This Page Intentionally Left Blank

CHAPTER 11
YANMAR ENGINE SERVICE

IMPORTANT:

The following is a YANMAR-supplied service manual, modified by Polaris, to depict the correct service and repair of the 3TMN72-APL.

This manual contains generic repair and maintenance procedures. Follow all directions and warnings. Do not attempt service of engine components without proper diesel engine instruction and training. Component failure from improper repairs may lead to engine failure.

Polaris gratefully acknowledges copyright permissions granted by Yanmar.

INTENTIONAL BLANK PAGE

YANMAR®

TNM series

SERVICE MANUAL

3TNM72

INDUSTRIAL ENGINES

This Service Manual has been developed for the exclusive use of service and repair

This *Service Manual* has been developed for the exclusive use of service and repair professionals such as authorized Distributors and 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 repair or service professional before before working on your engine.

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.

0709

TABLE OF CONTENTS

This Page Intentionally Left Blank

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, California ARB and / or the 97/68/EC Directive for industrial use.

Please use this manual for accurate, quick and safe servicing of the 3TNM72-APL 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.

This Page Intentionally Left Blank

Section 2

WARRANTY

Page

EMISSION SYSTEM WARRANTY

SEE VEHICLE OWNERS MANUAL FOR COMPLETE EMISSIONS AND ENGINE WARRANTY

Section 3

SAFETY

Page

This Page Intentionally Left Blank

SAFETY STATEMENTS

Polaris 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.

A 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

⚠ DANGER

The safety messages that follow have DANGER level hazards.

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.

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.

⚠ WARNING

The safety messages that follow have WARNING level hazards.

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.
Refer to Chapter 3 for fuel safety information.

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.

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.

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.

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. Seek immediate medical attention for burns.

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 any warning signals.

ALWAYS wear safety glasses while servicing the engine to prevent possible eye injury.

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.

⚠ CAUTION

The safety messages that follow have CAUTION level hazards.

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

The safety messages that follow have NOTICE level hazards.

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

If a continuously running engine is operated at greater than 20° in any direction or if an engine runs for short periods of time (less than 3 minutes) at an angle greater than 20° in any direction, the engine oil may enter the combustion chamber causing excessive speed and 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 the presence of chemical gases or fumes.
- Avoid operating in a corrosive atmosphere such as salt water spray.
- NEVER operate 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 +104°F (+40°C).
- If the ambient temperature exceeds +104°F (+40°C), the engine may overheat and cause the engine oil to break down.
- If ambient temperature is between -25°F (-31°C), and +5°F (-15°C) the engine will be hard to start and the engine oil may not flow easily. Polaris recommends the use of a cold start kit.
- Contact your authorized dealer or distributor if the engine will be operated outside the standard temperature range.

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.

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.

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

For maximum engine life, Yanmar recommends that before 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 exhaust system, to cool slightly before the engine is shut down.
The engine itself may be shut down at that time.

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

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 the Warranty in the owner's manual*.

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

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 dealer or distributor.
Tampering with limit screws may void warranty.

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.

This Page Intentionally Left Blank

Section 4

GENERAL SERVICE INFORMATION

Page

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. Image is a typical engine representation.

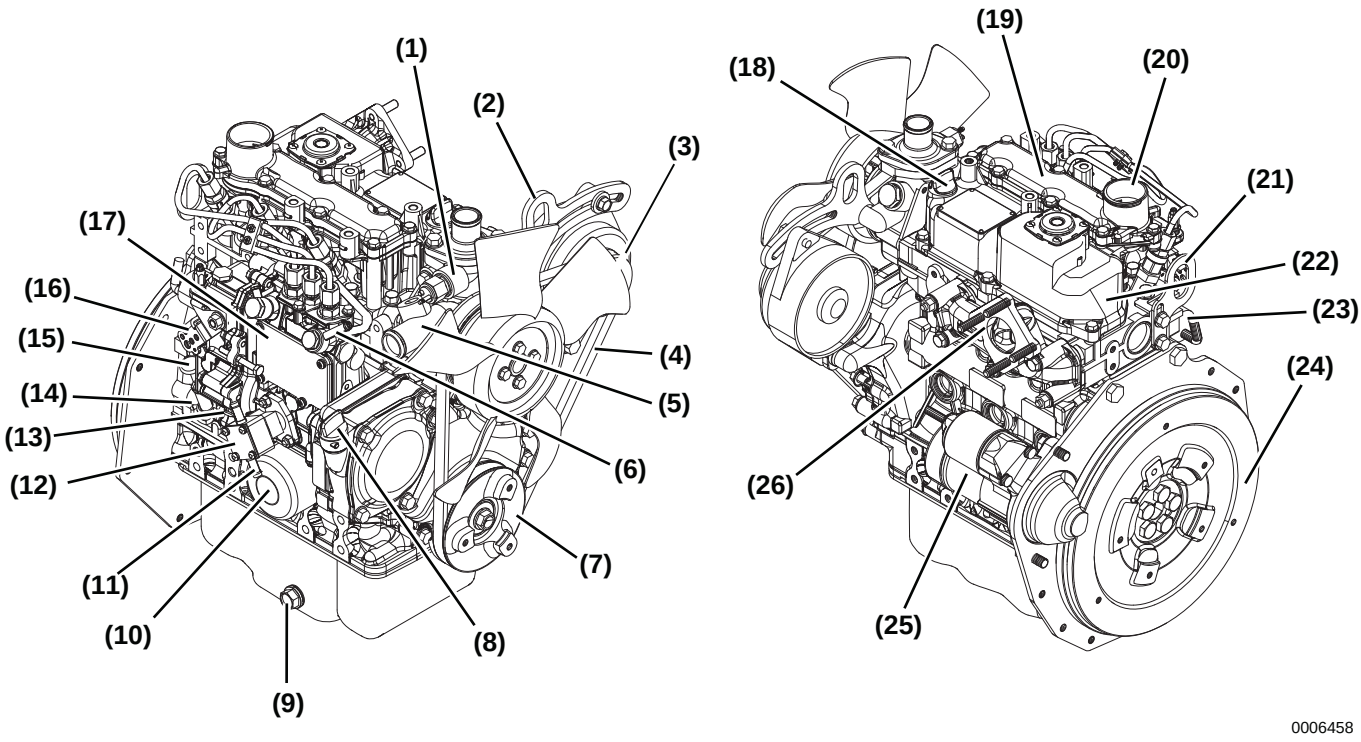


Figure 4-1

1 – Coolant Temperature Sensor
2 – Lifting Eye (engine cooling end)
3 – Alternator
4 – V-Belt
5 – Engine Coolant Pump
6 – Fuel Return to Fuel Tank
7 – Crankshaft V-Pulley
8 – Side Filler Port (engine oil)
9 – Drain Plug (engine oil)*
10 – Engine Oil Filter
11 – N/A
12 – N/A
13 – Fuel Inlet
14 – Oil Pressure Switch
15 – Dipstick (engine oil)
16 – Governor Lever
17 – Fuel Injection Pump
18 – Top Filler Port (engine oil)
19 – Intake Manifold
20 – Air Intake Port (from air cleaner)
21 – Lifting Eye (flywheel end)
22 – Rocker Arm Cover
23 – Stop Solenoid
24 – Flywheel
25 – Starter Motor
26 – Exhaust Manifold

* Illustration is for general reference only. 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.

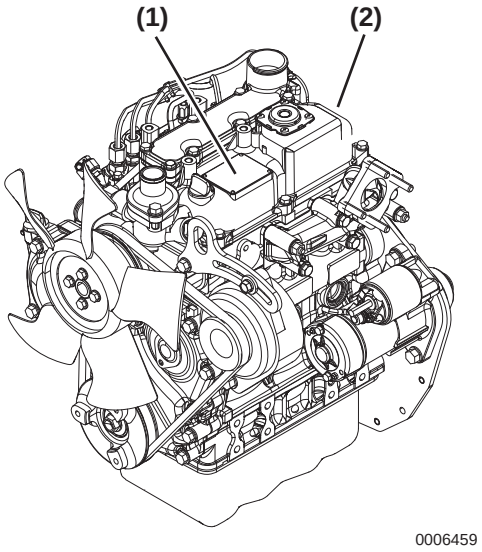
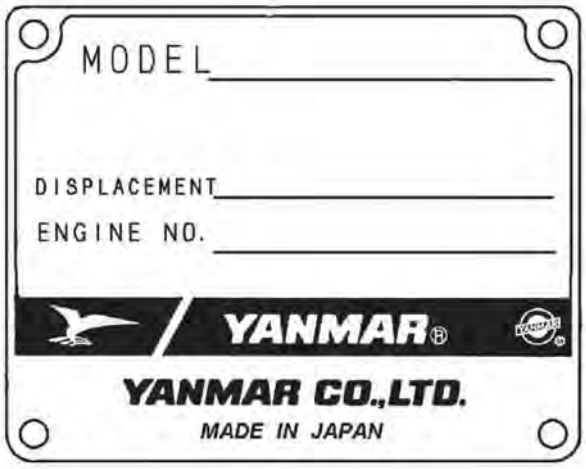


Figure 4-2

Engine Nameplate (Typical)



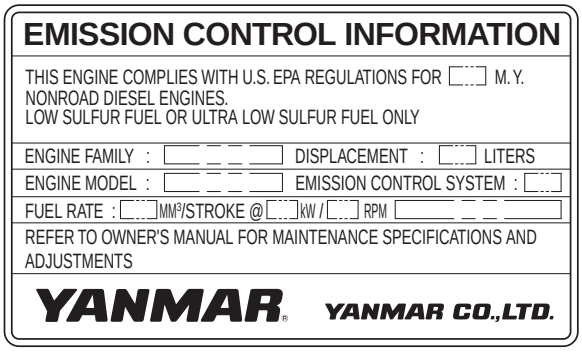
EPA / CARB EMISSION CONTROL REGULATIONS - USA ONLY

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.

EMISSION CONTROL LABELS

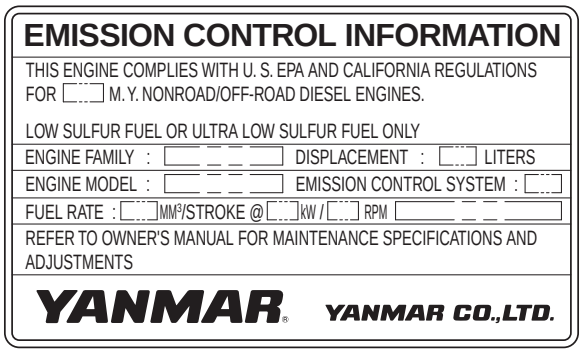
Since emission control regulations are being issued on a global basis, it is necessary to identify with which regulations a particular engine complies. We have listed several different types of labels you might find on your engine.

EPA / ARB Labels (Typical)



021751-00X

(EPA)



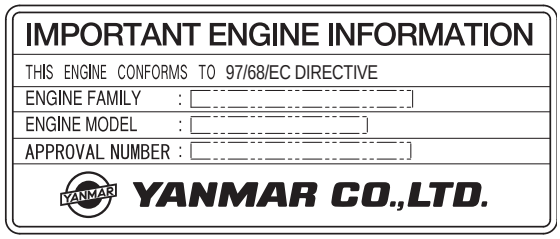
021752-00X

(EPA & ARB)

THE 97/68/EC DIRECTIVE CERTIFIED ENGINES

The engines described in this manual have been certified by the 97/68/EC Directive.

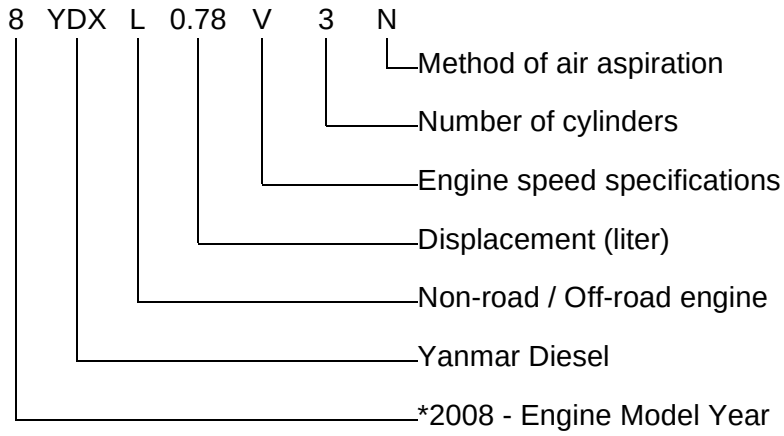
To identify the engines that meet this certification, the 97/68/EC emission control label is affixed on the engines.



(97/68/EC)

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:



* 8: 2008

9: 2009

10: 2010, etc.

FUNCTION OF MAJOR ENGINE COMPONENTS

Component	Function
Air Cleaner	The air cleaner prevents airborne contaminants from entering the engine. Periodic replacement of the air cleaner filter element is necessary. See the *Periodic Maintenance Schedule on page 5-4* for the replacement frequency.
Alternator	The alternator is driven by a V-belt which is powered by the crankshaft V-pulley. The alternator 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 12 VDC. 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 thePeriodic Maintenance Schedule on page 5-4* for the replacement frequency.
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 pump and the engine. Periodically drain the water from the fuel filter / water separator using the drain cock at the bottom of the separator.
Fuel Priming	The fuel system needs to be primed before you start the engine for the first time, if your run out of fuel, or if fuel system service is performed. To prime the system, operate the fuel pump for 10-15 seconds until the fuel filter is full.

Component	Function
Fuel Tank	The fuel tank is a reservoir that holds diesel fuel. When fuel leaves the tank via the fuel pump. it goes to the fuel filter / water separator. 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.
Side and Top Filler Port (Engine Oil)	You can fill the crankcase with engine oil from ***either the side or top filler port*** depending upon which one is most convenient. Refer to Chapter 2 for oil viscosity and type recommendation.
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, electric cooling fan, engine coolant pump, thermostat, and reserve tank. ***Note that all cooling system components are required for proper engine operation.***
Engine Cooling Fan	The cooling fan is driven by an electric motor controlled by a thermostatic relay system.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 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

Diesel Fuel Temperature Specification - USA

TEMPERATURE F° (C°)	NO. 2	NO. 1
+15° (9°)	100%	0%
Down to -20° (-29°)	50%	50%
Below -20° (-29°)	0%	100%

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.
- 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 Max. 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.

