

SERVICE MANUAL

INDUSTRIAL ENGINES

3TNM68

3TNM72

**California
Proposition 65 Warning**

Diesel engine exhaust and some of its constituents are known to the state of California to cause cancer, birth defects, and other reproductive harm.

**California
Proposition 65 Warning**

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

This Service 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 without notice. Yanmar and **YANMAR** are registered trademarks of Yanmar Co., Ltd. in Japan, the United States and/or other countries.

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Section 1

INTRODUCTION

This *Service Manual* describes the service procedures for the TNM series indirect injection engines. These engines are certified by the U.S. EPA and California ARB.

Please use this manual for accurate, quick and safe servicing of the engine. Since the directions in this manual are for a typical engine, some specifications and components may be different from your engine. Refer to the documentation supplied by the optional equipment manufacturer for specific service instructions.

Yanmar products are continuously undergoing improvement. This *Service Manual* might not address possible field modifications to the equipment. Contact an authorized Yanmar Industrial engine dealer or distributor for answers to any questions relating to field modifications.

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Section 2

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YANMAR LIMITED WARRANTY

What is Covered by this Warranty?

Yanmar warrants to the original retail purchaser that a new Yanmar TNM Series Industrial Engine will be free from defects in material and/or workmanship for the duration of the warranty period.

Note: Yanmar engines may be equipped with external components including, but not limited to: wiring harnesses, electrical devices, control panels, radiators, air filters, fuel filters, and/or exhaust systems that are supplied and/or installed by manufacturers other than Yanmar. For warranty information on such external components, please contact the machine or component manufacturer directly or see your authorized Yanmar dealer or distributor.

THIS WARRANTY IS PROVIDED IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED. YANMAR SPECIFICALLY DISCLAIMS ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, except where such disclaimer is prohibited by law. IF SUCH DISCLAIMER IS PROHIBITED BY LAW, THEN IMPLIED WARRANTIES SHALL BE LIMITED IN DURATION TO THE LIFE OF THE EXPRESSED WARRANTY.

How Long is the Warranty Period?

The Yanmar standard limited warranty period runs for a period of **twenty-four (24) months or two thousand (2000) engine operation hours**, whichever occurs first. An extended limited warranty of thirty-six (36) months or three thousand (3000) engine operating hours, whichever occurs first, is provided for these specific parts only: the cylinder block, cylinder head, crankshaft forging, connecting rods, flywheel, flywheel housing, camshaft, timing gear, and gear case. The Warranty Period for both the standard limited warranty and the extended limited warranty (by duration or operation hours) begins on the date of delivery to the original retail purchaser and is valid only until the applicable warranted duration has passed or the operation hours are exceeded, whichever comes first.

What the Engine Owner Must Do:

If you believe your Yanmar engine has experienced a failure due to a defect in material and/or workmanship, you must contact an authorized Yanmar Industrial engine dealer or distributor within thirty (30) days of discovering the failure. You must provide proof of ownership of the engine, proof of the date of the engine purchase and delivery, and documentation of the engine operation hours. Acceptable forms of proof of delivery date include, but are not limited to: the original warranty registration or sales receipts or other documents maintained in the ordinary course of business by Yanmar dealers and/or distributors, indicating the date of delivery of the Yanmar product to the original retail purchaser. This information is necessary to establish whether the Yanmar product is still within the warranty period. Thus, Yanmar strongly recommends you register your engine as soon as possible after purchase in order to facilitate any future warranty matters.

You are responsible for the transportation of the engine to and from the repair location as designated by Yanmar.

*Yanmar Limited Warranty - Continued***To Locate an Authorized Yanmar Industrial Engine Dealer or Distributor:**

You can locate your nearest authorized Yanmar Industrial engine dealer or distributor by visiting the Yanmar Corp., LTD. website at:

<http://www.yanmar.co.jp> (The Japanese language page will be displayed.) For English language “click” on “English Page.”)

- “Click” on “Network” in the website heading to view the “Yanmar Worldwide Network.”
- Choose and “Click” on the desired product group.
- “Click” on the Icon closest to your region.
- “Click” on the desired country or Associate company to locate your nearest authorized Yanmar Industrial engine dealer or distributor.
- You may also contact Yanmar by clicking on “Inquiry” in the website heading and typing in your question or comment.

What Yanmar Will Do:

Yanmar warrants to the original retail purchaser of a new Yanmar engine that Yanmar will make such repairs and/or replacements at Yanmar’s option, of any parts(s) of the Yanmar product covered by this Warranty found to be defective in material and/or workmanship. Such repairs and/or replacements will be made at a location designated by Yanmar at no cost to the purchaser for parts or labor.

What is Not Covered by this Warranty?

This Warranty does not cover parts affected by or damaged by any reason other than defective materials or workmanship including, but not limited to, accident, misuse, abuse, “Acts of God”, neglect, improper installation, improper maintenance, improper storage, the use of unsuitable attachments or parts, the use of contaminated fuels, the use of fuels, oils, lubricants, or fluids other than those recommended in your Yanmar *Operation Manual*, unauthorized alterations or modifications, ordinary wear and tear, and rust or corrosion. This Warranty does not cover the cost of parts and/or labor required to perform normal/scheduled maintenance on your Yanmar engine. This Warranty does not cover consumable parts such as, but not limited to, filters, belts, hoses, fuel injector nozzles, lubricants and cleaning fluids. This warranty does not cover the cost of shipping the product to or from the warranty repair facility.

*Yanmar Limited Warranty - Continued***Warranty Limitations:**

The foregoing is Yanmar's only obligation to you and your exclusive remedy for breach of warranty. Failure to follow the requirements for submitting a claim under this Warranty may result in a waiver of all claims for damages and other relief. **In no event shall Yanmar or any authorized industrial engine dealer or distributor be liable for incidental, special or consequential damages.** Such consequential damages may include, but not be limited to, loss of revenue, loan payments, cost of rental of substitute equipment, insurance coverage, storage, lodging, transportation, fuel, mileage, and telephone costs. The limitations in this Warranty apply regardless of whether your claims are based on breach of contract, tort (including negligence and strict liability) or any other theory. Any action arising hereunder must be brought within one (1) year after the cause of action accrues or it shall be barred. Some states and countries do not allow certain limitations on warranties or for breach of warranties. **This Warranty gives you specific legal rights, and you may also have other rights which vary from state to state and country to country.** Limitations set forth in this paragraph shall not apply to the extent that they are prohibited by law.

Warranty Modifications:

Except as modified in writing and signed by the parties, this Warranty is and shall remain the complete and exclusive agreement between the parties with respect to warranties, superseding all prior agreements, written and oral, and all other communications between the parties relating to warranties. **No person or entity is authorized to give any other warranty or to assume any other obligation on behalf of Yanmar, either orally or in writing.**

Questions:

If you have any questions or concerns regarding this Warranty, please call or write to the nearest authorized Yanmar Industrial engine dealer/distributor or other authorized facility.

Retail Purchaser Registration

It is very important for the original retail purchaser to register the Yanmar product. Registration enables Yanmar to provide the best support for your Yanmar product.

As soon as possible after the purchase of your engine, Yanmar highly recommends that you use the following website to register your purchase:

<http://www.yanmar.co.jp>

If it is not possible to access the website, please contact the nearest Yanmar dealer or distributor.

EMISSION SYSTEM WARRANTY

YANMAR CO., LTD. LIMITED EMISSION CONTROL SYSTEM WARRANTY - USA ONLY

Your Warranty Rights and Obligations:

California

The California Air Resources Board (CARB), the Environmental Protection Agency (EPA) and Yanmar Co., Ltd. hereafter referred to as Yanmar, are pleased to explain the **emission control system warranty** on your industrial compression-ignition engine. In California, model year 2000 or later off-road compression-ignition engines must be designed, built and equipped to meet the State's stringent anti-smog standards. In all states, 1998 and later non-road compression-ignition engines must be designed, built and equipped to meet the United States EPA emissions standards. Yanmar warrants the emission control system on your engine for the periods of time listed below provided there has been no abuse, neglect or improper maintenance of your engine.

Your emission control system may include parts such as the fuel injection system and the air induction system. Also included may be hoses, belts, connectors and other emission-related assemblies.

Where a warrantable condition exists, Yanmar will repair your non-road compression-ignition engine at no charge to you including diagnosis, parts and labor.

Manufacturer's Warranty Period:

The model year 1998 or later certified and labeled non-road compression-ignition engines are warranted for the periods listed below. If any emission-related part on your engine is found to be defective during the applicable warranty period, the part will be replaced by Yanmar.

Engine Type	Warranty Period by Number of Years or Hours of Operation
Constant speed engines rated at or above 50 hp SAE (37 kW)	The warranty period is five (5) years or 3,000 hours of use, whichever occurs first. In the absence of a device to measure the hours of use, the engine has a warranty period of five (5) years.
Constant speed engines rated under 50 hp SAE (37 kW) with rated speeds greater than or equal to 3,000 rpm (min ⁻¹)	The warranty period is two (2) years or 1,500 hours of use, whichever occurs first. In the absence of a device to measure the hours of use, the engine has a warranty period of two (2) years.
Constant speed engines rated under 50 hp SAE (37 kW) and engines rated at or above 26 hp SAE (19 kW) with rated speeds less than 3,000 rpm (min ⁻¹)	The warranty period is five (5) years or 3,000 hours of use, whichever occurs first. In the absence of a device to measure the hours of use, the engine has a warranty period of five (5) years.
Engines rated at or above 26 hp SAE (19 kW)	The warranty period is five (5) years or 3,000 hours of use, whichever occurs first. In the absence of a device to measure the hours of use, the engine has a warranty period of five (5) years.
Engines rated under 26 hp SAE (19 kW)	The warranty period is two (2) years or 1,500 hours of use, whichever occurs first. In the absence of a device to measure the hours of use, the engine has a warranty period of two (2) years.

Limited Emission Control System Warranty - USA Only - Continued**Warranty Coverage:**

This warranty is transferable to each subsequent purchaser for the duration of the warranty period. Repair or replacement of any warranted part will be performed at an authorized Yanmar Industrial engine dealer or distributor.

Warranted parts not scheduled for replacement as required maintenance in the *Operation Manual* shall be warranted for the warranty period. Warranted parts scheduled for replacement as required maintenance in the operation manual are warranted for the period of time prior to the first scheduled replacement. Any part repaired or replaced under warranty shall be warranted for the remaining warranty period.

During the warranty period, Yanmar is liable for damages to other engine components caused by the failure of any warranted part during the warranty period.

Any replacement part which is functionally identical to the original equipment part in all respects may be used in the maintenance or repair of your engine, and shall not reduce Yanmar's warranty obligations. Add-on or modified parts that are not exempted may not be used. The use of any non-exempted add-on or modified parts shall be grounds for disallowing a warranty.

Warranted Parts:

This warranty covers engine components that are a part of the emission control system of the engine as delivered by Yanmar to the original retail purchaser. Such components may include the following:

- Fuel Injection System
- Cold Start Enrichment System
- Intake Manifold
- Exhaust Manifold
- Positive Crankcase Ventilation System
- Hoses, belts, connectors and assemblies associated with emission control systems

Since emission-related parts may vary slightly between models, certain models may not contain all of these parts and other models may contain the functional equivalents.

Limited Emission Control System Warranty - USA Only - Continued**Exclusions:**

Failures other than those arising from defects in material and / or workmanship are not covered by this warranty. The warranty does not extend to the following: malfunctions caused by abuse, misuse, improper adjustment, modification, alteration, tampering, disconnection, improper or inadequate maintenance or use of non-recommended fuels and lubricating oils; accident-caused damage, and replacement of expendable items made in connection with scheduled maintenance. Yanmar disclaims any responsibility for incidental or consequential damages such as loss of time, inconvenience, loss of use of equipment / engine or commercial loss.

Owner's Warranty Responsibilities:

As the engine owner, you are responsible for the performance of the required maintenance listed in your owner's manual. Yanmar recommends that you retain all documentation, including receipts, covering maintenance on your non-road compression-ignition engine, but Yanmar cannot deny warranty solely for the lack of receipts, or for your failure to ensure the performance of all scheduled maintenance.

Yanmar may deny your warranty coverage of your non-road compression-ignition engine if a part has failed due to abuse, neglect, improper maintenance or unapproved modifications.

Your engine is designed to operate on diesel fuel only. Use of any other fuel may result in your engine no longer operating in compliance with applicable emissions requirements.

You are responsible for initiating the warranty process. You must present your engine to a Yanmar dealer as soon as a problem exists. The warranty repairs should be completed by the dealer as expeditiously as possible. If you have any questions regarding your warranty rights and responsibilities, or would like information on the nearest Yanmar dealer or authorized service center, you should contact Yanmar America Corporation at 1-800-872-2867.

Section 3

SAFETY

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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 TNM 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

Indicates a hazardous situation which, if not avoided, *will* result in death or serious injury.

WARNING

Indicates a hazardous situation which, if not avoided, *could* result in death or serious injury.

CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

NOTICE

Indicates a situation which can cause damage to the machine, personal property and/or the environment, or cause the equipment to operate improperly.

SAFETY PRECAUTIONS

The safety messages that follow have DANGER level hazards.

DANGER

Crush Hazard



- Never stand under a hoisted engine. If the hoist mechanism fails, the engine will fall on you.

- Always ensure the engine is solidly secured during service work.
- Always have a helper assist you attach the engine to a hoist and load it on a truck when you need to transport the engine for repair.

DANGER

Exhaust Hazard



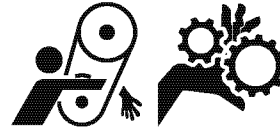
- Never operate the engine in an enclosed area such as a garage, tunnel, underground room, manhole or ship's hold without proper ventilation.
- Never block windows, vents or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide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

The safety messages that follow have WARNING level hazards.

⚠ WARNING**Fire and Explosion Hazard**

- Diesel fuel is flammable and explosive under certain conditions.

- Before you operate the engine, check for fuel leaks.
- If the unit has an electric fuel feed pump, when you prime the fuel system, turn the key switch to the ON position for 10 to 15 seconds to allow the electric fuel feed pump to prime the system.
- If the unit has a mechanical fuel feed pump, when you prime the fuel system, operate the fuel priming lever of the mechanical fuel feed pump several times until the fuel filter cup is filled with fuel.
- 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.
- Never use a shop rag to catch diesel fuel. Vapors from the rag are flammable and explosive.
- Wipe up any spills immediately.
- Never use diesel fuel as a cleaning agent.

⚠ WARNING**Entanglement/Sever Hazard**

- Always tie back long hair and keep hands and other body parts away from moving/rotating parts such as the cooling fan, flywheel or PTO shaft.
- Always wear tight-fitting clothing and keep your hair short or tie it back while the engine is running.
- Always remove all jewelry before you operate or service the engine.
- 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.
- Never wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing when you are working near moving/rotating parts such as the flywheel or PTO shaft.
- Check before starting the engine that any tools or shop rags used during maintenance have been removed from the area.
- Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it.

⚠ WARNING**Sudden Movement Hazard**

- 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.
- Never engage the transmission or PTO at an elevated engine speed.
- Always allow the engine to warm up for at least 5 minutes and allow the idle speed of the engine to return to normal before engaging the transmission or any PTOs.

⚠ WARNING**Burn Hazard**

Always keep your hands and other body parts away from hot engine surfaces such as the muffler, exhaust pipe 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.

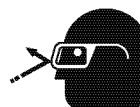
⚠ WARNING**Exposure Hazard**

- Always wear personal protective equipment such as gloves, work shoes, eye and hearing protection as required by the task at hand.
- Never operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the warning signals.
- Always wear safety glasses while servicing the engine to prevent possible eye injury.

⚠ WARNING**Alcohol and Drug Hazard**

- Never operate or service the engine while you are under the influence of alcohol or drugs.
- Never operate or service the engine when you are feeling ill.

The safety messages that follow have CAUTION level hazards.

⚠ 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.

The safety messages that follow have NOTICE level hazards.

NOTICE

If any problem is noted during the visual check, the necessary corrective action should be taken before you operate the engine.

NOTICE

Make sure the engine is installed on a level surface. If a continuously running engine is installed at an angle greater than 25° in any direction or if an engine runs for short periods of time (less than 3 minutes) at an angle greater than 30° in any direction, engine oil may enter the combustion chamber, causing excessive engine speed and white exhaust smoke. This may cause serious engine damage.

NOTICE

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.
- The standard range of ambient temperatures for the normal operation of Yanmar engines is from +5°F (-15°C) to +113°F (+45°C).
- If the ambient temperature exceeds +113°F (+45°C), the engine may overheat and cause the engine oil to break down.
- If the ambient temperature is below +5°F (-15°C), the engine will be hard to start and the engine oil may not flow easily.
- Contact your authorized Yanmar Industrial engine dealer or distributor if the engine will be operated outside of this standard temperature range.

NOTICE

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.

NOTICE

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

NOTICE

If any indicator fails to illuminate when the key switch is in the ON position, see your authorized Yanmar Industrial engine dealer or distributor for service before operating the engine.

NOTICE

For maximum engine life, Yanmar recommends that when shutting the engine down, you allow the engine to idle, without load, for 5 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.

NOTICE

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

NOTICE

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 4 to 5 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.

NOTICE

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 Warranty Section*.

NOTICE

When the battery indicator goes out, it should not come on again. The battery indicator only comes on during operation if the alternator fails. However, if an LED is used in the battery indicator, the LED will shine faintly during normal operation.

NOTICE

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the assembly process.

NOTICE

Never attempt to adjust the low or high idle speed limit screws. 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.

NOTICE

- 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.

NOTICE**Precautions for Handling Desiccant**

Disposal:

This material is disposable and non-flammable; however, the bag is flammable. If necessary, tear the bag and discard the bag and the contents separately.

It is recommended to bury the contents in the bag under ground.

Dispose in accordance with the disposal standards for industrial waste defined by local laws and regulations.

Handling:

The contents of the bag do not leak out during normal use.

Take the following emergency measures, however, if the contents leak out.

- If the contents get on the skin, rinse thoroughly with running water.
- If the contents get in the eyes, rinse thoroughly with water. Consult a doctor if any abnormalities are found.
- If the contents get in the mouth, rinse thoroughly with water. Drink water to dilute if the content is swallowed, though a small amount is harmless. Consult a doctor if any abnormalities are found.

Characteristics of Materials:

• Calcium Chloride (CaCl ₂)	Approx. 57%
• Grain Polysaccharide	Approx. 28%
• Grain Skins	Approx. 9%
• Ethylene Polymer (Bag)	Approx. 5%

Hazard Information:

• Explosiveness	None
• Flammability	Nonflammable
• Combustibility	None
• Oxidation	None

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Section 4

GENERAL SERVICE INFORMATION

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SAFETY PRECAUTIONS

Before performing any engine service procedures, review the *Safety section on page 3-1*.

COMPONENT IDENTIFICATION

Figure 4-1 shows where major engine components are located.

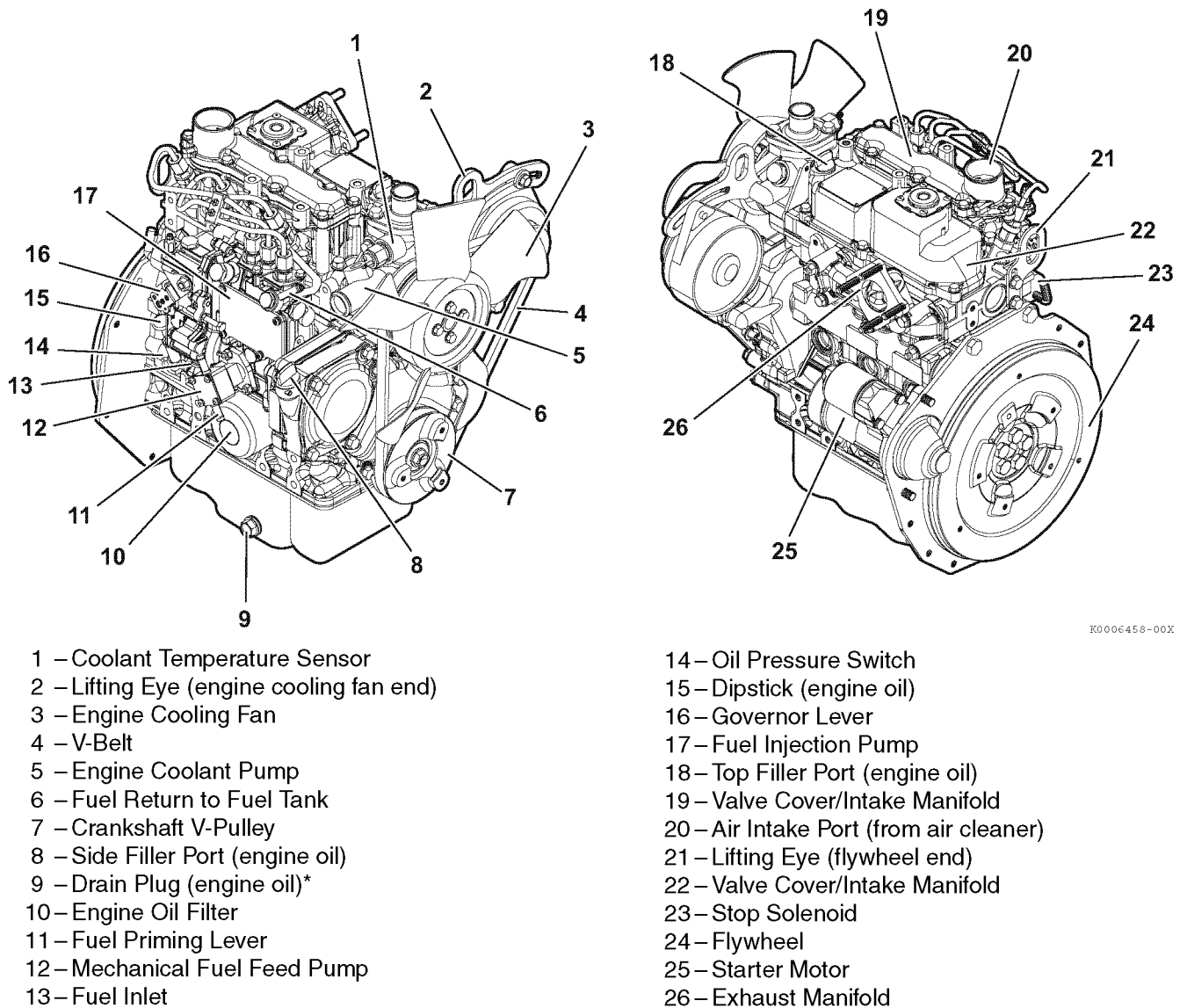


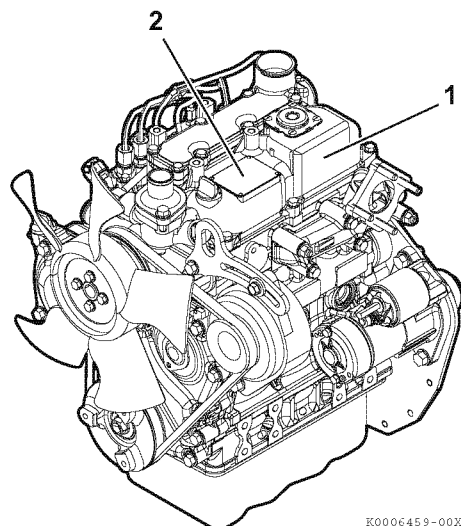
Figure 4-1

* Engine oil drain plug location may vary based on oil pan options.

LOCATION OF LABELS

Figure 4-2 shows the location of regulatory emission control (**Figure 4-2, (1)**) and engine nameplate (**Figure 4-2, (2)**) labels on Yanmar TNM series engines.

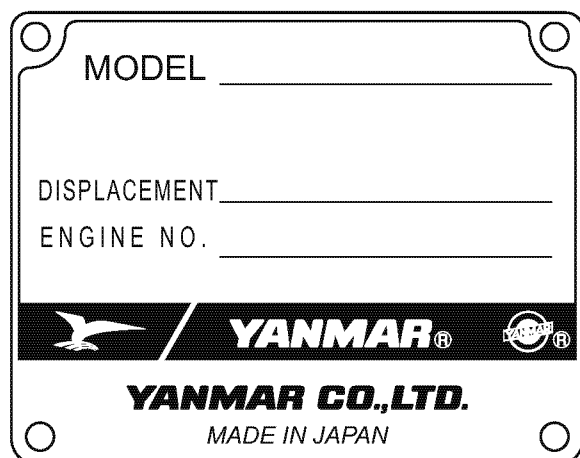
In addition to the engine nameplate, the engine model and serial numbers are stamped on flat pads on the left side of the crankcase.



K0006459-00X

Figure 4-2

Engine Nameplate (Typical)



032257-00X

EPA/CARB EMISSION CONTROL REGULATIONS - USA ONLY

Yanmar TNM engines meet Environmental Protection Agency (EPA) (U.S. Federal) emission control standards as well as the California Air Resources Board (CARB) regulations. Only engines that conform to CARB regulations can be sold in the State of California.

Refer to *Required EPA/ARB Maintenance - USA Only* on page 5-3 in the *Periodic Maintenance* section of this manual. Also refer to the *Yanmar Co., Ltd. Limited Emission Control System Warranty - USA Only* on page 2-6.

EMISSION CONTROL LABELS

Since emission control regulations are being issued on a global basis, it is necessary to identify with which regulations a particular engine complies. We have listed several different types of labels you might find on your engine.

EPA/ARB Labels (Typical)

(EPA)

EMISSION CONTROL INFORMATION	
THIS ENGINE COMPLIES WITH U.S. EPA REGULATIONS FOR <input type="text"/> M. Y. NONROAD DIESEL ENGINES. LOW SULFUR FUEL OR ULTRA LOW SULFUR FUEL ONLY	
ENGINE FAMILY : <input type="text"/>	DISPLACEMENT : <input type="text"/> LITERS
ENGINE MODEL : <input type="text"/>	EMISSION CONTROL SYSTEM : <input type="text"/>
FUEL RATE : <input type="text"/> MM ³ /STROKE @ <input type="text"/> kW / <input type="text"/> RPM <input type="text"/>	
REFER TO OWNER'S MANUAL FOR MAINTENANCE SPECIFICATIONS AND ADJUSTMENTS	
YANMAR. YANMAR CO.,LTD.	

021751-00X

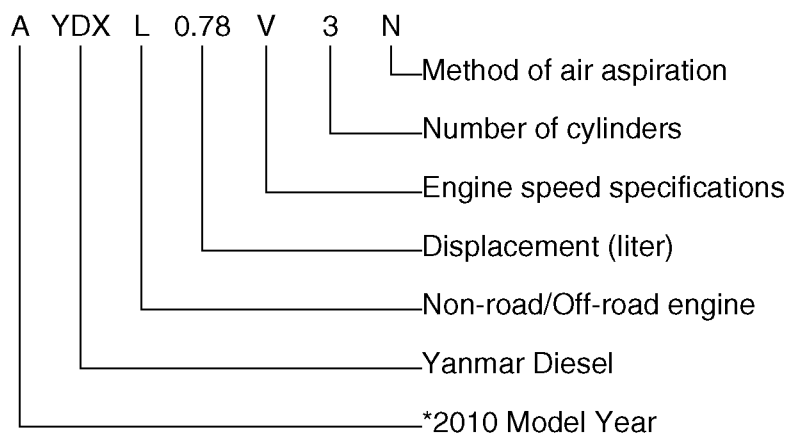
(EPA & ARB)

EMISSION CONTROL INFORMATION	
THIS ENGINE COMPLIES WITH U. S. EPA AND CALIFORNIA REGULATIONS FOR <input type="text"/> M. Y. NONROAD/OFF-ROAD DIESEL ENGINES. LOW SULFUR FUEL OR ULTRA LOW SULFUR FUEL ONLY	
ENGINE FAMILY : <input type="text"/>	DISPLACEMENT : <input type="text"/> LITERS
ENGINE MODEL : <input type="text"/>	EMISSION CONTROL SYSTEM : <input type="text"/>
FUEL RATE : <input type="text"/> MM ³ /STROKE @ <input type="text"/> kW / <input type="text"/> RPM <input type="text"/>	
REFER TO OWNER'S MANUAL FOR MAINTENANCE SPECIFICATIONS AND ADJUSTMENTS	
YANMAR. YANMAR CO.,LTD.	

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ENGINE FAMILY

The EPA/ARB labels and the 97/68/EC label all have an *Engine Family* field. The following is an explanation of the *Engine Family* designation:



- * A: 2010
- * B: 2011
- * C: 2012, etc.

FUNCTION OF MAJOR ENGINE COMPONENTS

Component	Function
Air Cleaner	The air cleaner prevents airborne contaminants from entering the engine. Since the air cleaner is application specific, it must be carefully selected by an application engineer. It is not part of the basic engine package as shipped from the Yanmar factory. Periodic replacement of the air cleaner filter element is necessary. See the <i>Periodic Maintenance Schedule on page 5-4</i> for the replacement frequency.
Dynamo	The dynamo is driven by a V-belt which is powered by the crankshaft V-pulley. The dynamo supplies electricity to the engine systems and charges the battery while the engine is running.
Dipstick (Engine Oil)	The engine oil dipstick is used to determine the amount of engine oil in the crankcase.
Electric Fuel Feed Pump	The electric fuel feed pump makes sure there is a constant supply of diesel fuel to the fuel injection pump. The electric fuel feed pump is electro-magnetic and runs on 12V DC. An electric fuel feed pump may be installed as standard equipment based on engine model and specification. If an electric fuel feed pump is installed, turn the key switch to the ON position for 10 to 15 seconds to prime the fuel system.
Engine Oil Filter	The engine oil filter removes contaminants and sediments from the engine oil. Periodic replacement of the engine oil filter is necessary. See the <i>Periodic Maintenance Schedule on page 5-4</i> for the replacement frequency.
Fuel Filter	The fuel filter removes contaminants and sediments from the diesel fuel. Periodic replacement of the fuel filter is necessary. See the <i>Periodic Maintenance Schedule on page 5-4</i> for the replacement frequency. Please note that the word “diesel” is implied throughout this manual when the word “fuel” is used.
Fuel Filter/Water Separator	The fuel filter/water separator removes contaminants, sediments and water from diesel fuel going to the fuel filter. This is a required component of the fuel system. This is standard equipment with every engine. The separator is installed between the fuel tank and the fuel pump. Periodically drain the water from the fuel filter/water separator using the drain cock at the bottom of the separator.
Fuel Priming Lever	If the unit has a mechanical fuel feed pump, a fuel priming lever on the mechanical fuel feed pump primes the fuel system. The fuel system needs to be primed before you start the engine for the first time, if you run out of fuel or if fuel system service is performed. To prime the fuel system, operate the fuel priming lever until the cup in the fuel filter is full of fuel.
Fuel Tank	The fuel tank is a reservoir that holds diesel fuel. When fuel leaves the fuel tank it goes to the fuel filter/water separator. Next, fuel is pumped to the fuel filter by the fuel pump. Next, the fuel goes to the fuel injection pump. Since fuel is used to keep the fuel injection pump cool and lubricated, more fuel than necessary enters the injection pump. When the injection pump pressure reaches a preset value, a relief valve allows excess fuel to be returned back to the fuel tank. The fuel tank is a required engine component.

Component	Function
Mechanical Fuel Feed Pump	The mechanical fuel feed pump is a diaphragm type of pump and is installed on the fuel injection pump body. The mechanical fuel feed pump is standard equipment on some engine models and is driven by a cam on the camshaft of the fuel injection pump. The mechanical fuel feed pump is not installed on the fuel injection pump if the electric fuel feed pump is installed.
Side and Top Filler Port (Engine Oil)	You can fill the crankcase with engine oil from <i>either the side or top filler port</i> depending upon which one is most convenient.
Starter Motor	The starter motor is powered by the battery. When you turn the key switch in the operator's console to the START position, the starter motor engages with the ring gear installed on the flywheel and starts the flywheel in motion.

FUNCTION OF COOLING SYSTEM COMPONENTS

Component	Function
Cooling System	The TNM engine is liquid-cooled by means of a cooling system. The cooling system consists of a radiator, radiator cap, engine cooling fan, engine coolant pump, thermostat and reserve tank. <i>Note that all cooling system components are required for proper engine operation. Since some of the components are application specific, they must be carefully selected by an application engineer. The application-specific items are not part of the basic engine package as shipped from the Yanmar factory.</i>
Engine Cooling Fan	The engine cooling fan is driven by a V-belt which is powered by the crankshaft V-pulley. The purpose of the engine cooling fan is to circulate air through the radiator.
Engine Coolant Pump	The engine coolant pump circulates the engine coolant through the cylinder block and cylinder head and returns the engine coolant to the radiator.
Radiator	The radiator acts as a heat exchanger. As the engine coolant circulates through the cylinder block it absorbs heat. The heat in the engine coolant is dissipated in the radiator. As the engine cooling fan circulates air through the radiator, the heat is transferred to the air.
Radiator Cap	The radiator cap controls the cooling system pressure. The cooling system is pressurized to raise the boiling point of the engine coolant. As the engine coolant temperature rises, the system pressure and the coolant volume increases. When the pressure reaches a preset value, the release valve in the radiator cap opens and the excess engine coolant flows into the reserve tank. As the engine coolant temperature is reduced, the system pressure and volume is reduced and the vacuum valve in the radiator cap opens, allowing engine coolant to flow from the reserve tank back into the radiator.
Reserve Tank	The reserve tank contains the overflow of engine coolant from the radiator. If you need to add engine coolant to the system, add it to the reserve tank, not to the radiator.
Thermostat	A thermostat is placed in the cooling system to prevent engine coolant from circulating into the radiator until the engine coolant temperature reaches a preset temperature. When the engine is cold, no engine coolant flows through the radiator. Once the engine reaches its operating temperature, the thermostat opens. By letting the engine warm up as quickly as possible, the thermostat reduces engine wear, deposits and emissions.

DIESEL FUEL

Diesel Fuel Specifications

NOTICE

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.

Diesel fuel should comply with the following specifications. The table lists several worldwide specifications for diesel fuels.

Diesel Fuel Specification	Location
ASTM D975 No. 1D S15, S500 No. 2D S15, S500	USA
EN590:96	European Union
ISO 8217 DMX	International
BS 2869-A1 or A2	United Kingdom
JIS K2204 Grade No. 2	Japan
KSM-2610	Korea
GB252	China

Additional Technical Fuel Requirements

- The fuel cetane number should be equal to 45 or higher.
- The sulfur content must not exceed 0.5% by volume. Less than 0.05% is preferred. Especially in U.S.A. and Canada, Low Sulfur (300 to 500 ppm (mg/kg) or Ultra Low Sulfur fuel should be used.
- Bio-Diesel fuels. *See Bio-Diesel Fuels on page 4-10.*
- Never mix kerosene, used engine oil or residual fuels with the diesel fuel.
- Water and sediment in the fuel should not exceed 0.05% by volume.
- Keep the fuel tank and fuel-handling equipment clean at all times.

- Poor quality fuel can reduce engine performance and/or cause engine damage.
- Fuel additives are not recommended. Some fuel additives may cause poor engine performance. Consult your Yanmar representative for more information.
- Ash content not to exceed 0.01% by volume.
- Carbon residue content not to exceed 0.35% by volume. Less than 0.1% is preferred.
- Total aromatics content should not exceed 35% by volume. Less than 30% is preferred.
- PAH (polycyclic aromatic hydrocarbons) content should be below 10% by volume.
- Metal content of Na, Mg, Si and Al should be equal to or lower than 1 mass ppm (test analysis method JPI-5S-44-95).
- Lubricity: Wear mark of WS1.4 should be maximum 0.018 in. (460 µm) at HFRR test.

Bio-Diesel Fuels

In Europe and in the United States, as well as some other countries, non-mineral oil based fuel resources such as RME (Rapeseed Methyl Ester) and SOME (Soybean Methyl Ester), collectively known as FAME (Fatty Acid Methyl Esters), are being used as extenders for mineral oil derived diesel fuels.

Yanmar approves the use of bio-diesel fuels that do not exceed a blend of 5% (by volume) of FAME with 95% (by volume) of approved mineral oil derived diesel fuel. Such bio-diesel fuels are known in the marketplace as B5 diesel fuels.

These B5 diesel fuels must meet certain requirements.

- The bio-fuels must meet the minimum specifications for the country in which they are used.
 - In Europe, bio-diesel fuels must comply with the European Standard EN14214.

- In the United States, bio-diesel fuels must comply with the American Standard ASTM D-6751.
- Bio-fuels should be purchased only from recognized and authorized diesel fuel suppliers.

Precautions and concerns regarding the use of bio-fuels:

- Free methanol in FAME may result in corrosion of aluminum and zinc FIE components.
- Free water in FAME may result in plugging of fuel filters and increased bacterial growth.
- High viscosity at low temperatures may result in fuel delivery problems, injection pump seizures and poor injection nozzle spray atomization.
- FAME may have adverse effects on some elastomers (seal materials) and may result in fuel leakage and dilution of the engine lubricating oil.
- Even bio-diesel fuels that comply with a suitable standard as delivered will require additional care and attention to maintain the quality of the fuel in the equipment or other fuel tanks. It is important to maintain a supply of clean, fresh fuel. Regular flushing of the fuel system, and / or fuel storage containers, may be necessary.
- The use of bio-diesel fuels that do not comply with the standards as agreed to by the diesel engine manufacturers and the diesel fuel injection equipment manufacturers, or bio-diesel fuels that have degraded as per the precautions and concerns above, may affect the warranty coverage of your engine. *See Yanmar Limited Warranty on page 2-3.*

B6 To B20 Bio-diesel Fuel Blend Usage

The following information is summarized from a Yanmar Service Advisory and is intended as reference only.

Approved Engines

Only the Yanmar TNM engine series listed below may operate with bio-diesel fuel concentrations up to B20.

NOTICE

When using any of the Yanmar TNM engines noted below with bio-diesel fuel blends from B6 to B20, Yanmar recommends observing the enhanced operation conditions; see Operating Conditions with B6 to B20 Bio-diesel Fuel Blends on page 4-12.

- 3TNM68
- 3TNM72

Approved Fuel

NOTICE

Raw pressed vegetable oils are not considered bio-diesel, and are unacceptable for use as fuel in any concentration in Yanmar engines.

Bio-diesel fuel blends up to B20 must comply with the following standards:

- EN14214 (European standard) and/or ASTM D-6751 (American standard).
- All applicable engines may operate with bio-diesel fuel up to a maximum B20 (20% bio-diesel blend) concentration.

Operating Conditions with B6 to B20 Bio-Diesel Fuel Blends

When operating the applicable Yanmar engine with bio-diesel blends above B5, Yanmar strongly recommends observing the operation, service and maintenance conditions:

1. The original service interval (per the *Operation Manual*) for the following should be halved (twice as frequently):
 - (a) Replacement interval of the engine oil filter, engine oil and fuel filter.
 - (b) Cleaning interval of the water separator.
 - (c) Drain interval of the fuel tank.
2. It is required to inspect, clean and adjust the fuel injector after every 1000 operation hours.
3. Replace the following components BEFORE using bio-diesel fuel: (see *Kit Parts List for B20 on page 4-13*.)
 - (a) Fuel hose
 - (b) Fuel feed pump (diaphragm type)
 - (c) If not already installed, a water separator must be installed
 - (d) O-ring of the fuel filter
 - (e) O-ring of the water separator
4. Yanmar does not recommend using bio-diesel fuel in ambient temperatures below 32°F (0°C).
5. Bio-diesel fuel usage requires the following DAILY maintenance:
 - (a) Check the engine oil level. If the oil level rises above the oil level of the previous day, the engine oil must be replaced immediately.
 - (b) Check the water level in the water separator. If the water level rises above the "max" indicator, immediately drain the water separator.
6. Bio-diesel fuel blends up to B20 can only be used for a limited time of up to 3 months from the date of bio-diesel fuel manufacture. Therefore, bio-diesel must be used at least within 2 months from the time of filling the fuel tank or within 3 months from the time of production by the fuel supplier, whichever comes first.
7. Before any long-term engine storage occurs, the bio-diesel fuel must be completely drained from the engine and operated at least 5 hours with conventional diesel fuel as indicated in the *Operation Manual*.

Kit Parts List for B20

		KIT-M368BGS-BI
		D19125-59250
FUEL TANK - / - FUEL TANK	No.	1
	Length	2000
	Part No.	129946-59050
	Part Name	FO-T CMP
	Number	2
FUEL FEED PUMP - FUEL FILTER	No.	2
	Length	380
	Part No.	119546-59030
	Part Name	CW-T CMP
	Number	1
FUEL FILTER - FUEL INJECTION PUMP	No.	5
	Length	220
	Part No.	129236-59000
	Part Name	CW-T CMP
	Number	1
FUEL INJECTION PUMP - FUEL FILTER	No.	10
	Length	400
	Part No.	129946-59220
	Part Name	FO-T CMP
	Number	1
CAP, FUEL INJECTION NOZZLE	Part No.	NO NEED
	Part Name	
	Number	
FUEL INJECTION NOZZLE - FUEL INJECTION NOZZLE	No.	NO NEED
	Length	
	Part No.	
	Part Name	
	Number	
FUEL INJECTION NOZZLE - FUEL INJECTION PUMP	No.	16
	Length	150
	Part No.	119546-59300
	Part Name	FO-T CMP
	Number	1
FUEL FILTER		NEED TO CHANGE ONLY O-RING. P44: 24316-000440
WATER SEPARATOR		NEED TO CHANGE ONLY O-RING. G75: 24326-000750 P16: 24316-000160 P7: 24316-000070

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

Engine Warranty

Damages, performance or service concerns determined by Yanmar to be caused by the use of bio-diesel fuel not meeting the specifications outlined above are not considered to be defects in material or factory workmanship and are not covered under Yanmar's engine warranty. The same applies to damages or other concerns induced by not complying with the recommended operating conditions of Yanmar engines with bio-diesel fuel.

Filling the Fuel Tank

WARNING

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.

- Never refuel with the engine running.
- Only fill the fuel tank with diesel fuel. Filling the fuel tank with gasoline may result in a fire and will damage the engine.
- Wipe up all spills immediately.
- Keep sparks, open flames or any other form of ignition (match, cigarette, static electricity source) well away when refueling.
- Never remove the fuel cap while the engine is running.
- Never overfill the fuel tank.
- Always put the 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.
- Store any containers containing fuel in a well-ventilated area, away from any combustibles or source of ignition.
- 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.

NOTICE

Replace rubberized fuel hoses every 2 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 2 years or 2000 hours of engine operation, whichever comes first.

NOTICE

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.

Note that a typical fuel tank is shown. The fuel tank on the equipment being serviced may be different.

1. Clean the area around the fuel cap (Figure 4-3, (1)).
2. Remove the fuel cap from the fuel tank (Figure 4-3, (2)).
3. Observe the fuel level sight gauge (Figure 4-3, (3)) and stop fueling when gauge shows fuel tank is full. Never overfill the fuel tank.
4. Replace the fuel cap and hand-tighten. Over-tightening the fuel cap will damage it.

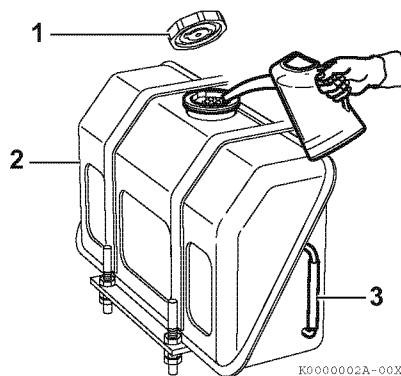


Figure 4-3

Priming the Fuel System

The fuel system needs to be primed under certain conditions:

- Before starting the engine for the first time
- After running out of fuel and fuel has been added to the fuel tank
- After fuel system maintenance such as changing the fuel filter and draining the fuel filter/water separator, or replacing a fuel system component

To prime the fuel system if an electric fuel feed pump is installed:

Turn the key to the ON position for 10 to 15 seconds. This will allow the electric fuel feed pump to prime the fuel system.

WARNING**Fire and Explosion Hazard**

Never open the air vent valve while the fuel system is being primed.

NOTICE

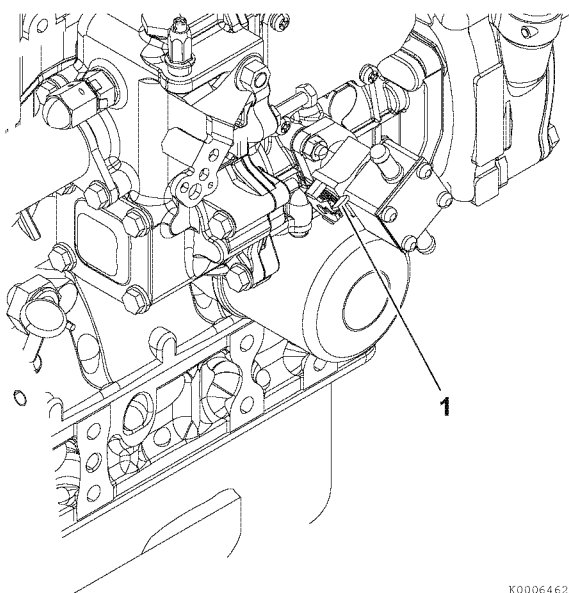
Never use the starter motor to crank the engine in order to prime the fuel system. This may cause the starter motor to overheat and damage the coils, pinion and/or ring gear.

To prime the fuel system if a mechanical fuel feed pump is installed:

Operate the fuel priming lever (Figure 4-4, (1)) several times until the fuel filter cup is filled with fuel.

NOTICE

Never use the starter motor to crank the engine in order to prime the fuel system. This may cause the starter motor to overheat and damage the coils, pinion and / or ring gear.



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Figure 4-4

ENGINE OIL

Engine Oil Specifications

NOTICE

- Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize or shorten engine life.
- Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

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

Service Categories

- API Service Categories: CD, CF, CF-4 and CI-4
- 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'Automobiles)
- JASO (Japanese Automobile Standards Organization)

NOTICE

- Be sure the engine oil, engine oil storage containers and engine oil filling equipment are free of sediments and water.
- Change the engine oil after the first 50 hours of operation and then every 250 hours thereafter.
- Select the oil viscosity based on the ambient temperature where the engine is being operated. See the SAE Service Grade Viscosity Chart (Figure 4-5).
- Yanmar does not recommend the use of engine oil "additives."

Additional Technical Engine oil Requirements:

The engine oil must be changed when the Total Base Number (TBN) has been reduced to 1.0 (mgKOH/g) test method; JIS K-201-5.2-2 (HCl), ASTM D4739 (HCl).

Engine Oil Viscosity

Select the appropriate engine oil viscosity based on the ambient temperature and use the SAE Service Grade Viscosity Chart (Figure 4-5).

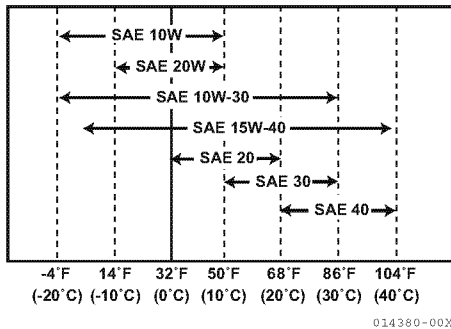


Figure 4-5

Checking Engine Oil

1. Make sure engine is level.
2. Remove dipstick (Figure 4-6, (1)) and wipe with clean cloth.

NOTICE

Prevent dirt and debris from contaminating the engine oil. Carefully clean the oil cap/dipstick and the surrounding area before you remove the cap.

3. Fully reinsert dipstick.
4. Remove dipstick. The oil level should be between upper (Figure 4-6, (2)) and lower (Figure 4-6, (3)) lines on the dipstick.

NOTICE

Always keep the oil level between the upper and lower lines on the dipstick.

5. Fully reinsert dipstick.

NOTICE

Never overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

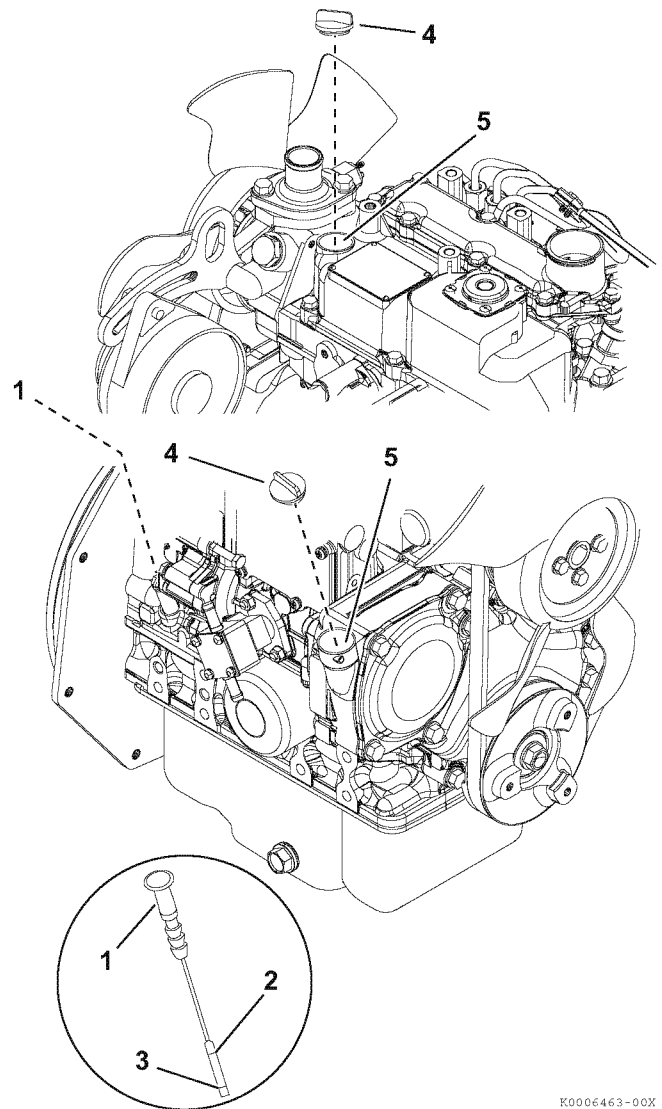


Figure 4-6

Adding Engine Oil

1. Make sure engine is level.
2. Remove oil cap (**Figure 4-6, (4)**).
3. Add indicated amount of engine oil at the top or side engine oil filler port (**Figure 4-6, (5)**).
4. Wait 3 minutes and check oil level.
5. Add more oil if necessary.
6. Replace oil cap (**Figure 4-6, (4)**) and hand-tighten. Over-tightening may damage the cap.

Engine Oil Capacity (Typical)

Note: These are the engine oil capacities associated with a “deep standard” oil pan. Oil capacity will vary depending upon which optional oil pan is used. Refer to the *Operation Manual* provided by the driven machine manufacturer for the actual engine oil capacity of your machine.

The following are the engine oil capacities for various Yanmar TNM engines:

Engine Model	Dipstick Upper Limit/Lower Limit
3TNM68	2.6/1.4 qt (2.5/1.3 L)
3TNM72	3.1/1.7 qt (2.9/1.6 L)

ENGINE COOLANT

WARNING

Scald Hazard

Always check the level of engine coolant by observing the reserve tank.

CAUTION

Coolant Hazard

Wear eye protection and rubber gloves when you handle Long Life Coolant (LLC) or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

Engine Coolant Specifications

NOTICE

- Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale, and/or shorten engine life.
- Never mix different types of engine coolant. This may adversely affect the properties of the engine coolant.

Use a Long Life Coolant (LLC) or an Extended Life Coolant (ELC) that meets or exceeds the following guidelines and specifications:

Additional Technical Coolant Specifications:

- ASTM D6210, D4985 (U.S.)
- JIS K-2234 (Japan)
- SAE J814C, J1941, J1034 or J2036 (International)

Alternative Engine Coolant

If an Extended or Long Life Coolant is not available, you may use an ethylene glycol or propylene glycol based conventional coolant (green).

NOTICE

- Always use a mix of coolant and water. Never use water only.
- Mix coolant and water per the mixing instructions on the coolant container.
- Water quality is important to coolant performance. Yanmar recommends that soft, distilled or demineralized water be used to mix with coolants.
- Never mix Extended or Long Life Coolants and conventional (green) coolants.
- Never mix different types and/or colors of extended life coolants.
- Replace the coolant every 1000 engine hours or once a year.

Filling Radiator with Engine Coolant

Fill the radiator and reserve tank as follows. This procedure is for filling the radiator for the first time or refilling it after it is flushed. Note that a typical radiator is illustrated.

WARNING

Burn Hazard

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

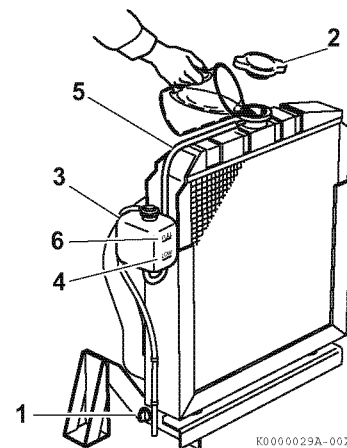


Figure 4-7

1. Check to be sure the radiator drain plug is installed and tightened or the drain cock (**Figure 4-7, (1)**) is closed. Also make sure the coolant drain plug (**Figure 4-8, (1)**) in the cylinder block is closed.

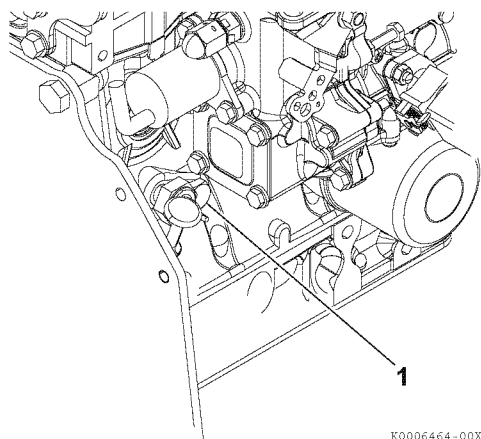


Figure 4-8

2. Clean all dirt and debris surrounding the radiator cap.

NOTICE

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and surrounding area before you remove the cap.

3. Remove the radiator cap (**Figure 4-7, (2)**) by turning it counterclockwise about 1/3 of a turn.

WARNING

Scald Hazard

Never remove the radiator cap if the engine is hot. Steam and hot engine coolant will spray out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

4. Pour the engine coolant *slowly* into the radiator until it is even with the lip of the engine coolant filler port. Make sure that air bubbles do not develop as you fill the radiator.
5. Install the radiator cap. Align the tabs on the back of the radiator cap with the notches on the engine coolant filler port. Press down and turn the cap clockwise about 1/3 of a turn.

WARNING

Scald Hazard

Always tighten the radiator cap securely after you check the radiator. Steam can spray out during engine operation if the cap is loose.

6. Remove the cap of the reserve tank (**Figure 4-7, (3)**), and fill it to the LOW (COLD) mark (**Figure 4-7, (4)**) with engine coolant. Install the cap.
7. Check the hose (**Figure 4-7, (5)**) that connects the reserve tank to the radiator. Be sure it is securely connected and there are no cracks or damage. If the hose is damaged, engine coolant will leak out instead of going into the reserve tank.
8. Run the engine until it is at operating temperature. Check the level of engine coolant in the reserve tank. When the engine is running and the engine coolant is at normal temperature, the coolant level in the tank should be at or near the FULL (HOT) mark (**Figure 4-7, (6)**). If the engine coolant is not at the FULL (HOT) mark, add additional engine coolant to the reserve tank to bring the level to the FULL (HOT) mark.

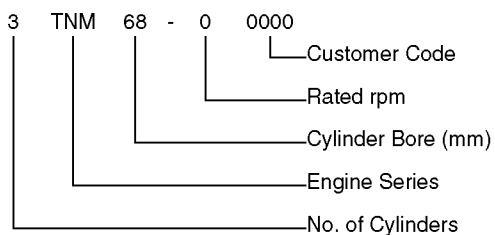
Engine Coolant Capacity (Typical)

Note: Capacities listed are only for engines without a radiator. Refer to the *Operation Manual* provided by the driven machine manufacturer for actual engine coolant capacity on your machine.

The following are the engine coolant capacities for various Yanmar TNM engines.

Engine Model	Engine Coolant Capacity
3TNM68, 3TNM72	1.1 qt (1.0 L)

Description of Model Number



Engine Speed Specifications

Notation	Available Engine Speed	Intended Uses
VH	3200 ~ 3600 rpm (min ⁻¹)	Lawn Mower, Construction, Industrial Machine
VM	2000 ~ 3000 rpm (min ⁻¹)	Agricultural, Constructive, Industrial Machines
CH	3000 ~ 3600 rpm (min ⁻¹)	2-pole Generator Sets, Irrigation Pumps
CL	1500 or 1800 rpm (min ⁻¹)	4-pole Generator Sets, Irrigation Pumps

CL: Constant Low Speed

Engine General Specifications

Type	Vertical In-line, Water Cooled, 4-Cycle Diesel Engine
Combustion System	Swirl Chamber (Ball Type)
Starting System	Electric Starting
Cooling System	Radiator
Lubricating System	Forced Lubrication with Trochoid Pump
PTO Position	Flywheel End
Direction of Rotation	Counterclockwise Viewed from Flywheel End

Note: The information described in *Principal Engine Specifications* is for a “standard” engine. To obtain the information for the engine installed in your driven machine, please refer to the manual provided by the driven machine manufacturer. Engine rating conditions are as follows (SAE J1349, ISO 3046/1):

- Atmospheric Condition: Room temperature 77°F (25°C), Atmospheric pressure 29.53 in.Hg (100 kPa, 750 mmHg), Relative humidity 30%
- Fuel Temperature at Fuel Injector Pump Inlet: 104°F (40°C)
- With Cooling Fan, Air Cleaner, Muffler: Yanmar Standard
- After Engine Break-In Period; Output Allowable Deviation: $\pm 3\%$
- 1 PS = 0.7355 kW
- 1 hp SAE (Society of Automotive Engineers) = 0.7457 kW

PRINCIPAL ENGINE SPECIFICATIONS

3TNM68 (EPA Tier 4)

Engine Model		3TNM68												
Version		CL		VM						CH		VH		
Type		Vertical In-line Diesel Engine												
Combustion System		Ball-Type Swirl Chamber												
Aspiration		Natural												
No. of Cylinders		3												
Bore × Stroke		2.67 x 2.83 in. (68 × 72 mm)												
Displacement		47.8 cu in. (0.784 L)												
Continuous Rated Output	rpm (min ⁻¹)	1500	1800						3000	3600				
	hp SAE	7.3	8.8						14.8	17.8				
	kW	5.5	6.6						11.1	13.3				
	PS	7.5	9.0						15.1	18.0				
Max. Rated Output (Net)	rpm (min ⁻¹)	1500	1800	2000	2200	2400	2600	2800	3000	3000	3600	3200	3400	3600
	hp SAE	8.1	9.7	10.9	12.2	13.4	14.4	15.6	16.8	16.3	19.5	17.1	18.1	18.9
	kW	6.1	7.3	8.2	9.1	10.0	10.8	11.7	12.6	12.2	14.6	12.8	13.5	14.1
	PS	8.3	10.0	11.1	12.3	13.6	14.7	15.9	17.1	16.6	19.9	17.4	18.3	19.2
High Idling	rpm (min ⁻¹) ± 25	1600	1900	2185	2380	2595	2805	3020	3235	3175	3770	3415	3630	3840
Engine Weight (Dry) with Flywheel Housing*		229 lb (104 kg) SAE#5		174 lb (79 kg)						229 lb (104 kg)		174 lb (79 kg)		
PTO Position		Flywheel End												
Direction of Rotation		Counterclockwise Viewed from Flywheel End												
Cooling System		Liquid-Cooled with Radiator												
Lubricating System		Forced Lubrication with Trochoid Pump												
Normal Oil Pressure at Rated Engine Speed		35 - 57 psi (0.240 - 0.390 MPa, 2.45 - 4.00 kgf/cm ²)		42 - 64 psi (0.290 - 0.440 MPa, 2.96 - 4.49 kgf/cm ²)										
Normal Oil Pressure at Low Idle Speed		8.5 psi (0.06 MPa, 0.6 kgf/cm ²) or greater												
Starting System***		Electric Starting - Starter Motor: DC12V, 1.6 hp (1.2 kW)												
		Dynamo: DC12V, 20A												
		Recommended Battery Capacity: 12V, 36 Amp-Hour (5h rating)												
Dimensions (L × W × H)*		20.4 x 16.3 x 19.6 in. (520 × 416 × 500 mm)		19.0 x 16.3 x 19.6 in. (483 × 416 × 500 mm)						20.4 x 16.3 x 20.7 in. (520 × 416 × 528 mm)		16.9 x 16.3 x 19.6 in. (431 × 416 × 500 mm)		
Engine Oil Pan Capacity**		2.6/1.4 qt (2.5/1.3 L) (Dipstick Upper Limit/Lower Limit)								3.4/1.8 qt (3.2/1.7 L) (Dipstick Upper Limit/Lower Limit)		2.6/1.4 qt (2.5/1.3 L) (Dipstick Upper Limit/Lower Limit)		
Engine Coolant Capacity		0.26 gal (1.0 L) Engine Only												
Standard Cooling Fan***		11.4 in. (290 mm) O.D., 5 Blade Pusher-Type												
Crank/Fan V-pulley Dia.***		3.9/3.5 in. (100 mm/90 mm)												

* Engine specifications without radiator

** Engine oil capacity for a "Deep Standard" oil pan. Refer to the Operation Manual provided by the driven machine manufacturer for the actual engine oil capacity of your machine.

