-contact type (optical reflection or magnetic pulse) to measure engine speed in the operating state.
4	Thermo-couples Standard K-Type Thermo-couples can be used for all measurements.	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	Data Logger	Automatic data recording of engine temperature and engine speed.
6	Vibration Meter	Measures acceleration and amplitude. Make sure electrical power supply is available on the test site. Bring adhesive and metal fittings for mounting the pickup.
7	Angle meter	Measures the hill climbing angle of a vehicle.
8	Manometer	Checks intake and exhaust restriction, range 0 - 50 in. (1.5 m) min. H_2O. Can also use Analog Differential Pressure gauge.

Engine Parts

<table>
<tr><th></th><th></th><th>L48V</th><th>L70V</th><th>L100V</th></tr>
<tr><td rowspan="3">1</td><td>Exhaust Gasket Part Code</td><td colspan="2">114299-13200</td><td>114310-13200</td></tr>
<tr><td>Bolt Hole Pitch</td><td colspan="2">54mm</td><td>56 mm</td></tr>
<tr><td>Inside Diameter</td><td colspan="2">26 mm</td><td>30 mm</td></tr>
<tr><td>2</td><td>Dipstick Drilled with Thermocouple installed (Figure 8-5)</td><td>114299-01760</td><td colspan="2">114699-01760</td></tr>
</table>

Tools

	Tool	Tool Use
1	Phillips and straight-edge screwdrivers	For digital thermometer terminal and coolant hose band.
2	Wrench set	For bolts of the exhaust outlet port, installed muffler, air cleaner, and for fixing the thermocouple.
3	Super glue	To fix metal fixtures of vibration measuring pick-up.
4	Double-Adhesive tape	To mount vibration meter pick-up, in case the subject machine is a finished product to be sold.
5	Pliers	To mount high pressure pipe type tachometer pick-up.
6	Cutting pliers	For various works.
7	Tape measure	To measure the speed of the running vehicle.
8	Needle file	To modify exhaust gaskets.
9	Inflating needle	For intake measurement.
10	Drill and Bit	To fit thermocouple if gasket location not possible.
11	Exhaust back pressure probe	0.125 in copper tubing is commonly used.
12	Circle compass knife	To slit rubber hoses for thermocouple or pressure tap.
13	Electrical or Duct tape (good quality)	For fixing thermocouples and leads.
14	Zip or Wire Ties	For securing wires.

Documentation

	Data recording forms	Comments
1	Sample machine data	Rated speed performance curve and load performance curve during operation. Specific fuel consumption data also effective depending on the case.
2	Test plan	Arrangements for the matching test.
3	Measured data recording sheet	See the separate publication, LV Series Engine Installation Evaluation.
4	Installed state check sheet	See the separate publication, LV Series Engine Installation Evaluation.
5	Memo pad	
6	Tape Measure	
7	Digital Camera	
8	LV Operation Manual	
9	LV Service Manual	

INSTRUCTIONS FOR MOUNTING MEASURING INSTRUMENTS

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.

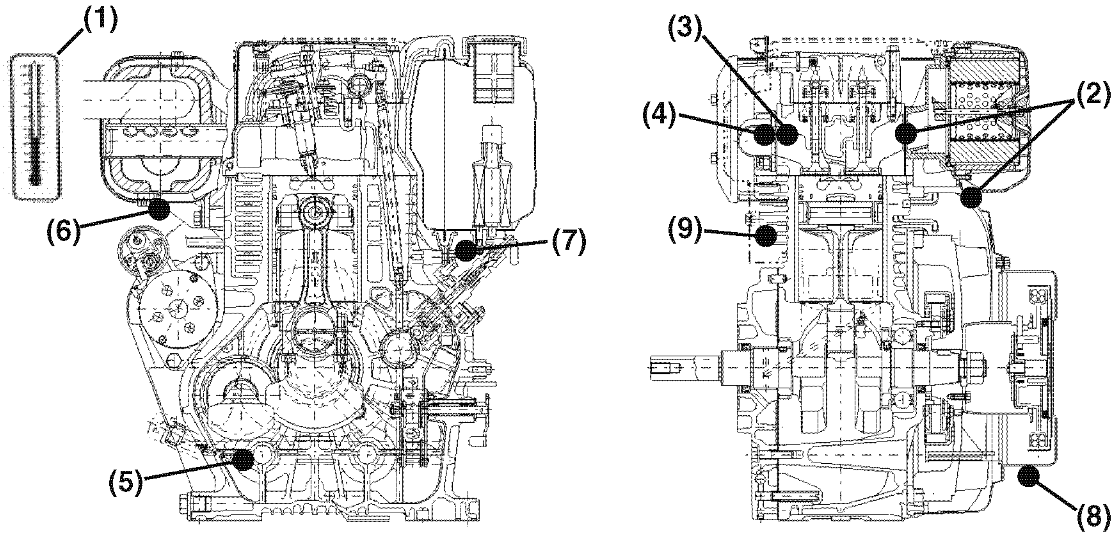


Figure 8-1

Atmospheric Temperature

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

- The preferred measurement instrument is a thermocouple in conjunction with a data logger. A dry and wet-bulb thermometer can be used as an alternative.
- 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

See **(Figure 8-1, (2))**:

- The preferred measurement instrument is a thermocouple in conjunction with a data logger.
- Secure the end of the thermocouple to the air cleaner or within 20 mm from the intake extension hose end.
- Avoid the heat radiated from the exhaust system or other engine components.

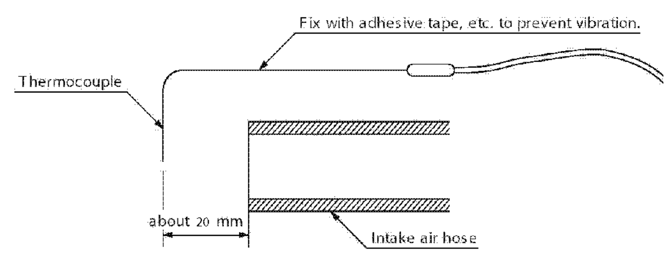


Figure 8-2

Exhaust Temperature

See **(Figure 8-1, (3))**:

- The preferred measurement instrument is a thermocouple in conjunction with a data logger.
- Measure the exhaust temperature at the exhaust port outlet.
- 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.
- It may be necessary to use multiple stacked gaskets for thermocouples that are thicker than are standard K-Type thermocouples which are 1/16 in.
- The thermocouple may be positioned in the silencer pipe within 1 in. (25 mm) of the exhaust mating surface.
- Make sure you keep the end of the thermocouple at the center of the exhaust port.

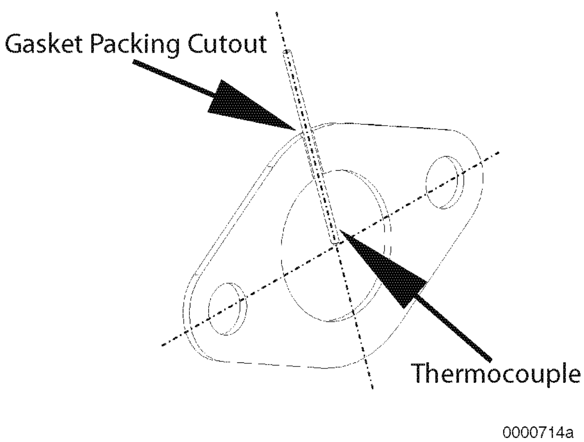


Figure 8-3

Measurement of Exhaust Back Pressure

See **(Figure 8-1, (4))**:

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 or Delta pressure gauge 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 3 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 coil form. Make sure the manometer is filled with water before running the test.

If using a Delta pressure gauge, verify that it is properly calibrated and “zeroed” per the manufactures directions.

Fully equip the engine with exhaust system parts that will be used on the driven machine. Verify the exhaust back pressure under a full load condition. Under full load the exhaust back pressure and temperature will be at their highest.

The measuring device will be generally configured as follows:

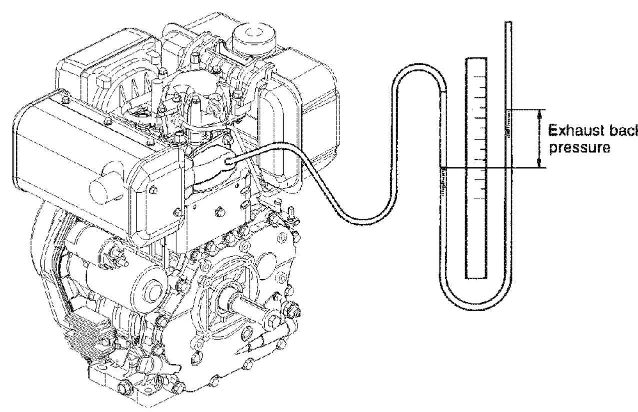


Figure 8-4

Engine Oil Temperature

See **(Figure 8-1, (5))**:

- Measure the temperature of the engine oil in the oil pan.
- 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.
- Secure the lead of the thermocouple to the dipstick. Make sure that the end of the thermocouple will not separate from the dipstick during the test.

Note: Never cover the end of the thermocouple with glue because it may act as an insulator and cause inaccurate measurement readings.

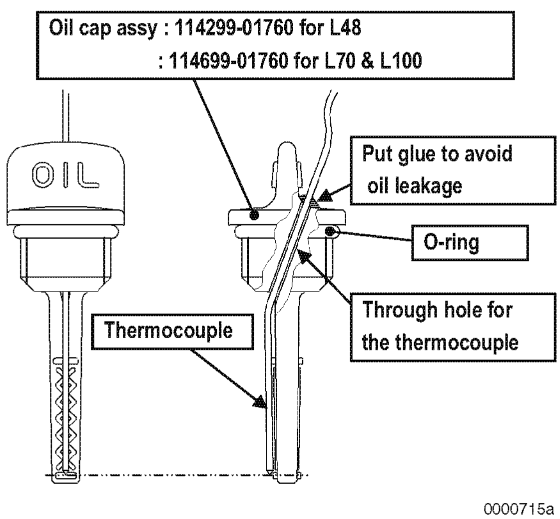


Figure 8-5

Ambient Temperature Around Starter Motor

See **(Figure 8-1, (6))**:

- Starter motor temperature is measured by installing a thermocouple between hot parts (muffler or exhaust extension pipe) and starter motor, about 10mm from the surface of the starter motor.

Ambient Temperature Around Fuel Injection Pump

See **(Figure 8-1, (7))**:

- Fuel injection pump temperature is measured by installing a thermocouple between the fuel injection pump and fuel tank.

Cooling Air Temperature (before cooling the engine)

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

- Engine cooling air is measured by installing a thermocouple on the engine recoil starter.
- The thermocouple must be fixed 25mm from the lower window of the recoil starter.

Cooling Air Temperature (after cooling the engine)

See **(Figure 8-1, (9))**:

- Engine cooling air is measured by installing a thermocouple on the engine cylinder cover.
- The thermocouple must be in a fixed position to measure air (out) temperature between the head and cylinder.

Engine Speed

A contact tachometer is effective for measuring the engine speed of stationary and moving driven machine applications. The high pressure pipe tachometer mounts the pick-up to the high pressure pipe near the fuel injection valve. Secure the pick-up to the injector pipe per the manufactures instructions.

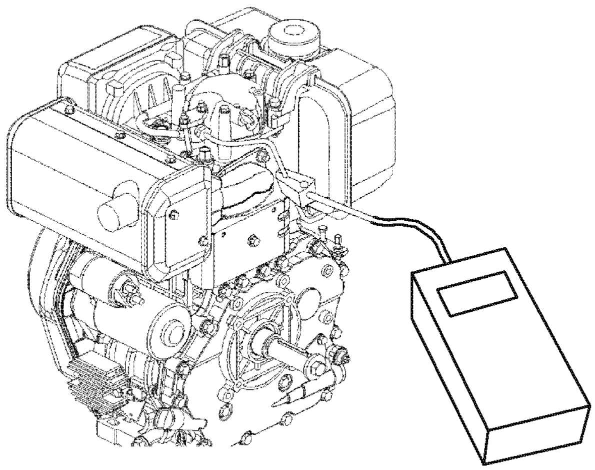


Figure 8-6

Other Temperature Measurements (Use Thermocouple, etc.)

See **(Figure 8-1, (7))**:

Measure the temperature of engine components as required:

1. Temperature inside the engine compartment
2. Ambient temperature around the electrical parts.
3. Fuel temperature at injection pump inlet.

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

On canopy applications, check to ensure engine airflow is not obstructed by equipment components. This will avoid an increase in engine temperature during engine operation. While the machine is warming up, check for leakage of oil, 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 may be designed for a different duty cycle. Consult with the driven machine manufacturer and Yanmar to determine the correct setup before actually starting the matching test.

The machine manufacture should verify the following items:

1. Test is made under a load actually applied by the user.
2. Test by following the work pattern designated by the driven machine manufacturer.
3. 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 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 exhaust temperature change sharply, but the engine oil temperature will remain comparatively stable. The oil temperature should rise or fall depending on the ambient temperature around the engine, this is normal.

If using an automatic data logger, it is recommended that you start your data collection once the engine starts as it is not necessary to wait until the engine temperature stabilizes. When using an automatic data logger, the sample rate should be set for every 5-10 seconds throughout the test cycle. The engine has reached its stabilized temperature when the oil temperature remains relatively constant. A minimum of five minutes of stabilized temperature readings are recommended for calculation air to boil and maximum operating temperatures. Additional minutes of data beyond the five minutes may be required depending on the application, installation and duty cycle.

How to Interpret Test Data 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	Depending on customer's specification, the allowable maximum atmospheric temperature shall normally be 40°C (104°F). This will be the baseline you should use when you analyze the data for the engine components.	Consider intended application and location to decide if 40°C (104°F) is realistic or if a different ambient should be considered.
2	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 115°C (239°F) if the atmospheric temperature is corrected to 40°C (104°F). Using the conversion rate, you can also determine whether the converted atmospheric temperature would be 40°C (104°F) if the engine oil temperature is 115°C (239°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 (1.8 °F), the engine oil temperature would rise 0.8°C (1.4°F).	Engine compartment shape (air outlet and inlet), recirculation of hot air, load capacity, duty cycle
3	Intake air temperature	Set the development target for the allowable intake air temperature so it is no more than 5°C (9°F) above the atmospheric temperature. If the intake air temperature cannot be lowered to 10°C (18°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

Measured Temperature Item		Allowable Maximum Temperature (Criteria)	Improvement Review Item
4	Temperature inside engine compartment	Set the development target for the allowable engine compartment temperature so it is no more than 10°C (18°F) above the atmospheric temperature. This is sometimes difficult to achieve, optimize 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
5	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 power 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
6	Ambient temperature around electrical parts	Set the development target for ambient temperature around electrical parts such as the starting motor, generator, respective relays to 80°C or below regardless of atmospheric temperature. Even if the ambient temperature is under 80°C (176°F), 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
7	Exhaust temperature	For exhaust temperature, *See Output Matching Test on page 8-15*.	

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_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_{mo}	: Allowable maximum engine oil temperature	115°C (239°F)
T_{co}	: Engine oil use limit atmospheric temperature	°C (°F)
T_{dif}	: Intake air temperature rise value (T_x - T_a)	°C (°F)

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 To are known.

Calculate the estimated T_{co} as follows:

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

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

$$= 36.5°C\ (97.7°F)$$

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:

(Target T_{co} - Test result T_{co}) × 0.8

= (40°C [104°F] - 36.5°C [97.7°F) × 0.8

= 2.8°C (5.0°F)(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_a	: Ambient temperature	19°C
T_x	: Intake air temperature	34°C
T_{dif}	: Intake air temperature rise value (T_x - T_a)	°C

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

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

$$= 34°C - 19°C$$

$$= 15°C$$

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 or below.

Depending on the results of the output matching (*See Output Matching Test on page 8-15*), there is no major effect on engine output if T_{dif} is below 10°C. In the calculation example above, T_{dif} is 15°C, 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 engine oil and intake air temperatures are important in the heat balance test.

To evaluate the temperature of other engine components, refer to *How to Interpret Test Data and Criteria on page 8-12*.

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.

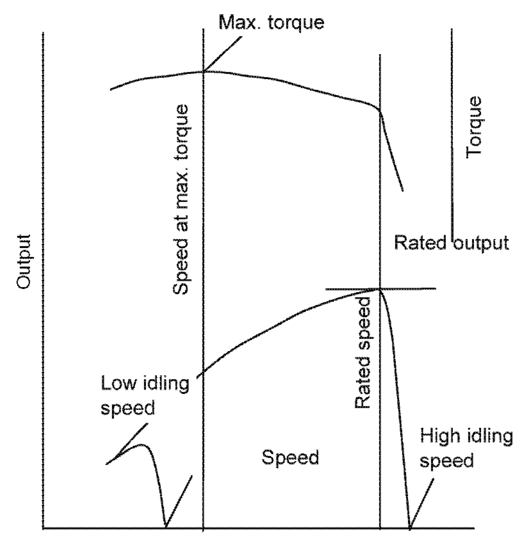


Figure 8-7

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.

1. Output setting under ISO standard atmospheric conditions

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

2. Fuel temperature at output setting: 38 ± 3°C (100.4 ± 3°F)
3. Fuel meeting JIS specifications (density, cetane number)
4. Output setting tolerance: ±3%
5. Torque setting tolerance: ±5%
6. Engine output: Median of tolerance
7. 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 8-8)** and **(Figure 8-9)** 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 factory 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 5-3 and Altitude Characteristics on page 5-10*.

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.

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

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.

1. The ambient temperature during matching test is expressed with T_t.
2. Find the output ratio from the fuel temperature and **(Figure 8-8)**. For example, when the fuel temperature T_{tf} is 55°C (131°F), the output ratio P_{rtf} is 97% (0.97).
3. Find the output ratio from the intake air temperature and **(Figure 8-9)**. For example, when the intake air temperature T_{ta} is 45°C (113°F), the output ratio P_{rta} is 96% (0. 96).
4. 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%.
5. This means that the engine output has been reduced to 93.1% of the performance guaranteed in *Engine Performance starting on page 6-1*. This reduction of output occurred because both the fuel temperature and intake air temperature are higher than those for guaranteed performance.
6. 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 8-10)**.
7. The result is the performance curve indicated by the dotted line in **(Figure 8-10)**. This curve represents the engine performance under the ambient conditions of the matching test.

Evaluation of Machine Load

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

1. Plot the engine speed in each operation pattern on the performance curve.
2. The intersection of the speed curve and the dotted performance curve indicates the load at the operation pattern.
3. The largest load of all the operation patterns is the maximum machine load.
4. The estimated machine load is deemed to be unaffected by the atmospheric conditions.
5. 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.

1. The maximum ambient temperature specified by the machine manufacturer is expressed with T_x.
2. 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.

3. 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:

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

   $T_{xa} = T_{ta} + (T_x - Tt)$

4. Plot these T_{xf} and T_{xa} on **(Figure 8-8)** and **(Figure 8-9)**, respectively.
5. The output ratio P_{rxf} at fuel temperature T_{xf} is expressed with a, and the output ratio P_{rxa} at intake air temperature T_{xa} is b.
6. Then, the total output ratio P_{rx} at the maximum ambient temperature T_x is given by the following formula.

   $P_{rx} = a \times b$

7. 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 8-10)**.
8. The result is the performance curve shown in **(Figure 8-10)** 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 8-16).*

Plot this load on the performance curve shown with dot-and-dash line on **(Figure 8-10)**, and perform the following examination.

1. Evaluation of output matching at the normal operation of the machine
   - Normal operation of the machine refers to the type of use the engine will usually be subjected to. It could be high idle or it could be rated speed with a load.
   - 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.
2. Evaluation of output matching at the rare operation of the machine (shown with * in **(Figure 8-10)**)
   - 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}.

Evaluation Notes

Be careful of the following when handling the data.

1. Fuel temperature

   The allowable limit of fuel temperature is 80°C (176°F). When it is estimated that the fuel temperature Txf in *Evaluation of Output Matching for General Purpose Industrial Machines on page 8-16* exceeds 80°C (176°F), consider taking the sixth action described in *How to Interpret Test Data and Criteria on page 8-12*. However, if the engine output is set at 38°C (100.4°F), power correction according to **(Figure 8-8)** should be necessary.

2. Intake air temperature

   When the rise of the intake air temperature (T_{ta} – T_t) exceeds 10°C (18°F), consider taking the fourth action described in *How to Interpret Test Data and Criteria on page 8-12*.

Evaluation of Output Matching of Generator

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 8-16*.

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 6-3*.

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 8-17*. Plot the load on the performance curve shown with dot-and-dash line in **(Figure 8-11)** to perform the following examination.

1. 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 8-11)**.

   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)

2. 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.

   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.