1. 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.
2. Bio-fuels should be purchased only from recognized and authorized diesel fuel suppliers.

Precautions and concerns regarding the use of bio-fuels:

1. Free methanol in FAME may result in corrosion of aluminum and zinc fuel injection components.
2. Free water in FAME may result in plugging of fuel filters and increased bacterial growth.
3. High viscosity at low temperatures may result in fuel delivery problems, injection pump seizures, and poor injection nozzle spray atomization.
4. FAME may have adverse effects on some elastomers (seal materials) and may result in fuel leakage and dilution of the engine lubricating oil.
5. 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.
6. 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.

B6 To B20 Bio-diesel Fuel Blend Usage

B6 to B20 bio-diesel is not approved for this engine application

Approved Engines

Only the Yanmar TNM engine series listed below may operate with bio-diesel fuel concentrations up to B5 for Polaris applications.

NOTICE: Do not exceed bio-diesel fuel blend B5 for this Polaris application.

- 3TNM72-APL

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 B5 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 B5 (5% bio-diesel blend) concentration.

Operating Conditions with B5 Bio-diesel Fuel Blends

Engine Warranty

Damages, performance or service concerns determined 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 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. Refer to Chapter 2 for more information.

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 **(Figure 4-3, (1))** from the fuel tank **(Figure 4-3, (2))**.
3. Observe the fuel level gauge and stop fueling when gauge shows the 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.

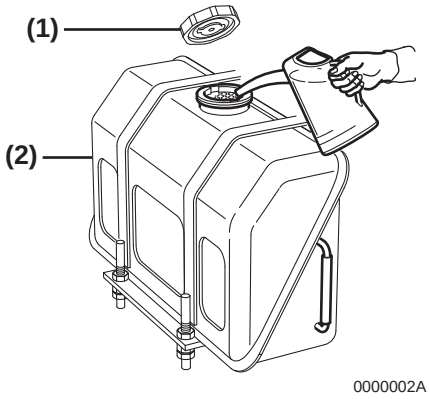


Figure 4-3

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 or 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.

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.

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

Definitions

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

Note:

1. Be sure the engine oil, engine oil storage containers and engine oil filling equipment are free of sediments and water.
2. Change the engine oil after the first 50 hours of operation and then every 100 hours thereafter.
3. 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)**.
4. 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 (HCI), ASTM D4739 (HCI).

Engine Oil Viscosity

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

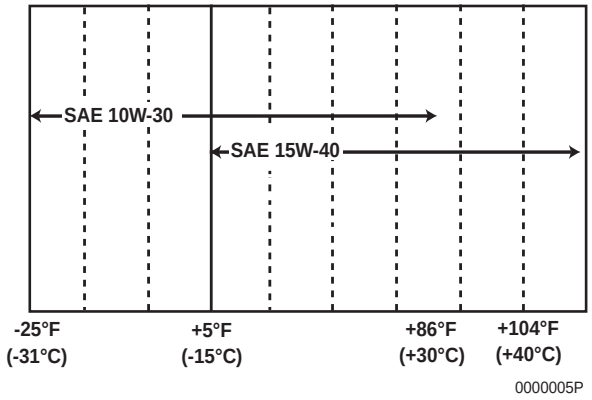


Figure 4-5

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.*

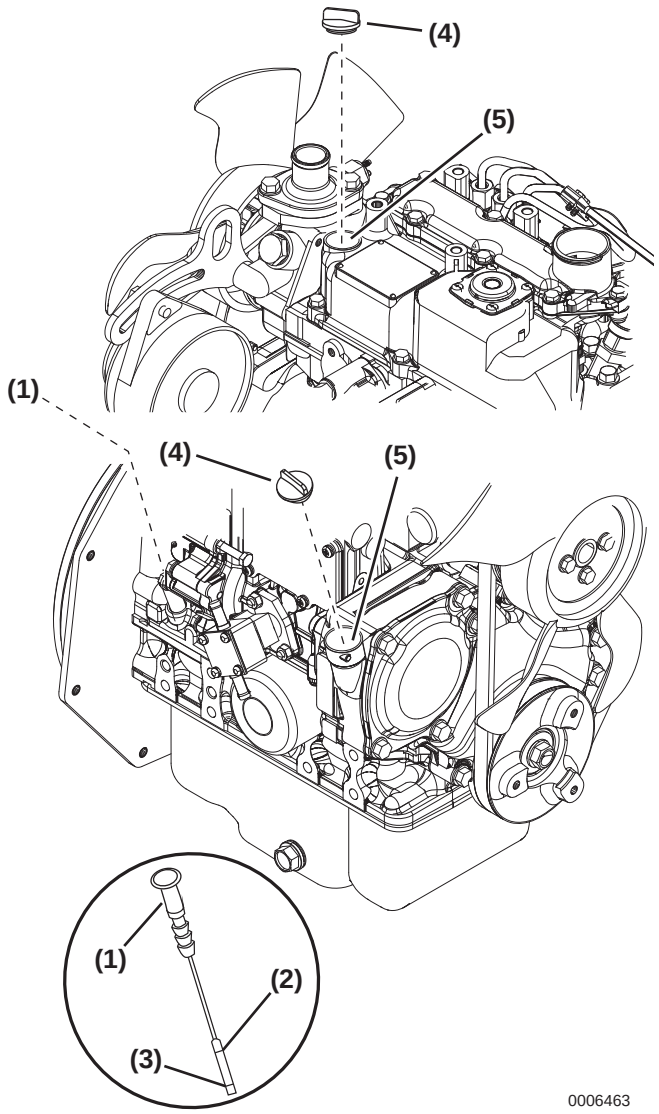


Figure 4-6

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))**.

   Note: Either fill location may be used.
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 the 3TNM72-APL oil pan.

Refer to the operation manual provided by the driven machine manufacturer for the actual engine oil capacity of your machine.

The following is the engine oil capacities for Yanmar 3TNM72-APL engine:

Engine Model	Engine Capacity Limit / Lower Limit
3TNM72-APL	1.8 qt. (1.70 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.

NOTICE: NEVER mix different types of engine coolant. This may adversely affect the properties of the engine coolant.

Alternative Engine Coolant

ONLY use an ethylene glycol or propylene glycol based conventional coolant.

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 2000 engine hours or once every two (2) years, which ever comes first.*

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.***

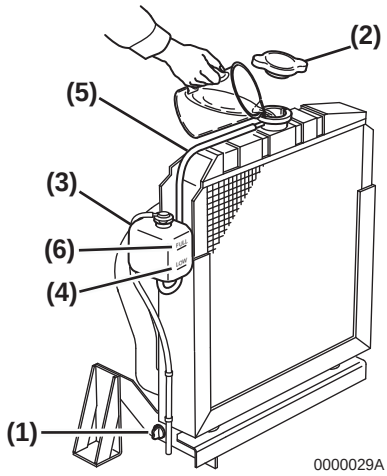


Figure 4-7

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 installed.

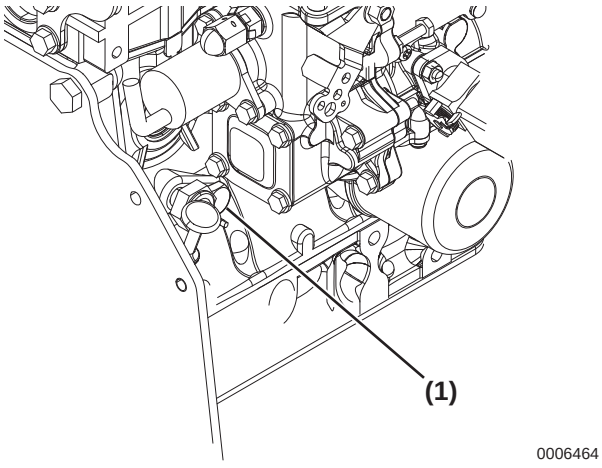


Figure 4-8

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. Reinstall the radiator cap **(Figure 4-7, (2))**. 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. Reinstall the cap.
7. Check the hose **(Figure 4-7, (5))** that connects the reserve tank **(Figure 4-7, (3))** 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 **(Figure 4-7, (6))**, add additional engine coolant to the reserve tank to bring the level to the FULL (HOT) mark.

Engine Coolant Capacity (Typical)

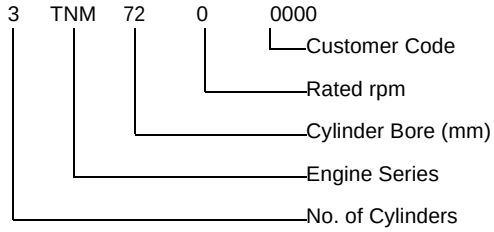
Note: Capacities listed are for engine only without a radiator. Refer to the operation manual provided by the driven machine manufacturer for actual engine coolant capacity on your machine.

Refer to Chapter 3 for engine coolant capacity and bleeding procedure for the Yanmar 3TNM72 -APL engine.

Engine Model	Engine Coolant Capacity
3TNM72	Refer to Chapter 3

SPECIFICATIONS

Description of Model Number



When ordering parts or making an inquiry about the engine you are working on, be sure to include the complete model and serial numbers as shown on the engine nameplate. *See Location of Labels on page 4-4.*

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: ± 3%
- 1 PS = 0.7355 kW
- 1 hp SAE (Society of Automotive Engineers) = 0.7457 kW

PRINCIPAL ENGINE SPECIFICATIONS

This Page Intentionally Left Blank

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})	---	---	---	---	---	---	---	---	---	---	---	---	---
	hp SAE	---	---	---	---	---	---	---	---	---	---	---	---	---
	kW	---	---	---	---	---	---	---	---	---	---	---	---	---
	PS	---	---	---	---	---	---	---	---	---	---	---	---	---
Max. Rated Output (Net)	rpm (min^{-1})	---	---	---	---	---	---	---	---	---	---	---	---	3600
	hp SAE	---	---	---	---	---	---	---	---	---	---	---	---	---
	kW	---	---	---	---	---	---	---	---	---	---	---	---	---
	PS---	---	---	---	---	---	---	---	---	---	---	---	---	
High Idling	rpm (min^{-1}) ± 25	---	---	---	---	---	---	---	---	---	---	---	---	3840
Engine Weight (Dry) with Flywheel Housing*												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		34.8 - 63.8 psi (0.240 -0.440 MPa, 2.4 - 4.4 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)												
		Alternator 55A DC 12V												
		See Chapeter 10 of the Polaris Ranger Diesel Service Manual												
Dimensions (L × W × H)`		19.5 x 16.8 x 21.3 in. (497 × 427 × 542 mm)												
Engine Oil Pan Capacity**		*1.8 Qts.*												
Engine Coolant Capacity		See Chapter 3 of the Polaris Diesel Service Manual												
Standard Cooling Fan***		Polaris-Supplied Electric Fan												
Crank / V-pulley Dia.***		150 mm / 120 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	*See Checking and Adjusting Fuel Injection Timing on page 7-16*		
Fuel Injection Pressure		1784 - 1929 psi (12.3 - 13.3 MPa; 125 - 136 kgf / cm^2)	-
Compression Pressure at 250 rpm (250 min^{-1})	3TNM72	470 ± 15 psi (3.24 ± 0.1MPa; 33 ± 1 kgf / cm^2)	370 ± 15 psi (2.55 ± 0.1 MPa; 26 ± 1 kgf / cm^2)
Lubricating Oil Pressure	At rated output	41 - 55 psi (0.28 - 0.38 MPa; 2.86 - 3.87 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)

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 mm	87 in.-lb (9.8 N·m; 1.0 kgf·m)	-
	1/4 mm	173 in.-lb (19.6 N·m; 2.0 kgf·m)	
	3/8 mm	22 ft-lb (29.4 N·m; 3.0 kgf·m)	
	1/2 mm	43 ft-lb (58.8 N·m; 6.0 kgf·m)	

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'Automobilies
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

°F = (1.8 x °C) + 32
°C = 0.556 x (°F - 32)

This Page Intentionally Left Blank

Section 5

PERIODIC MAINTENANCE

Page

This Page Intentionally Left Blank

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.

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*.

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. Consult 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 an authorized Polaris dealer

System	Check Item	Daily	Periodic Maintenance Interval					
			Every 50 hours	Every 100 hours	Every 150 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 Pump V-Belt		○1st time	○ 2nd and after				
	Drain, Flush and Refill Cooling System with New Coolant					◇ or every 2 yr. which-ever 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 and Replace Filter		◇1st time	◇				
	Replace Engine Oil Filter							
Emission Control Warranty	Inspect, Clean and Test Fuel Injectors, if necessary						●	
	Inspect Crankcase Breather System						●	
Fuel	Check and Refill Fuel Tank Level	○						
	Drain Fuel Filter / Water Separator		○					
	Check Fuel Filter / Water Separator	○						
	Inspect Fuel Filter / Water Separator Lines/Fittings		○					
	Replace Fuel Filter / Water Separator				◇			
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.

- **Replace Engine Oil and Engine Oil Filter**
- **Check and Adjust Cooling Pump V-Belt**

Replace 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.

NOTICE: NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

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.

NOTICE: 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.