*** May vary depending on application

3TNM72 (EPA Tier 4)

Engine Model		3TNM72												
Version		CL		VM						CH		VH		
Type		Vertical In-line Diesel Engine												
Combustion System		Ball-Type Swirl Chamber												
Aspiration		Natural												
No. of Cylinders		3												
Bore × Stroke		2.83 x 2.91 in. (72 × 74 mm)												
Displacement		55.1 cu in. (0.904 L)												
Continuous Rated Output	rpm (min ⁻¹)	1500	1800						3000	3600				
	hp SAE	8.8	10.4						17.7	21.3				
	kW	6.6	7.8						13.2	15.9				
	PS	9.0	10.6						17.9	21.6				
Max. Rated Output (Net)	rpm (min ⁻¹)	1500	1800	2000	2200	2400	2600	2800	3000	3000	3600	3200	3400	3600
	hp SAE	9.7	11.5	12.7	14.2	15.6	16.8	18.2	19.7	19.4	23.4	20.9	22.1	23.6
	kW	7.3	8.6	9.5	10.6	11.7	12.6	13.6	14.7	14.5	17.5	15.6	16.5	17.6
	PS	9.9	11.7	12.9	14.4	15.9	17.1	18.5	20.0	19.7	23.8	21.2	22.4	23.9
High Idling	rpm (min ⁻¹) ± 25	1600	1900	2185	2380	2595	2805	3020	3235	3175	3770	3415	3630	3840
Engine Weight (Dry) with Flywheel Housing*		242 lb (110 kg) SAE#5		205 lb (93 kg)						242 lb (110 kg) SAE#5		187 lb (85 kg)		
PTO Position		Flywheel End												
Direction of Rotation		Counterclockwise Viewed from Flywheel End												
Cooling System		Liquid-Cooled with Radiator												
Lubricating System		Forced Lubrication with Trochoid Pump												
Normal Oil Pressure at Rated Engine Speed		35 - 57 psi (0.240 - 0.390 MPa, 2.45 - 4.00 kgf/cm ²)		42 - 64 psi (0.290 - 0.440 MPa, 2.96 - 4.49 kgf/cm ²)										
Normal Oil Pressure at Low Idle Speed		8.5 psi (0.06 MPa, 0.6 kgf/cm ²) or greater												
Starting System***		Electric Starting - Starter Motor: DC12V, 1.6 hp (1.2 kW)												
		Dynamo: DC12V, 20A												
		Recommended Battery Capacity: 12V, 36 Amp-Hour (5h rating)												
Dimensions (L × W × H)*		19.5 x 16.8 x 21.3 in. (497 × 427 × 542 mm)												
Engine Oil Pan Capacity		3.1/1.7 qt (2.9/1.6 L) (Dipstick Upper Limit/Lower Limit)								4.1/2.2 qt (3.9/2.1 L) (Dipstick Upper Limit/Lower Limit)		3.3/1.9 qt (3.1/1.8 L) (Dipstick Upper Limit/Lower Limit)		
Engine Coolant Capacity**		0.26 gal (1.0 L) Engine Only												
Standard Cooling Fan***		12.2 in. (310 mm) O.D., 5 Blade Pusher-Type												
Crank/Fan V-pulley Dia.***		3.9/3.5 in. (100 mm/90 mm)												

* Engine specifications without radiator

** Engine oil capacity for a "Deep Standard" oil pan. Refer to the Operation Manual provided by the driven machine manufacturer for the actual engine oil capacity of your machine.

*** May vary depending on application

ENGINE SERVICE INFORMATION

Inspection Item		Standard	Limit
Intake/Exhaust Valve Gap		0.006 - 0.010 in (0.15 - 0.25 mm)	-
Fuel Injection Timing	<i>See Checking and Adjusting Fuel Injection Timing on page 7-17</i>		
Fuel Injection Pressure		1784 - 1929 psi (12.3 - 13.3 MPa; 125 - 136 kgf/cm ²)	-
Compression Pressure at 250 rpm (min ⁻¹)	3TNM68 3TNM72	470 ± 15 psi (3.24 ± 0.1 MPa; 33 ± 1 kgf/cm ²)	370 ± 15 psi (2.55 ± 0.1 MPa; 26 ± 1 kgf/cm ²)
Lubricating Oil Pressure	At rated output	CL: 35 - 57 psi (0.240 - 0.390 MPa, 2.45 - 4.00 kgf/cm ²) CH, VM, VH: 42 - 64 psi (0.290 - 0.440 MPa, 2.96 - 4.49 kgf/cm ²)	-
	When idling	8.5 psi (0.06 MPa; 0.6 kgf/cm ²) or greater	-
Thermostat		Valve Opening Temperature	Full Opening Lift Temperature
		157° - 163°F (70° - 73°C)	0.32 in. (8 mm) or Above 185°F (85°C)
Temperature Coolant Switch		225° - 235°F (107° - 113°C)	-

TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS

Use the correct amount of torque when you tighten the fasteners on the machine. Applying excessive torque may damage the fastener or component and not enough torque may cause a leak or component failure.

NOTICE

The tightening torque in the Standard Torque Chart (see General Service Information section) should be applied only to the bolts with a "7" head. (JIS strength classification: 7T)

- Apply 60% torque to bolts that are not listed.
- Apply 80% torque when tightened to aluminum alloy.



Item	Nominal Thread Diameter x Pitch	Tightening Torque	Remarks
Hexagon Bolt (7T) and Nut	M6 x 1.0 mm	87 - 104 in.-lb (9.8 - 11.8 N·m; 1.0 - 1.2 kgf·m)	Use 80% of the value at left when the tightening part is aluminum. Use 60% of the value at left for 4T bolts and lock nuts.
	M8 x 1.25 mm	200 - 251 in.-lb (22.6 - 28.4 N·m; 2.3 - 2.9 kgf·m)	
	M10 x 1.5 mm	33 - 40 ft-lb (44.1 - 53.9 N·m; 4.5 - 5.5 kgf·m)	
	M12 x 1.75 mm	58 - 72 ft-lb (78.4 - 98.0 N·m; 8.0 - 10 kgf·m)	
	M14 x 1.5 mm	94 - 108 ft-lb (127.5 - 147.1 N·m; 13 - 15 kgf·m)	
	M16 x 1.5 mm	159 - 174 ft-lb (215.7 - 235.4 N·m; 22 - 24 kgf·m)	
PT Plug	1/8	87 in.-lb (9.8 N·m; 1.0 kgf·m)	-
	1/4	173 in.-lb (19.6 N·m; 2.0 kgf·m)	
	3/8	22 ft-lb (29.4 N·m; 3.0 kgf·m)	
	1/2	43 ft-lb (58.8 N·m; 6.0 kgf·m)	

GENERAL SERVICE INFORMATION Tightening Torques for Standard Bolts and Nuts

Item	Nominal Thread Diameter x Pitch	Tightening Torque	Remarks
Pipe Joint Bolt	M8	112 - 148 in.-lb (12.7 - 16.7 N·m; 1.3 - 1.7 kgf·m)	-
	M10	173 - 225 in.-lb (19.6 - 18.734 N·m;; 2.0 - 3.5 kgf·m)	
	M12	18 - 25 ft-lb (24.5 - 34.3 N·m; 2.5 - 3.5 kgf·m)	
	M14	29 - 36 ft-lb (39.2 - 49.0 N·m; 4.0 - 5.0 kgf·m)	
	M16	36 - 43 ft-lb (49.0 - 58.8 N·m; 5.0 - 6.0 kgf·m)	

Note: Torque values shown in this manual are for clean, non-lubricated fasteners unless otherwise specified.

ABBREVIATIONS AND SYMBOLS

Abbreviations

A	ampere
AC	alternating current
ACEA	Association des Constructeurs Européens d'Automobiles
Ah	ampere-hour
API	American Petroleum Institute
ARB	Air Resources Board
ATDC	after top dead center
BTDC	before top dead center
°C	Celsius
CARB	California Air Resources Board
CCA	cold cranking amp
cm	centimeter
cm³	cubic centimeter
cm³/min	cubic centimeter per minute
cu. in.	cubic inch
DC	direct current
DI	direct injection
DVA	direct volt adapter
EPA	Environmental Protection Agency
ESG	electronic speed governor
°F	degree Fahrenheit
fl oz	fluid ounce (U.S.)
fl oz/min	fluid ounce (U.S.) per minute
ft	foot
ft-lb	foot pound*
ft-lbf/min	foot pound force per minute
g	gram
gal	gallon (U.S.)
gal/hr	gallon (U.S.) per hour
GL	gear lubricant
hp	horsepower (metric)
hrs	hours
I.D.	inside diameter
IDI	indirect injection
in.	inch
in.Aq	inches of water
in.Hg	inches of mercury
in.-lb	inch pound**
JASO	Japanese Automobile Standards Organization
kg	kilogram
kgf/cm²	kilogram force per square centimeter
kgf-cm	kilogram force centimeter
kgf-m	kilogram force meter
km	kilometers
kPa	kilopascal
kW	kilowatt
L	liter
L/hr	liter per hour
lb	pound

lbf	pound-force
lb-ft	pound foot (Tightening Torque)
lb-in.	pound inch (Tightening Torque)
min	minute
mL	milliliter
mm	millimeter
mm³/st	millimeters cubed stere
mmAq	millimeters of water
MPa	megapascal
mV	millivolt
N	newton
N-m	newton meter
No.	number
O.D.	outside diameter
oz	ounce
PS	horsepower (Deutsch)
psi	pound per square inch
qt	quart (U.S.)
rpm	revolutions per minute
SAE	Society of Automotive Engineers
sec	second
t	short ton (2000 lb)
TBN	Total Base Number
TDC	top dead center
V	volt
V AC	volt alternating current
V DC	volt direct current
W	watt
WOT	Wide-Open Throttle

Symbols

°	angular degree
+	plus
-	minus
±	plus or minus
Ω	ohm
μ	micro
%	percent
~	approximate

* Work torque such as engine torque

** Work torque such as starter motor torque

UNIT CONVERSIONS

Unit Prefixes

Prefix	Symbol	Power
mega	M	x 1,000,000
kilo	k	x 1,000
centi	c	x 0.01
milli	m	x 0.001
micro	μ	x 0.000001

Units of Length

mile	x	1.6090	= km
ft	x	0.3050	= m
in.	x	2.5400	= cm
in.	x	25.4000	= mm
km	x	0.6210	= mile
m	x	3.2810	= ft
cm	x	0.3940	= in.
mm	x	0.0394	= in.

Units of Volume

gal (U.S.)	x	3.78540	= L
qt (U.S.)	x	0.94635	= L
cu in.	x	0.01639	= L
cu in.	x	16.38700	= mL
fl oz (U.S.)	x	0.02957	= L
fl oz (U.S.)	x	29.57000	= mL
cm ³	x	1.00000	= mL
cm ³	x	0.03382	= fl oz (U.S.)

Units of Mass

lb	x	0.45360	= kg
oz	x	28.35000	= g
kg	x	2.20500	= lb
g	x	0.03527	= oz

Units of Force

lbf	x	4.4480	= N
lbf	x	0.4536	= kgf
N	x	0.2248	= lbf
N	x	0.1020	= kgf
kgf	x	2.2050	= lbf
kgf	x	9.8070	= N

Units of Torque

lb-ft	x	1.3558	= N·m
lb-ft	x	0.1383	= kgf·m
lb-in.	x	0.1130	= N·m
lb-in.	x	0.0115	= kgf·m
kgf·m	x	7.2330	= lb-ft
kgf·m	x	86.8000	= lb-in.
kgf·m	x	9.8070	= N·m
N·m	x	0.7376	= lb-ft
N·m	x	8.8510	= lb-in.
N·m	x	0.1020	= kgf·m

Units of Pressure

psi	x	0.0689	= bar
psi	x	6.8950	= kPa
psi	x	0.0703	= kgf/cm ²
bar	x	14.5030	= psi
bar	x	100.0000	= kPa
bar	x	29.5300	= in.Hg (60°F)
kPa	x	0.1450	= psi
kPa	x	0.0100	= bar
kPa	x	0.0102	= kgf/cm ²
kgf/cm ²	x	98.0700	= psi
kgf/cm ²	x	0.9807	= bar
kgf/cm ²	x	14.2200	= kPa
in.Hg (60°)	x	0.0333	= bar
in.Hg (60°)	x	3.3770	= kPa
in.Hg (60°)	x	0.0344	= kgf/cm ²

Units of Power

hp (metric or PS)	x	0.9863201	= hp SAE
hp (metric or PS)	x	0.7354988	= kW
hp SAE	x	1.0138697	= hp (metric or PS)
hp SAE	x	0.7456999	= kW
kW	x	1.3596216	= hp (metric or PS)
kW	x	1.3410221	= hp SAE

Units of Temperature

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

$$^{\circ}\text{C} = 0.556 \times (^{\circ}\text{F} - 32)$$

Section 5

PERIODIC MAINTENANCE

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SAFETY PRECAUTIONS

Before performing any maintenance procedures, review the *Safety section on page 3-1*.

INTRODUCTION

This section of the *Service Manual* describes the procedures for proper care and maintenance of the engine.

PRECAUTIONS

The Importance of Periodic Maintenance

Engine deterioration and wear occurs in proportion to length of time the engine has been in service and the conditions the engine is subject to during operation. Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.

Performing Periodic Maintenance

Perform periodic maintenance procedures in an open, level area free from traffic. If possible, perform the procedures indoors to prevent environmental conditions, such as rain, wind or snow, from damaging the machine.

Yanmar Replacement Parts

Yanmar recommends that you use genuine Yanmar parts when replacement parts are needed. Genuine replacement parts help ensure long engine life.

Required EPA/ARB Maintenance - USA Only

To maintain optimum engine performance and compliance with the Environmental Protection Agency (EPA) Regulations Non-road Engines and the California Air Resources Board (ARB, California), it is essential that you follow the *Periodic Maintenance Schedule on page 5-4* and *Periodic Maintenance Procedures on page 5-6*.

EPA/ARB Installation Requirements - USA Only

The following are the installation requirements for the EPA/ARB. Unless these requirements are met, the exhaust gas emissions will not be within the limits specified by the EPA and ARB.

Maximum Exhaust Gas Restriction shall be:

3TNM68 and 3TNM72: 1.70 psi (11.76 kPa; 1200 mmAq) or less

Maximum air intake restriction shall be 0.90 psi (6.23 kPa; 635 mmAq) or less. Clean or replace the air cleaner element if the air intake restriction exceeds the above value.

PERIODIC MAINTENANCE SCHEDULE

Daily and periodic maintenance is important to keep the engine in good operating condition. The following is a summary of maintenance items by periodic maintenance intervals. Periodic maintenance intervals vary depending on engine application, loads, diesel fuel and engine oil used and are hard to establish definitively. The following should be treated only as a general guideline.

Establish a periodic maintenance plan according to the engine application and make sure you perform the required periodic maintenance at intervals indicated.

CAUTION

Unsafe Operation Hazard

Failure to follow these guidelines will impair the engine's safety and performance characteristics, shorten the engine's life and may affect the warranty coverage on your engine. *See Yanmar Limited Warranty on page 2-3.* Consult your authorized Yanmar Industrial engine dealer or distributor for assistance when checking items marked with a ●.

NOTICE

It is important to perform daily checks. Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.

○:Check ◇:Replace ●: Contact your authorized Yanmar industrial engine dealer or distributor

System	Check Item	Daily	Periodic Maintenance Interval					
			Every 50 hours	Every 250 hours	Every 500 hours	Every 1000 hours	Every 1500 hours	Every 2000 hours
Cooling System	Check and Refill Engine Coolant	○						
	Check and Clean Radiator Fins			○				
	Check and Adjust Cooling Fan V-Belt		○1st time	○2nd and after				
	Drain, Flush and Refill Cooling System with New Coolant					◇ or every 1 yr. whichever comes first		
Cylinder Head	Adjust Intake/Exhaust Valve Clearance					●		
	Lap Intake/Exhaust Valve Seats (if required)							●
Electrical Equipment	Check Indicators	○						
	Check Battery		○					
Engine Oil	Check Engine Oil Level	○						
	Drain and Fill Engine Oil		◇1st time	◇2nd and after				
	Replace Engine Oil Filter							
Engine Speed Control	Check and Adjust Governor Lever and Engine Speed Control	○		○				
Emission Control Warranty	Inspect, Clean and Test Fuel Injectors, if necessary						●	
	Inspect Crankcase Breather System						●	
Fuel	Check Fuel Tank Level and Refill	○						
	Drain Fuel Tank			○				
	Drain Fuel Filter/Water Separator		○					
	Check Fuel Filter/Water Separator	○						
	Clean Fuel Filter/Water Separator				○			
	Replace Fuel Filter				◇			
Hoses	Replace Fuel System and Cooling System Hoses							● or every 2 yrs.
Intake and Exhaust	Clean or Replace Air Cleaner Element			○	◇			
Complete Engine	Overall Visual Check Daily	○						

Note: These procedures are considered normal maintenance and are performed at the owner's expense.

PERIODIC MAINTENANCE PROCEDURES

After Initial 50 Hours of Operation

Perform the following maintenance after the initial 50 hours of operation.

- Replacing Engine Oil and Engine Oil Filter
- Checking and Adjusting Cooling Fan V-Belt

Replacing Engine Oil and Engine Oil Filter

WARNING

Burn Hazard

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

NOTICE

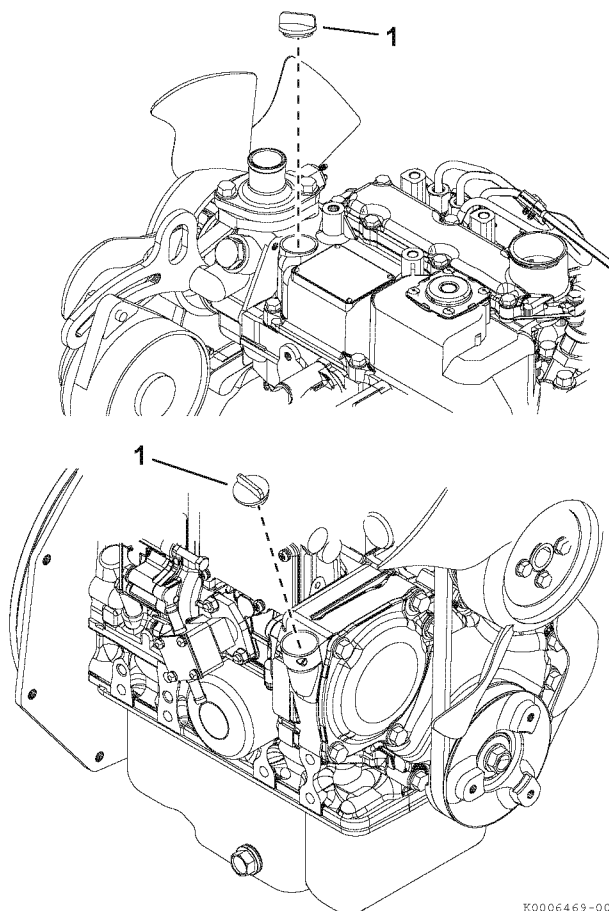
- Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize or shorten engine life.
- Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.
- Prevent dirt and debris from contaminating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

The engine oil on a new engine becomes contaminated from the initial break-in of internal parts. It is very important that the initial oil and filter change is performed as scheduled.

Note: The oil drain plug may be in another location if an optional oil pan is used.

Drain the engine oil as follows:

1. Make sure the engine is level.
2. Start the engine and bring it up to operating temperature.
3. Stop the engine.
4. Remove the oil filler cap (**Figure 5-1, (1)**) to vent the engine crankcase and allow the engine oil to drain more easily.
5. Position a container under the engine to collect waste oil.



K0006469-00X

Figure 5-1

6. Remove the oil drain plug (**Figure 5-2, (1)**). Allow oil to drain.
7. After all oil has been drained from the engine, install the oil drain plug and tighten to 39.8 to 47.0 ft-lb (53.9 to 63.7 N·m, 5.5 to 6.5 kgf·m).

8. Dispose of used oil properly.

NOTICE

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.

Remove the engine oil filter as follows:

1. Turn the engine oil filter (**Figure 5-2, (2)**) counterclockwise (**Figure 5-2, (3)**) using a filter wrench.

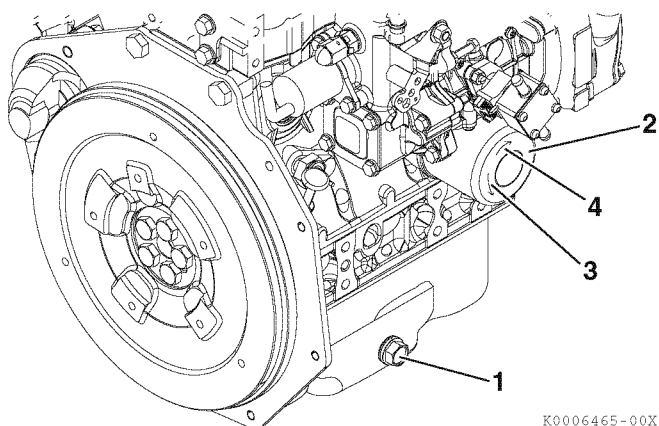


Figure 5-2

2. Clean the engine oil filter mounting face.
3. Lightly coat the gasket on the new oil filter with clean engine oil. Install the new engine oil filter manually by turning it clockwise (**Figure 5-2, (4)**) until it contacts the mounting surface. Tighten to 14 to 17 ft-lb (19.6 to 23.5 N·m, 2.0 to 2.4 kgf·m) or one additional turn using the filter wrench.

Applicable Engine Oil Filter Part No.

3TNM68	119305-35160
3TNM72	

4. Add new engine oil to the engine as specified in *Adding Engine Oil* on page 4-17.

NOTICE

Never overfill the engine with engine oil. Always keep the oil level between the upper and lower lines on the oil cap/dipstick.

Checking and Adjusting Cooling Fan V-Belt

The V-belt will slip if it does not have the proper tension. This will prevent the alternator from generating sufficient power. Also, the engine will overheat due to the engine coolant pump pulley slipping.

NOTICE

Never get any oil on the belt(s). Oil on the belt causes slipping and stretching. Replace the belt if damaged.

Check and adjust the V-belt tension (deflection) as follows:

1. Press the V-belt down with your thumb with a force of approximately 22 ft-lb (98 N·m, 10 kgf·m) to check the deflection.

There are three positions to check for V-belt tension (**Figure 5-3, (A), (B) and (C)**). You can check the tension at whichever position is the most accessible. The proper deflection of a used V-belt at each position is:

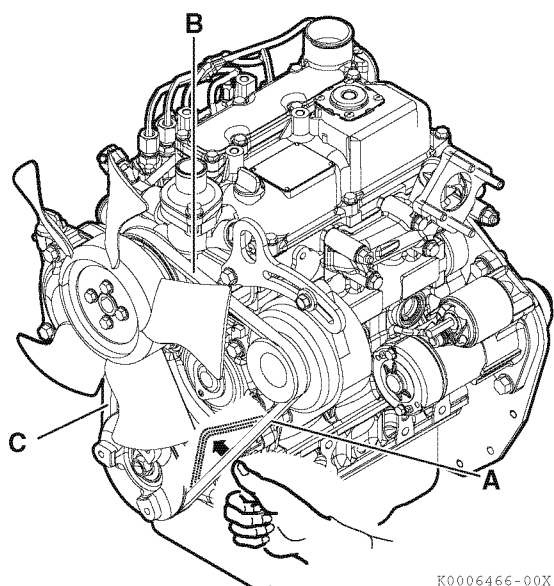


Figure 5-3

Used V-Belt Tension		
A	B	C
3/8 - 1/2 in. (10 - 14 mm)	1/4 - 3/8 in. (7 - 10 mm)	5/16 - 1/2 in. (9 - 13 mm)

- If necessary, adjust the V-belt tension. Loosen the adjusting bolt (**Figure 5-4, (1)**) and move the alternator (**Figure 5-4, (2)**) with a pry bar (**Figure 5-4, (3)**) to tighten the V-belt to the desired tension. Then tighten the adjusting bolt.

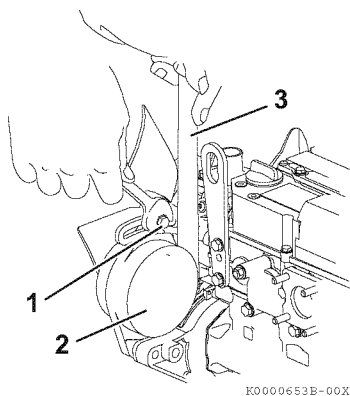


Figure 5-4

- There must be clearance (**Figure 5-5, (1)**) between the V-belt and the bottom of the pulley groove. If there is no clearance (**Figure 5-5, (2)**) between the V-belt and the bottom of the pulley groove, replace the V-belt.

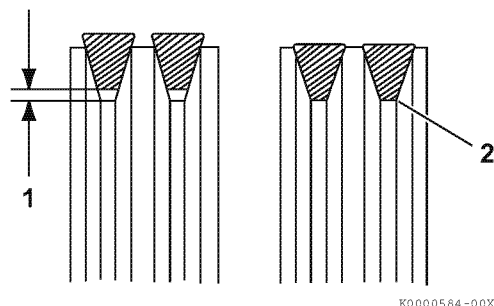


Figure 5-5

- Check the V-belt for cracks, oil or wear. If any of these conditions exist, replace the V-belt.

NOTICE

Always use the specified V-belt. Using a non-specified V-belt will cause inadequate charging and shorten the belt life.

- “New V-belt” refers to a V-belt which has been used less than 5 minutes on a running engine.
 - “Used V-belt” refers to a V-belt which has been used on a running engine for 5 minutes or more.
- If installing a new V-belt, refer to the table for proper tension.

New V-Belt Tension		
A	B	C
5/16 - 7/16 in. (8 - 12 mm)	3/16 - 5/16 in. (5 - 8 mm)	1/4 - 7/16 in. (7 - 11 mm)

- After adjusting, run the engine for 5 minutes or more. Check the tension again using the specifications for a used V-belt.

Used V-Belt Tension		
A	B	C
3/8 - 1/2 in. (10 - 14 mm)	1/4 - 3/8 in. (7 - 10 mm)	5/16 - 1/2 in. (9 - 13 mm)

Every 50 Hours of Operation

After you complete the initial 50 hour maintenance procedures, perform the following procedures every 50 hours thereafter.

- Draining Fuel Filter/Water Separator
- Checking Battery

Draining Fuel Filter/Water Separator

⚠ WARNING

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.

- When you remove any fuel system component to perform maintenance (such as changing the fuel filter), put an approved container under the opening to catch the fuel.
- Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.
- Never use diesel fuel as a cleaning agent.

⚠ WARNING

Exposure Hazard

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Drain the fuel filter/water separator whenever there are contaminants, such as water, collected in the bottom of the cup. Never wait until the scheduled periodic maintenance if contaminants are discovered.

The cup of the separator is made from semi-transparent material. In the cup is a red-colored float ring. The float ring will rise to the surface of the water to show how much needs to be drained. Also, some optional fuel filter/water separators are equipped with a sensor to detect the amount of contaminants. This sensor sends a signal to an indicator to alert the operator.

Drain the fuel filter/water separator as follows:

1. Position an approved container under the fuel filter/water separator cup (**Figure 5-6, (1)**) to collect the contaminants.

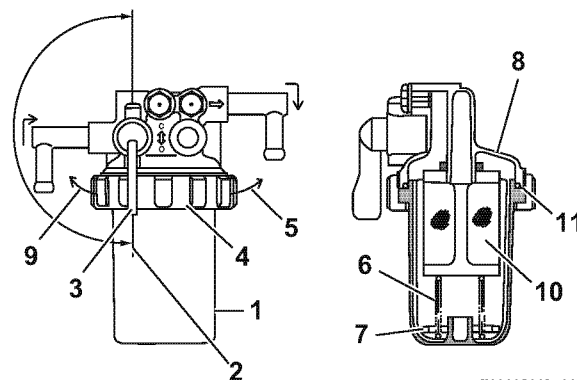


Figure 5-6

2. Turn the fuel cock (**Figure 5-6, (3)**) to the closed position (**Figure 5-6, (2)**).
3. Turn the retaining ring (**Figure 5-6, (4)**) to the left (**Figure 5-6, (9)**).
4. Carefully remove the cup. Remove the retaining spring (**Figure 5-6, (6)**) and float (**Figure 5-6, (7)**) from the cup. Pour the fuel into an approved container and dispose properly. Hold the bottom of the cup with a shop towel to prevent the fuel from dripping. Wipe up any spills immediately.

NOTICE

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.

5. Clean the inside of the cup.
6. Inspect the condition of the mesh filter (**Figure 5-6, (10)**). Clean the mesh filter if necessary.

7. Inspect the condition of the O-ring (Figure 5-6, (11)). Replace the O-ring if necessary.
8. Put the float (Figure 5-6, (7)) and retaining spring (Figure 5-6, (6)) inside the cup.
9. Install the cup to the mounting flange (Figure 5-6, (8)) and turn the retaining ring (Figure 5-6, (4)) to the right (Figure 5-6, (5)). Hand-tighten only.
10. Open the fuel cock (Figure 5-6, (3)).
11. Be sure to prime the fuel system. See *Priming the Fuel System* on page 4-14.
12. Check for fuel leaks.

⚠ WARNING

High-Pressure Hazard

**Never check for a fuel leak with your hands.
Always use a piece of wood or cardboard.**

Checking Battery

⚠ WARNING

Fire and 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.**
- **Always keep the area around the battery well-ventilated. While the engine is running or the battery is charging, hydrogen gas is produced and 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.**

⚠ WARNING

Burn Hazard

- **Batteries contain sulfuric acid. Never allow battery fluid to come in contact with clothing, skin or eyes. Severe burns will 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.**

NOTICE

Use a specialized battery charger to recharge a battery with a voltage of 8 volts or less. Booster-starting a battery with a voltage of 8 volts or less will generate an abnormally high voltage and destroy electrical equipment.

When the amount of fluid nears the lower limit (Figure 5-7, (3)), fill with distilled water (Figure 5-7, (2)) so it is at the upper limit (Figure 5-7, (1)). If operation continues with insufficient battery fluid, the battery life is shortened, and the battery may overheat and explode. During the summer, check the fluid level more often than specified.

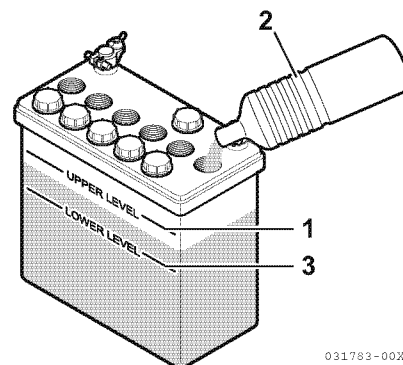


Figure 5-7

If the engine cranking speed is so slow that the engine does not start, recharge the battery.

If the engine still will not start after charging, have your authorized Yanmar Industrial engine dealer or distributor check the battery and the engine's starting system.

If operating the machine where the ambient temperature could drop to 5°F (-15°C) or less, remove the battery from the machine at the end of the day. Store the battery in a warm place until the next use. This will help start the engine easily at low ambient temperatures.

NOTICE

Do not reverse the positive (+) and negative (-) ends of the battery cable. The alternator diode and stator coil will be damaged.

Every 250 Hours of Operation

Perform the following maintenance every 250 hours of operation.

- Draining Fuel Tank
- Replacing Engine Oil and Engine Oil Filter
- Checking and Cleaning Radiator Fins
- Checking and Adjusting Cooling Fan V-Belt
- Checking and Adjusting the Governor Lever and Engine Speed Control
- Cleaning Air Cleaner Element

Draining Fuel Tank

WARNING

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.

- When you remove any fuel system component to perform maintenance (such as changing the fuel filter), put an approved container under the opening to catch the fuel.
- Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.
- Never use diesel fuel as a cleaning agent.

WARNING

Exposure Hazard

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Note that a typical fuel tank is illustrated.

1. Position an approved container under the diesel fuel tank (**Figure 5-8, (1)**) to collect the contaminates.

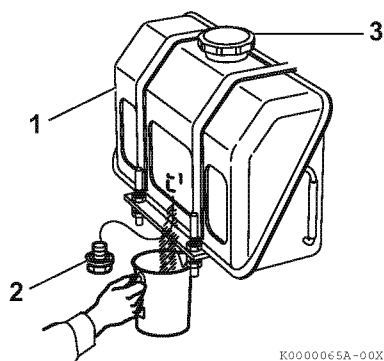


Figure 5-8

2. Remove the fuel cap (**Figure 5-8, (3)**).
3. Remove the drain plug (**Figure 5-8, (2)**) of the fuel tank to drain the contaminants (water, dirt, etc.) from the bottom of the tank.
4. Drain the tank until clean diesel fuel with no water or dirt flows out. Install and tighten the drain plug firmly.
5. Install the fuel cap.
6. Dispose of waste properly.

NOTICE

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.

7. Check for fuel leaks.

⚠ WARNING

High-Pressure Hazard

**Never check for a fuel leak with your hands.
Always use a piece of wood or cardboard.**

Replacing Engine Oil and Engine Oil Filter

⚠ WARNING

Burn Hazard

If you must drain the engine oil while it is still hot, stay clear of the hot engine oil to avoid being burned.

NOTICE

- Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize or shorten engine life.
- Never mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.
- 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 overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

Change the engine oil every 250 hours of operation after the initial change at 50 hours. Replace the engine oil filter at the same time. *See Replacing Engine Oil and Engine Oil Filter on page 5-6.*

Checking and Cleaning Radiator Fins

⚠ 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.

NOTICE

Never use high-pressure water or compressed air at greater than 28 psi (193 kPa; 19,686 mmAq) or a wire brush to clean the radiator fins. Radiator fins damage easily.

Dirt and dust adhering to the radiator fins reduce the cooling performance, causing overheating. Make it a rule to check the radiator fins daily and clean as needed.

Note that a typical radiator is shown in **Figure 5-9** for illustrative purposes only.

1. Blow off dirt and dust from fins and radiator with 28 psi (0.19 MPa; 2 kgf/cm²) or less of compressed air (**Figure 5-9, (1)**). Be careful not to damage the fins with the compressed air.
2. If there is a large amount of contamination on the fins, apply detergent, thoroughly clean and rinse with tap water.

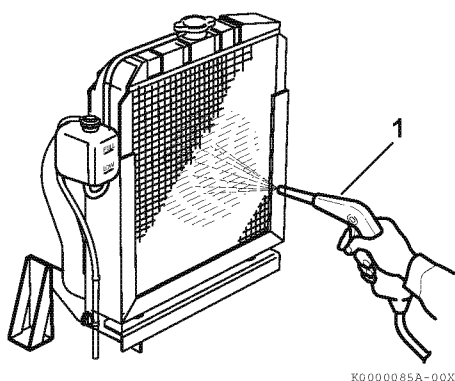


Figure 5-9

Checking and Adjusting Cooling Fan V-Belt

Check and adjust the cooling fan V-belt every 250 hours of operation after the initial 50 hour V-belt maintenance. See *Checking and Adjusting Cooling Fan V-Belt* on page 5-7.

Checking and Adjusting the Governor Lever and Engine Speed Control

The governor lever and engine speed control (throttle lever, accelerator pedal, etc.), are connected together by a cable or linkage. If the cable becomes stretched, or the linkage wears or loosens, the governor lever may not respond to a change in the position of the engine speed control.

NOTICE

Never force the throttle cable or pedal to move. This may deform the governor lever or stretch the cable and cause irregular operation of the engine speed control.

1. Check that the governor lever (**Figure 5-10, (1)**) makes firm contact with the high idle stop (**Figure 5-10, (2)**) and the low idle speed limit screw (**Figure 5-10, (3)**) when the engine speed control is in the FULL SPEED or LOW IDLE SPEED positions.
2. If the governor lever does not make proper contact with the high idle stop or the low idle speed limit screw, adjust the throttle cable or linkage as necessary.

NOTICE

- DO NOT FORCE the throttle cable or linkage to move. This may damage the governor lever, the throttle cable or linkage, and cause irregular operation of the engine speed control.
- The engine speed control (throttle lever, accelerator pedal, etc.), should be equipped with stops to prevent the application of excessive pressure by the governor lever to either the high idle stop or low idle speed limit screw.

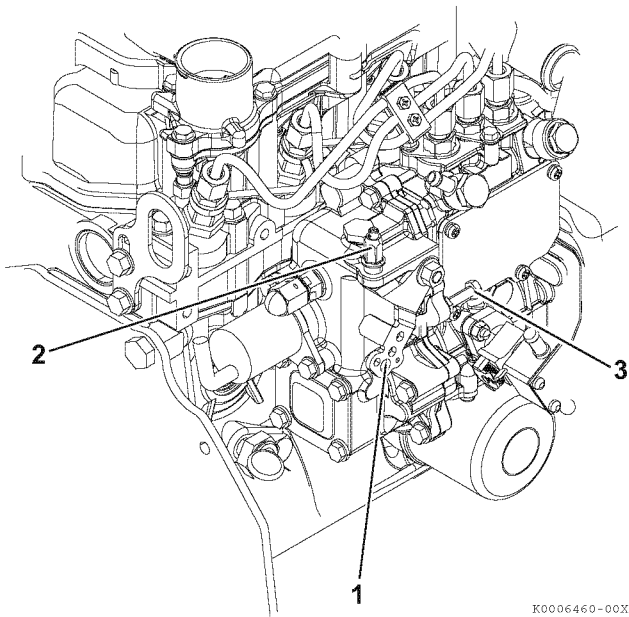


Figure 5-10

Cleaning Air Cleaner Element

NOTICE

- 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.

Note that a typical air cleaner is shown in **Figure 5-11** and **Figure 5-12** for illustrative purposes only.

The engine performance is adversely affected when the air cleaner element is clogged with dust. Be sure to clean the air filter element periodically.

1. Unlatch and remove the air cleaner cover (**Figure 5-11, (1)**).
2. Remove the element (**Figure 5-11, (2)**) (outer element only if equipped with two elements).

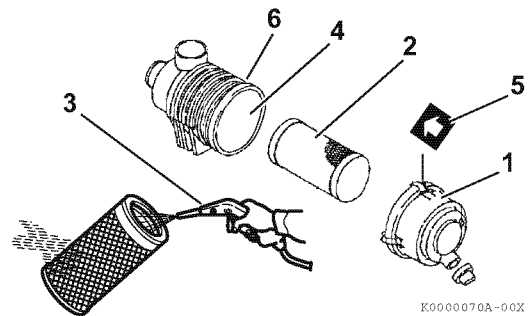


Figure 5-11

3. Blow air (**Figure 5-11, (3)**) through the element from the inside out using 42 to 71 psi (0.29 to 0.49 MPa; 3.0 to 5.0 kgf/cm²) compressed air to remove the particulates. Use the lowest possible air pressure to remove the dust without damaging the element.

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.

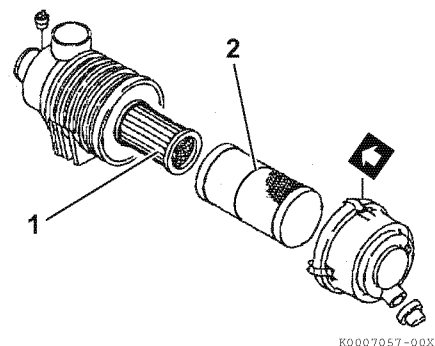


Figure 5-12

NOTICE

The inner element should not be removed when cleaning or replacing the outer element. The inner element is used to prevent dust from entering the engine while servicing the outer element.

NOTICE

If the air cleaner is equipped with a double element, **ONLY** remove and replace the inner element (**Figure 5-12, (1)**) if the engine lacks power or the dust indicator actuates (if equipped) after replacing or cleaning the outer element.

4. Replace the element with a new one if the element is damaged, excessively dirty or oily.
5. Clean inside of the air cleaner cover.
6. Install the element into the air cleaner case (**Figure 5-11, (4)**).

NOTICE

If there is a red line (**Figure 5-12, (2)**) on the outer element, insert the element until the red line and the end of the air cleaner housing align.

7. Install the air cleaner cover making sure you match the arrow (**Figure 5-11, (5)**) on the cover with the arrow on the case (**Figure 5-11, (6)**).
8. Latch the air cleaner cover to the case.

Every 500 Hours of Operation

Perform the following maintenance every 500 hours of operation.

- **Replacing Air Cleaner Element**
- **Replacing Fuel Filter**
- **Cleaning Fuel Filter/Water Separator**

Replacing Air Cleaner Element**NOTICE**

Protect the air cleaner and electric components from damage when you use steam or high-pressure water to clean the engine.

Replace the air cleaner element (**Figure 5-11, (2)**) every 500 hours even if it is not damaged or dirty.

NOTICE

The maximum air intake restriction, in terms of differential pressure measurement, must not exceed 0.90 psi (6.23 kPa; 635 mmAq). Clean or replace the air cleaner element if the air intake restriction exceeds the above value.

When replacing the element, clean the inside of the air cleaner case (**Figure 5-11, (4)**).

If the air cleaner is equipped with a double element, only remove and replace the inner element (**Figure 5-12, (1)**) if the engine lacks power or the dust indicator actuates (if equipped). This is in addition to replacing the outer element.

Replacing Fuel Filter

⚠ WARNING

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.

- When you remove any fuel system component to perform maintenance (such as changing the fuel filter), put an approved container under the opening to catch the fuel.
- Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.
- Never use diesel fuel as a cleaning agent.

⚠ WARNING

Exposure Hazard

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Replace the fuel filter at specified intervals to prevent contaminants from adversely affecting the diesel fuel flow.

1. Stop the engine and allow it to cool.
2. Close the fuel cock of the fuel filter/water separator.
3. Turn the retaining ring (Figure 5-13, (1)) to the left (Figure 5-13, (5)).

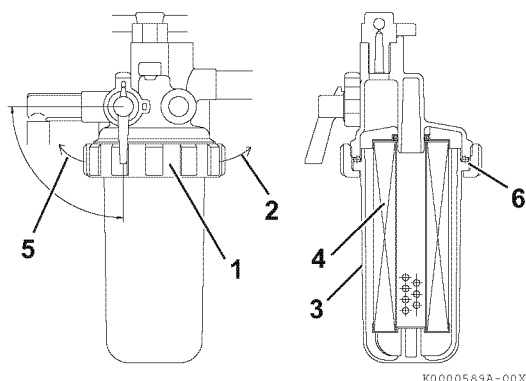


Figure 5-13

4. Carefully remove the cup (Figure 5-13, (3)), pour the fuel into an approved container and dispose of waste properly. Hold the bottom of the cup with a shop towel to prevent the fuel from dripping. Wipe up any spills immediately.

NOTICE

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.

5. Remove the element (Figure 5-13, (4)) by pulling it down.
6. Replace the element with a new one.

Applicable Fuel Filter Part No.	
3TNM68 3TNM72	129053-55620

7. Wash the inside of the cup with clean fuel.
8. Check the condition of the cup O-ring (Figure 5-13, (6)). Replace if necessary.
9. Install the cup to the mounting flange and turn the retaining ring (Figure 5-13, (1)) to the right (Figure 5-13, (2)). Hand-tighten only.
10. Open the fuel cock of the fuel filter/water separator.
11. Prime the fuel system. See *Priming the Fuel System* on page 4-14.
12. Check for fuel leaks.

⚠ WARNING

High-Pressure Hazard

High-Pressure Hazard. Never check for a fuel leak with your hands. Always use a piece of wood or cardboard.

Cleaning Fuel Filter/Water Separator

WARNING

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.

- When you remove any fuel system component to perform maintenance (such as changing the fuel filter), put an approved container under the opening to catch the fuel.
- Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.
- Never use diesel fuel as a cleaning agent.

WARNING

Exposure Hazard

Always wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Periodically clean the fuel filter/water separator element and the inside of the cup.

NOTICE

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.

1. Position an approved container under the cup (Figure 5-14, (1)) of the fuel filter/water separator to collect the contaminants.

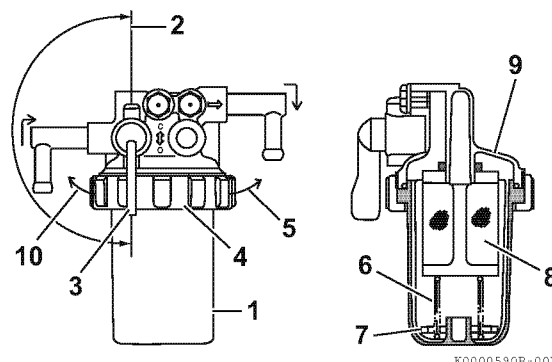


Figure 5-14

2. Close (Figure 5-14, (2)) the fuel cock (Figure 5-14, (3)).
3. Turn the retaining ring (Figure 5-14, (4)) to the left (Figure 5-14, (10)).
4. Carefully remove the cup and pour the fuel into an approved container and dispose of properly. Hold the bottom of the cup with a shop towel to prevent the fuel from dripping. Wipe up any spills immediately.
5. Keep the retaining spring (Figure 5-14, (6)) and float (Figure 5-14, (7)) nearby for assembly.
6. Remove the element (Figure 5-14, (8)) by pulling it down.
7. Replace the element with a new one.

Applicable Element Part No.	
3TNM68 3TNM72	119810-55650

8. Wash the inside of the cup with clean diesel fuel.
9. Check the condition of the cup O-ring. Replace if necessary.
10. Put the float (Figure 5-14, (7)) and retaining spring (Figure 5-14, (6)) inside the cup.
11. Install the cup to the mounting flange (Figure 5-14, (9)) and turn the retaining ring (Figure 5-14, (4)) to the right (Figure 5-14, (5)). Hand-tighten only.

12. Open the fuel cock (Figure 5-14, (3)).
13. Prime the fuel system. *See Priming the Fuel System on page 4-14.*
14. Check for fuel leaks.

WARNING

High-Pressure Hazard

High-Pressure Hazard. Never check for a fuel leak with your hands. Always use a piece of wood or cardboard.

Every 1000 Hours of Operation

Perform the following maintenance every 1000 hours of operation.

- Draining, Flushing and Refilling Cooling System with New Coolant
- Adjusting Intake/Exhaust Valve Clearance

Draining, Flushing and Refilling Cooling System with New Coolant

WARNING

Scald Hazard

Always check the level of engine coolant by observing the reserve tank.

WARNING

Burn Hazard

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

CAUTION

Exposure Hazard

Always wear eye protection and rubber gloves when you handle Long Life Coolant (LLC) or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

NOTICE

- Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale, and/or shorten engine life.
 - Never mix different types of engine coolant. This may adversely affect the properties of the engine coolant.
-

Engine coolant contaminated with rust or scale reduces the cooling effect. Even when extended life engine coolant is properly mixed, the engine coolant gets contaminated as its ingredients deteriorate. Drain, flush and refill the cooling system with new coolant every 1000 hours or once a year, whichever comes first.

1. Allow engine and coolant to cool.

⚠ WARNING

Scald Hazard

Scald Hazard. Never remove the radiator cap if the engine is hot. Steam and hot engine coolant will spray out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.

2. Remove the radiator cap (Figure 5-15, (1)).

NOTICE

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and surrounding area before you remove the cap.

3. Remove the drain plug or open the drain cock (Figure 5-15, (2)) at the lower position of the radiator and drain the engine coolant.

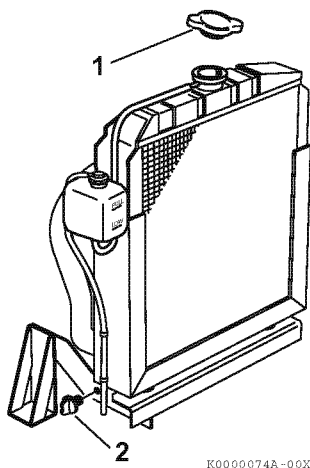


Figure 5-15

4. Drain the coolant from the engine block. Remove the coolant drain plug (Figure 5-16, (1)) from the engine block.

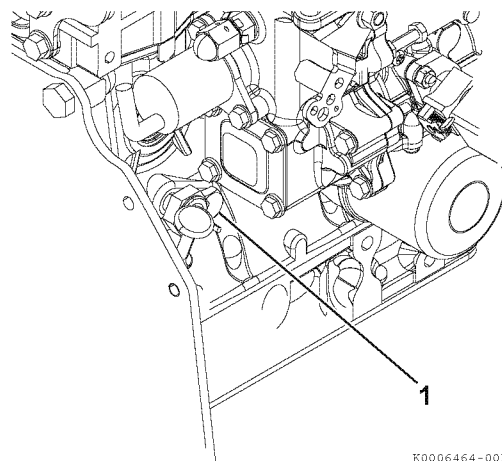


Figure 5-16

5. After draining the engine coolant, flush the radiator and engine block to remove any rust, scale and contaminants.

NOTICE

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.

6. Install and tighten the drain plug or close the drain cock at the radiator. Install and tighten the engine block drain plug.

7. Fill radiator and engine with engine coolant.
See Filling Radiator with Engine Coolant on page 4-18.

⚠ WARNING

Scald Hazard

Always tighten the radiator cap securely after you check the radiator. Steam can escape during engine operation if the cap is loose.

Adjusting Intake/Exhaust Valve Clearance

Proper adjustment is necessary to maintain the correct timing for opening and closing the valves. Improper adjustment will cause the engine to run noisily, resulting in poor engine performance and engine damage. *See Measuring and Adjusting Valve Clearance on page 6-30.*

Every 1500 Hours of Operation

Perform the following maintenance every 1500 hours of operation.

- Inspecting, Cleaning and Testing Fuel Injectors, if necessary
- Inspecting Crankcase Breather System

Inspecting, Cleaning and Testing Fuel Injectors

⚠ WARNING

Exposure Hazard

- Always 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.

Proper operation of the fuel injectors is required to obtain the optimum injection pattern for full engine performance. The EPA/ARB requires that the fuel injectors are inspected, cleaned and tested every 1500 hours. *See Testing the Fuel Injectors on page 7-23.*

This procedure is considered normal maintenance and is performed at the owner's expense. This procedure is not covered by the Yanmar Limited Warranty.

Inspecting Crankcase Breather System

Proper operation of the crankcase breather system is required to maintain the emission requirements of the engine. The EPA/ARB requires that the crankcase breather system is inspected every 1500 hours.

The TNM engines use a crankcase breather system that has a spring-backed diaphragm (**Figure 5-17, (1)**) in the valve cover (**Figure 5-17, (2)**). When the crankcase pressure reaches a predetermined value, the diaphragm opens a passage that allows crankcase fumes to be routed to the intake manifold.

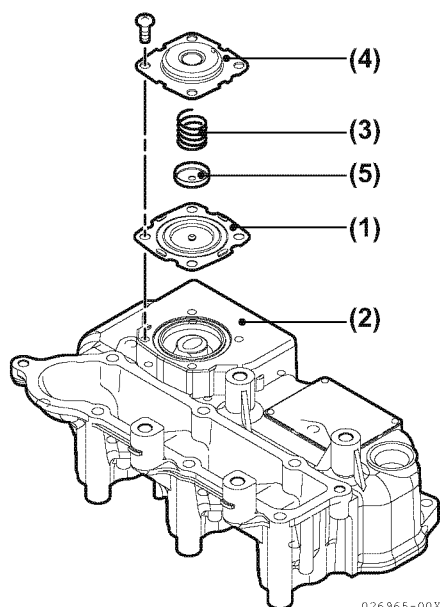


Figure 5-17

To inspect the diaphragm and spring (**Figure 5-17, (3)**):

1. Remove the bolts retaining the diaphragm cover (**Figure 5-17, (4)**).
2. Remove the diaphragm cover, spring, diaphragm plate (**Figure 5-17, (5)**) and diaphragm.
3. Inspect the diaphragm for tears. Inspect the spring for distortion. Replace components if necessary.

4. Install the diaphragm, diaphragm plate, spring and diaphragm cover. Tighten the diaphragm bolts to the specified torque. See *Tightening Torques for Standard Bolts and Nuts* on page 4-25.

NOTICE

Failure of the diaphragm and/or spring will cause the loss of pressure control and allow an excessive amount of crankcase fumes to be routed to the intake manifold. This could result in excessive deposits in the intake system, high engine exhaust smoke levels, excessive engine oil consumption and/or engine run-on due to the burning of the engine oil.

Every 2000 Hours of Operation

Perform the following maintenance every 2000 hours of operation.

- **Checking and Replacing Fuel Hoses and Engine Coolant Hoses**
- **Lapping the Intake and Exhaust Valves**

Checking and Replacing Fuel Hoses and Engine Coolant Hoses

Regularly check the fuel system and engine coolant system hoses. If they are cracked or degraded, replace them. Replace the hoses at least every 2 years. *See Checking and Replacing Fuel Hoses and Engine Coolant Hoses on page 5-22.*

NOTICE

Replace rubberized fuel hoses every 2 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 2 years or 2000 hours of engine operation, whichever comes first.

Lapping the Intake and Exhaust Valves

Adjustment is necessary to maintain proper contact of the valves and seats. *See Inspecting the Intake and Exhaust Valves on page 6-23.*

Section 6

ENGINE

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SAFETY PRECAUTIONS

Before performing any engine service procedures, review the following message and the *Safety section on page 3-1*.

NOTICE

Always protect the air cleaner and electric components, including the relays and harness couplers, from damage when you use steam or high-pressure water to clean the engine.

INTRODUCTION

This section of the *Service Manual* describes servicing of the engine.

CYLINDER HEAD SPECIFICATIONS

Adjustment Specifications

Model	Valve Clearance
All	0.006 - 0.010 in. (0.15 - 0.25 mm)

Cylinder Head

Inspection Item		Standard	Limit	Reference Page
Top of Piston to Cylinder Head Surface Clearance	3TNM68	0.0269 - 0.0326 in. (0.684 - 0.828 mm)	-	-
	3TNM72	0.0270 - 0.0326 in. (0.685 - 0.828 mm)	-	
Combustion Surface Distortion (Flatness)		0.0020 in. (0.05 mm) or less	0.0059 in. (0.15 mm)	See Valve Recession on page 6-23
Valve Recession	Intake	0.0157 - 0.0236 in. (0.4 - 0.6 mm)	0.0354 in. (0.9 mm)	
	Exhaust	0.0157 - 0.0236 in. (0.4 - 0.6 mm)	0.0315 in. (0.8 mm)	
Valve Seat	Seat Angle	Intake	120°	See Valve Face and Valve Seat on page 6-24
		Exhaust	90°	
	Seat Correction Angle		40°, 150°	

Intake / Exhaust Valve and Guide

Inspection Item		Standard		Limit		Reference Page
		3TNM68	3TNM72	3TNM68	3TNM72	
Intake	Guide Inside Diameter	0.2165 - 0.2172 in. (5.500 - 5.516 mm)	0.2362 - 0.2367 in. (6.000 - 6.012 mm)	0.2197 in. (5.580 mm)	0.2394 in. (6.080 mm)	See Inspecting the Valve Springs on page 6-24
	Valve Stem Outside Diameter	0.2152 - 0.2157 in. (5.465 - 5.480 mm)	0.2346 - 0.2356 in. (5.960 - 5.985 mm)	0.2126 in. (5.400mm)	0.2323in. (5.900mm)	
	Oil Clearance	0.0008 - 0.0020 in. (0.020 - 0.051 mm)	0.0006 - 0.0020 in. (0.015 - 0.052 mm)	0.0063 in. (0.15 mm)	0.0063 in. (0.15 mm)	
	Valve Stem Bend	-		0.0004 in. (0.010 mm)		
Exhaust	Guide Inside Diameter	0.2165 - 0.2172 in. (5.500 - 5.516 mm)	0.2362 - 0.2367 in. (6.000 - 6.012 mm)	0.2197 in. (5.580 mm)	0.2394 in. (6.080 mm)	
	Valve Stem Outside Diameter	0.2144 - 0.2150 in. (5.445 - 5.460 mm)	0.2341 - 0.2350 in. (5.945 - 5.970 mm)	0.2126 in. (5.40 mm)	0.2323 in. (5.90 mm)	
	Oil Clearance	0.0016 - 0.0028 in. (0.040 - 0.071 mm)	0.0012 - 0.0026 in. (0.030 - 0.067 mm)	0.0067 in. (0.17 mm)	0.0067 in. (0.17 mm)	
	Valve Stem Bend	-		0.0004 in. (0.010 mm)		
Valve Guide Projection from Cylinder Head		0.3268 - 0.3445 in. (8.30 - 8.75 mm)	0.3858 - 0.3937 in. (9.8 - 10.0 mm)	-		See Assembling the Valve Guides on page 6-25
Valve Stem Seal Projection from Cylinder Head		0.484 in. (12.3 mm)	0.543 in. (13.8 mm)	-		
Valve Guide Installation Method		Cold-fitted		-		

Push Rod

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Push Rod Bend	Less than 0.0012 in. (0.03 mm)		0.0012 in. (0.03 mm)		See Push Rod Bend on page 6-21

Valve Spring

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Free Length	1.3268 in. (33.7 mm)	1.4882 in. (37.8 mm)	-		See Inspecting the Valve Springs on page 6-24
Squareness	-		0.0512 in. (1.3 mm)		

Rocker Arm and Shaft

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Arm Shaft Hole Diameter	0.3937 - 0.3945 in. (10.000 - 10.020 mm)	0.4724 - 0.4732 in. (12.000 - 12.020 mm)	0.3965 in. (10.07 mm)	0.4752 in. (12.07 mm)	See Inspecting the Rocker Arm Assembly on page 6-21
Shaft Outside Diameter	0.3925 - 0.3933 in. (9.97 - 9.99 mm)	0.4711 - 0.4718 in. (11.966 - 11.984 mm)	0.3913 in. (9.94 mm)	0.4701 in. (11.94 mm)	
Oil Clearance	0.0004 - 0.0020 in. (0.010 - 0.050 mm)	0.0006 - 0.0021 in. (0.016 - 0.054 mm)	0.0051 in. (0.13 mm)	0.0051 in. (0.13 mm)	

CAMSHAFT AND TIMING GEAR TRAIN SPECIFICATIONS

Camshaft

Inspection Item			Standard		Limit		Reference Page
			3TNM68	3TNM72	3TNM68	3TNM72	
End Play			0.0020 - 0.0059 in. (0.05 - 0.15 mm)		0.0098 in. (0.25 mm)		See Removing the Camshaft on page 6-37
Bend			0 - 0.0008 in. (0 - 0.02 mm)		0.0020 in. (0.05 mm)		
Cam Lobe Height			1.2100 - 1.2152 in. (30.735 - 30.865 mm)	1.3596 - 1.3648 in. (34.535 - 34.665 mm)	1.2287 in. (31.21 mm)	1.3499 in. (34.287 mm)	See Inspecting the Camshaft on page 6-47
Shaft Outside Diameter /Bearing Inside Diameter	Gear End	Inside Diameter	1.4173 - 1.4183 in. (36.000 - 36.025 mm)	1.5748 - 1.5758 in. (40.000 - 40.025 mm)	1.5807 in. (40.150 mm)	1.5787 in. (40.100 mm)	
		Camshaft Outside Diameter	1.4150 - 1.4157 in. (35.940 - 35.960 mm)	1.5724 - 1.5732 in. (39.940 - 39.960 mm)	1.4138 in. (35.911 mm)	1.5711 in. (39.906 mm)	
		Oil Clearance	0.0016 - 0.0033 in. (0.04 - 0.085 mm)		0.0061 in. (0.154 mm)		
	Interme- diate	Inside Diameter	1.4173 - 1.4183 in. (36.000 - 36.025 mm)	1.5748 - 1.5758 in. (40.000 - 40.025 mm)	1.4210 in. (36.093 mm)	1.5787 in. (40.100 mm)	
		Camshaft Outside Diameter	1.4138 - 1.4148 in. (35.910 - 35.935 mm)	1.5713 - 1.5722 in. (39.910 - 39.935 mm)	1.4126 in. (35.881mm)	1.5699 in. (39.875 mm)	
		Oil Clearance	0.0026 - 0.0045 in. (0.065 - 0.115 mm)		0.0089 in. (0.225 mm)		
	Flywheel End	Inside Diameter	1.4173 - 1.4183 in. (36.000 - 36.025 mm)	1.5748 - 1.5758 in. (40.000 - 40.025 mm)	1.4209 in. (36.092 mm)	1.5787 in. (40.100 mm)	
		Camshaft Outside Diameter	1.4150 - 1.4157 in. (35.940 - 35.960 mm)	1.5724 - 1.5732 in. (39.940 - 39.960 mm)	1.4138 in. (35.911 mm)	1.5711 in. (39.906 mm)	
		Oil Clearance	0.0016 - 0.0033 in. (0.040 - 0.085 mm)		0.0061 in. (0.154 mm)		

Idler Gear Shaft and Bushing

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Shaft Outside Diameter	1.1795 - 1.1803 in. (29.959 - 29.980 mm)		1.1779 in. (29.919 mm)		See Inspecting the Idler Gear and Shaft on page 6-48
Bushing Inside Diameter	1.1811 - 1.1821 in. (30.000 - 30.025 mm)		1.1837 in. (30.066 mm)		
Oil Clearance	0.0008 - 0.0026 in. (0.020 - 0.066 mm)		0.0058 in. (0.147mm)		

Timing Gear Backlash

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Crank Gear, Cam Gear, Idler Gear, Fuel Injection Pump Gear	0.0024 - 0.0047 in. (0.06 - 0.12 mm)		0.0055 in. (0.14 mm)		See Checking Timing Gear Backlash on page 6-34

CRANKSHAFT AND PISTON SPECIFICATIONS

Crankshaft

Note: Check appropriate parts catalog for undersized replacement main bearing inserts.