Deration for Fuel Temperature (38°C (100.4°F) = 100)

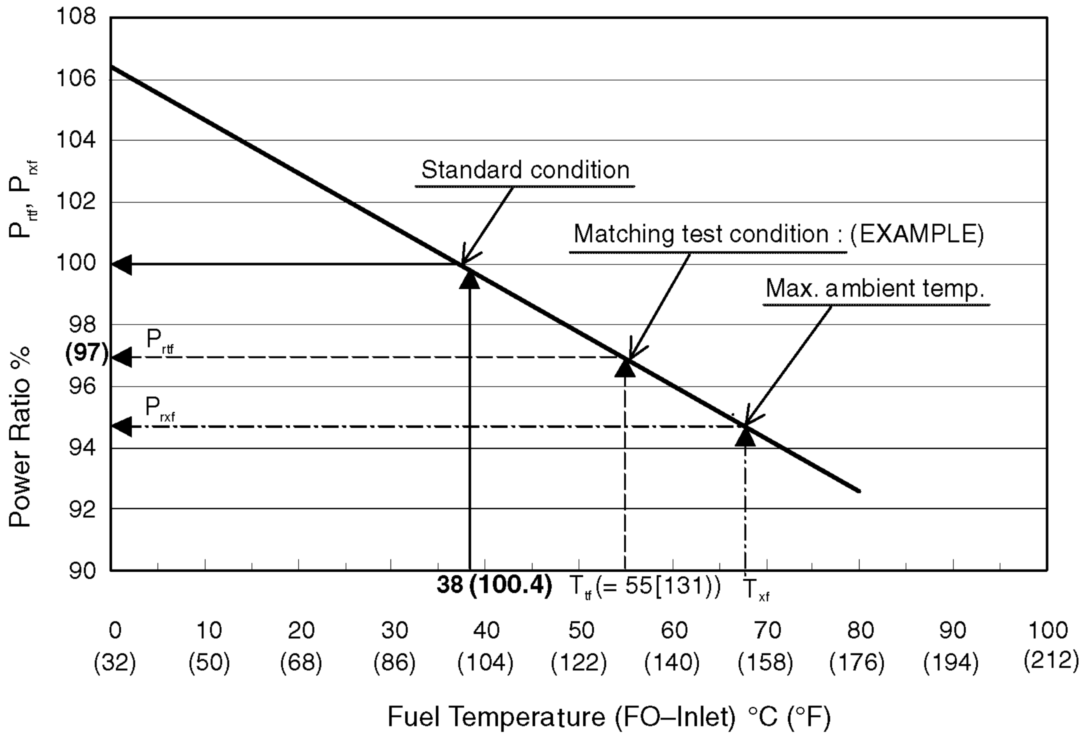


Figure 8-8

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

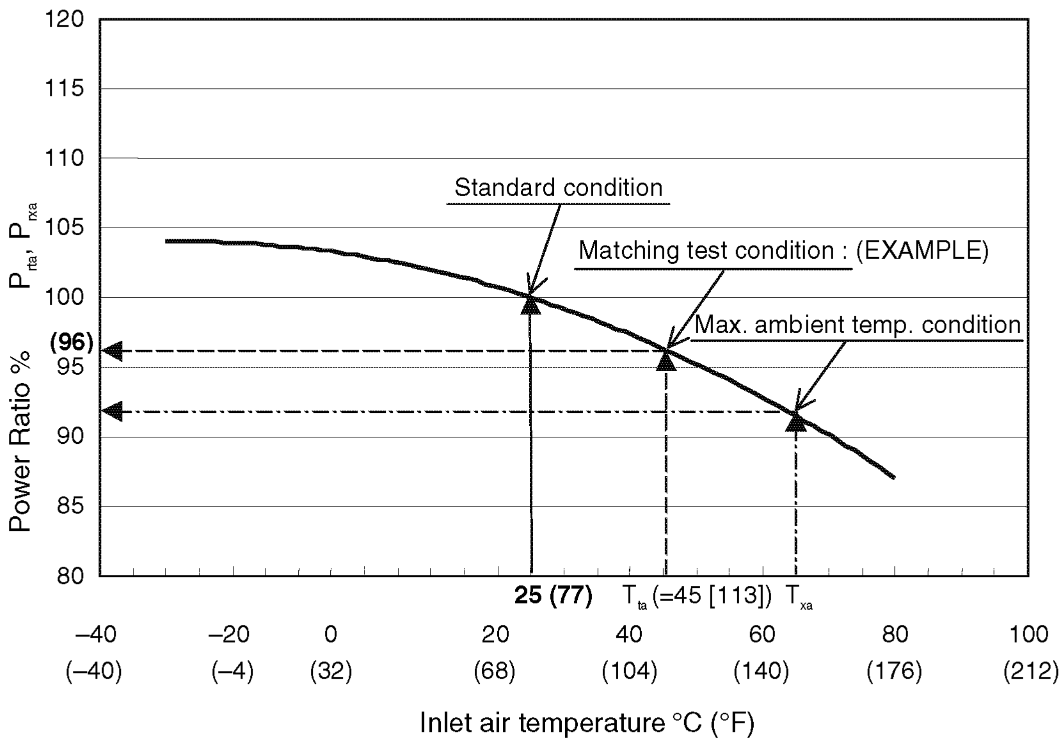


Figure 8-9

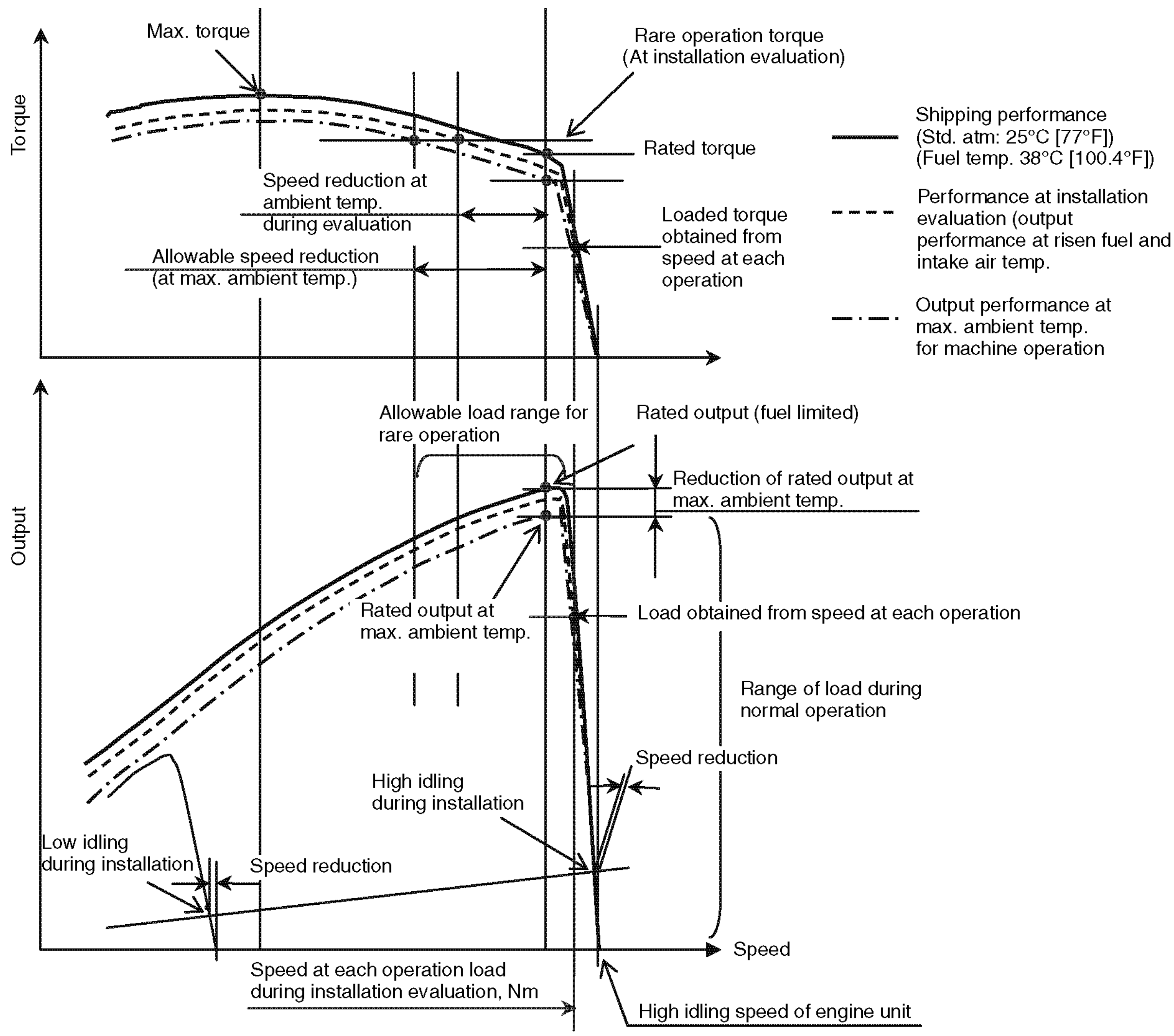

Torque
Max. torque
Rare operation torque
(At installation evaluation)
Rated torque
Speed reduction at
ambient temp.
during evaluation
Allowable speed reduction
(at max. ambient temp.)
Loaded torque
obtained from
speed at each
operation
Shipping performance
(Std. atm: 25°C [77°F])
(Fuel temp. 38°C [100.4°F])
Performance at installation
evaluation (output
performance at risen fuel and
intake air temp.
Output performance at
max. ambient temp.
for machine operation
Output
Allowable load range for
rare operation
Rated output (fuel limited)
Reduction of rated output at
max. ambient temp.
Rated output at
max. ambient temp.
Load obtained from speed at each operation
Range of load during
normal operation
Speed reduction
High idling
during installation
Low idling
during installation
Speed reduction
Speed
Speed at each operation load
during installation evaluation, Nm
High idling speed of engine unit

Figure 8-10

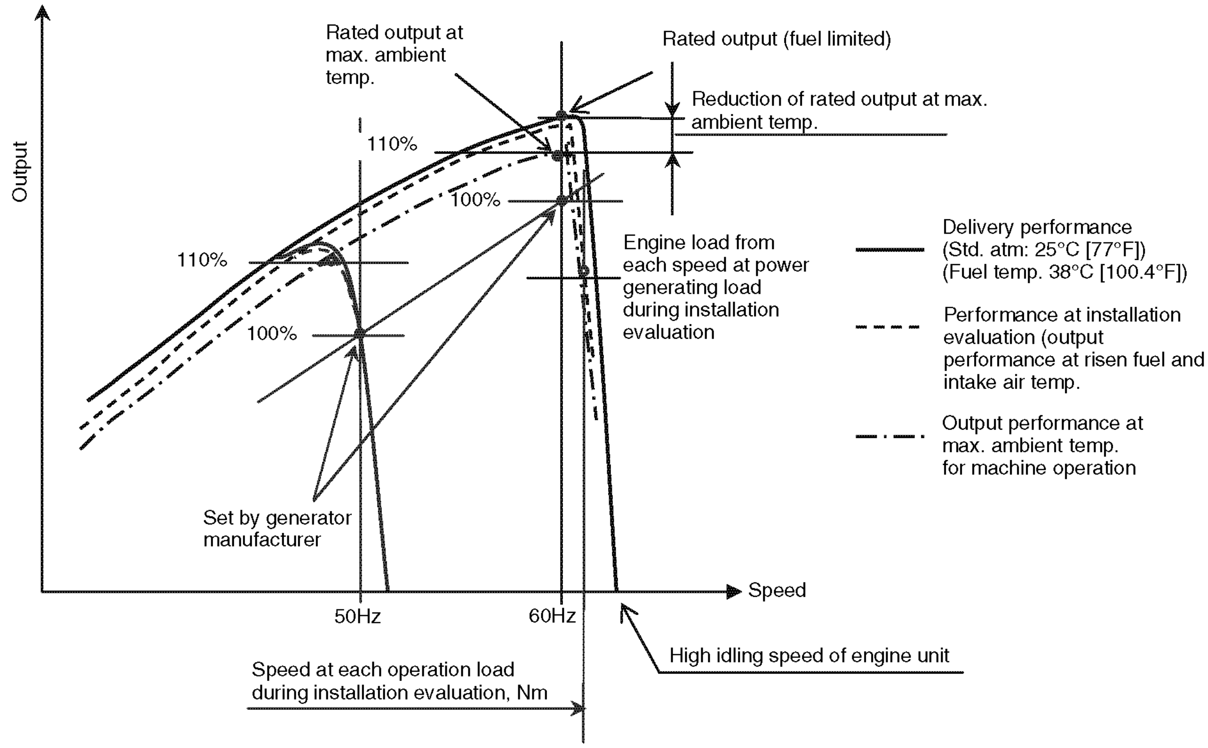

Output
Rated output at
max. ambient
temp.
Rated output (fuel limited)
Reduction of rated output at max.
ambient temp.
110%
100%
110%
100%
Engine load from
each speed at power
generating load
during installation
evaluation
Delivery performance
(Std. atm: 25°C [77°F])
(Fuel temp. 38°C [100.4°F])
Performance at installation
evaluation (output
performance at risen fuel and
intake air temp.
Output performance at
max. ambient temp.
for machine operation
Set by generator
manufacturer
Speed
50Hz
60Hz
High idling speed of engine unit
Speed at each operation load
during installation evaluation, Nm

Figure 8-11

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 not 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. Upper surface of fuel oil tank when the engine has fuel oil tank.
2. Mounting part of engine feet when the engine doesn't have fuel oil tank.
3. Top of bonnet when you cannot measure at (2) position.

Standard for Vibration

Measuring Condition	Acceleration m/s^2 (RMS)	Amplitude mm (Peak Ave.)	Remarks
(1)	Under 55.5	(Under 1.0)	Low pass filter: 1000Hz If possible, please measure the amplitude
(2) or (3)	Under 34.7	(Under 0.5)	

[Notice] If the vibration level exceeds the standard value, please consult with YANMAR.

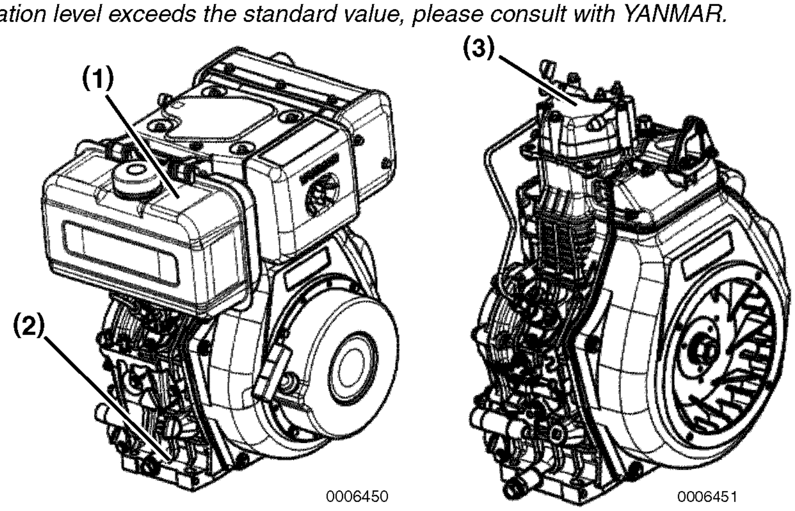


Figure 8-12

INSTALLATION STATE CHECK

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

- Serviceability
- Interference of fuel and coolant 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. See the separate publication, LV Series Engine Installation Evaluation for check sheet examples.

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Section 9

COLD STARTING AIDS

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COLD STARTING SYSTEMS

CAUTION

NEVER use any type of engine starting aids. No chemicals, liquids, gases, or aerosols of any type should ever be used to start the engine. Engine damage will result to the engine cylinder, pistons and piston rings.

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The Yanmar LV series engine can easily be started with recoil starting system even at low ambient temperature because of its direct injection system and high compression ratio.

Starting at lower ambient temperature is possible by attaching a starter motor.

Recoil Starting

Lowest possible starting temperature with recoil starting system is as follows.

Lowest possible starting temperature:

Engine oil: *See Engine Oil on page 13-4*

Fuel: *See Diesel Fuel on page 12-7*

	Lowest Possible Starting Temperature
Without Starting Aid Agent	0°C
With Starting Aid Agent (Engine Oil) - L48V Only	-5°C

Note: Only use engine oil as starting aid. Do not use volatile starting aids such as gasoline or any aerosol product in the intake port of the engine. These cause excessive combustion pressure and poor lubrication that may cause engine damage. An appropriate amount of engine oil is 2 cc. Feeding too much oil requires more force on the recoil starter and could cause a problem with the intake valve, exhaust valve, piston ring, etc. due to carbon generated by incomplete combustion of engine oil. Refer to the proper Operation Manual for cold starting methods.

Electric Starting

Starting in cold conditions is made possible up to -10°C to -15°C by adopting an electric starting system.

Model	Lowest Possible Starting Temperature	Battery Capacity (5hr)
L48V	-10°C	minimum 24AH
L70V		minimum 24AH
L100V		minimum 36AH

Note: When an electric starting system is used, engine oil has no starting aid effect.

INDUCTION AIR HEATER (OPTIONAL)

Standard specification LV series engines are hard to start in severe cold (ambient temperature of -15°C (258 K/5°F) or lower, as in Alaska, Canada or Northern Europe).

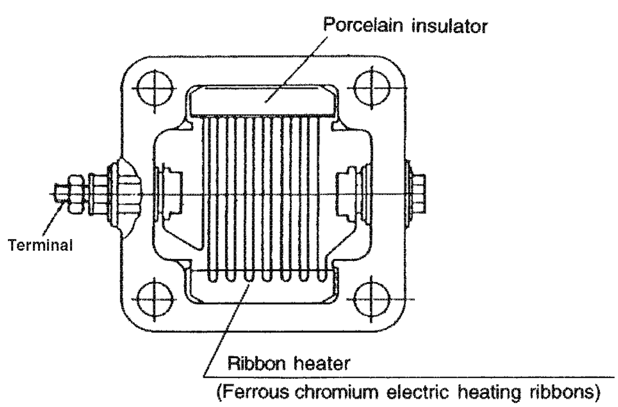
An air heater is available to start in these conditions if ambient temperature is higher than -30°C (243 K / -22°F).

This system heats the intake air. This system only heats the air that is taken into the engine. Oxygen in the air is not consumed for preheating.

Model	L48V		L70V		L100V	
Ambient Temperature	≥ -10°C	≥ -30°C	≥ -10°C	≥ -30°C	≥ -10°C	≥ -20°C
Battery	24 Ah or better	30 Ah or better	24 Ah or better	35 Ah or better	35 Ah or better	45 Ah or better
Starter	12V - 0.8 kW		12V - 0.8 kW		12V - 0.8 kW	
Air heater	Non	12V - 400W	Non	12V - 400W	Non	12V - 400W
Operation	—	15 - 30 sec ON	—	15 - 30 sec ON	—	15 - 30 sec ON
Diesel Fuel	Diesel Fuel Matching Ambient Temperature					
Engine Oil	SAE - 10W-30	5W-30*	10W-30	5W-30*	10W-30	5W-30*

If not available, a 5W-30 synthetic engine oil may be used For starter characteristics, See Starter Motor on page 14-3.

Induction Air Heater Structure



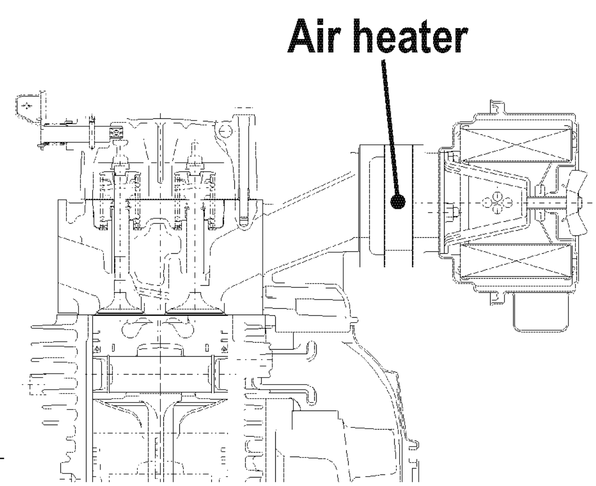


Figure 9-1

Control Circuit Diagram for Standard Induction Air Heater

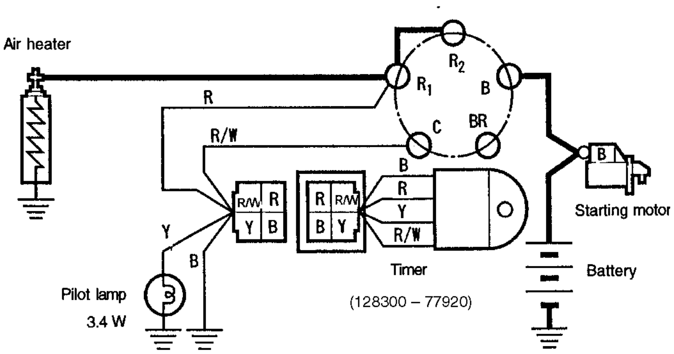


Figure 9-2

Induction Air Heater Capacity and Power Relay

(Figure 9-2) shows the basic induction air heater wiring connection. A large current flows in the standard type induction air heater. Depending on conditions, a larger capacity is produced by combining various types of induction air heaters to improve engine startability.