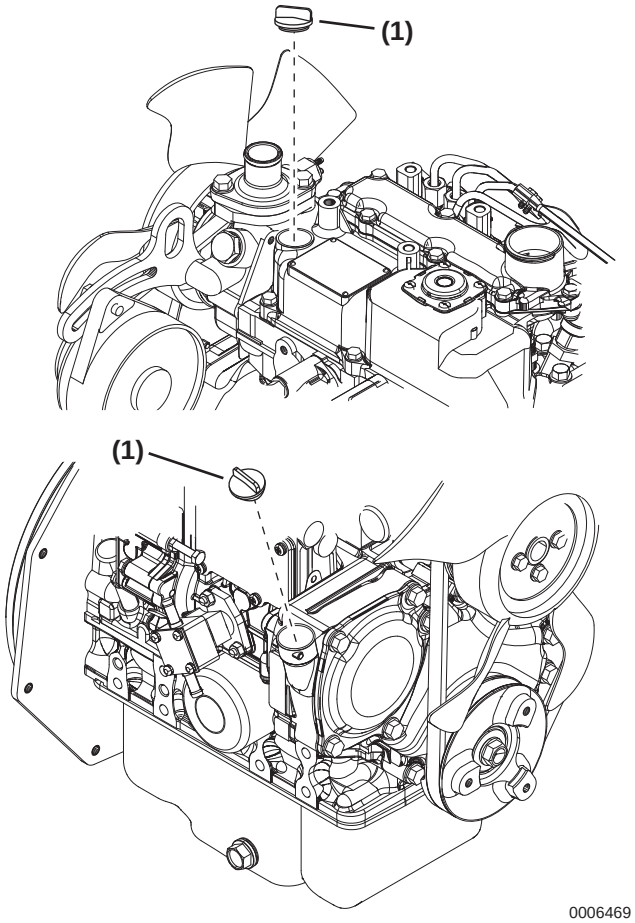


Figure 5-1

6. Remove the oil drain plug **(Figure 5-2, (1))**. Allow oil to drain.
7. After all oil has been drained from the engine, reinstall the oil drain plug **(Figure 5-2, (1))** and tighten to 25 ft-lb (33.8 N·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.

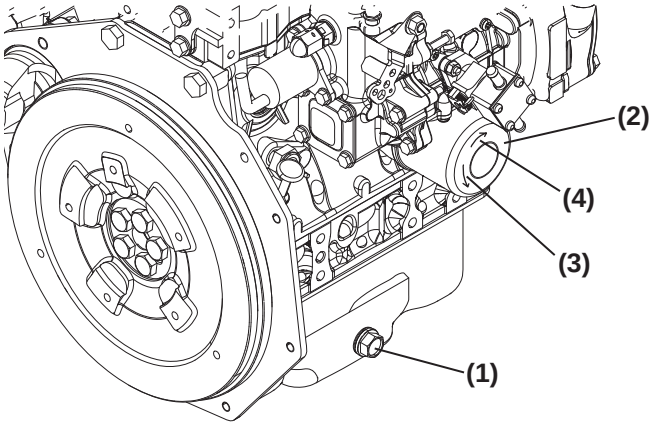


Figure 5-2

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, (3))** 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.
4. Add new engine oil to the engine as specified in *Adding Engine Oil on page 4-15*. *NOTICE: NEVER overfill the engine with engine oil. ALWAYS keep the oil level between the upper and lower lines on the oil cap / dipstick.*

Check and Adjust Cooling Pump 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:

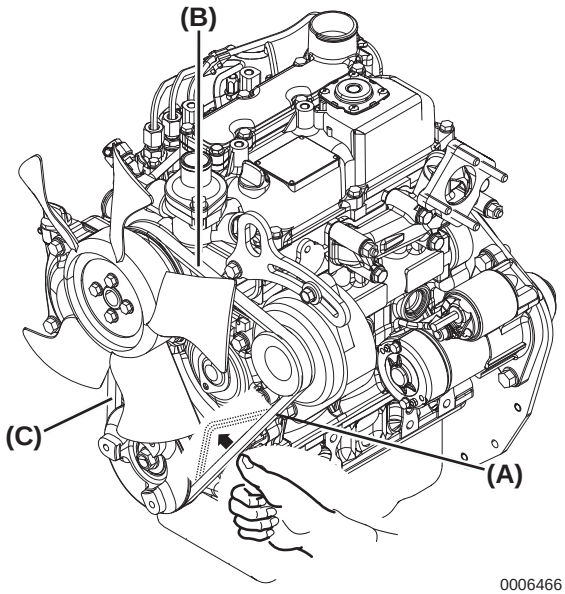


Figure 5-3

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)

2. 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.

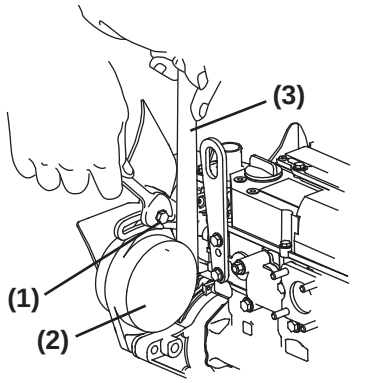


Figure 5-4

3. Tighten the V-belt to the proper tension. 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.

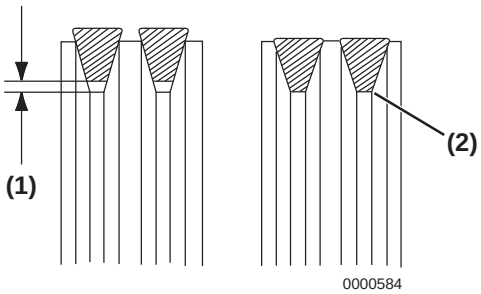


Figure 5-5

4. 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.
5. Inspect the condition of the used V-belt. 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.
6. Install the 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)

7. 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.

- **Drain Fuel Filter / Water Separator**
- **Check Battery**

Drain 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 periodically to check for contaminants, such as water, etc. that may be collected in the filter. NEVER wait until the scheduled periodic maintenance interval, if contaminants are discovered, to replace the filter.

Drain the fuel filter / water separator as follows:

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

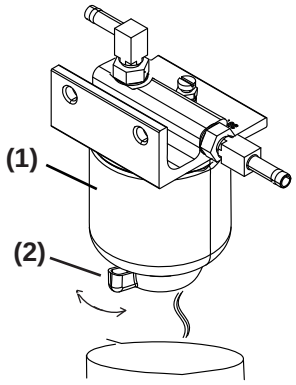


Figure 5-6

2. Open the drain petcock **(Figure 5-6, (2))**. Allow filter / separator to drain until clear.
3. Close the drain petcock **(Figure 5-6, (2))** once filter / separator draining is complete.
4. Pour the fuel into an approved container and dispose properly. Hold the bottom of the cup with a shop towel to prevent 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. Prime the fuel system by running the fuel pump 10-15 seconds by turning the key ON.

Check 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 or voltage meeter 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.***

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, 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.

Conventional Battery Level Check

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. This information is provided in the event the OEM-supplied low-maintenance battery was replaced with a conventional lead-acid battery.

When the amount of fluid nears the lower limit **(Figure 5-7, (1))**, fill with distilled water **(Figure 5-7, (2))** so it is at the upper limit **(Figure 5-7, (3))**. 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.

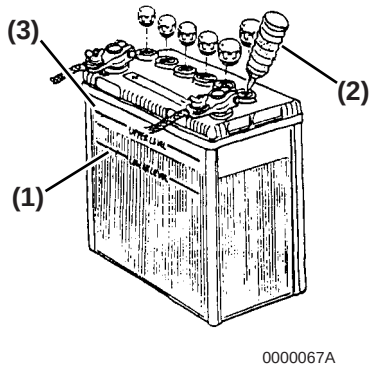


Figure 5-7
(Conventional Lead-Acid Battery)

At 50 Hours of Operation (Break-in)

Perform the following break-in maintenance at 50 hours of operation.

- **Replace Engine Oil and Engine Oil Filter**
- **Check and Adjust Cooling Pump V-Belt**
- **Drain Fuel Filter / Water Separator Element**
- **Check and Clean Radiator Fins**

Every 100 Hours of Operation

Perform the following maintenance every 100 hours of operation.

- **Replace Engine Oil and Engine Oil Filter**
- **Drain Fuel Filter / Water Separator Element**
- **Check and Clean Radiator Fins**

Every 150 Hours of Operation

Perform the following maintenance every 150 hours of operation.

- **Check and Clean Radiator Fins**
- **Check and Adjust Cooling Pump V-Belt**
- **Replace Air Cleaner Element**
- **Replace Fuel Filter / Water Separator Element**

Replace 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.

NOTICE: NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

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.

NOTICE: NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.

Change the engine oil every 100 hours of operation after the initial change at 50 hours. Replace the engine oil filter at the same time. *See Replace Engine Oil and Engine Oil Filter on page 5-6.*

Check and Clean 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.

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

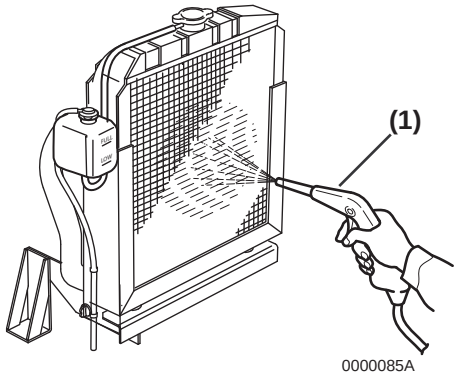


Figure 5-9

Check and Adjust Cooling Pump V-Belt

Check and adjust the cooling pump V-belt every 250 hours of operation after the initial 50 hour V-belt maintenance. *See Check and Adjust Cooling Pump V-Belt on page 5-7.*

Check and Adjust 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.

NOTICE: Refer to Chapter 2 for throttle cable or linkage adjustment.

Replace Air Cleaner Element

NOTICE: When the engine is operated in dusty conditions, clean the air cleaner element more frequently.

NOTICE: 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** 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, (4))**.
2. Remove the element **(Figure 5-11, (2))**.

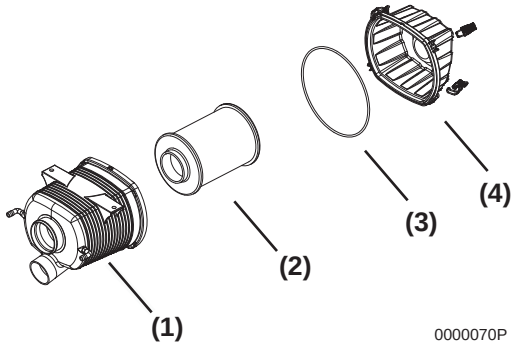


Figure 5-11

3. Replace the element with a new one if the element is damaged, excessively dirty or oily.
4. Apply grease to the air filter sealing surface.
5. Clean inside of the air cleaner cover.
6. Install the element into the air cleaner case **(Figure 5-11, (1))**.
7. Install the air cleaner cover seal (if removed) **(Figure 5-11, (3))**.
8. Latch the air cleaner cover to the case, making sure the clips are secured **(Figure 5-11, (4))**.

Replace the Fuel Filter / Water Separator Element

NOTICE: Polaris recommends that the fuel filter / water separator element be replaced at 150 hours. Refer to the element replacement instructions in the 150 hour interval on page 5-15.

Every 150 Hours of Operation

Perform the following maintenance every 150 hours of operation.

- **Replace Air Cleaner Element**
- **Replace Fuel Filter / Water Separator**

Replace 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 150 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 mentioned 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.

Replace 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.***

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

1. Stop the engine and allow it to cool.
2. Position an approved container under the fuel filter / water separator **(Figure 5-13, (1))** to collect the contaminants.

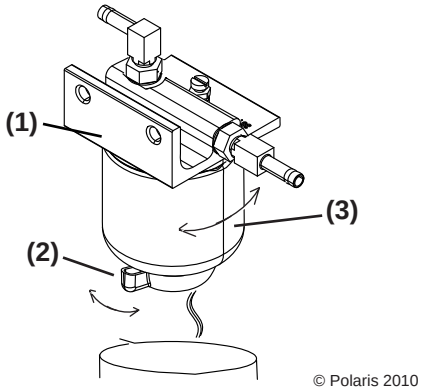


Figure 5-13

3. Open the drain petcock **(Figure 5-13, (2))**. Allow filter / separator draining.
4. Close the drain petcock **(Figure 5-13, (2))** once filter / separator draining is complete.
5. Pour the fuel into an approved container and dispose properly. Hold the bottom of the cup with a shop towel to prevent fuel from dripping. Wipe up any spills immediately.
6. Remove the filter element **(Figure 5-13, (3))** by turning it counter-clockwise (as viewed from the bottom).
7. Replace the element with a new one by threading it onto the assembly. Turn the filter an additional 1/2 to 3/4 turn after gasket contact with the sealing surface

Fuel Safety Reminders

WARNING! ***Fire and Explosion Hazard. Diesel fuel is flammable and explosive under certain conditions.***

NOTICE: 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.

NOTICE: NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.

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

NOTICE: NEVER use diesel fuel as a cleaning agent.

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.

Every 1000 Hours of Operation

Perform the following maintenance every 1000 hours of operation.

- **Drain, Flush and Refill Cooling System with New Coolant**
- **Adjust Intake / Exhaust Valve Clearance**

Drain, Flush and Refill 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 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.

NOTICE: 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.

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. 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.

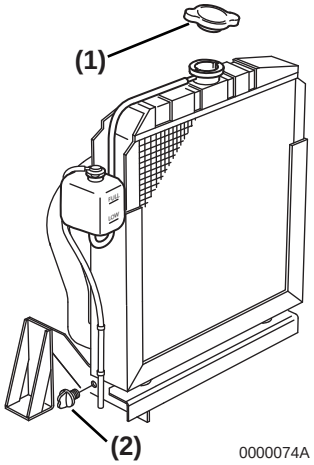


Figure 5-15

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

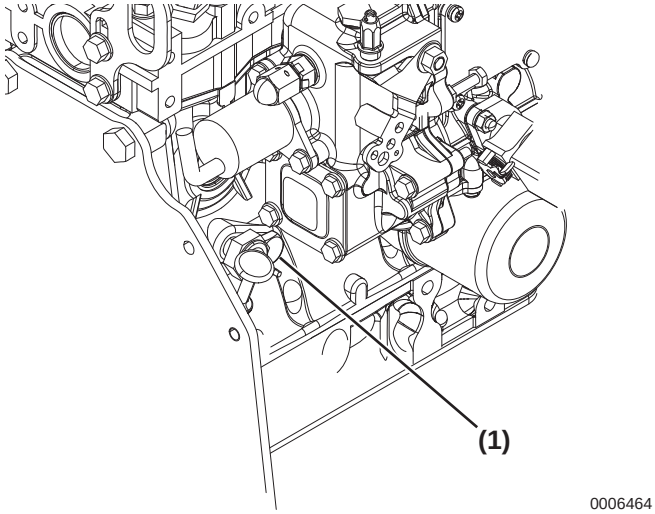


Figure 5-16

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. Reinstall and tighten the drain plug or close the drain cock at the radiator. Reinstall and tighten the engine block drain plug.
7. Fill radiator and engine with engine coolant. *See Filling Radiator with Engine Coolant on page 4-17.* **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.***

Adjust 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.