Inspection Item		Standard		Limit		Reference Page
		3TNM68	3TNM72	3TNM68	3TNM72	
Bend		-		0.0008 in. (0.02 mm)		See Inspecting the Crankshaft on page 6-46
Roundness		0.0004 in. (0.01 mm) or less		0.0008 in. (0.02 mm)		
Connecting Rod Journals	Journal Outside Diameter	1.4942 - 1.4946 in. (37.952 - 37.962 mm)		1.4725 in. (37.402 mm)		
	Bearing Inside Diameter	1.4954 - 1.4965 in. (37.982 - 38.010 mm)		-		
	Bearing Insert Thickness	0.0592 - 0.0594 in. (1.503 - 1.509 mm)		-		
	Oil Clearance	0.0008 - 0.0023 in. (0.020 - 0.058 mm)		0.0043 in. (0.110 mm)		

(Crankshaft Cont.)

Inspection Item		Standard		Limit		Reference Page
		3TNM68	3TNM72	3TNM68	3TNM72	
Main Bearing Journal	Journal Outside Diameter	1.7311 - 1.7315 in. (43.970 - 43.980 mm)		1.7293 in. (43.924 mm)		See Inspecting the Crankshaft on page 6-46
	Bearing Inside Diameter	1.7328 - 1.7338 in. (44.014 - 44.038 mm)		-		
	Bearing Insert Thickness	0.0786 - 0.0791 in. (1.996 - 2.008 mm)		-		
	Oil Clearance	0.0013 - 0.0027 in. (0.034 - 0.068 mm)		0.0047 in. (0.120 mm)		

Crankshaft Reconditioning

Item	Finishing Precision	Reference Page
Connecting Rod Journal Undersize Finished Size	1.4853 - 1.4857 in. (37.726 - 37.736 mm)	See Reconditioning the Crankshaft on page 6-47
Main Bearing Journal Undersize Finished Size	1.7219 - 1.7223 in. (43.736 - 43.746 mm)	
Journal Radius	0.138 - 0.150 in. (3.5 - 3.8 mm)	
Journal Face Finish	0.8S (Super Polish)	
Thrust Face Finish	1.6	

Thrust Bearing

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Crankshaft End Play - All Models	0.0044 - 0.0098 in. (0.111 - 0.250 mm)		0.0110 in. (0.28 mm)		See Removing the Crankshaft on page 6-40
Bearing Thickness	0.0760 - 0.0780 in. (1.930 - 1.980 mm)		0.0728 in. (1.850 mm)		

Piston

Inspection Item		Standard		Limit		Reference Page
		3TNM68	3TNM72	3TNM68	3TNM72	
Piston Outside Diameter		2.6756 - 2.6768 in. (67.961 - 67.991 mm)	2.8331 - 2.8343 in. (71.960 - 71.990 mm)	3.8550 in. (97.916 mm)	2.8313 in. (71.915 mm)	See Inspecting the Pistons, Piston Rings and Wrist Pin on page 6-43
Piston Diameter Measurement Location		0.3937 - 0.5118 in. (10 - 13 mm)		-		
Piston-to-Cylinder Clearance		0.0004 - 0.0027 in. (0.009 - 0.069 mm)	0.0004 - 0.0028 in. (0.010 - 0.070 mm)	-		
Wrist Pin	Hole Inside Diameter	0.7874 - 0.7877 in. (20.000 - 20.008 mm)	0.8661 - 0.8665 in. (22.000 - 22.009 mm)	0.7889 in. (20.039 mm)	0.8677 in. (22.039 mm)	
	Pin Outside Diameter	0.7872 - 0.7874 in. (19.995 - 20.000 mm)	0.8659 - 0.8661 in. (21.995 - 22.000 mm)	0.7860 in. (19.965 mm)	0.8648 in. (21.965 mm)	
	Oil Clearance	0.0000 - 0.0005 in. (0.000 - 0.013 mm)	0.0000 - 0.0006 in. (0.000 - 0.014 mm)	0.0029 in. (0.074 mm)	0.0029 in. (0.074 mm)	

Piston Ring

Inspection Item		Standard		Limit		Reference Page
		3TNM68	3TNM72	3TNM68	3TNM72	
Top Compression Ring	Ring Groove Width	0.0610 - 0.0618 in. (1.550 - 1.570 mm)		-		See Inspecting the Pistons, Piston Rings and Wrist Pin on page 6-43
	Ring Width	0.0579 - 0.0587 in. (1.470 - 1.490 mm)		0.0571 in. (1.450 mm)		
	Side Clearance	0.0024 - 0.0039 in. (0.060 - 0.100 mm)		-		
	End Clearance	0.0059 - 0.0118 in. (0.150 - 0.300 mm)	0.0039 - 0.0098 in. (0.100 - 0.250 mm)	0.0154 in. (0.390 mm)	0.0013 in. (0.034 mm)	
Middle Compression Ring	Ring Groove Width	0.0622 - 0.0628 in. (1.580 - 1.595 mm)		0.0667 in. (1.695 mm)		
	Ring Width	0.0579 - 0.0587 in. (1.470 - 1.490 mm)		0.0571 in. (1.450 mm)		
	Side Clearance	0.0035 - 0.0049 in. (0.090 - 0.125 mm)		0.0096 in. (0.245 mm)		
	End Clearance	0.0098 - 0.0157 in. (0.250 - 0.400 mm)		0.0193 in. (0.490 mm)		
Oil Control Ring	Ring Groove Width	0.1185 - 0.1191 in. (3.010 - 3.025 mm)		0.1232 in. (3.130 mm)		
	Ring Width	0.1170 - 0.1177 in. (2.970 - 2.990 mm)		0.1161 in. (2.950 mm)		
	Side Clearance	0.0008 - 0.0022 in. (0.020 - 0.055 mm)		0.0071 in. (0.180 mm)		
	End Clearance	0.0059 - 0.0138 in. (0.150 - 0.350 mm)	0.0079 - 0.0177 in. (0.200 - 0.450 mm)	0.0173 in. (0.440 mm)	0.0217 in. (0.550 mm)	

Connecting Rod

Connecting Rod Small End

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Wrist Pin Bushing Inside Diameter	0.7884 - 0.7891 in. (20.025 - 20.042 mm)	0.8671 - 0.8678 in. (22.025 - 22.042 mm)	0.7902 in. (20.072 mm)	0.7902 in. (20.072 mm)	See Inspecting the Connecting Rod on page 6-45
Wrist Pin Outside Diameter	0.7872 - 0.7874 in. (19.995 - 20.000 mm)	0.8659 - 0.8661 in. (21.995 - 22.000 mm)	0.7861 in. (19.967 mm)	0.7861 in. (19.967 mm)	
Oil Clearance	0.0010 - 0.0019 in. (0.025 - 0.047 mm)		0.0041 in. (0.105 mm)		

Connecting Rod Big End

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Side Clearance	0.0079 - 0.0157 in. (0.20 - 0.40 mm)		-		See Inspecting the Connecting Rod on page 6-45
Bearing Inside Diameter and Oil Clearance	See Crankshaft on page 6-6		-		

Connecting Rod Distortion

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Twist and Bend per 3.937 in.(100 mm)	Less than 0.001 in. (0.03 mm)		0.003 in. (0.08 mm)		See Inspecting the Connecting Rod on page 6-45

Tappet

Inspection Item	Standard		Limit		Reference Page
	3TNM68	3TNM72	3TNM68	3TNM72	
Tappet Bore (Block) Inside Diameter	0.7087 - 0.7094 in. (18.000 - 18.018 mm)	0.8268 - 0.8276 in. (21.000 - 21.021 mm)	0.7102 in. (18.038 mm)	0.8284 in. (21.041 mm)	See Inspecting the Tappets on page 6-46
Tappet Stem Outside Diameter	0.7067 - 0.7074 in. (17.950 - 17.968 mm)	0.8239 - 0.8252 in. (20.927 - 20.960 mm)	0.7059 in. (17.930mm)	0.8231 in. (20.907 mm)	
Oil Clearance	0.0013 - 0.0027 in. (0.032 - 0.068 mm)	0.0016 - 0.0037 in. (0.040 - 0.094 mm)	0.0043 in. (0.108 mm)	0.0053 in. (0.134 mm)	

CYLINDER BLOCK SPECIFICATIONS

Cylinder Block

Inspection Item		Standard		Limit		Reference Page
		3TNM68	3TNM72	3TNM68	3TNM72	
Cylinder Inside Bore		2.6772 - 2.6783 in. (68.000 - 68.030 mm)	2.8346 - 2.8358 in. (72.000 - 72.030 mm)	2.6850 in. (68.200 mm)	2.8425 in. (72.200 mm)	See Inspecting the Cylinder Block on page 6-43
Cylinder Bore	Roundness	0.0004 in. (0.01 mm) or less		0.0012 in. (0.03 mm)		
	Taper					

SPECIAL TORQUE CHART

Tightening Torque for Special Bolts

Component		Model	Thread Diameter and Pitch	Tightening Torque	Lubricating Oil Application	Reference Page
Cylinder Head Bolts		3TNM68	M8 x 1.25 mm	31 - 34 ft-lb (42.1 - 46.1 N·m; 4.3 - 4.7 kgf·m)	Applied	See Assembling the Cylinder Head on page 6-27
		3TNM72	M9 x 1.25 mm	40 - 43 ft-lb (53.9 - 57.9 N·m; 5.5 - 5.9 kgf·m)	Applied	
Connecting Rod Bolts			M7 x 1.0 mm	17 - 20 ft-lb (22.6 - 27.5 N·m; 2.3 - 2.8 kgf·m)	Applied	See Installing the Pistons on page 6-54
Flywheel Bolts			M10 x 1.25 mm	59 - 64 ft-lb (80.4 - 86.4 N·m; 8.2 - 8.8 kgf·m)	Applied	See Installing the Crankshaft on page 6-52
Crankshaft Pulley Bolts	Cast		M12 x 1.25 mm	61 - 69 ft-lb (83.4 - 93.1 N·m; 8.5 - 9.5 kgf·m)	Applied	See Installing the Crankshaft on page 6-52
	Forged			83 - 90 ft-lb (113 - 123 N·m; 11.5 - 12.5 kgf·m)		
Glow Plug			M10 x 1.25 mm	11 - 15 ft-lb (14.7 - 19.6 N·m; 1.5 - 2.0 kgf·m)	Not Applied	See Assembling the Intake Manifold/Valve Cover on page 6-29
			M4 x 0.7 mm	1.1 - 1.4 ft-lb (1.5 - 2.0 N·m; 0.15 - 0.20 kgf·m)	Not Applied	
Main Cap Bolt			M9 x 1.25 mm	33 ± 1.5 ft-lb (45 ± 2 N·m; 4.6 ± 0.2 kgf·m)	Applied	-
Ladder Frame Bolt			M9 x 1.25 mm	33 ± 1.5 ft-lb (45 ± 2 N·m; 4.6 ± 0.2 kgf·m)	Applied	-
Fuel Injection Nozzle Nut			M20 x 1.5 mm	36 - 39 ft-lb (49.0 - 52.9 N·m; 5.0 - 5.4 kgf·m)	Not Applied	-
Fuel High Pressure Pipe Nut			M12 x 1.5 mm	22 - 25 ft-lb (29.4 - 34.3 N·m; 3.0 - 3.5 kgf·m)	Not Applied	-
Fuel Pump Gear Bolt			M8 x 1.0 mm	24 - 27 ft-lb (32.3 - 36.3 N·m; 3.3 - 3.7 kgf·m)	Not Applied	-
Fuel Pump End Nut			M12 x 1.25 mm	43 - 51 ft-lb (58.8 - 68.6 N·m; 6.0 - 7.0 kgf·m)	Applied	-
Oil Sump Bolts			M6 x 1.0 mm	7.4 ± 0.7 ft-lb (10 ± 1 N·m; 1.0 ± 0.1 kgf·m)	Applied	-

See Tightening Torques for Standard Bolts and Nuts on page 4-25 for standard hardware torque values.

Note: Torx bolts are used for oil sump mounting bolts and rudder frame mounting bolts.

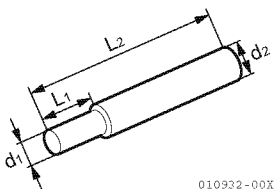
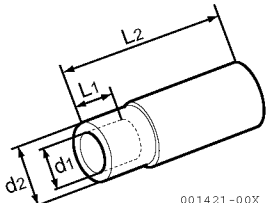
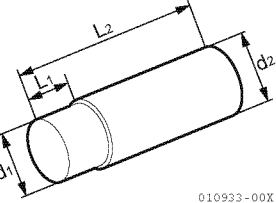
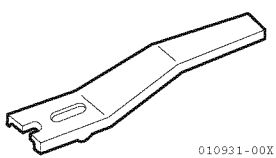
Specialized tool (Torx bolt wrench) is required.

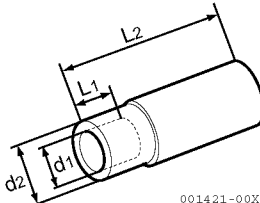
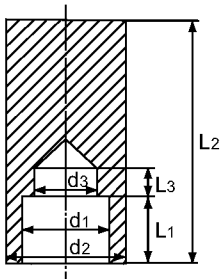
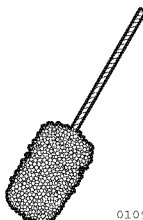
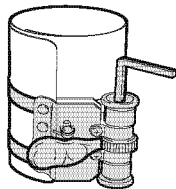
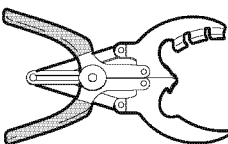
Oil Sump Bolts: TORX E8

Ladder Frame: TORX E12

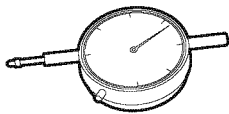
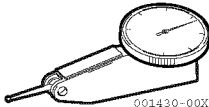
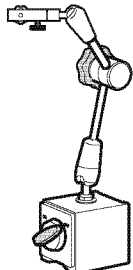
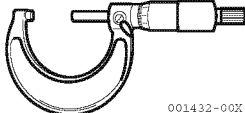
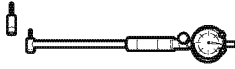

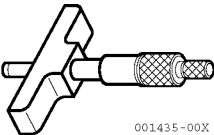
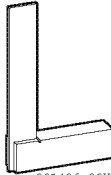
SPECIAL SERVICE TOOLS

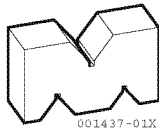
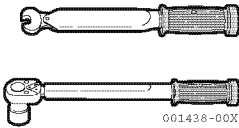
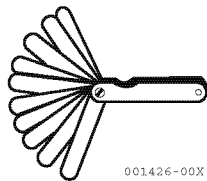
Note: Tools without Yanmar part numbers must be acquired locally.

No	Tool Name	Applicable Model and Tool Size				Illustration
1	Valve Guide Tool (For Removing Valve Guides)					 010932-00X
		L1	L2	d1	d2	
		0.787 in. (20 mm)	2.953 in. (75 mm)	0.217 in. (5.5 mm)	0.374 in. (9.5 mm)	
		Locally Manufactured				
2	Valve Guide Tool (For Installing Valve Guides)					 001421-00X
		L1	L2	d1	d2	
		3TNM68 : 0.335 in. (8.5 mm) 3TNM72 : 0.394 in. (10 mm)	2.362 in. (60 mm)	0.433 in. (11 mm)	0.669 in. (17 mm)	
		Locally Manufactured		Allowance L1: 0 to -0.0118 in. (0 to -0.3 mm)		
3	Wrist Pin Bushing Tool (For Removing / Installing Wrist Pin Bushings)					 010933-00X
		L1	L2	d1	d2	
		0.984 in. (25 mm)	3.346 in. (85 mm)	3TNM68 : 0.787 in. (20 mm) 3TNM72 : 0.866 in. (22 mm)	0.984 in. (25 mm)	
		Locally Manufactured		Allowance d1: -0.0118 to -0.0236 in. (-0.3 to -0.6 mm)	Allowance d2: -0.0118 to -0.0236 in. (-0.3 to -0.6 mm)	
4	Valve Spring Compressor (For Removing / Installing Valve Springs)	Yanmar Part No. 129100-92630				 010931-00X

No	Tool Name	Applicable Model and Tool Size						Illustration												
5	Stem Seal Tool (For Installing Stem Seals)	<table><tr><td>d1</td><td>d2</td><td>d3</td><td>L1</td><td>L2</td><td>L3</td></tr><tr><td>0.591 in. (15 mm)</td><td>0.827 in. (21 mm)</td><td>0.472 in. (12 mm)</td><td>0.433 in. (11 mm)</td><td>2.559 in. (65 mm)</td><td>0.157 in. (4 mm) or more</td></tr></table>						d1	d2	d3	L1	L2	L3	0.591 in. (15 mm)	0.827 in. (21 mm)	0.472 in. (12 mm)	0.433 in. (11 mm)	2.559 in. (65 mm)	0.157 in. (4 mm) or more	 
		d1	d2	d3	L1	L2	L3													
0.591 in. (15 mm)	0.827 in. (21 mm)	0.472 in. (12 mm)	0.433 in. (11 mm)	2.559 in. (65 mm)	0.157 in. (4 mm) or more															
Allowance: d1: ±0.00787 in. (±0.2 mm) L1: ±0.00393 in. (±0.1 mm) Locally Manufactured																				
6	Flex-Hone (For Preparing Cylinder Walls)	<table><tr><td>Yanmar Part No.</td><td>Cylinder Bore</td></tr><tr><td>129400-92410</td><td>2.756 - 2.992 in. (70 - 76 mm)</td></tr></table>		Yanmar Part No.	Cylinder Bore	129400-92410	2.756 - 2.992 in. (70 - 76 mm)													
Yanmar Part No.	Cylinder Bore																			
129400-92410	2.756 - 2.992 in. (70 - 76 mm)																			
7	Piston Ring Compressor (For Installing Pistons)	Yanmar Part No. 955500-02476 The Piston Insertion Tool is Applicable for 2.362 - 4.921 in. (60 - 125 mm) Diameter Pistons																		
8	Piston Ring Tool (For Removing / Installing Piston Rings)	Available Locally																		

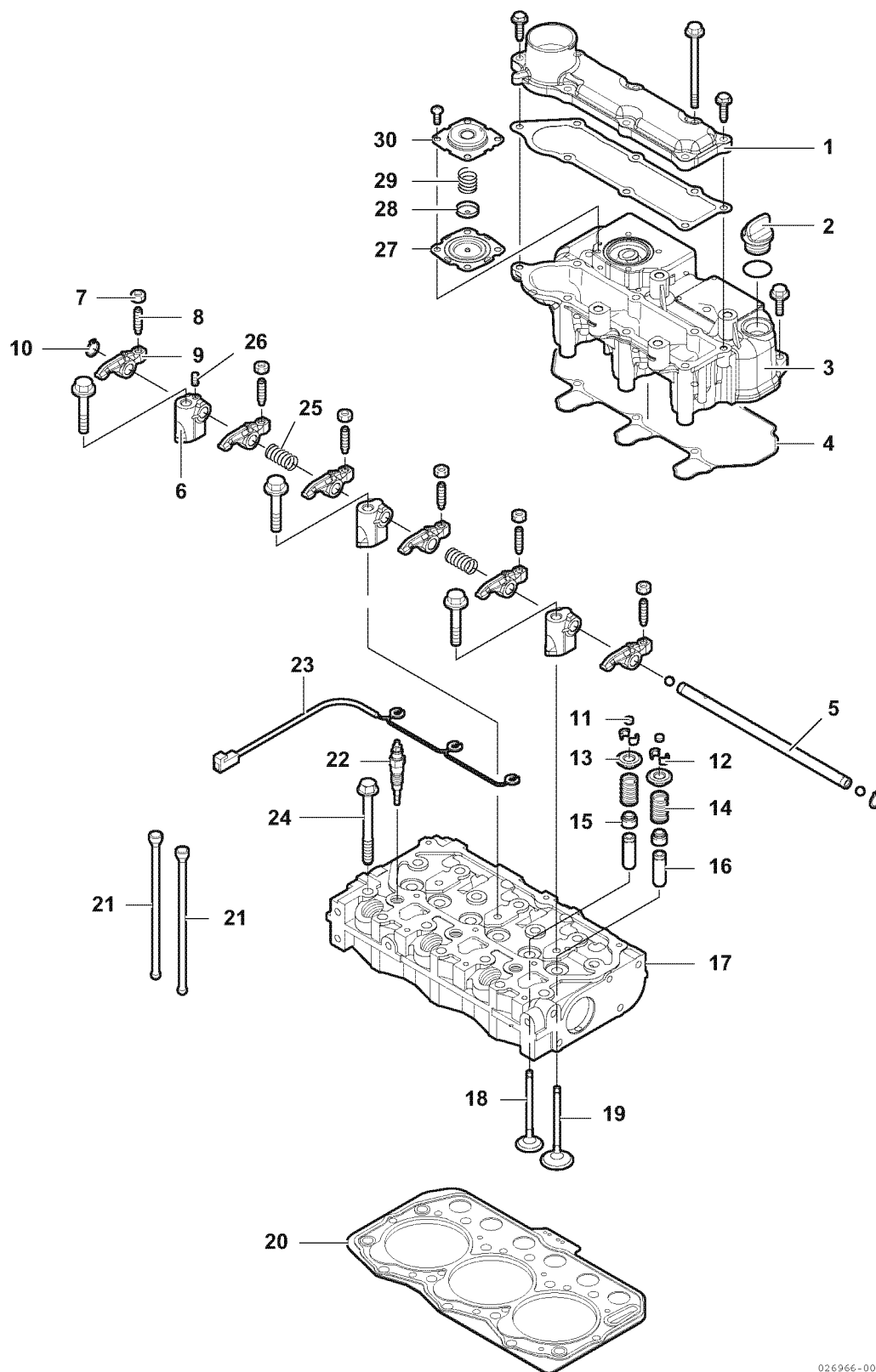
MEASURING INSTRUMENTS

No.	Instrument Name	Application	Illustration
1	Dial Indicator (Available Locally)	Measure shaft bend and end play	 001429-00X
2	Test Indicator (Available Locally)	Measurements of narrow or deep portions that cannot be measured by dial gauge	 001430-00X
3	Magnetic Stand (Available Locally)	For holding the dial gauge when measuring.	 001431-00X
4	Micrometer (Available Locally)	For measuring the outside diameters of crankshaft, pistons, piston pins, etc.	 001432-00X
5	Cylinder Bore Gauge (Available Locally)	For measuring the inside diameters of cylinder liners, bearing bores, etc.	 001433-00X
6	Calipers (Available Locally)	For measuring outside diameters, depth, thickness and width	 001434-00X
7	Depth Micrometer (Available Locally)	For measuring of valve recession	 001435-00X
8	Square (Available Locally)	For measuring valve spring inclination and straightness of parts	 001436-00X

No.	Instrument Name	Application	Illustration
9	V-Block (Available Locally)	For measuring shaft bend	 001437-01X
10	Torque Wrench (Available Locally)	For tightening nuts and bolts to the specified torque	 001438-00X
11	Feeler Gauge (Available Locally)	For measuring piston ring gaps, piston ring clearance and valve adjustment clearance	 001426-00X

CYLINDER HEAD

Cylinder Head Components



026966-00X

Figure 6-1

- 1 – Baffle Plate
- 2 – Oil Fill Cap
- 3 – Valve Cover/Intake Manifold
- 4 – Gasket
- 5 – Rocker Arm Shaft
- 6 – Rocker Arm Shaft Support
- 7 – Adjuster Lock Nut
- 8 – Valve Adjuster Screw
- 9 – Rocker Arm
- 10 – Circlip
- 11 – Valve Cap
- 12 – Keeper
- 13 – Valve Spring Retainer
- 14 – Valve Spring
- 15 – Valve Stem Seal
- 16 – Valve Guide
- 17 – Cylinder Head
- 18 – Exhaust Valve
- 19 – Intake Valve
- 20 – Cylinder Head Gasket
- 21 – Push Rod (2 per cylinder)
- 22 – Glow Plug
- 23 – Glow Plug Wiring Harness
- 24 – Cylinder Head Bolt

Disassembling the Cylinder Head

Prepare a clean, flat working surface on a work bench large enough to accommodate the cylinder head assembly. Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals when assembling the cylinder head.

NOTICE

- Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the assembly process.
 - Record all measurements taken during disassembly.
-
1. Drain coolant from engine into a suitable container. *See Draining, Flushing and Refilling Cooling System with New Coolant on page 5-18.*
 2. Remove the coolant pump. *See Disassembling the Engine Coolant Pump on page 8-6.*
 3. Remove the high-pressure fuel lines and fuel injectors from the cylinder head. *See Removing the Fuel Injectors on page 7-22.*

NOTICE

Remove and install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to install the fuel lines.

Removing the Intake Manifold/Valve Cover

1. Remove the intake manifold bolts (Figure 6-2, (1)) and valve cover bolts (Figure 6-2, (2)).
2. Remove the valve cover/intake manifold (Figure 6-2, (3)). Discard gasket (Figure 6-2, (4)).

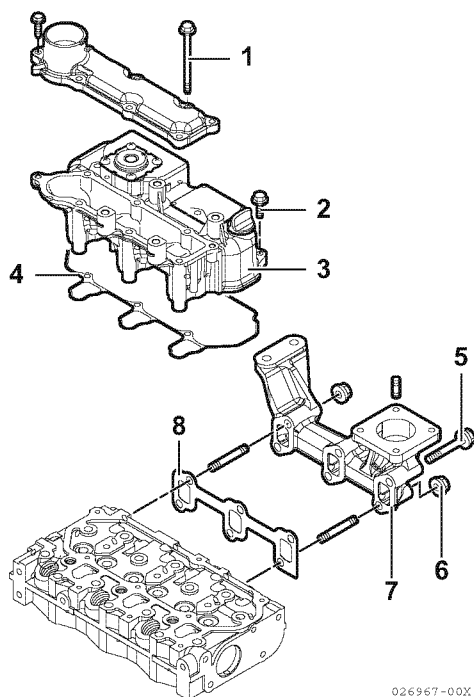


Figure 6-2

3. Remove the exhaust manifold bolts (Figure 6-2, (5)) and nuts (Figure 6-2, (6)). Remove the exhaust manifold (Figure 6-2, (7)) and the exhaust manifold gasket (Figure 6-2, (8)).

Removing the Glow Plugs

NOTICE

The glow plugs must be removed from the cylinder head before the cylinder head is removed to prevent damage to the tips of the glow plugs.

1. Disconnect the glow plug harness (Figure 6-3, (2)) from the glow plugs (Figure 6-3, (1)).
2. Remove the glow plugs from the cylinder head.

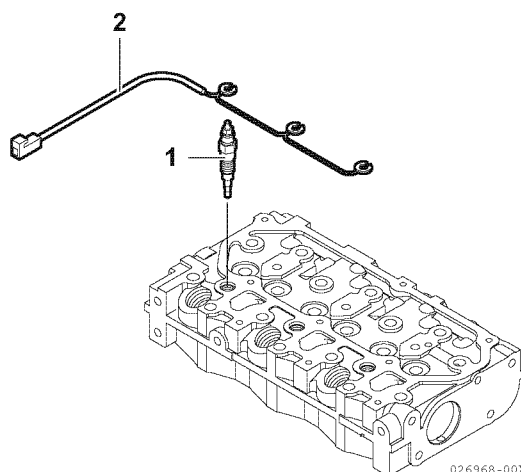


Figure 6-3

Removing the Rocker Arm Assembly

1. Remove the bolts (Figure 6-4, (1)) that retain the rocker arm shaft supports.
2. Remove the rocker arm shaft assembly from the cylinder head.

NOTICE

Identify the push rods so they can be installed in their original locations.

3. Remove the push rods and identify for installation.

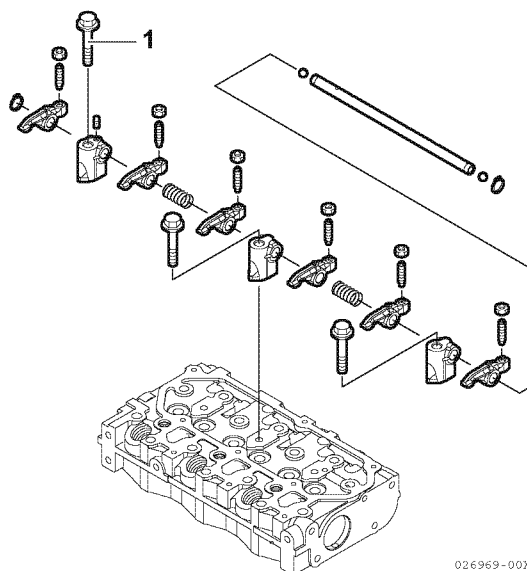


Figure 6-4

Disassembling the Rocker Arm Assembly

1. Remove the rocker arm shaft alignment setscrew (**Figure 6-5, (6)**) from support.

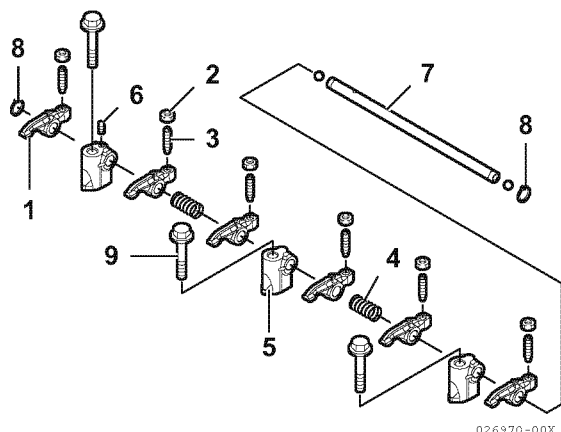


Figure 6-5

2. Remove two circlips (**Figure 6-5, (8)**).

NOTICE

The rocker arm shaft fits tightly in the rocker arm supports. Clamp the support in a padded vise. Twist and pull out on the rocker arm shaft to remove. Reverse this process when installing the rocker arm shaft into the supports.

3. Slide the rocker arm shaft (**Figure 6-5, (7)**) out of the rocker arm supports (**Figure 6-5, (5)**), springs (**Figure 6-5, (4)**) and rocker arms (**Figure 6-5, (1)**).

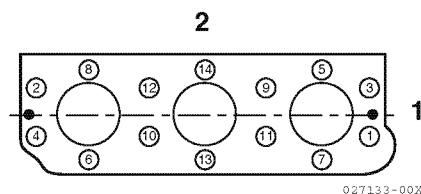
NOTICE

Mark the rocker arms so they can be installed with the original matching valve and push rod.

4. Remove the valve adjusting screw (**Figure 6-5, (3)**) and lock nut (**Figure 6-5, (2)**) from the rocker arms. Mark parts so they can be installed on the same rocker arm.

Removing the Cylinder Head

1. Loosen the cylinder head bolts following the sequence shown in **Figure 6-6**.



- 1 – Cooling Fan End
2 – Camshaft Side

Figure 6-6

2. Remove the cylinder head bolts (**Figure 6-7, (1)**).
3. Lift the cylinder head away from the cylinder block. Discard the cylinder head gasket (**Figure 6-7, (2)**). Position the cylinder head on the work bench to prevent damage to the combustion surface.

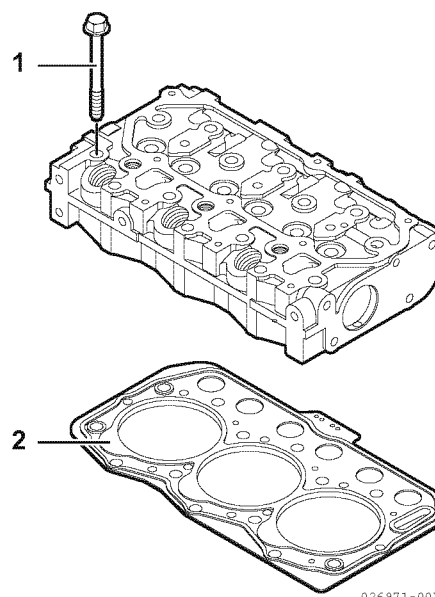


Figure 6-7

Removing the Intake/Exhaust Valves

1. Put the cylinder head on the work bench with the combustion side down (**Figure 6-8**).

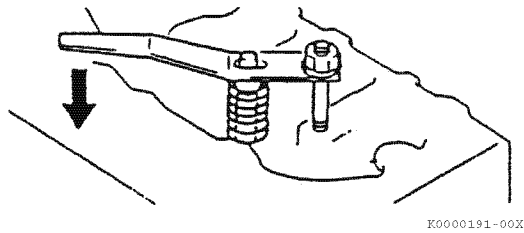


Figure 6-8

2. Remove the valve stem cap (**Figure 6-9, (1)**) and keep with the valve it was installed on.
3. Using the valve spring compressor tool, compress one of the valve springs (**Figure 6-8**).
4. Remove the valve keepers (**Figure 6-9, (2)**).
5. Slowly release the tension on the valve spring.
6. Remove the spring retainer (**Figure 6-9, (3)**) and valve spring (**Figure 6-9, (4)**).

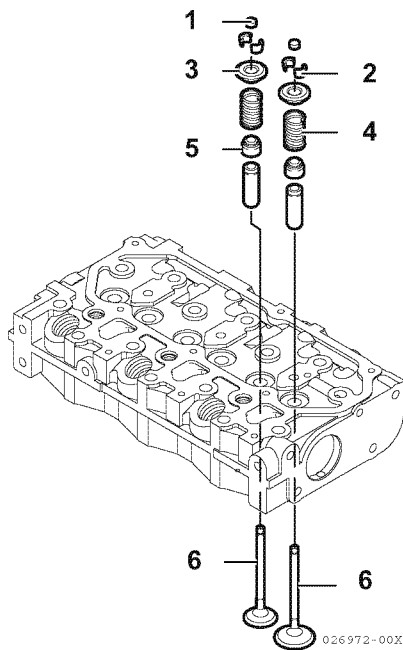


Figure 6-9

7. Repeat procedure with all remaining valves.

NOTICE

If the valves are to be reused, identify them so they can be installed in their original location.

8. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves (**Figure 6-9, (6)**) from the cylinder head.
9. Remove the valve stem seals (**Figure 6-9, (5)**).

Removing the Valve Guides

NOTICE

Removing the valve guides should be postponed until inspection and measurement procedures have been performed. See *Inspecting the Valve Guides* on page 6-22.

If the valve guides are not within specifications, use a drift pin and hammer to drive the valve guides (**Figure 6-10, (1)**) out of the cylinder head.

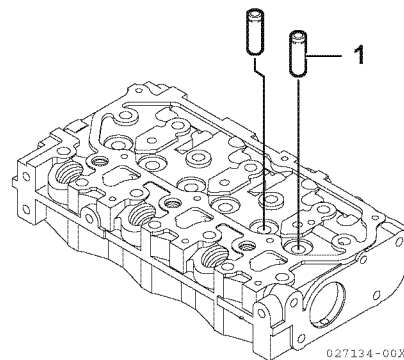


Figure 6-10

Cleaning the Cylinder Head Components

⚠ WARNING

Fume/Burn Hazard

Always read and follow safety-related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Thoroughly clean all components using a non-metallic brush and an appropriate solvent. Each part must be free of carbon, metal filings and other debris.

Inspecting the Cylinder Head Components

Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted or otherwise damaged. Discard any parts that do not meet specified limits.

NOTICE

- Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.
- Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.
- Mark all valve train components so they can be installed in their original locations.
- Record all measurements taken during inspection.

Inspecting the Push Rods

Push Rod Bend

Determine if the bend of the push rods is within the specified limit.

1. Place the push rods on a flat inspection block or layout bed.
2. Roll the push rods until a gap can be observed between a portion of the push rod and the surface of the block or layout bed.
3. Use a feeler gauge to measure the gap (**Figure 6-11**). See *Push Rod* on page 6-4 for the service limit.

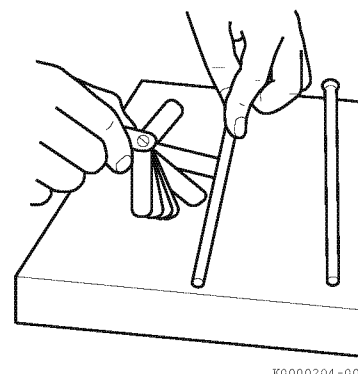


Figure 6-11

Inspecting the Rocker Arm Assembly

Rocker Arm Shaft Hole Diameter

Use a telescoping gauge and micrometer to measure the inside diameter of all the rocker arm support brackets and the rocker arms (**Figure 6-12**). Record the measurements. See *Rocker Arm and Shaft* on page 6-5 for the service limit.

Inspect contact areas (**Figure 6-12, (1)**) for excessive wear or damage.

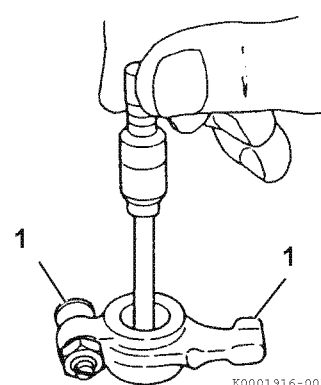
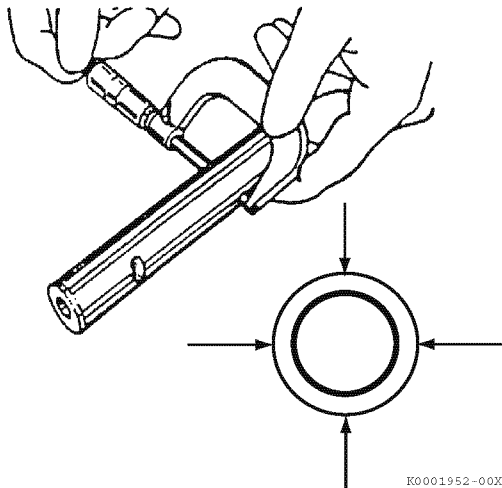


Figure 6-12

Rocker Arm Shaft Outside Diameter

Use a micrometer to measure rocker arm shaft diameter. Measure at each rocker arm location in two directions 90° apart (**Figure 6-13**). Record the measurements. See *Rocker Arm and Shaft* on page 6-5 for the service limit.

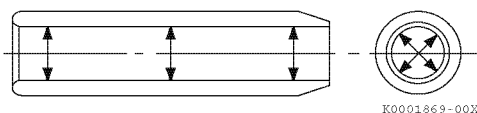
**Figure 6-13****Inspecting the Valve Guides**

Visually inspect the valve guides for distortions, scoring or other damage.

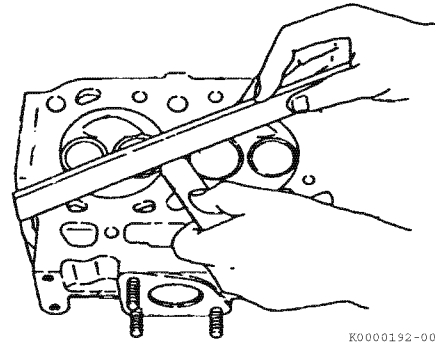
NOTICE

Measure valve guides while they are installed in cylinder head.

Use a telescoping gauge and micrometer to measure the inside diameter of the valve guide. Measure in three places and 90° apart (**Figure 6-14**). Record the measurements. See *Intake / Exhaust Valve and Guide* on page 6-4 for the service limit. Replace valve guides if not within specification.

**Figure 6-14****Inspecting the Cylinder Head****Cylinder Head Distortion**

Put the cylinder head flat and inverted (combustion side up) on the bench. Use a straightedge and feeler gauge to measure cylinder head distortion (**Figure 6-15**). Measure diagonally and along each side. Record the measurements. See *Cylinder Head* on page 6-3 for the service limit.

**Figure 6-15**

If distortion exceeds the service limit, resurface or replace the cylinder head.

NOTICE

Remove only enough material to make the cylinder head flat. Do not remove more than 0.008 in. (0.20 mm) or head will need to be replaced.

Inspecting the Intake and Exhaust Valves

Visually inspect the intake and exhaust valves. Replace any valves that are obviously discolored, heavily pitted or otherwise damaged.

Valve Stem Diameter

Use a micrometer to measure the valve stem diameter. Measure the valve stem near the combustion end and near the opposite end (**Figure 6-16, (1)**). Record the measurements. See *Intake / Exhaust Valve and Guide on page 6-4 for the service limit*.

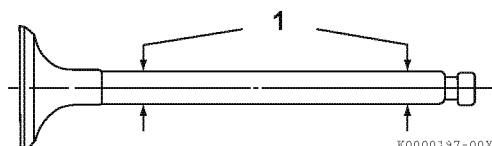


Figure 6-16

Valve Stem Bend

Place the valve stem on a flat inspection block or layout bed. Roll the valve until a gap can be observed between a portion of the valve stem and the surface of the block or bed. Use a feeler gauge to measure the gap (**Figure 6-17**). Record the measurements. See *Intake / Exhaust Valve and Guide on page 6-4 for the service limit*.

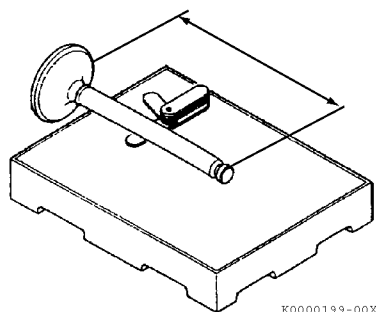


Figure 6-17

Valve Recession

NOTICE

The valve guides must be installed to perform this check.

Insert the valves into their original locations and press them down until they are fully seated. Use a depth micrometer (**Figure 6-18**) to measure the difference between the cylinder head gasket surface and the combustion surface of each exhaust and intake valve (**Figure 6-19**). Record the measurements. See *Cylinder Head on page 6-3 for the service limit*.

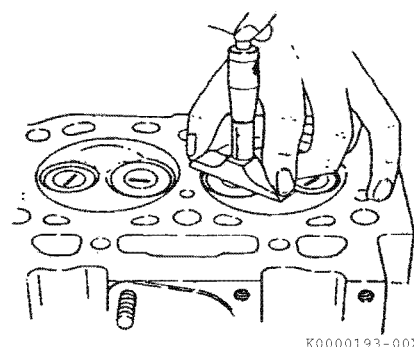


Figure 6-18

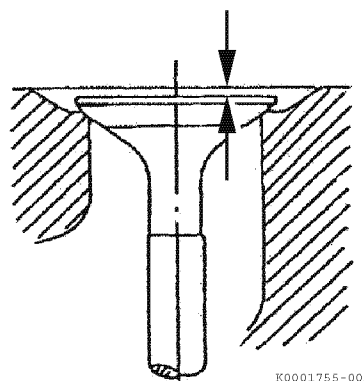


Figure 6-19

Valve Face and Valve Seat

Always check the clearance between the valve and valve guide before grinding or lapping the valve seats. See *Intake / Exhaust Valve and Guide* on page 6-4 for the service limit. If the clearance exceeds the limit, replace the valve and/or valve guide to bring the clearance within the limit.

Roughness or burrs will cause poor seating of a valve. Visually inspect the seating surfaces of each valve and valve seat to determine if lapping or grinding is needed.

Visually inspect all valve faces and valve seats for pitting, distortion, cracking or evidence of overheating. Usually the valves and valve seats can be lapped or ground to return them to serviceable condition. Severely worn or damaged components will require replacement.

Coat the valve seat with a thin coat of bluing compound. Install valve and rotate to distribute bluing onto the valve face. The contact pattern should be approximately centered on the valve face (**Figure 6-20, (1)**) and even in width.

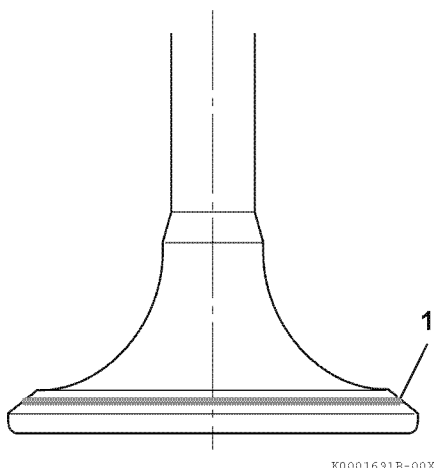


Figure 6-20

Also visually inspect the valve seat for even contact.

Light cutting can be performed using a hand-operated cutter (**Figure 6-21, (3)**).

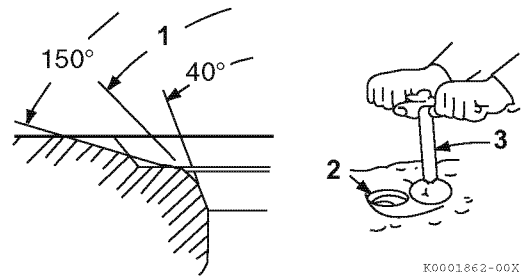


Figure 6-21

Valve seat diameter can be adjusted by top-grinding with a 150° stone to make the seat diameter smaller, and bottom-grinding using a 40° stone to make the seat diameter larger. Once the seat location has been corrected, grind and lap the seat angle (**Figure 6-21, (1)**) to specification. See *Cylinder Head* on page 6-3 for the service limit.

Grind the valve face and / or valve seat only enough to return them to serviceable condition. Grinding is needed if the valve and the valve seat do not contact correctly. Check the valve recession after grinding.

If the valve or seat require grinding, lap the valve after grinding. Lap the valve face to the valve seat using a mixture of valve lapping compound and engine oil.

Be sure to thoroughly wash all parts to remove all grinding powder or compound.

Inspecting the Valve Springs

Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs. Record the measurements.

Fractures

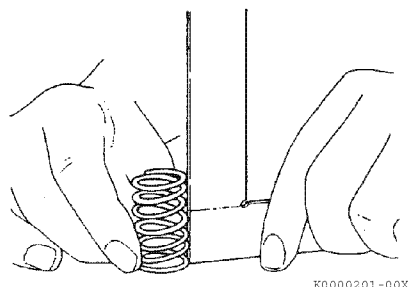
Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the valve spring.

Corrosion

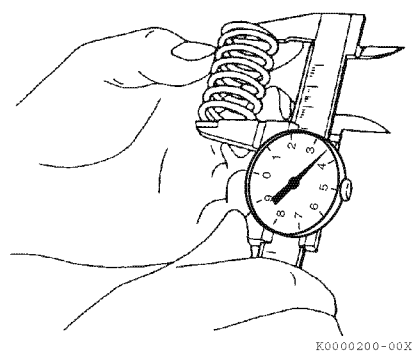
Check for corrosion of spring material caused by oxidation.

Squareness

Use a flat surface and a square to check each spring for squareness (**Figure 6-22**). See *Valve Spring* on page 6-4 for the service limit.

**Figure 6-22****Free Length**

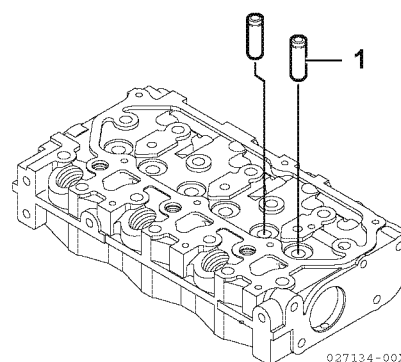
Use a caliper to measure the length of the spring (**Figure 6-23**). See *Valve Spring* on page 6-4 for the service limit.

**Figure 6-23****Assembling the Cylinder Head****NOTICE**

- Use new gaskets, O-rings and seals for the assembling the cylinder head.
- Liberally oil all components during assembly to prevent premature wear or damage.

Assembling the Valve Guides

1. The valve guides are installed into the cylinder head with an extremely tight press-fit. Before installing the valve guides, place the valve guides in a freezer for at least 20 minutes. This will cause the valve guides to contract, making it easier to install the valve guides in place.
2. Immediately after removing the valve guides from the freezer, insert the valve guides (**Figure 6-24, (1)**) in their proper positions.

**Figure 6-24**

3. Finish installing the valve guides (Figure 6-25, (1)) to the proper height (Figure 6-25, (3)) using the valve guide installation tool (Figure 6-25, (2)). See Valve Guide Projection specification on page 6-4.

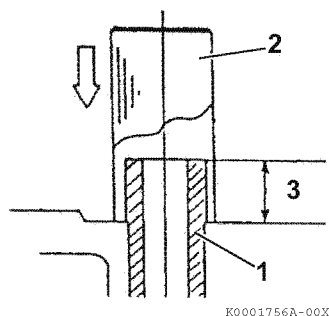


Figure 6-25

Assembling the Intake and Exhaust Valves

NOTICE

- Always install new valve stem seals.
- For 3TNM72 engines, the exhaust valve stem seals are different than the intake valve stem seals and can be identified by the color of the seal spring (Figure 6-26, (4)). For 3TNM68 engines, all stem seals are the same. Ensure they are installed in the correct locations.

Engine Model	Marking	
	Intake	Exhaust
3TNM68	Silver (Seal Spring)	Silver (Seal Spring)
3TNM72	White (Seal Spring)	White mark (on the Body)

1. Oil the lip of the valve stem seal (Figure 6-26, (2)). Using the valve stem seal installation tool (Figure 6-26, (1)), install a new valve stem seal on each of the valve guides (Figure 6-26, (3)).

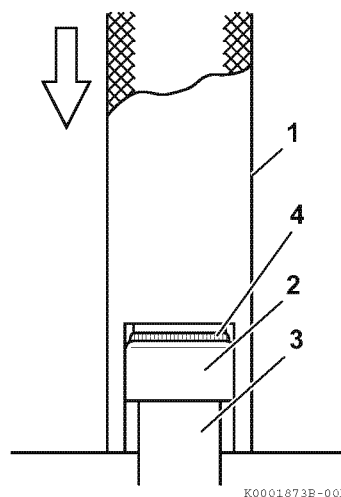


Figure 6-26

2. Measure the distance (Figure 6-27, (1)) from the cylinder head to valve stem seal to ensure proper clearance (Figure 6-27, (2)) between the valve guide and seal. See Valve Stem Seal Projection specification on page 6-4.

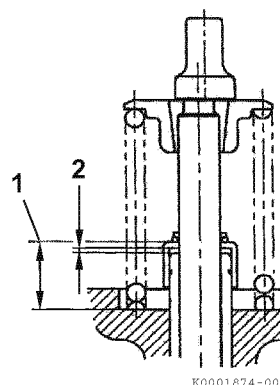


Figure 6-27

3. Put the cylinder head assembly on its exhaust port side.

4. Install all the valves (**Figure 6-28, (6)**) in their proper location in the cylinder head.

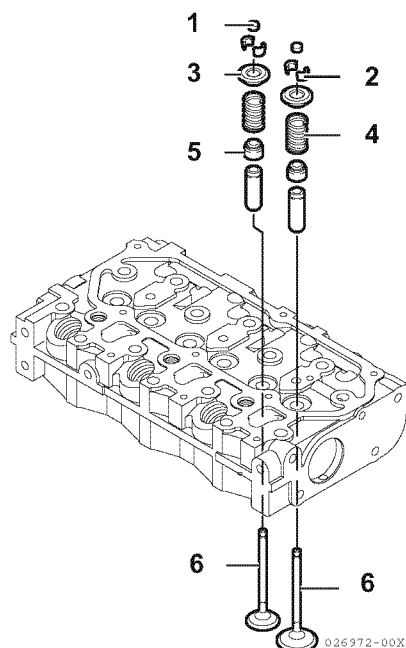


Figure 6-28

5. Put the cylinder head on the work bench with the combustion side down to install the valve springs. Install the valve spring (**Figure 6-28, (4)**) and spring retainer (**Figure 6-28, (5)**).
6. Using a valve spring compressor tool, compress the valve spring.
7. Insert the valve keeper (**Figure 6-28, (2)**) and slowly release the tension in the valve spring. Install the valve cap (**Figure 6-28, (1)**). Repeat steps on all remaining valves.

Assembling the Cylinder Head

1. Carefully clean both the combustion surface of the cylinder head and the top surface of the cylinder block. Install a new cylinder head gasket (**Figure 6-29, (2)**) on the cylinder block.
2. Position the cylinder head on the cylinder head gasket.

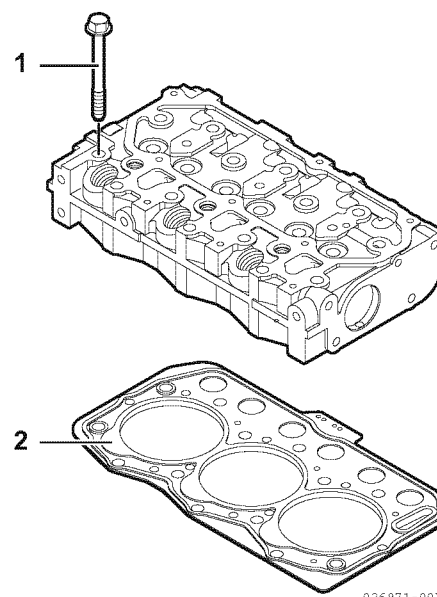
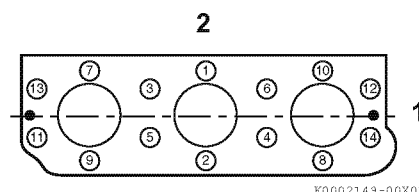


Figure 6-29

3. Lightly oil the threads of the cylinder head bolts (**Figure 6-29, (1)**). Tighten the bolts to the specified torque shown in the chart below. Tighten in the sequence shown in **Figure 6-30**. See *Tightening Torque for Special Bolts* on page 6-11.

First Step	1/2 of final torque
Second Step	Final torque



- 1 – Cooling Fan End
2 – Camshaft Side

Figure 6-30

4. Insert the push rods in their respective positions.

Assembling the Rocker Arm Assembly

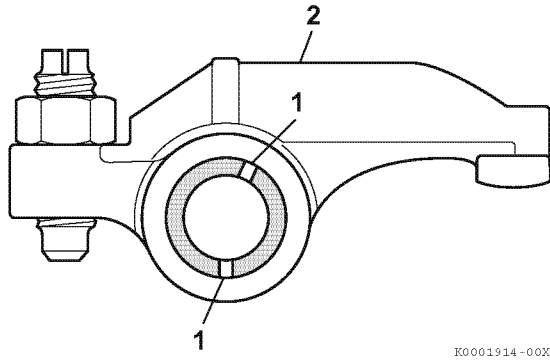


Figure 6-31

NOTICE

- Ensure the lubrication holes in the rocker arm shaft (**Figure 6-31, (1)**) are oriented correctly with respect to the rocker arms (**Figure 6-31, (2)**).
- The hole in the shaft for the setscrew must be installed to the flywheel side.

1. Lubricate the rocker arm shaft. Slide the rocker arm supports (**Figure 6-32, (5)**), springs (**Figure 6-32, (4)**) and rocker arms (**Figure 6-32, (1)**) onto the shaft.

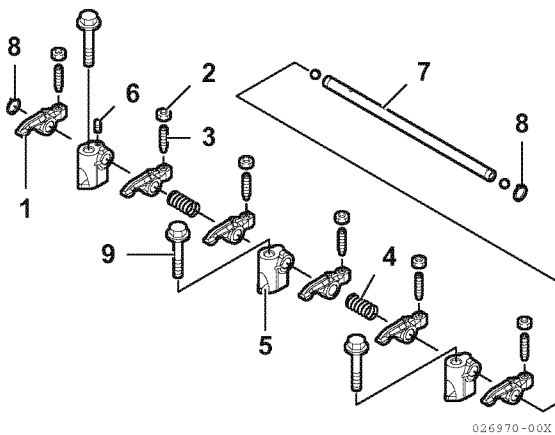


Figure 6-32

NOTICE

- The rocker arm shaft fits tightly in the rocker arm supports. Clamp the support in a padded vise. Twist and push on the rocker arm shaft to install.
- The setscrew is located in the flywheel side support.