Before starting, check the contact capacity of the key switch preheating circuit B-R and B-R2 to determine if it is sufficient for the required current flow from the induction air heaters.

If the contact capacity (allowable current) of the key switch preheating circuit is smaller than the required current of the induction air heater, the current to the induction 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 9-3)**.

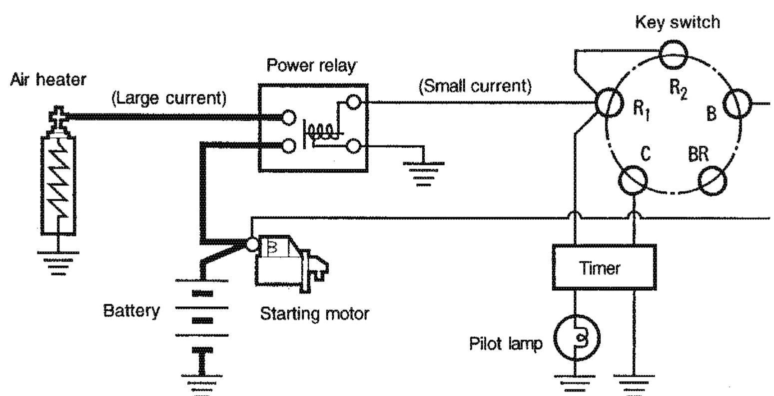


Figure 9-3

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 induction air heater when the key switch is in the START position. Startability improves significantly if the current to the induction 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 induction 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 induction air heater current should be cut off during cranking.

Induction Air Heater Control Circuit Components

Power Relay

Use a power relay if the wiring distance between the engine and the key switch is too long or if the key switch used is not rated for the current. As the length of wire between the engine and key switch increases, so does the resistance of the wire.

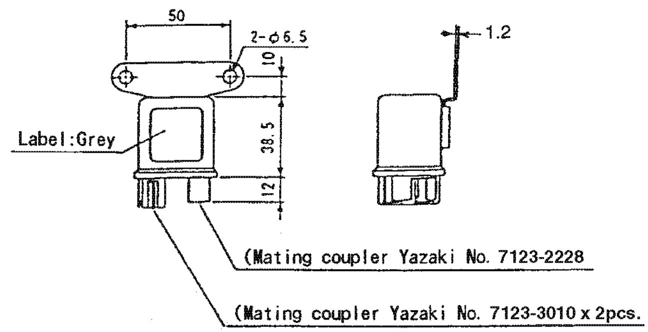


Figure 9-4

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

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. 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 R1 of the key switch is not powered during the START mode.

12 VDC 15-sec Timer

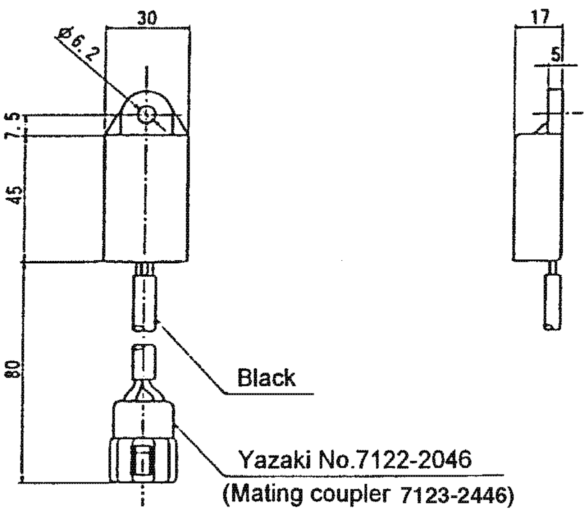


Figure 9-5

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

AFTERMARKET BATTERY WARMERS AND RADIANT SUMP HEATERS

In applications that require extreme cold starting capability there are aftermarket companies that supply products to aid in engine starting.

Battery warmers and blankets can increase available cranking amps. Radiant heaters can warm the lubrication oil and the engine to provide higher cranking speeds and assist in warming the intake air for combustion.

Please follow the manufacturer's recommendations regarding the capacity, installation and application of these products.

Contact your Yanmar Authorized Distributor for further assistance with engine specifications.

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Section 10

AIR INTAKE SYSTEM

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INTRODUCTION

The air induction system has a great affect on engine output, fuel consumption, exhaust gas and the life of the engine.

AIR FILTER DUTY CLASSIFICATION

The air filter can be divided into the following categories according to the duties it performs:

Normal Duty

The semi-wet paper element is made of paper soaked with special oil and is maintenance-free.

Heavy Duty

When the engine is exposed to dust, a large capacity air cleaner must be used. This air cleaner has a wet paper-type element with a filtration area of 0.15m^2 (1.61 ft^2) or 2.5 times that of the normal duty air cleaner.

AIR FLOW

The capacity and life of the air filter affects the air intake capacity of the engine.

Required Engine Air Intake Capacity

The required air taken into the engine can be determined as follows:

$$Q_1 = V_s \times N \times C \times \eta \times 10^{-3}$$

Where:

Q_1	:	Air taken in	(m^3 / min)
V_s	:	Engine displacement	(liter)
N	:	Engine speed	(rpm)
C	:	0.5	(4-cycle constant value)
η	:	Intake efficiency	(usually 85%)

The life of the air filter can be determined from the required air intake of the engine.

Model	Displacement (l)	3000 RPM	3600 RPM
L48V	0.219	0.279	0.335
L70V	0.320	0.407	0.489
L100V	0.435	0.555	0.665

Apparent Amount of Air Intake

Initial resistance of the air filter can be determined from the amount of apparent air intake. The apparent air intake can be calculated as follows:

$$Q_2 = K \times V_s \times N \times C \times \eta \times 10^{-3} = K \times Q_1$$

For a Natural Aspirated Engine:

1-cylinder K: 3.4

Generally K is expressed as: $K = \frac{4}{\text{No. of cylinders}}$

Model	Displacement (l)	3000 rpm (min^1)	3600 rpm (min^1)
L48V	0.219	0.949	1.139
L70V	0.320	1.387	1.665
L100V	0.435	1.886	2.263

Rated (Maximum) Flow of Air Cleaner

CAUTION

The maximum air intake restriction shall be:

- **L48V: 0.10 psi (0.69 kPa; 70 mmAq) or less**
- **L70V: 0.20 psi (1.37 kPa; 140 mmAq) or less**
- **L100V: 0.21 psi (1.47 kPa; 150 mmAq) or less.**

Clean or replace the air cleaner element if the air intake restriction exceeds the above mentioned value.

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The capacity of the air cleaner is generally expressed in the rated (maximum) flow. The rated air volume is the maximum air volume of a specified air cleaner and volume under the standard conditions (temperature: 25°C (77°F), atmospheric pressure: 750 mmHg (100 kPa), relative humidity: 30%). The rated air volume is expressed in cubic meters per minute (m^{-3} / min).

INDUCED AIR FLOW RESTRICTION

Air flow will be more restricted with an air filter. For industrial engines, air flow is restricted by the air filter and the air flow piping. For air flow restriction for the industrial LV engine, *See Application Standard on page 4-3*.

Air Flow Restriction

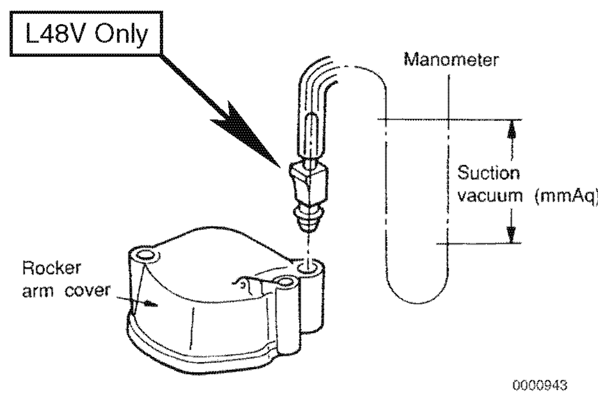

Figure 10-1

Vacuum Measuring Tool

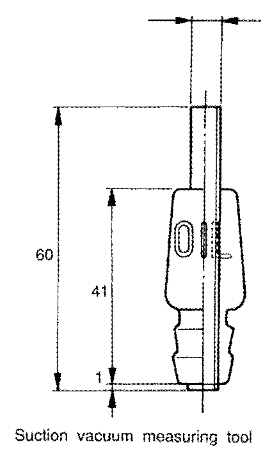

Figure 10-2

Intake air restriction should be measured with a manometer. Measure vacuum at starting agent (oil) feeding port.

Section 11

EXHAUST SYSTEM

Page

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INTRODUCTION

CAUTION

- **NEVER attempt to modify the engine's design or safety features such as defeating the engine speed limit control or the fuel injection quantity control.**
- **Failure to comply may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may affect the warranty coverage of your engine.**
- **See Yanmar Limited Warranty in Yanmar LV Operation Manual.**

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It is necessary to keep the value of the resistance to exhaust gas flow (back pressure) as low as possible. Back pressure is influenced by the following factors:

- Gas flow (volume of flow)
- Gas temperature
- Piping length
- Number of bends in the exhaust system

BACK PRESSURE

Back pressure is produced by the resistance to the flow of exhaust gas. Back pressure is greatly affected by the exhaust pipe and muffler fittings. If the back pressure is too great, volumetric efficiency is reduced and fuel consumption is increased. If the air intake efficiency worsens, the fuel/air ratio is also reduced.

The following can greatly increase exhaust back pressure.

- Pipe caliber too small
- Muffler resistance too great
- Muffler and manifold too long
- Bends in exhaust piping too sharp

Effects of Back Pressure

As stated above, the engine output can be affected if the back pressure is too great.

Loss of Horsepower

If back pressure is greater than the allowable maximum, there is a loss of horsepower equivalent to roughly 1% for each 50 mmAq (1.97 in.Aq).

Fuel Consumption

If back pressure is greater than the allowable maximum, fuel consumption increases by roughly 1% for every 50 mmAq (1.97 in.Aq).

Exhaust Gas Temperature

If back pressure is greater than the allowable maximum, exhaust gas temperature rises roughly 5% for every 50 mmAq (1.97 in.Aq).

Allowable Back Pressure

For allowable back pressure for the Yanmar LV engines, *See Application Standard on page 4-3*.

The exhaust back pressure should be measured by installing a manometer about 50 mm (1.97 in.) from the exhaust manifold outlet **(Figure 11-1)**.

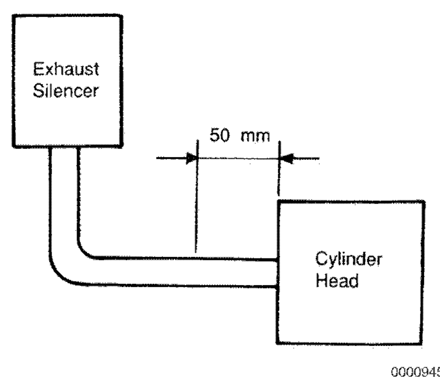

Figure 11-1

EXHAUST MUFFLER

The exhaust muffler is designed with the following factors in mind:

- Effectiveness
- Exhaust noise characteristics (particularly exhaust noise frequency)
- Configuration of muffler
- Cost

The following types of exhaust mufflers are generally recommended:

- Expansion type
- Baffle type
- Absorption type

EXHAUST PIPE WORK

The length of the exhaust gas tail pipe also affects engine output. If the exhaust muffler is fitted directly to the exhaust manifold then the tail pipe should be less than 500 mm long (19.68 in.).

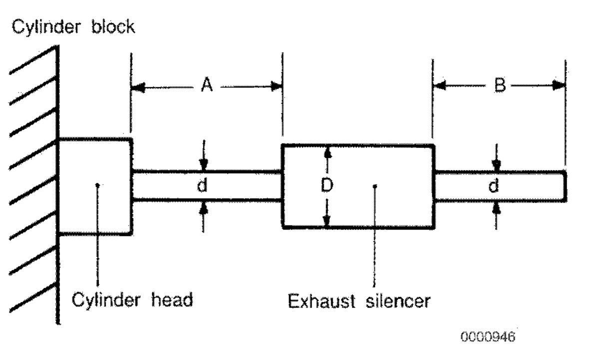

Figure 11-2

The following points regarding the exhaust piping should be considered **(Figure 11-2)**:

- Muffler volume: Capacity should be four to six times that of the volume of exhaust gas. Yanmar's standard muffler volume is more than six times the engine displacement.
- Tail pipe diameter: The diameter of the muffler should be three to five times greater than the tail pipe diameter (D/d). A greater ratio is better.
- The length of the manifold and muffler pipe should be as short as possible (A).
- When bending the pipe, be sure to make the bending radius more than 2.5 x d to reduce exhaust resistance.
- Direction of ejection of exhaust gas: If exhaust gas passes back through the air intake channel or if the fuel tank, the engine oil filter and electrical equipment are heated by the exhaust gas. Both the engine output and the functioning of each component part are affected. The direction of the tail pipe must be carefully considered.
- Exhaust system water drain: Water is one of the by-products of the combustion reaction. Draining this water must be considered along with possible infiltration of rainwater through the tail pipe, particularly if the exhaust piping is arranged vertically. For these reasons it is necessary to use a water trap on the exhaust system. The drain plug for the water trap should be set at the lowest position on the exhaust system.
- Where the engine is under a vibration system different from that of the muffler, fit the exhaust pipe between the engine and muffler to a structure capable of absorbing engine vibrations.

Section 12

FUEL SYSTEM

Page

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INTRODUCTION

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- ALWAYS fill the fuel tank only with specified diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.
- NEVER refuel with the engine running.
- ALWAYS wipe up all spills immediately.
- ALWAYS keep sparks, open flames or any other form of ignition (match, cigarette, static electric source) well away when refueling.
- NEVER overfill the fuel tank.
- Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- Place an approved container under the air bleed port when you prime the fuel system. Never use a shop rag to catch the fuel. Wipe up any spills immediately. ALWAYS close the air bleed port after you complete priming the system.
- Wear eye protection. The fuel system is under pressure and fuel could spray out when you open the air bleed port.
- If the unit has an electric fuel pump, turn the key switch to the ON position for 10 to 15 seconds, or until the fuel coming out of the air bleed port is free of bubbles, to allow the electric fuel pump to prime the system.
- If the unit has a mechanical fuel pump, operate the fuel priming pump several times until the fuel coming out of the air bleed port is free of bubbles.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- NEVER remove the fuel cap with the engine running.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- NEVER use diesel fuel as a cleaning agent.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- ALWAYS put an approved container under any opening to catch the fuel when removing any fuel system component to perform maintenance (such as changing the fuel filter).
- NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive.
- ALWAYS wipe up any spills immediately.
- ALWAYS wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- ALWAYS put diesel fuel container on the ground when transferring the diesel fuel from the pump to the container. Hold the hose nozzle firmly against the side of the container while filling it. This prevents static electricity buildup which could cause sparks and ignite fuel vapors.
- NEVER place diesel fuel or other flammable material such as oil, hay or dried grass close to the engine during engine operation or shortly after shutdown.
- Failure to comply will result in death or serious injury.

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⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- Diesel fuel is flammable and explosive under certain conditions.
- ALWAYS check for fuel leaks before you operate the engine. Replace rubberized fuel hoses every two years or every 2000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2000 hours of engine operation, whichever comes first.
- Failure to comply will result in death or serious injury.

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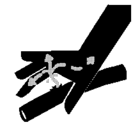
⚠ WARNING



HIGH PRESSURE HAZARD!

- Avoid skin contact with high pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high pressure fuel spray obtain prompt medical treatment.
- NEVER check for a fuel leak with your hands. ALWAYS use a piece of wood or cardboard.
- Failure to comply could result in death or serious injury.

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CAUTION

- Only use diesel fuels recommended by Yanmar for the best engine performance, to prevent engine damage and to comply with EPA / ARB warranty requirements.
- Only use clean diesel fuel.
- NEVER remove inlet fuel screen from the filler port. If removed, dirt and debris could get into the fuel system causing blockage or damage to the fuel system components.

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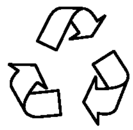
CAUTION



- **ALWAYS be environmentally responsible.**
- **Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.**
- **NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.**
- **Failure to follow these procedures may seriously harm the environment.**

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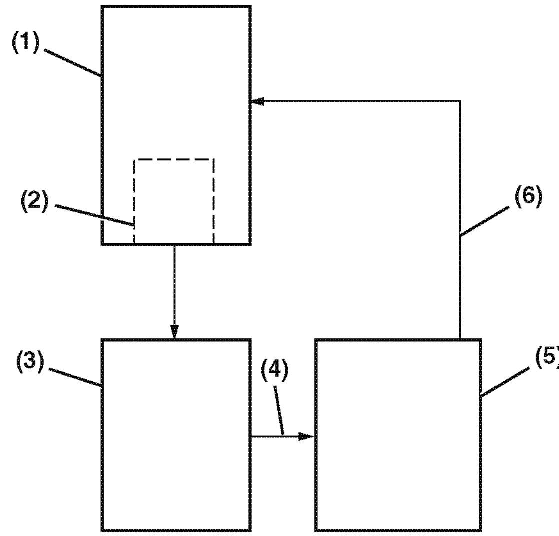

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1 – Fuel Tank
2 – Fuel Filter
3 – Injector Pump
4 – High Pressure Fuel
5 – Injector
6 – Return Line

Figure 12-1

Fuel Line

The fuel line is an essential part of a diesel engine. If the fuel line becomes damaged, engine performance will be adversely affected and the fuel injection equipment may be damaged.

DIESEL FUEL

For L-V engine use fuel as specified below or the equivalent.

		BS 2869	ASTM No. 2-D	DIN 51 601	JIS No. 2
Flash Point	°C / (°F)	Min 56/(132.8)	Min 52/(125.6)	Min 55/(131)	Min 50/(122)
90% Distillation Temperature	°C / (°F)	Max 357/(674.6)	282-338/ (539.6-640.4)	Max 357/(674.6)	Max 350/(662)
Pour Point	°C / (°F)	Summer Max 0°C/(32) Winter Max -9°C/(15.8)	—	Summer Max 0°C/(32) Winter Max -12°C/(10.4)	Max -10/(14)
Carbon Residue on 10% Residuum	%	Max 0.2	Max 0.35	Max 0.1	Max 0.10
Cetane Number		Min 50	Min 45	Min 45	Min 45 (cetane index)
Kinematic Viscosity	cSt or mm^2 / S	1.5 - 5.0 (at 40°C/(104°F))	1.9 - 4.1 (at 40°C/(104°F))	2.0 - 8.0 (at 20°C/(68°F))	Min 2.5 (at 30°C/(86°F))
Sulphur	% Wt	Max 0.3	Max 0.5	Max 0.5	Max 0.50
Ash	% Wt	Max 0.01	Max 0.01	Max 0.02	—

Use fuel of cetane number above 45. Engine performance drops when fuel temperature is high. Keep fuel temperature less than 60°C/(140°F) with atmospheric temperature 40°C/(104°F) at the entrance of fuel injection pump.

FILTRATION SYSTEM

When the fuel tank is installed locally, use the following fuel filter or equivalent:

Yanmar Part No.	:	114250-55500
Description	:	Fuel filter
Filtration Area	:	333 cm^2 (51.6 in^2)
Filtration Grain Diameter	:	5μ or less

DIESEL FUEL TANK

For the LV series engine, the fuel filter is in the fuel tank. There is a throttle in the fuel passage to the fuel injection pump so automatic air venting of the fuel passage makes restarting of the engine easy.

In order to utilize the automatic air venting mechanism effectively, use the fuel tank equipped on the engine. If you have to install a different fuel tank, pay attention to the following points and perform sufficient tests and safety checks on the air venting of the fuel piping, pre-starting performance, continuous operation, etc.

Automatic Air Venting System

When Fuel Remains in the Fuel Tank

Opening the fuel cock raises the pressure at the passage to the fuel injection pump because of spill pressure from the pump. Air bubbles escape smoothly from the air vent at the top of the filter **(Figure 12-2)**.

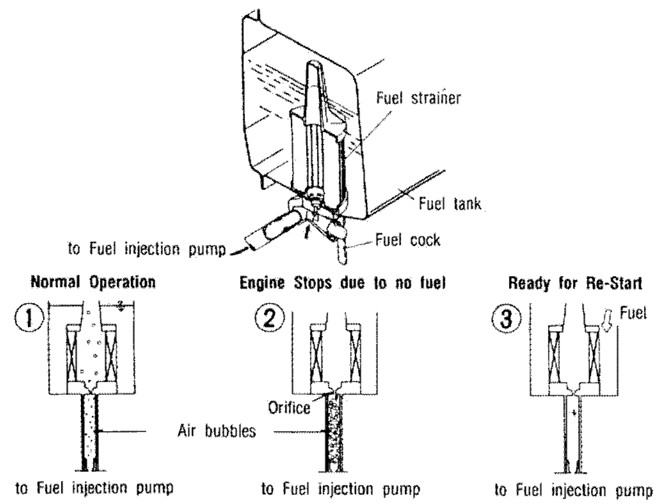

Figure 12-2

When No Fuel Is Left in the Fuel Tank

When the fuel level drops to the throttle position, pressure in the passage drops and there are many bubbles. Fuel supply is interrupted and the engine stops.