- **Inspect, Clean and Test Fuel Injectors, if necessary**
- **Inspect Crankcase Breather System**

Inspect, Clean and Test 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 of Fuel Injectors on page 7-21.*

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

Inspect 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.

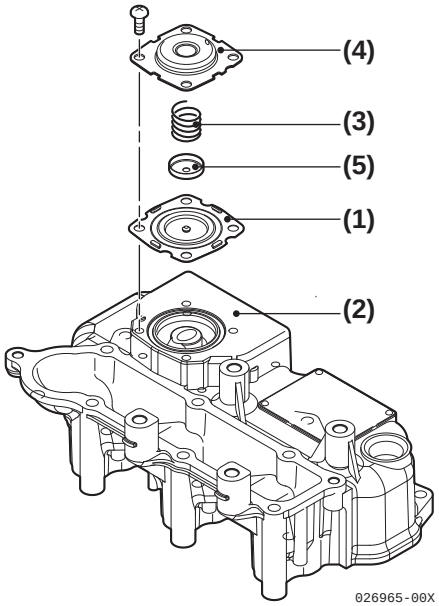


Figure 5-17

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. Reinstall 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 4-24*.

   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.

- **Check and Replace Fuel Hoses and Engine Coolant Hoses**
- **Lap the Intake and Exhaust Valves**

Check and Replace 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 two years.

NOTICE:
Replace rubberized fuel hoses every two years or every 2000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2000 hours of engine operation, whichever comes first.

Lap the Intake and Exhaust Valves

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

Section 6

ENGINE

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)		*See Inspecting the Camshaft on page 6-47*
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)	
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

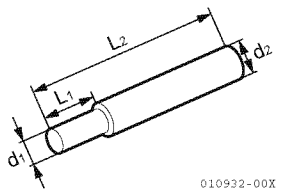
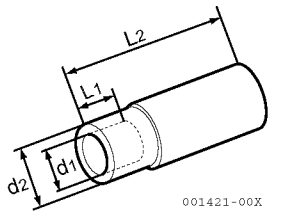
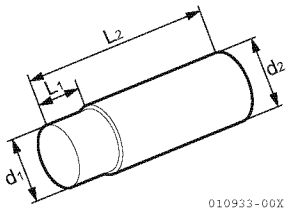
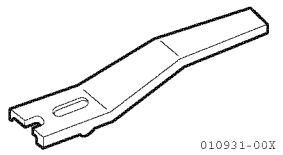
Component		Model	Thread Diameter and Pitch	Tightening Torque	Lubricating Oil Application	Reference Page
Cylinder Head Bolts		3TNM68	M8 x 1.25 mm	31 - 34 ft-lb (42.1 - 46.1 N·m; 4.3 - 4.7 kgf·m)	Applied	*See Assembling the Cylinder Head on page 6-27*
		3TNM72	M9 x 1.25 mm	40 - 43 ft-lb (53.9 - 57.9 N·m; 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	-

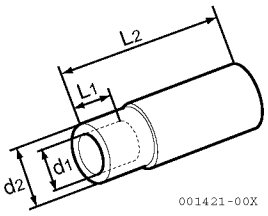
See Tightening Torques for Standard Bolts and Nuts on page 4-25 for standard hardware torque values.

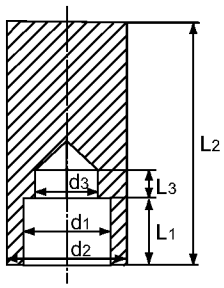
Note: Torx bolts are used for oil sump mounting bolts and rudder frame mounting bolts.
Specialized tool (Torx bolt wrench) is required.
Oil Sump Bolts: TORX E8
Ladder Frame: TORX E12

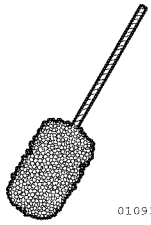
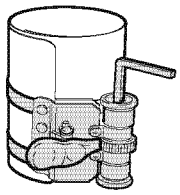
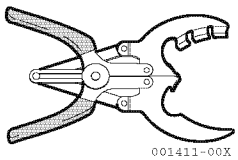
SPECIAL SERVICE TOOLS

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

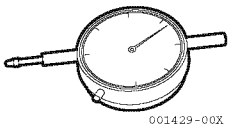
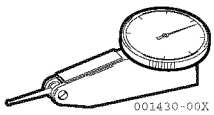
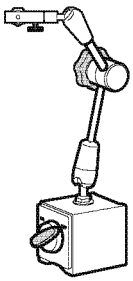
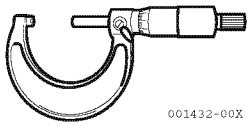
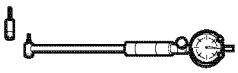
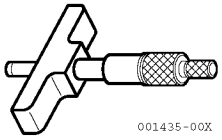
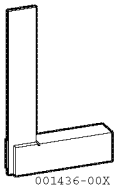
<table>
<tr><th>No</th><th>Tool Name</th><th>Applicable Model and Tool Size</th><th>Illustration</th></tr>
<tr><td>1</td><td>Valve Guide Tool (For Removing Valve Guides)</td><td>
<table>
<tr><th>L1</th><th>L2</th><th>d1</th><th>d2</th></tr>
<tr><td>0.787 in.
(20 mm)</td><td>2.953 in.
(75 mm)</td><td>0.217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

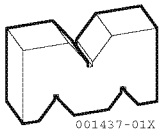
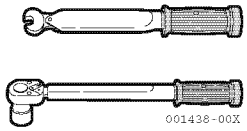
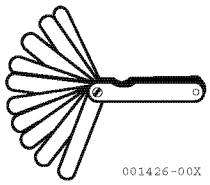
<table>
<tr><th>No</th><th>Tool Name</th><th>Applicable Model and Tool Size</th><th>Illustration</th></tr>
<tr><td>5</td><td>Stem Seal Tool
(For Installing
Stem Seals)</td><td>
<table>
<tr><th>d1</th><th>d2</th><th>d3</th><th>L1</th><th>L2</th><th>L3</th></tr>
<tr><td>0.591 in.
(15 mm)</td><td>0.827 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>
Allowance:
d1: ±0.00787 in. (±0.2 mm)
L1: ±0.00393 in. (±0.1 mm)
Locally Manufactured
</td><td> 

001421-00X


001422-00X</td></tr>
<tr><td>6</td><td>Flex-Hone
(For Preparing
Cylinder Walls)</td><td>
<table>
<tr><th>Yanmar Part No.</th><th>Cylinder Bore</th></tr>
<tr><td>129400-92410</td><td>2.756 - 2.992 in.
(70 - 76 mm)</td></tr>
</table>
</td><td> 
010930-00X</td></tr>
<tr><td>7</td><td>Piston Ring
Compressor
(For Installing
Pistons)</td><td>Yanmar Part No. 955500-02476
The Piston Insertion Tool is Applicable for
2.362 - 4.921 in. (60 - 125 mm) Diameter Pistons</td><td> 
010472-00X</td></tr>
<tr><td>8</td><td>Piston Ring Tool
(For Removing /
Installing Piston
Rings)</td><td>Available Locally</td><td> 
001411-00X</td></tr>
</table>

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

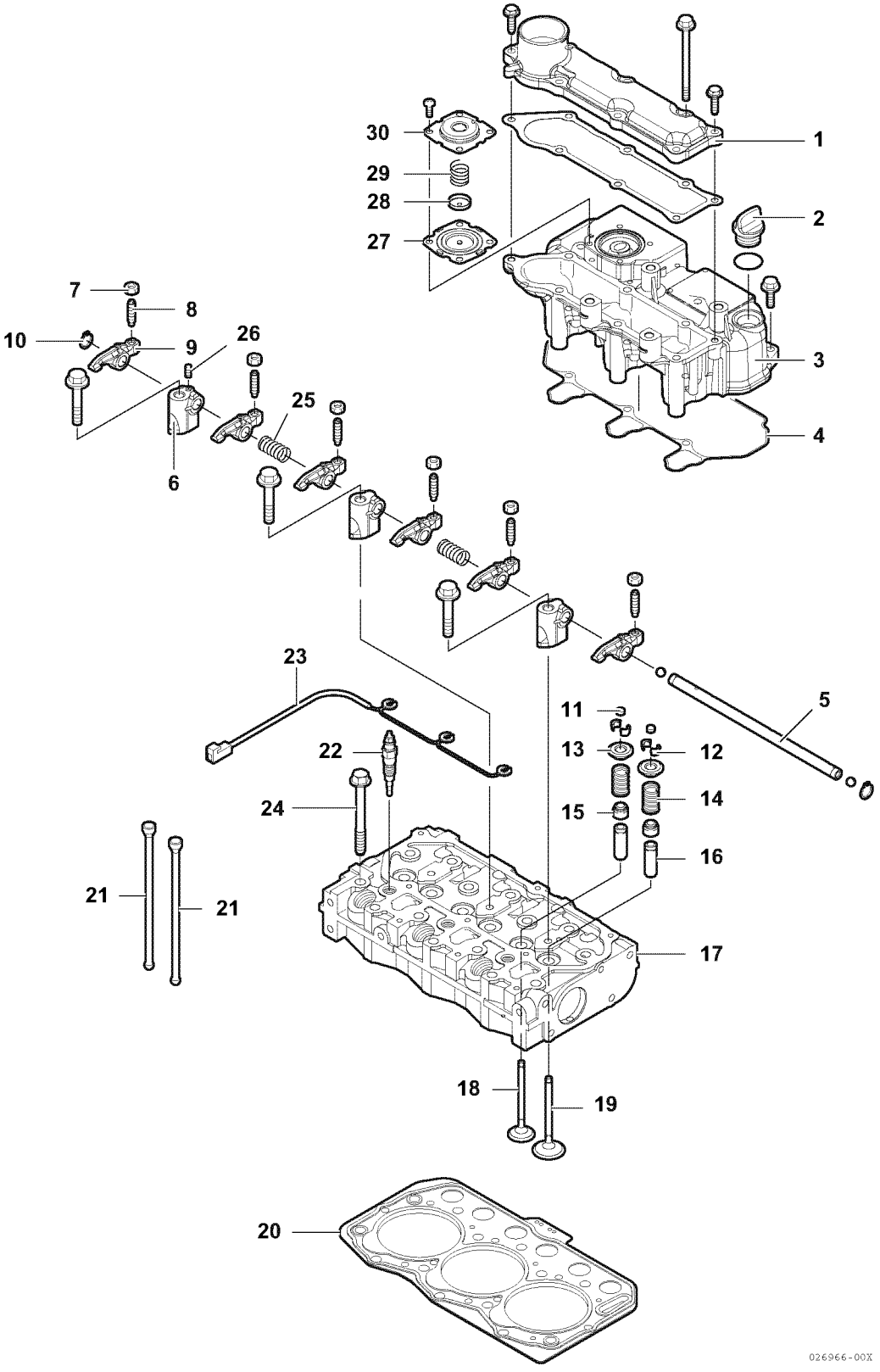


Figure 6-1

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))**.

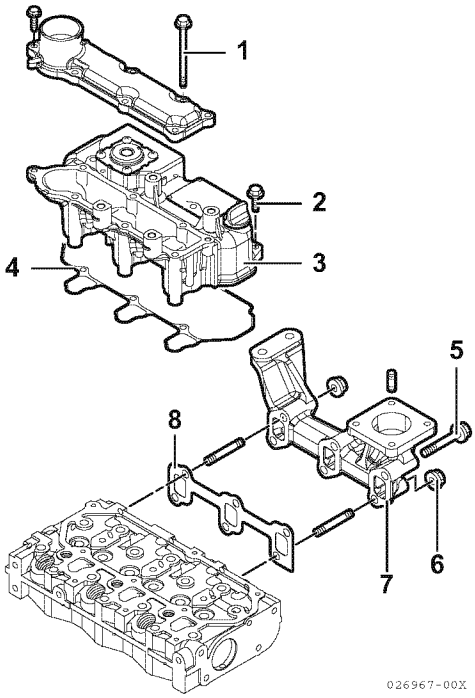


Figure 6-2

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.

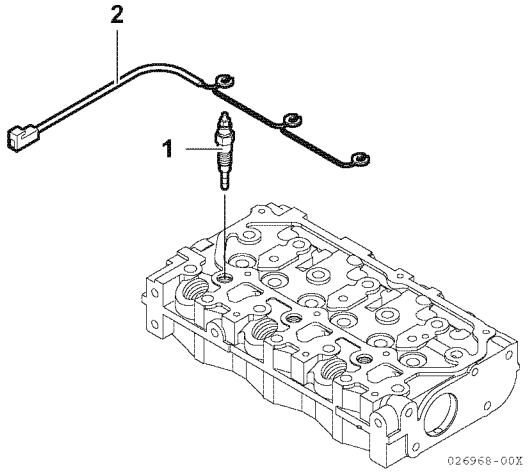


Figure 6-3

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.