2. Align the hole in the rocker arm shaft (**Figure 6-32, (7)**) and the hole in the rocker arm support. Install the alignment setscrew (**Figure 6-32, (6)**).
3. Place the rocker arm shaft assembly onto the cylinder head.
4. If removed, install the valve adjusting screws (**Figure 6-32, (3)**) and lock nuts (**Figure 6-32, (2)**).
5. Align the push rods with their respective rocker arms.
6. Install and tighten the rocker arm shaft retaining bolts to the specified torque.
7. Tighten the rocker arm shaft alignment screw.
8. Adjust the valve clearance. *See Measuring and Adjusting Valve Clearance on page 6-30.*

Assembling the Intake Manifold/Valve Cover

1. Install the glow plugs (**Figure 6-33, (1)**) and tighten to specification. Install the electrical harness (**Figure 6-33, (2)**).

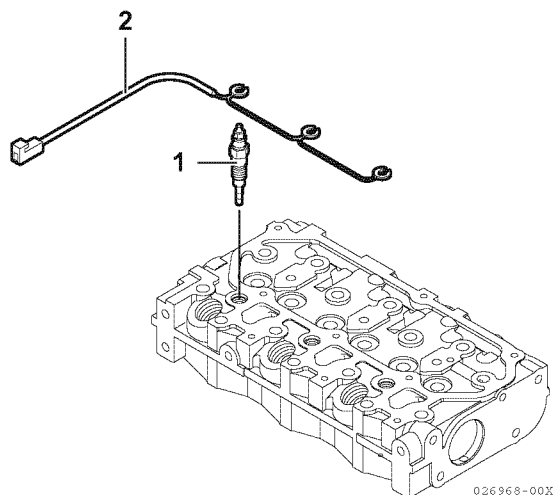


Figure 6-33

2. Lightly grease a new valve cover gasket (**Figure 6-34, (4)**). Place the gasket in the groove of the intake manifold/valve cover (**Figure 6-34, (3)**).
3. Place the intake manifold/valve cover on the cylinder head.
4. Install and tighten bolts (**Figure 6-34, (1 and 2)**) securely.

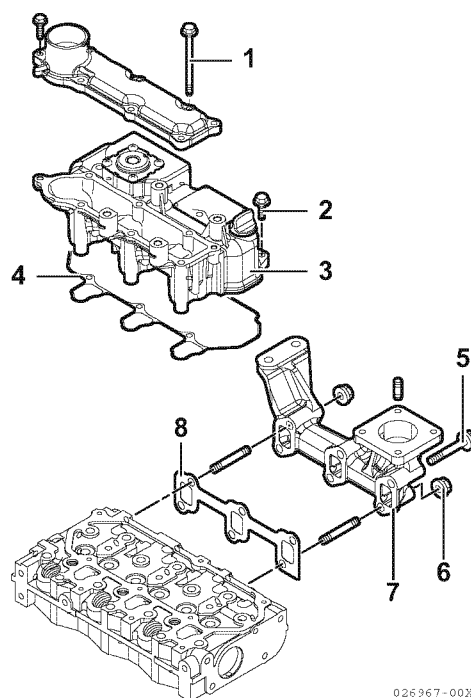


Figure 6-34

5. Install the exhaust manifold using a new gasket (**Figure 6-34, (8)**). Tighten the bolts and nuts (**Figure 6-34, (5 and 6)**) securely.
6. Install the fuel injectors. *See Installing the Fuel Injectors on page 7-26.*
7. Install the high-pressure and return fuel injection lines. *See Installing the Fuel Injectors on page 7-26.*
8. Install the coolant pump. *See Assembling the Engine Coolant Pump on page 8-8.*
9. Install the alternator. *See Installing the Alternator on page 11-14.*

Measuring and Adjusting Valve Clearance

Measure and adjust while the engine is cold.

NOTICE

- The No. 1 piston position is on the flywheel end of the engine, opposite end of the radiator. The firing order is 1-3-2.
- Engines fire every 240° of crankshaft rotation.
- Valve clearance of both the intake and exhaust valves can be checked with the piston for that cylinder at top dead center (TDC) of the compression stroke. When a piston is at TDC of the compression stroke, both rocker arms will be loose and the cylinder TDC mark on the flywheel will be visible in the timing port of the flywheel housing.
- If there is no valve clearance, and the piston is at TDC of the compression stroke, extreme wear or damage to the cylinder head or valves may be possible.
- If adjusting each cylinder individually, the cylinder to be adjusted first does not have to be the No. 1 cylinder. Select and adjust the cylinder where the piston is nearest to the top dead center after turning. Adjust the remaining cylinders in the order of firing by turning the crankshaft each time.
- To decrease the number of rotations required to check all cylinders, use the chart as indicated below.

Example: With the No. 1 piston at TDC on the compression stroke (both valves closed), the valves indicated on the top line of the chart can be adjusted without rotating the crankshaft. To adjust the remaining two valves, rotate the crankshaft until the No. 1 piston is at TDC on the exhaust stroke (exhaust valve only open).

Cylinder No.	1		2		3	
Valve	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
No. 1 Cylinder at TDC Compression	•	•	•			•
No. 1 Cylinder at TDC Exhaust				•	•	

1. Remove the intake manifold/valve cover. See *Removing the Intake Manifold/Valve Cover on page 6-18*.
2. Rotate the crankshaft clockwise as seen from the coolant pump end, to bring No. 1 piston to TDC of the compression stroke while watching the rocker arm motion and timing grid on the flywheel. (Position so both the intake and exhaust valves are closed.)
3. Insert a feeler gauge (**Figure 6-35, (1)**) between rocker arm and valve cap and record the measured valve clearance. (Use the data for estimating wear.)

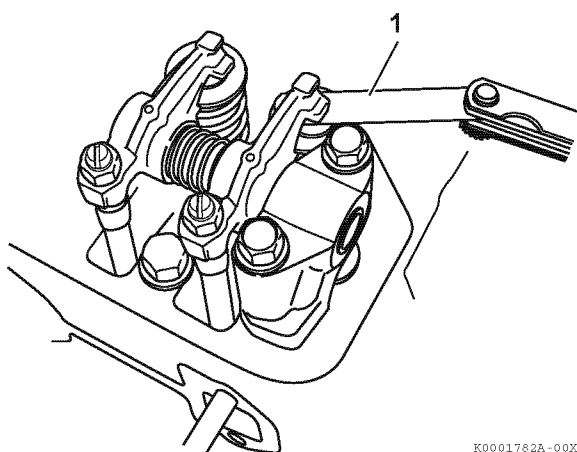


Figure 6-35

4. If adjustment is required, proceed to the next step.
5. Loosen the valve adjusting screw locknut (**Figure 6-36, (1)**) and valve adjusting screw (**Figure 6-36, (2)**) on the rocker arm. Check the valve for inclination of the valve cap, entrance of dirt or wear.

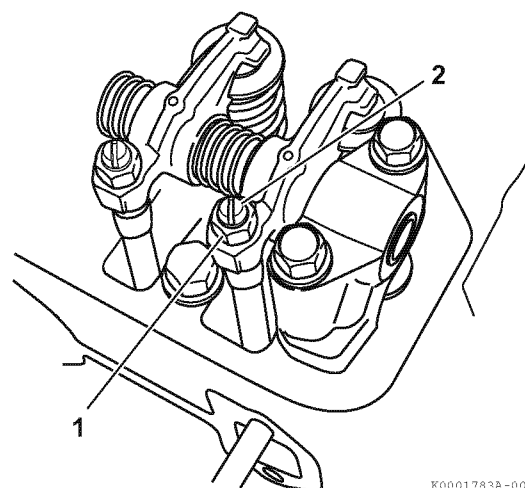


Figure 6-36

6. Insert a feeler gauge of the correct thickness (**Figure 6-35, (1)**) between rocker arm and valve cap. Turn the valve adjustment screw to adjust the valve clearance so there is a slight "drag" on the feeler gauge when sliding it between the rocker arm and valve cap. Hold the adjusting screw while tightening the valve adjusting screw locknut (**Figure 6-36, (1)**). Recheck the clearance (see *Adjustment Specifications on page 6-3*).

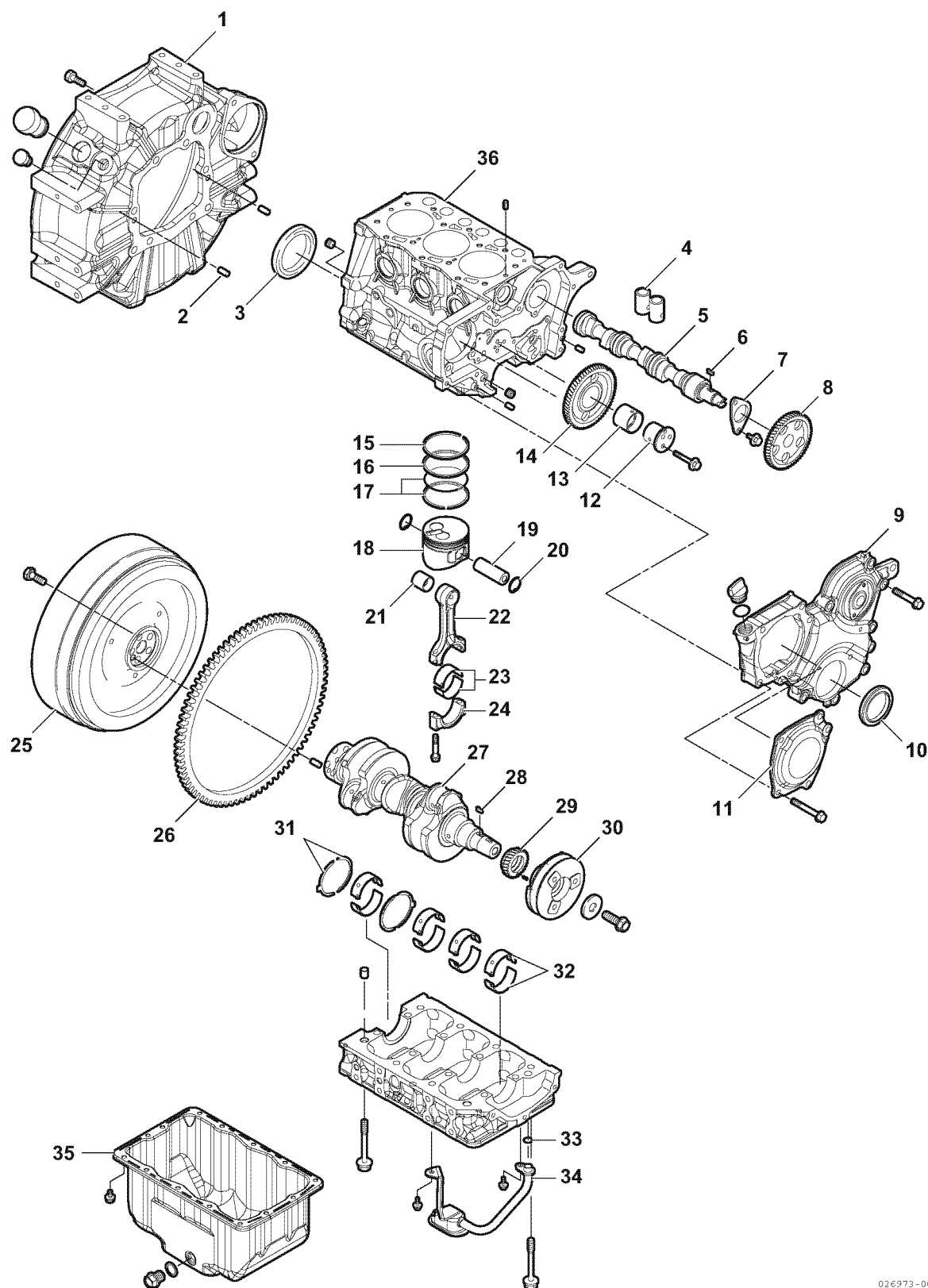
NOTICE

There is a tendency for the clearance to decrease slightly when the locknut is tightened. It is suggested that the initial clearance adjustment be made slightly on the "loose" side before tightening the locknut.

7. Apply oil to the contact surface between adjusting screw and push rod.
8. Rotate the crankshaft and measure the next cylinder. Continue until all valves are adjusted.

CYLINDER BLOCK

Crankshaft and Camshaft Components



026973-00X

Figure 6-37

- 1 – Flywheel Housing
- 2 – Dowel (2 used)
- 3 – Crankshaft Rear Seal
- 4 – Tappets
- 5 – Camshaft
- 6 – Camshaft Gear Key
- 7 – Camshaft End Plate
- 8 – Camshaft Gear
- 9 – Gear Case Cover
- 10 – Front Crankshaft Seal
- 11 – Fuel Injection Pump Gear Cover
- 12 – Idler Gear Shaft
- 13 – Idler Gear Bushing
- 14 – Idler Gear
- 15 – Top Compression Ring
- 16 – Second Compression Ring
- 17 – Oil Ring
- 18 – Piston
- 19 – Wrist Pin
- 20 – Circlip
- 21 – Wrist Pin Bushing
- 22 – Connecting Rod
- 23 – Connecting Rod Bearing Inserts
- 24 – Connecting Rod Cap
- 25 – Flywheel
- 26 – Ring Gear
- 27 – Crankshaft
- 28 – Crankshaft Gear Key
- 29 – Crankshaft Gear
- 30 – Crankshaft Pulley
- 31 – Thrust Bearings
- 32 – Main Bearing Inserts
- 33 – Oil Pickup O-Ring
- 34 – Oil Pickup
- 35 – Oil Pan
- 36 – Cylinder Block

Disassembling the Cylinder Block Components

Prepare a clean, flat working surface on a work bench large enough to accommodate the engine components. Discard all used gaskets, O-rings and seals. Use new gaskets, O-rings and seals for assembling the engine.

NOTICE

- Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the assembly process.
- Record all measurements taken during disassembly.

If the engine will be completely disassembled, the following preliminary steps should be performed:

1. Disconnect the battery cables at the battery. Always disconnect the negative (-) cable first.
2. Remove the throttle cable, electrical connections, intake and exhaust system connections, and fuel supply lines from the engine.
3. Remove the alternator. *See Removing the Alternator on page 11-10.*
4. Drain the engine coolant from the radiator and cylinder block. *See Draining, Flushing and Refilling Cooling System with New Coolant on page 5-18.* Remove the cooling system components from the engine.
5. Remove the engine from the machine. Mount the engine to a suitable engine repair stand having adequate weight capacity.

WARNING

Crush Hazard

When working on the engine, make sure it is solidly secured to prevent injury or damage to parts.

6. Clean the engine by washing with solvent, air or steam cleaning. Carefully operate to prevent any foreign matter or fluids from entering the engine, fuel system or electrical components remaining on the engine.
7. Drain the engine oil into a suitable container. Remove oil filter.
8. Remove the cylinder head. *See Disassembling the Cylinder Head on page 6-17.*
9. Remove the fuel injection pump from the gear case only if it must be sent out for repair, or will interfere with other procedures such as "hot tank" cleaning. *See Removing the Fuel Injection Pump on page 7-12.*
10. Remove the starter motor. *See Removing the Starter Motor on page 10-8.*

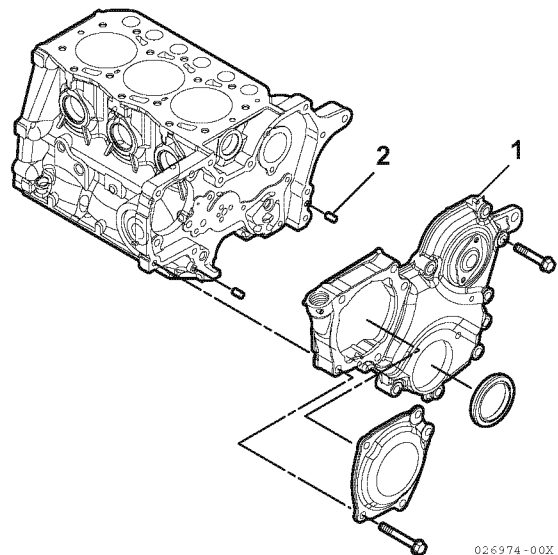


Figure 6-38

Disassembling the Camshaft and Timing Components

Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals on assembling the camshaft and timing components.

Removing the Timing Gear Case Cover

1. Remove the bolt and washer retaining the crankshaft pulley.

NOTICE

Use care not to damage the threads in the end of the crankshaft when removing the crankshaft pulley.

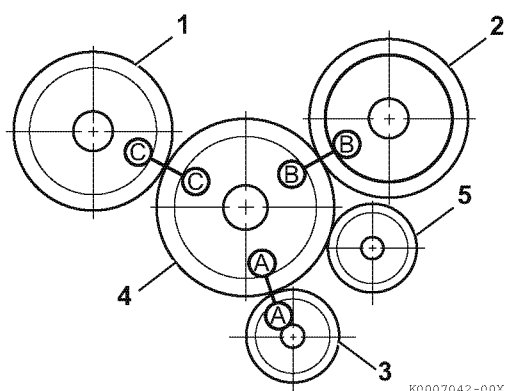
2. Remove the crankshaft pulley with a gear puller.
3. Remove the bolts that retain the gear case cover to the cylinder block and oil pan.
4. Remove the gear case cover (**Figure 6-38, (1)**).
5. Remove the dowel pins (**Figure 6-38, (2)**).

Checking Timing Gear Backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

NOTICE

Check the backlash between each pair of mating gears. If not within specification, replace both mating gears. Do not allow the gear being checked to move axially, as excess end play could cause a false reading. *See Timing Gear Backlash on page 6-6 for service limits.*



- 1 – Fuel Injection Pump Drive Gear
 2 – Camshaft Drive Gear
 3 – Crankshaft Drive Gear
 4 – Idler Gear
 5 – Oil Pump Gear

Figure 6-39

Measuring Idler Gear-to-Crankshaft Gear Backlash

1. Install a dial indicator as shown in **Figure 6-40**.

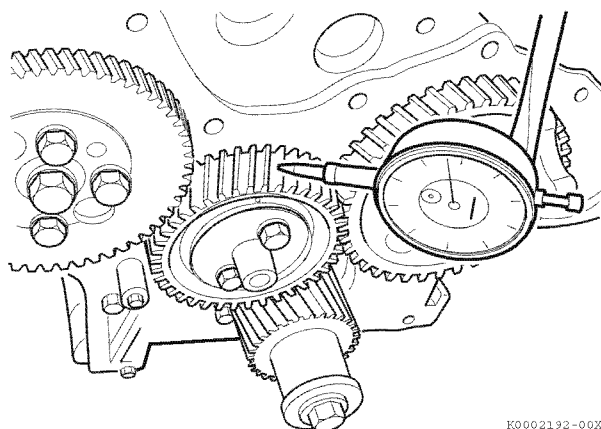


Figure 6-40

2. Rotate the idler gear back and forth to check idler gear-to-crankshaft gear backlash. Total indicator reading is backlash. Record the measurement.

Measuring Idler Gear-to-Camshaft Gear Backlash

1. Drive a small wooden wedge between the crankshaft gear and idler gear to prevent the idler gear from rotating.
2. Install a dial indicator to read camshaft gear backlash. Rotate camshaft drive gear against idler gear to measure backlash. Record the measurement.
3. Check the idler gear-to-fuel injection pump drive gear backlash in the same manner as the camshaft drive gear. Record the measurement.

Removing the Timing Gears

1. Remove the bolts from the idler gear shaft (**Figure 6-41, (1)**). Remove the idler gear shaft, idler gear (**Figure 6-41, (3)**) and bushing (**Figure 6-41, (2)**).

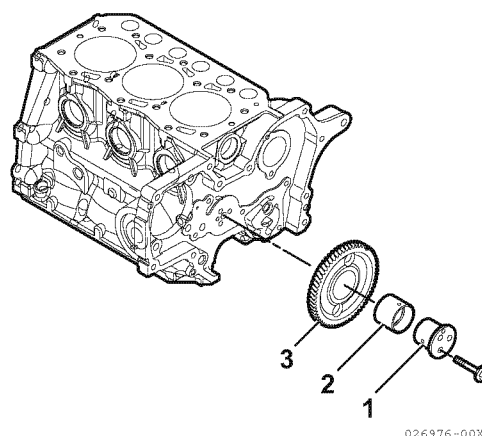


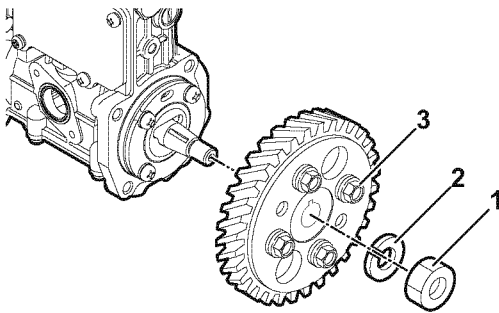
Figure 6-41

2. Do not remove the crankshaft gear unless it is damaged and requires replacement. If the gear must be removed, remove it with a gear puller.
3. Removing the camshaft gear requires the gear to be removed with a press. Do not remove the camshaft gear unless it or the camshaft is damaged and requires replacement. See *Removing the Camshaft* on page 6-37.

NOTICE

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub.

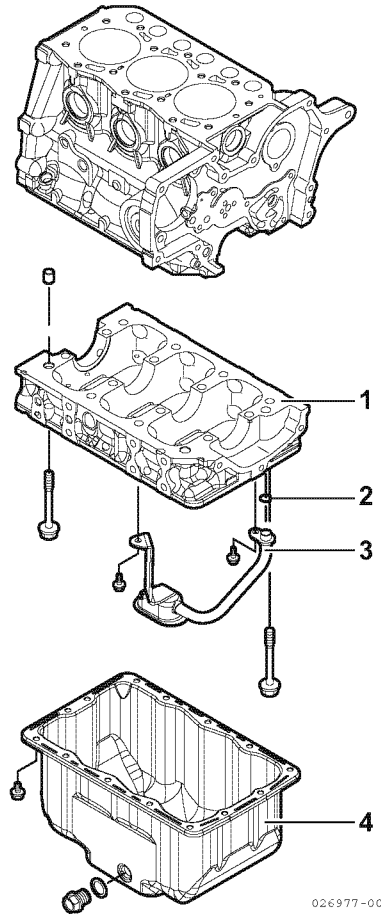
4. Do not remove the fuel injection pump drive gear unless absolutely necessary due to damage to the gear or pump. Do not loosen or remove the four bolts (Figure 6-42, (3)) retaining pump drive gear to the hub. Only remove the nut (Figure 6-42, (1)) and washer (Figure 6-42, (2)), leaving the hub attached to the gear. Remove the pump drive gear and hub as an assembly using a gear puller.



027136-00X

Figure 6-42**Removing the Oil Pan**

1. Invert the engine (oil pan up) on the engine stand.
2. Remove the oil pan (Figure 6-43, (4)).
3. Remove the ladder frame (Figure 6-43, (1)).



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Figure 6-43

4. Remove the oil pickup tube (Figure 6-43, (3)) and O-ring (Figure 6-43, (2)).

Note: Torx bolts are used for oil sump mounting bolts and ladder frame mounting bolts. Specialized tool (Torx bolt wrench) is required.

Oil Sump Bolts: TORX E8

Ladder Frame: TORX E12

Removing the Camshaft

- Before removing the camshaft, check the camshaft end play.
 - Method A:** Install a dial indicator (**Figure 6-44, (1)**) on the cylinder block. Move the camshaft and gear (**Figure 6-44, (2)**) in and out to measure the end play. Record the measurement. See *Camshaft* on page 6-5 for the service limit.

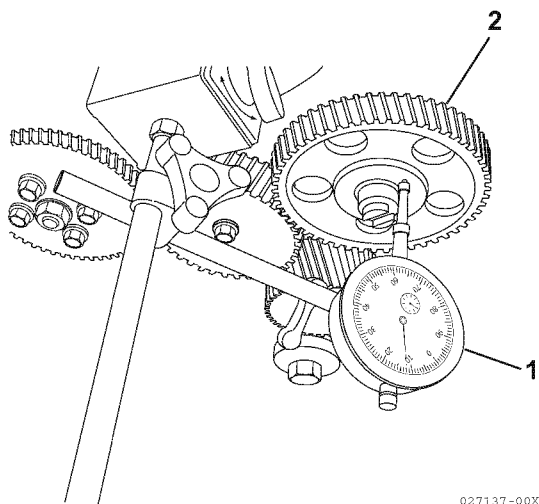


Figure 6-44

- Method B:** Use a feeler gauge to measure the clearance between the thrust plate (**Figure 6-45, (1)**) and front camshaft bearing (**Figure 6-45, (2)**). Record the measurement. See *Thrust Bearing* on page 6-7 for the service limit.

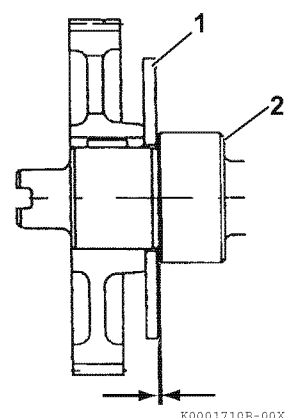


Figure 6-45

- Remove two bolts (**Figure 6-46, (3)**) retaining the camshaft thrust plate (**Figure 6-46, (1)**).

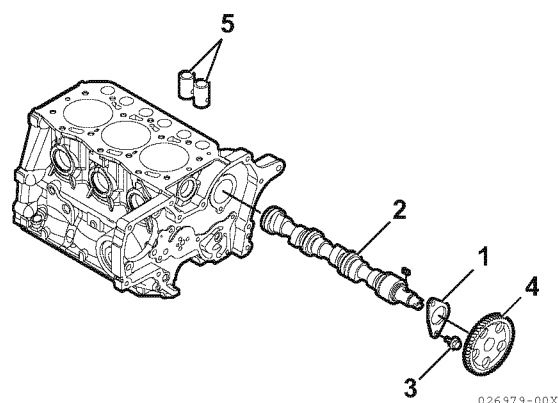


Figure 6-46

- Extract the tappets (**Figure 6-46, (5)**) through the top of the cylinder block. Mark the tappets so they can be installed in the same location.
- Slowly pull the camshaft (**Figure 6-46, (2)**) assembly out of the engine, being careful not to damage the front camshaft bushing.
- Remove the camshaft gear (**Figure 6-46, (4)**) only if the gear or camshaft require replacement. Use a knife-edge puller and a press to remove the gear. The gear is a shrink-fit and will need to be heated to 356° to 392°F (180° to 200°C) to remove.

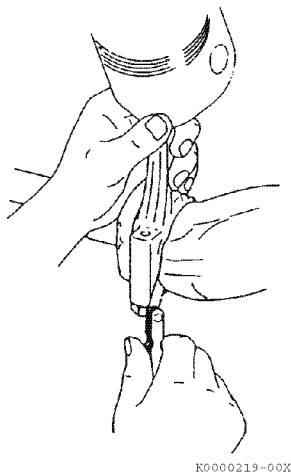
Disassembling the Crankshaft and Piston Components

Removing the Pistons

NOTICE

- Keep the piston pin parts, piston assemblies and connecting rod assemblies together to be returned to the same position during the assembly process. Label the parts using an appropriate method.
- Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.
- Pistons can fall from the cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.

1. Using a feeler gauge, measure the connecting rod side clearance (**Figure 6-47**). See *Connecting Rod* on page 6-9 for the standard limit. If the measurement is out of specification, replace the crankshaft, connecting rod or both.



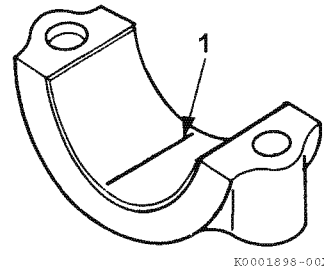
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Figure 6-47

NOTICE

Mark the connecting rod caps and connecting rods so the caps and connecting rods stay together.

2. Remove the bearing cap. Do not remove the bearing inserts at this time.
3. Wipe oil from the bearing insert and crankshaft journal surfaces.
4. Place a piece of PLASTIGAGE® (**Figure 6-48, (1)**) along the full width of the bearing insert.



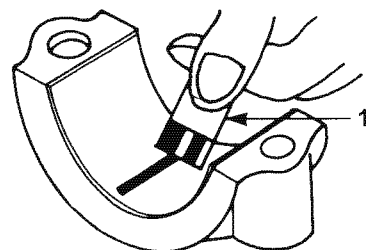
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Figure 6-48

NOTICE

Do not rotate crankshaft when using PLASTIGAGE. A false reading may result.

5. Install the bearing cap and tighten to specification. See *Special Torque Chart* on page 6-11.
6. Remove the bearing cap.



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Figure 6-49

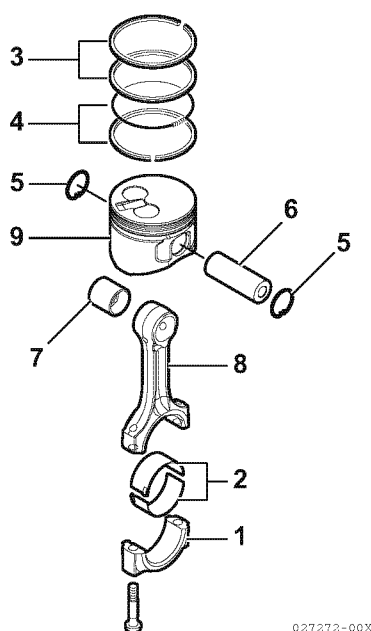
7. Compare the width of the flattened PLASTIGAGE (**Figure 6-49, (1)**) to the graduation marks on the package. The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance. Record the measurements. See *Crankshaft on page 6-6*.
8. Repeat with the remaining connecting rods.

NOTICE

Do not allow the connecting rod to contact the crankshaft journal during piston removal. Damage to the bearing journal may result.

9. Use a wooden dowel against the connecting rod and tap the piston/connecting rod assembly out of the cylinder.
10. Mark the cylinder number on the piston and connecting rod.
11. Remove the bearing inserts (**Figure 6-50, (2)**).
12. Remove the compression rings (**Figure 6-50, (3)**) from the piston using a piston ring expander.
13. Remove the oil control ring (**Figure 6-50, (4)**) from the piston using a piston ring expander.

14. Remove the circlips (**Figure 6-50, (5)**) from the wrist pin.
15. Remove the wrist pin (**Figure 6-50, (6)**) and connecting rod (**Figure 6-50, (8)**) from the piston (**Figure 6-50, (9)**).
16. Repeat steps until all pistons are removed and disassembled.



027272-00X

Figure 6-50

Removing the Crankshaft

1. Remove the flywheel (**Figure 6-51, (1)**) from the crankshaft.
2. Remove the bolts from the flywheel housing assembly (**Figure 6-51, (2)**). Remove the flywheel housing from the engine.

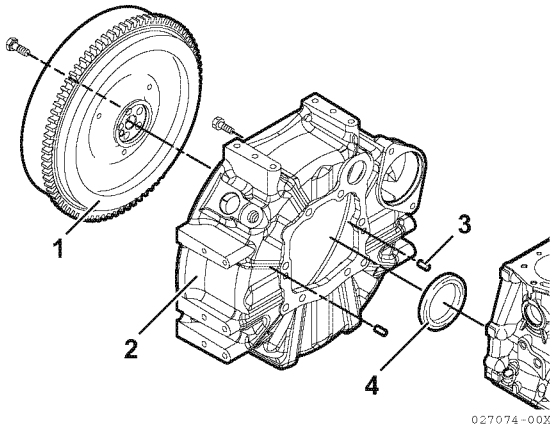


Figure 6-51

3. Before removing the main bearing, measure the crankshaft end play. Use either of the following two methods:

- **Method A:** Install a dial gauge (**Figure 6-52, (1)**) on the cylinder block. Move the crankshaft (**Figure 6-52, (2)**) in and out to measure the end play. Record the measurement.

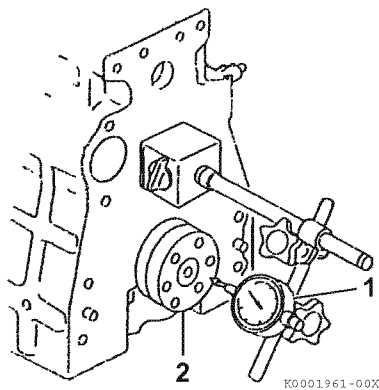


Figure 6-52

- **Method B:** Use a feeler gauge to measure the clearance (**Figure 6-53, (3)**) between the thrust bearing (**Figure 6-53, (1)**) and crankshaft (**Figure 6-53, (2)**). Record the measurement. See *Thrust Bearing* on page 6-7 for the service limit.

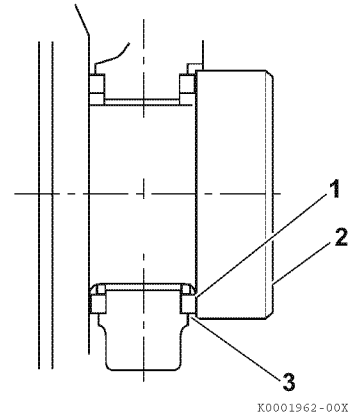


Figure 6-53

4. Remove the ladder frame. Do not remove the bearing inserts at this time.
5. Wipe oil from the bearing insert and crankshaft journal surfaces.
6. Place a piece of PLASTIGAGE® (**Figure 6-54, (1)**) along the full width of the bearing insert.

NOTICE

Do not rotate the crankshaft when using PLASTIGAGE. A false reading may result.

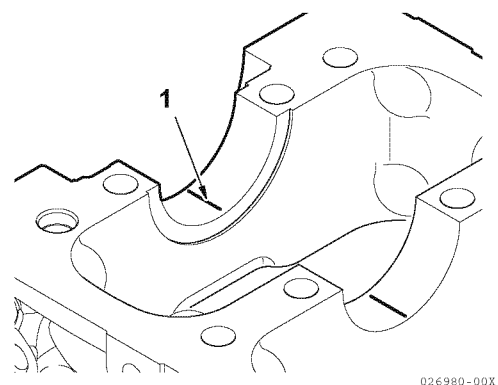
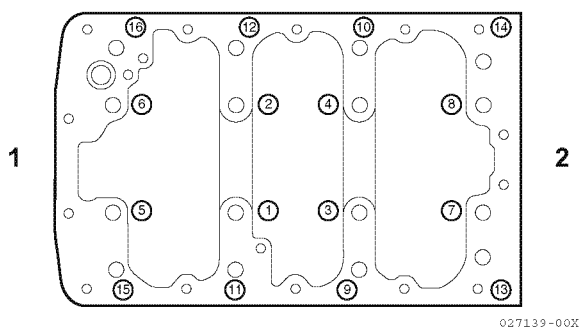


Figure 6-54

7. Install the ladder frame and tighten to specification. *See Special Torque Chart on page 6-11.*



1 – Gear Case Side
2 – Flywheel Side

Figure 6-55

8. Remove the ladder frame.

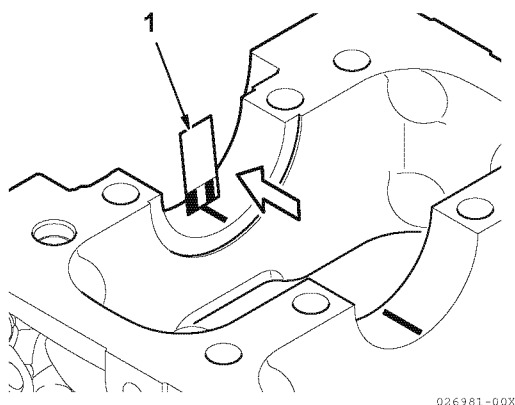


Figure 6-56

9. Compare the width of the flattened PLASTIGAGE (**Figure 6-56, (1)**) to the graduation marks on the package. The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance. Record the measurement. *See Crankshaft on page 6-6 for clearance specifications.*

10. Repeat with the remaining main bearings.

NOTICE

Be sure to note the markings on the main bearing, or make marks so they can be installed in the same order as they were removed.

11. Remove the crankshaft from the engine.

NOTICE

Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

12. If necessary, remove the crankshaft gear (**Figure 6-57, (1)**) and key (**Figure 6-57, (2)**). If using a gear puller, be careful not to damage the threads in the end of the crankshaft.

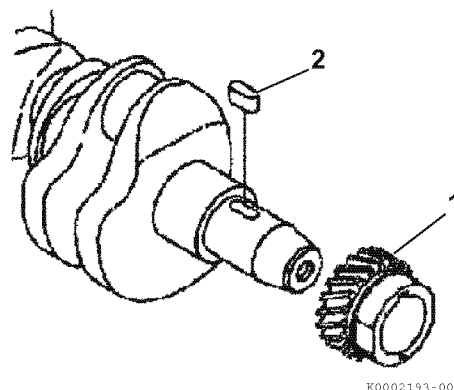


Figure 6-57

Inspecting the Crankshaft and Camshaft Components

WARNING

Fume/Burn Hazard

Always read and follow safety-related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

NOTICE

- Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.
- Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

Thoroughly clean all components using a brush and appropriate solvent. Each part must be free of carbon, gasket material, metal filings and other debris.

NOTICE

Record all measurements taken during inspection.

Replacing the Crankshaft Oil Seals

- Remove the seal (**Figure 6-58, (2)**) from the gear case cover (**Figure 6-58, (1)**).
- Install a new seal in the gear case cover with the lip facing in, away from the crankshaft pulley. Apply lithium grease to the lip of the seal.

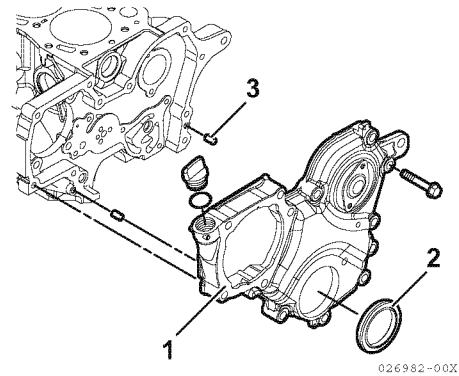


Figure 6-58

- Remove the rear oil seal (**Figure 6-59, (1)**) from the flywheel housing (**Figure 6-59, (2)**).

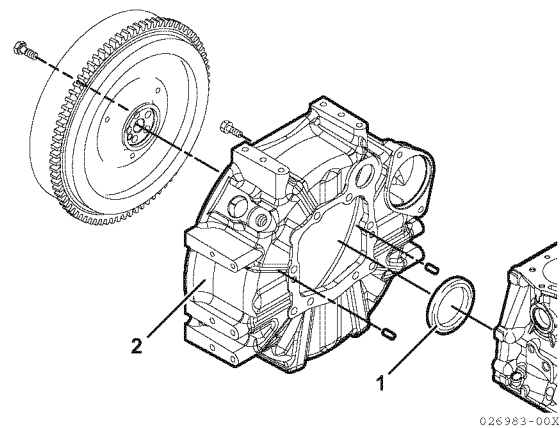


Figure 6-59

- Install a new seal in the flywheel housing with the lip facing in, away from the flywheel. Apply lithium grease to the lip of the seal.

Measuring Crankshaft Bearing Oil Clearance

Oil clearance should be checked during disassembly to determine the extent of wear, and during assembly to ensure long engine life. The same procedure is done for both connecting rods and main bearings. See *Removing the Pistons* on page 6-38 or *Removing the Crankshaft* on page 6-40 for specific information.

Inspecting the Cylinder Block

1. Ensure that oil passages are clear and unobstructed.
 2. Check for discoloration or evidence of cracks. If a fracture is suspected, use the color check method or the MAGNAFLUX® method to determine if the cylinder block is fractured.
 3. Measure cylinders for roundness and taper, and inspect for evidence of scoring. Consider honing, re-boring or replacing the cylinder block if the measurements are not within specification.
- Take measurements at three places (**Figure 6-60, (a, b, and c)**), and in two directions (**d and e**) in each cylinder. Collect and record the measurements. *See Cylinder Block on page 6-10 for specifications.*

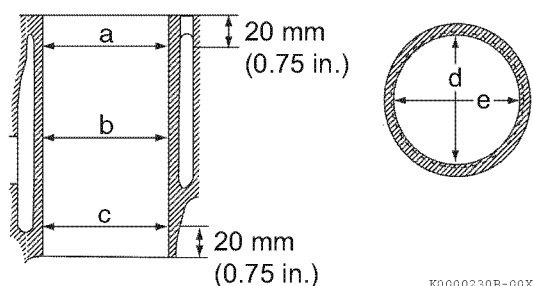


Figure 6-60

Roundness

Roundness can be calculated by subtracting the smaller measured value from the larger measured value of **d** or **e** at each measuring location **a**, **b**, and **c**.

Taper

Taper can be calculated by subtracting the minimum measured value from the maximum measured value of locations **a**, **b**, and **c**. Calculate along both the **d** axis and **e** axis and use the larger of the two calculations as the value to compare to the specifications.

Inspecting the Pistons, Piston Rings and Wrist Pin

NOTICE

- On an engine with low hours, the pistons and piston rings may be reused if they are found to be within specifications. The pistons and piston rings must be installed in the same cylinders from which they were originally removed.
- On an engine with high hours, the piston rings should be replaced and the cylinder honed (*see Honing and Boring on page 6-48*) or replaced. The piston should be replaced as necessary.

1. Clean piston ring grooves using a piston ring groove cleaning tool. Follow manufacturer's instructions for correct operation.
2. Wash the pistons in an appropriate solvent using a soft brush.
3. Visually inspect each piston for cracks. Pay particular attention to the ring lands between the piston ring grooves.
4. Measure the diameter of the piston skirt at 90° to the wrist pin bore as shown (**Figure 6-61**). Measurements must be taken at a specified distance (**Figure 6-61, (1)**) from the bottom of the piston, based on engine model. Record the measurements. *See Piston on page 6-8 for specifications.*

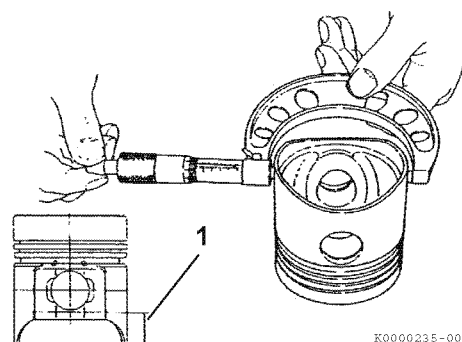


Figure 6-61

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection (see *Inspecting the Cylinder Block on page 6-43*) to obtain piston-to-cylinder clearance. Record the measurements. See *Piston on page 6-8 for specifications*.
6. Measure the diameter of the wrist pin bore on both sides of the piston (**Figure 6-62**). See *Piston on page 6-8 for specifications*. Record the measurements.

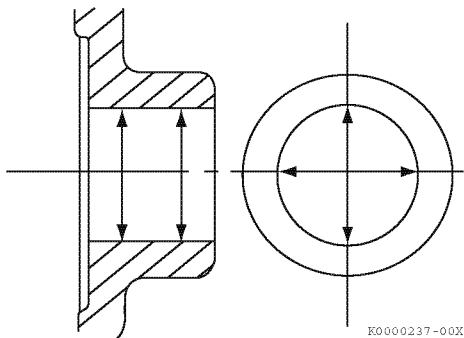


Figure 6-62

7. Measure the outside diameter of the wrist pin in three places and at 90° (**Figure 6-63**). See *Piston on page 6-8 for specifications*. Record the measurements.

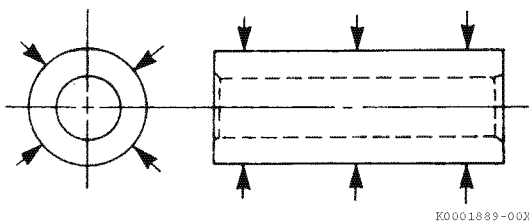


Figure 6-63

8. Using a micrometer, measure the thickness of each piston ring. See *Piston Ring on page 6-8 for specifications*. Record the measurements.

NOTICE

- On an engine with low hours, the pistons, piston rings and cylinders may be reused if they are found to be within specifications.
- On an engine with high hours, the piston rings should be replaced and the cylinder honed (see *Honing and Boring on page 6-48*) or replaced. The piston should be replaced as necessary.

9. Place each compression piston ring in the groove as shown (**Figure 6-64**). Use a feeler gauge to measure the clearance between the piston ring and the piston ring land. Record the measurements. See *Piston Ring on page 6-8 for specifications*. Replace the piston if not within specification.

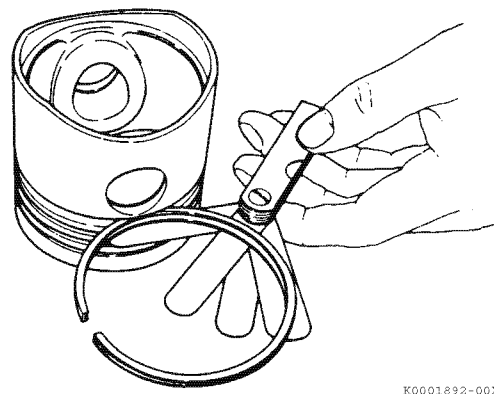


Figure 6-64

10. To measure piston ring end gap, insert each compression piston ring (**Figure 6-65, (1)**), one at a time, into the cylinder. Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 1.18 in. (30 mm) (**Figure 6-65, (2)**) from the bottom of the bore. Remove the piston. Measure the end gap (**Figure 6-65, (3)**) of each piston ring. Record the measurements. See *Piston Ring on page 6-8 for specifications*.

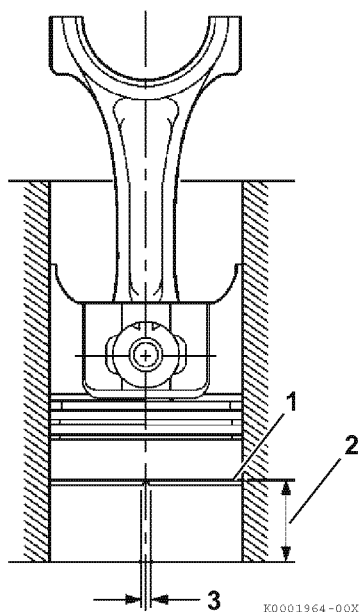


Figure 6-65

NOTICE

Always check the piston ring end gap when installing new piston rings. See *Piston Ring* on page 6-8 for specifications. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

11. Repeat the above steps for each cylinder and piston assembly.

Inspecting the Connecting Rod

1. Measure the wrist pin bushing bore using a bore gauge (Figure 6-66, (1)). Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end (Figure 6-66, (2)). Record the measurements. See *Connecting Rod* on page 6-9 for specifications.

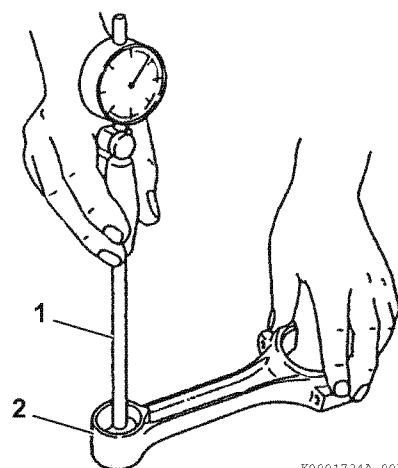


Figure 6-66

2. Measure the connecting rod twist (Figure 6-67, (1)) and bend (Figure 6-67, (2)) using a connecting rod alignment tool (Figure 6-68). Record the measurements. See *Connecting Rod* on page 6-9 for specifications.

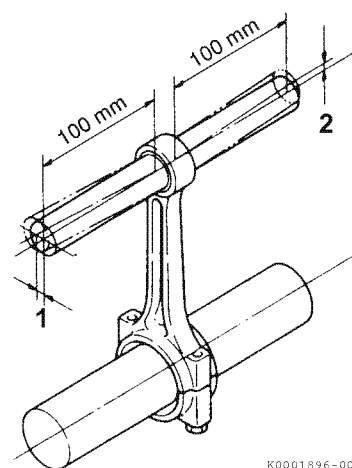


Figure 6-67

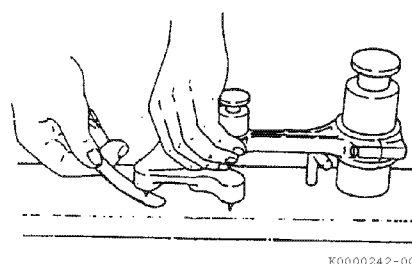


Figure 6-68

- Place the connecting rod bearing inserts into the connecting rod and connecting rod cap. Install the rod cap and tighten the bolts to the specified torque.
- Measure the inside diameter. Record the measurements. *See Crankshaft on page 6-6 for specifications.*

Inspecting the Tappets

- Inspect the tappet contact surfaces for abnormal wear (**Figure 6-69, (1)**). Normal wear will be even as shown in **Figure 6-69, (2)**. Slight surface defects can be corrected using an oilstone.

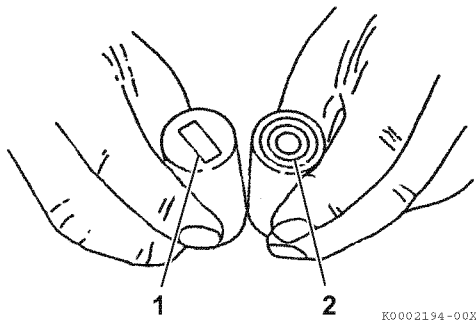


Figure 6-69

- Measure the outside diameter of the tappet stem (**Figure 6-70**). Record the measurements. *See Tappet on page 6-9 for the service limit.*

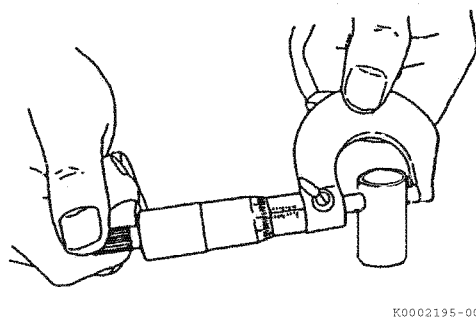


Figure 6-70

- Measure the tappet bores in the cylinder block. Record the measurements. *See Tappet on page 6-9 for the service limit.*

Inspecting the Crankshaft

- Put the crankshaft end journals (**Figure 6-71, (4)**) on V-blocks.
- Place a dial indicator (**Figure 6-71, (3)**) on a center main bearing surface.

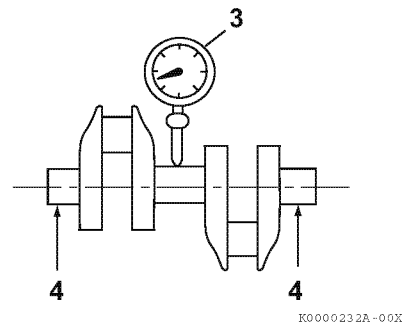
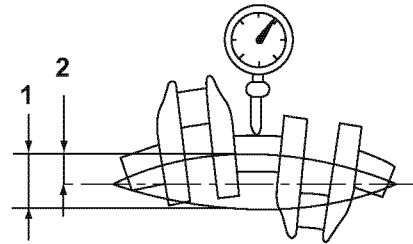


Figure 6-71

- Rotate the crankshaft and observe runout. Record the measurements. *See Crankshaft on page 6-6 for specifications.*
- Use the color check method or MAGNAFLUX to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures is found.
- Measure the outside diameter of each crankpin (**Figure 6-72, (2)**) and main bearing journal (**Figure 6-72, (1)**). *See Crankshaft on page 6-6 for specifications.* Take measurements at several places around each bearing surface. If not within specification, grind the journals and install undersize bearings, or replace the crankshaft. Record the measurements.

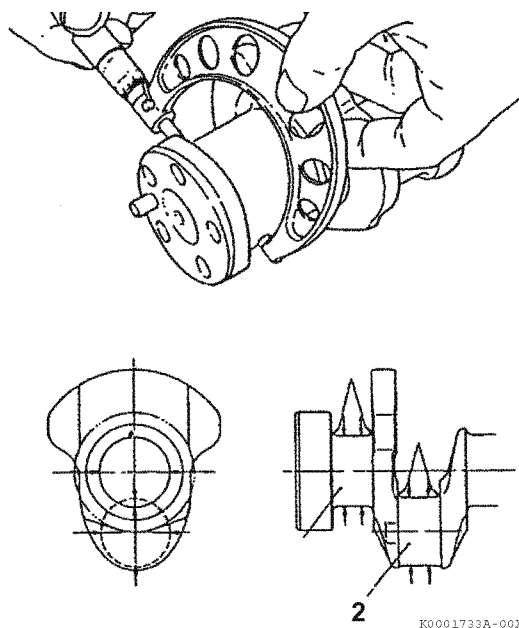


Figure 6-72

Reconditioning the Crankshaft

If any of the crankshaft journals do not meet the specifications, it may be possible to grind any or all of them to an undersize. The connecting rod bearings, main bearings and thrust bearing inserts are available as 0.010 in. (0.25 mm) undersize. If the journals are ground undersize, the following finishing standards (**Figure 6-73**) must be adhered to:

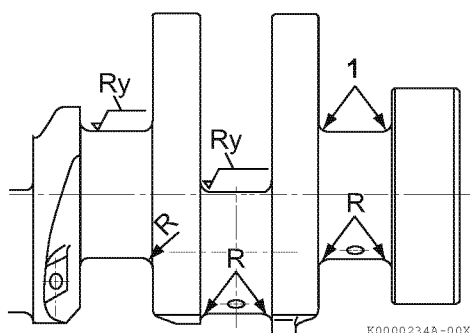


Figure 6-73

Inspecting the Camshaft

1. Use V-blocks and a dial indicator to check camshaft bend (**Figure 6-74**). Place the indicator on the center bearing journal.

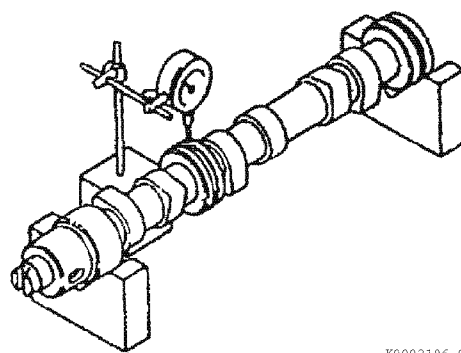


Figure 6-74

2. Rotate the camshaft and observe the runout. Record the measurements. See *Camshaft* on page 6-5 for specifications.
3. Measure the height of each lobe (**Figure 6-75, (1)**). Record the measurements. See *Camshaft* on page 6-5 for specifications.

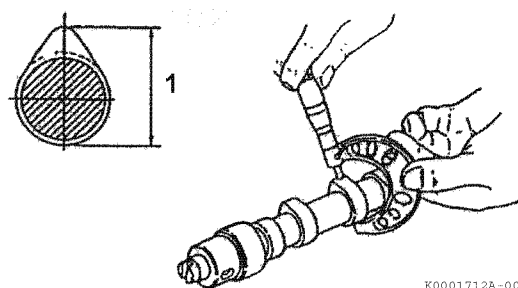


Figure 6-75

4. Measure the diameter of the gear end (**Figure 6-76, (1)**), intermediate (**Figure 6-76, (2)**) and flywheel end (**Figure 6-76, (3)**) bearing journals. Record the measurements. *See Camshaft on page 6-5 for specifications.*

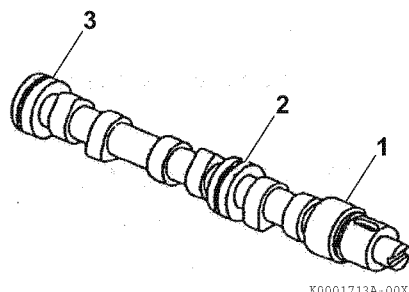


Figure 6-76

Inspecting the Camshaft Insert Bores

Camshaft bushing is not applicable in TNM engines. Therefore, measure the bore I.D. of the camshaft insertion portion in the cylinder block. If the bore I.D. is not within specification, replace the cylinder block.

Inspecting the Idler Gear and Shaft

1. Measure the outside diameter (**Figure 6-77, (1)**) of the idler gear shaft (**Figure 6-77, (2)**). Record the measurements. *See Idler Gear Shaft and Bushing on page 6-6 for specifications.*
2. Measure the inside diameter (**Figure 6-77, (3)**) of the idler gear bushing (**Figure 6-77, (4)**). Record the measurements. *See Idler Gear Shaft and Bushing on page 6-6 for specifications.*

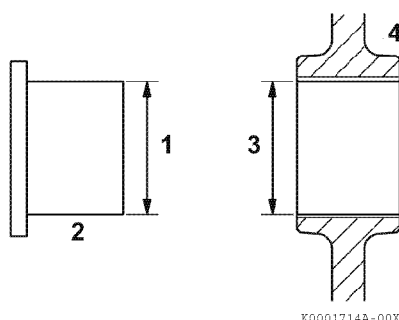


Figure 6-77

Honing and Boring

Pistons must move freely in the cylinders while maintaining adequate compression and oil sealing. If the cylinder walls are scuffed, scored, out-of-round or tapered beyond specifications, rebore and hone to restore cylinders to usable condition. Slight imperfections can be corrected by honing alone.

1. **Boring** - Significant cylinder damage may be corrected by boring the cylinder to an oversize dimension. Refer to the appropriate parts catalog for available oversize pistons and piston rings.
 - Boring a cylinder should always be done in a properly equipped machine shop.
 - A bored cylinder should always be finished with a hone to properly prepare the cylinder surface so the new piston rings will seat properly.
 - After the cylinder has been bored and honed, install the appropriate oversize pistons and piston rings.
2. **Honing** - Minor cylinder imperfections may be corrected by using a rigid cylinder hone (**Figure 6-79, (1)**). Be sure not to exceed the maximum cylinder bore specification.

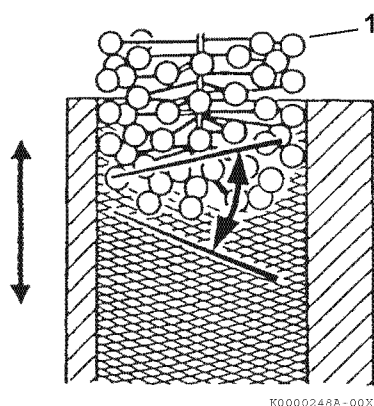
Deglazing - A used cylinder that did not require boring or honing should always be deglazed with a ball hone (**Figure 6-79, (2)**) before installing new piston rings. This will properly prepare the cylinder surface to allow new piston rings to seat properly.

NOTICE

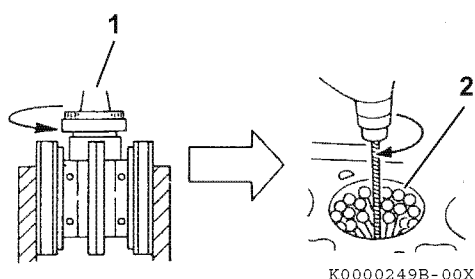
When honing a cylinder, with either a ridged hone or a ball hone (**Figure 6-78, (1)**), move the rotating hone up and down in the cylinder bore to accomplish a 30° to 40° crosshatch pattern (**Figure 6-78**). This will provide the ideal surface for the proper seating of new piston rings.

NOTICE

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

**Figure 6-78**

- Use a 50:50 mixture of diesel fuel and engine oil as a honing fluid.
- Use a 300-grit hone at 300 to 1200 rpm (min^{-1}) (Figure 6-79).

**Figure 6-79**

- When honing is completed, wash the cylinder block with hot water and soap.

NOTICE

- Solvents will not adequately remove honing residue, resulting in premature piston and ring wear. Always wash cylinders using hot, soapy water.
- The cylinder wall is adequately cleaned when a white rag wiped in cylinder comes out clean. Use brushes to clean all passages and crevices. Rinse with hot water and dry with compressed air. Apply clean engine oil to all steel surfaces to prevent rusting.

Assembling the Crankshaft and Piston Components

Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.

NOTICE

- Use new gaskets, seals and O-rings during assembly.
- Liberally apply clean engine oil to all internal parts during assembly.
- Tighten all fasteners to the specified torque. If a special torque is not provided in the *Special Torque Chart on page 6-11*, tighten to standard torque specifications. See *Tightening Torques for Standard Bolts and Nuts on page 4-25*.