After the Engine Is Stopped

Bubbling stops. Air bubbles escape from the air vent of the fuel filter. Fuel is left in the passage to the fuel injection pump and the plunger port is filled with fuel.

Restarting of the Engine

Add fuel. The passage is filled with fuel and restarting is possible.

Optional Separate Tank

The separate fuel tank **(Figure 12-3)** supplied by Yanmar as an option for the LV series engine has an exclusive fuel filter inside.

When installing the tank and piping, consider the following points:

Location of the Fuel Tank

Be sure to install the fuel tank **(Figure 12-3)** so the fuel cock attached at the bottom of the fuel tank is higher than the fuel entrance in the fuel injection pump.

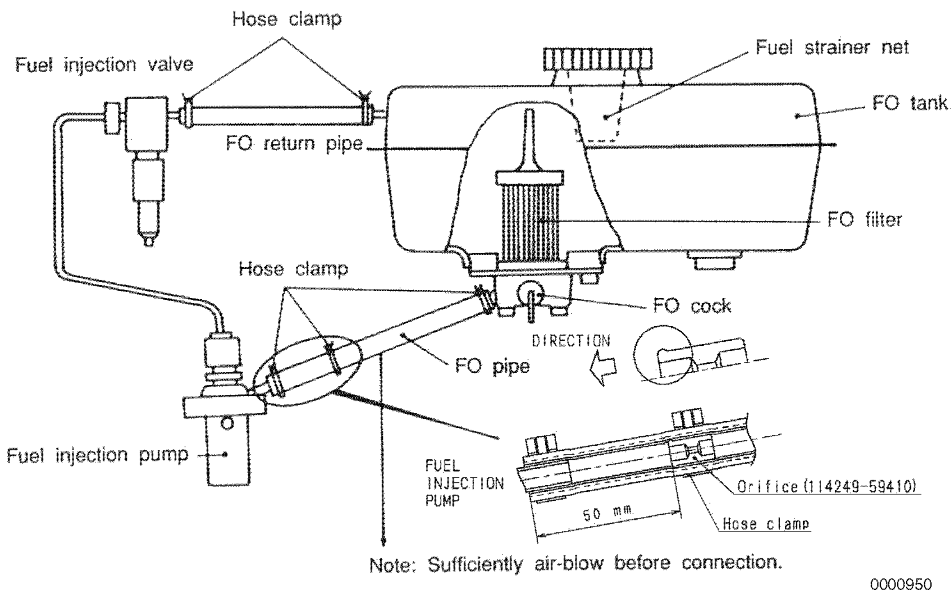

Figure 12-3

Fuel Pipe (Passage)

Use a reinforced rubber pipe with an inner diameter of 8 mm (0.314 in.).

Recommended counter-pressure: 1.0 MPa

When connecting the pipe (passage), be sure to fasten both ends securely with clamps. Connect the pipe so there is no slack.

Installation of Throttle

Install a throttle (piece) in the fuel pipe for automatic air venting.

Push it into the fuel pipe from the fuel injection pump entrance side and fasten with a clamp at a position 50 mm from the end.

Yanmar Part No.	114249-59410
Description	Orifice

Return Fuel Pipe

Use a nitrile rubber pipe with a 5 mm inner diameter.

Note: Be sure to clean the fuel pipe thoroughly when installing.

Different Fuel Tank

When arranging locally for a different fuel tank other than that supplied optionally by Yanmar, consider the following points:

Fuel Tank

Provide pre-filter of 100-150 mesh in the fuel feed port so that dirt does not enter the fuel tank.

Install the fuel intake port 10 mm (0.394 in.) above the bottom of tank so that it does not lie in the dirt that accumulates in the bottom of the tank.

Fuel Filter

Be sure to install the fuel filter optionally supplied by Yanmar or the equivalent at a position higher than fuel entrance to the fuel injection pump.

Location of Fuel Tank

Be sure to install the fuel tank higher than fuel filter.

When the fuel tank has to be installed lower than fuel filter, it is necessary to install a fuel feed pump.

Fuel Pipe (Passage)

Use a reinforced rubber pipe with an inner diameter of 8 mm (0.314 in.).

Recommended counter-pressure: 1.0 MPa

When connecting the pipe, be sure to fix both ends securely with clamps. Connect the pipe so that there is no slack.

Note: Never use PVC hoses. These are not suitable for engine fuel pipes because of thermal deformation.

Return Fuel Pipe

Use a nitrile rubber pipe with 5 mm (0.197 in.) inner diameter.

When the fuel tank is arranged locally, the automatic air venting system cannot be applied. Loosen the air venting screw attached to the fuel filter when you need to vent air.

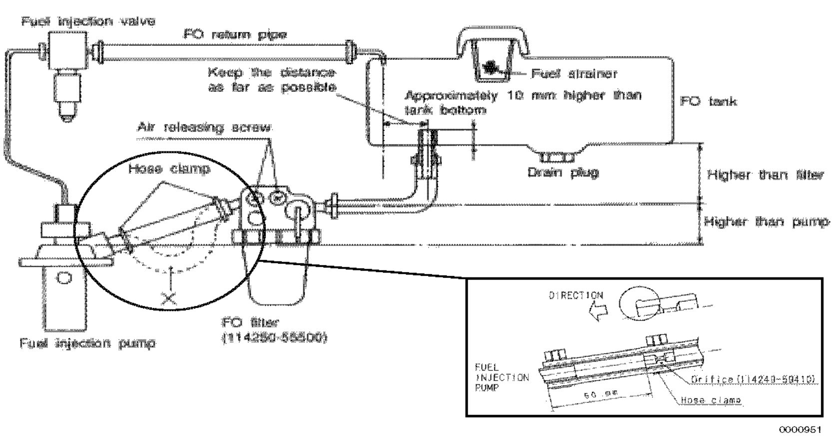

Figure 12-4

Fuel Tank Capacity

Determine a tank capacity according to the intended working hours of the driven machine. Calculate the effective capacity of the engine with “h” in **(Figure 12-5)**.

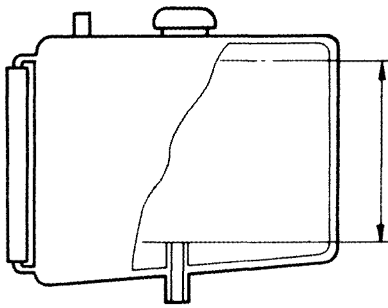

Figure 12-5

Calculation of fuel consumption:

The fuel consumption of the engine is obtained in 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/kWh
P_e	:	Engine output	kW
d	:	Specific gravity of fuel	approx. 0.83

Calculation Example:

Calculate the fuel consumption per hour when b = 270 g/kWh, P_e = 20 kW and d = 0.83.

$$Q = \frac{270 \times 20}{1000 \times 0.83}$$ = Approximately 6.5 liters per hour

FUEL FEED PUMP

When the fuel tank is to be installed lower than the fuel filter, it is necessary to install an electrical fuel feed pump.

Select fuel feed pump capacity as follows.

$Q_c > (2\text{-}3)\, Q_e$

Where:

Q_c	:	Fuel feed pump capacity	(cm^3/min)
Q_e	:	Diesel fuel capacity	(cm^3/min)
		L48V	: Q_e = 18 (cm^3/min)
		L70V	: Q_e = 24 (cm^3/min)
		L100V	: Q_e = 36 (cm^3/min)

FUEL INJECTION PUMP

The function of the fuel injection pump is to feed the quantity of fuel required by the engine at the correct pressure and set intervals via the fuel injector.

The amount of fuel injected is set by the movement of the control sleeve equipped on the fuel pump, which in turn is controlled by the governor. This changes the effective stroke of the plunger.

The effective stroke of the plunger is governed by the combination of both the top end and lower leads on the plunger and the port of the barrel.

The LV series engine is equipped with Yanmar's original Bosch-type fuel injection pump (Yanmar YPFE-M type).

Control of the fuel injection by the Bosch pump is governed by either the turning of the plunger or the change in the plunger's effective stroke.

Note: Injection timing is controlled by the adjusting shims between the pump mounting and the cylinder block.

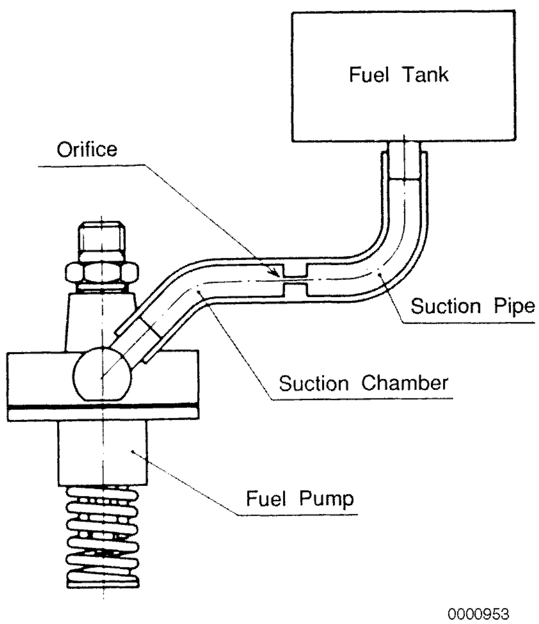

Figure 12-6

FUEL INJECTOR

When diesel fuel pumped by the fuel injection pump reaches the injection nozzle, it pushes up the nozzle valve (held down by spring) and is injected into the combustion chamber at high pressure.

The fuel is atomized by the nozzle to mix uniformly with the air in the combustion chamber. How well the fuel is mixed with high temperature air directly affects the combustion efficiency, engine performance and fuel economy.

Accordingly, the fuel injection nozzles must be kept in top condition to maintain performance and operating efficiency.

Types of Injector

The LV series engine is direct injection and equipped with a VCO-type injection nozzle.

VCO Nozzle

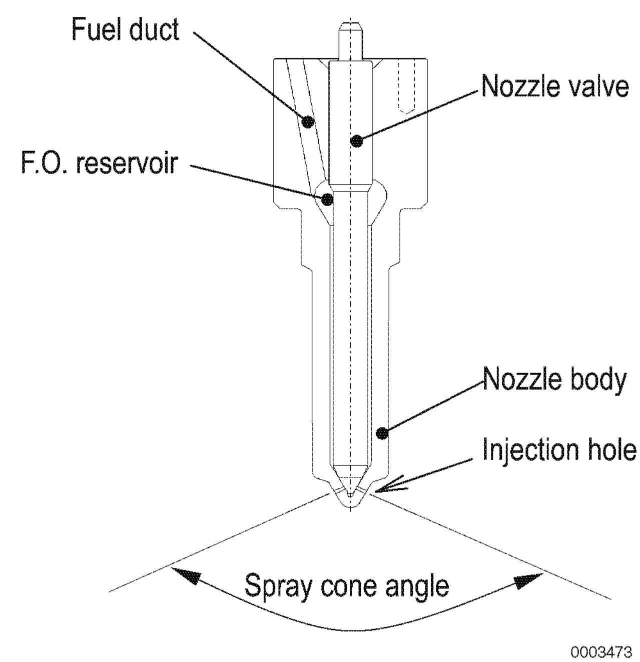

Figure 12-7

Nozzle Assembly

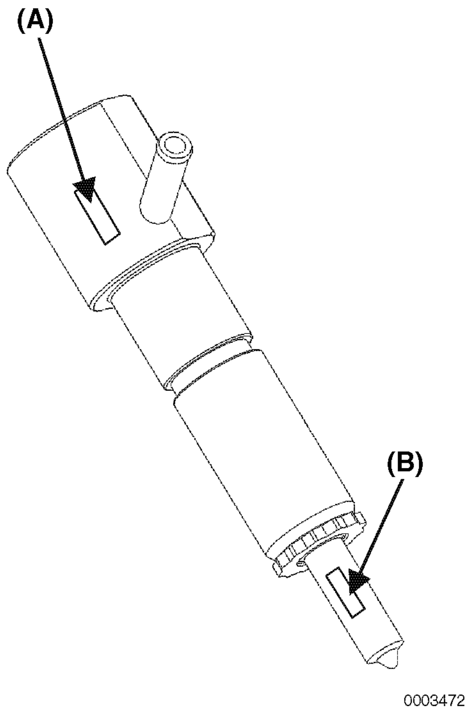

Figure 12-8

Injector Assembly

Yanmar Part No.	ID (A)
714210-53100	364
714310-53100	363
714775-53101	DD1

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Section 13

LUBRICATING SYSTEM

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INTRODUCTION

Lubrication is vital for engines. Inadequate lubrication will cause engine seizure, fires and permanent damage.

This chapter deals with the following points:

- Lubrication Circuit
- Engine Oil
- Engine Oil Pump
- Engine Oil Filter
- Oil Pan
- Breather System
- Engine Oil Pressure Control System

LUBRICATION CIRCUIT

Engines usually have a wet sump or dry sump lubrication system.

The sump system differs according to how the engine will be used. Yanmar engines use a wet sump system. This system uses an oil pan full of lubricant that is pumped throughout the engine. The engine oil circuit is shown in **(Figure 13-1)**.

Standard

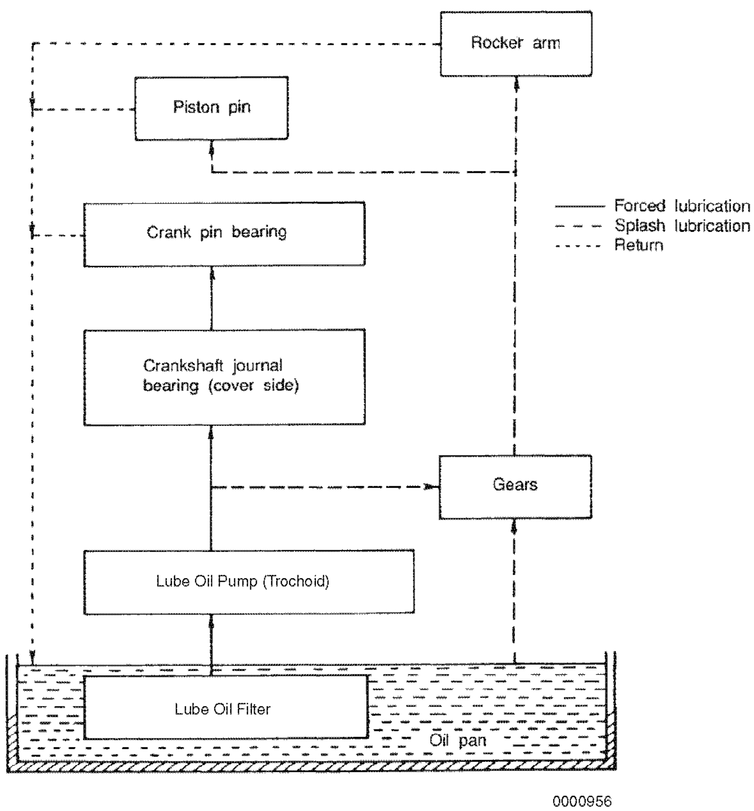

Figure 13-1

ENGINE OIL

CAUTION

- **ALWAYS use only the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.**
- **ALWAYS prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.**
- **NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.**
- **NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.**

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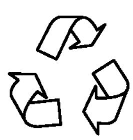
CAUTION



- **ALWAYS be environmentally responsible.**
- **Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.**
- **NEVER dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.**
- **Failure to follow these procedures may seriously harm the environment.**

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The engine oil to be used depends on the engine application and / or its operating environment. For this reason, engine oils are classified by their service requirements.

Engine manufacturers generally recommend engine oil according to the API classification and SAE viscosity grade system.

Engine Oil Specifications

Engine oil, engine oil storage containers, and engine oil filling equipment must be kept free of debris, sediments and water at all times.

Use an engine oil that meets or exceeds the following guidelines and classifications:

Service Categories

- API Service Categories CD or higher
- ACEA Service Categories E-3, E-4, and E-5
- JASO Service Category DH-1

Definitions

- API Classification (American Petroleum Institute)
- ACEA Classification (Association des Constructeurs Européens d'Automobilies)
- JASO (Japanese Automobile Standards Organization)

SAE Service Grade

The viscosity of engine oil for SAE Service Grades must be chosen according to the temperature of the engine operating environment **(Figure 13-2)**. For example, if the number of hours that the engine will be in operation is extremely low, a service grade engine oil that can cope with large variations in temperature can be used. The reference table below gives SAE Service Grades and their equivalent operating temperatures:

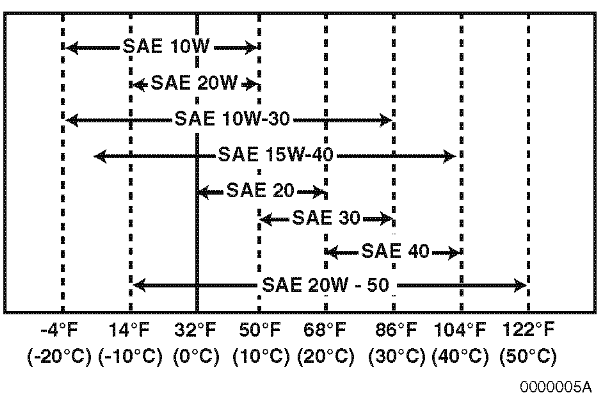

Figure 13-2

Oil Temperature

Lubricating oil temperature during running has great influence on the service life and durability of the engine. When the driven machine has been determined, be sure to carry out heat balance tests.

API Classification	Maximum Temperature of Engine Oil	Change Engine Oil	Fuel Used
CD or higher	≤ 115C (≤ 239°F)	After first 50 hours Then every 200 hours	Diesel Fuel

For a sound-insulated type of driven machine, employ a design to circulate air around the oil pan in order to prevent lubricating oil temperature rise.

Gradients

CAUTION

Make sure the engine is installed on a level surface. If a continuously running engine is installed at an angle greater than 20° (in any direction) or if an engine runs for short periods of time (less than three minutes) at an angle greater than 30° in any direction, engine oil may enter the combustion chamber causing excessive engine speed and generate white smoke. This may cause serious engine damage.

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Continuous running: Up to 20° in all directions.

Intermittent operation of up to three minutes: Up to 30° in all directions.

When installing an inboard engine, keep maximum inclination angle to less than 10° if the engine is operated and oil is supplied with PTO in a downward direction (inclination is fixed as PTO downward direction).

1. Allowable inclination angle of LV series engine when operating continuously is 20°. This angle is allowable when the engine is supplied oil at horizontal condition and made inclined at operating condition only.
2. Use the oil-feeding port at fuel injection pump side only, when the inclination is fixed at PTO downward condition. To supply oil from oil feeding port at exhaust silencer side is prohibited (install blind plug) because effective oil amount is reduced by 50% as compared to horizontal condition.
3. Never supply oil with inclination angle fixed at an angle exceeding 10° because upper limit of oil level becomes too high and could result in an increase of engine oil consumption or occurrence of overrun in extreme cases.

ENGINE OIL PUMP

The main types of lubrication system are:

- Forced lubrication
- Splash lubrication
- Grease lubrication

The forced lubricating system uses an engine oil pump. Most engine oil pumps are gear pumps or trochoid pumps.

The performance of the engine oil pump is governed by its discharge capacity, discharge pressure and head pressure.

The engine oil pump used in the LV engine is the trochoid type. The pump performance is described as follows:

	Unit	L48V	L70V	L100V
Discharge Pressure	kg / cm^2	4 - 4.5 (56.8-64 psi)		
Discharge Volume at Rated Speed	m^3 / min	3.7	4.2	4.5
Engine Oil Temperature	°C	80 (176°F)		

ENGINE OIL FILTER

Engine oil supplied to each sliding part of the engine must be clean. It is the function of the engine oil filter to keep engine oil clean.

Wear of each sliding part is hastened by impurities such as dust in the engine oil and abnormal wear or seizure could occur depending on the kind, quantity and size of impurities.

Impurities caught by the filter, accumulate in the filter and block engine oil flow. This restriction causes the delivery amount and/or delivery pressure of the engine oil pump to drop. The result is insufficient lubrication of each sliding part.

The engine oil filter must have proper filtration size and capacity and should be checked and cleaned according to the LV *Operation Manual*. The engine oil filter filtration of 60 mesh is equipped in the LV series engines.

OIL PAN

The oil pan is designed as the part of the crankcase to function at extreme angles at which the engine is expected to operate. These angles are explained in *Application Standard on page 4-3* and *Gradients* on page *13-6*.