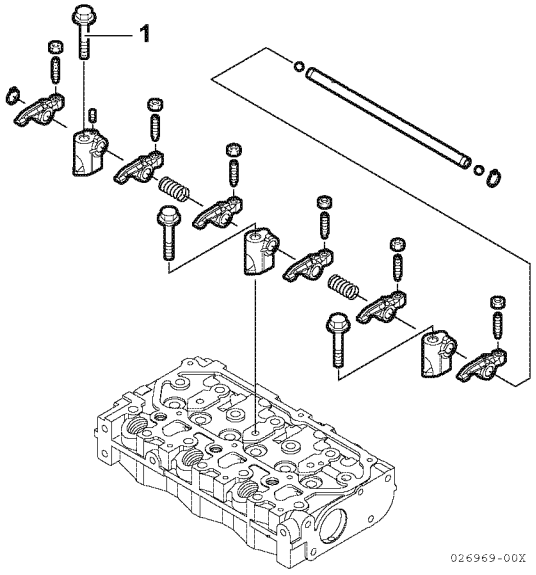


Figure 6-4

Disassembling the Rocker Arm Assembly

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

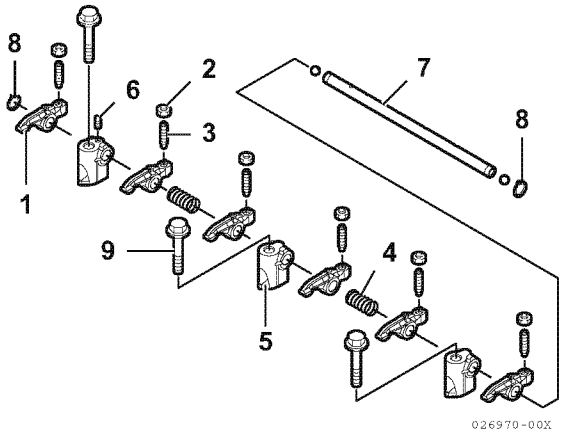


Figure 6-5

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))**.

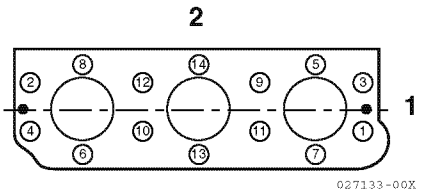
NOTICE

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.

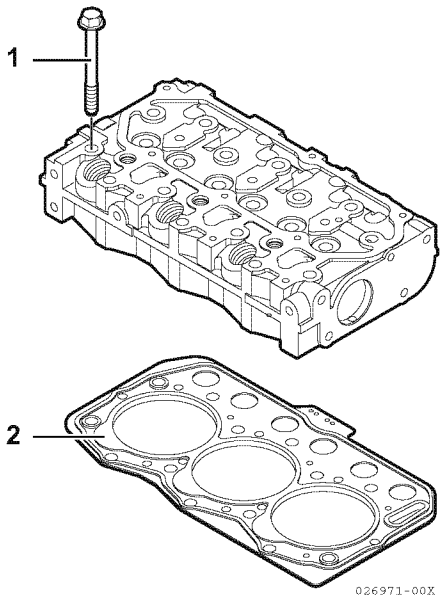


Figure 6-7

Removing the Intake/Exhaust Valves

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

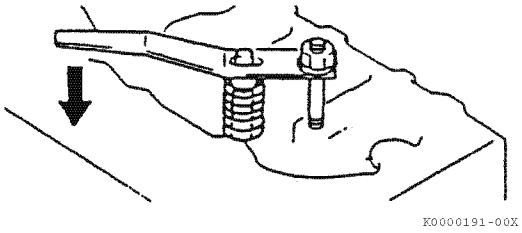


Figure 6-8

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))**.

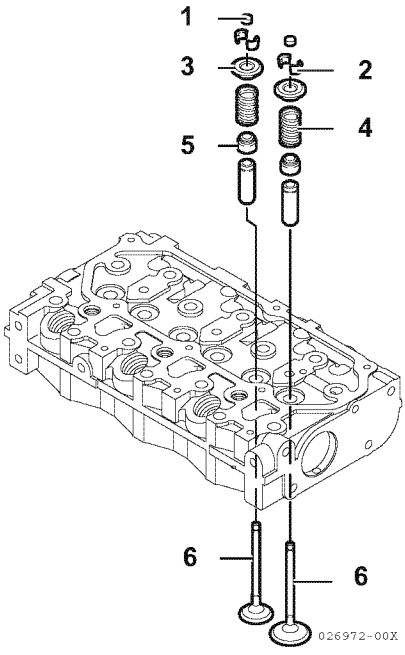


Figure 6-9

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.

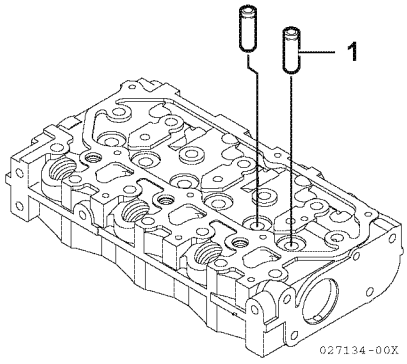


Figure 6-10

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.*

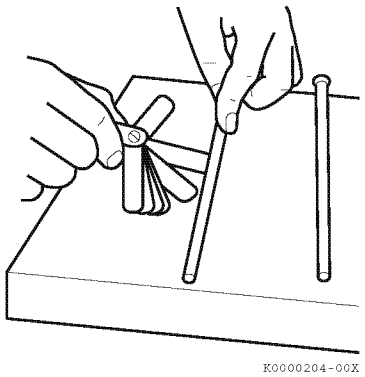


Figure 6-11

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.

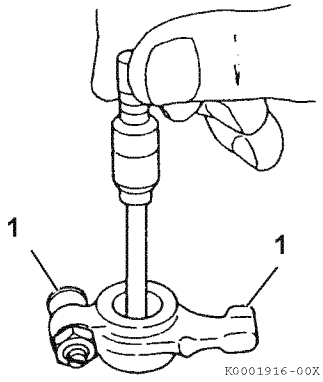


Figure 6-12

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.*

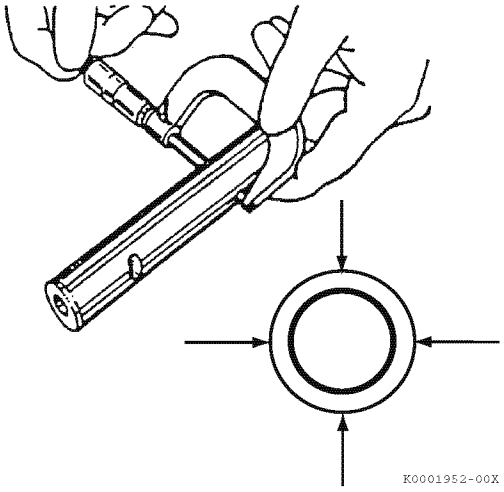


Figure 6-13

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.

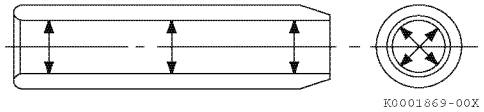


Figure 6-14

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.*

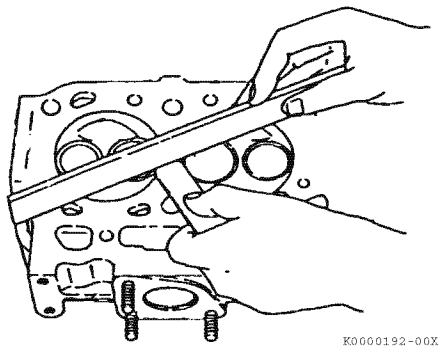


Figure 6-15

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.*

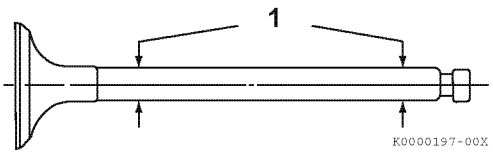


Figure 6-16

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.*

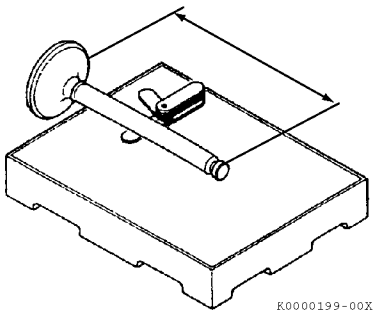


Figure 6-17

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.*

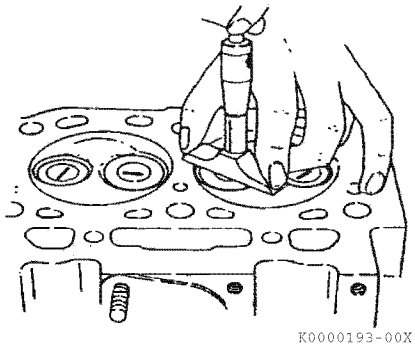


Figure 6-18

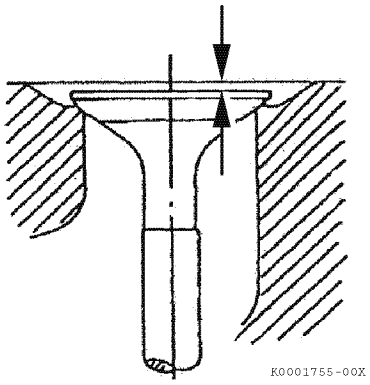


Figure 6-19

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.

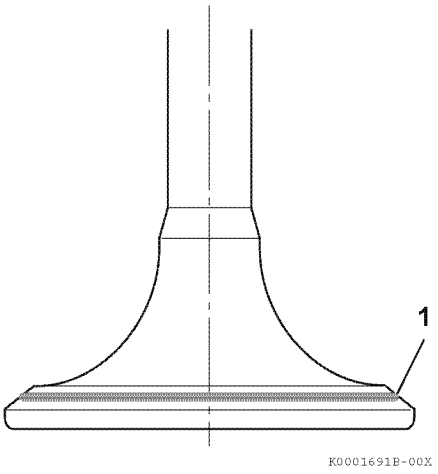


Figure 6-20

Also visually inspect the valve seat for even contact.

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

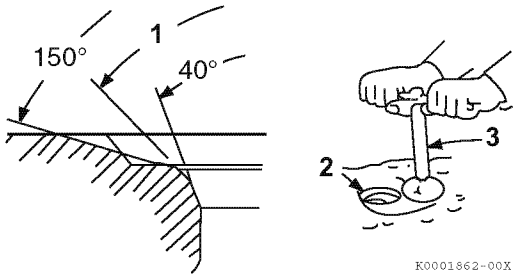


Figure 6-21

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.*

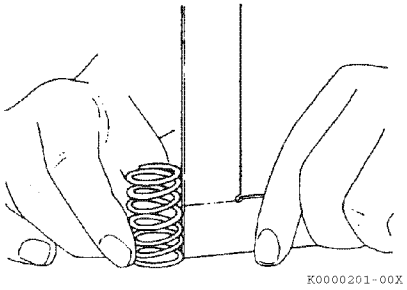


Figure 6-22

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.*

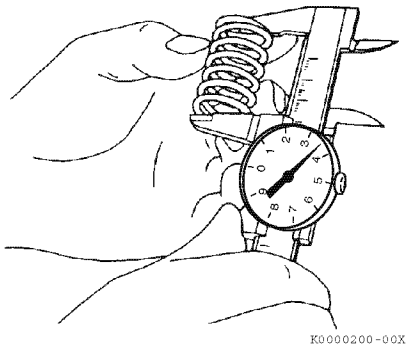


Figure 6-23

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.

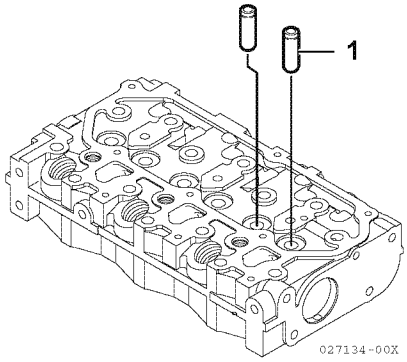


Figure 6-24

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.*

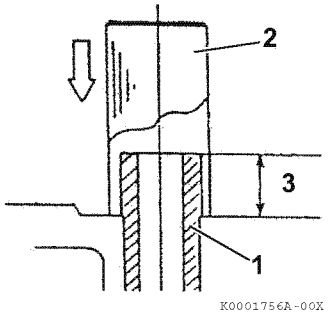


Figure 6-25

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))**.

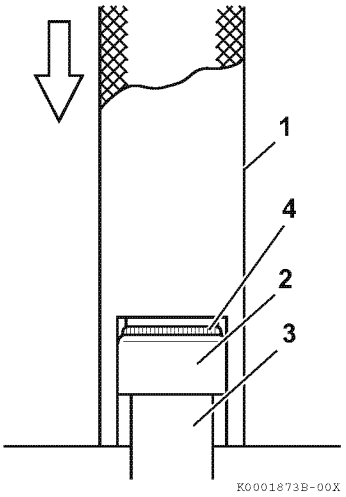


Figure 6-26

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.*

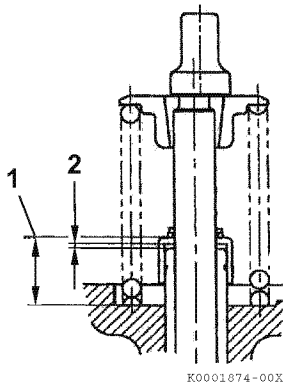


Figure 6-27

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.

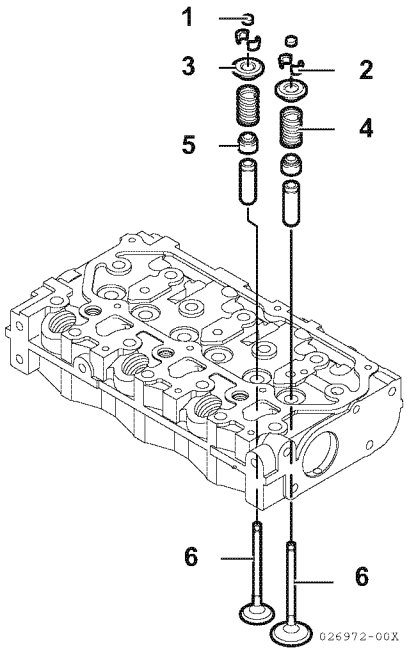


Figure 6-28

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.