Assembling the Pistons

1. Select the parts needed to assemble the piston and connecting rod for one cylinder.
2. If removed, install a new wrist pin bushing (**Figure 6-80, (7)**) using a press and the appropriate service tool. Be sure to align the oil holes.

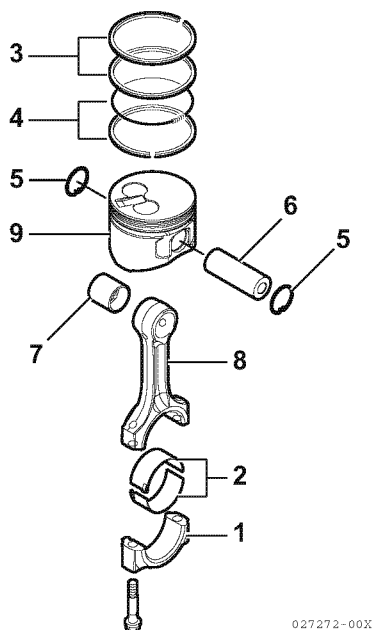


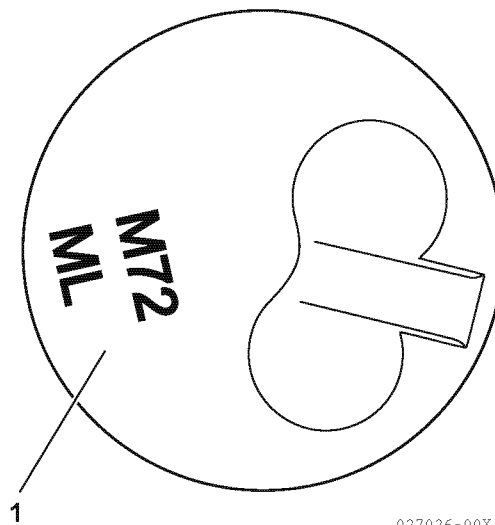
Figure 6-80

3. Install one circlip (**Figure 6-80, (5)**) into the piston. Ensure the circlip is securely seated in the groove.

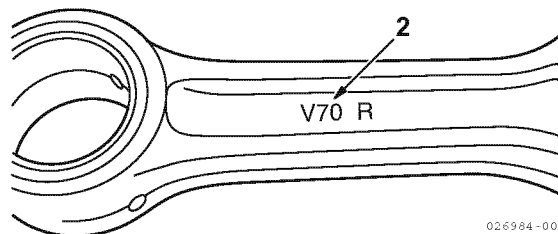
NOTICE

The piston and connecting rod must be assembled with the correct orientation. When correctly assembled, the piston identification mark (**Figure 6-81, (1)**) stamped into the top of the piston will be on the opposite side of the connecting rod as the match marks (**Figure 6-81, (3)**) stamped into the connecting rod and connecting rod cap. When installed in the cylinder, the embossed mark (**Figure 6-81, (2)**) cast into the beam of connecting rod will face the flywheel end of the engine.

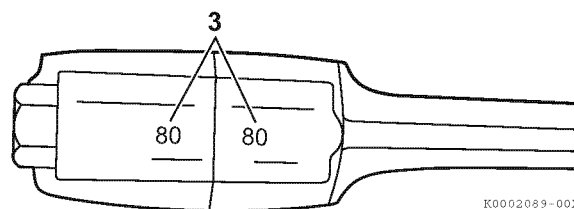
Note: The actual appearance of the match marks will vary but they will always be in the same locations.



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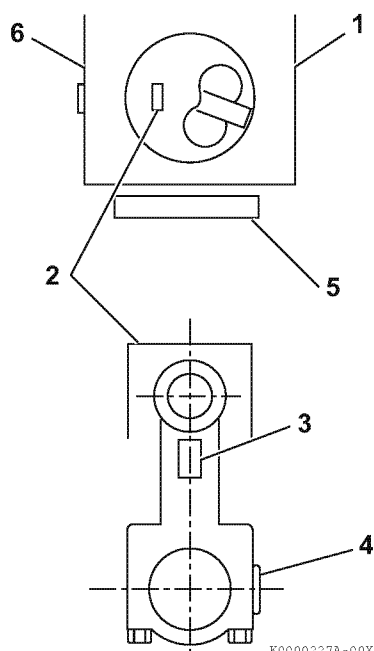
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Figure 6-81

4. Place the connecting rod into the piston. The match marks (**Figure 6-82, (4)**) on the connecting rod and cap must be on the opposite side as the piston identification mark (**Figure 6-82, (2)**) on the top of the piston.



- 1 – Fuel Injection Pump Side of Engine
 2 – Piston Identification Mark
 3 – Embossed Mark on Connecting Rod
 4 – Connecting Rod and Cap Match Marks
 5 – Flywheel End of Engine
 6 – Camshaft Side of Engine

Figure 6-82

5. Lubricate and install the wrist pin (**Figure 6-83, (6)**) through the piston and connecting rod.
6. Install the second circlip (**Figure 6-83, (5)**) and ensure it is securely seated in the groove.

NOTICE

If installing new piston rings, the end gap must be checked and adjusted as necessary. See *Inspecting the Pistons, Piston Rings and Wrist Pin* on page 6-43. Use a piston ring end gap filing tool to adjust the piston ring end gap on new piston rings.

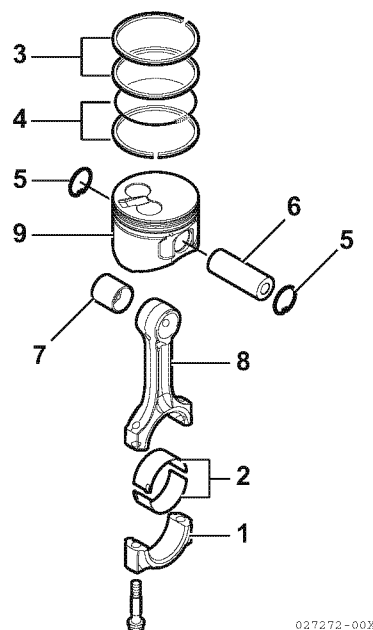


Figure 6-83

NOTICE

Install the top and second piston rings with the stamped “makers mark” (**Figure 6-84, (1)**) facing the top of the piston. The “makers mark” may vary in appearance but will always be located on the top surface of the piston ring adjacent to the piston ring gap. The oil ring and oil ring expander can be installed either side up.

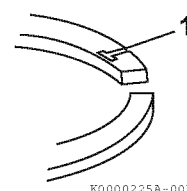


Figure 6-84

NOTICE

Always use a piston ring expander when installing piston rings. Never attempt to install piston rings by hand.

7. Install the oil ring expander (Figure 6-85, (4)). Install the oil ring (Figure 6-85, (3)) with the end gap at 180° from the expander end gap.
8. Install the middle compression ring (Figure 6-85, (2)). This ring is identified by its dark color and tapered face profile.
9. Install the top compression ring (Figure 6-85, (1)). This ring is identified by its silver color and barrel-shaped face profile.

NOTICE

The oil ring expander end gap must be located 180° from the oil ring end gap.

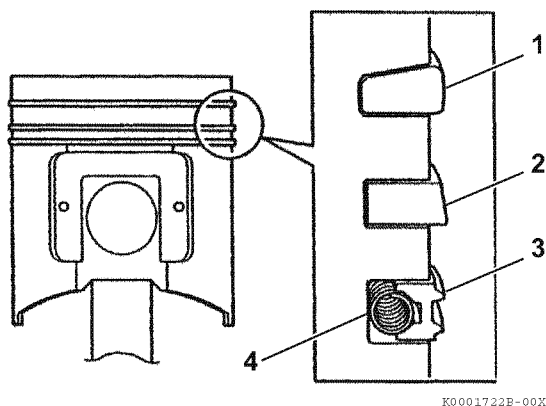
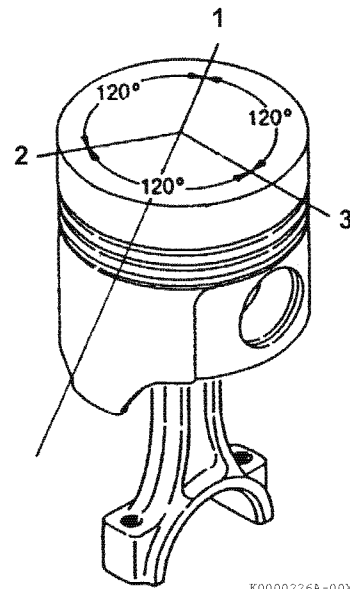


Figure 6-85

10. Stagger the piston ring end gaps at 120° intervals (Figure 6-86, (1, 2, and 3)). Do not position the top piston ring end gap in line with the wrist pin.



- 1 – Top Compression Ring End Gap
- 2 – Middle Compression Ring End Gap
- 3 – Oil Control Ring End Gap

Figure 6-86

Installing the Crankshaft

1. If removed, install the key and timing gear on crankshaft.
2. Install new bearing inserts (Figure 6-87, (1)) and thrust bearing (Figure 6-87, (2)) in the cylinder block and main bearing caps. Be sure the oil holes in the upper bearing shells align with the oil ports in the cylinder block. Apply a liberal coat of clean engine oil to the bearings and crankshaft journals.

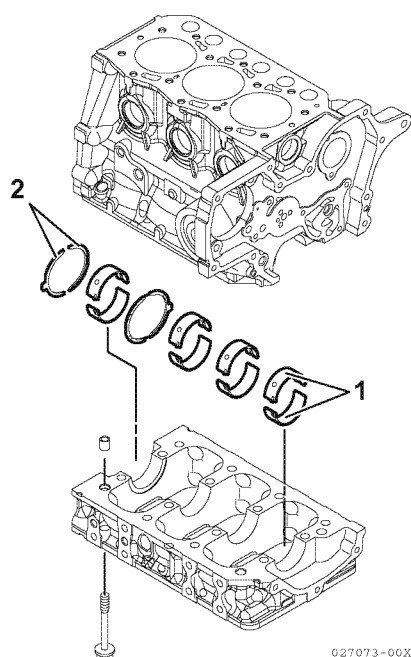


Figure 6-87

3. Install the thrust bearing (side gap).
 - Install the thrust bearing on the flywheel side.
 - The installation procedure is indicated as follows (the same procedure for both sides).
- (a) Install the thrust bearing (without a tab) to the cylinder block after the crankshaft assembly (the crankshaft is omitted).

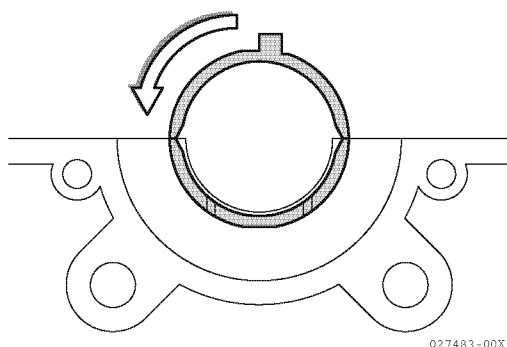


Figure 6-88

- (b) Mount the thrust bearing (with a tab) and turn it 90 degrees counterclockwise.

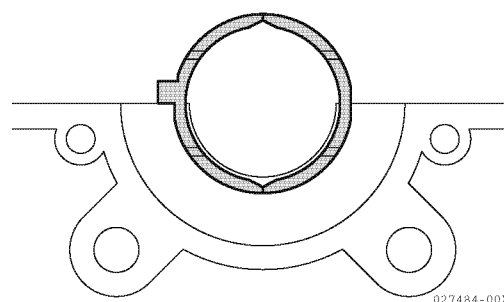


Figure 6-89

4. Install the upper main bearing, thrust bearing and crankshaft into the engine.

NOTICE

The main bearings are numbered and have arrows for proper positioning. The No. 1 bearing is at the flywheel end.

5. Install the lower main bearing into the ladder frame.
6. Apply a light coat of clean engine oil to the ladder frame mounting bolts and tighten the bolts to the specified torque in two stages (1/2 then full torque). See *Special Torque Chart* on page 6-11.

NOTICE

Apply plenty of liquid packing to these portions (in the flywheel side) until protruding to the oil seal insertion hole, and wipe off the protruded liquid packing.

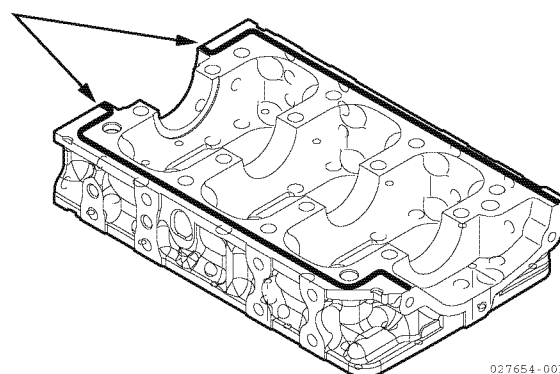
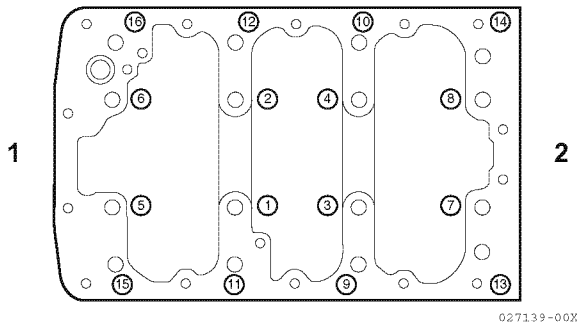


Figure 6-90

7. The surface difference between the surfaces on the flywheel side and the gear case side and the ladder frame surface should be ± 0.004 in. (0.1 mm) or less.



1 – Gear Case Side
2 – Flywheel Side

Figure 6-91

8. Rotate the crankshaft to ensure it turns freely.
9. Apply ThreeBond Liquid Gasket No. 1212, Yanmar Part No. 977770-01212, to the mounting flange of the flywheel housing (**Figure 6-92, (2))**.
10. Align the flywheel housing with the two dowel pins (**Figure 6-92, (3))**.
11. Install flywheel housing and seal assembly.
12. Install the flywheel (**Figure 6-92, (1))** and tighten the bolts to the specified torque. See *Special Torque Chart on page 6-11*.

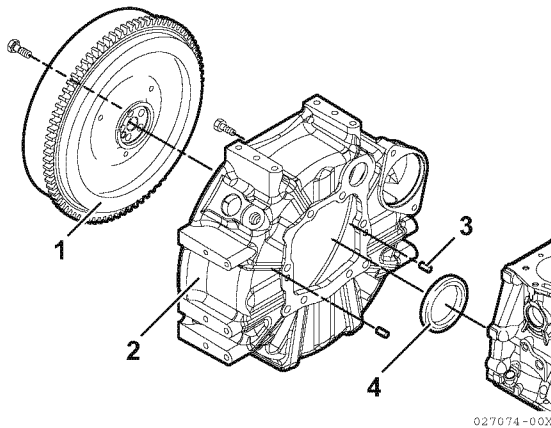


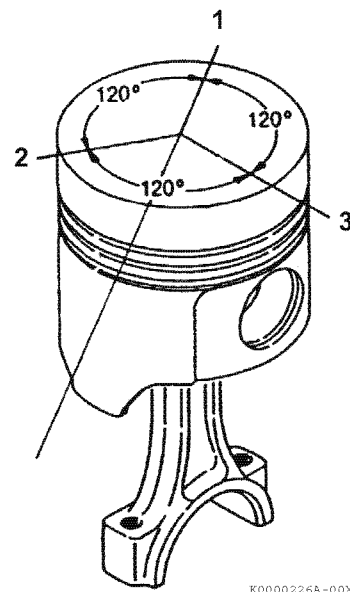
Figure 6-92

Installing the Pistons

NOTICE

Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft bearing journal may result.

1. Lubricate piston, piston rings and cylinder with clean engine oil or assembly lubricant.
2. Rotate the crankshaft so the crankpin for the piston being installed is near bottom dead center.



1 – Top Compression Ring End Gap
2 – Middle Compression Ring End Gap
3 – Oil Control Ring End Gap

Figure 6-93

NOTICE

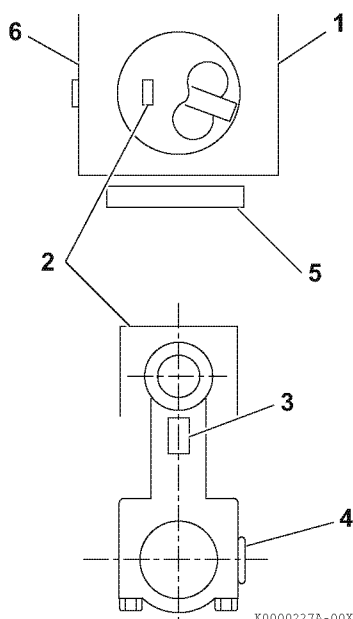
Ensure piston ring gaps are located correctly (**Figure 6-93**).

3. Using a piston ring compressor, compress the piston rings.

4. Carefully install the piston and rod assembly. Be sure the match marks (**Figure 6-94, (4)**) stamped into the connecting rod and cap are facing the fuel injection pump side of the cylinder block, and the piston identification mark (**Figure 6-94, (2)**) stamped into the piston top is facing the camshaft side (**Figure 6-94, (6)**). The embossed mark cast into the connecting rod beam (**Figure 6-94, (3)**) will be facing the flywheel end of the engine (**Figure 6-94, (5)**).

NOTICE

The piston and connecting rod must be installed with the correct orientation. When installed correctly, the identification mark (**Figure 6-94, (2)**) stamped into the top of the piston will be on the same side of the engine as the fuel injection pump (**Figure 6-94, (1)**) and the embossed mark (**Figure 6-94, (3)**) cast into the connecting rod beam will face the flywheel end of the engine (**Figure 6-94, (5)**).



- 1 – Fuel Injection Pump Side of Engine
- 2 – Piston Identification Mark
- 3 – Embossed Mark on Connecting Rod
- 4 – Rod and Cap Match Marks
- 5 – Flywheel End of Engine
- 6 – Camshaft Side of Engine

Figure 6-94

5. Install the bearing inserts (**Figure 6-95, (1)**) in the connecting rod and cap.
6. Apply a liberal coat of clean engine oil to the bearing inserts and crankshaft journal.
7. Apply a light coat of clean engine oil to the rod cap bolts. Install the connecting rod cap (**Figure 6-95, (2)**). Tighten the connecting rod bolts to the specified torque in two stages (1/2 then full torque). See *Special Torque Chart* on page 6-11.

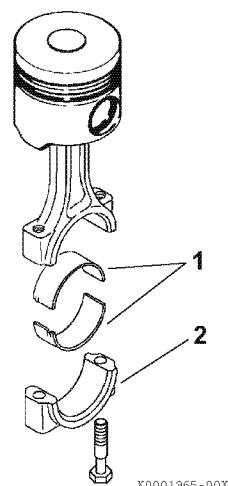


Figure 6-95

8. Install the remaining pistons in their respective cylinders.

Assembling the Camshaft and Timing Components

Installing the Camshaft

NOTICE

The gear housing must be installed prior to installing the camshaft.

1. If removed, install the camshaft end plate (**Figure 6-96, (1)**), key and camshaft gear (**Figure 6-96, (4)**) onto the camshaft using a press.

Heat the gear to 356° to 392°F (180° to 200°C) and press onto the end of the camshaft.

2. Lubricate the camshaft (**Figure 6-96, (2)**) with clean engine oil or assembly lube. Slowly insert the camshaft through the front of the engine.
3. Install and tighten the capscrews (**Figure 6-96, (3)**).

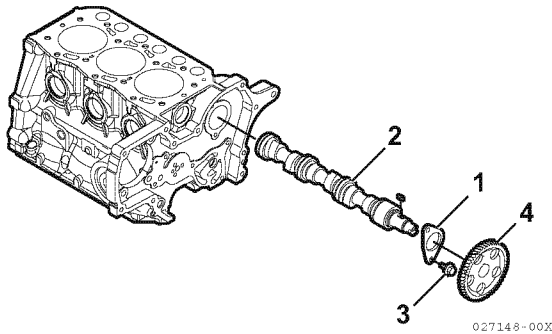


Figure 6-96

4. Lubricate the camshaft lobes and tappets with clean oil or assembly lube. Install the tappets in their respective locations in the cylinder block. Push the tappets fully into the tappet bores until they make solid contact with the camshaft.
5. If removed, install the fuel injection pump. Adjust the fuel injection timing after installation. See *Checking and Adjusting Fuel Injection Timing* on page 7-17.

Installing the Timing Gears

1. Set No. 1 piston to top dead center.
2. Rotate the camshaft until mark (**Figure 6-98, (B)**) is approximately at the 8 o'clock position.
3. Lubricate the idler gear (**Figure 6-97, (3)**), bushing (**Figure 6-97, (2)**) and idler gear shaft (**Figure 6-97, (1)**) with clean engine oil or assembly lube.

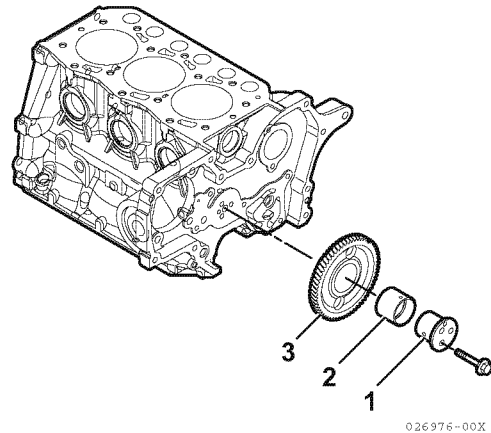
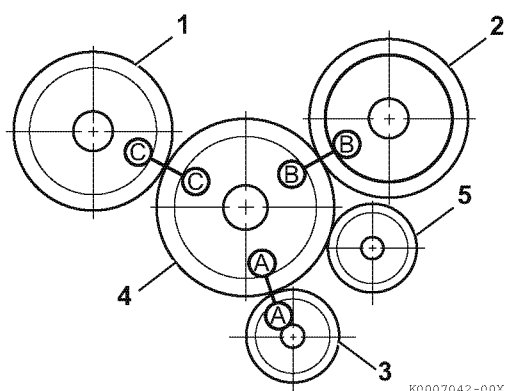


Figure 6-97

4. Align the timing gears as shown in **Figure 6-98**.
5. Install the idler gear and idler gear shaft. Be sure the oil hole in the bushing is facing toward the top of the engine.
6. Ensure all three timing marks (**Figure 6-98, (A, B, and C)**) are aligned.



- 1 – Fuel Injection Pump Gear
 2 – Camshaft Gear
 3 – Crankshaft Gear
 4 – Idler Gear
 5 – Oil Pump Gear

Figure 6-98

7. When all gears are properly aligned, tighten the idler gear retaining bolts to specified torque. See *Special Torque Chart* on page 6-11 for specifications.

Installing the Gear Case Cover

1. Apply a continuous bead of ThreeBond Liquid Gasket No. 1212, Yanmar Part No. 977770-01212, to the mounting area of the gear case cover (**Figure 6-99, (1)**). Be sure to circle the bolt holes.

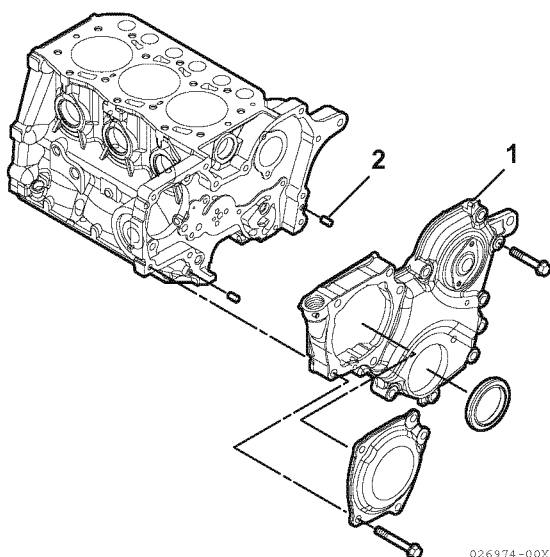


Figure 6-99

2. Install the dowels (**Figure 6-99, (2)**).
 3. Install the timing gear case cover.
 4. Install and tighten the gear case cover bolts.
 5. Install the crankshaft pulley.
 6. Install the washer and bolt. Tighten to the specified torque. See *Special Torque Chart* on page 6-11 for specifications.

Installing the Oil Pan

1. Install the oil pickup tube (**Figure 6-100, (1)**) and a new O-ring (**Figure 6-100, (2)**).

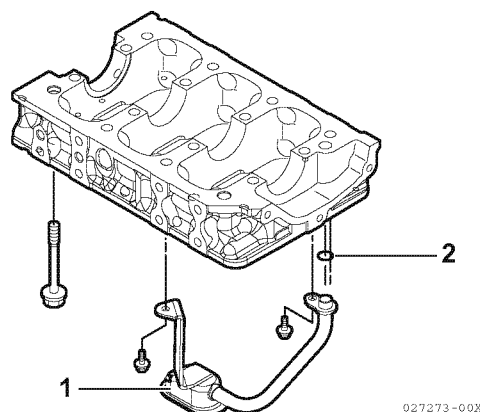


Figure 6-100

2. Apply a continuous bead of ThreeBond Liquid Gasket No. 1212, Yanmar Part No. 977770-01212, to the mounting surface of the oil pan (**Figure 6-101, (2)**) and crankcase extension (if equipped) (**Figure 6-101, (1)**). Be sure to circle each bolt hole.
 3. If equipped, install the crankcase extension. Install the oil pan and tighten the bolts securely.

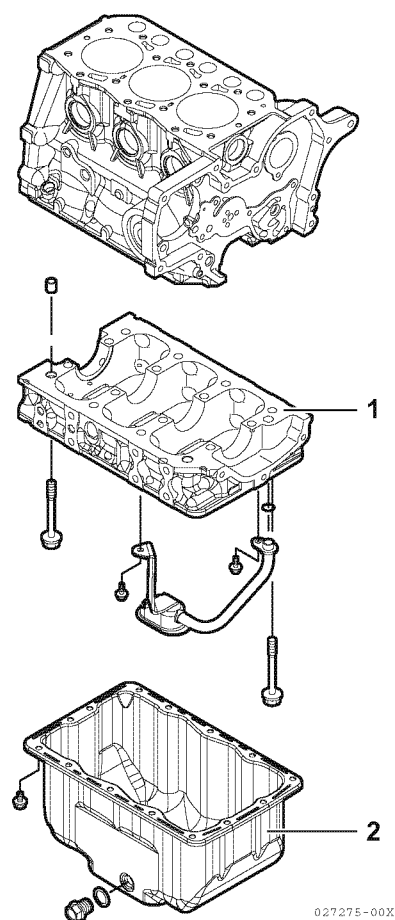


Figure 6-101

Final Assembling of the Engine

1. Install the starter motor.
2. Install the cylinder head. *See Assembling the Cylinder Head on page 6-27.*
3. Install the engine in the machine.
4. Connect the fuel and coolant lines.
5. Install the alternator.
6. Connect and adjust the throttle cable.
7. Connect all electrical connections.
8. Fill the engine with oil and coolant.
9. Connect the battery cables, negative (-) cable last.

Section 7

FUEL SYSTEM

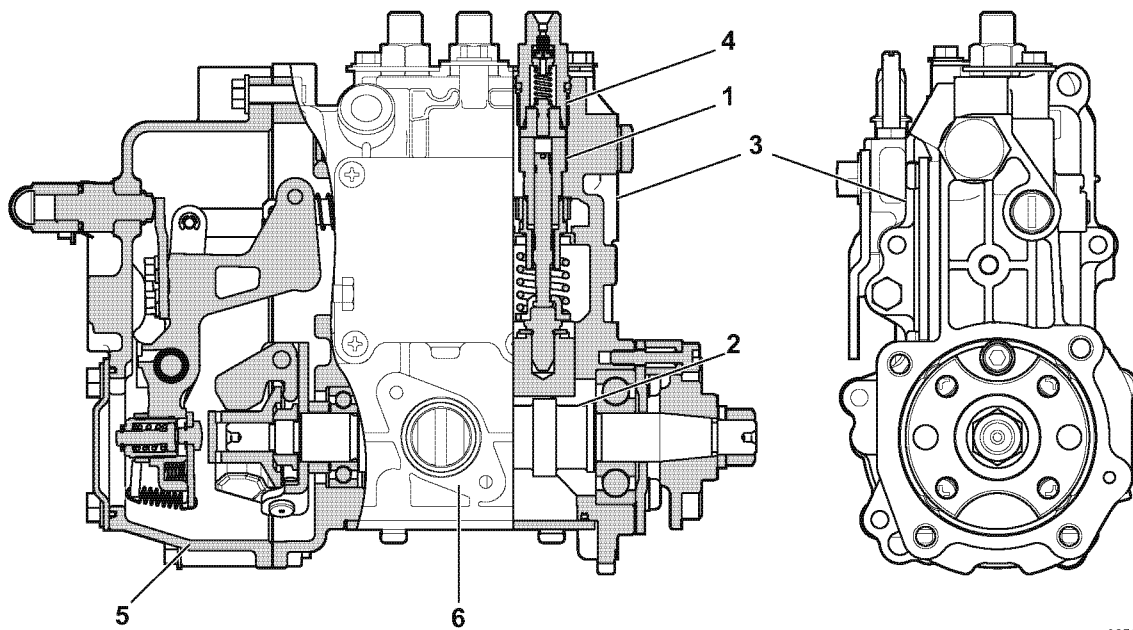
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SAFETY PRECAUTIONS

Before performing any fuel system service procedures, review the *Safety section on page 3-1*.

INTRODUCTION



027014-00X

Figure 7-1

This section of the *Service Manual* describes the procedures necessary to remove, install and time the MC fuel injection pump and its associated system components.

Fuel Injection Pump

NOTICE

If the MC fuel injection pump itself requires servicing, it must be taken to an authorized Yanmar FIE (Fuel Injection Equipment) repair facility.

NOTICE

- Never remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.
- Never attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations, and then replace the tamper-proof seals.
- Tampering with or removing these devices may void the "Yanmar Limited Warranty."

The following describes the features of the MC fuel injection pump, manufactured by Yanmar.

The fuel injection pump is a very important component of the engine. It is capable of making very precise fuel delivery adjustments according to the varied loads applied to the engine.

All of the fuel injection pump components are very precisely machined. It is extremely important to follow good service practices and maintain cleanliness when servicing the fuel injection pump.

The Yanmar MC Fuel Injection Pump is an in-line type pump which consists of a fuel supply plunger (**Figure 7-1, (1)**) for each cylinder, a camshaft (**Figure 7-1, (2)**) and a pump housing (**Figure 7-1, (3)**). A delivery valve (**Figure 7-1, (4)**) connects to a high-pressure fuel line for each cylinder. The fuel injection pump housing contains a governor (**Figure 7-1, (5)**).

Fuel from the fuel tank to the fuel injection pump is delivered by a low-pressure electric fuel feed pump. On a few special models, a mechanical fuel feed pump is used instead of an electric pump. The mechanical fuel feed pump is mounted to the fuel injection pump housing in place of the cover plate (**Figure 7-1, (6)**).

Fuel to be injected into the cylinders is pressurized by the up and down motion of each camshaft-driven plunger, and is then supplied by the high-pressure fuel lines to the respective fuel injector.

The fuel injector is essentially a spring-loaded valve. When fuel pressure from the fuel injection pump reaches a pre-determined level, the pintle (valve) is forced off its seat and fuel is atomized as it passes between the pintle and seat. The timing and quantity of the fuel injected into the cylinder is controlled by the fuel injection pump and governor assembly.

Stop Solenoid

The ML fuel injection pumps are equipped with a stop solenoid that controls the fuel flow inside the fuel injection pump.

With the starter switch in the OFF position, no current flows to the stop solenoid and the solenoid plunger is extended, holding the fuel injection pump fuel rack in the "closed" position and not allowing fuel to flow through the injection pump and to the engine.

When the starter switch is turned to the start position, the "pull coil" (36.5-amp draw / white wire) inside the solenoid is activated and pulls the solenoid plunger into the solenoid. This releases the fuel injection pump fuel rack, allowing fuel to flow through the injection pump and allowing the engine to start and run.

When the starter switch is returned to the ON or RUN position, the "pull coil" no longer receives current and the "hold coil" (0.5-amp draw / red wire) inside the solenoid is activated. The "hold coil" holds the solenoid plunger in the RUN position, allowing fuel to continue flowing and the engine to continue running.

To stop the engine, the key switch is turned to the OFF position. Current no longer flows to the stop solenoid "hold coil," and the solenoid plunger extends and moves the injection pump fuel rack to the "closed" position, shutting off the fuel flow and stopping the engine.

Failure of the stop solenoid could result in the engine not starting, the engine stopping suddenly, the engine continuing to run with the key switch returned to the ON or RUN position or the engine failing to stop when the key switch is turned to the OFF position. Use a VOA multimeter or continuity light to check for a good ground and 12V at the stop solenoid in the correct sequence.

FUEL SYSTEM SPECIFICATIONS

Special Torque Chart

Component	Tightening Torque	Lubricating Oil Application (Thread Portion and Seat Surface)
Fuel Injector	36.1 - 39.1 ft-lb (49 - 53 N·m; 5.0 - 5.4 kgf·m)	Not Applied
Fuel Pump Drive Gear Nut	44 - 51 ft-lb (59 - 69 N·m; 6 - 7 kgf·m)	Not Applied
High-Pressure Fuel Injection Line Nuts	22 - 25 ft-lb (29 - 34 N·m; 3.0 - 3.5 kgf·m)	Not Applied
Fuel Return Line Nuts	18 - 24 ft-lb (24 - 33 N·m; 2.5 - 3.3 kgf·m)	Not Applied
Fuel Injection Pump Mounting Bolts	17 - 21 ft-lb (23 - 28 N·m; 2.3 - 2.9 kgf·m)	Not Applied
Fuel Injector Nozzle Case Nut	21.4 - 36.1 ft-lb (29 - 49 N·m; 3.0 - 5.0 kgf·m)	Not Applied

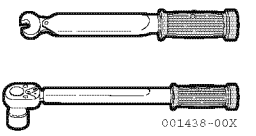
Test and Adjustment Specifications

Fuel Injector Pressure	Fuel Injection Timing
1784 - 1929 psi (12.3 - 13.3 MPa; 125 - 136 kgf/cm ²)	See <i>Checking and Adjusting Fuel Injection Timing</i> on page 7-17

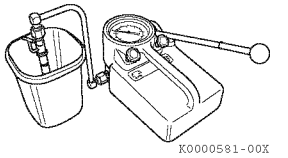
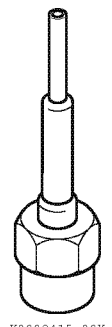
Note: Fuel injector pressures given are for used parts. New injectors (5 hours operation or less) will read approximately 72.5 psi (0.5 MPa; 5 kgf/cm²) higher.

SPECIAL SERVICE TOOLS

Note: Tools without Yanmar part numbers must be acquired locally.

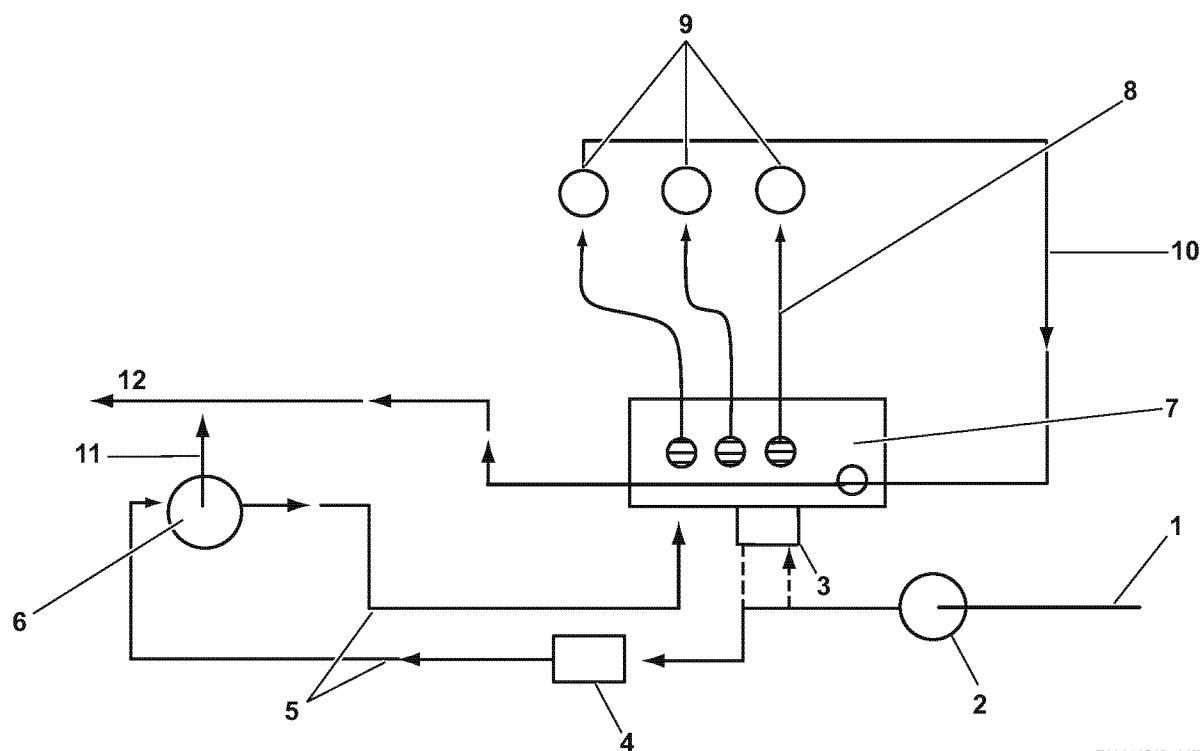
No.	Tool Name	Application	Illustration
1	Torque Wrench (Locally Available)	For tightening nuts and bolts to the specified torque	 001438-00X

MEASURING INSTRUMENTS

No.	Instrument Name	Application	Illustration
1	Fuel Injector Tester (Locally Available)	For observing injection spray pattern of fuel injection nozzle and measuring injection pressure	 K0000581-00X
2	"Spill-Timing" Tool (Shop Fabricated)*	Used to set fuel injection timing	 K0002415-00X

* Make from a short piece of the end of a high-pressure fuel line, a high-pressure fuel line nut and a short piece of clear plastic tubing (a thin nozzle from an aerosol spray can works well). Drill out the end of the fuel line to accept the nozzle. Use a small amount of silicone sealant to seal the nozzle into the fuel line.

FUEL SYSTEM DIAGRAM



K0001058A-00X

- | | |
|---|--|
| 1 - Diesel Fuel Supply | 6 - Fuel Filter |
| 2 - Fuel Filter/Water Separator | 7 - Fuel Injection Pump |
| 3 - Mechanical Fuel Feed Pump
(Used in place of the electric fuel feed pump on
some models) | 8 - High-Pressure Fuel Injection Lines |
| 4 - Electric Fuel Feed Pump (Used on models
without mechanical fuel feed pump) | 9 - Fuel Injectors |
| 5 - Low-Pressure Fuel Supply Lines | 10 - Fuel Return from Fuel Injectors |
| | 11 - Air Bleed Orifice |
| | 12 - Fuel Return to Tank |

Figure 7-2

FUEL SYSTEM COMPONENTS

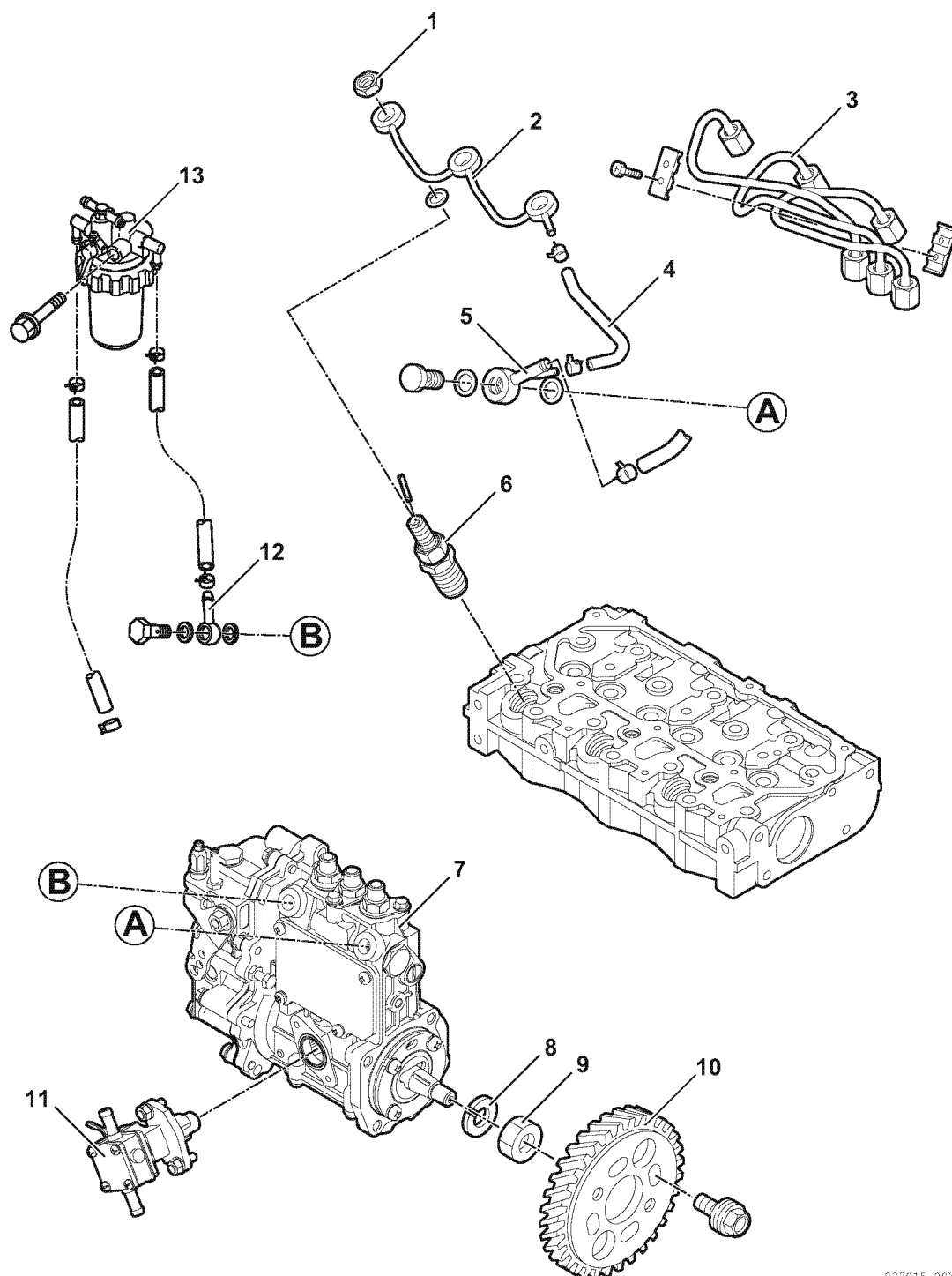


Figure 7-3

- 1 – Fuel Return Line Nut
- 2 – Fuel Return Line
- 3 – High-Pressure Fuel Injection Lines
- 4 – Fuel Return Hose
- 5 – Fuel Return Fitting
- 6 – Fuel Injector
- 7 – Fuel Injection Pump
- 8 – Lock Washer
- 9 – Fuel Injection Pump Drive Gear Nut
- 10 – Fuel Injection Pump Drive Gear Assembly (DO NOT remove or loosen the four bolts that fasten the injection pump drive gear to the injection pump drive gear hub!)
- 11 – Mechanical Fuel Feed Pump (Optional on some models)
- 12 – Low-Pressure Fuel Inlet Fitting
- 13 – Fuel Filter

FUEL INJECTION LINES

Removing the High-Pressure Fuel Injection Lines

NOTICE

- Remove and install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to install the fuel lines.
- To prevent “rounding” the fuel line nuts, always use a “line” or “flare nut” wrench.

1. Close any fuel valves in the fuel supply line.
2. Clean the area to keep contaminants from entering the fuel system.
3. Place a drain pan under the fuel injection pump to catch any spillage.
4. Loosen the fuel line nuts at the fuel injection pump.
5. Next, loosen the fuel line nuts at the fuel injectors. Use one wrench to hold the fuel return line nut and fuel return line from rotating. Use a second wrench to loosen the fuel line nut (**Figure 7-4**). Repeat with the remaining fuel injectors.

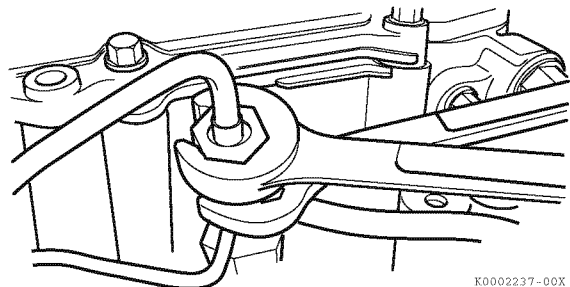


Figure 7-4

6. Finish loosening all the fuel line nuts and remove the high-pressure fuel lines as an assembly, being careful not to bend any of the fuel lines. Be sure to protect the fuel system from contamination by plugging or covering all open connections.
7. Plug or cap all openings to minimize leakage and prevent contamination.

Installing the High-Pressure Fuel Injection Lines

NOTICE

- Remove and install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to install the fuel lines.
- To prevent “rounding” the fuel line nuts, always use a “line” or “flare nut” wrench.

1. Start all the fuel line nuts by hand. Then use a wrench to “snug” all the fuel line nuts.
2. Tighten the fuel line nuts on the fuel injection pump to the specified torque. *See Special Torque Chart on page 7-6.*
3. When tightening the fuel line nuts on the fuel injectors, use one wrench to hold the fuel return line nut and fuel return line from rotating. Use a second wrench to tighten the fuel line nuts (**Figure 7-4**). *See Special Torque Chart on page 7-6.*

Removing the Fuel Return Line

NOTICE

The fuel return line is a one-piece assembly. Use care not to bend or twist the fuel return line.

1. Clean the area to keep contaminants from entering the fuel system.
2. Remove the high-pressure fuel injection lines as an assembly. *See Removing the High-Pressure Fuel Injection Lines on page 7-10.*
3. Remove all fuel return line nuts (**Figure 7-5, (2)**) from the injectors (**Figure 7-5, (4)**).

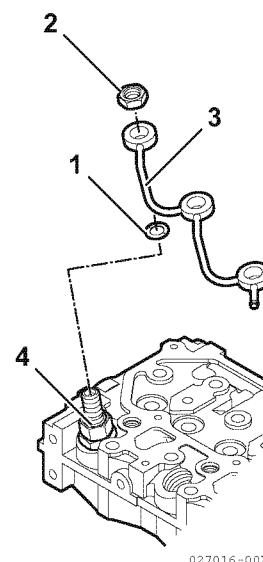


Figure 7-5

4. Remove the fuel return hose from the fuel return fitting on the fuel injection pump.
5. Carefully remove the fuel return line assembly (**Figure 7-5, (3)**).
6. Remove and discard the copper gasket (**Figure 7-5, (1)**) from each fuel injector.
7. Plug or cap all openings to minimize leakage and prevent contamination.

Installing the Fuel Return Line

NOTICE

The fuel return line is a one-piece assembly. Use care not to bend or twist the fuel return line.

1. Install a new copper gasket on each fuel injector.
2. Carefully install the fuel return line assembly.
3. Install and hand-tighten the fuel return line nuts.
4. Tighten the fuel return line nuts to the specified torque. *See Special Torque Chart on page 7-6.*
5. Install the fuel return hose.
6. Install the high-pressure fuel injection line assembly. *See Installing the High-Pressure Fuel Injection Lines on page 7-11.*

FUEL INJECTION PUMP

⚠ WARNING

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.

- When you remove any fuel system component to perform maintenance (such as changing the fuel filter), put an approved container under the opening to catch the fuel.
- Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.
- Never use diesel fuel as a cleaning agent.

⚠ WARNING

Exposure Hazard

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Removing the Fuel Injection Pump

1. Loosen the cooling fan V-belt (**Figure 7-6, (1)**).
2. Remove the engine cooling fan guard (if equipped), engine cooling fan (**Figure 7-6, (2)**), spacer (**Figure 7-6, (3)**) (if equipped), V-pulley (**Figure 7-6, (4)**) and cooling fan V-belt.

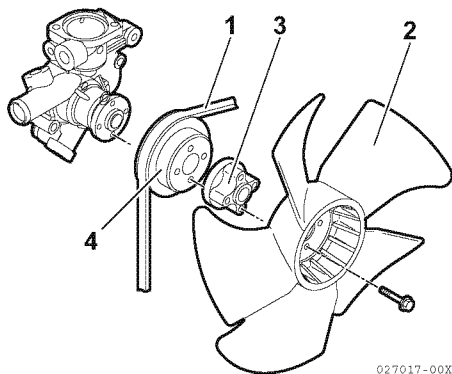


Figure 7-6

3. Close any fuel valves in the fuel supply line.
4. Place a drain pan under the fuel injection pump to catch any spillage.

5. Clean the area to keep contaminants from entering the fuel system.
6. Remove the high-pressure fuel injection lines as an assembly. *See Removing the High-Pressure Fuel Injection Lines on page 7-10.*
7. Disconnect the fuel return lines from the fitting on the fuel injection pump (**Figure 7-7, (1)**). Plug the open ends of the lines to minimize leakage and prevent contamination.
8. Remove the fuel supply line (**Figure 7-7, (2)**) from the fitting on the fuel injection pump.
9. Plug or cap all openings to minimize leakage and prevent contamination.
10. Remove the throttle cable from the fuel injection pump.
11. Disconnect the stop solenoid wiring connector (**Figure 7-7, (3)**).

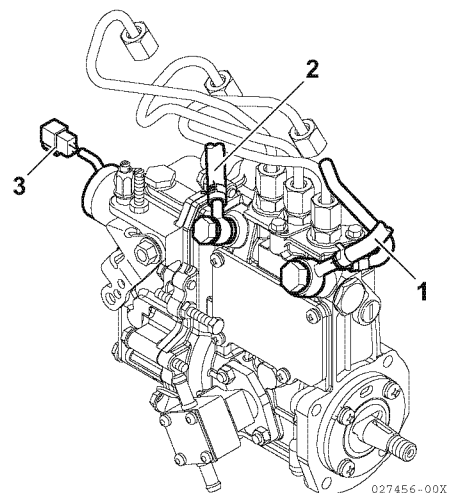


Figure 7-7

12. Remove the fuel injection pump drive gear access cover (**Figure 7-8, (1)**) from the gear case cover (**Figure 7-8, (2)**).

NOTICE

The cover is secured with an adhesive sealant. Use a gasket scraper to separate the cover from the gear case cover.

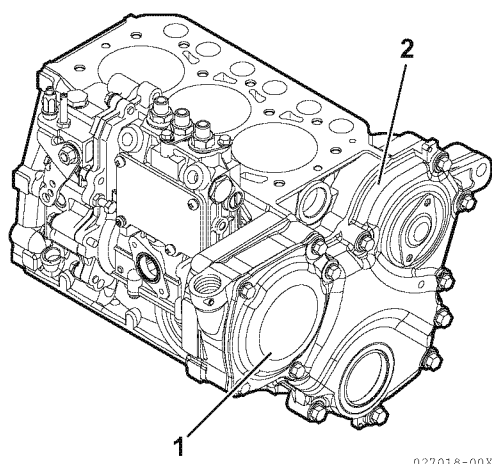


Figure 7-8

13. To aid in assembly, make alignment marks (**Figure 7-9, (1)**) on the pump drive gear and idler gear.

NOTICE

- Mark the gears with something that will not rub off or be affected by oil and become illegible. If the gears are not marked or are illegible during installation, the gear case cover must be removed to properly time the injection pump gear.
- After marking the position of the pump drive gear, do not rotate the engine crankshaft. Rotating the crankshaft will cause the fuel injection pump to become misaligned.

14. Hold the gear train stationary using a wrench on the crankshaft pulley bolt. Remove the fuel injection pump drive gear retaining nut and washer (**Figure 7-9, (2)**).

NOTICE

Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub.

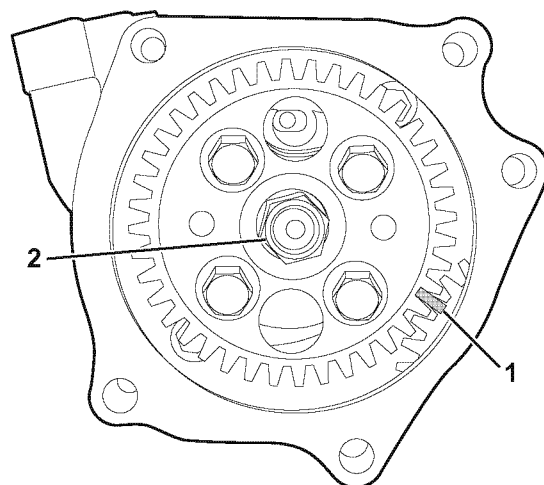


Figure 7-9

15. Thread the drive gear nut onto the injection pump shaft until it is even with the end of the shaft. This will prevent the gear from falling off of the shaft when using the puller.
16. Remove the injection pump drive gear and hub from the injection pump drive shaft as an assembly using an appropriate gear puller (**Figure 7-10**).
17. Once the fuel injection pump drive gear and hub assembly have “popped” loose from the tapered fuel injection pump drive shaft, carefully remove the drive gear nut (**Figure 7-10, (1)**) and remove gear and hub assembly.

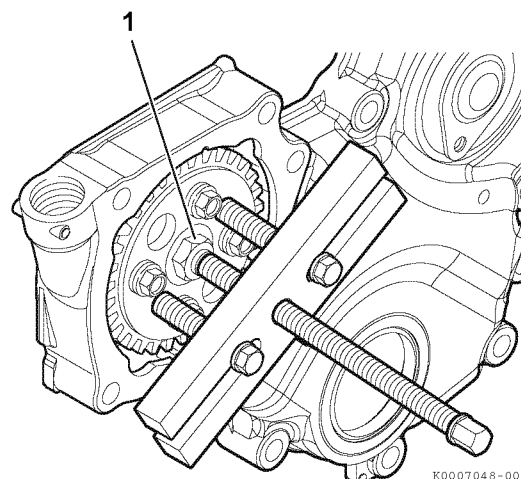
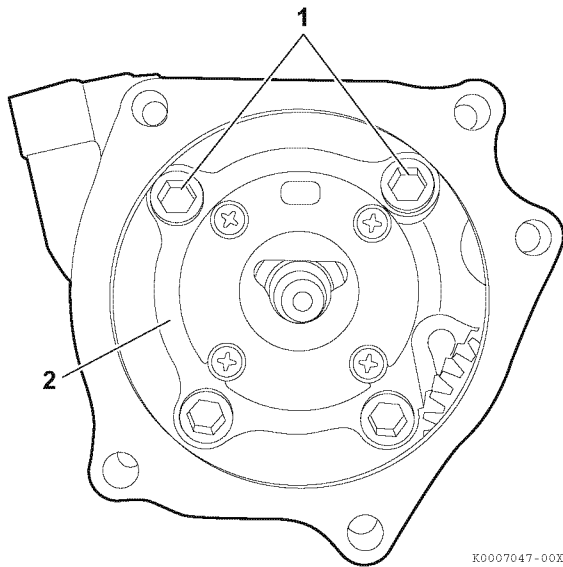


Figure 7-10

18. Remove the four bolts (**Figure 7-11, (1)**) and metal gasket (**Figure 7-11, (2)**) fastening the fuel injection pump to the cylinder block. Remove the fuel injection pump.

NOTICE

Do not rotate the crankshaft with the injection pump removed.

**Figure 7-11**

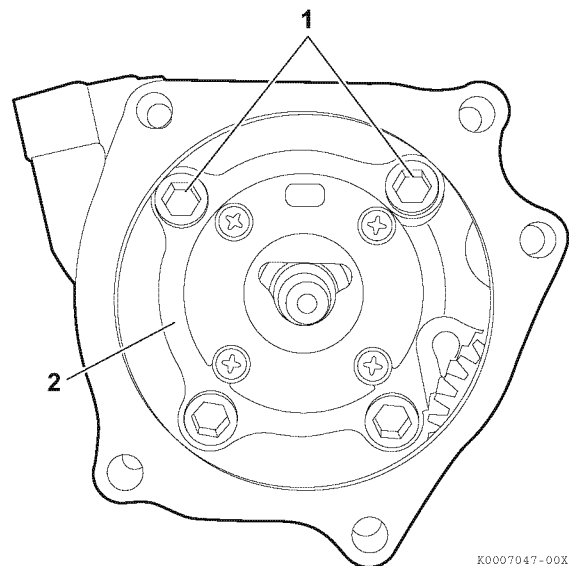
19. If the fuel injection pump requires servicing, it must be sent to an authorized Yanmar FIE repair facility for repair and calibration, or replaced with a new fuel injection pump.

NOTICE

- Never remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.
- Never attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations, and then replace the tamper-proof seals.
- Tampering with or removing these devices may void the "Yanmar Limited Warranty."

Installing the Fuel Injection Pump

1. Install a new gasket to the mounting surface of the injection pump.
2. Install pump to the engine block using the four bolts (**Figure 7-12, (1)**) and metal gasket (**Figure 7-12, (2)**). Tighten to the specified torque.

**Figure 7-12**

NOTICE

Ensure the tapered surface of the fuel injection pump shaft is clean and dry.

3. Align the key on the fuel injection pump shaft with the keyway in the fuel injection pump drive gear hub. Ensure the fuel injection pump drive gear is aligned with the idler gear using the reference marks made earlier (Figure 7-13, (1)).

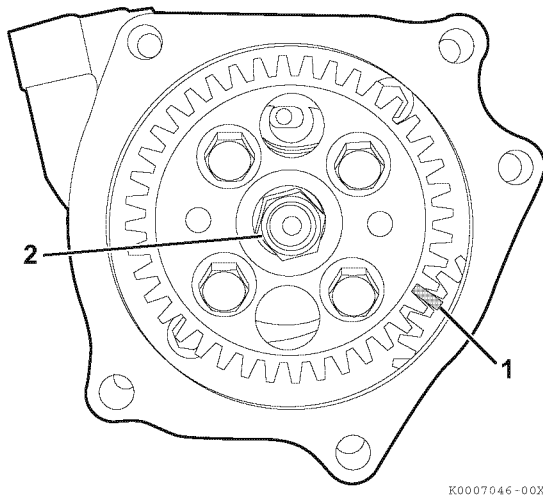
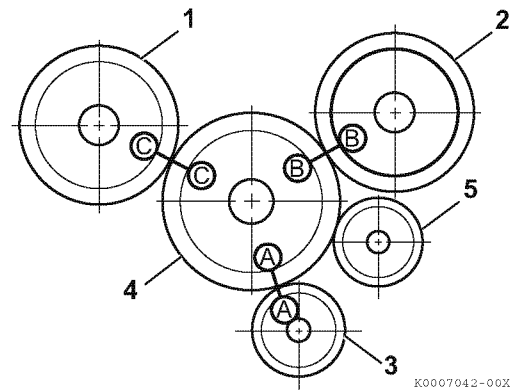


Figure 7-13

4. If installing the fuel injection pump on an engine with the front gear case cover removed, the fuel injection pump drive gear can be aligned with the idler gear by aligning the stamped marks (Figure 7-14, (A, B, C)) on the fuel injection pump drive gear, idler gear, camshaft gear and crankshaft drive gear. Ensure all three timing marks (A, B, C) are aligned.



- 1 – Fuel Injection Pump Drive Gear
- 2 – Camshaft Drive Gear
- 3 – Crankshaft Drive Gear
- 4 – Idler Gear
- 5 – Oil Pump Gear

Figure 7-14

5. Install the fuel injection pump drive gear lock washer (Figure 7-15, (1)) and nut (Figure 7-15, (2)). Do not lubricate threads of the nut or shaft. Hold the crankshaft pulley bolt with a wrench and tighten the pump drive gear nut to the specified torque. See *Special Torque Chart* on page 7-6.