Oil Supply and Oil Level Check

CAUTION

- **Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life.**
- **Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap / dipstick and the surrounding area before you remove the cap.**
- **NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.**
- **NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.**
- **ALWAYS check the oil level with the engine sitting on a level surface.**
- **ALWAYS keep the oil level between the upper and lower lines on the cap/dipstick.**

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Add engine oil through the oil filler port on the cylinder block. Check the oil level with the dipstick integrated into the cap of the oil fill port **(Figure 13-3)**.

		L48V	L70V	L100V
Lube Oil Capacity	Liter(s) (U.S. Quart)	0.80 (0.85)	1.10 (1.16)	1.60 (1.69)
Effective Range (High to Low)		0.25 (0.26)	0.40 (0.42)	0.60 (0.63)

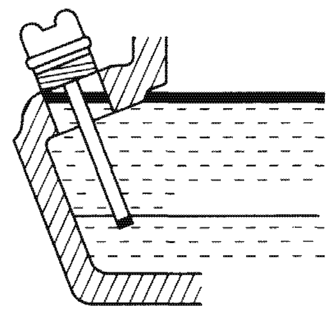

Figure 13-3

Drain Plug

The drain plug is provided on the side of the oil pan.

Bypass Oil Filter and Piping

A bypass filter is optionally available.

Type: Paper element

Filtration grain diameter: 10-15μ (Standard filter: nylon, 60 mesh)

BREATHER SYSTEM

The crankcase fills up with blowby gas and the pressure rises. The inner pressure varies due to the reciprocating motion of the piston.

The purpose of the breather system is to exhaust blowby gas and at the same time reduce pressure rise and fluctuation in the crankcase. This system reduces dirt in the lubricating oil and prevents oil seal leaks.

The LV series engine draws the blowby gas back into the cylinder together with outside air in order to prevent air pollution **(Figure 13-4)**.

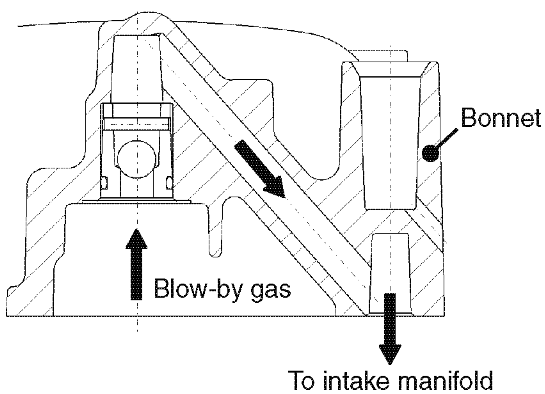

Figure 13-4

ENGINE OIL PRESSURE SWITCH

Drops in the pressure of the engine oil can cause irreparable damage to the engine. A pressure switch monitors the pressure of the engine oil. If the pressure drops below the required amount, a warning lamp and warning buzzer are switched on.

Section 14

ELECTRICAL SYSTEM

Page

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INTRODUCTION

Engines that run on gasoline are started with an electric ignition system. Diesel engines do not need an electric system for ignition. Unlike gasoline engines, the fuel is ignited by compression combustion. Other electric systems fitted to diesel engines include:

- Starter motor
- Charging generator and regulator
- Warning lamps and buzzer, headlight and turn signal lights for mobile equipment.

Yanmar engines are all electrically grounded on the NEGATIVE (-) side.

STARTER MOTOR

⚠ DANGER

FIRE AND EXPLOSION HAZARD!

- **Only use the key switch to start the engine.**
- **NEVER jump-start the engine. Sparks caused by shorting the battery to the starter terminals may cause a fire or explosion.**
- **Failure to comply will result in death or serious injury.**

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Types of Starter Motors

The main types of starter motors are:

- Armature shift
- Bendix
- Cell-dynamo
- Magnetic shift (roller clutch, multi-disc clutch).

The magnetic shift system is most commonly used. Yanmar engines use this system.

Starting Revolutions and Starter Motor Capacity

A starter motor is not only required to start an engine, but it is also required to turn the engine at a speed equivalent to that produced by the first explosion in the combustion chamber. It is necessary to have a starter motor of large capacity in case the explosions in the chamber are not successive. The lowest rotational speed (minimum cranking speed) required to start the engine will increase as the air temperature gets lower **(Figure 14-1)**.

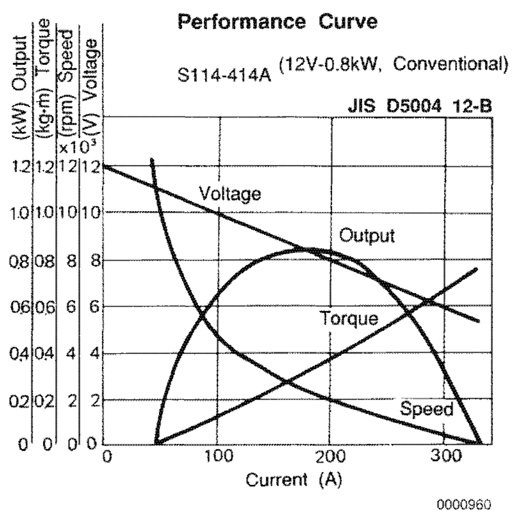

Figure 14-1

Hot Engine Restart

A warm engine should start immediately.

If the engine was shut down during normal operation, wait until engine temperatures have stabilized.

1. Remove any load to the engine and set throttle to idle speed for five minutes.
2. Shut off the engine.
3. Engage the starter motor. Never crank starter motor for more than 10 seconds in order to prevent damaging the starter motor.

Engine Model		Unit	L48V - L100V
Mfg· Code			S114 - 414A
Rated Time		S	30
Rated Output		V-kW	12 - 0.8
Direction of Rotation (Viewed From Pinion Side)			Counterclockwise
Weight		kg (lb)	3.6 (7.9)
Clutch Type			Overrunning
Engagement System			Magnetic Shift
Number of Teeth			8
Pinion Coming Out Voltage		V	8
No-Load	Terminal Voltage	V	11.5
	Current	A	60 (maximum)
	Speed	rpm	7000 (minimum)
Loaded Characteristics	Terminal Voltage	V	8
	Current	A	200
	Torque	kg·m (ft·lb) / rpm	0.32 (2.31) (min) / 1850 (min)

Construction

The starter motor is composed of three major parts **(Figure 14-2)**:

- Magnetic Switch (Solenoid) - Moves the plunger to engage and disengage the pinion gear and opens and closes the main contact (moving contact) to start and stop the starter motor.
- Motor - A direct current series motor that generates rotation.
- Pinion Gear - Transfers power from motor to ring gear. An over-running clutch is employed to prevent damage when the engine runs. The overrun clutch is composed of the roller and clutch outer, as illustrated below. The roller is held down by the roller in tapered part.

The over-run clutch is composed of the roller and clutch outer **(Figure 14-3)**. The roller is kept pressed by the roller spring. The clutch outer houses the roller in tapered part.

Conventional-Type Starter Motor (Standard Electric Starter)

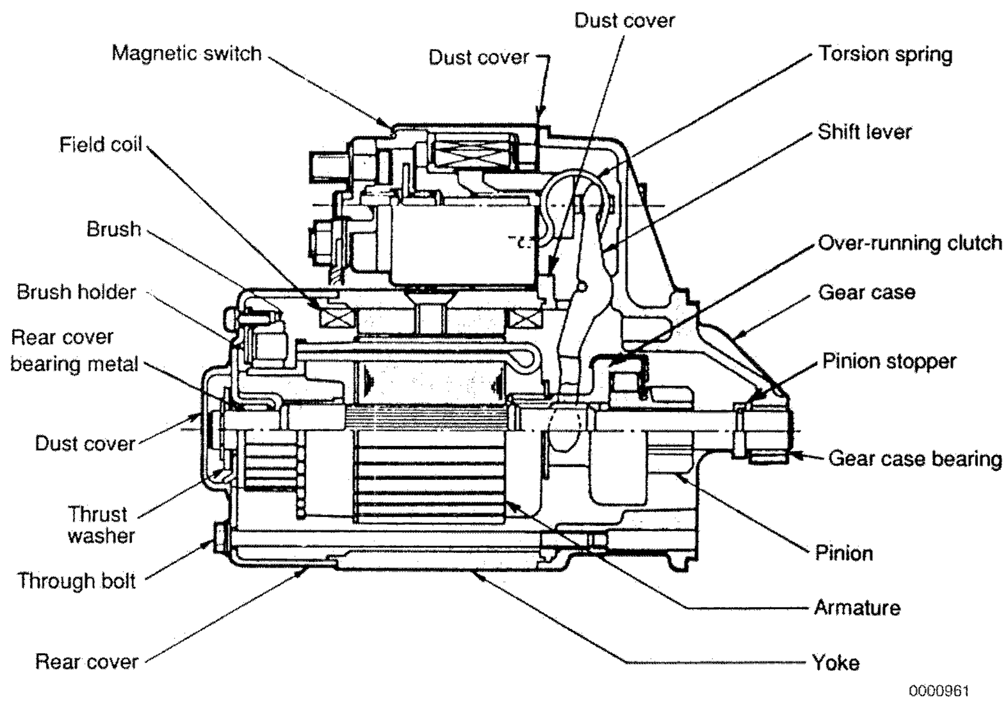

Figure 14-2

Over-Running Clutch (Conventional Type)

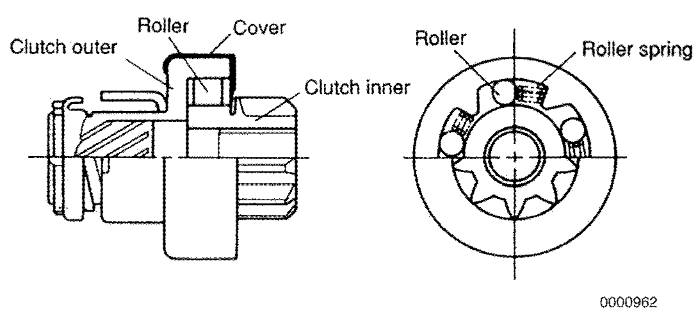

Figure 14-3

CHARGING EQUIPMENT

The engine's electrical systems uses current from the battery for their operation. However, the battery has a limited capacity and produces lower voltage as it is used until it is discharged. The battery or rectifier is recharged as the engine is running. A generator and a regulator are used to charge the battery.

Generator

The Yanmar LV series engine can be equipped with a flywheel magnet-type dynamo.

Nominal Output	For Charging	For Lighting
12V - 15A	YES	N/A

Regulator

The regulator detects the charge (voltage) of the battery and controls the voltage output of the generator to charge the battery while making reference to a set voltage.

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.

DANGER

EXPLOSION HAZARD!

- **ALWAYS keep the area around the battery well-ventilated. While the engine is running or the battery is charging, hydrogen gas is produced which can be easily ignited.**
- **ALWAYS keep sparks, open flame and any other form of ignition away while the engine is running or battery is charging.**
- **Failure to comply will result in death or serious injury.**

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⚠ DANGER

EXPLOSION HAZARD!

- **NEVER check the remaining battery charge by shorting out the terminals. This will result in a spark and may cause an explosion or fire. Use a hydrometer to check the remaining battery charge.**
- **If the electrolyte is frozen, slowly warm the battery before you recharge it.**
- **Failure to comply will result in death or serious injury.**

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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 14-9*.
- 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-l oad 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.

Starting 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.

WIRING

Correct wires must be used in the electrical system. If wire of the correct cross-sectional area is not used it can lead to overheating and burning due to excessive voltage drops and current flow in the wire. Bear in mind the following points when making a choice of wiring:

- Required current can be sustained.
- Voltage drop remains within the allowable range.
- Adequate insulation.
- Wiring is as short as possible. Sharp bends to be avoided.
- Connections must be well made with no slack or danger of shorting.
- Wiring is well protected if there is a danger that it will come into contact with oil or heat. If necessary, reroute the wiring to other areas.
- Make sure wiring is clamped well enough to withstand vibration.

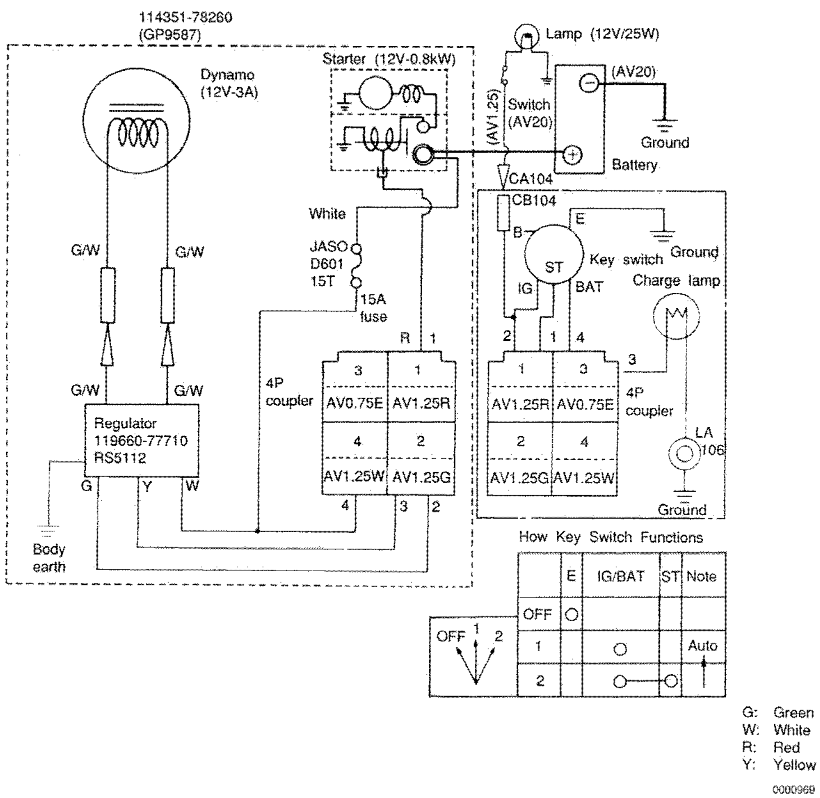

Figure 14-4

Wiring Capacity

The cable should be selected with these points in mind, also referring to the notes below.

Voltage Drop for Starter Motor Circuit

The starter motor circuits, excluding motor, relay and solenoid, should be designed so that the difference between the voltage at the storage battery terminals and the starter motor terminals (including connections) should not exceed those shown below.

Cable Type	Permissible Length (m)	Conductor Resistance of Cable (ohm/m)
AV20	≤ 1.3	0.00089
*AV30	≤ 2.3	0.00052
*AV40	≤ 2.8	0.00043

JISC 3406: Low-voltage cables for automobiles

- Calculate the cable length with the following equation:

$$\text{Cable length} = \frac{\text{Permissible cable resistance (0.0012 ohm)}}{\text{Permissible cable conductor resistance}}$$

- Use a copper or copper alloy bolt to secure the grounding wire.
- Securely connect the wiring to terminals using couplers or screws.

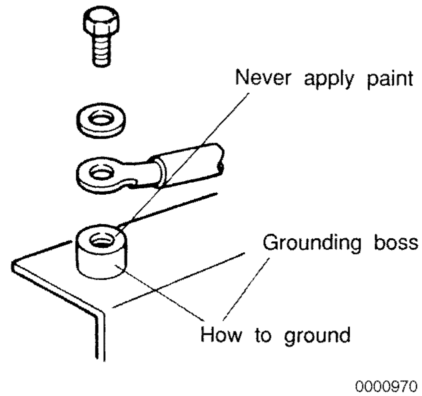

Figure 14-5

- Place the battery in a cool place easily accessible for checks for electrolyte levels and maintenance.

Battery Cables

The total resistance value of the battery cable should be less than 5/100 ohms. The resistance of the terminal should be 15/1000 ohms for each connecting lug and 0 ohms if held with screws.

Section 15

COOLING SYSTEM

Page

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INTRODUCTION

Engine cooling protects the of the cylinder, cylinder head, etc. and prevents reduced combustion and air intake efficiency. When installing the engine in a room or enclosure, a proper ventilation hole should be provided to avoid decreased performance. Usually the cooling loss of an air-cooled diesel engine is 20-25% of the energy supplied to the engine.

COOLING AIR FLOW

Required cooling air flow of the L-V series engine is approximately 1m^3 hp/min.

	L48V	L70V	L100V
Cooling Air Flow at Rated Speed ($Q_1 m^3$ / min)	5	7	10

INSTALLATION WITHIN AN ENCLOSURE

When the engine is used in an enclosure, avoid performance drop due to temperature rise in the enclosure **(Figure 15-1)**.

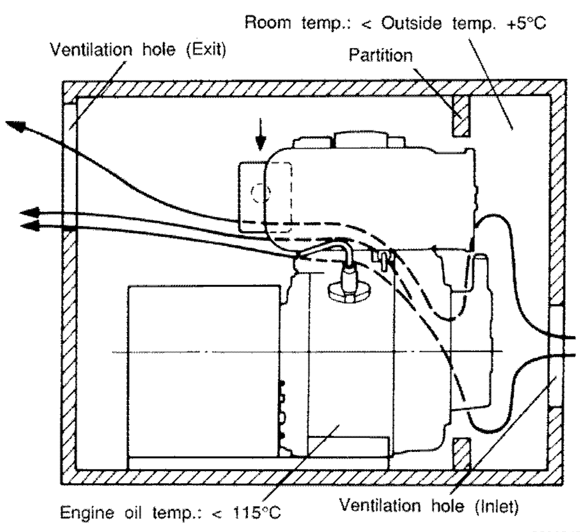

Figure 15-1

1. Consider the size of inlet and exit passage of ventilation hole. Airflow speed (v) at the passage should be less than 5 m/s.
2. Place exhaust exit outside the room.

Calculation to Determine the Passage Size

When operating the engine, the engine oil temperature should be kept at less than 115°C (239°F).

$$Q = (Q_1 + Q_2) \times K$$

$$A = \frac{Q}{V \times 60}$$

Where:

Q	: Flow to be calculated to determine the size of the ventilation hole	m^3 / min
Q_1	: Cooling air flow	m^3 / min
Q_2	: Engine air intake volume	m^3 / min
K	: Constant (=2)	
V	: Air speed at ventilation hole	less than 5 m/s
A	: Effective passage area of ventilation hole	m^2

$$Q_2 = V_c \times \frac{n}{2} \times \eta$$

V_c	: Displacement	m^3
n	: Engine speed	min^{-1}
η	: L48 = 80% L70, L100 = 70%	

AUTO-CLEAN RECOIL AND MUD PROOF RECOIL

The L-V series engine is force-cooled by a flywheel fan.

	L48V	L70V	L100V
Q_1 (m^3 / min)	5	7	10
Q_2 (m^3 / min)	0.33	0.46	0.64
Q (m^3 / min)	10.66	14.92	21.28
A (m^2)	0.036	0.045	0.070

Cooling air is drawn in at the recoil starter and exhausted from the PTO-side cylinder fin.

When the engine is used on a driven machine that scatters fragments of material such as straw, grass, or muddy water, the engine could overheat due to this material entering through the cooling air intake and sticking to the fins of the cylinder and cylinder head.

To prevent this, use the auto-clean or mud-proof recoil.

For a selection of auto-clean recoil and mud-proof recoil refer to the *Option Menu*.

Section 16

PTO SYSTEM

Page

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INTRODUCTION

Power take-off method, position and maximum allowable power take-off must all be considered carefully if damage to the engine is to be avoided.

CLASSIFICATION OF OUTPUT SHAFT AND SELECTION OF DRIVE METHOD

The LV series engine has optional crankshaft PTO specifications.

Selection should be according to the characteristics of the driven machine.

Specification	Model	PTO Shaft max. RPM	Direction of Revolution	Drive Method
Crankshaft PTO	L40V - L100V	3600 RPM	* Counter-clockwise	Direct coupled and Belt drive

* When viewed from the crankshaft end.

MOUNTING FLANGE

The Yanmar flange is constructed according to international SAE specifications.

Flange	L48V	L70V - L100V
SAE*	Equivalent to flange A	Equivalent to flange B
5 inch	-	5 inch flange*

Yanmar flanges and SAE flanges are shown in figures.

Note: SAE J609a (recommended practice) applies to engines of less the 6-BHP rating, of both 4-stroke cycle and 2-stroke cycle designs.

Note: SAE flange A is intended for use on engines of less than 3 BHP, flange B on engines of over 3 BHP.