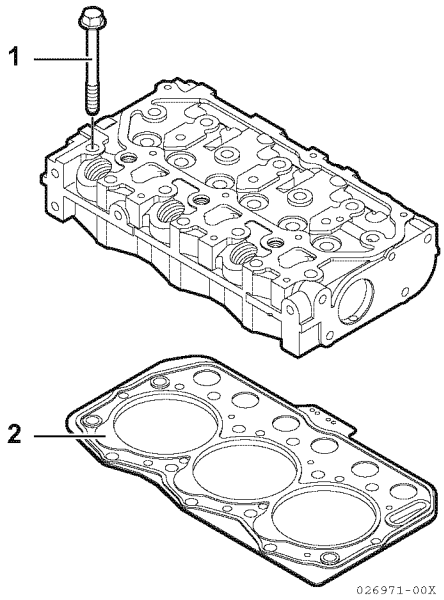
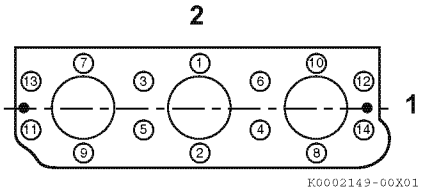


Figure 6-29

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

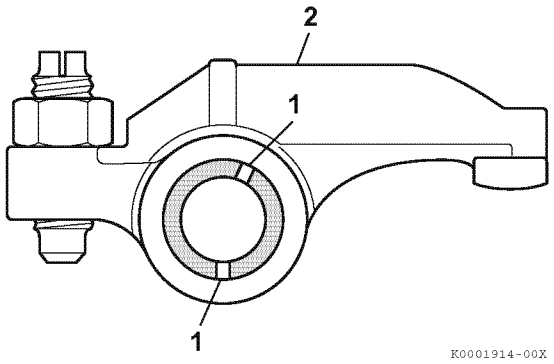


Figure 6-31

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.

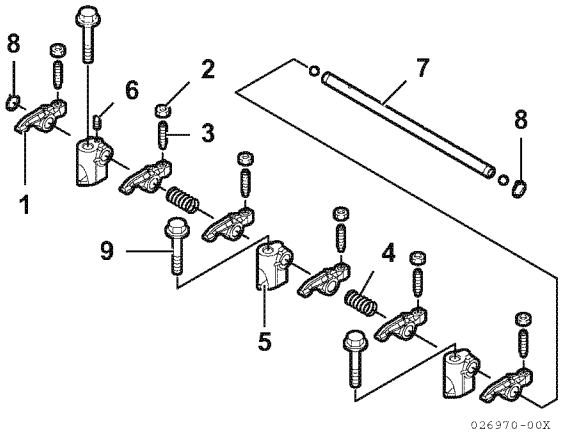


Figure 6-32

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))**.

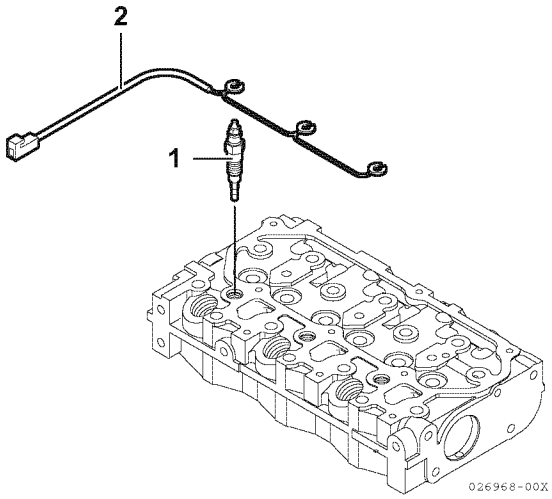


Figure 6-33

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.

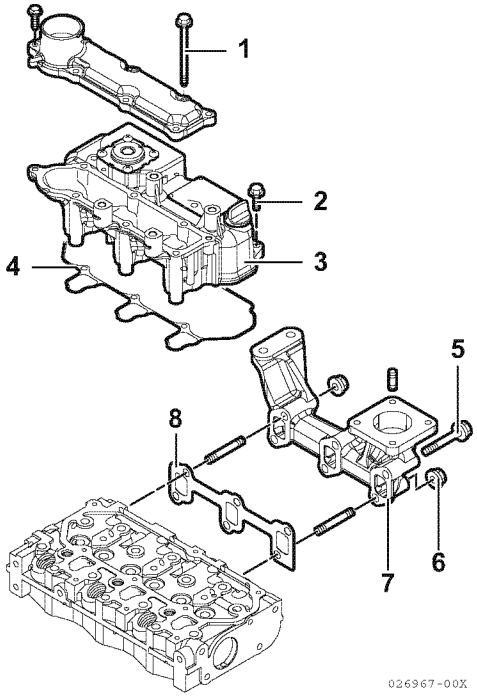


Figure 6-34

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.)

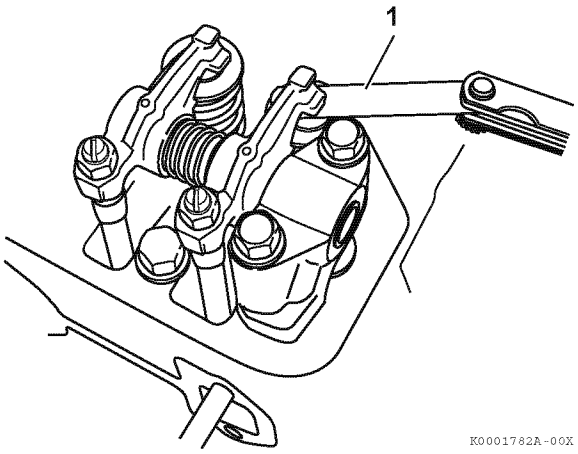


Figure 6-35

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.

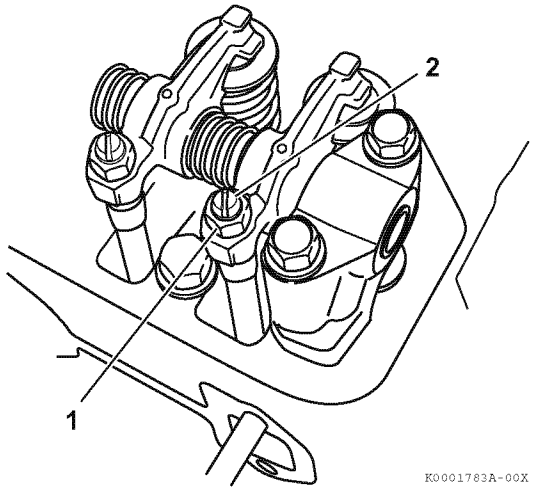


Figure 6-36

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

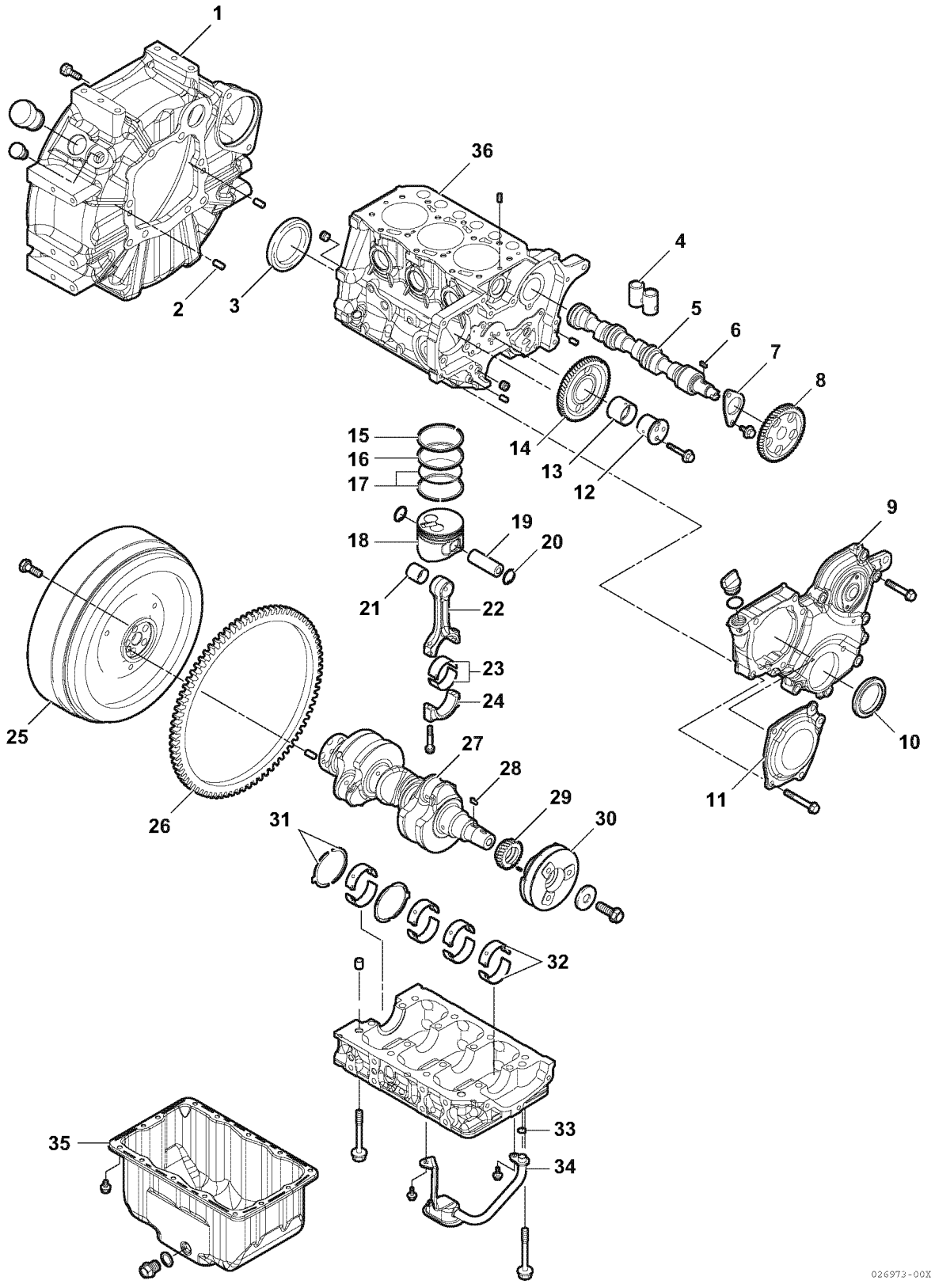


Figure 6-37

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.*

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))**.

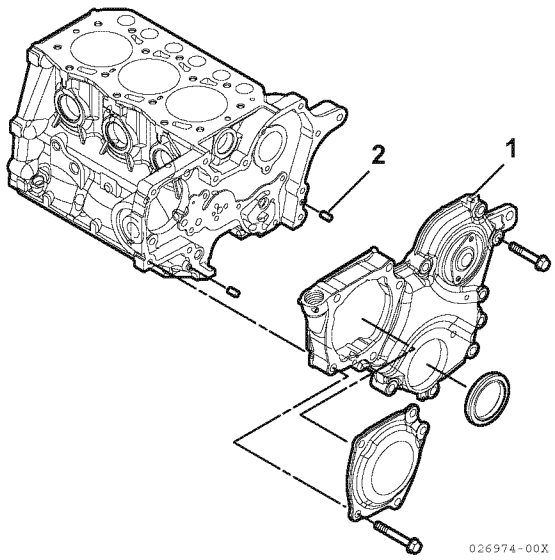


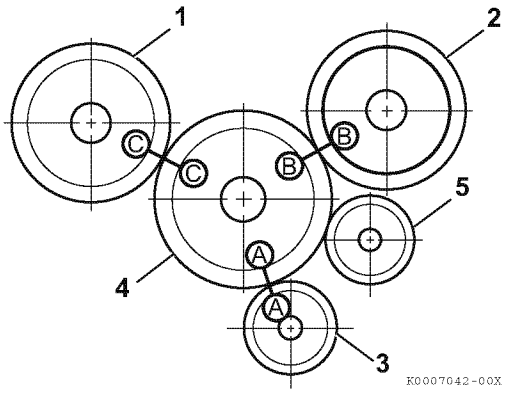
Figure 6-38

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**.

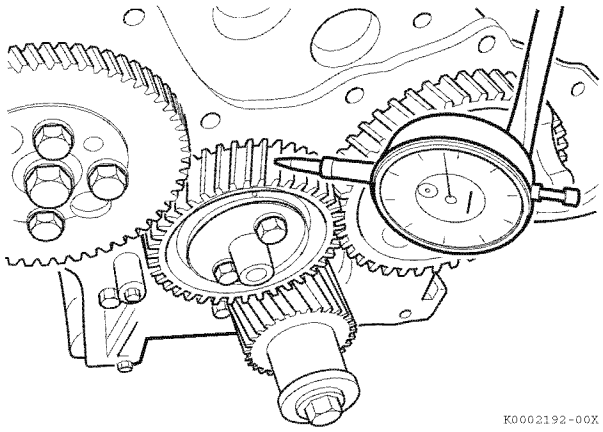


Figure 6-40

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))**.

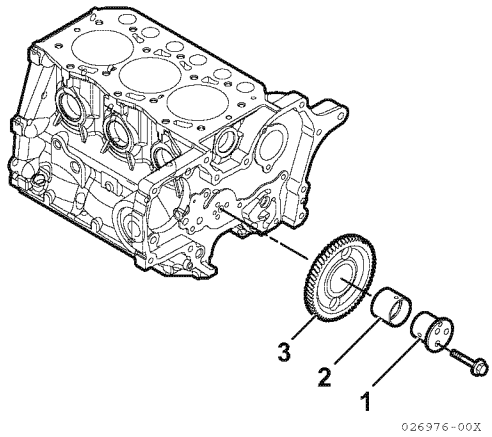


Figure 6-41

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.