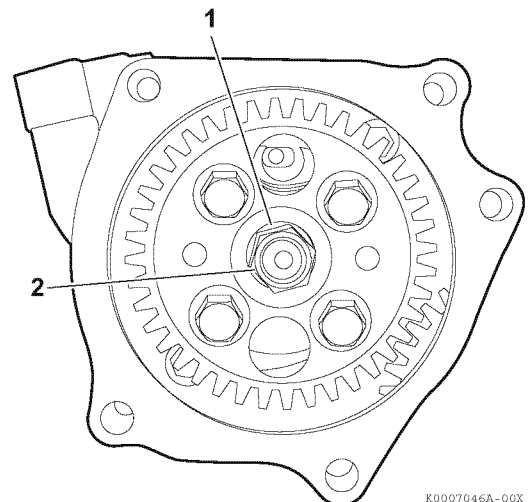


Figure 7-15

6. Connect the fuel supply and return lines to the fuel injection pump.
7. Connect the throttle linkage and stop solenoid wire connector.

8. If installing a new or recalibrated fuel injection pump, check the fuel injection timing before completing the installation of the fuel injection pump. See *Checking and Adjusting Fuel Injection Timing* on page 7-17.

NOTICE

While it is not required to check the injection timing when installing the original fuel injection pump, it is recommended that it be done.

9. After adjusting the fuel injection timing, apply ThreeBond Liquid Gasket No. 1212, Yanmar Part No. 977770-01212, or equivalent sealant to the sealing surface of the fuel injection pump drive gear access cover. Install the cover on the front of the gear case and tighten the bolts.
10. Install the fuel injection high-pressure lines. See *Installing the High-Pressure Fuel Injection Lines* on page 7-11.

NOTICE

When installing a new or repaired fuel injection pump, it is important to add engine oil to the fuel injection pump to provide lubrication for initial start-up. Add 5 to 7 oz (150 to 200 cc) of clean engine oil to the fuel injection pump at the fill plug (**Figure 7-16, (1)**) located in the upper outside section of the governor housing.

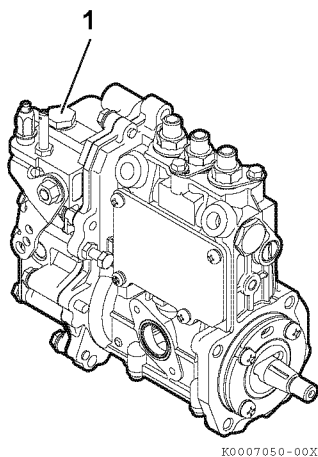


Figure 7-16

11. Install the coolant pump V-pulley (**Figure 7-17, (4)**), spacer (**Figure 7-17, (3)**) (if equipped) and engine cooling fan (**Figure 7-17, (2)**).

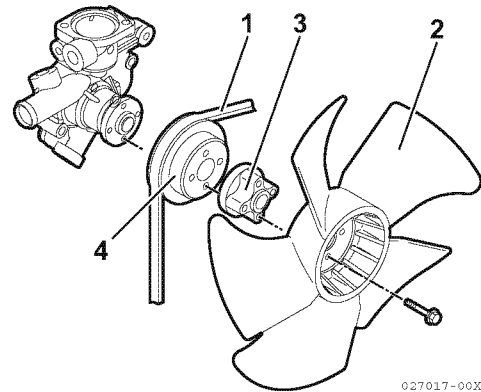


Figure 7-17

12. Install the cooling fan V-belt (**Figure 7-17, (1)**). Adjust as described in *Checking and Adjusting Cooling Fan V-Belt* on page 5-13.
13. Install the cooling fan guard (if equipped).
14. Prime the fuel system. See *Priming the Fuel System* on page 4-14.
15. Operate the engine and check for fuel and lube oil leaks.

CHECKING AND ADJUSTING FUEL INJECTION TIMING

Note: The following procedure is performed on the No. 1 cylinder. While checking and adjusting the timing on only No. 1 cylinder is usually sufficient, the same procedure can be performed on any or all cylinders.

Checking Fuel Injection Timing

Some fuel may drain from the fuel injection pump during this process. Make provisions to contain any such spillage.

WARNING

Fire and Explosion Hazard

Use an approved container to catch fuel. Never use a shop rag to catch fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.

1. Ensure the fuel injection pump is primed with fuel. See *Priming the Fuel System* on page 4-14.
2. Clean the area around the fuel injection pump.

NOTICE

- Clean the area around the fuel injection pump to prevent any contamination when the fuel injection pump plunger plug is removed.
- The stop solenoid must be removed to allow fuel to flow through the fuel injection pump.

3. Remove two screws (**Figure 7-18, (1)**).
4. Remove the stop solenoid (**Figure 7-18, (2)**) and O-ring (**Figure 7-18, (3)**).

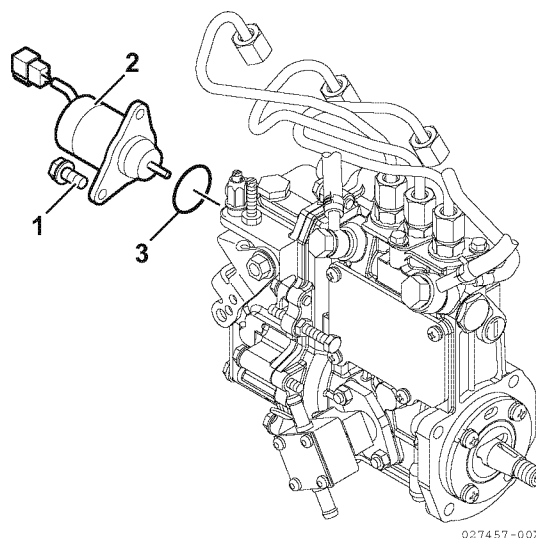


Figure 7-18

5. Set the throttle to the HIGH-IDLE position.
6. Using a wrench on the crankshaft pulley bolt, rotate the crankshaft in a clockwise direction while looking through the flywheel inspection port. Rotate the crankshaft until the injection timing marks on the flywheel are visible for No. 1 cylinder.
7. Typical flywheel markings are as shown in **Figure 7-19**.

Note: A typical flywheel will have multiple timing grids depending on the number of cylinders. Any grid and its corresponding cylinder can be used to check the fuel injection timing.

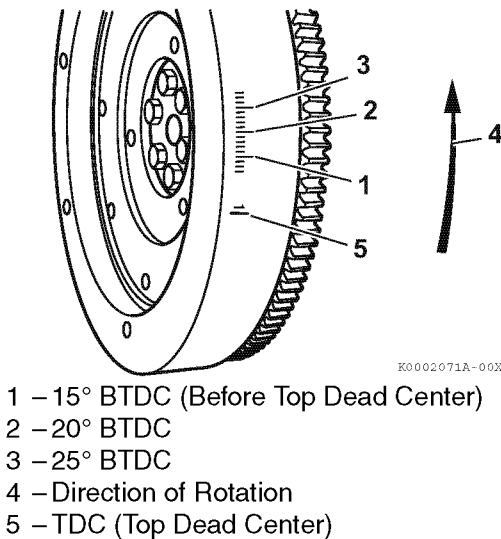


Figure 7-19

8. The flywheel shown in **Figure 7-19** is for a Yanmar “Standard Specification” IDI engine. Flywheels used on some “OEM Specific” IDI engines may be marked differently. You should contact that specific OEM for information on the identification of the timing marks.

Note: The TDC (Top Dead Center) mark can be identified by the cylinder numbers stamped near the TDC mark (**Figure 7-19, (5)**) on the flywheel.

9. If you are uncertain as to the timing degree designation of the timing marks on the flywheel timing grid, you can determine the timing degree designation by measuring the timing grid.
- First measure the distance between two of the “longer” marks on the timing grid. (They are 5° apart.) Then measure the distance from the TDC mark to the first “longer” mark on the timing grid. Divide that measurement by the distance between the two “longer” marks. The resulting answer will tell you how many degrees there are between the TDC mark and the first “longer” mark.

- EXAMPLE: If the distance between the two “longer” marks is approximately 2.0 cm and the distance from the TDC mark is approximately 4.0 cm, the answer is approximately 2. This indicates there is 10° (2 x 5°) between the TDC mark and the first “longer” mark on the timing grid. That means the first “longer” mark on the timing grid indicates 10° BTDC, the second “longer” mark indicates 15° BTDC and the third timing mark indicates 20°. If the answer is 3, that indicates there is 15° (3 x 5°) between the TDC mark and the first “longer” mark and that the first “longer” mark indicates 15° BTDC with the second and third “longer” marks indicating 20° BTDC and 25° BTDC respectively.

10. Highlight the timing reference mark on the flywheel housing (**Figure 7-20, (2)**) or engine back plate (**Figure 7-21, (2)**). Highlight the TDC mark (**Figure 7-20, (1)**), (**Figure 7-21, (1)**) on the flywheel.

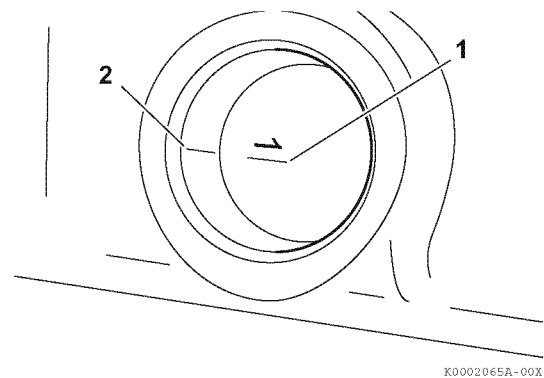


Figure 7-20

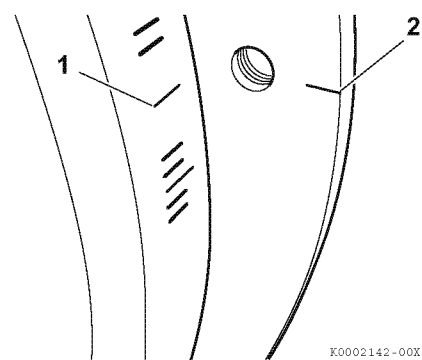


Figure 7-21

11. Highlight the target timing mark
(**Figure 7-21, (1)**), (**Figure 7-22, (1)**) on the flywheel timing grid as the injection timing measured before the fuel injection pump removal.

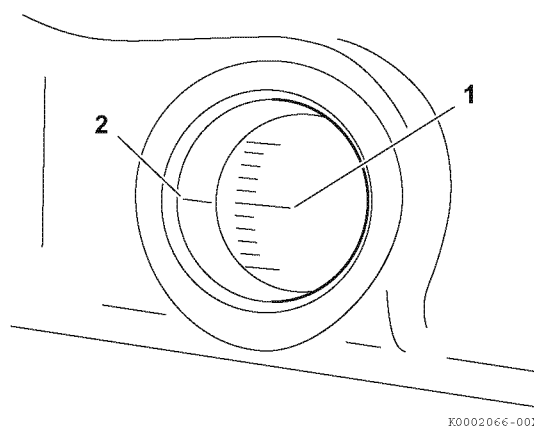


Figure 7-22

Injection Timing (FID)

	CL	VM						CH	VH		
rpm (min-1)	1500/ 1800	2000	2200	2400	2600	2800	3000	3000/ 3600	3200	3400	3600
3TNM68	17.0	17.0	18.0	19.0			20.0	22.0	20.0	21.0	22.0
3TNM72	16.0	n/a				17.0	18.0	20.0	19.0		20.0

12. Remove all high-pressure fuel injection lines.
See Removing the High-Pressure Fuel Injection Lines on page 7-10.
13. Turn on all fuel supply valves.

NOTICE

As the injection pump injects fuel to a cylinder only once every two engine revolutions, it may be necessary to rotate the crankshaft twice to see fuel being pumped from the timing tool or delivery valve of the cylinder you are using to check injection timing.

14. Install the “spill-timing” tool (**Figure 7-23, (1)**) onto the delivery valve for the cylinder being checked. *See Measuring Instruments on page 7-7.*

NOTICE

If a timing tool is not available, timing can be checked by watching the fuel in the delivery valve itself.

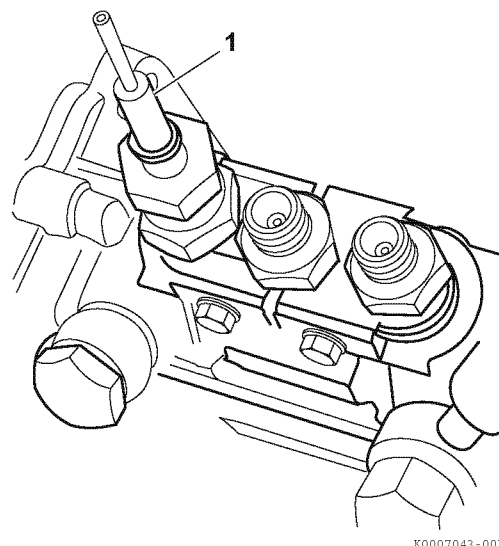


Figure 7-23

NOTICE

The following references to the direction of rotation are made facing the cooling fan end of the engine and are adjusted by turning the crankshaft.

15. Slowly rotate the crankshaft clockwise using a wrench on the crankshaft pulley bolt until fuel is pumped from the nozzle of the “spill-timing” tool or delivery valve.
16. Slowly rotate the crankshaft clockwise approximately two more revolutions until the timing grid on the flywheel (for the cylinder being checked) is at approximately 30° BTDC.

NOTICE

The fuel injection pump injects fuel to a cylinder only once every two engine revolutions.

17. “Flick” the nozzle of the timing tool with a finger to remove bubbles and establish a fuel level of approximately half the height of the nozzle.
18. Very slowly rotate the crankshaft clockwise until the fuel level in the nozzle of the “spill-timing” tool, or in the delivery valve, just begins to move. Immediately stop rotating the crankshaft.
19. Check the position of the flywheel target timing mark (**Figure 7-22, (1)**) on the flywheel grid in relation to the timing reference mark (**Figure 7-22, (2)**) on the flywheel housing or back plate. If the two marks are aligned, the fuel injection timing is correct. If the marks do not align, the fuel injection timing must be adjusted. See *Adjusting Fuel Injection Timing* on page 7-20.
20. Repeat Steps 14-18 two or three times to verify timing.
21. Remove the “spill-timing” tool.
22. Install the shut-off solenoid.
23. Install the high-pressure fuel injection lines. See *Installing the High-Pressure Fuel Injection Lines* on page 7-11.
24. Replace the flywheel inspection port cover.
25. Prime the fuel system. Operate the engine and check for leaks.

Adjusting Fuel Injection Timing

If the timing marks did not align when performing the *Checking Fuel Injection Timing* on page 7-17, the following steps must be performed to properly time the engine.

The fuel injection pump of TNM engines is fixed with four bolts. Adjust the injection timing by rotating the pump drive gear on the pump flange.

1. Leave the “spill-timing” tool installed in the fuel injection pump.
2. Determine if the timing is “advanced” or “retarded” by comparing the position of the target timing mark on the flywheel grid (**Figure 7-24, (1)**) with the timing mark on the flywheel housing or back plate (**Figure 7-24, (2)**).

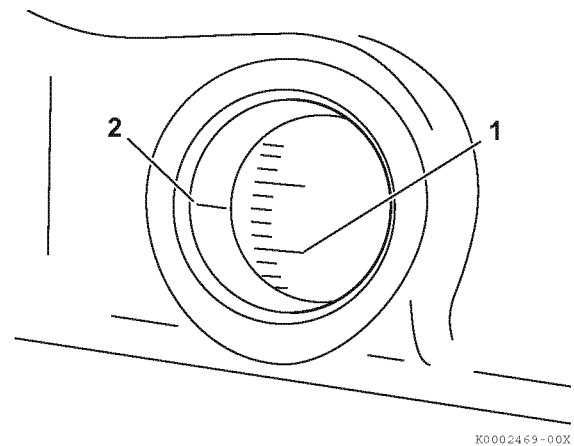


Figure 7-24

3. The new injection pump will come with a timing grid sticker. Each line on the timing grid sticker is 1°. Each line on the flywheel grid is also 1°.

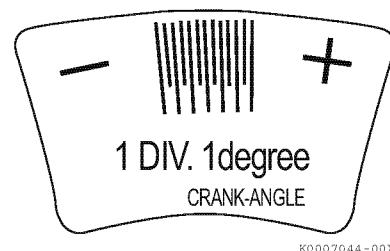


Figure 7-25

4. Observe the flywheel grid again and determine how many degrees you need to advance or retard the timing.
5. Clean the area of the gear by the pointer on the timing cover and put the sticker on the drive gear, aligning the timing mark on the timing cover (**Figure 7-26, (1)**) with the center of the sticker.
6. Loosen the four bolts (**Figure 7-26, (2)**) fastening the injection pump drive gear to the flange.

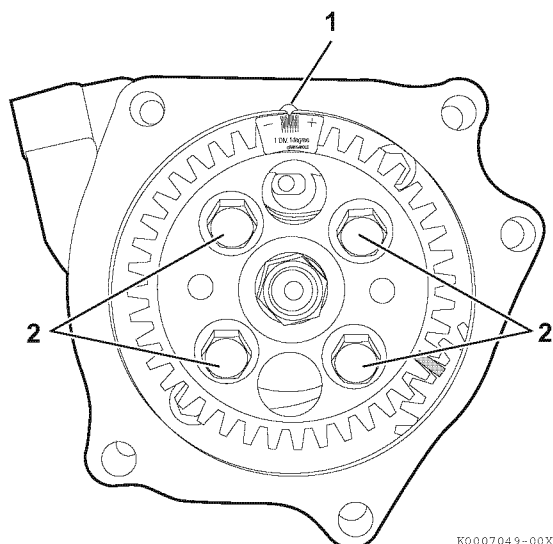


Figure 7-26

7. If the injection timing was less than the target timing, the injection timing is “retarded” and will need to be “advanced.”

To “advance” the injection timing: Rotate the crankshaft counterclockwise.

If the injection timing was greater than the target timing, the injection timing is “advanced” and will need to be “retarded.”

To “retard” the injection timing: Rotate the crankshaft clockwise.

8. Slowly rotate the crankshaft while watching the pointer on the timing cover and the timing grid sticker on the injection pump gear. Turn it the required number of degrees that was determined earlier when observing the flywheel grid.
9. Tighten the pump drive gear mounting bolts.
10. Recheck the fuel injection timing. Repeat the fuel injection timing and adjustment procedures until the timing is correct.
11. Remove the sticker from the pump drive gear.
12. Remove the “spill-timing” tool.
13. Install the shut-off solenoid.
14. Install the high-pressure fuel injection lines. See *Installing the High-Pressure Fuel Injection Lines* on page 7-11.
15. Apply ThreeBond Liquid Gasket No. 1212, Yanmar Part No. 977770-01212, or equivalent sealant to the sealing surface of the fuel injection pump drive gear access cover. Install the cover on the front of the gear case and tighten the bolts.
16. Replace the flywheel inspection port cover.
17. Prime the fuel system. Operate the engine and check for leaks.

FUEL INJECTORS

Removing the Fuel Injectors

⚠ WARNING

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.

- When you remove any fuel system component to perform maintenance (such as changing the fuel filter), put an approved container under the opening to catch the fuel.
- Never use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.
- Never use diesel fuel as a cleaning agent.

⚠ WARNING

Exposure Hazard

Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

1. Close any fuel valves in the fuel supply line.
2. Clean the area around the fuel injection pump and fuel injectors to keep contaminants from entering the engine or fuel system.
3. Remove the intake manifold/valve cover assembly. *See Removing the Intake Manifold/Valve Cover on page 6-18.*
4. Remove the high-pressure fuel injection lines as an assembly. *See Removing the High-Pressure Fuel Injection Lines on page 7-10.*
5. Remove nut (**Figure 7-27, (1)**). Remove the fuel return line (**Figure 7-27, (2)**) and copper washer (**Figure 7-27, (3)**) from the fuel injectors. *See Removing the Fuel Return Line on page 7-11.*

NOTICE

The fuel injectors used on IDI engines screw into the cylinder head.

6. Remove the fuel injectors (**Figure 7-27, (4)**).

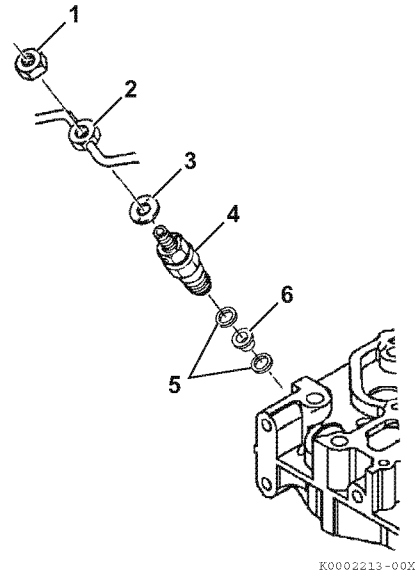


Figure 7-27

7. Remove the injector nozzle gaskets (**Figure 7-27, (5)**) and protector (**Figure 7-27, (6)**) from the cylinder head.

Testing the Fuel Injectors

NOTICE

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Thoroughly clean the fuel injector nozzle using clean diesel fuel and a brass wire brush.
2. Visually inspect the fuel injectors and nozzle protectors for deposits or damage. Clean, repair or replace as necessary.

NOTICE

Test the fuel injector using an injection nozzle tester. Operate the tester following the information provided by the tester manufacturer. Use clean, filtered fuel or FIE calibration fluid for the test.

3. Using the correct adapter, connect a fuel injector to a nozzle tester. Aim the fuel injector into a suitable container to catch the fuel spray (Figure 7-28).

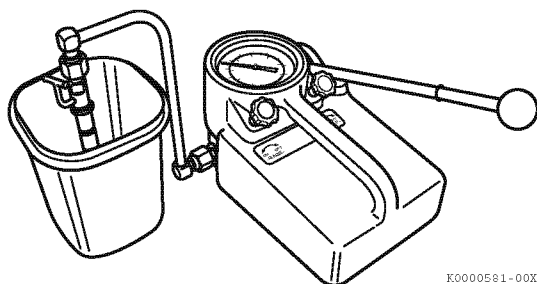


Figure 7-28

WARNING

High-Pressure Hazard

Never inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.

WARNING

Fire and Explosion Hazard

Never inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.

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.

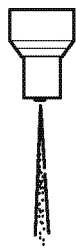

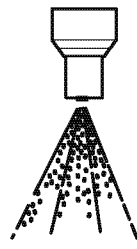


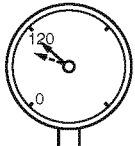
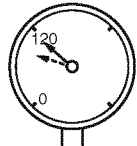
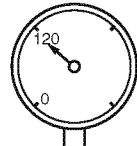
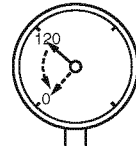
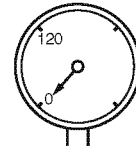
4. Pump the operating lever of the tester slowly, observing the pressure reading at the point where the fuel injector begins spraying fuel. See *Test and Adjustment Specifications* on page 7-6 for correct pressure readings.

NOTICE

Opening pressure of a new fuel injector will be approximately 72.5 psi (0.5 MPa; 5 kgf/cm²) higher than one that has been operated for 5 hours or longer.

5. Pump the operating lever slowly to hold the pressure steady at a point just below the opening pressure and hold that pressure for 5 seconds. Observe the injector to see that it is sealing properly and is not "dripping." If fuel leaks from the return line fitting, check that the nozzle case nut is tight. Service or replace the injector if fuel continues to leak from either the return line fitting or nozzle.
6. Pump the operating lever more rapidly to repeatedly "pop" the injector and observe the spray pattern. The pattern should be a very fine uniform spray. If dripping or an uneven pattern is seen, service or replace the injector. See *Fuel Injector Test Results* on page 7-24.

Fuel Injector Test Results

	A	B	C	D	E
Injection Pattern					
Pressure Gauge Reading	 Gauge needle fluctuates around the valve opening pressure.	 Gauge needle fluctuates around the valve opening pressure.	 Gauge needle stays at a position near the valve opening pressure.	 Although the gauge needle reaches the valve opening pressure, the pressure drop is large.	 Pressure does not increase even when the tester lever is operated.
Atomization Pattern	5°-10° cone and roughly uniform.	Atomization is excessively one-sided.	Although atomized (burner like shape), the needle does not pulsate.	Bar shape with excessive after drops.	Drops.
Possible Cause	(Normal, injector is good)	Normally caused by carbon contamination of the nozzle tip. Sometimes caused by flaws in or damage to the needle tip.	Caused by excessive carbon contamination of the nozzle tip. Sometimes caused by internal contamination.	Damage to the seat. Contamination of seat by fine foreign particles. Excessively worn seat.	Sticking of needle. Excessively damaged or worn seat. Contamination of seat by foreign matter. Damaged or broken internal parts or nozzle case nut.

NOTICE

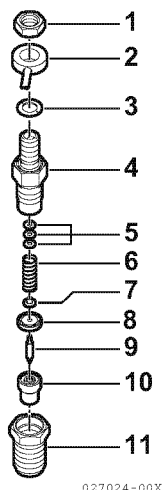
If the fuel injector fails any tests, it should be serviced or replaced as necessary. If the pressure is outside specified limits, adjust the pressure. See *Adjusting Fuel Injector Pressure* on page 7-26.

Disassembling and Inspecting the Fuel Injectors

NOTICE

Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Clean carbon from used injectors using clean diesel fuel. Hardened deposits or varnish can be cleaned using a brass wire brush.



- 1 – Return Fuel Fitting Nut
- 2 – Return Fuel Fitting
- 3 – Seal (PK)
- 4 – Injector Body
- 5 – Pressure Adjusting Shims
- 6 – Spring
- 7 – Spring Seat
- 8 – Valve Stop Spacer
- 9 – Nozzle Valve
- 10 – Nozzle Body
- 11 – Nozzle Case Nut

Figure 7-29

2. Place the fuel injector in a soft-jawed vise with the nozzle pointing up.
3. Remove the nozzle case nut.
4. Carefully remove the injector from the vise.

5. Turn the injector over and remove the nozzle body, nozzle valve, valve stop spacer, nozzle spring seat, nozzle spring and shims.
6. Inspect the sealing surfaces (**Figure 7-30, (2)**) between the valve stop spacer and nozzle body for nicks or scratches. Check the contact area between the valve stop spacer and the nozzle valve (**Figure 7-30, (1)**) for scoring or pitting. Use a magnifying glass to inspect.

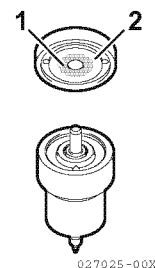


Figure 7-30

7. Perform a nozzle valve slide test:
 - (a) Wash nozzle body and valve in clean diesel fuel.
 - (b) While holding the nozzle body vertical, pull the nozzle valve about 2/3 of the way out (**Figure 7-31**).
 - (c) Release the valve. It should fall smoothly to its seat by its own weight.

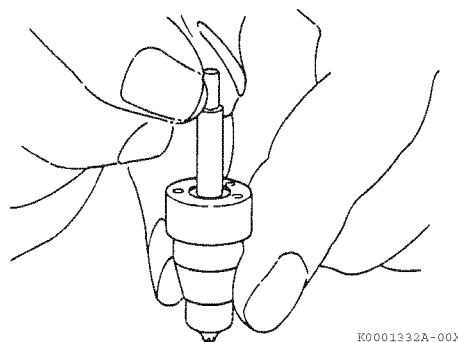


Figure 7-31

Replace the fuel injector assembly if it fails any inspection.

Adjusting Fuel Injector Pressure

The fuel injectors open when pressure reaches a predetermined pressure threshold. They close when the pressure is reduced below that threshold. The pressure threshold can be adjusted by adding or removing shims.

Fuel Injector Shim Kit	
Yanmar Part No. 114250-53400	
(Includes one each of the following shims)	
114250-53420	0.0197 in. (0.50 mm)
114250-53500	0.0217 in. (0.55 mm)
114250-53430	0.0236 in. (0.60 mm)
114250-53510	0.0256 in. (0.65 mm)
114250-53440	0.0276 in. (0.70 mm)
114250-53520	0.0295 in. (0.75 mm)
114250-53450	0.0315 in. (0.80 mm)
114250-53530	0.0335 in. (0.85 mm)
114250-53540	0.0354 in. (0.90 mm)
114250-53550	0.0374 in. (0.95 mm)
114250-53560	0.0394 in. (1.00 mm)

The injection pressure will change by approximately 100 to 142 psi (0.69 to 0.98 MPa; 7 to 10 kgf/cm²) for every 0.004 in. (0.1 mm) shim thickness.

See the parts catalog for available shims.

1. Disassemble the fuel injector assembly. See *Disassembling and Inspecting the Fuel Injectors* on page 7-25.
2. Remove or add adjusting shims as needed.
3. Assemble the fuel injector assembly. See *Assembling the Fuel Injectors* on page 7-26.
4. Test the fuel injector. See *Testing the Fuel Injectors* on page 7-23. If the injector cannot be adjusted to the appropriate pressure, discard the fuel injector.

Assembling the Fuel Injectors

1. Secure the injector in a soft-jawed vise with the nozzle end up.
2. Install the shims, nozzle spring, nozzle spring seat, valve stop spacer, nozzle valve and nozzle body.
3. Install the nozzle case nut. Tighten it to specification.

Installing the Fuel Injectors

1. Insert the nozzle gaskets (**Figure 7-32, (5)**) and nozzle protector (**Figure 7-32, (6)**) in the cylinder head.
2. Install the fuel injector (**Figure 7-32, (4)**) in the cylinder head and tighten to specification.
3. Install new copper washers (**Figure 7-32, (3)**) and high-pressure and return fuel lines (**Figure 7-32, (2)**). See *Installing the High-Pressure Fuel Injection Lines* on page 7-11 and *Installing the Fuel Return Line* on page 7-11. Tighten fuel line nuts (**Figure 7-32, (1)**) to specifications.
4. Install the intake manifold/valve cover. See *Assembling the Intake Manifold/Valve Cover* on page 6-29.
5. Prime the fuel system. See *Priming the Fuel System* on page 4-14.
6. Operate the engine and check for fuel leaks.

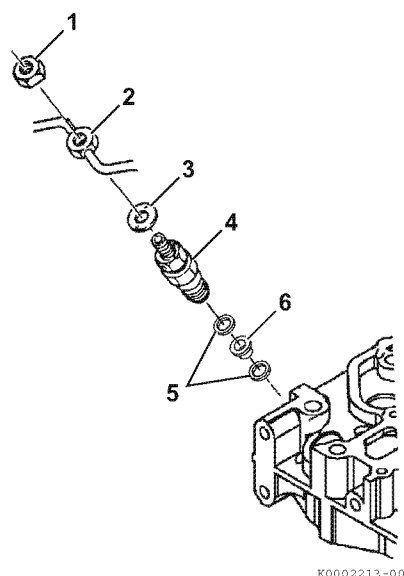


Figure 7-32

Section 8

COOLING SYSTEM

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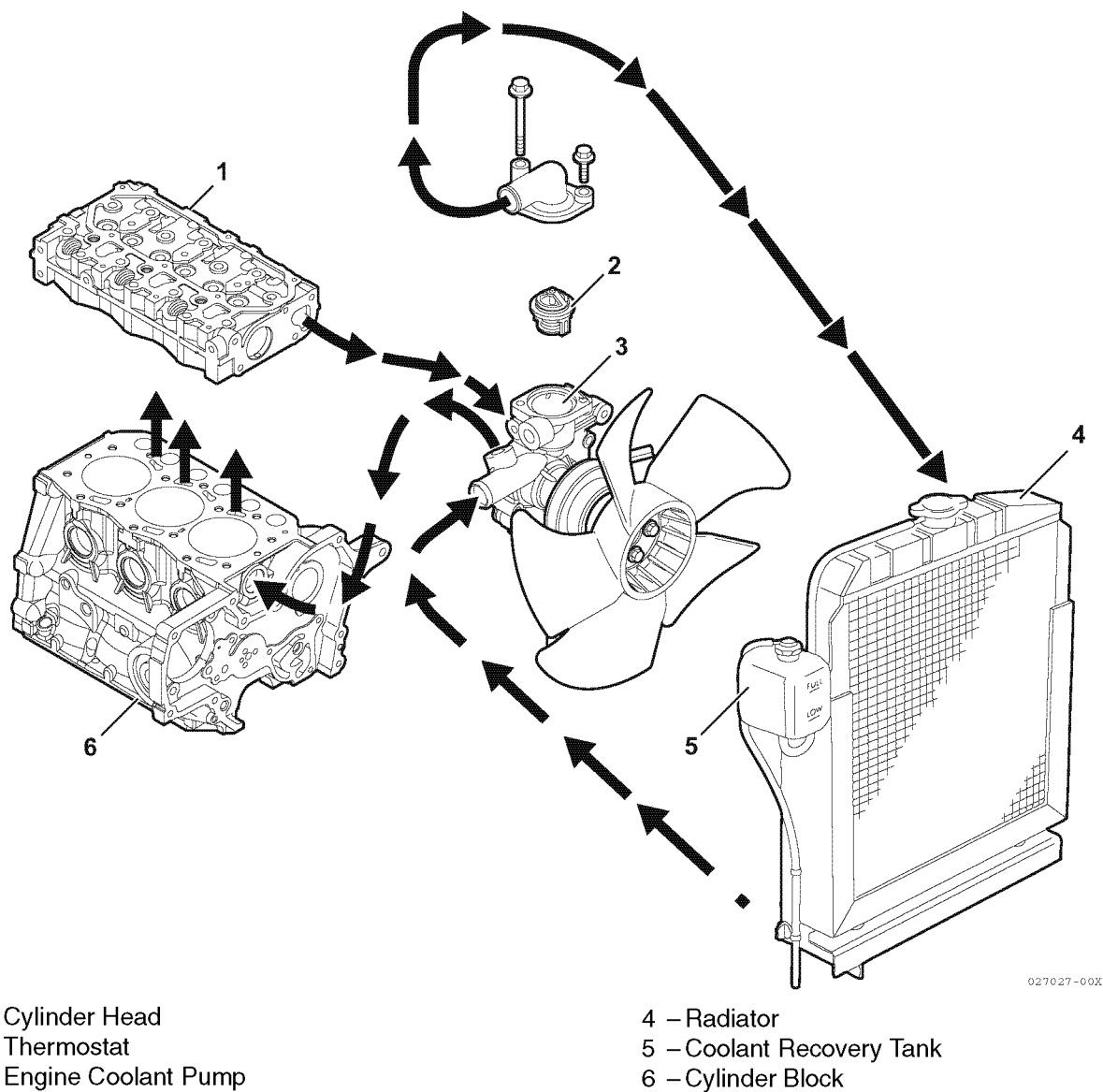
SAFETY PRECAUTIONS

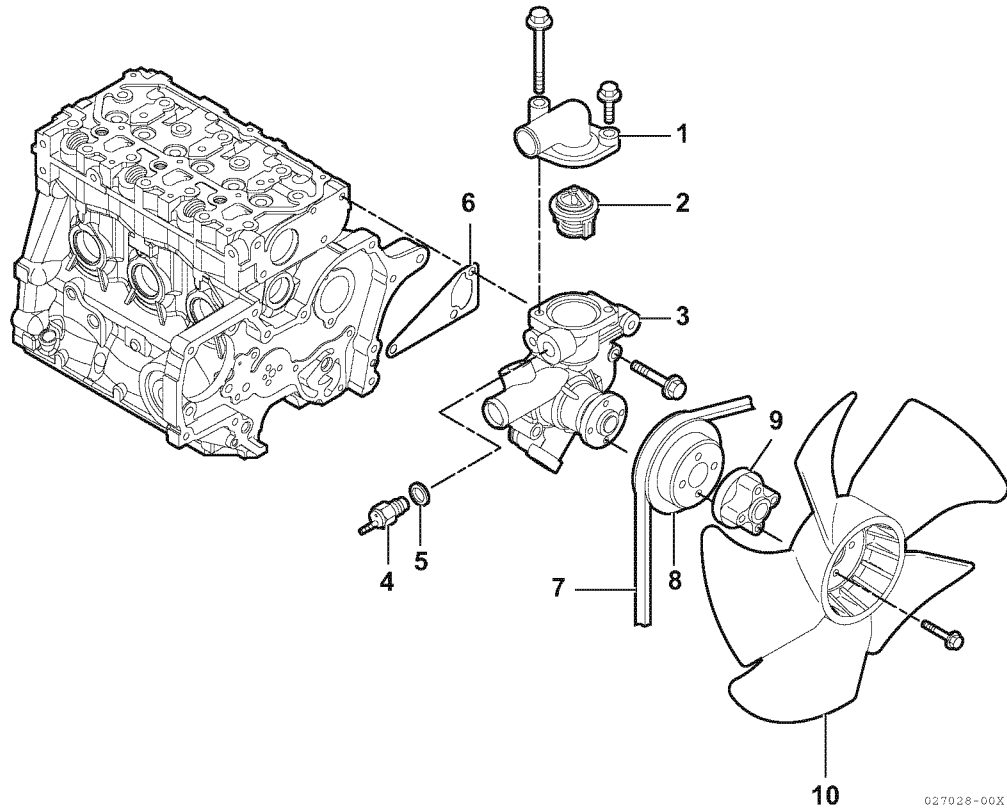
Before performing any cooling system service procedures, review the *Safety section on page 3-1*.

INTRODUCTION

This section of the *Service Manual* describes the procedures necessary to service the 3TNM68 and 3TNM72 engine coolant pump.

COOLING SYSTEM DIAGRAM

**Figure 8-1**

ENGINE COOLANT PUMP COMPONENTS

- 1 – Thermostat Cover
- 2 – Thermostat
- 3 – Engine Coolant Pump
- 4 – Temperature Switch
- 5 – Gasket

- 6 – Engine Coolant Pump Gasket
- 7 – V-Belt
- 8 – Engine Coolant Pump V-Pulley
- 9 – Spacer
- 10 – Engine Coolant Fan

Figure 8-2

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ENGINE COOLANT SYSTEM CHECK

Check the engine coolant system for leakage.

1. With the radiator properly filled, install a cooling system tester (**Figure 8-3, (1)**).

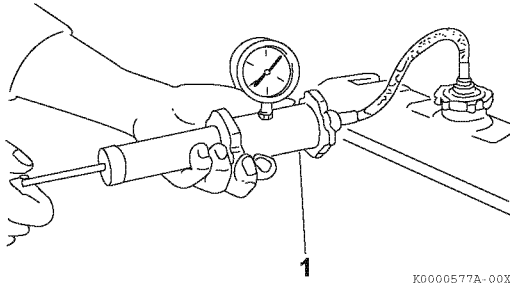


Figure 8-3

2. Apply 10.8 to 14.8 psi (75 to 105 kPa; 0.75 to 1.05 kgf/cm²) to the cooling system. If the pressure reading drops, the engine coolant system is leaking. Identify the source of the leak and repair.

ENGINE COOLANT PUMP

⚠ WARNING

Burn Hazard

Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Disassembling the Engine Coolant Pump

Verify the condition of the engine coolant pump before disassembling it from the engine. Check the engine coolant pump shaft bearing for abnormal noise, sticking, excessive play and water leakage. Replace the coolant pump if any of these conditions are present.

NOTICE

If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.

1. Make sure the engine and engine coolant are not hot.
2. Before removing the engine coolant pump or thermostat, it will be necessary to drain the engine coolant. Drain the coolant from the radiator. See steps 1-4 in *Draining, Flushing and Refilling Cooling System with New Coolant* on page 5-18. Drain the coolant into a clean container if the coolant is to be reused. Otherwise, properly dispose of the coolant.
3. Loosen the alternator mounting bolts. Loosen and remove the V-belt and rotate the alternator away from the engine and out of the way.

⚠ CAUTION

Pinch Hazard

Carefully rotate the alternator toward the cylinder block while loosening the V-belt.

4. Remove the engine coolant fan guard (if equipped), engine coolant fan (**Figure 8-4, (1)**), spacer (**Figure 8-4, (2)**) and engine coolant pump V-pulley (**Figure 8-4, (3)**).

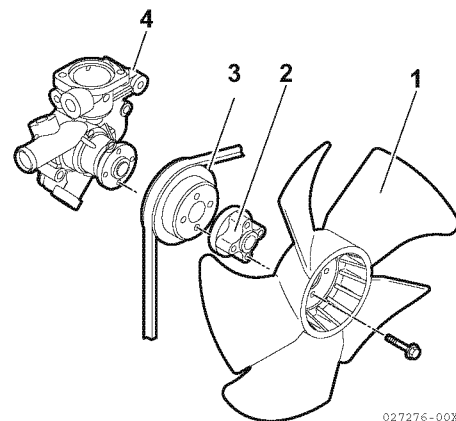


Figure 8-4

5. Disconnect the coolant hoses and the temperature switch lead wire from the engine coolant pump.
6. Remove the engine coolant pump (**Figure 8-4, (4)**). Discard the gasket.
7. Remove the thermostat cover (**Figure 8-5, (1)**).

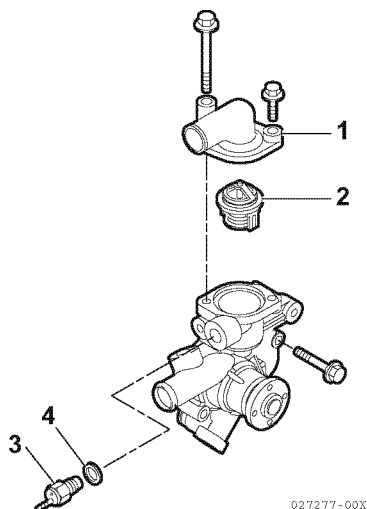


Figure 8-5

8. Remove the thermostat (**Figure 8-5, (2)**).
9. Remove the temperature switch (**Figure 8-5, (3)**) and gasket (**Figure 8-5, (4)**). Discard the gasket.

Cleaning and Inspection

Temperature Switch

1. Check for proper operation of the temperature switch. Connect a continuity light or ohmmeter to the temperature switch. Connect one lead to the terminal of the switch (**Figure 8-6, (1)**) and the other lead to the metal portion of the switch (**Figure 8-6, (2)**).

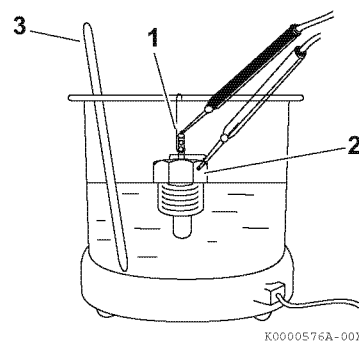


Figure 8-6

2. Place the temperature switch and an accurate thermometer (**Figure 8-6, (3)**) in engine coolant.
3. Slowly increase temperature of the fluid using an external heat source.
4. The temperature switch is normal if the continuity light or ohmmeter indicates continuity when the fluid temperature reaches 225° to 235°F (107° to 113°C).

Thermostat

1. Check for proper operation of the thermostat. Place the thermostat (**Figure 8-7, (1)**) and an accurate thermometer (**Figure 8-7, (2)**) in warm water.

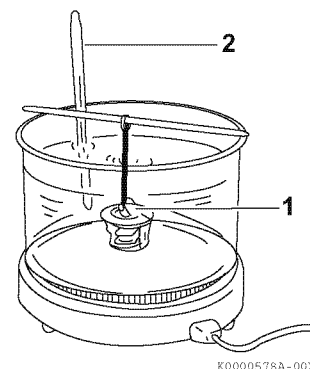


Figure 8-7

2. Slowly increase temperature of the water using an external heat source.
3. The thermostat is normal if it starts to open at the temperature value stamped on the flange of the thermostat, and fully opens as the temperature of the water is increased.

Radiator Cap

Check for proper operation of the radiator cap.

1. Install the radiator cap (**Figure 8-8, (1)**) on a cooling system tester.

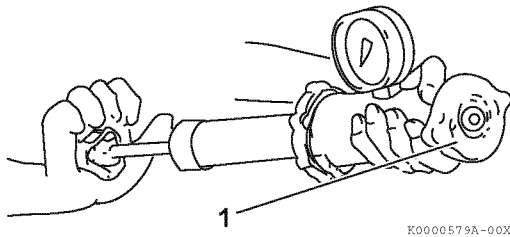


Figure 8-8

2. Apply 10.8 to 14.8 psi (75 to 105 kPa; 0.75 to 1.05 kgf/cm²) to the radiator cap. The radiator cap relief valve must open within the specified range.

Assembling the Engine Coolant Pump

1. Install the thermostat (**Figure 8-9, (1)**).

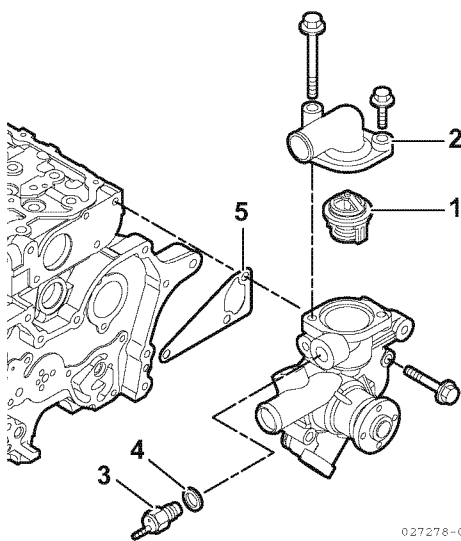


Figure 8-9

2. Install the thermostat cover (**Figure 8-9, (2)**). Tighten the thermostat cover bolts.
3. Install the temperature switch (**Figure 8-9, (3)**) and a new gasket (**Figure 8-9, (4)**).

4. Position the engine coolant pump on the engine and install a new gasket (**Figure 8-9, (5)**).

NOTICE

Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.

5. Install the engine coolant pump bolts. Tighten the bolts.
6. Inspect and install the coolant hoses and the temperature switch lead wire.
7. Install the engine coolant pump V-pulley (**Figure 8-10, (3)**), spacer (**Figure 8-10, (2)**), engine coolant fan (**Figure 8-10, (1)**) and engine coolant fan guard (if equipped).

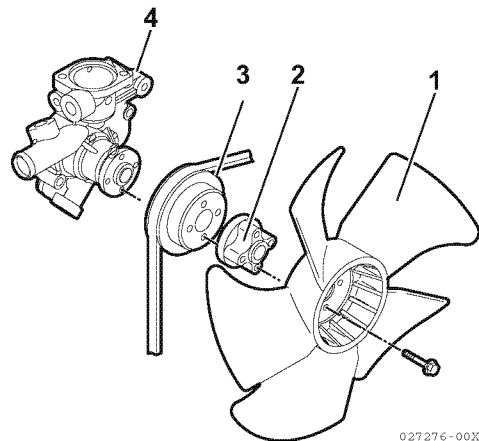


Figure 8-10

8. Inspect the condition of the V-belt. There must be clearance **(Figure 8-11, (1))** between the V-belt and the bottom of the pulley groove. If there is no clearance **(Figure 8-11, (2))** between the V-belt and the bottom of the pulley groove, replace the V-belt.

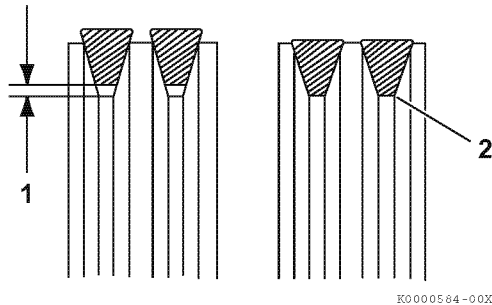


Figure 8-11

9. Install the V-belt. Tighten the V-belt to the proper tension. *See Checking and Adjusting Cooling Fan V-Belt on page 5-13.*
10. Install and tighten the drain plug or close the drain cock in the radiator. Install and tighten the engine block drain plug or connect the coolant hose at the oil cooler.
11. Fill radiator and engine with engine coolant. *See Draining, Flushing and Refilling Cooling System with New Coolant on page 5-18.*

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Section 9

LUBRICATION SYSTEM

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SAFETY PRECAUTIONS

Before performing any lubrication system service procedures, review the *Safety section on page 3-1*.

INTRODUCTION

This section of the *Service Manual* describes the procedures necessary to service the 3TNM68 and 3TNM72 trochoid oil pumps.

See *Replacing Engine Oil and Engine Oil Filter on page 5-12* for engine oil and engine oil filter replacement procedures.

OIL PUMP SERVICE INFORMATION

Engine Oil Pressure

Model	at Rated Engine rpm	at Low Idle Speed
3TNM68-CH, VM, VH	42 - 64 psi (0.29 - 0.44 MPa 2.96 - 4.49 kgf/cm ²)	8.5 psi (0.06 MPa; 0.6 kgf/cm ²) or greater
3TNM72-CH, VM, VH		
3TNM68-CL	35 - 51 psi (0.24 - 0.35 MPa 2.44 - 3.57 kgf/cm ²)	
3TNM72-CL		

Outer Rotor Outside Clearance

Model	Standard	Limit
3TNM68 3TNM72	0.0039 - 0.0063 in. (0.10 - 0.16 mm)	0.0098 in. (0.25 mm)

Outer Rotor Side Clearance

Model	Standard	Limit
3TNM68 3TNM72	0.0019 - 0.0039 in. (0.05 - 0.10 mm)	0.0059 in. (0.15 mm)

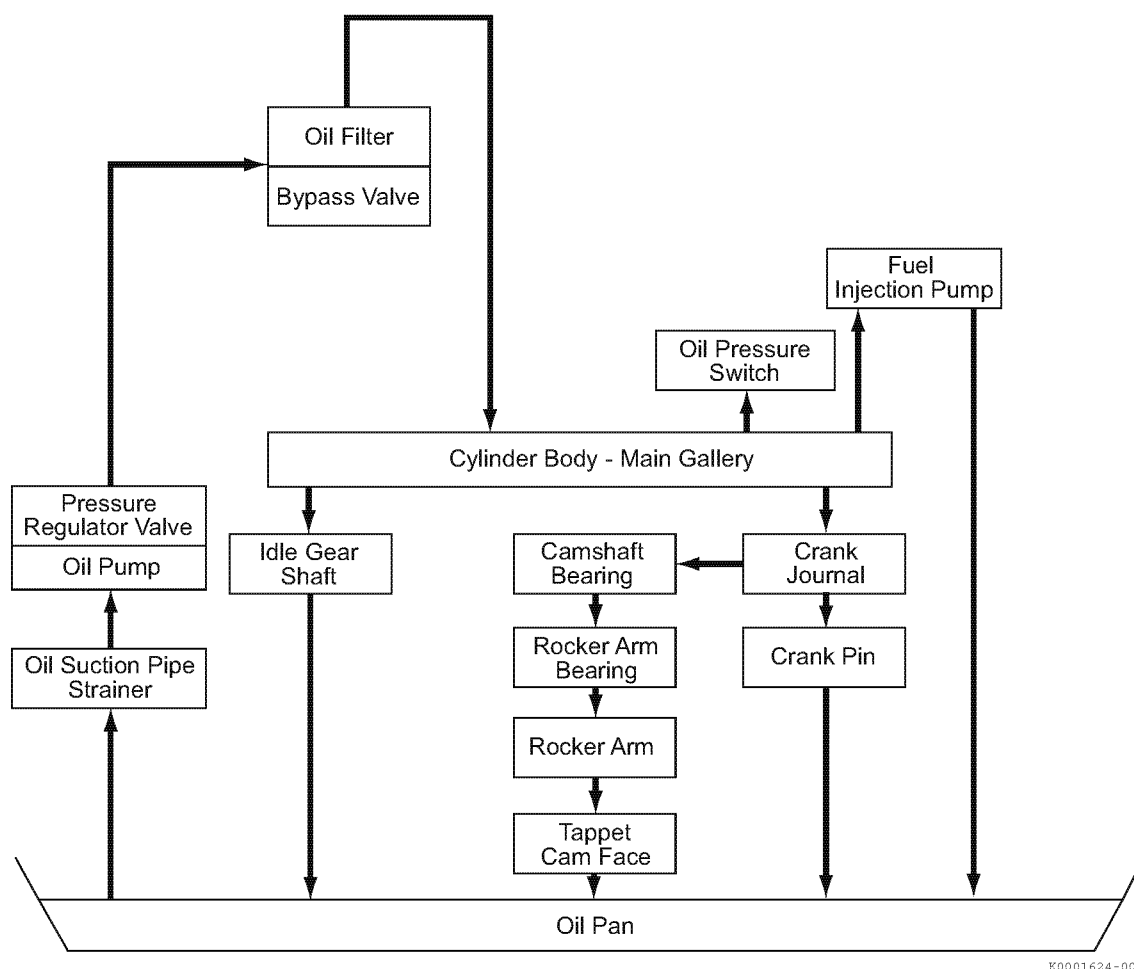
Outer Rotor to Inner Rotor Tip Clearance

Model	Standard	Limit
3TNM68 3TNM72	-	0.0063 in. (0.16 mm)

Rotor Shaft to Cover Clearance

Model	Standard	Limit
3TNM68 3TNM72		

LUBRICATION SYSTEM DIAGRAM



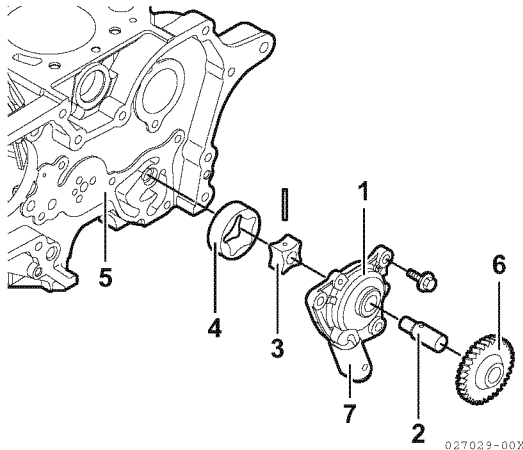
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Figure 9-1

TROCHOID OIL PUMP

Components

The oil pump on TNM engines is located in the front gear case and is driven by the same gear train that drives the camshaft and fuel injection pump. You must remove the front gear case cover to gain access to the oil pump.



- 1 – Body
- 2 – Shaft
- 3 – Inner rotor
- 4 – Outer rotor
- 5 – Cover
- 6 – Drive Gear
- 7 – Pressure Regulator Valve

Figure 9-2

Disassembling the Oil Pump

NOTICE

If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.

1. Remove the coolant fan guard (if equipped), cooling fan (**Figure 9-3, (3)**), spacer (**Figure 9-3, (2)**), coolant pump V-pulley (**Figure 9-3, (1)**) and V-belt.

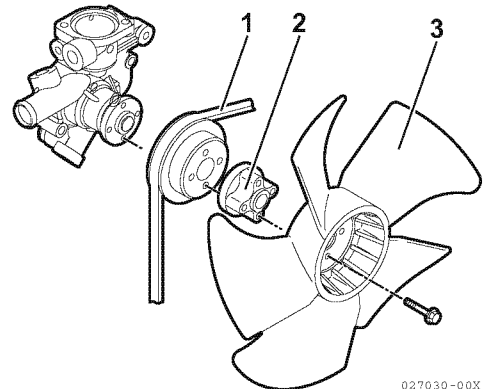


Figure 9-3

2. Remove the crankshaft pulley and gear case cover. See *Removing the Timing Gear Case Cover* on page 6-34.
3. Remove the lubricating oil pump assembly mounting bolts. Remove the lubricating oil pump assembly (**Figure 9-4, (1)**) from the gear case flange (**Figure 9-4, (2)**).
4. You can remove by hand the lubricating oil pump cover (**Figure 9-2, (5)**) and outer rotor (**Figure 9-2, (4)**).

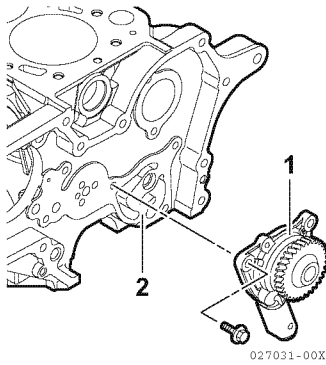


Figure 9-4

Cleaning and Inspection

Clean the lubricating oil pump, pressure regulator valve (**Figure 9-2, (7)**) and rotor inserting portion. Check the parts for wear or flaw. Replace the parts with new ones as needed.

NOTICE

If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.

Checking Outer Rotor Outside Clearance

Inspect the outside diameter clearance of the outer rotor. To inspect this, insert a feeler gauge between the outer rotor (**Figure 9-5, (1)**) and the lubricating oil pump body (**Figure 9-5, (2)**).

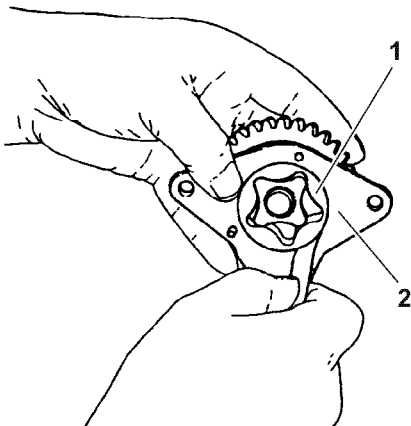


Figure 9-5

Record the measurement(s) and see *Outer Rotor Outside Clearance* on page 9-3 for the service limits.

Checking Outer Rotor to Inner Rotor Tip Clearance

Inspect the tip clearance between the outer and inner rotors. To inspect this, insert a feeler gauge between the inner rotor tooth tip (**Figure 9-6, (1)**) and the outer rotor tooth tip (**Figure 9-6, (2)**), and measure the clearance.

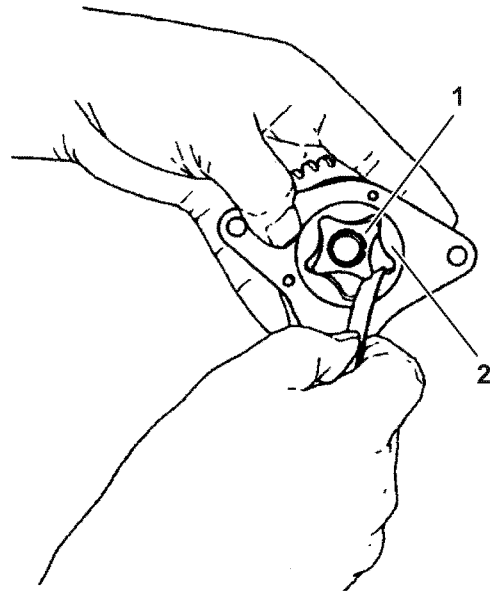


Figure 9-6

Record the measurement(s) and see *Outer Rotor to Inner Rotor Tip Clearance* on page 9-3 for the service limits.

Checking Outer Rotor Side Clearance

Inspect the side clearance between the lubricating oil pump body and the outer rotor. To measure the side clearance, use a straightedge and feeler gauge (as shown in **Figure 9-7**) or a depth micrometer.

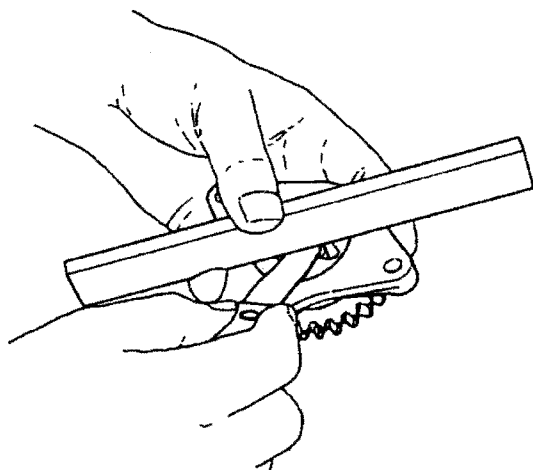


Figure 9-7

Record the measurement(s) and see *Outer Rotor Side Clearance* on page 9-3 for the service limits.