Dimension of Mounting Flange

L48V - Mounting Flange

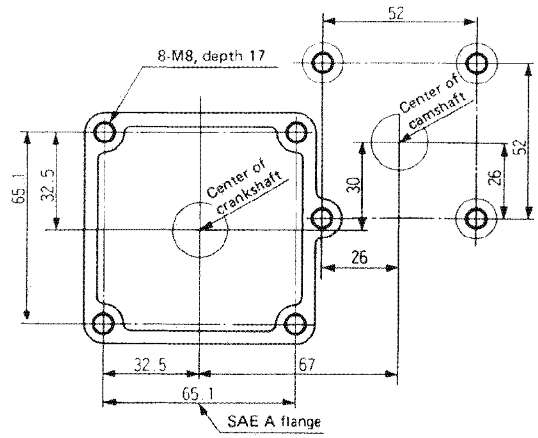

Figure 16-1

L70V - For Water Pump, Generator Set

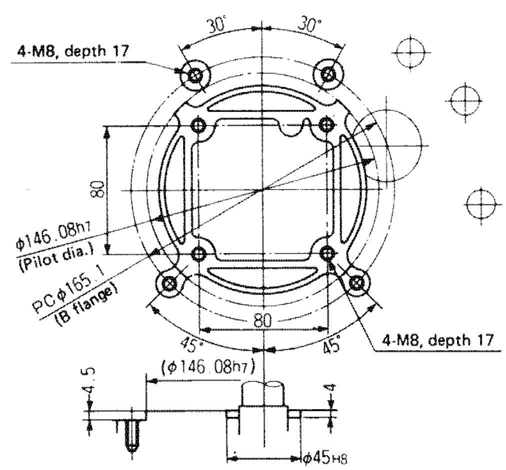

Figure 16-2

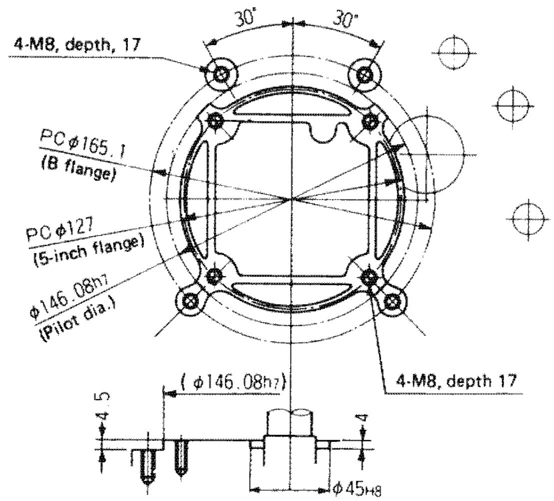

Figure 16-3

L100V

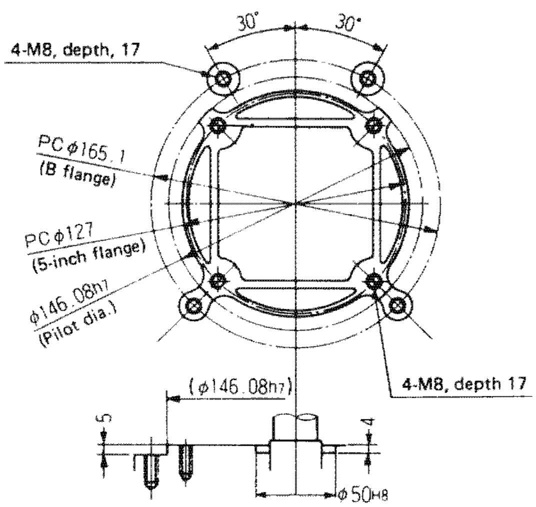

Figure 16-4

PTO SHAFT

A variety of PTO shafts are available for the LV series engine in order to match them with as wide a range of driven machines as possible. Select one from the *Option Menu* according to the use and power transmission method of the driven machines.

SAE J609a describes the “recommended practice” in which the PTO shaft for small engines is specified. The Yanmar inch-sized shaft is designed on the basis of the SAE shaft.

Installation of Driving Pulley

Careful consideration should be given to installing the driving pulley on the PTO shaft to operate any driven machine. The shape and dimension of the driving pulley end must match those of the PTO end shaft.

Cylindrical Shaft End

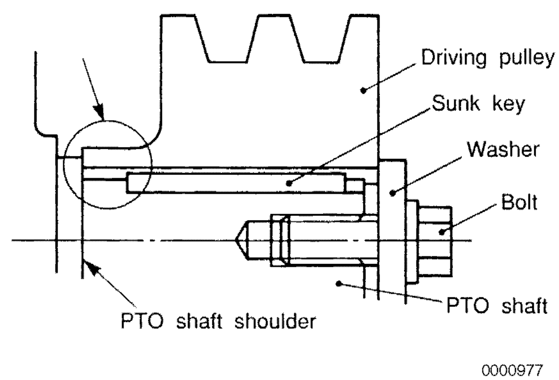

Figure 16-5

Fitting of PTO Shaft with Driving Pulley

The PTO shaft should preferably be fitted with the driving pulley, with proper interference between them. However, it is common practice to design a clearance fit under a less changing load to facilitate the assembly or replacement of the pulley.

CAUTION

Do not apply impact to the crankshaft ball bearing when installing or removing the pulley. Otherwise, the bearing will be badly damaged.

Push the pulley on the shaft until it is against the shaft shoulder. Tighten the pulley with the bolt and washer.

Notes:

1. Chamfer the edge of the bore of the pulley so it fits the corner radius of the shaft shoulder.
2. Do not tighten the pulley on the shaft in the radial direction using a bolt. Otherwise, the pulley is likely to move during operation and may damage or break the shaft.

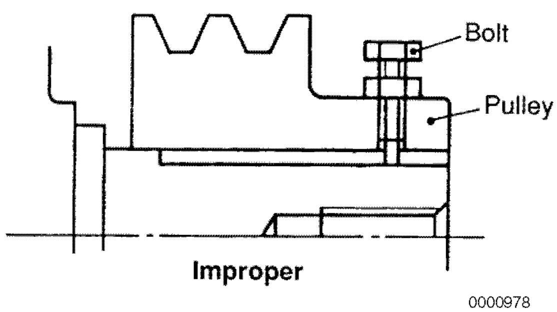

Figure 16-6

In the power transmission system, provide a clutch on the driven machine side, as required (note the clutch capacity).

$$T = i \times T_o \times k$$

Where:

T	: Clutch capacity (driven side)	kg·m
T_o	: Engine maximum torque	kg·m
i	: Reduction ratio	$\frac{\text{driven pulley diameter}}{\text{engine pulley diameter}}$
k	: Torque factor	

Taper End Shaft

The taper end shaft is used for generators, light-duty automobiles, etc. The taper end shaft should be employed with the following precautions taken:

Accuracy of Taper (Fitting)

The shaft is precision tapered and the mating bore (such as the rotor bore of a generator) should be precision-machined accordingly.

Ratio of the taper contact between crankshaft and the opponent hole: must be at least 80%

An excessively small contact area causes vibration to score the contact surface during operation leading to breakage of the PTO shaft.

Shaft Alignment (For Direct Coupling)

When a driven machine is directly coupled with the PTO shaft, the allowable misalignment of the shaft depends greatly on the strength of the shaft.

Misalignment (flection) at the shaft end of the driven machine: less than 0.30 mm (0.0118 in) of the total indicator reading, measured on the bearing hole of the driven machine housing.

Balancing of Rotor

An unbalanced rotor not only has an adverse affect on the strength of the PTO shaft but increases the vibration of the machine. Design and manufacture the rotor to ensure dynamic balance.

Rotor Shaft End

The tapered part at the rotor shaft end should preferably be longer than that of the PTO shaft to protect the tapered part of the PTO shaft against breakage (*See Pump Shaft on page 16-6*).

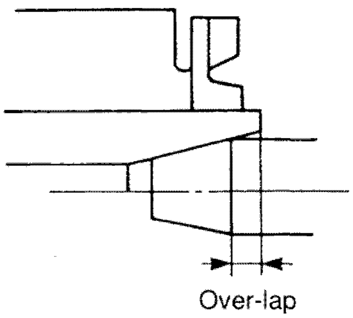

Figure 16-7

Pump Shaft

The pump shaft of the LV series engine is available in two unit sizes: the mm-size shaft and inch-size shafts.

A gap between the pump impeller and casing is called side gap, which has influence on priming performance of water and is generally adjusted to approximately 0.5 - 0.9 mm (0.020 - 0.034 in). To adjust the side gap, one or more adjusting shims are inserted between the pump impeller and PTO shaft.

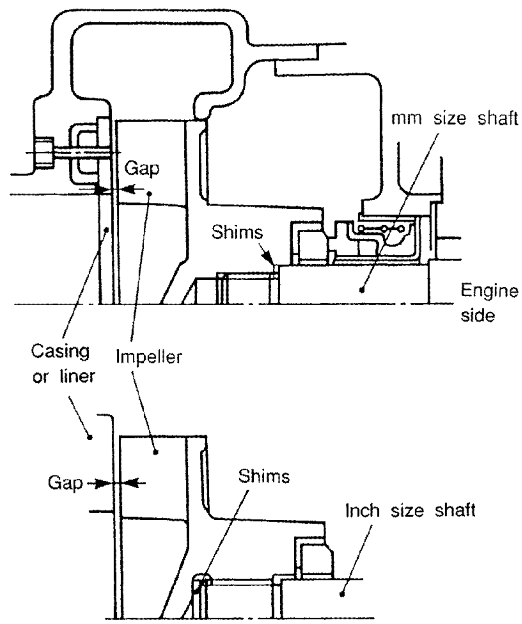

Figure 16-8

PTO Dimensions

Keyway shaft (E-D-spec)

Unit: mm (in.)

L48V

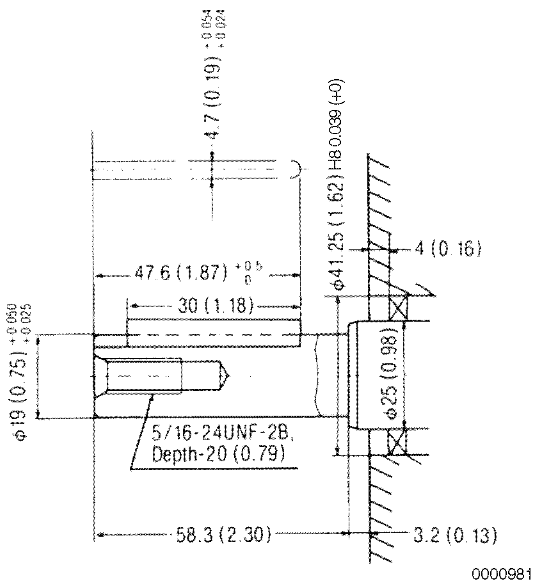

Figure 16-9

L70V

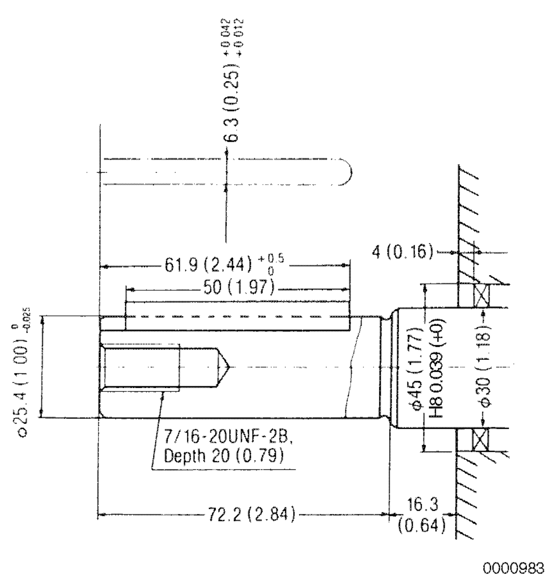

Figure 16-10

L100V

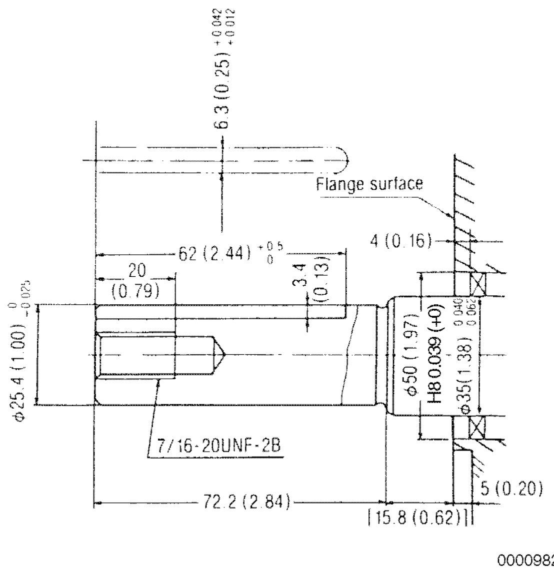

Figure 16-11

Water Pump

Thread Shaft (E-D-spec)

Unit: mm (in.)

L48V

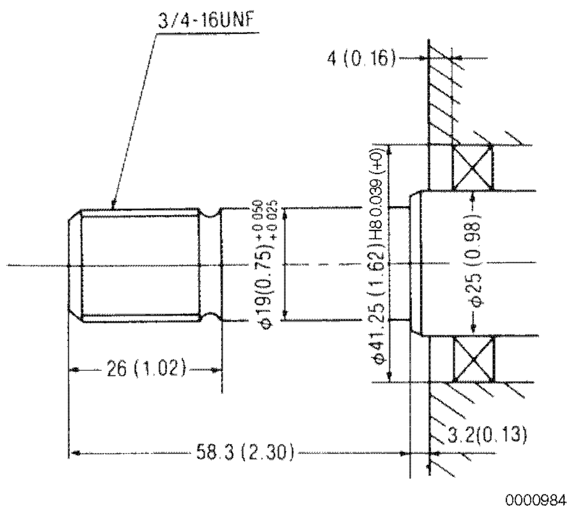

Figure 16-12

L70V

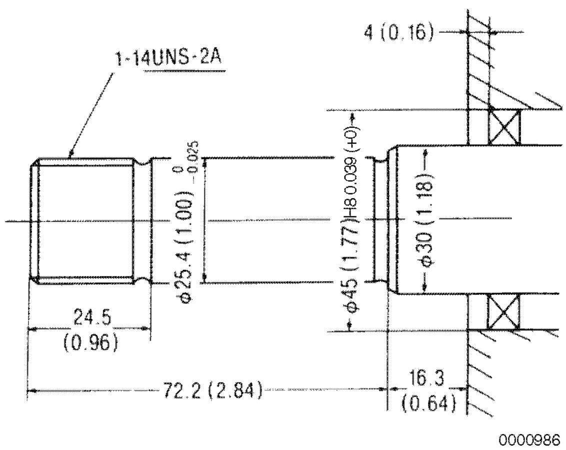

Figure 16-13

L100V

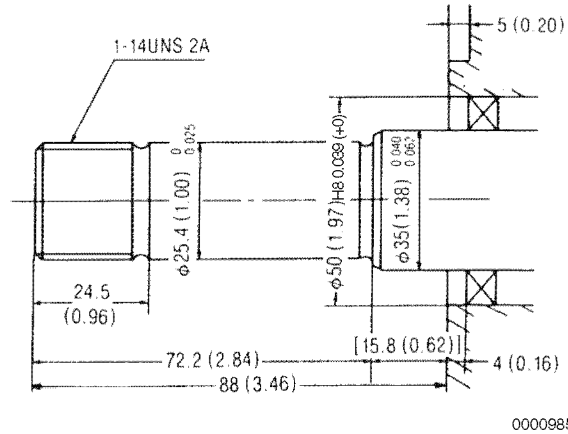

Figure 16-14

Generator

Taper Shaft (E-DG-spec)

Unit: mm (in.)

L48V

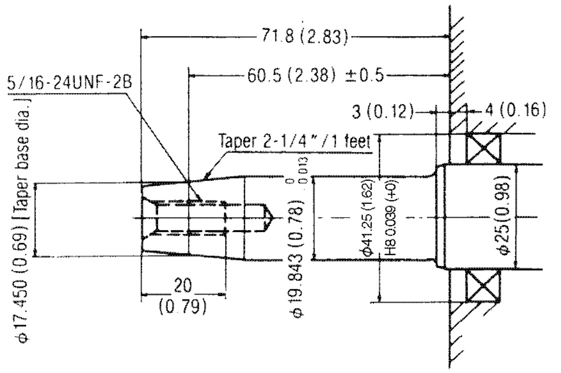

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Figure 16-15

L70V

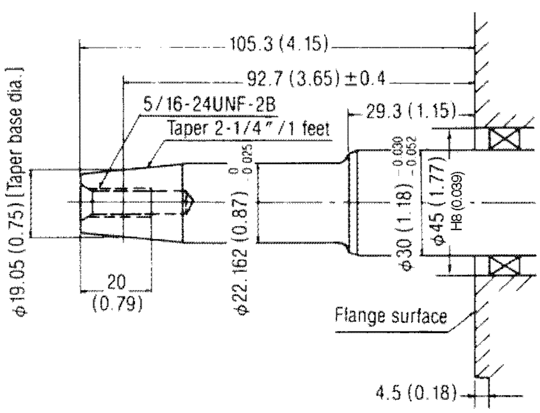

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Figure 16-16

L100V

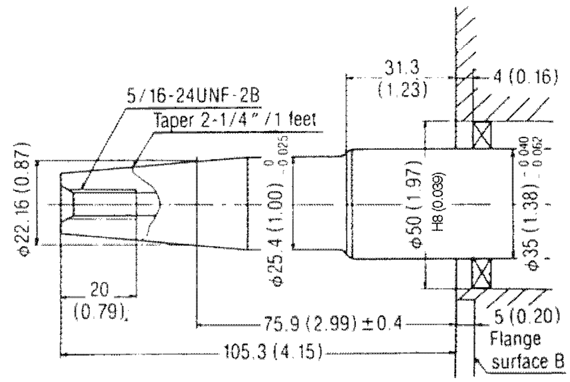

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Figure 16-17

V-PULLEY AND V-BELT

Allowable Tension of V-Belt Pulleys

The overhang distance "ℓ" **(Figure 16-18)** is the length between the PTO shaft shoulder and the center of the pulley groove at the farthest outside position.

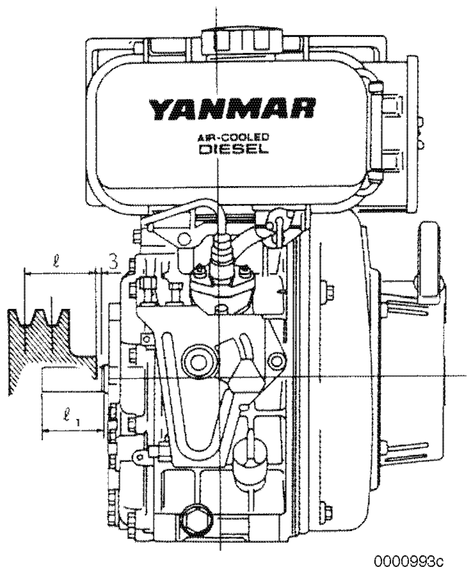

Figure 16-18

Crankshaft PTO L48V V-Belt Tension (kg)

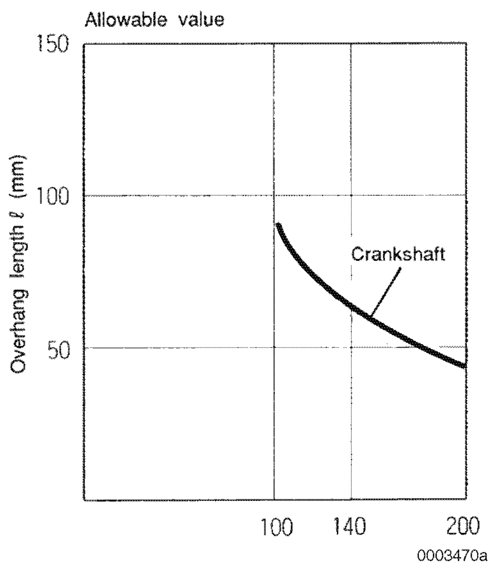

Figure 16-19

Crankshaft PTO L70-100V V-Belt Tension (kg)

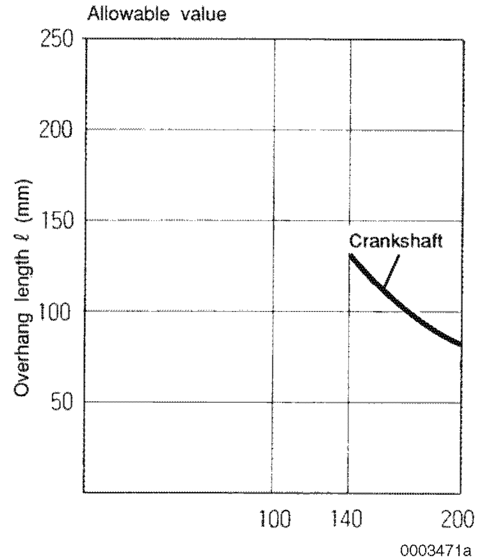

Figure 16-20

Model	ℓ Dimension mm (in.)	Load kg	Type of V-belt	No. of V-belt
L48V	≤ 60 (2.36)	≤ 140	B	2
L70V - L100V	≤ 130 (5.11)	≤ 140	B	2
L100V	≤ 80 (3.15)	≤ 210	B	3
L48V	≤ 80 (3.15)	≤ 100	A	2

Model	L48V	L70V - L100V
ℓ_1 dimension mm (in.)	50 (1.97)	60 (2.36)

Shape of V-Belt

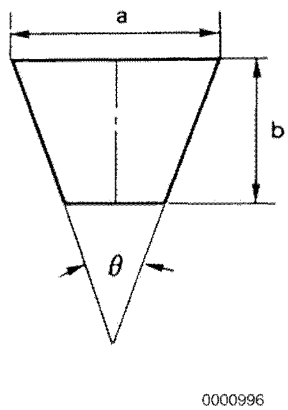

Figure 16-21

	B Belt	A Belt
a	13.3	17.3
b	8.0	9.5
θ	38	38
Belt: Low edge plain silver Low edge multiply silver		

Direction of V-Belt Tension

CAUTION

- **For camshaft PTO, the belt may be positioned in any direction.**
- **For crankshaft PTO, the belt must be positioned in a downward angle of 240°. Never position the V-belt 120° upward.**

For the V-belt drive engine, where L48V, L70V or L100V is used for V-belt drive, be sure to position the V-belt within a downward angle of 240°.