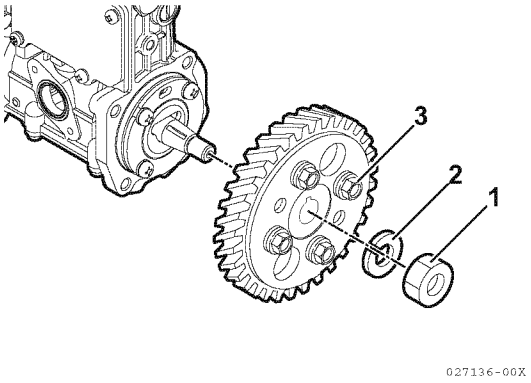


Figure 6-42

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))**.

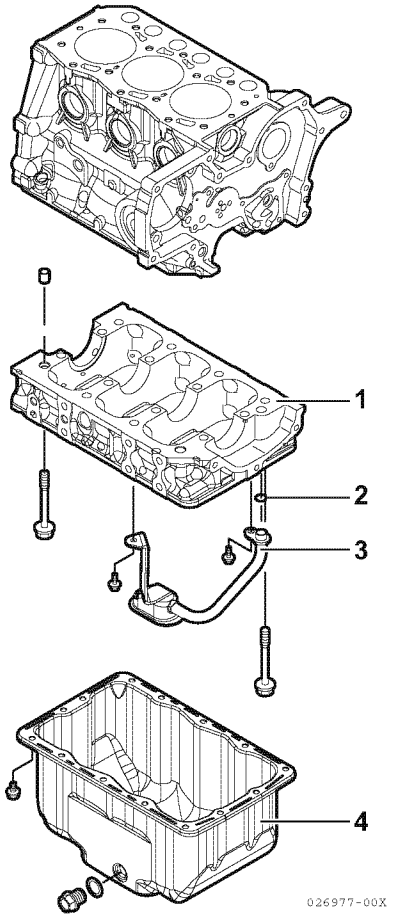


Figure 6-43

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

1. 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.*

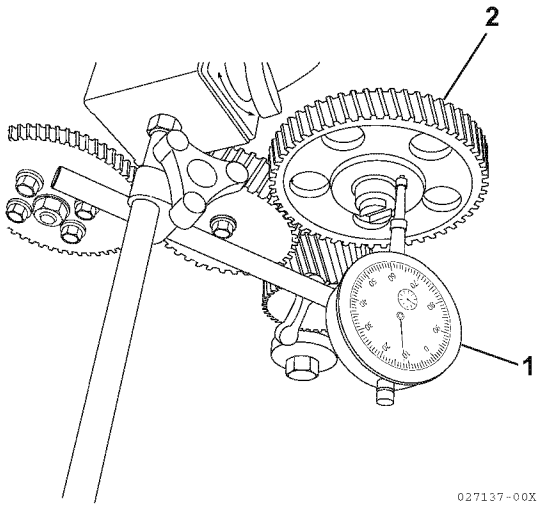


Figure 6-44

   - **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.*

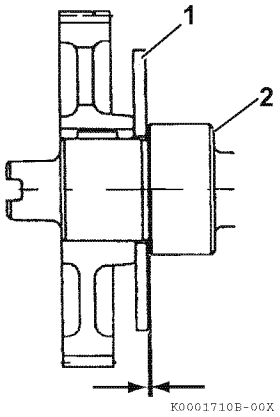


Figure 6-45

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

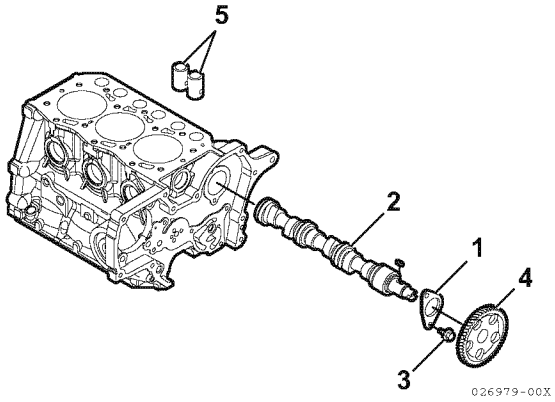


Figure 6-46

3. 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.
4. Slowly pull the camshaft **(Figure 6-46, (2))** assembly out of the engine, being careful not to damage the front camshaft bushing.
5. 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.

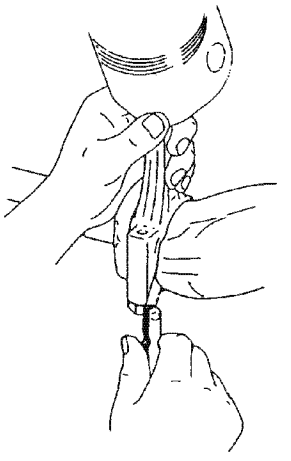


Figure 6-47

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.

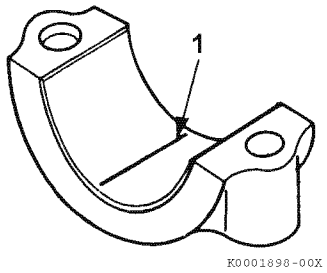


Figure 6-48

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.

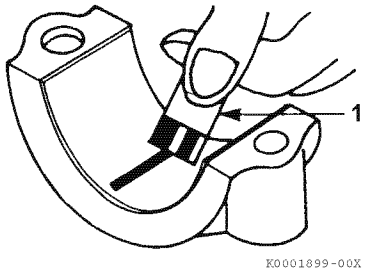


Figure 6-49

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.

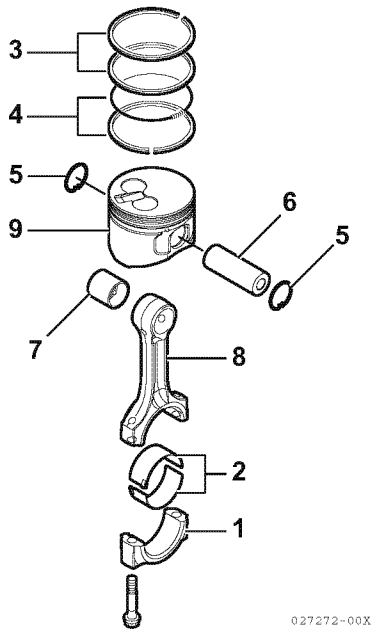


Figure 6-50

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.

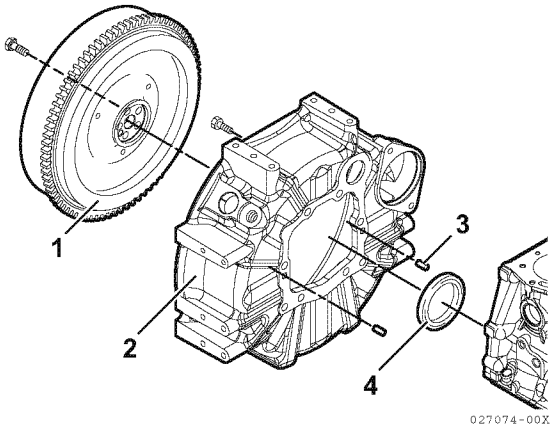


Figure 6-51

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.

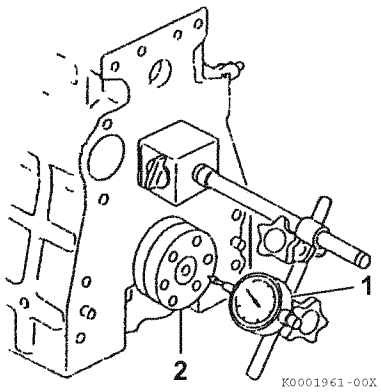


Figure 6-52

   - **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.*

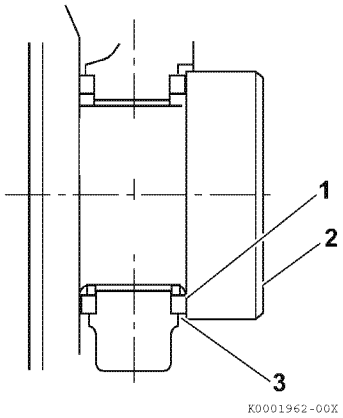


Figure 6-53

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.

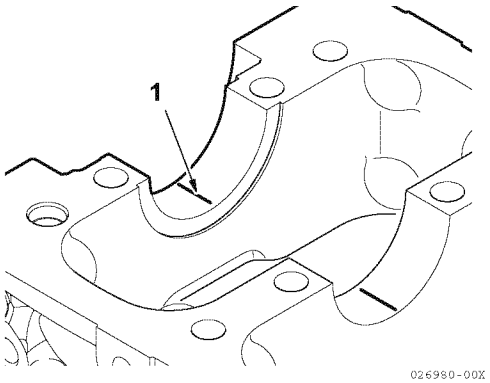
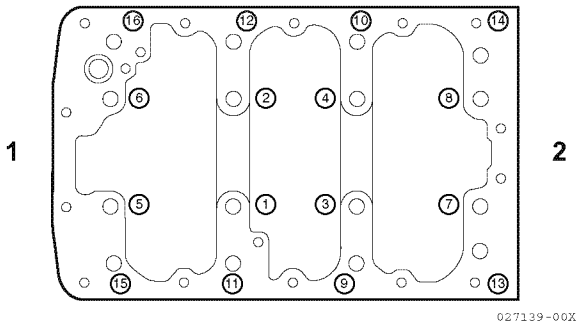


Figure 6-54

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.

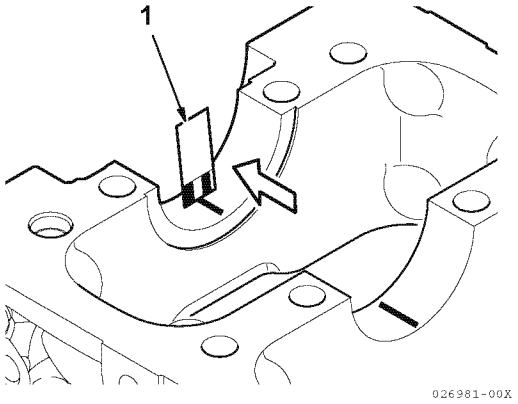


Figure 6-56

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.

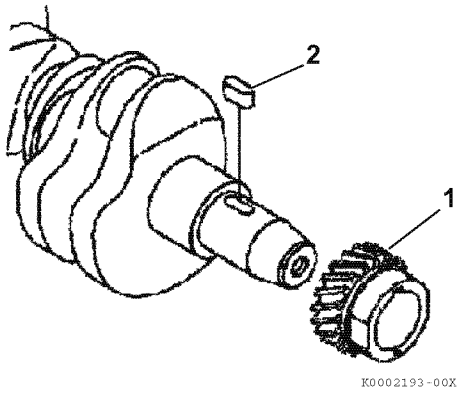


Figure 6-57

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

1. Remove the seal **(Figure 6-58, (2))** from the gear case cover **(Figure 6-58, (1))**.
2. 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.

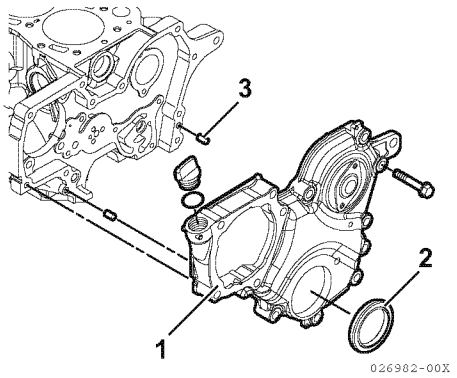


Figure 6-58

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

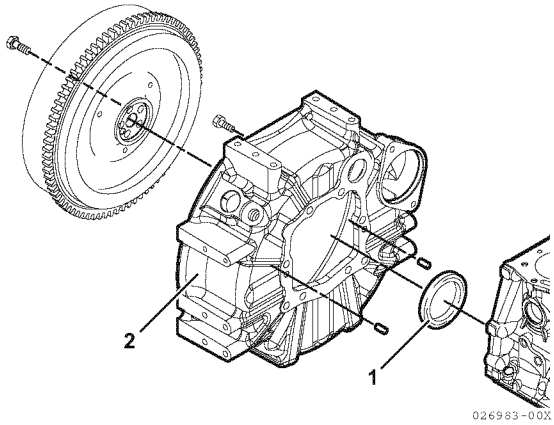


Figure 6-59

4. 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.*

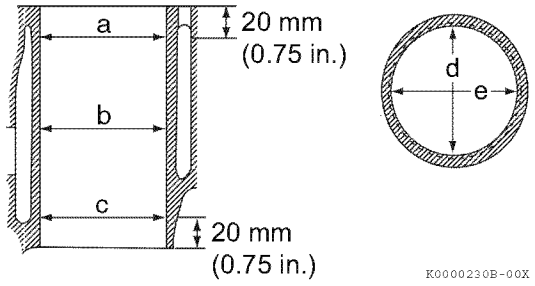


Figure 6-60

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.*

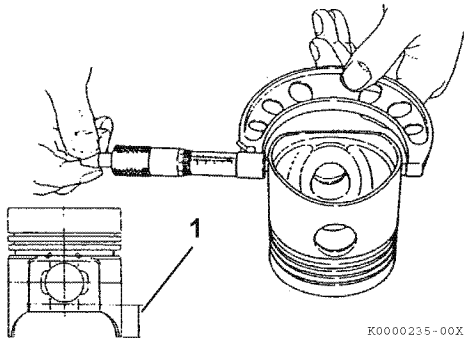


Figure 6-61

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.

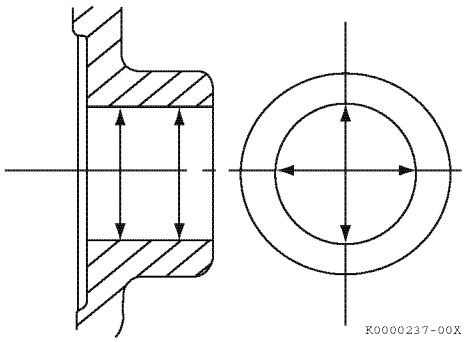


Figure 6-62

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.

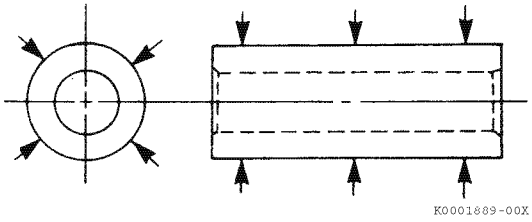


Figure 6-63

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.