Checking Rotor Shaft Clearance

Inspect the rotor shaft clearance. Measure the outside diameter of the rotor shaft (**Figure 9-8, (1)**) and the inside diameter of the cover.

Determine the clearance by subtracting the outside diameter of the rotor from the inside diameter of the cover.

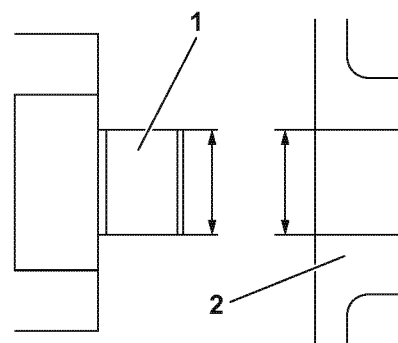


Figure 9-8

Assembling the Oil Pump

1. Apply clean lubricating oil to the lubricating oil pump body and inner rotor assembly as well as to the outer rotor.
2. Insert the outer rotor into the lubricating oil pump body and inner rotor assembly and install the cover.
3. Replace the packing with new one.
4. Install the lubricating oil pump assembly to the gear case flange by tightening the bolts with the specified torque.
5. Install the gear case cover. For more information, see *Installing the Gear Case Cover* on page 6-57.
6. Install the crankshaft pulley.
7. Install the coolant pump V-pulley (**Figure 9-9, (1)**), spacer (**Figure 9-9, (2)**), coolant fan (**Figure 9-9, (3)**) and fan guard (if equipped).

Item	Specification
Rotor Shaft O.D.	0.499 - 0.500 in. (12.685 - 12.695 mm)
Cover I.D.	0.500 - 0.501 in. (12.711 - 12.734 mm)
Clearance	0.000630 - 0.00193 in. (0.016 - 0.049 mm)

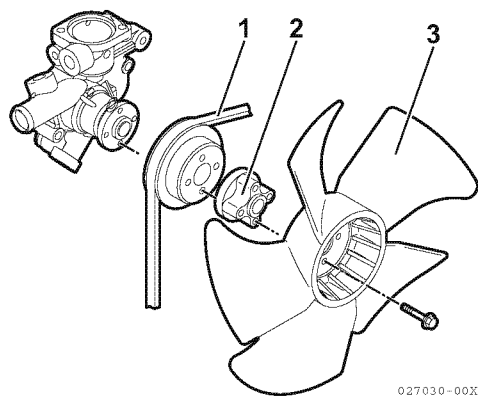


Figure 9-9

8. Install the V-belt. Adjust the belt to uniform tensile strength in accordance with the instructions given in *Checking and Adjusting Cooling Fan V-Belt* on page 5-7.

Section 10

STARTER MOTOR

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SAFETY PRECAUTIONS

Before performing any starter motor service procedures, review the following messages and the *Safety section on page 3-1*.

NOTICE

- The starter motor is waterproofed according to JIS D 0203, R2, which protects the motor from rain or general cleaning. Do not use high-pressure wash or submerge the starter motor in water.
- Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated in the Battery Cable Resistance chart in the Electric Wiring section of this manual. The starter motor will malfunction and fail if the resistance is higher than the specified value.
- The starter motor can be damaged if operated continuously longer than 10 seconds at a time. Allow a 30-second pause between each use of the starter motor if operated continuously.
- Never engage the starter motor while the engine is running. This may damage the starter motor pinion and/or ring gear.

INTRODUCTION

This section of the *Service Manual* covers the servicing of the starter motor. Yanmar Part No. 119717-77010 is standard equipment on 3TNM68 and 3TNM72 model engines and is used in this section to show the service procedures for a representative starter motor. For specific part detail, see the *Yanmar Parts Catalog* for the engine being serviced.

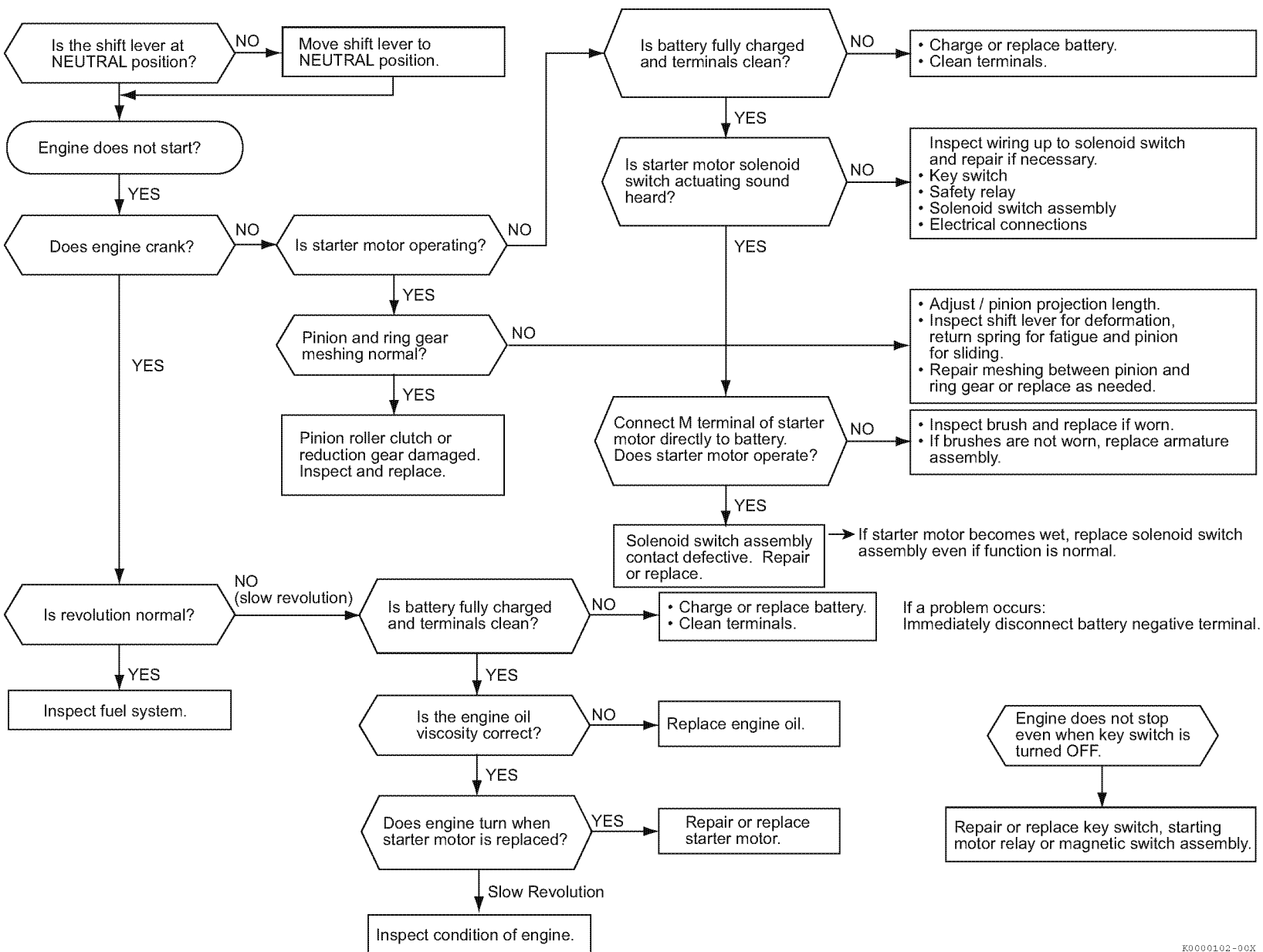
STARTER MOTOR INFORMATION

YANMAR Part Number	Mfg.	Mfg. Model Number	Specification	No Load			Loaded			
				Terminal Voltage	Amperage Draw	RPM	Terminal Voltage	Amperage Draw	Torque	RPM
119515- 77010	Denso	428000- 2190	DC12V -1.3 hp (1.0 kW)	11.5	90A (Max.)	3000 (Min.)	8.0	200 (Max.)	42 in.-lb (4.7 N·m; 0.48 kgf·m)	1240 (Min.)
119717- 77010	Denso	428000- 1590	DC12V -1.5 hp (1.1 kW)	11.5	90A (Max.)	3000 (Min.)	8.7	230 (Max.)	61 in.-lb (6.9 N·m; 0.70 kgf·m)	1130 (Min.)
119740- 77010	Denso	428000- 3310	DC12V -1.9 hp (1.4 kW)	11.5	90A (Max.)	3000 (Min.)	8.5	350 (Max.)	119 in.-lb (13.5 N·m; 1.38 kgf·m)	1000 (Min.)
119125- 77010	Hitachi	S114-940	DC12V -1.6 hp (1.2 kW)	11.0	90A (Max.)	3440 (Min.)	8.4	250 (Max.)	51 in.-lb (5.8 N·m; 0.59 kgf·m)	1500 (Min.)

STARTER MOTOR SPECIFICATIONS

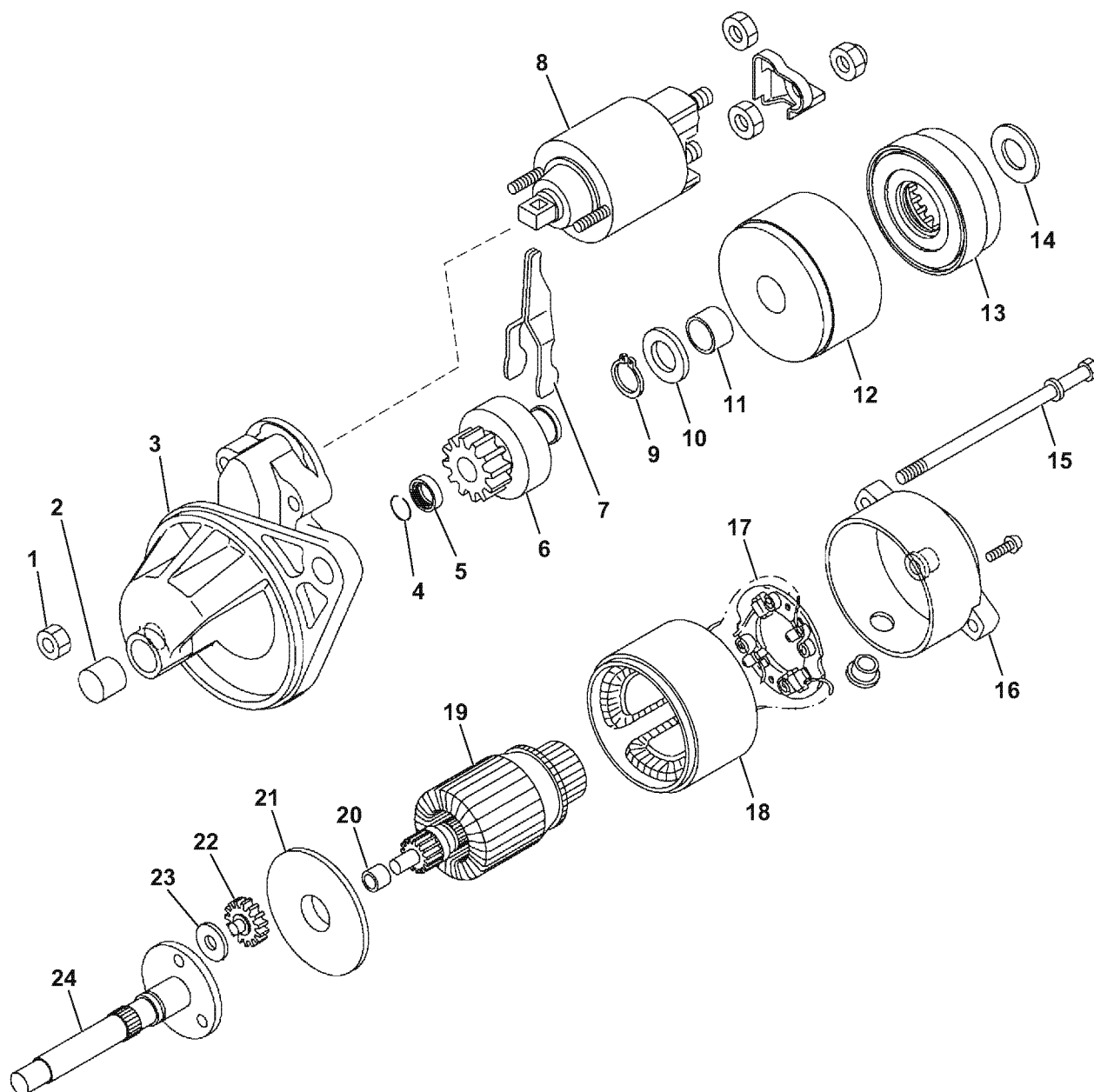
Yanmar Part Number			119717-77010
Nominal Output			1.5 hp (1.1 kW)
Weight			6.6 lb (3.0 kg)
Revolution Direction (As Viewed From Pinion)			Clockwise
Engagement System			Magnetic Shift
No-load	Terminal Voltage/Current		11.5 V/90 A max
	Revolution		3000 rpm (min ⁻¹)
Loaded	Terminal Voltage/Current		8.7 V/230 A
	Torque		61 in.-lb (6.9 N·m; 0.70 kgf·m)
	Revolution		1130 rpm (min ⁻¹)
Stalled	Terminal Voltage/Current		2.5 V/325 A max
	Torque		73 in.-lb (8.24 N·m; 0.84 kgf·m) minimum
Clutch System			Overrunning
Pinion Projection Voltage at 212°F (100°C)			8.0 V max
Pinion DP or Module/Number of Teeth			M2.54/9
Application			Standard
Brush	Spring Force		3.1 - 4.0 lbf (13.7 - 17.6 N; 1.4 - 1.8 kgf)
	Length	Standard	0.55 in. (14 mm)
		Service Limit	0.44 in. (11.1 mm)
Solenoid Switch	Pull-In Coil Resistance		0.484 W at 68°F (20°C)
	Hold-In Coil Resistance		1.055 W at 68°F (20°C)
Commutator	Outside Diameter	Standard	1.102 in. (28.0 mm)
		Service Limit	1.063 in. (27.0 mm)
	Run-Out	Standard	0.001 in. (0.02 mm)
		Service Limit	0.002 in. (0.05 mm)
	Insulation Depth	Standard	0.024 in. (0.6 mm)
		Service Limit	0.008 in. (0.2 mm)

STARTER MOTOR TROUBLESHOOTING



K0000102-00X

STARTER MOTOR COMPONENTS



K0002486-00X

Figure 10-1

- 1 – Nut
- 2 – Needle Bearing
- 3 – Pinion Housing
- 4 – Pinion Retaining Ring
- 5 – Pinion Stop
- 6 – Pinion
- 7 – Shift Lever
- 8 – Solenoid Switch Assembly
- 9 – Snap Ring
- 10 – Washer
- 11 – Bushing
- 12 – Intermediate Housing
- 13 – Reduction Gear
- 14 – Washer
- 15 – Through Bolt
- 16 – End Housing
- 17 – Brush Plate and Holder
- 18 – Field Assembly
- 19 – Armature
- 20 – Bushing
- 21 – Plate
- 22 – Planetary Gear (3 used)
- 23 – Washer (3 used)
- 24 – Pinion Shaft

STARTER MOTOR

⚠ WARNING

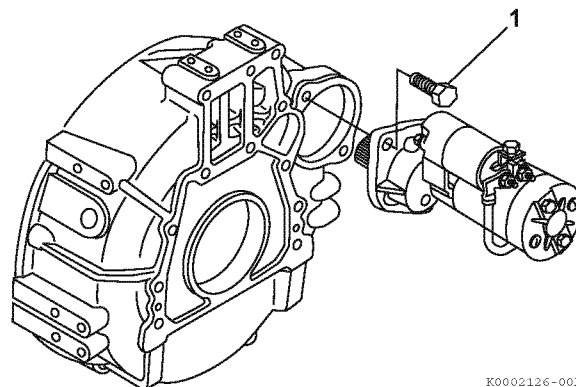
Shock Hazard

- 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.

Note: While starter motor design varies between models, the basic repair procedures are the same. The following procedures are typical and may differ from the starter being serviced.

Removing the Starter Motor

1. Disconnect the battery cables at the battery, negative (-) cable first.
2. Remove the electrical wires from the solenoid switch assembly.
3. Remove the starter mounting bolts (**Figure 10-2, (1)**). Remove the starter motor from the flywheel housing.



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Figure 10-2

Disassembling the Starter Motor

1. Make alignment marks across all mating joints.
2. Disconnect the field wire from the solenoid switch (Figure 10-3).

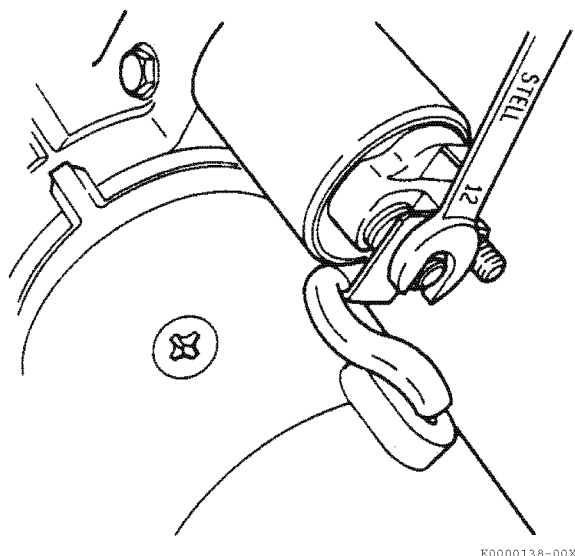


Figure 10-3

3. Remove the two bolts or nuts retaining the solenoid switch assembly (Figure 10-4, (1)) to the pinion housing. Remove the solenoid switch assembly and dust covers (Figure 10-4, (2)). Remove the plunger (Figure 10-4, (4)) and torsion spring (Figure 10-4, (3)) from the pinion housing.

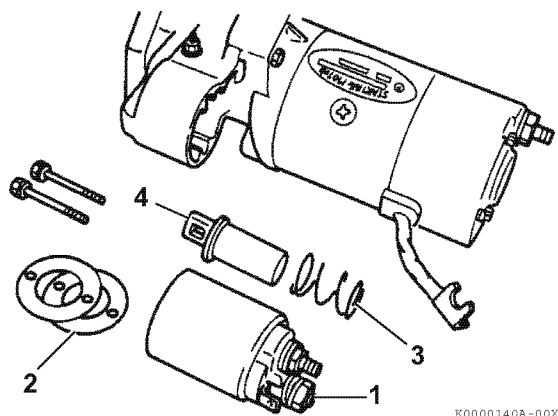


Figure 10-4

4. Remove the two screws (Figure 10-5, (1)) securing the rear cover (Figure 10-5, (2)) to the brush holder assembly (Figure 10-5, (3)).

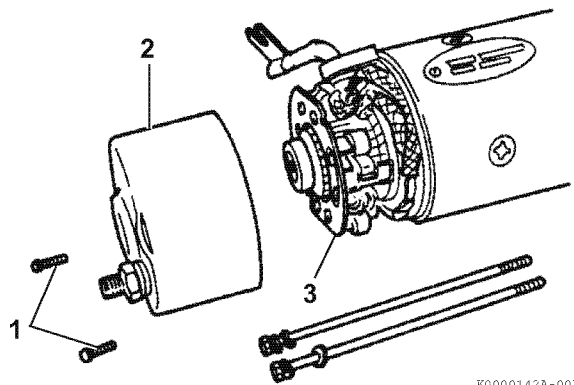


Figure 10-5

5. Remove the two through-bolts. Remove the rear cover (Figure 10-5, (2)).
6. Pull the brush springs up using a brush spring puller. On the negative (-) side, bring the brush spring into contact with the side of the brushes to hold the brushes clear of the commutator surface. On the positive (+) side, remove the brushes from the brush holder assembly (Figure 10-6).

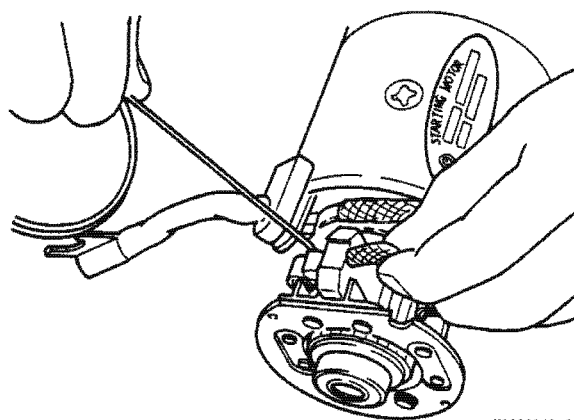


Figure 10-6

7. Remove the brush plate and holder (Figure 10-7, (1)).

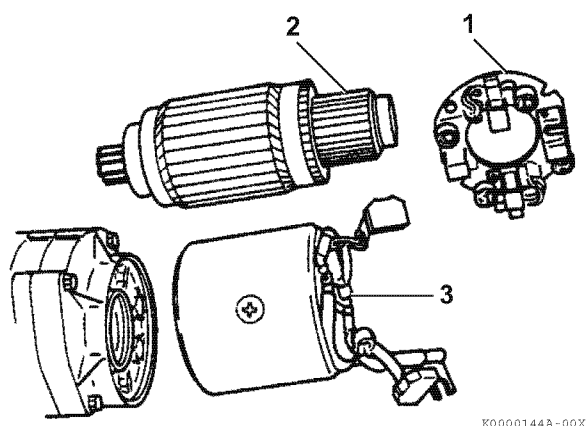


Figure 10-7

8. Pull the field assembly (Figure 10-7, (3)) off the armature assembly (Figure 10-7, (2)).
9. Remove the armature from the intermediate housing.
10. Remove the intermediate housing, gear and pinion shaft assembly (Figure 10-8, (4)) from the pinion housing (Figure 10-8, (3)). Disengage from the shift lever as it is removed.
11. Remove the shift lever (Figure 10-8, (2)), pin and spacer (Figure 10-8, (1)).

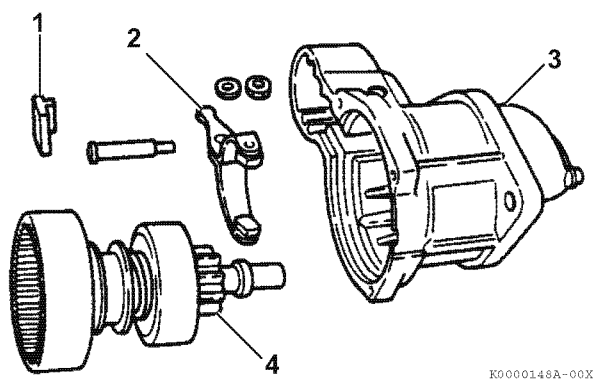


Figure 10-8

12. Pull the pinion stop (Figure 10-9, (1)) down to expose the retaining ring. Using a flat-blade screwdriver, remove the retaining ring (Figure 10-9, (2)) from the pinion shaft.

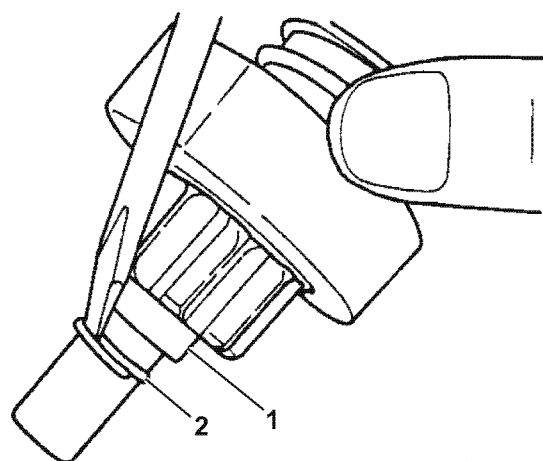


Figure 10-9

13. Remove the pinion stop (Figure 10-10, (3)), return spring (if equipped) and pinion clutch assembly (Figure 10-10, (2)) from the pinion shaft (Figure 10-10, (1)).

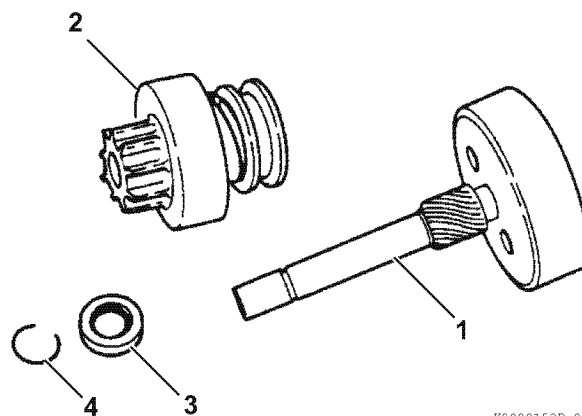


Figure 10-10

14. Remove the snap ring (**Figure 10-11, (1)**).
Remove the pinion shaft (**Figure 10-11, (5)**), planetary gears (**Figure 10-11, (6)**), washers and reduction gear (**Figure 10-11, (4)**) from the intermediate housing (**Figure 10-11, (3)**).

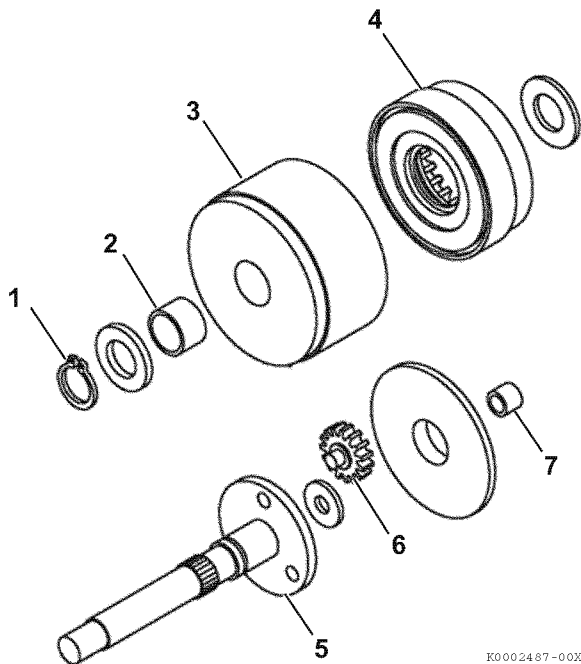


Figure 10-11

15. Inspect the intermediate bushing (**Figure 10-11, (2)**) and replace if worn or damaged.
16. Inspect armature bushing (**Figure 10-11, (7)**) and replace if worn or damaged.

Cleaning and Inspection

Armature

Inspecting Commutator Surface

If the commutator surface is rough, polish the surface with a #500 to #600 emery cloth.

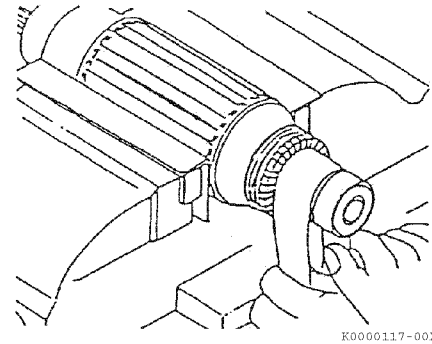


Figure 10-12

Measuring Commutator Outside Diameter

Measure the commutator outside diameter. Replace the armature if the measurement is less than the limit. See *Starter Motor Specifications* on page 10-5.

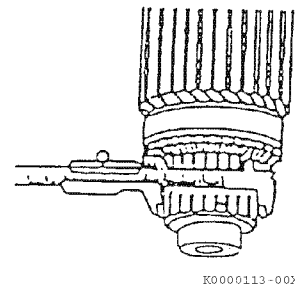


Figure 10-13

Measuring Commutator Insulation Depth

Measure the depth of the insulating material (Figure 10-14, (1)) between commutator segments (Figure 10-14, (2)). If the depth measures less than the limit, use a hacksaw blade (Figure 10-14, (3)) to remove the insulating material until the depth is within the limit. See *Starter Motor Specifications on page 10-5 for service limit*.

A normal commutator condition is indicated in Figure 10-14, (4). An abnormal commutator condition is indicated in Figure 10-14, (5).

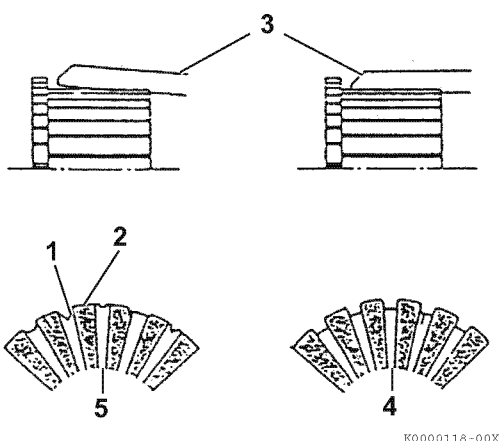


Figure 10-14

Armature Coil Continuity Test

Check for continuity between the commutator segments using a multimeter (Figure 10-15). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the armature.

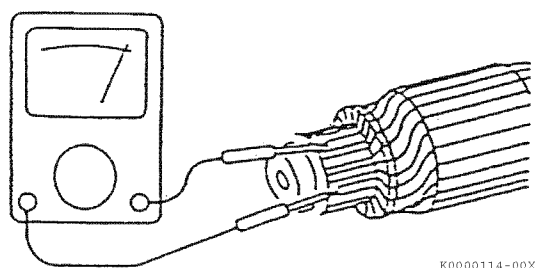


Figure 10-15

Armature Coil Insulation Test

Check for continuity between a commutator segment and the shaft or armature using a multimeter (Figure 10-16). The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the armature.

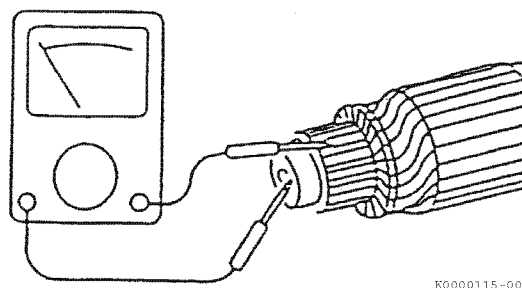


Figure 10-16

Measuring Armature and Commutator Run-Out

Measure the armature core run-out and the commutator run-out using a dial indicator (Figure 10-17). Replace the armature if either of the measurements is not within specifications. See *Starter Motor Specifications on page 10-5 for service limit*.

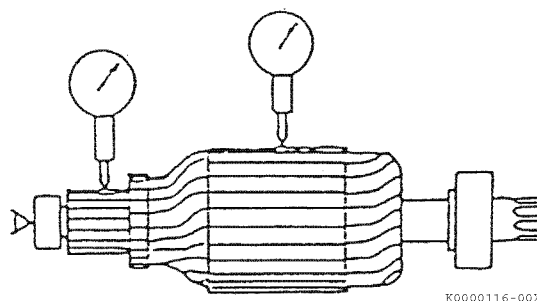


Figure 10-17

Field Coil

Field Coil Continuity Test

Check for continuity between the field coil terminals using a multimeter (**Figure 10-18**). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the field coil assembly.

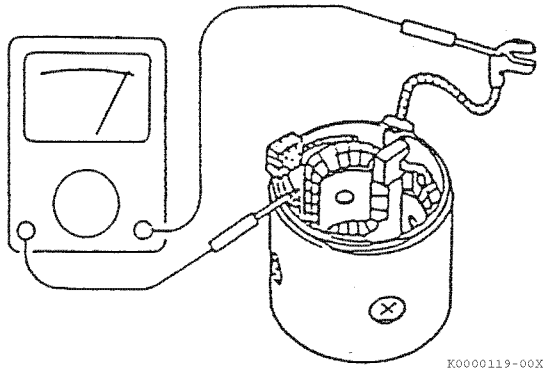


Figure 10-18

Field Coil Insulation Test

Check for continuity between either field coil terminal and the yoke using a multimeter (**Figure 10-19**). The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the field coil assembly.

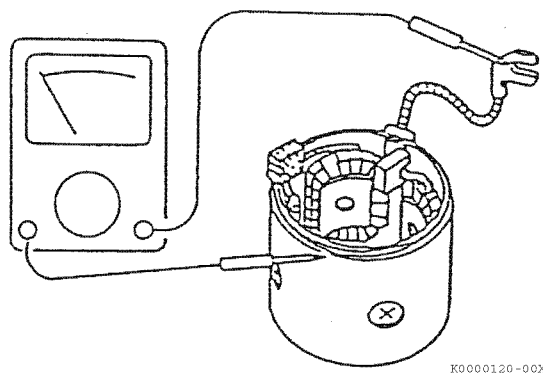


Figure 10-19

Measuring Brush Length

Measure the length of the brush (**Figure 10-20**). Replace the brush if the length is less than the limit. See *Starter Motor Specifications* on page 10-5 for service limit.

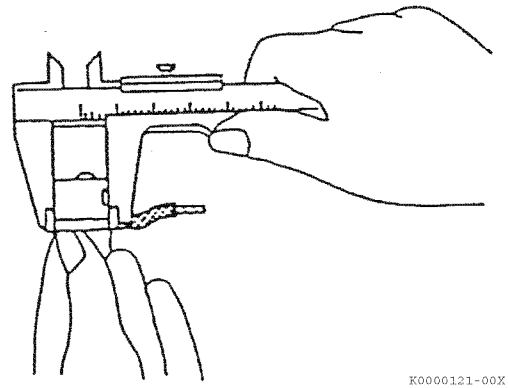


Figure 10-20

Brush Holder

Brush Holder Insulation Test

Check for continuity between each brush holder and the base using a multimeter (**Figure 10-21**). The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the brush holder.

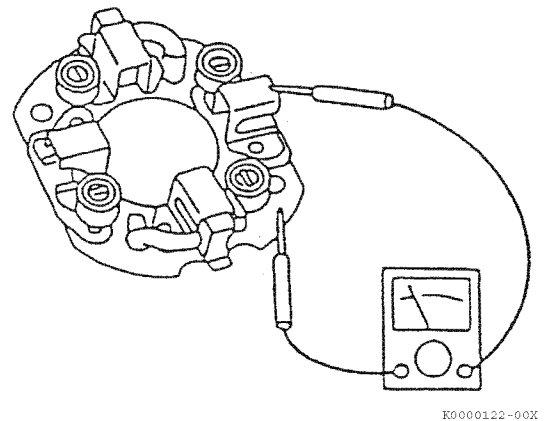


Figure 10-21

Brush Spring Test

Test the spring force for each brush spring (Figure 10-22). Replace the brush spring if the force is not within the range. See *Starter Motor Specifications* on page 10-5 for the service limit.

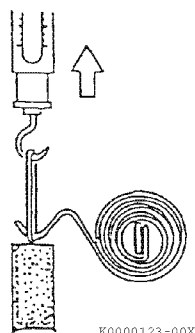


Figure 10-22

Solenoid Switch

If the starter motor becomes wet, replace the solenoid switch even if the solenoid switch assembly function is normal.

Shunt Coil Continuity Test

Check for continuity between the “S” terminal and the switch body using a multimeter (Figure 10-23). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the solenoid switch.

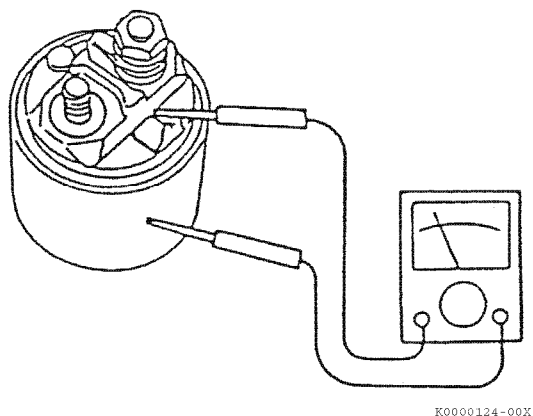


Figure 10-23

Series Coil Continuity Test

Check for continuity between the “S” and “M” terminals using a multimeter (Figure 10-24). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the solenoid switch.

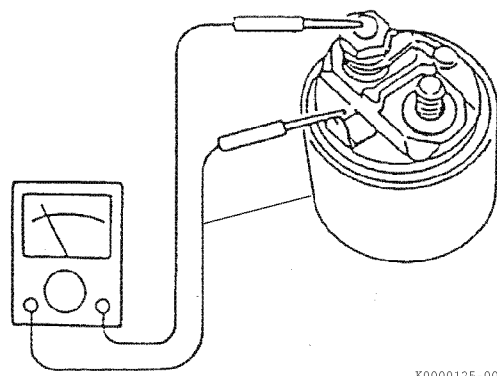


Figure 10-24

Coil Resistance Test

See *Starter Motor Specifications* on page 10-5 for service limit.

Contact Continuity Test

Depress the plunger at the bottom of the solenoid switch. Check for continuity between the “B” and “M” terminals using a multimeter (Figure 10-25). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the solenoid switch.

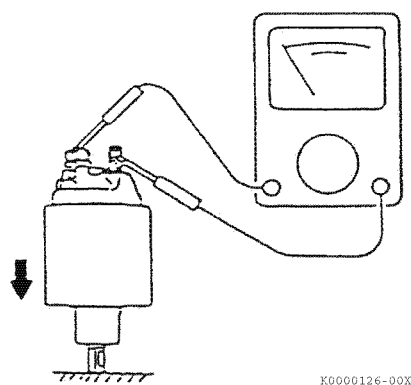


Figure 10-25

Pinion Clutch Assembly

Inspecting Pinion Clutch Assembly

Manually rotate the pinion clutch assembly in the drive direction. It should rotate freely in the drive direction and is locked by turning it in the opposite direction (**Figure 10-26**). Replace the pinion clutch assembly if the results are different.

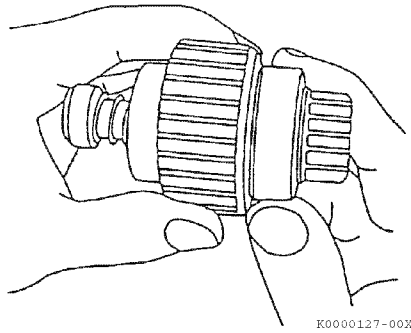


Figure 10-26

Slide the pinion clutch assembly on the shaft (**Figure 10-27**). It should slide smoothly on the shaft. Rust, too much grease or damage could prevent the pinion clutch from sliding smoothly. If the pinion clutch assembly does not slide smoothly, clean the shaft and pinion clutch assembly or replace the damaged component.

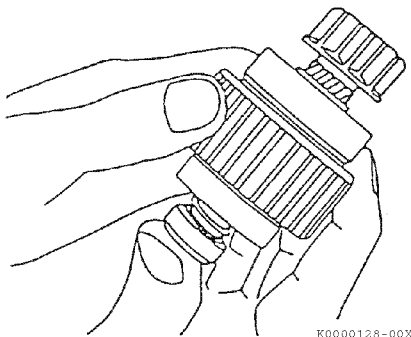


Figure 10-27

Assembling the Starter Motor

1. Apply a appropriate starter bendix grease (obtain locally) to the pinion shaft.
2. Assemble the reduction gear (**Figure 10-28, (4)**), pinion shaft (**Figure 10-28, (5)**), planetary gears (**Figure 10-28, (6)**) and washers into the intermediate housing (**Figure 10-28, (3)**). Install snap ring (**Figure 10-28, (1)**).

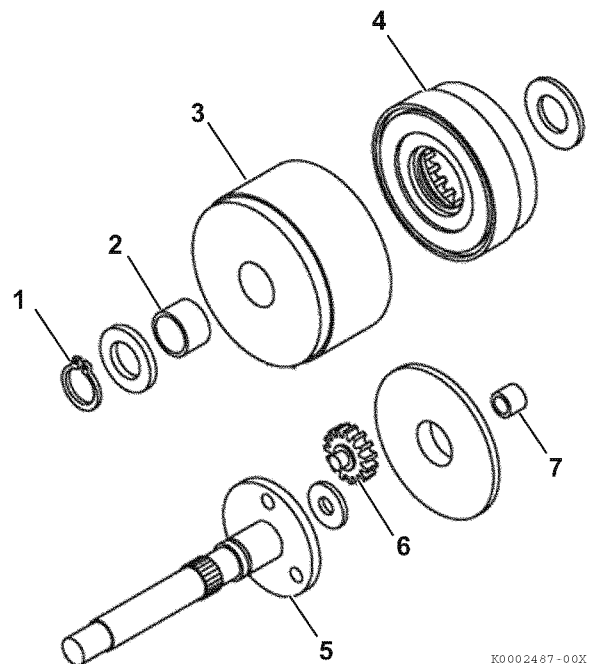
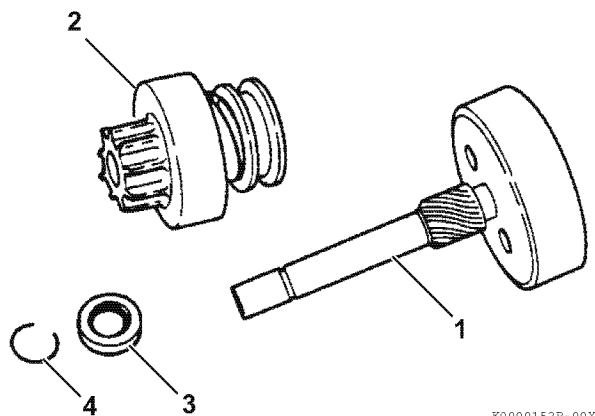


Figure 10-28

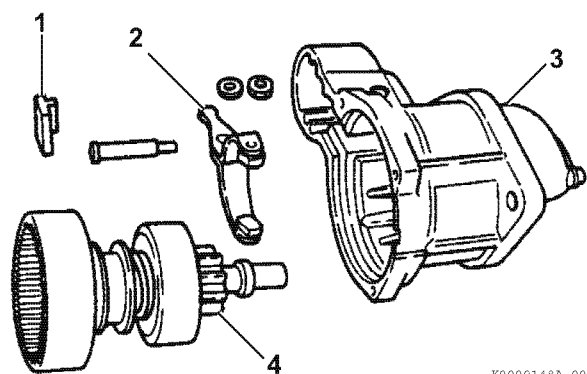
3. Install the pinion clutch assembly (**Figure 10-29, (2)**), return spring (if equipped) and pinion stop (**Figure 10-29, (3)**) onto the pinion shaft (**Figure 10-29, (1)**). Install the retaining ring (**Figure 10-29, (4)**) in the groove in the pinion shaft. Slide the pinion stop over the retaining ring.



K0000152B-00X

Figure 10-29

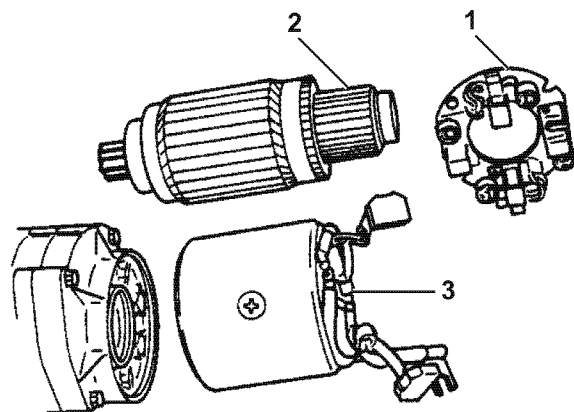
4. Apply a small amount of high-temperature lithium grease (obtain locally) to the contact surfaces of the shift lever. Assemble the shift lever (**Figure 10-30, (2)**), spacer (if equipped) (**Figure 10-30, (1)**) and pin.
5. Install the pinion shaft assembly (**Figure 10-30, (4)**) in the pinion housing (**Figure 10-30, (3)**). Be sure the shift lever properly engages the pinion.



K0000148A-00X

Figure 10-30

6. Apply a small amount of high-temperature lithium grease (obtain locally) to the surface of the plunger and the hole that engages the shift lever.
7. Attach the plunger to the shift lever.
8. Install the plate onto the intermediate housing and carefully install the armature assembly (**Figure 10-31, (2)**) into the pinion shaft assembly.



K0000144A-00X

Figure 10-31

9. Install the field assembly (**Figure 10-31, (3)**) over the armature assembly and align to the pinion housing.
10. Position the brush springs in brush holders. Install the brushes in the brush holders. Reversing the brushes will cause the starter motor to turn backwards.

11. Carefully install the brush holder (Figure 10-32, (3)) assembly.
12. Install the rear cover (Figure 10-32, (2)) and secure with two screws (Figure 10-32, (1)).

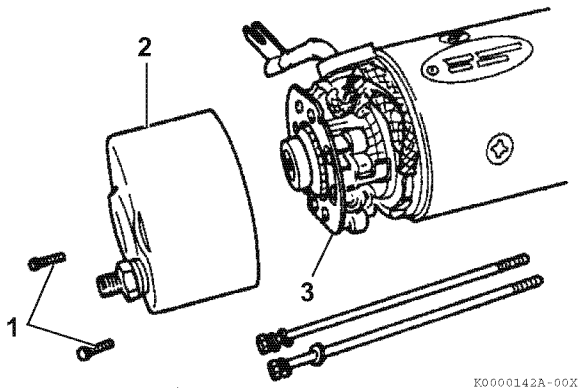


Figure 10-32

13. Install the two through-bolts and tighten securely.
14. Install the return spring (if equipped) (Figure 10-33, (3)) on the solenoid plunger (Figure 10-33, (4)). Install the solenoid switch coil (Figure 10-33, (1)) and dust covers (Figure 10-33, (2)). Secure with nuts or bolts.

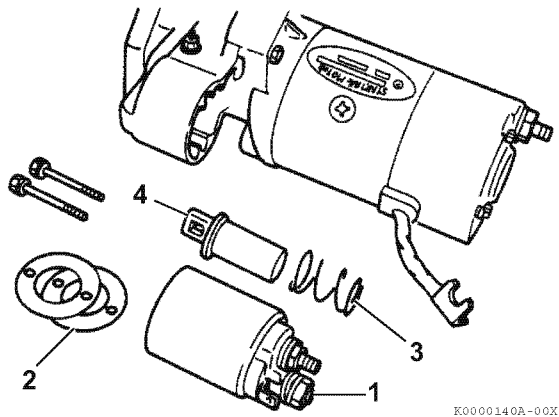


Figure 10-33

15. Connect the wire to the solenoid switch assembly. Tighten the nut. Install the cover over the connection.

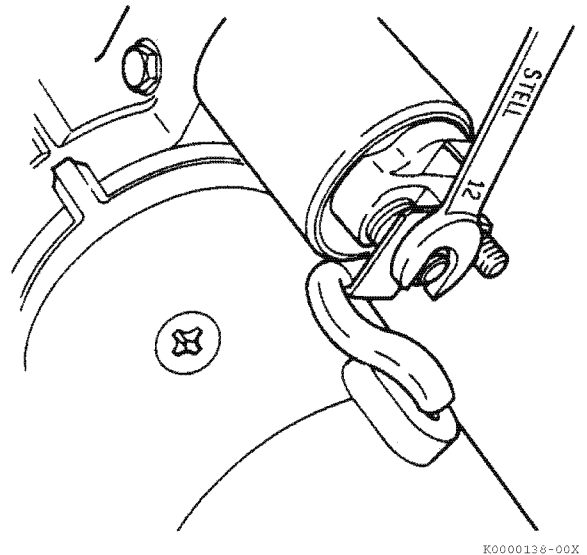


Figure 10-34

Checking Pinion Projection Length

1. Connect the positive (+) lead from a battery to the "S" terminal.
2. Connect the negative (-) lead to the "M" terminal.
3. Lightly pull the pinion away from the gear housing.
4. Turn the switch on and measure the pinion moving distance, dimension L, in the thrust direction (Figure 10-35). Perform this test within 10 seconds.

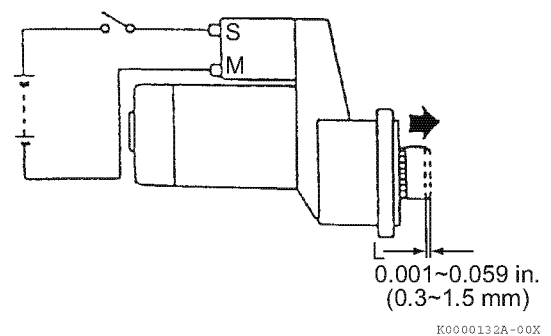


Figure 10-35

See Starter Motor Specifications on page 10-5 for service limit.

5. If the measured L dimension is outside the standard range, adjust the dust covers to obtain the standard range. Dust covers **(Figure 10-36, (1))** are available in 0.020 in. (0.5 mm) and 0.031 in. (0.8 mm) thicknesses.

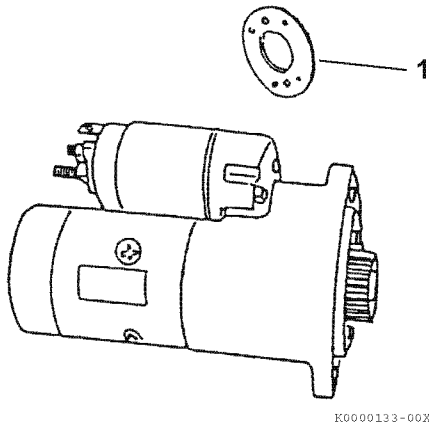


Figure 10-36

No-Load Test

Test the characteristics of the starter motor by performing a no-load test.

NOTICE

The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test. Allow a 30-second pause between each use of the starter motor if operated continuously.

1. Secure the starting motor in a vise or other suitable fixture.
2. Connect an ammeter **(Figure 10-37, (1))** in series between the battery positive (+) terminal **(Figure 10-37, (2))** and the main positive (+) terminal **(Figure 10-37, (3))** on the starter motor.

NOTICE

The ammeter and all wire leads used in this test must have a capacity equal to or greater than the amperage draw specification for the starter motor being tested.

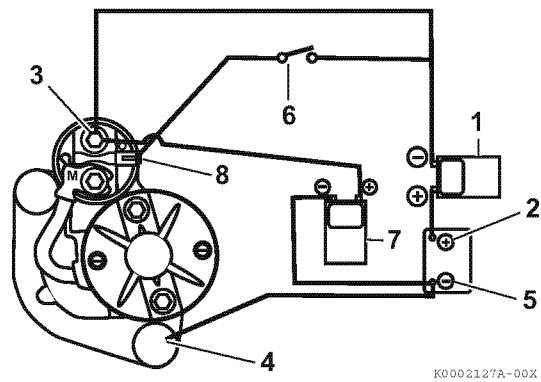


Figure 10-37

3. Connect a wire lead between the mounting base of the starter motor **(Figure 10-37, (4))** and the battery negative terminal **(Figure 10-37, (5))**.
4. Connect a voltmeter **(Figure 10-37, (7))** to the battery negative (-) terminal **(Figure 10-37, (5))** and the main positive (+) battery terminal **(Figure 10-37, (3))** on the starter motor.
5. Install a switch **(Figure 10-37, (6))** in a circuit between the battery positive (+) terminal **(Figure 10-37, (2))** and the starter solenoid switch terminal **(Figure 10-37, (8))** on the starter motor.
6. Use a suitable tachometer to monitor the rpm of the starter.
7. Turn the switch to the ON position to energize the solenoid and operate the starter. Monitor the rpm, amperage draw and voltage. For test specifications, see *Starter Motor Information on page 10-4* for the appropriate starter motor.

Installing the Starter Motor

1. Install the starter motor to the flywheel housing.
2. Install the starter mounting bolts
(Figure 10-38, (1)). Tighten the bolts to specification. *See Tightening Torques for Standard Bolts and Nuts on page 4-25.*

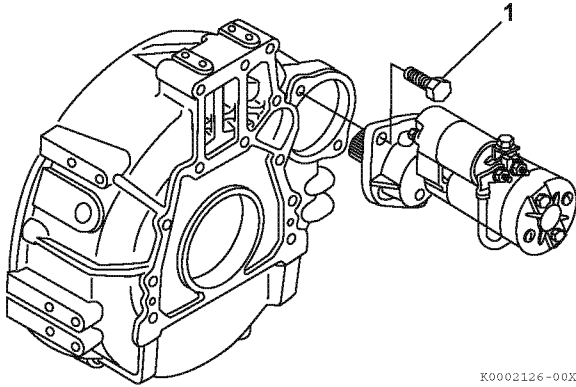


Figure 10-38

3. Connect the electrical wires to the solenoid switch assembly. Be sure to place the cover over the battery positive (+) cable connection.
4. Connect the battery, negative (-) cable last.

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Section 11

ALTERNATOR

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ALTERNATOR

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SAFETY PRECAUTIONS

Before performing any alternator service procedures, review the following messages and the *Safety section on page 3-1*.

NOTICE

- Do not operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.
- Do not turn the battery switch off while the engine is operating. Damage to the alternator will result.
- Do not use a high-pressure wash directly on the alternator. Water will damage the alternator and result in inadequate charging.

INTRODUCTION

This section of the *Service Manual* describes the servicing of the dynamos and alternators. Yanmar Part No. 129423-77200 alternator is used in this section to show the service procedures for the representative alternator. Yanmar Part No. 119626-77200 dynamo is used in this section to show the service procedures for the representative dynamo. For specific part detail, see the *Parts Catalog* for the engine you are working on.

STANDARD AND OPTIONAL DYNAMO INFORMATION

YANMAR Part Number	Mfg.	Mfg. Part Number	Specification
171301-77201	Kokusan	GP8138	DC12V-15A
119910-77200	Kokusan	GP9191	DC12V-20A
119626-77200	Kokusan	GP9186	DC12V-20A

STANDARD AND OPTIONAL ALTERNATOR INFORMATION

YANMAR Part Number	Mfg.	Mfg. Part Number	Specification
119620-77201	Denso	100211-4531	DC12V-40A
129423-77200	Denso	101211-1170	DC12V-40A with Pulse
129961-77200	Denso	101211-2591	DC12V-55A
119626-77210	Denso	101211-2951	DC12V-55A with Pulse

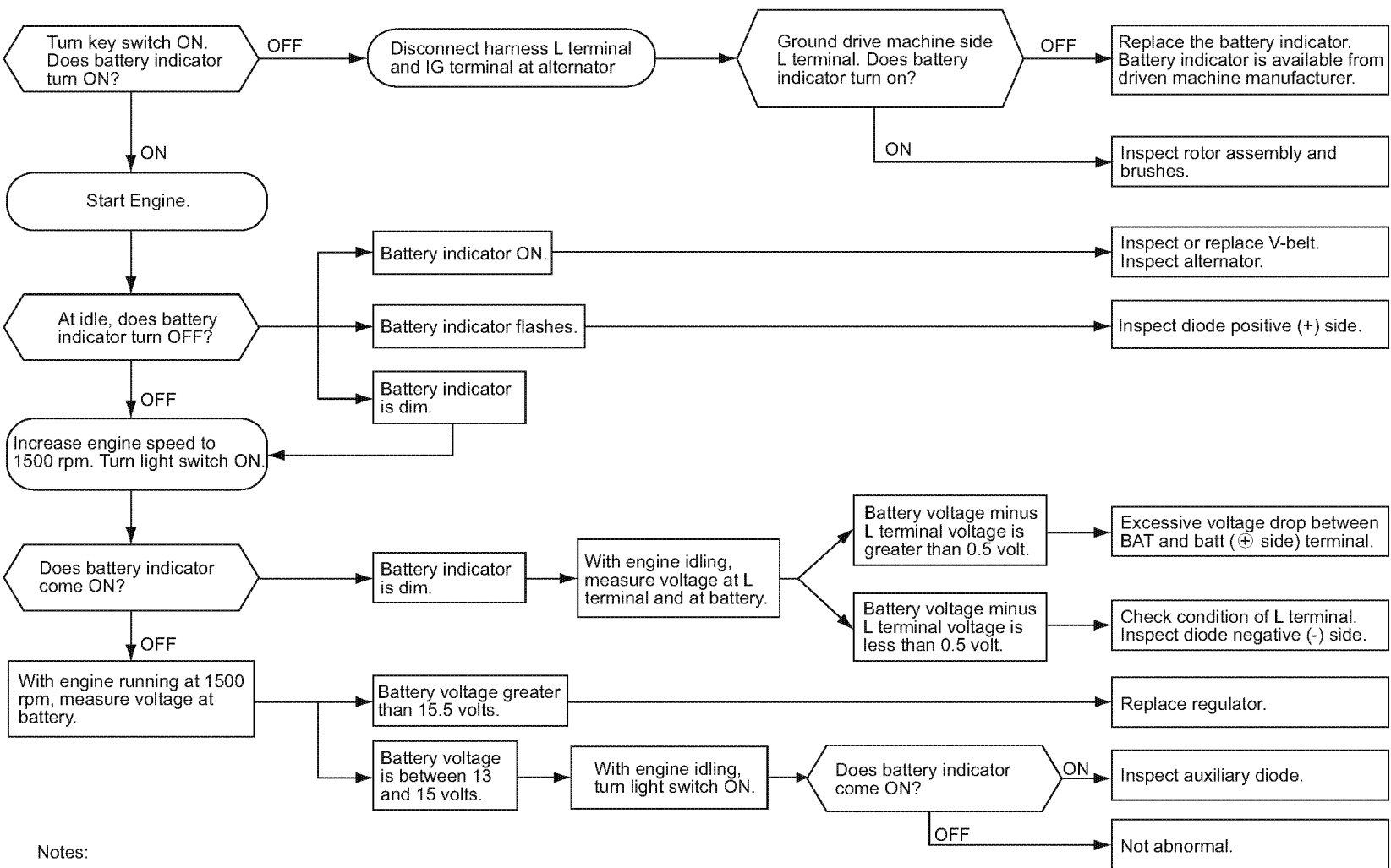
ALTERNATOR SPECIFICATIONS

Yanmar Part Number	129423-77200
Nominal Output (13.5 Volts Heat)	40 Amps
Weight	6.17 lb (2.8 kg)
Revolution Direction (as viewed from pulley)	Clockwise
Rating	Continuous
Battery Voltage	12 Volts
Rated Revolution	5000 rpm (min ⁻¹)
Operating Range	1350 - 18000 rpm (min ⁻¹)
Grounding Characteristics	Negative (-) Side of Circuit
Integrated Regulator	IC Regulator
Outside Diameter of Pulley	2.724 in. (69.2 mm)
Belt Shape	Type A

DYNAMO SPECIFICATIONS

Yanmar Part Number		119910-77200/119626-77200
Nominal Output		20 Amps
Weight		3.97 lb (1.8 kg)
Revolution Direction (as viewed from pulley)		Clockwise
Rating		Continuous
Battery Voltage		12 Volts
Rated Revolution		3500 rpm (min ⁻¹)
Operating Range		1400 - 6600 rpm (min ⁻¹)
Grounding Characteristics		Negative (-) Side of Circuit
Regulator		Current Limiter (Part No. 119653-77710)
Outside Diameter of Pulley	A-Belt	2.56 in. (65 mm)
	Special M-Belt	2.28 in. (58 mm)
Belt Shape		Type A or Type Special M

ALTERNATOR TROUBLESHOOTING

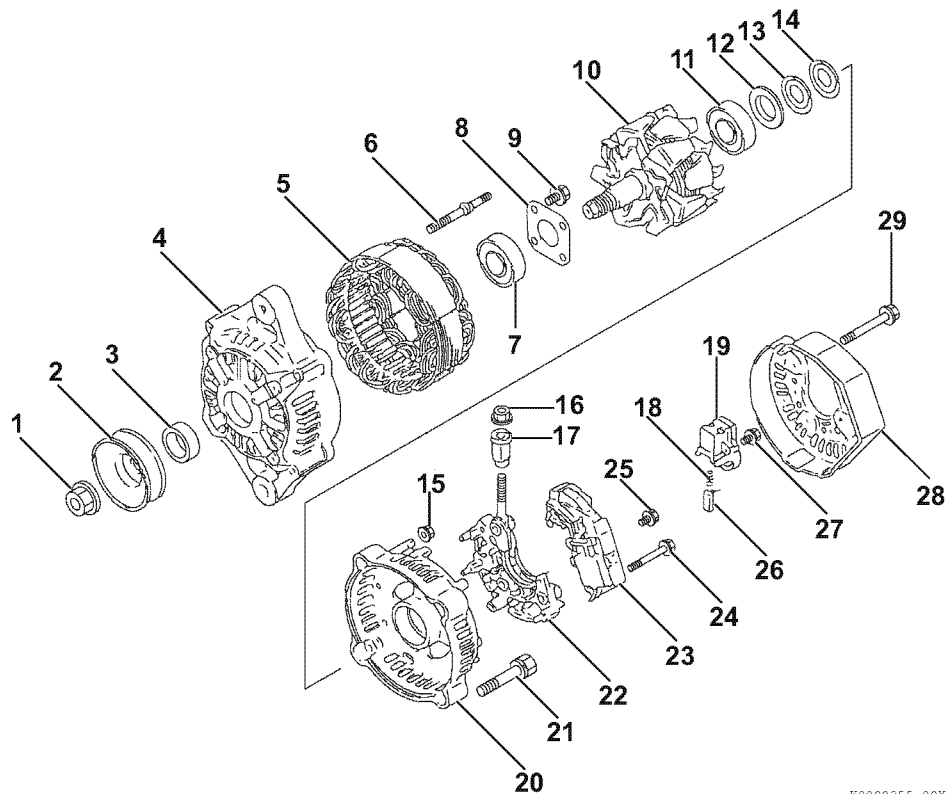


Notes:

- 1) Use a fully charged battery
- 2) DC voltmeter: 0 to 30 V, 0.5 class
- 3) The check method is also applicable to the bench test

ALTERNATOR COMPONENTS

Yanmar Part No. 129423-77200 alternator is used in this section to show the service procedures for the representative alternator. For specific part detail, see the *Parts Catalog* for the engine you are working on.