Never position the V-belt 120° upward at any time.

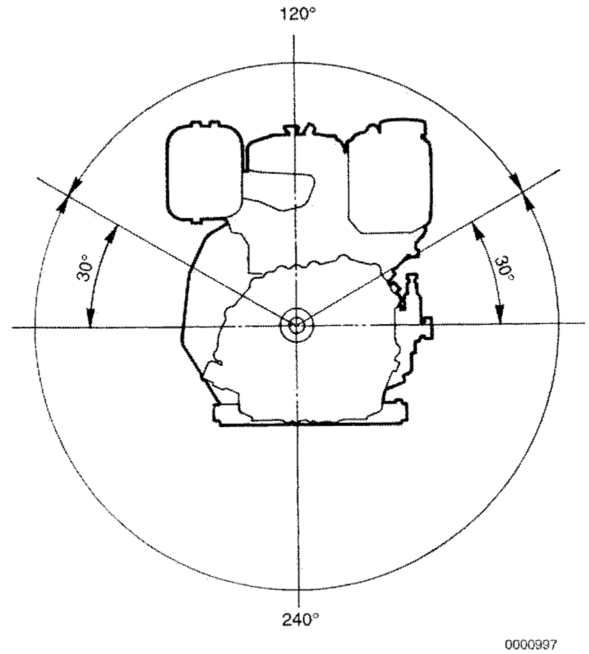

Figure 16-22

Thrust Load

The following table shows the permissible thrust load.

	L48V	L70V	L100V
Permissible Static Thrust Load (kg)	below 130	below 180	below 210

Calculation for Side Pull Load

For V-belt driven machines (side-pull method), it is essential to have the proper overhang distance and proper V-belt tension. If these are not to specification, the required horsepower will not be fully transmitted. This will not only shorten the V-belt's life, but may cause serious damage to the engine's main bearing and crankshaft.

How to Calculate the Overhang Distance

Side-Pull Load (F) Calculation

When the engine's horsepower and rpms, pulley diameter, inter-shaft distance, belt size and number of belts used are known, calculate the side-pull load (F) according to the following formula:

Initial Tension of V-Belt (T_s)

$$T_s = \left(37.5 \times \frac{(2.5 - f(\phi))HP}{f_\phi \bullet N \bullet V} + \frac{W \bullet V^2}{9.8}\right)0.9K_i$$

$$= \left(37.5 \times \frac{K' \times HP}{N \times V} + \frac{W \times V^2}{9.8}\right)0.9K_i$$

$f_{(\phi)}$: Arc of constant correction — From the following table

K' :

HP : Design horsepower — $= P \times K_s$

P : Rated horsepower of driven machines

K_s : Service factor — See table on page 16-15

N : Number of belts

V : Belt speed — m/sec

$$= \left(\frac{3.14 \times \text{Pulley dia.} \times \text{Engine rpm}}{60}\right)$$

W : Service — See table on page 16-15

K_i : Factor for initial tension — = 1-1.5

Side-Pull Load

$$F_s = 2 \times N \times T_s \times \sin\frac{\phi}{2}\ \text{kg}$$

Compensation coefficient of V-Belt Contact Angle f(ϕ)

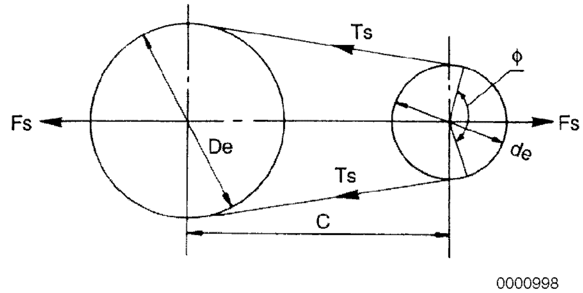

Figure 16-23

Where:

D_e : Large pulley pitch diameter
d_e : Small pulley pitch diameter
C : Center distance
ϕ : Contact angle (small pulley)

$\frac{D_e - d_e}{C}$	ϕ	$f(\phi)$	K'	$\sin\frac{\phi}{2}$
0.00	180°	1.00	1.500	1.000
0.10	174°	0.99	1.525	0.999
0.20	169°	0.97	1.577	0.995
0.30	163°	0.96	1.604	0.989
0.40	157°	0.94	1.660	0.980
0.50	151°	0.93	1.688	0.968
0.60	145°	0.91	1.747	0.954
0.70	139°	0.89	1.809	0.937
0.80	133°	0.87	1.874	0.917
0.90	127°	0.85	1.941	0.895
1.00	120°	0.82	2.049	0.866

$$K' = \frac{2.5 - f(\phi)}{f(\phi)}$$

Calculation of Overhang Distance

After calculating \the shaft load (F), determine the correct overhang distance by consulting Figures. Then find the proper pulley position so that the belt center is placed within the allowed overhang value.

Calculation Example

Engine Model: L60AE-S (1 Hr rating 6.0 Hp/1800 rpm)

Driven machine: Plunger pump P = 3.5 Hp/1000 rpm

Center distance: C = 350 mm

Design horsepower: $P \times Ks = 3.5 \times 1.5 = 5.25$
(Ks = 1.5, from Table 1)

Belt section: B (from Table 2)

Pitch dia. of small sheave: de = 115 mm (from Table 3)

Number of belt: 2

Speed ratio (i) = 1800/1000 = 1.8

Pitch dia. of large sheave: $De = de \times i = 115 \times 1.8 = 207$ mm

$$\frac{De - de}{C} = \frac{207 - 115}{350} = 0.263 \doteqdot 0.3$$

$f(\phi) = 0.96$ K' = 1.604 $\sin\frac{\phi}{2} = 0.989$

V-belt speed:

$$V = \frac{3.14 \times 0.115 \times 1800}{60} = 10.8$$

Initial tension (Max.):

$$Ts = (37.5 \times \frac{1.604 \times 5.25}{2 \times 10.8} + \frac{0.2 \times 10.8^2}{9.8}) \times 1.5 \times 0.9$$

$$= 17 \times 1.5 \times 0.9 = 23 \text{ (kg/PC)}$$

Side-pull load:

$$Fs = 2 \times N \times Ts \times \sin(\frac{\phi}{2})$$

$$= 2 \times 2 \times 23 \times 0.989$$

$$= 91$$

Overhang: $L \leq 155$ mm

How to Obtain the Proper Belt Tension

Calculation of Belt Flection Amount and Flection Load

The proper belt flection (d), and the flection load (P min – P max) per belt which satisfy the initial tensile strength of belt (Ts), as obtained in formula (1) above, are calculated as follows:

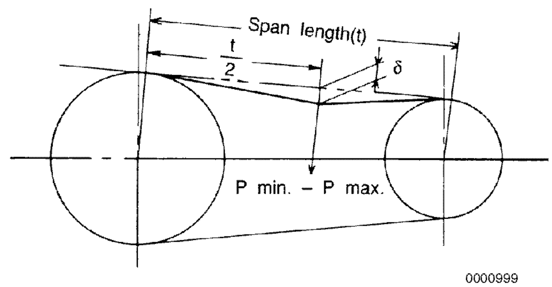

Figure 16-24

Calculation of Flection

$$\delta = 0.016 \times t$$

Where:

δ	: flection per belt	mm
t	: Span length	mm

Calculation of Deflection Force: F

Multiple V-Belt Drives:

$$F = \frac{T_s + Y}{16}$$

Single V-Belt Drives:

$$F = \frac{T_s + (t/L)Y}{16}$$

Where:

T_s	: Initial tension of belt	kg
Y	: Additional belt tension when deflection force is given	kg
t	: Span length	mm
L	: Belt length	mm

Note: For the "Y" value, refer to the belt manufacturer's instructions.

Belt Section	A	B	C	3V	5V
Y (kg)	1.5	2.0	3.0	2.0	4.0

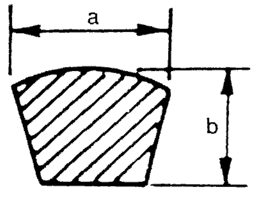

Figure 16-25

Belt Tension Adjustment

1. Measure the span length, t.
2. At the center of the span (t) apply a force (perpendicular to the span) large enough to deflect the belt 1.6 mm for 100 mm of span length.
3. Compare the applied force with the calculated values.

If the applied force is between the values of “force min” and “force max”, the belt tension should be satisfactory. A force below the value of “force min” indicates an under tensioned belt. If the force exceeds the value of “force max,” the belt is tighter than it needs to be.

However, a new belt should be tightened initially to the value of “force mean-force max” to allow for the normal decrease in tension during run-in. Be careful as over tensioning shortens the life of the belt, bearings and crankshaft of the engine. Readjustment after run-in operation is applied the value of “force mean.”

Note: For belt tension adjustments, use data provided by the belt manufacturer. When using special belts, follow the instructions of the belt maker.

Table 1: Service Factor K_S

Types of Driven Machines	Normal Service (8 - 10 hours daily)
Agitators for Liquids Blowers and Exhaust Fans Centrifugal Pumps and - Compressors Fans up to 10 HP Light Duty Conveyors	1.2
Belt Conveyors for Sand, Grain, etc. Dough Mixers Fans Over 10 HP Generators Line Shafts Laundry Machinery Machine Tools Punch Press-Shears Printing Machinery Positive Displacement Rotary - Pumps Rotating Drums and Vibrating - Screens	1.3
Brick Machinery Bucket Elevators Exciters Piston Compressors Conveyors (Drag-Pan-Screw) Hammer Mills Paper Mill Beaters Piston Pumps Positive Displacement Blowers Pulverizers Saw Mill and Woodworking Blowers Saw Mill and Woodworking Machinery Textile Machinery	1.5

Suggested Service Factor for V-belt Drives

The selection of a V-belt drive for any application should be based on the nature of the load and the type of driving unit. Service factors for different kinds of driven machines combined with different types of driving units are show in the above table. The driven machines are representative samples only. Select a machine whose load characteristics most closely approximate those of the machine being considered.

Cross-Section of Belt	Weight per 1m W (kg/m)	a (mm)	b (mm)
A	0.12	12.5	9
B	0.20	16.5	11
C	0.35	22	14
3V	0.08	9.5	8
5V	0.20	16	13.5

Pulley

Minimum Sheave Diameter of Pulley

The smaller the sheave diameter, the shorter the belt life because not only does the belt sustain excessive stress when bending, but its transmitting power is also reduced.

It is essential that the belt shall not be run on sheaves that are below the minimum recommended for each belt cross-section.

Belt Cross Section	Minimum Diameter (mm)	Recommended Diameter (mm)
A	65	95
B	115	145
C	175	225
3V	67	
5V	180	

V-Belt

Conventional V-Belt Length

$$L_n = 1.57 \times (D_e + d_e) + 2C + \frac{(D_e - d_e)^2}{4C}$$

Where:

L_n	: Pitch length of belt	mm
D_e	: Pitch diameter of large sheave	mm
d_e	: Pitch diameter of small sheave	mm
C	: Center distance	mm

Caution on Belts and Pulleys

If two or more V-belts are to be used, they should have the same length. V-belts with different lengths cause the pulley to run out during operation and shorten belt life.

Multiple Belts

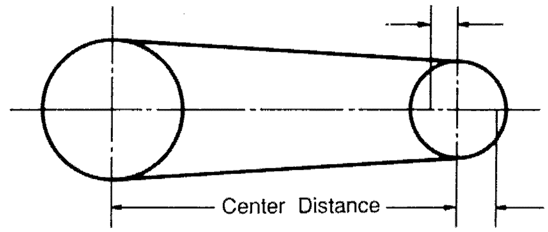

Figure 16-26

Sheave Alignment

Check the sheave alignment. Misalignment of the sheave will shorten the belt life. Keep deflection angle less than 1/3.

Belt Installation and Take-Up

After calculating the center distance, provide for adjusting the center distance as in the following table (reference) to allow for installation of the belts without damage and for maintaining proper tension throughout the life of the belt.

Standard Length Designation	Minimum Allowance Below Center Distance for Installation of Belt (mm)					Minimum Allowance Above Center Distance for Maintaining Tension (mm)		
	A	B	C	3V	5V	A, B, C	3V	5V
60 in. and less	20	25	-	-	-	25	-	-
60 - 90 in.	20	25	40	-	-	40	-	-
3V250 thru 3V475	-	-	-	13	-	-	25	-
3V500 thru 3V710	-	-	-	19	-	-	31	-
3V750 thru 3V1060	-	-	-	19	-	-	38	-
3V1120 thru 3V1250	-	-	-	19	-	-	45	-
3V1320 thru 3V1400	-	-	-	19	-	-	57	-
5V500 thru 5V710	-	-	-	-	25	-	-	32
5V750 thru 5V1060	-	-	-	-	25	-	-	39
5V1120 thru 5V1250	-	-	-	-	25	-	-	45
5V1320 thru 5V1700	-	-	-	-	25	-	-	58

Determining Type of V-belt

Select a type of V-belt to be used from **(Figure 16-27)**.

V-belt Selection Table

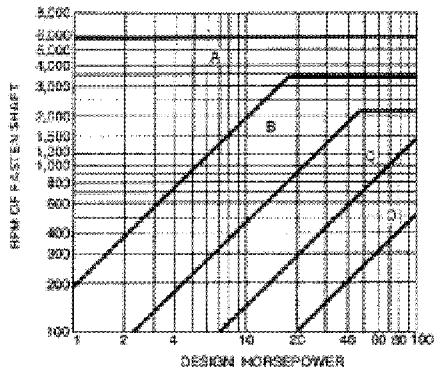

Figure 16-27

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.

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Section 17

VIBRATION AND 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

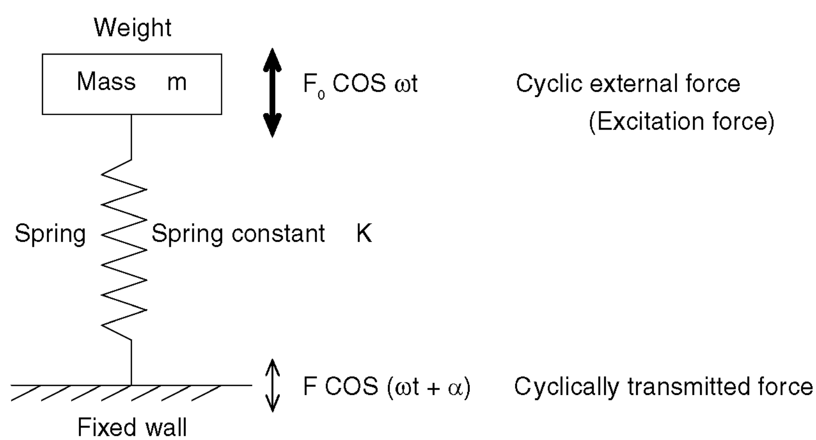


Figure 17-1

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).

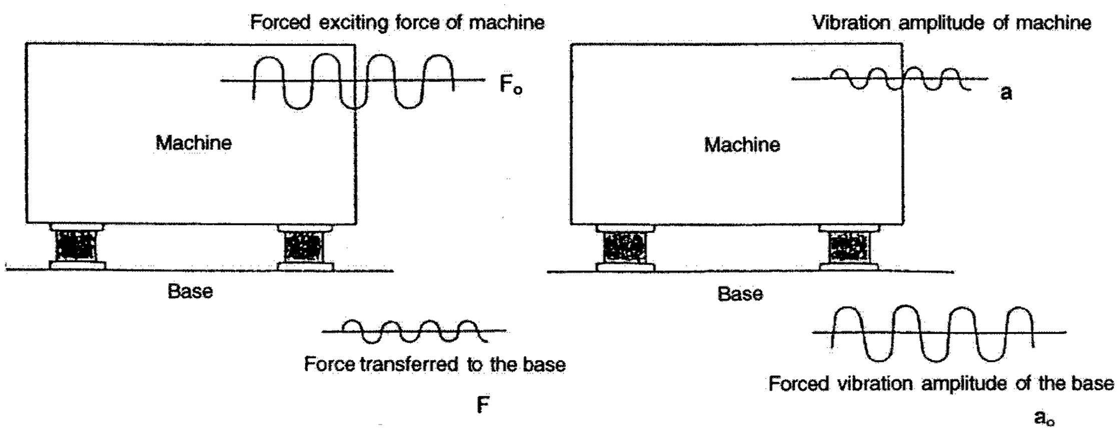


Figure 17-2

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 given by equation (1):

(1)

$$\tau = \frac{F}{F_0} = \frac{a}{a_0} = \left|\frac{1}{1-\left(\frac{n}{f}\right)^2}\right|$$

- 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 curves of vibration transmissibility in **(Figure 17-3)** are graphic representations of Equation (1).

Transmissibility Versus Frequency Ratio Curve

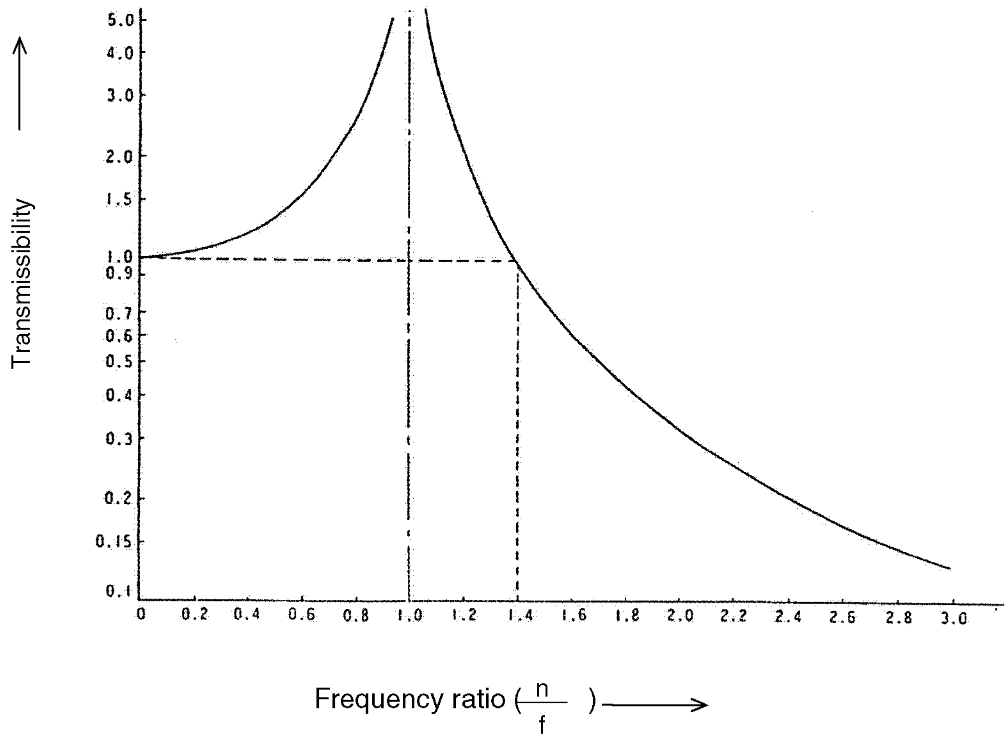


Figure 17-3

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 equation (2) using the machine weight and the spring constant of the rubber isolator.

(2)

$$f = \frac{1}{2\pi}\sqrt{\frac{K \times g}{W}}$$

f	:	Natural frequency	Hz
K	:	Dynamic spring constant of rubber isolator (1.4 times the catalog value)	kg/cm
g	:	Acceleration of gravity	980 cm/sec^2
W	:	Load on one piece of rubber isolator	

Graphic representation of equation (2).

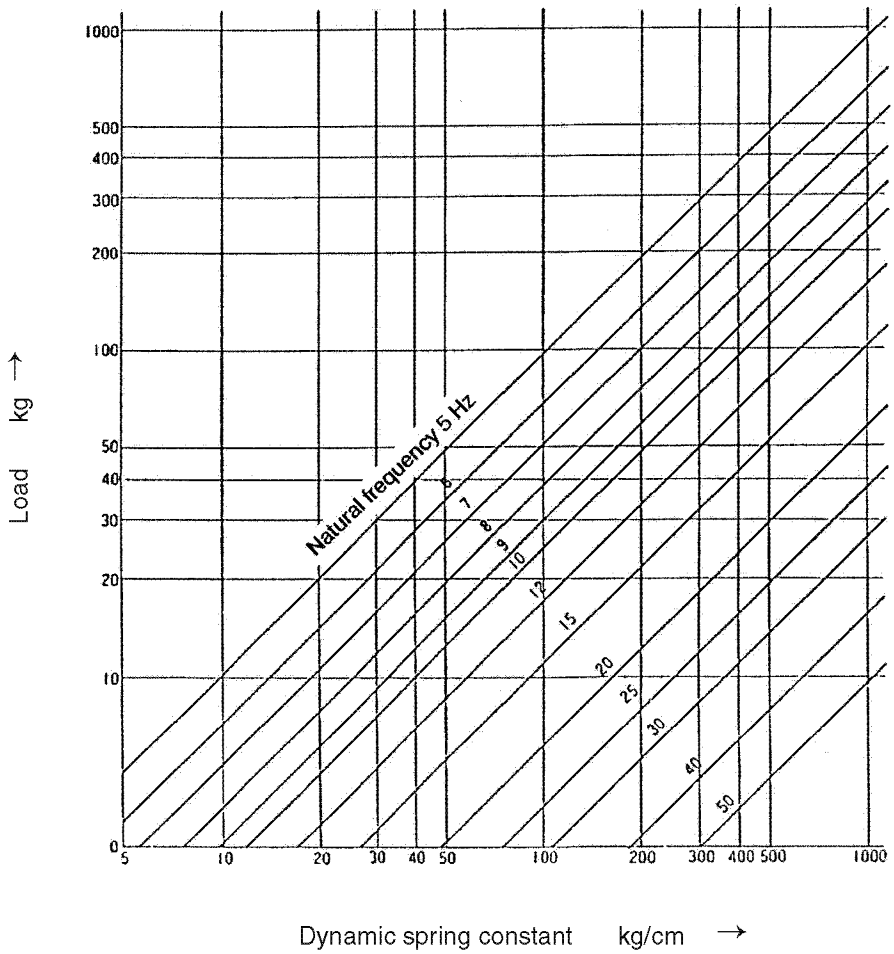


Figure 17-4

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	: Generator	
Weight	: Engine	: 47.5 kg
	Generator	: 20 kg
	Coupling and bed	: 2 kg
Engine speed	: Normal	: 3600 min^{-1} (=60 Hz)
	2nd order reciprocating excitation force (n=120 Hz)	
Support points	: 4	

Calculation of Static Spring Constant

Support Load

Static load (W) at each support point is obtained from the following equation:

W = 69.5/4 = 17.4 kg

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 = n/3 = 3600*2/3 = 2400 cpm = (40) Hz

Calculation of Dynamic Spring Constant

Because the static load per point is 385 kg, the dynamic spring constant can be calculated from:

$$f = \frac{1}{2\pi}\sqrt{\frac{K \times g}{W}}\ \text{Hz}$$

$$K = (2\pi f)^2 \times \frac{W}{g}$$

K = (2x3.14x40)^2x17.4/980=1120 kg/cm

Calculation of Static Spring Constant

From the following equation for static spring constant:

$$\text{Static spring constant} = \frac{\text{Dynamic spring constant}}{1.4}$$

Ks = K/1.4 = 1120/1.4 = 800 kg/cm

Selection of Rubber Isolator

The result of the above calculation:

Static load per support point of rubber isolator	: 17.4 kg
Static spring constant	: 800 kg/cm

Verification of Vibration Isolation Effect

Suppose that the following rubber vibration isolators are selected as closest to the above result:

Allowable load	: 329 kg
Static spring constant	: 824 kg/cm

Then,

1. Natural frequency of the support system is obtained from the following equation:

f = 1/(2π)xsqrt(1.4x824x980/329) = 9.33 Hz

2. The vibration transfer ratio is obtained from the following equation:

$$\tau = \frac{1}{\left(\frac{n}{f}\right)^2 - 1} \times 100$$

τ = 1/((120/9.33)^2-1)x100 = 0.6%

3. Vibration isolation effect

100 - τ = 100 - 0.6% = 99.4%

Therefore, the vibration isolation effect is 99.4%.

Verification by the On-board Installation Test

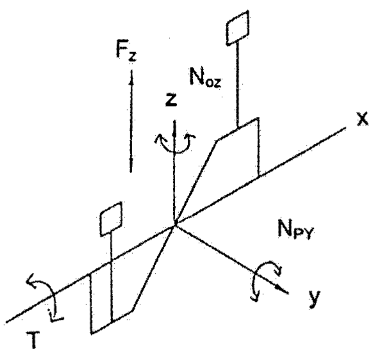
Verify that the same effect is obtained as calculated from the actual machine test. If the effect is insufficient, conduct further verification with machine tests by using rubber isolator types preceding or following the tested isolator to find the most effective rubber vibration isolator.

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 kg·m	F_z kg		N_{oz} kg·m	N_{py} kg·m	
1	1/2 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

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Section 18

REFERENCE MATERIALS

Page

INTRODUCTION

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	1.0139
0.7355	0.9863	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 x 10	1.01972×10^{5}	7.50062×10^{3}
9.80665 x 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 x 10	1

1	kgf/cm^2	=	98	kPa		1	kPa	=	0.0102	kgf/cm^2
		=	0.098	MPa		1	MPa	=	10.2	kgf/cm^2
750	mmHg	=	100	kPa		1	Pa	=	1	N/m^2

Specific Fuel and Lubrication Oil Consumption

g/kWh	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:

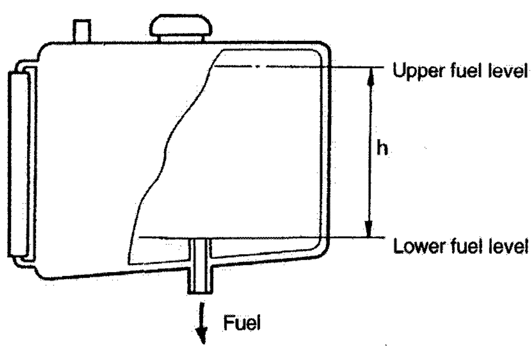
$$Q = \frac{b \times P_e}{1000 \times d}$$

Where,

Q	:	Fuel consumption by engine	ℓ/h
b	:	Specific fuel consumption	g/kWh
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/kWh, P_e = 20 kW and d = 0.83.

$$Q = \frac{270 \times 20}{1000 \times 0.83}$$ = 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/kWh
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 L100V series diesel engine, the continuous rating at 3600 rpm is 6.8 kW and the fuel consumption is 279 g/kWh. For how many hours will a fuel tank having an effective capacity of 20L last at the continuous rating?

Fuel Consumption

$$B = \frac{b \times P_e}{d} \times 10^{-3}$$

$$= \frac{279 \times 6.8}{0.83} \times 10^{-3}$$

$$= 2.29 \text{ ℓ/h}$$

B	:	Fuel consumption	ℓ/h
b	:	Specific fuel consumption	245 g/kWh
P_e	:	Rated output	13.5 kW
d	:	Specific gravity of fuel	Diesel fuel 0.83

Fuel Tank Holding Time h

$$t = \frac{V}{B}$$

$$= \frac{20}{2.29}$$

$$= 8.7 \text{ h}$$

t	:	Fuel tank holding time	h
V	:	Effective fuel capacity	20 ℓ
B	:	Fuel consumption	2.29 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/kWh
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 L100V series diesel engine, the effective volume capacity of the standard oil pan is 0.6 ℓ.

When driven at the continuous rating of 6.8 kW for 3600 rpm, for how many hours will the oil pan last? The specific engine oil consumption is 0.3 g/kWh.

Engine Oil Consumption ℓ/h

$$C = \frac{c \times P_e}{d} \times 10^{-3}$$

$$= \frac{0.3 \times 6.8}{0.89} \times 10^{-3}$$

$$= 2.29 \times 10^{-3} \text{ ℓ/h}$$

C	:	Engine oil consumption	ℓ/h
c	:	Specific engine oil consumption Reference only: Specific engine oil consumption for LV.	0.3 g/kWh
P_e	:	Continuous rating	6.8 kW
d	:	Specific gravity of engine oil	0.89

Oil Specific Consumption			
Engine	**L48V**	**L70V**	**L100V**
g/kWh	0.3	0.3	0.3

Oil Pan Holding Time

$$t = \frac{V}{C}$$

$$= \frac{0.6}{2.29 \times 10^{-3}}$$

$$= 262 \text{ h}$$

t	:	Oil pan holding time	h
V	:	Effective capacity of oil pan	0.6 ℓ
C	:	Engine oil consumption	2.29×10^{-3} ℓ/h

MEAN PISTON SPEED

Mean Piston Speed m/s

$$V_m = \frac{2S \cdot n}{60} \times 10^{-3}$$

V_m	: Mean piston speed	m/s
S	: Engine stroke	mm
n	: Engine speed	rpm

Example

According to the specification sheet for the L100V series diesel engine, the piston stroke is 75 mm. What is the mean piston speed for 3600 rpm of engine speed.

$$V_m = \frac{2(S \cdot n)}{60} \times 10^{-3}$$

$$= \frac{2 \times 75 \times 3600}{60} \times 10^{-3}$$

$$= 9.0 \text{ m/s}$$

V_m	: Mean piston speed	m/s
S	: Engine stroke	75 mm
n	: Engine speed	3600 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 L100V series diesel engine, the cylinder bore is 86 mm, and the piston stroke is 75 mm. What is the total displacement of this engine?

$$V_{st} = \frac{\pi}{4} D^2 SN \times 10^{-3}$$

$$= \frac{\pi}{4} \times 86^2 \times 75 \times 1 \times 10^{-3}$$

$$= 436 \text{ cc}^*$$

V_{st}	: Total displacement	ℓ
D	: Bore	86 mm
S	: Stroke	75 mm
N	: Number of cylinders	1
π	: Pi	3.14159

* 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 L100V series diesel engine, the rated output for a rated speed of 3600 rpm is 6.8 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 6.8 kW
n : Engine speed 3600 rpm

To obtain the rated torque in N·m:

$$T_{tq} = 9550 \times \frac{P_e}{n}$$

$$= 9550 \times \frac{6.8}{3600}$$

$$= 18 \text{ N·m}$$

To obtain the rated torque in kgf·m:

$$T_{tq} = 973.8 \times \frac{P_e}{n}$$

$$= 973.8 \times \frac{6.8}{3600}$$

$$= 1.84 \text{ kgf·m}$$

NET MEAN EFFECTIVE PRESSURE

Net Mean Effective Pressure P_{me}

Output unit Pe		Net mean effective pressure Pme kPa	Net mean effective pressure Pme 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 L100V series diesel engine, the rated output for the rated speed of 3600 rpm is 6.8 kW. What is the net mean effective pressure? The total displacement of the engine is 435cc.

Since the unit is in kW, equation (a) is used.

P_e : Output 6.8 kW
V_{st} : Total displacement 0.435 ℓ
n : Engine speed 3600 rpm

To obtain the net mean effective pressure in kPa:

$$P_{me} = \frac{120.0 \times P_e}{V_{st} \times n} \times 10^3$$

$$= \frac{120.0 \times 6.8}{0.435 \times 3600} \times 10^3$$

= 521 kPa

To obtain the net mean effective pressure in kgf/cm²:

$$P_{me} = \frac{1224 \times P_e}{V_{st} \times n}$$

$$= \frac{1224 \times 6.8}{0.435 \times 3600}$$

$= 5.31 kgf/cm^2$

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	: 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 L100V series diesel engine, the rated output for the rated speed of 3600 rpm is 6.8 kW and the specific fuel consumption is 279 g/kWh. What is the injection quantity?

Q	: Fuel injection quantity	g/1000 st
b	: Specific fuel consumption	279 g/kWh
P_e	: Output	6.8 kW
n	: Engine speed	3600 rpm
N	: Number of engine cylinders	1

$$Q = \frac{b \times P_e}{60 \times (n/2) \times N} \times 10^3$$

$$= \frac{279 \times 6.8}{60 \times (3600/2) \times 1} \times 10^3$$

$$= \frac{17.6g}{1000}$$

CYCLIC IRREGULARITY (OR COEFFICIENT OF SPEED FLUCTUATION)

Meaning of Cyclic Irregularity

$$\delta = \frac{\omega_{max} - \omega_{min}}{\omega_{mean}} \times 100$$

δ	: Cyclic irregularity	%
ωmax	: Maximum angular velocity during 1 cycle	rad/sec
ωmin	: Minimum angular velocity during 1 cycle	rad/sec
ωmean	: 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 super-charger	Sass's constant K
1	-	-	51×10^6

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 L100V series diesel engine, the rated output for a rated speed of 3600 rpm is 6.8 kW. Based on the torsional vibration materials in *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.* *on page 17-3*, the inertia weight GD^2 of a flywheel is $0.52\ kg \cdot m^2$. What is cyclic irregularity for this combination?

To find the cyclic irregularity when output is in kW:

$$\delta = \frac{1}{\dfrac{n^3 \times GD^2}{K \times P_i} \times 0.7355}$$

$$= \frac{1}{\dfrac{3600^3 \times 0.52}{51 \times 10^6 \times 8.5} \times 0.7355}$$

$$= \frac{1}{41}$$

δ	:	Cyclic irregularity	
n	:	Engine speed	3600 rpm
GD^2	:	Inertia weight of flywheel	$0.52\ kg \cdot m^2$
K	:	Sass's constant (1-cylinder)	51×10^6
P_i	:	Indicated output of engine $P_i = P_e / 0.8$	8.5 kW (6.8 / 0.8)
P_e	:	Rated output of engine	6.8 kW

THERMAL EFFICIENCY AND HEAT LOSS

Thermal Efficiency η

$$\eta = \frac{1}{b \cdot H_u} \cdot C_f \cdot 100$$

where

b : Diesel fuel specific fuel consumption unit measurement

H_u : Diesel fuel lower calorific

C_f : Conversion factor value

If specific fuel consumption is in kW:

$$\frac{\dfrac{g}{kW \cdot h}}{10300\,\dfrac{kcal}{kg}} \approx 8.6 \cdot 10^6$$

1 kW = 8.6000 x 10^2 kcal/h

If specific fuel consumption is in hp:

$$\frac{\dfrac{g}{HP \cdot h}}{10300\,\dfrac{kcal}{kg}} \approx 6.41 \cdot 10^6$$

1 hp = 6.23610 x 10^2 kcal/h

If specific fuel consumption is in PS:

$$\frac{\dfrac{g}{PS \cdot h}}{10300\,\dfrac{kcal}{kg}} \approx 6.33 \cdot 10^6$$

1 PS = 6.32529 x 10^2 kcal/h

Example

The specific fuel consumption for the L100V series diesel engine for a rated output of 6.8 kW at the rated speed of 3600 rpm is 279 g/kWh. What is the thermal efficiency?

To find thermal efficiency when specific fuel consumption is in kW:

η	:	Thermal efficiency	%
P_e	:	Engine output	6.8 kW
H_u	:	Lower calorific value of diesel fuel	10300 kcal/kg
b	:	Specific fuel consumption	279 g/kWh

$$\eta = \frac{83.50}{b} \times 10^2$$

$$= \frac{83.50}{279} \times 10^2$$

$$= 0.299 \times 10^2$$

$$= 30\,\%$$

Exhaust Loss ϕ_{ex}

ϕ_{ex}	:	Exhaust loss	%
V_{st}	:	Total displacement	ℓ
n	:	Engine speed	rpm
ηt	:	Intake efficiency	if unknown, use 0.85
C_p	:	Specific heat at constant pressure	kcal/Nm3° C
t_{ex}	:	Exhaust temperature	°C

$$\phi_{ex} = \frac{\{n_t \times V_{st} \times 10^{-3} \times n/(2 \times 60)\} \times c \times t_{ex}}{H_u \times b \times 10^{-3} \times P_e/3600} \times 10^2$$

Exhaust Temperature t_{ex} °C	Mean specific heat c kcal/Nm3°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 L100V series diesel engine for the rated output of 6.8 kW at the rated speed of 3600 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	0.435 ℓ
n	: Engine speed	3600 rpm
η_t	: Intake efficiency	0.85
c_p	: Specific heat at constant pressure	0.321 kcal/Nm³°C
t_{ex}	: Exhaust temperature	500°C
b	: Specific fuel consumption	279 g/kWh
P_e	: Engine output	6.8 kW

$$\phi_{ex} = 2.9126 \times 10^{-3} \times \frac{V_{st} \times n \times \eta_t \times c_p \times t_{ex}}{b \times P_e} \times 10^2$$

$$= 2.9126 \times 10^{-3} \times \frac{0.435 \times 3600 \times 0.85 \times 0.321 \times 500}{279 \times 6.8} \times 10^2$$

$$= 0.328 \times 10^2$$

$$= 32.8\ \%$$

GENERATOR

Relation of Capacity (Output), Voltage and Current of AC Generator

Single Phase AC Generator

$$C = E \times I \times 10^{-3}$$

C	: Capacity	kVA
O	: Output	kW
E	: Voltage	V
I	: Current	A
pf	: Power factor	1.0 for a single-phase AC generator

$$O = C \times pf$$

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	Check generator application data plate.

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)

1 kW = 1.0000 x 10^3 x N·m/s = 102.0 kgf·m/

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

P	:	Discharge pressure	kPa (kgf/cm^2)
Q_t	:	Theoretical discharge	ℓ/min

		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	$\frac{P \times Q_t}{60 \times 0.7355} \times 10^{-3}$	$\frac{P \times Q_t}{6 \times 75}$

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 hv	Overall efficiency hp
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/cm²
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/cm²)
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	$\frac{\gamma \times Q \times H}{60 \times 102.0 \times \eta_m}$
	hp	$\frac{\gamma \times Q \times H}{60 \times 76.04 \times \eta_m}$
	PS	$\frac{\gamma \times Q \times H}{60 \times 75 \times \eta_m}$

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

Under normal atmospheric conditions.

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

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.

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

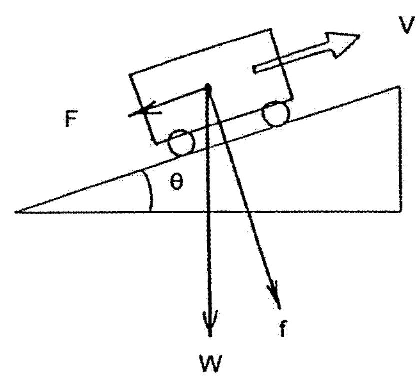
The required horsepower for a driven machine having gross vehicle weight W to climb a grade of incline angle θ at running speed V can be obtained from the calculation formula given in the table below:

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 x 10^3 N·m/s = 102.0 kgf·m/s
1 hp = 0.7457 x 10^3 N·m/s = 76.04 kgf·m/s
1 PS = 0.7355 x 10^3 N·m/s = 75 kgf·m/s



	Gross Vehicle Weight W	
	N	kgf
kW	$V \times W\sin\theta \times 10^{-3}$	$\frac{V \times W\sin\theta}{102.0}$
hp	$\frac{V \times W\sin\theta}{0.7457} \times 10^{-3}$	$\frac{V \times W\sin\theta}{76.04}$
PS	$\frac{V \times W\sin\theta}{0.7355} \times 10^{-3}$	$\frac{V \times W\sin\theta}{75}$

Allowable Hill Climbing Angle

A driven machine that has an engine that meets the required hill climbing horsepower does not necessarily climb the hill. Another point that must be considered is the limit of climbing angle generated from the coefficient of friction between the traveling device or from the characteristics of the road surface itself.

In other words, it is meaningless to consider the hill climbing horsepower beyond the limit of slipping between the traveling device and the road surface or in case of collapse of the road surface itself.

The driven machine manufacturer's data are needed for the dynamic coefficient of friction between the traveling device and various road surface conditions and the characteristics of the road surface material itself. Supposing that the coefficient is, the allowable hill climbing angle will be as follows:

$$F < \mu \times f$$
$$W \sin\theta < \mu \times W \cos\theta$$
$$\tan\theta < \mu$$
$$\theta < \tan^{-1}\mu$$

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.

MESH NUMBER AND SIZE OF

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

$°C = \frac{5}{9} \times (°F - 32)$ $°F = \left(\frac{9}{5} \times °C\right) + 32$

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

Centigrade °C	Fahrenheit °F	Centigrade °C	Fahrenheit °F	Centigrade °C	Fahrenheit °F
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

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Section 19

CONVERSION FACTORS

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CONVERSION FACTOR CHART

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)

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 Old Metric	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	0.0981		
nm^3/hr	nm^3/min	0.0176		

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