- 1 – Nut
- 2 – Pulley
- 3 – Collar
- 4 – Front Frame Housing
- 5 – Stator Assembly
- 6 – Stud (2 used)
- 7 – Front Frame Housing Bearing
- 8 – Bearing Cover
- 9 – Bearing Cover Bolt (4 used)
- 10 – Rotor Assembly
- 11 – Rear Frame Housing Bearing
- 12 – Bearing Cover
- 13 – Thrust Washer
- 14 – Thrust Washer
- 15 – Nut (2 used)

- 16 – Nut
- 17 – Insulation Bushing
- 18 – Spring (2 used)
- 19 – Brush Holder
- 20 – Rear Frame Housing
- 21 – Bolt (2 used)
- 22 – Holder
- 23 – IC Regulator Assembly
- 24 – Bolt (2 used)
- 25 – Bolt
- 26 – Brush (2 used)
- 27 – Bolt
- 28 – Rear Cover
- 29 – Bolt (3 used)

Figure 11-1

ALTERNATOR WIRING DIAGRAM

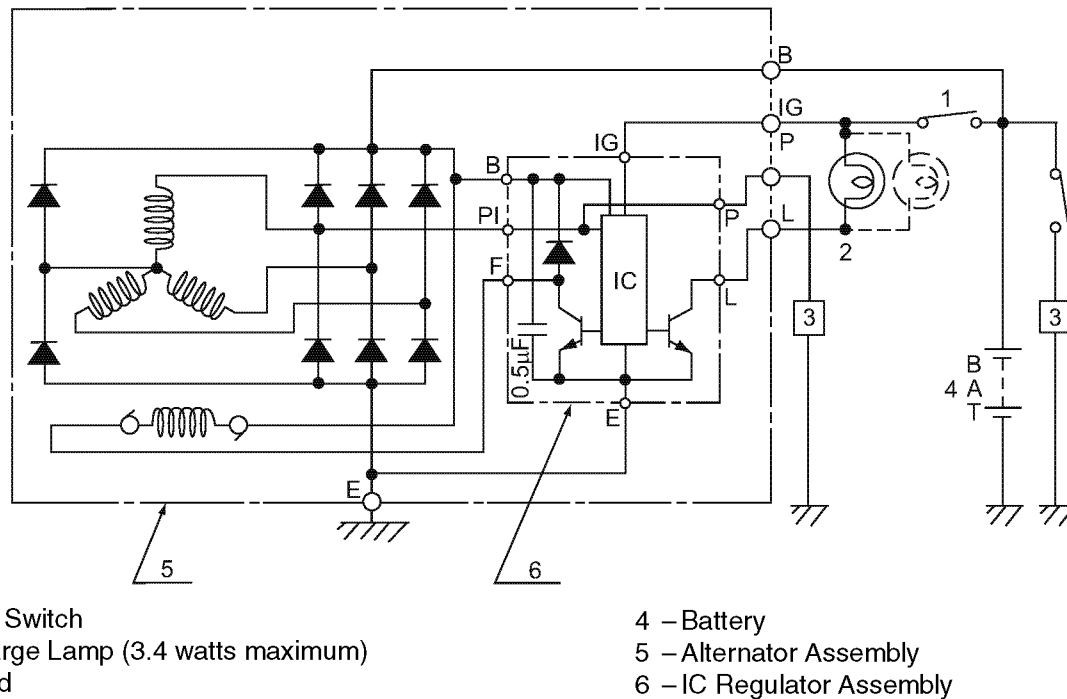


Figure 11-2

NOTICE

- Do not short-circuit the charging system between alternator terminals IG and L. Damage to the alternator will result.
- Do not connect a load between alternator terminals L and E. Damage to the alternator will result.
- Do not remove the positive (+) battery cable from alternator terminal B while the engine is operating. Damage to the alternator will result.
- Agricultural or other chemicals, especially those with a high sulfur content, can adhere to the IC regulator. This will corrode the conductor and result in battery over-charging (boiling) and charging malfunctions. Consult Yanmar before using the equipment in such an environment or the warranty is voided.

ALTERNATOR STANDARD OUTPUT

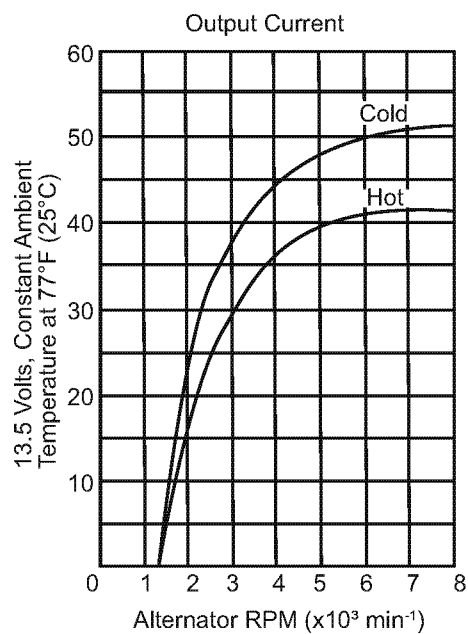


Figure 11-3

ALTERNATOR

⚠ WARNING

Electrical Shock Hazard

- 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.

Removing the Alternator

1. Disconnect the electrical wires from the alternator.
2. Loosen the V-belt.

⚠ CAUTION

Pinch Hazard

Carefully rotate the alternator toward the cylinder block while loosening the V-belt.

3. Remove the V-belt adjuster from the alternator bolt (Figure 11-4, (1)).
4. Remove the nut (Figure 11-4, (2)) from the gear case stud. Remove the alternator.

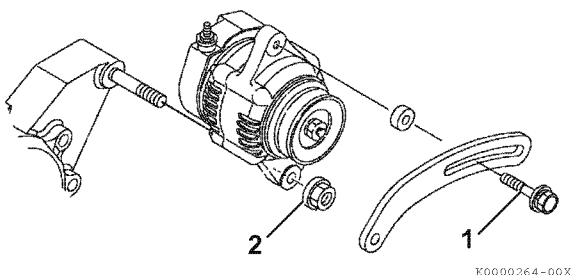


Figure 11-4

Disassembling the Alternator

1. Remove the nut (Figure 11-5, (1)) from the shaft of the rotor assembly. Remove the pulley (Figure 11-5, (2)).

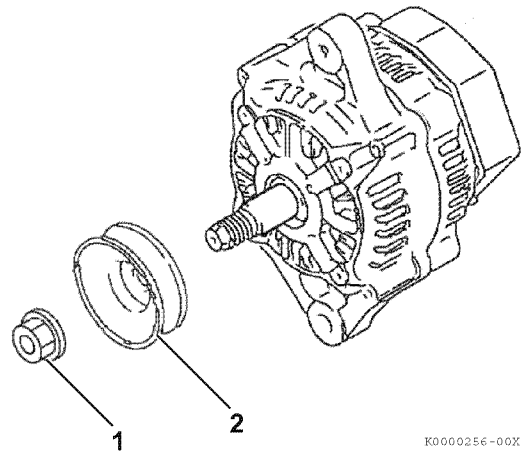


Figure 11-5

2. Remove the three bolts (Figure 11-6, (1)) retaining the rear cover (Figure 11-6, (2)) to the rear frame assembly.

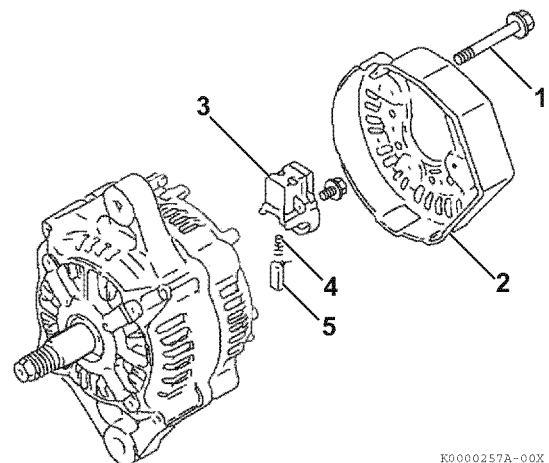


Figure 11-6

3. Remove the brush holder (**Figure 11-6, (3)**). Remove the brush springs (**Figure 11-6, (4)**) and brushes (**Figure 11-6, (5)**).
4. Remove the bolt retaining the regulator assembly (**Figure 11-7, (1)**) to the holder (**Figure 11-7, (2)**).

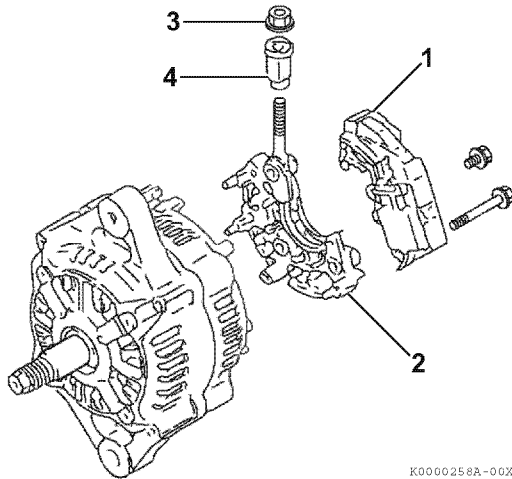


Figure 11-7

5. Remove the bolts retaining the holder (**Figure 11-7, (2)**) to the rear frame housing. Remove the holder.
6. Remove the nut (**Figure 11-7, (3)**) retaining the insulation bushing (**Figure 11-7, (4)**). Remove the insulation bushing.

7. Remove the two bolts (**Figure 11-8, (1)**) and two nuts (**Figure 11-8, (2)**) securing the rear frame housing to the front frame housing.

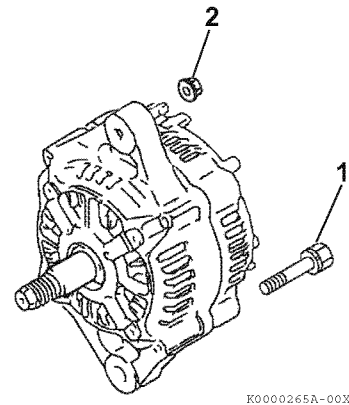


Figure 11-8

8. Using a press, remove the rotor assembly (**Figure 11-9, (1)**) from the front frame housing (**Figure 11-9, (2)**) and rear frame housing (**Figure 11-9, (3)**).

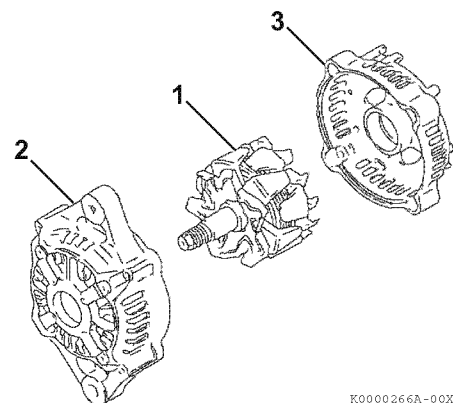


Figure 11-9

9. Remove the stator assembly (**Figure 11-10, (1)**) from the front frame housing.

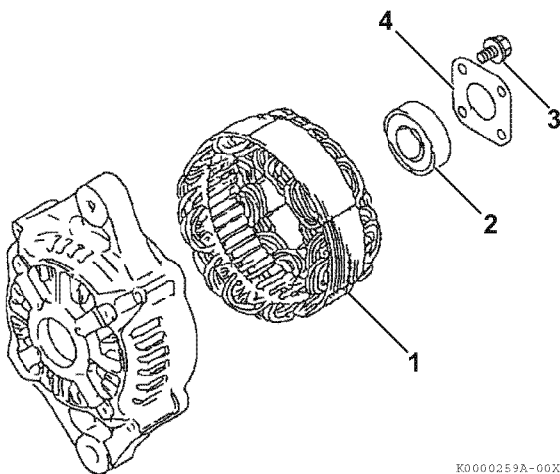


Figure 11-10

10. If it is necessary to replace the bearing (**Figure 11-10, (2)**) in the front frame housing, remove the four bolts (**Figure 11-10, (3)**) securing the plate (**Figure 11-10, (4)**) to the front frame housing. Remove the plate. Use a puller to remove the bearing. Discard the bearing.
11. If it is necessary to replace the bearing (**Figure 11-11, (1)**) in the rear frame housing, use a puller to remove. Discard the bearing. Remove the bearing cover (**Figure 11-11, (2)**) and two thrust washers (**Figure 11-11, (3)**).

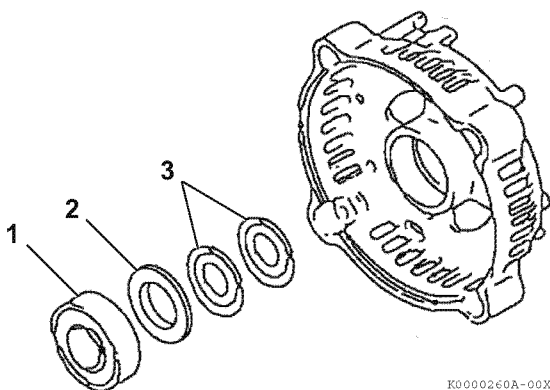


Figure 11-11

Assembling the Alternator

1. If removed, install the two thrust washers (**Figure 11-12, (3)**) and bearing cover (**Figure 11-12, (2)**) in the rear frame housing. Lubricate the outside diameter of a new bearing (**Figure 11-12, (1)**). Press the bearing into the rear frame housing.

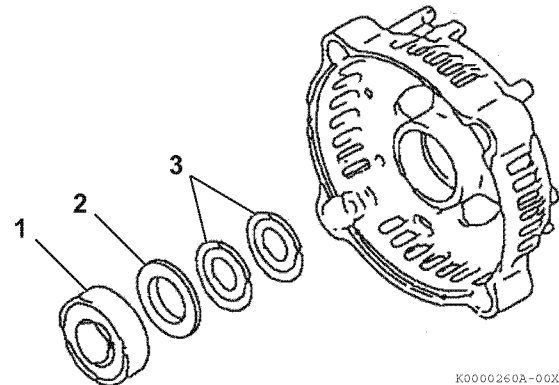


Figure 11-12

2. If removed, lubricate the outside diameter of a new front frame housing bearing. Press the bearing (**Figure 11-13, (2)**) into the front frame housing. Install the plate (**Figure 11-13, (4)**) to the front housing. Tighten the four bolts (**Figure 11-13, (3)**).

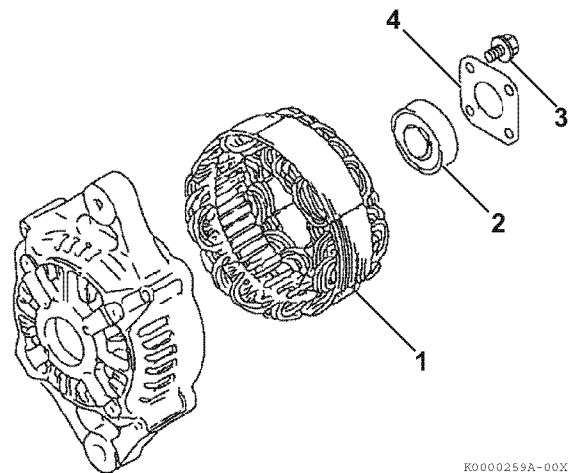


Figure 11-13

3. Position the stator assembly (**Figure 11-13, (1)**) on the front frame housing studs.
4. Lubricate the shaft of the rotor assembly (**Figure 11-14, (1)**). Press the rotor assembly into the front frame housing (**Figure 11-14, (2)**) and rear frame housing (**Figure 11-14, (3)**).

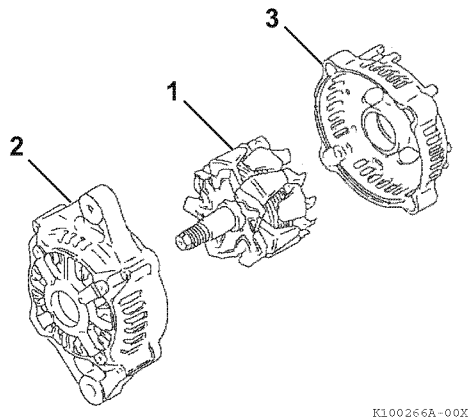


Figure 11-14

5. Align the front frame housing with the rear frame housing. Install the two bolts (**Figure 11-15, (1)**) and two nuts (**Figure 11-15, (2)**).

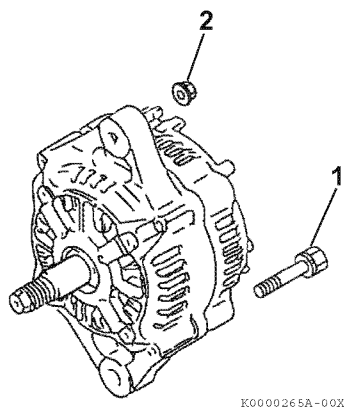


Figure 11-15

6. Install the insulation bushing (**Figure 11-16, (4)**) and nut (**Figure 11-16, (3)**).

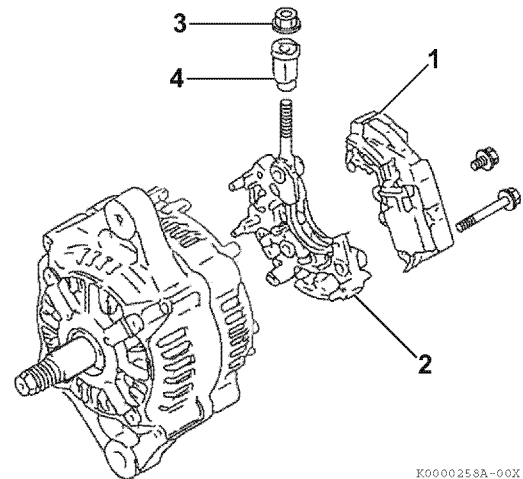


Figure 11-16

7. Assemble the regulator assembly (**Figure 11-16, (1)**) to the holder (**Figure 11-16, (2)**).
8. Install the brush holder (**Figure 11-17, (3)**), springs (**Figure 11-17, (4)**) and brushes (**Figure 11-17, (5)**).
9. Attach the regulator assembly and holder to the rear frame housing.

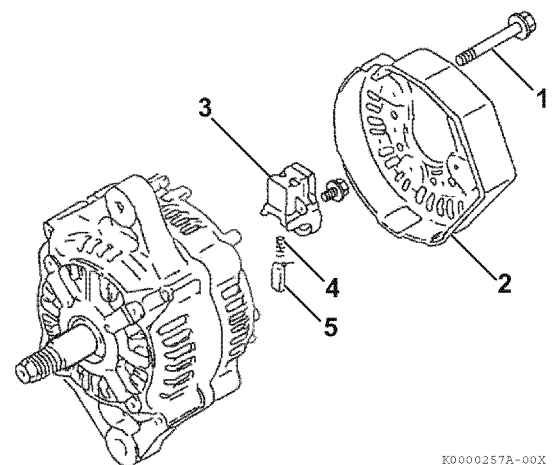


Figure 11-17

10. Install the rear cover (**Figure 11-17, (2)**) to the rear frame housing with three bolts (**Figure 11-17, (1)**).

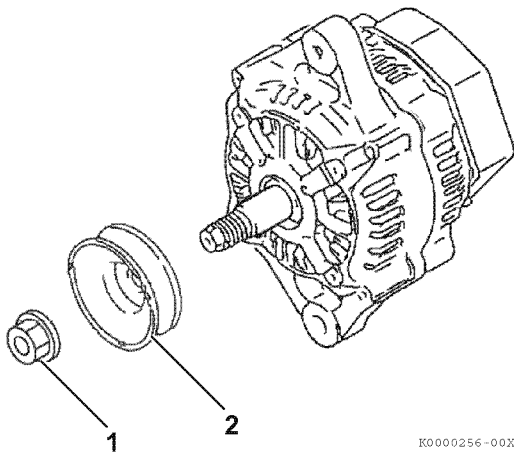


Figure 11-18

11. Assemble the pulley (**Figure 11-18, (2)**) and nut (**Figure 11-18, (1)**) to the shaft of the rotor assembly. Tighten the nut.

Installing the Alternator

1. Position the alternator on the gear case. Loosely install the nut (**Figure 11-19, (2)**) on the gear case stud and the V-belt adjuster bolt (**Figure 11-19, (1)**).

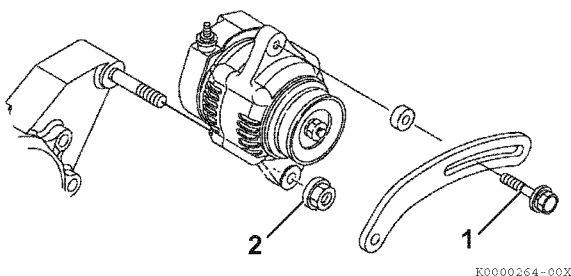


Figure 11-19

2. Connect the electrical wires to the alternator. Tighten the nuts to 15 to 20 in.-lb (1.7 to 2.3 N·m; 17 to 23 kgf·m).

3. Install the V-belt. Tighten the V-belt to the proper tension. See *Checking and Adjusting Cooling Fan V-Belt* on page 5-13.

NOTICE

Using a non-specified V-belt will cause inadequate charging and shorten the belt life. Use the specified belt.

4. Start the engine. Listen for any unusual sounds from the alternator.

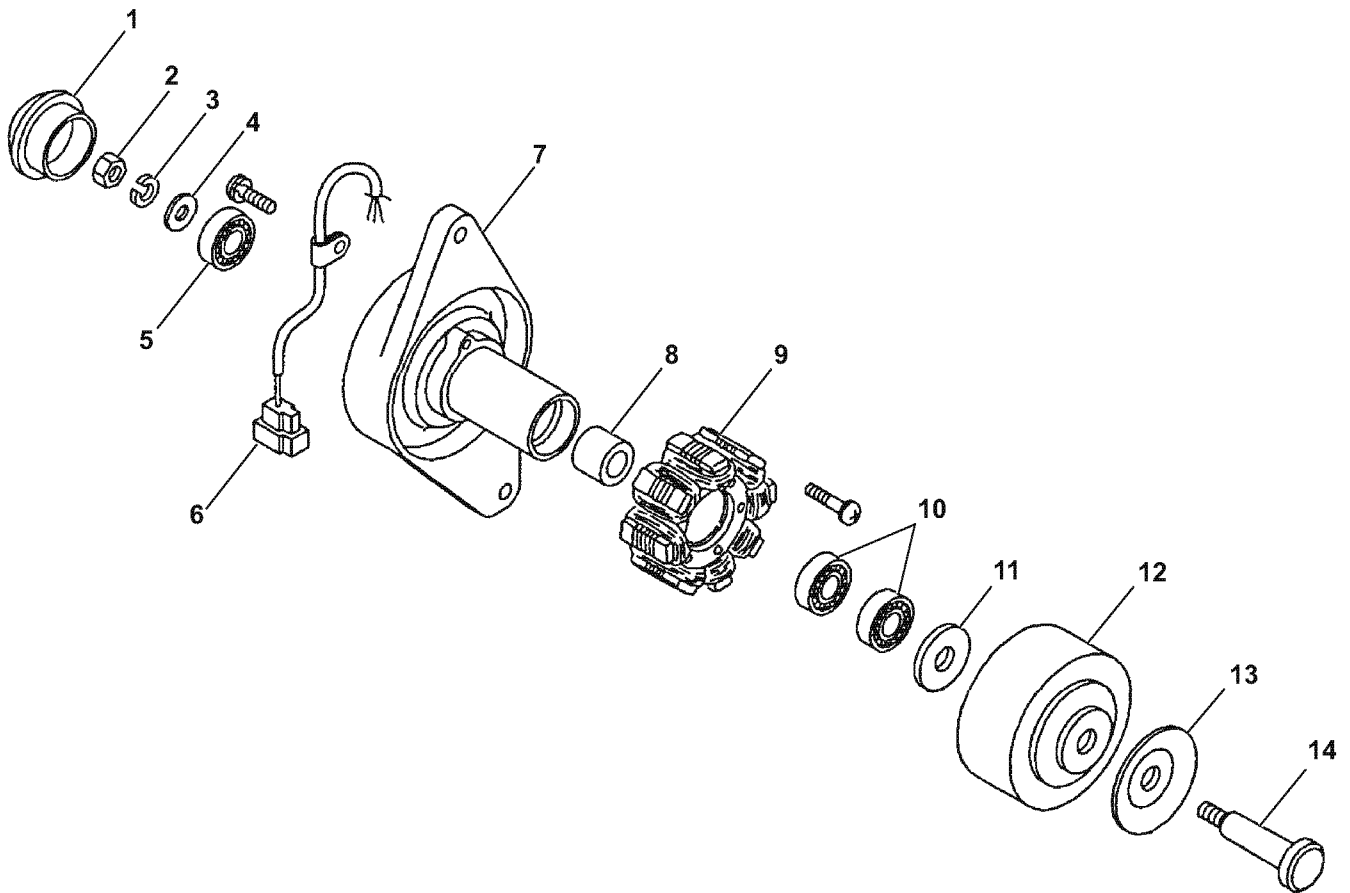
NOTICE

Do not operate the engine if the alternator is producing unusual sounds.

5. Verify that the charge indicator is on while the engine is operating. If the charge indicator is not on, repair the problem before operating the engine.

DYNAMO COMPONENT LOCATION

Yanmar Part No. 119626-77200 dynamo is used in this section to show the service procedures for the representative dynamo. For specific part detail, see the *Parts Catalog* for the engine you are working on.



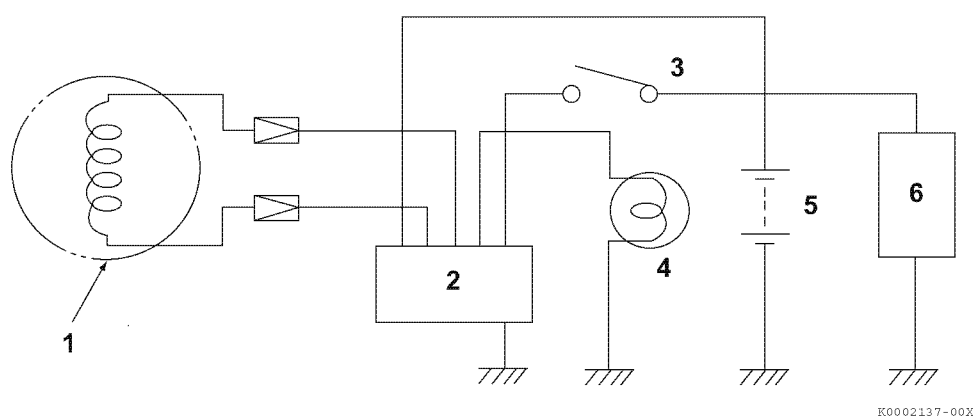
K0002140-00X

- 1 – Rear Cover
- 2 – Nut
- 3 – Lock Washer
- 4 – Flat Washer
- 5 – Rear Bearing
- 6 – Output Wire and Connector
- 7 – Plate

- 8 – Spacer
- 9 – Stator Assembly
- 10 – Front Bearing (2 used)
- 11 – Flat Washer
- 12 – Flywheel Assembly
- 13 – Pulley Half
- 14 – Through-Bolt

Figure 11-20

DYNAMO WIRING DIAGRAM



- 1 – Dynamo
- 2 – Current Limiter Assembly
- 3 – Key Switch

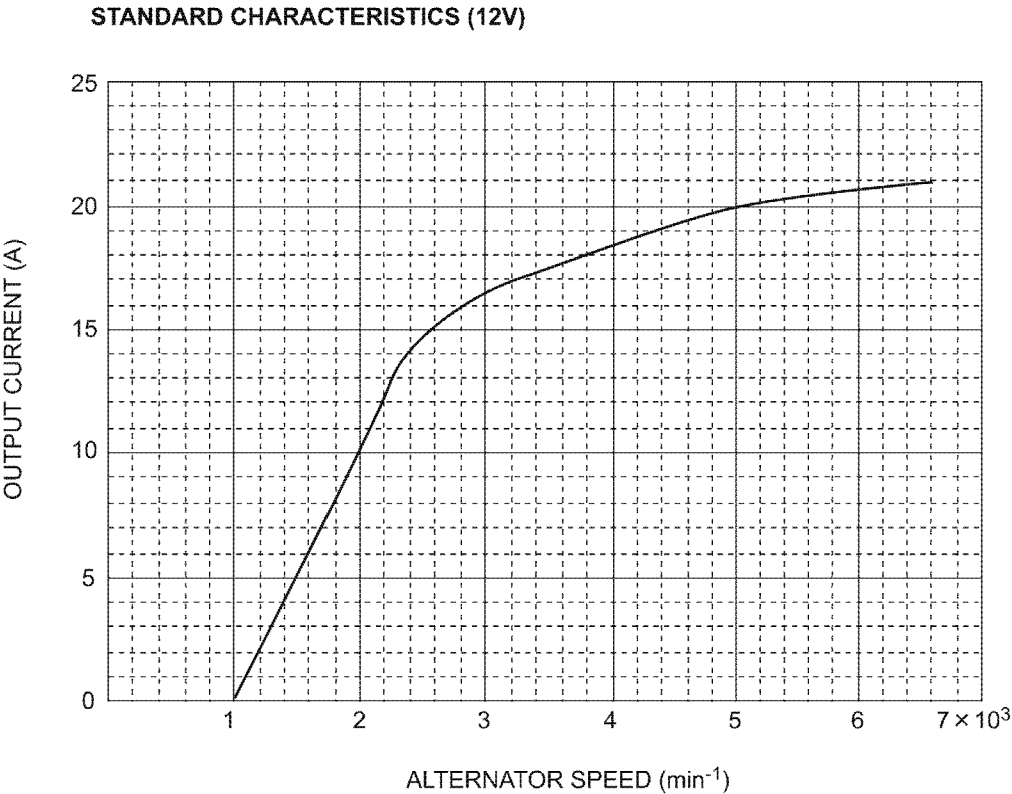
- 4 – Charge Lamp (3.4 watts maximum)
- 5 – Battery
- 6 – Load

Figure 11-21

DYNAMO OPERATION

The dynamo consists of a series of permanent magnets that rotate around a stationary stator coil. The magnets are attached to the flywheel which is rotated via the engine cooling fan drive belt. The resultant output is an AC (alternating current) signal. The AC is converted to DC (direct current) by the current limiter. The current limiter outputs charging DC current to the battery.

DYNAMO STANDARD OUTPUT



K0002138-00X

Figure 11-22

TESTING THE DYNAMO

Use a circuit tester or multimeter to perform the following tests.

Testing Stator Coil Continuity

1. Disconnect the dynamo output wire connector.
2. Connect one meter lead to each of the stator wire terminals and read the meter.

Results: The meter reading should indicate continuity. If continuity is not indicated, the windings are open and the stator must be replaced.

Testing Stator Coil Short-to-Ground

1. Disconnect the dynamo output wire connector.
2. Test continuity between each stator wire terminal and engine ground.

Results: The meter reading should indicate infinity. If the meter reading indicates continuity, the windings are shorted to ground and the stator must be replaced.

Testing Dynamo Regulated Output

1. Test and record the battery voltage with the engine off.
2. Start the engine and operate it at normal operating rpm.
3. Check the battery voltage with the engine running.

Results: The meter reading with the engine running must be higher than with the engine not running.

- If results are not correct, test the stator for continuity and shorts to the ground.
- Check the charging system wiring.
- If no problems are found in previous checks, replace the IC regulator.

DYNAMO

Removing the Dynamo

1. Disconnect the output wire connector from the dynamo.
2. Loosen the V-belt.

CAUTION

Pinch Hazard

Carefully rotate the alternator toward the cylinder block while loosening the V-belt.

3. Remove the V-belt adjuster from the dynamo bolt (Figure 11-23, (1)).
4. Remove the nut (Figure 11-23, (2)) from the gear case stud. Remove the dynamo.

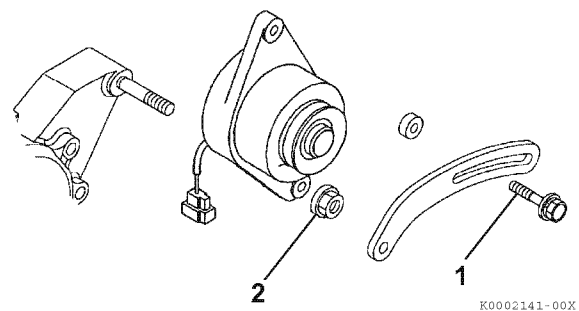


Figure 11-23

Disassembling the Dynamo

1. Remove the rear cover (Figure 11-24, (1)).
2. Remove the nut (Figure 11-24, (2)), lock washer (Figure 11-24, (3)) and flat washer (Figure 11-24, (4)).

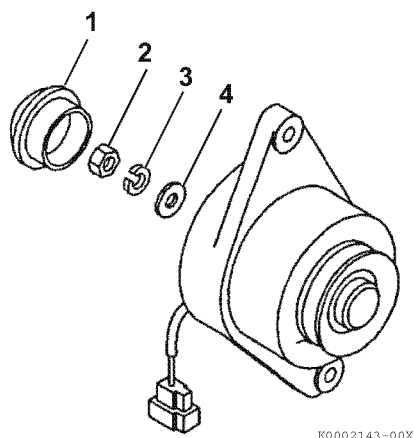


Figure 11-24

3. Remove the through-bolt (Figure 11-25, (1)), pulley half (Figure 11-25, (2)), flywheel (Figure 11-25, (3)), flat washer (Figure 11-25, (4)), bearings (Figure 11-25, (5)) and spacer (Figure 11-25, (6)).

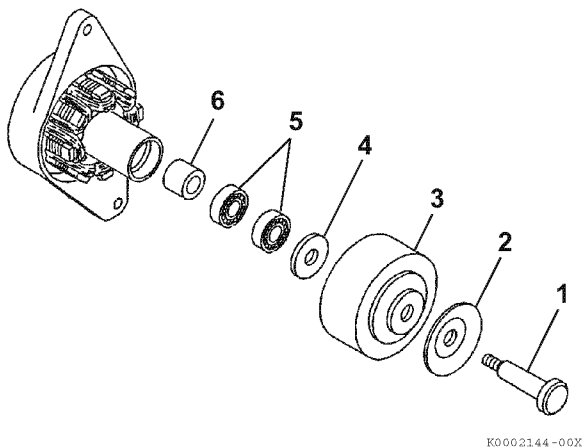


Figure 11-25

4. Remove the screws (Figure 11-26, (1)) and the stator assembly (Figure 11-26, (2)).
5. Remove the rear bearing (Figure 11-26, (3)).

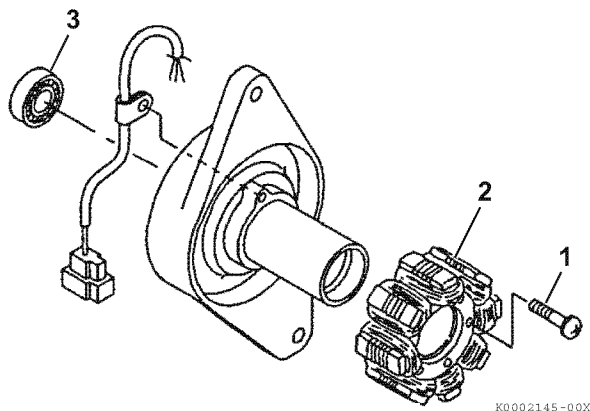


Figure 11-26

Assembling the Dynamo

1. Install the rear bearing (Figure 11-26, (3)).
2. Install the stator (Figure 11-26, (2)).
3. Install screws (Figure 11-26, (1)).
4. Install the front bearings (Figure 11-27, (5)) and spacer (Figure 11-27, (6)).
5. Install the flat washer (Figure 11-27, (4)), flywheel (Figure 11-27, (3)), pulley half (Figure 11-27, (2)) and through-bolt (Figure 11-27, (1)).

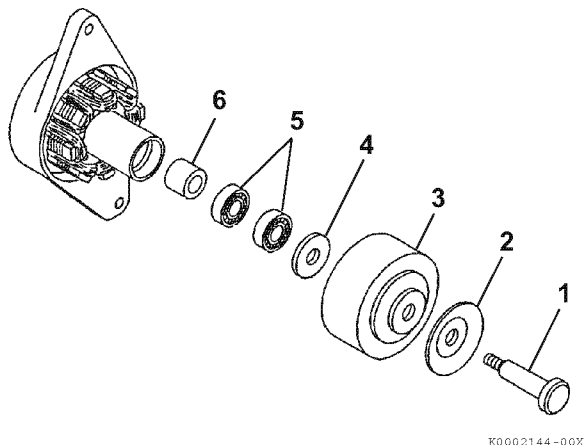


Figure 11-27

6. Install the flat washer (**Figure 11-28, (4)**), lock washer (**Figure 11-28, (3)**) and nut (**Figure 11-28, (2)**). Tighten the nut to the specified torque.
7. Install the rear cap (**Figure 11-28, (1)**).

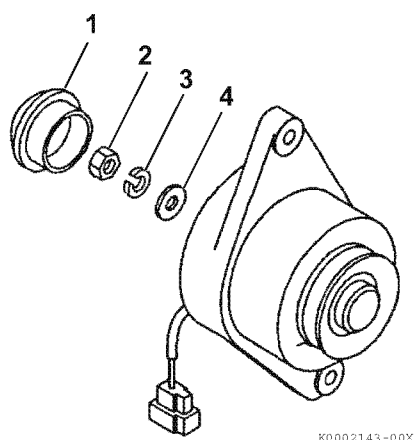


Figure 11-28

Installing the Dynamo

1. Position the dynamo on the gear case. Loosely install the nut (**Figure 11-29, (2)**) on the gear case stud and the V-belt adjuster bolt (**Figure 11-29, (1)**).

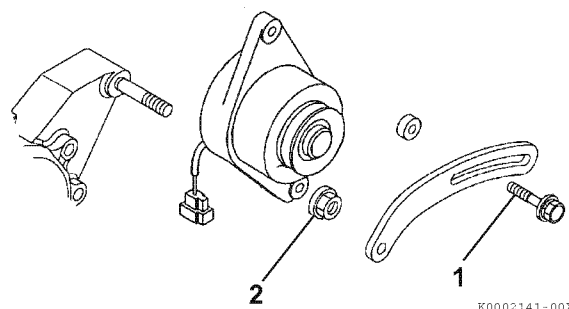


Figure 11-29

2. Connect the dynamo output wire connector.
3. Install the V-belt. Tighten the V-belt to the proper tension. *See Checking and Adjusting Cooling Fan V-Belt on page 5-13.*
4. Start the engine. Listen for any unusual sounds from the alternator.

NOTICE

Do not operate the engine if the alternator is producing unusual sounds.

5. Verify that the charge indicator is on while the engine is operating. If the charge indicator is not on, repair the problem before operating the engine.

Section 12

ELECTRIC WIRING

	Page
Safety Precautions.....	12-3
Electric Wire Resistance	12-4
Battery Cable Resistance.....	12-5
Electrical Wire Sizes - Voltage Drop.....	12-6
Conversion of AWG to European Standards.....	12-7

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SAFETY PRECAUTIONS

Before performing any electrical component service procedures, review the following messages and the *Safety section on page 3-1*.

Failure to follow these precautions may result in the failure of an electrical component and the loss of warranty coverage on that item as well as related items. Make sure that all users read and understand these precautions.

WARNING

Electrical Shock Hazard

- 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.

NOTICE

Do not reverse the positive (+) and negative (-) ends of the battery cable. The alternator diode and stator coil will be damaged.

NOTICE

When the battery indicator goes out, it should not come on again. The battery indicator only comes on during operation if the alternator fails. However, if an LED is used in the battery indicator, the LED will shine faintly during normal operation.

NOTICE

Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated in the Battery Cable Resistance chart in the Electric Wiring section of this manual. The starter motor will malfunction and fail if the resistance is higher than the specified value.

NOTICE

Removing the battery cables or the battery while the engine is operating may cause damage to the current limiter depending on the electrical equipment being used. This situation could cause loss of control of output voltage. The continuous high voltage of 23 to 24 volts (for 5000 rpm [min⁻¹] dynamo) will damage the current limiter and other electrical equipment.

NOTICE

Reversing the battery cable connections at the battery or on the engine will destroy the SCR diode in the current limiter. This will cause the charging system to malfunction and may cause damage to the electrical harnesses.

NOTICE

Protect the air cleaner and electric components from damage when you use steam or high-pressure water to clean the engine.

ELECTRIC WIRE RESISTANCE

AWG	Metric Nominal mm ²	Ohms/Foot
20	0.5	0.009967
18	0.8	0.006340
16	1.25	0.004359
14	2	0.002685
12	3	0.001704
10	5	0.001073
8	8	0.000707
6	15	0.000421
4	20	0.000270
2	30	0.000158
1	40	0.000130
0 (1/0)	50	0.000103
00 (2/0)	60	0.000087
000 (3/0)	85	0.000066
0000 (4/0)	100	0.000051

Wiring voltage drop should not exceed 5% $[0.05] \times 12 \text{ Volts} = 0.6 \text{ Volts}$.

Voltage Drop = Current [Amps] x Length of Wire [Feet] x Resistance per Foot [Ohms]

Example:

Current draw of 100 Amps x 3 feet of 4 AWG wire

$100 \text{ Amps} \times 3 \text{ Feet} \times 0.000270 = 0.08 \text{ Volts [Voltage Drop]}$

BATTERY CABLE RESISTANCE

AWG	mm ²	Maximum Total Battery Cable Length (Positive Cable + Negative Cable + a*) 12V Starter Motor Output			
		Less Than 2.68 hp (2 kW)		Greater Than 2.68 hp (2 kW)	
		ft	m	ft	m
6	15	4.75	1.5	N/A	N/A
4	20	7.4	2.3	N/A	N/A
2	30	12.6	3.8	7.5	2.3
1	40	15.3	4.6	9.2	2.8
0 (1/0)	50	19.5	5.9	11.6	3.5
00 (2/0)	60	22.8	7.0	13.7	4.2
000(3/0)	85	30.5	9.3	18.3	5.6
0000 (4/0)	100	39.0	11.9	23.4	7.1
00000 (5/0)	125	N/A	N/A	27.3	8.3
000000 (6/0)	150	N/A	N/A	33.3	10.1

Note: Total allowable resistance of the complete battery cable circuit (positive cable + negative cable + a*)
(a*: Resistance (Ω) of a battery switch or other electrical equipment having high resistance)

Note: For starter motors of less than 2.68 HP (2 kW): the total resistance must be less than 0.002 Ω. For
starter motors of greater than 2.68 HP (2 kW): the total resistance must be less than 0.0012 Ω.

ELECTRICAL WIRE SIZES - VOLTAGE DROP

Total current on circuit in amps	Length of conductor from source of current to device and back to source (in feet)																			
	10	15	20	25	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	
12 Volts	Wire Size (AWG)																			
5	18	16	14	12	12	10	10	10	8	8	8	6	6	6	6	6	6	6	6	
10	14	12	10	10	10	8	6	6	6	6	4	4	4	4	2	2	2	2	2	
15	12	10	10	8	8	6	6	6	4	4	2	2	2	2	2	1	1	1	1	
20	10	10	8	6	6	6	4	4	2	2	2	2	1	1	1	0	0	0	2/0	
25	10	8	6	6	6	4	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0	
30	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	3/0	3/0	3/0	3/0	
40	8	6	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	3/0	4/0	4/0	4/0	4/0	
50	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0					
60	6	4	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0	4/0							
70	6	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0									
80	6	4	2	2	1	0	3/0	3/0	4/0	4/0										
90	4	2	2	1	0	2/0	3/0	4/0	4/0											
100	4	2	2	1	0	2/0	3/0	4/0												
24 Volts																				
5	18	18	18	16	16	14	12	12	12	10	10	10	10	10	8	8	8	8	8	
10	18	16	14	12	12	10	10	10	8	8	8	6	6	6	6	6	6	6	6	
15	16	14	12	12	10	10	8	8	6	6	6	6	6	4	4	4	4	4	2	
20	14	12	10	10	10	8	6	6	6	6	4	4	4	4	2	2	2	2	2	
25	12	12	10	10	8	6	6	6	4	4	4	4	2	2	2	2	2	2	1	
30	12	10	10	8	8	6	6	4	4	4	2	2	2	2	2	1	1	1	1	
40	10	10	8	6	6	6	4	4	2	2	2	2	1	1	1	0	0	0	2/0	
50	10	8	6	6	6	4	4	2	2	2	1	1	0	0	0	2/0	2/0	2/0	3/0	
60	10	8	6	6	4	4	2	2	1	1	0	0	0	2/0	2/0	3/0	3/0	3/0	3/0	
70	8	6	6	4	4	2	2	1	1	0	0	2/0	2/0	3/0	3/0	3/0	3/0	4/0	4/0	
80	8	6	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	3/0	4/0	4/0	4/0	4/0	
90	8	6	4	4	2	2	1	0	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0	4/0	4/0		
100	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0	4/0	4/0	4/0					

CONVERSION OF AWG TO EUROPEAN STANDARDS

Conductor Size (AWG)	Conductor Diameter (mm)	Conductor Cross-sectional Area (mm ²)
25	0.455	0.163
24	0.511	0.205
23	0.573	0.259
22	0.644	0.325
21	0.723	0.412
20	0.812	0.519
19	0.992	0.653
18	1.024	0.823
17	1.15	1.04
16	1.29	1.31
15	1.45	1.65
14	1.63	2.08
13	1.83	2.63
12	2.05	3.31
11	2.30	4.15
10	2.59	5.27
9	2.91	6.62
8	3.26	8.35
7	3.67	10.6
6	4.11	13.3
5	4.62	16.8
4	5.19	21.2
3	5.83	26.7
2	6.54	33.6
1	7.35	42.4
0 (1/0)	8.25	53.4
00 (2/0)	9.27	67.5
000(3/0)	10.40	85.0
0000 (4/0)	11.68	107.2
00000 (5/0)	13.12	135.1
000000 (6/0)	14.73	170.3
1.1 circular mil (CM) \cong 0.0005067 mm ²		

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Section 13

TROUBLESHOOTING

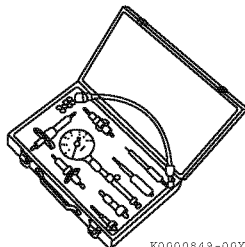
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Standard Compression Pressure	13-5
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SAFETY PRECAUTIONS

Before performing any troubleshooting procedures, review the *Safety section on page 3-1*.

SPECIAL SERVICE TOOLS

Compression Gauge Kit	For measuring compression pressure Yanmar Part No. TOL-97190080	 K0000849-00X
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TROUBLESHOOTING BY MEASURING COMPRESSION PRESSURE

Compression pressure drop is one of major causes of increasing blow-by gas (engine oil contamination or increased engine oil consumption as a resultant phenomenon) or starting failure. The compression pressure is affected by the following factors:

- Degree of clearance between piston and cylinder
- Degree of clearance at intake/exhaust valve seat
- Gas leak from nozzle gasket or cylinder head gasket

The pressure will drop due to increased parts wear. Pressure drop reduces the durability of the engine.

A pressure drop may also be caused by scratched cylinder or piston by dust entrance from the dirty air cleaner element or worn or broken piston ring. Measure the compression pressure to determine the condition of the engine.

Compression Pressure Measurement Method

1. Warm up the engine.
2. Stop the engine. Remove the high-pressure fuel injection lines as an assembly from the engine. *See Removing the High-Pressure Fuel Injection Lines on page 7-10.* Remove the fuel injector from the cylinder to be measured. *See Removing the Fuel Injectors on page 7-22.*

NOTICE

Remove and install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to install the fuel lines.

3. Turn off the fuel supply valve in the fuel supply line. Disconnect the fuel injection stop solenoid at the connector. Crank the engine for a few seconds with the stop solenoid disconnected (no injection state) before installing the compression gauge adapter (**Figure 13-1, (1)**), **this will expel any residual fuel from the cylinder.**
4. Install one injector gasket at the tip end of the compression gauge adapter. Install the compression gauge and the compression gauge adapter at the cylinder to be measured.
5. Crank the engine until the compression gauge reading is stabilized.

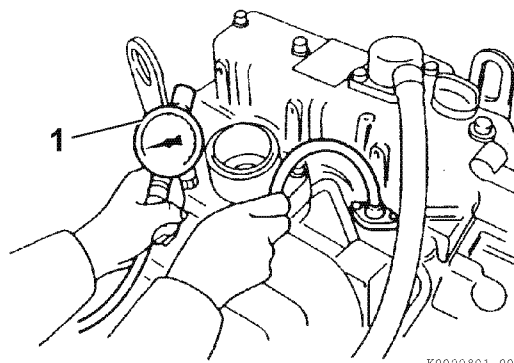


Figure 13-1

6. After performing the compression check, remove the compression gauge and compression gauge adapter from the cylinder. Install the fuel injector, high-pressure fuel injection lines and connect the stop solenoid. *See Installing the Fuel Injectors on page 7-26 and Installing the High-Pressure Fuel Injection Lines on page 7-11.*
7. Turn on the fuel supply valve and connect the injection pump stop solenoid.
8. Prime the fuel system. Check for leaks. Test the engine.

Standard Compression Pressure

Engine compression pressure list (reference value):

Engine Model	Compression Pressure at 250 rpm (min ⁻¹)		Deviation Between Cylinders
	Standard	Limit	
3TNM68 3TNM72	470 ± 15 psi (3.24 ± 0.1 MPa; 33 ± 1 kgf/cm ²)	370 ± 15 psi (2.55 ± 0.1 MPa; 26 ± 1 kgf/cm ²)	29 to 43 psi (0.2 to 0.3 MPa; 2 to 3 kgf/cm ²)

Measured Value and Troubleshooting

When the measured compression pressure is below the limit value, inspect each part by referring to the table below.

No.	Item	Cause	Corrective Action
1	Air Cleaner Element	Clogged element	Clean the element.
		Broken element	Replace the element.
		Defect at element seal portion	
2	Valve Clearance	Excessive or no clearance	Adjust the valve clearance.
3	Valve Timing	Incorrect valve clearance	Adjust the valve clearance.
4	Cylinder Head Gasket	Gas leak from gasket	Replace the gasket.
			Tighten the cylinder head bolts to the specified torque.
5	Intake/Exhaust Valve	Sticking valve	Replace the intake/exhaust valve.
	Valve Seat	Gas leak due to worn valve seat or foreign matter trapped in valve	Lap the valve seat.
6	Piston	Gas leak due to scratching or wear	Perform honing and use an oversized part.
	Piston Ring		
	Cylinder		

QUICK REFERENCE TABLE FOR TROUBLESHOOTING

The following table summarizes the general trouble symptoms and their causes. If any trouble symptom occurs, take corrective action before it becomes a serious problem so as not to shorten the engine service life.

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Trouble Symptom Cause		Starting Problem			Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion		Uneven Combustion Sound	Engine Surging			Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil				Excessive Blow-by Gas	Engine Coolant		Air Intake			Corrective Action	Reference Page			
		Engine Does Not Start	Engine Starts But Stops Soon			Exhaust Color			During Work				During Idling	During Work Operation				Excessive Engine Vibration	Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Coolant		Low Oil Pressure	Overheat	Low Coolant Temperature	Pressure Drop				Pressure Rise	Exhaust Temperature Rise	
			None	Little	Much	Ordinary	White	Black	White																							Black
Engine System	Improper Intake/Exhaust Valve Clearance	O	O			O					O													O		O	Adjust the Valve Clearance.	See Measuring and Adjusting Valve Clearance on page 6-30				
	Compression Leakage from Valve Seat					O		O		O							O				O		O		O	Lap the Valve Seat.	See Valve Face and Valve Seat on page 6-24					
	Intake/Exhaust Valve Seizure	O			O	O		O		O			O	O				O			O					O	Correct or Replace Intake / Exhaust Valve.	See Inspecting the Intake and Exhaust Valves on page 6-23				
	Cylinder Head Gasket Blowout					O												O			O						Replace the Gasket.	See Disassembling the Cylinder Head on page 6-17				
	Seized or Broken Piston Ring	O			O		O		O			O		O				O	O			O	O			O	Replace the Piston Ring.	See Assembling the Cylinder Head on page 6-27				
	Worn Piston Ring, Piston or Cylinder	O			O		O		O									O	O			O					Perform Honing and Use Oversize Parts.	See Honing and Boring on page 6-48				
	Seized Crankpin Metal or Bearing	O	O									O		O	O	O						O						Repair or Replace.	See Inspecting the Crankshaft and Camshaft Components on page 6-42			
	Improper Arrangement of Piston Ring Gaps		O				O											O				O						Correct the Ring Joint Positions.	See Assembling the Pistons on page 6-50			

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Cause		Trouble Symptom		Starting Problem			Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Oil				Excessive Blow-by Gas	Engine Coolant		Air Intake		Exhaust Temperature Rise	Corrective Action	Reference Page				
				Engine Does Not Start	Engine Starts But Stops Soon			Exhaust Color			During Work				During Idling	During Work Operation				Excessive Engine Vibration	Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Excessive Oil Consumption		Dilution by Diesel Fuel	Oil with Coolant	Low Oil Pressure	Overheat				Low Coolant Temperature	Pressure Drop	Pressure Rise	
					None	Little	Much	Ordinary	White	Black	White																								Black
Engine System - Continued	Reverse Assembling the Piston Rings							O		O									O								Assemble Correctly.	See Assembling the Pistons on page 6-50							
	Worn Crankpin and Journal Bearing							O				O		O	O					O							Measure and Replace.	See Inspecting the Crankshaft and Camshaft Components on page 6-42							
	Loose Connecting Rod Bolt											O				O										Tighten to the Specified Torque.	See Special Torque Chart on page 6-11								
	Foreign Matter Trapped in Combustion Chamber		O									O						O									Disassemble and Repair.	See Disassembling the Cylinder Block Components on page 6-33							
	Excessive Gear Backlash											O															Adjust Gear Meshing.	See Checking Timing Gear Backlash on page 6-34							
	Worn Intake/Exhaust Valve Guide								O									O									Measure and Replace.	See Inspecting the Valve Guides on page 6-22							
	Governor Adjusted Incorrectly			O										O	O	O	O										Make Adjustment.	See Checking and Adjusting the Governor Lever and Engine Speed Control on page 5-13							
	Improper Open/Close Timing of Intake/Exhaust Valves		O						O	O	O	O		O													Adjust the Valve Clearance.	See Measuring and Adjusting Valve Clearance on page 6-30							

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Trouble Symptom <	
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Trouble Symptom Cause		Starting Problem				Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion		Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil				Excessive Blow-by Gas	Engine Coolant		Air Intake			Corrective Action	Reference Pages		
		Engine Does Not Start	Engine Starts but Stops Soon			Exhaust Color			During Work						During Idling	During Work Operation			Excessive Engine Vibration	Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Coolant		Low Oil Pressure	Overheat	Low Coolant Temperature	Pressure Drop				Pressure Rise	Exhaust Temperature Rise
			None	Little	Much	Ordinary	White	Black	White	Black																						
Fuel System	Air in Fuel System	○	○			○																					Bleed the Air.	See Priming the Fuel System on page 4-14				
	Clogged or Cracked Fuel Line	○	○			○																					Clean or Replace.	See Checking and Replacing Fuel Hoses and Engine Coolant Hoses on page 5-22				
	Insufficient Fuel Supply to Fuel Injection Pump	○	○			○																				Check the Fuel Tank Cock, Fuel Filter, Fuel Line and Fuel Feed Pump.	See the appropriate procedure in Periodic Maintenance on page 5-1					
	Uneven Injection Volume from Fuel Injection Pump						○	○	○	○			○	○	○	○									○	Check and Adjust.	See Testing the Fuel Injectors on page 7-23					
	Excessive Fuel Injection Volume									○								○	○					○	○	Check and Adjust.	See Testing the Fuel Injectors on page 7-23					
	Poor Spray Pattern from Fuel Injection Nozzle						○	○	○	○			○	○	○	○		○								Check and Adjust.	See Testing the Fuel Injectors on page 7-23					
	Priming Failure	○																								Foreign Matter Trapped in the Valve Inside the Priming Pump (Disassemble and Clean).	See Fuel System Components on page 7-9					
	Clogged Strainer at Feed Pump Inlet					○																				Clean the Strainer.	See Draining Fuel Tank on page 5-11					

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Trouble Symptom		Cause		Starting Problem		Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		Excessive Engine Vibration	Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil				Excessive Blow-by Gas	Engine Coolant		Air Intake		Exhaust Temperature Rise	Corrective Action	Reference Pages		
						Engine Does Not Start			Exhaust Color					During Work					Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Coolant	Low Oil Pressure		Overheat	Low Coolant Temperature		Pressure Drop				Pressure Rise	
None	Little	Much	Ordinary	White	Black	White	Black	High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	During Idling	During Work Operation	Excessive Engine Vibration	Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Coolant	Low Oil Pressure	Excessive Blow-by Gas	Overheat	Low Coolant Temperature	Pressure Drop	Pressure Rise	Exhaust Temperature Rise	Corrective Action	Reference Pages					

Air/Exhaust Gas System	Clogged Air Filter				O			O	O			O												O			Clean Air Filter.	See Cleaning Air Cleaner Element on page 5-14
	Engine Used at High Temperatures or at High Altitude						O		O						O							O		O			Study Output Drop and Load Matching.	-
	Clogged Exhaust Pipe							O		O			O													O	Clean Exhaust Pipe.	-
Electrical System	Starting Motor Defect	O																									Repair or Replace Stater Motor.	See Starter Motor on page 10-8
	Alternator Defect	O																									Repair or Replace Alternator.	See Removing the Alternator on page 11-10 or Removing the Dynamo on page 11-18
	Open-Circuit in Wiring	O																									Repair Open Circuit.	-
	Battery Voltage Drop	O																									Inspect and Charge the Battery.	See Checking Battery on page 5-10

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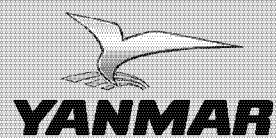
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