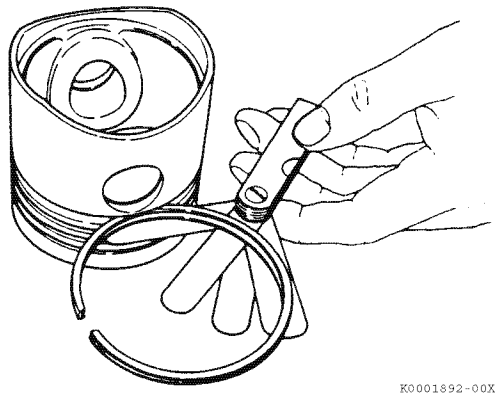


Figure 6-64

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.*

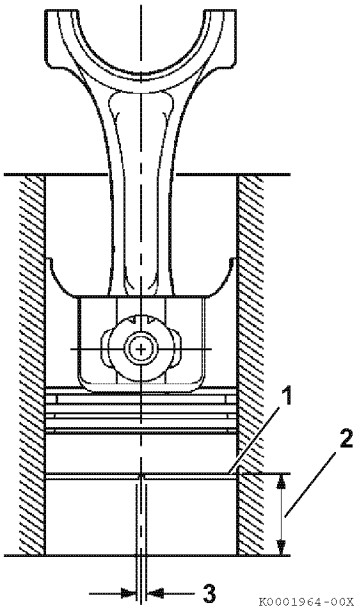


Figure 6-65

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.*

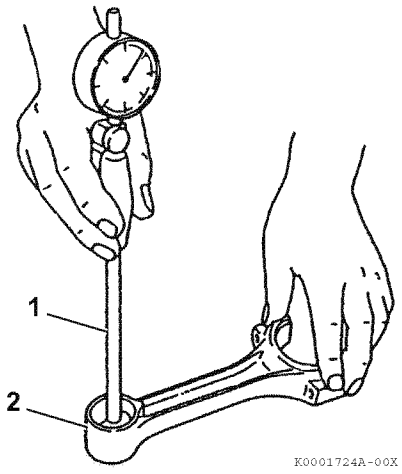


Figure 6-66

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.*

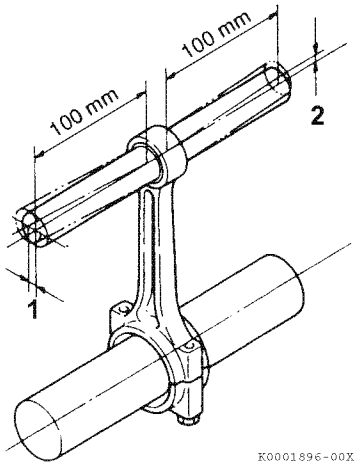


Figure 6-67

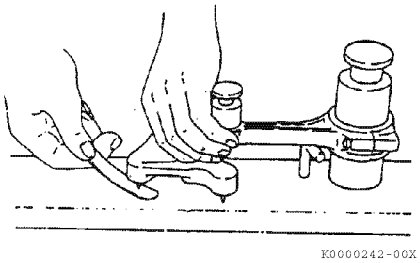


Figure 6-68

3. 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.
4. Measure the inside diameter. Record the measurements. *See Crankshaft on page 6-6 for specifications.*

Inspecting the Tappets

1. 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.

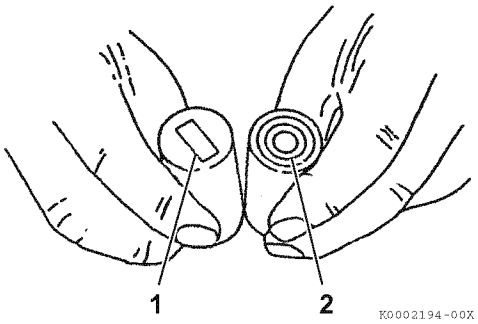


Figure 6-69

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

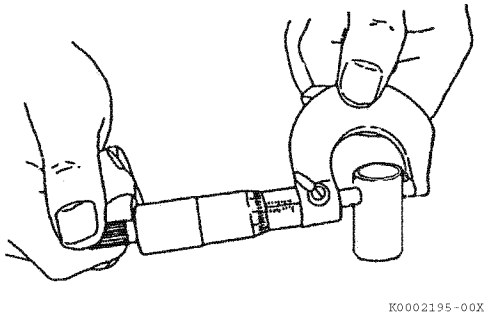


Figure 6-70

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

Inspecting the Crankshaft

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

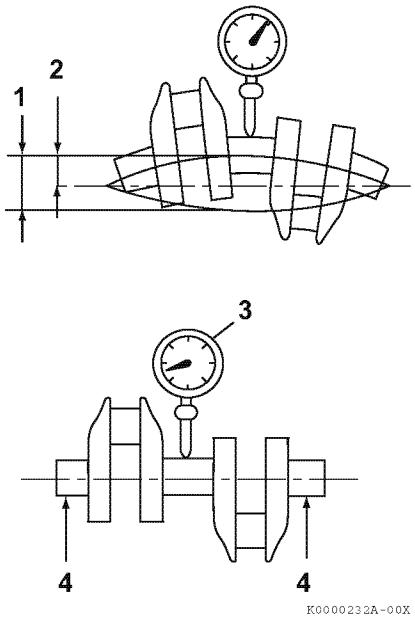


Figure 6-71

3. Rotate the crankshaft and observe runout. Record the measurements. *See Crankshaft on page 6-6 for specifications.*
4. Use the color check method or MAGNAFLUX to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures is found.
5. 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.

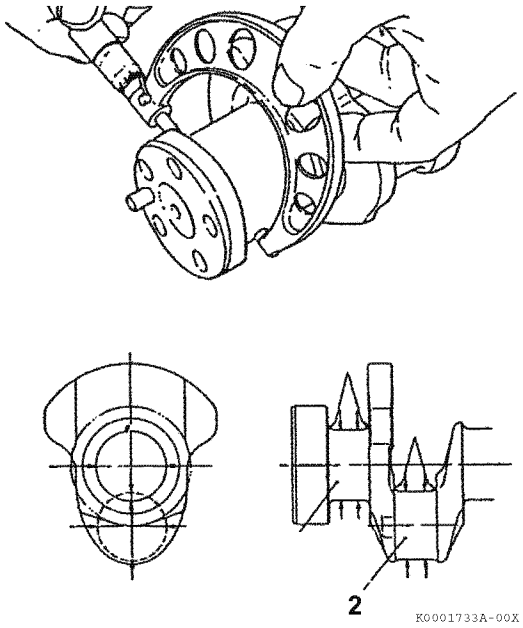


Figure 6-72

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:

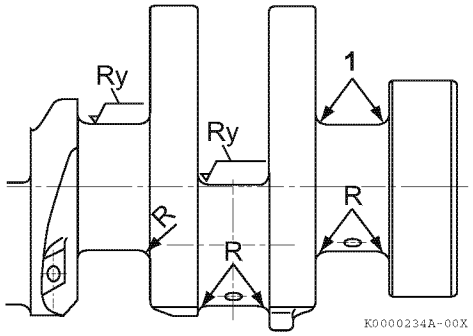


Figure 6-73

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.

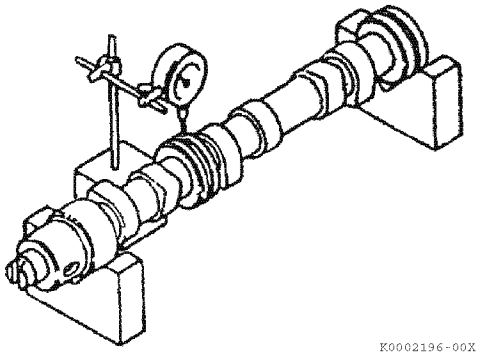


Figure 6-74

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.*

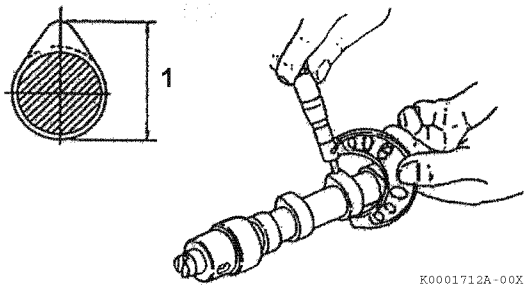


Figure 6-75

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.*

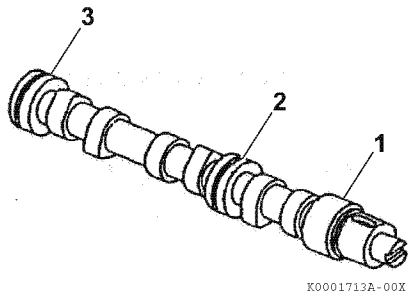


Figure 6-76

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.*

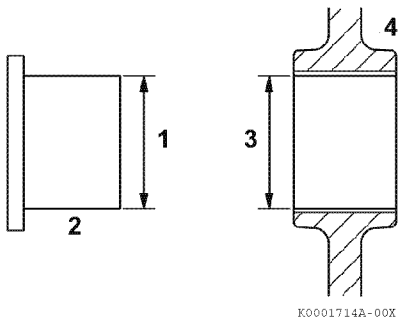


Figure 6-77

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.

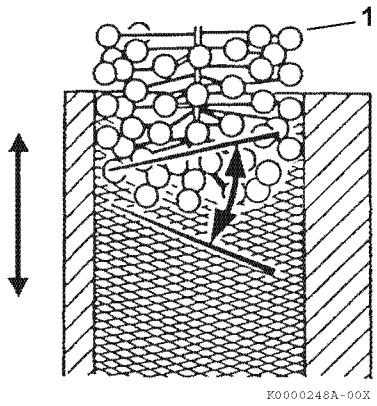


Figure 6-78

- 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)**.

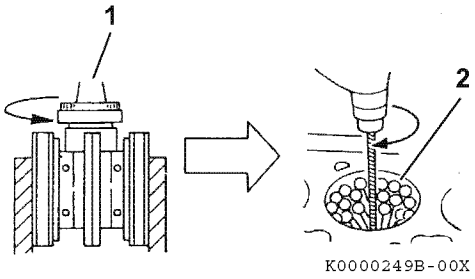


Figure 6-79

- 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.

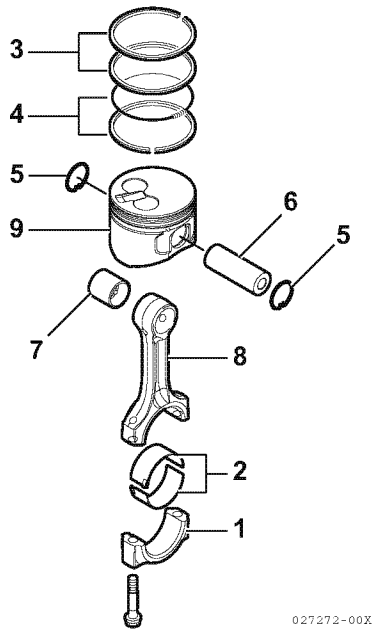


Figure 6-80

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.

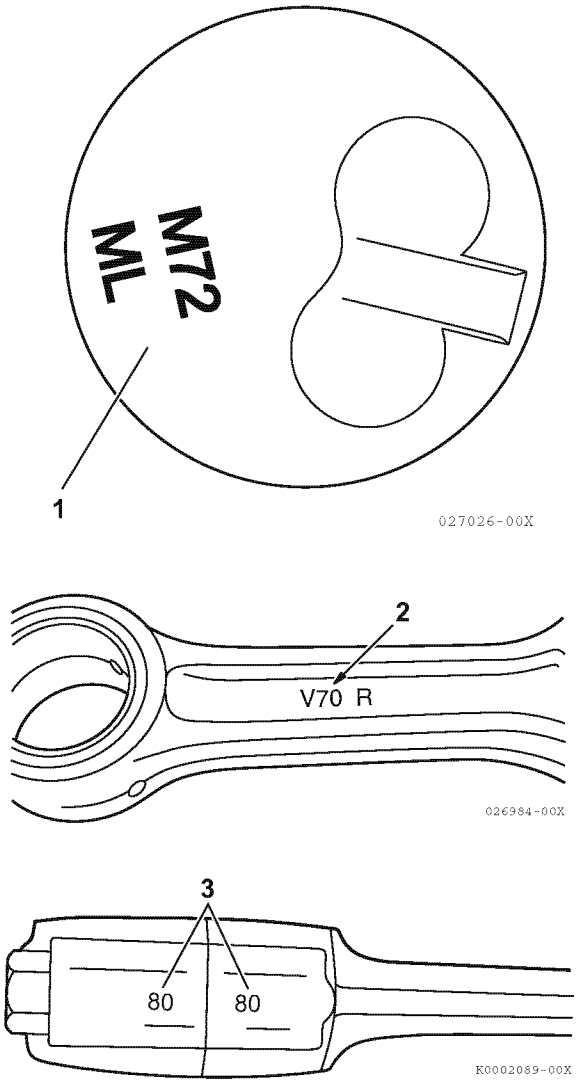
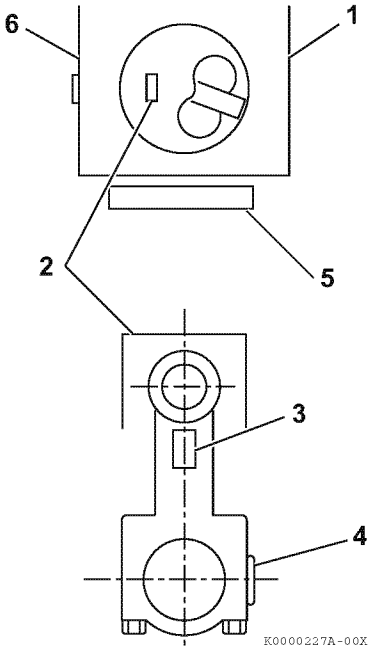


Figure 6-81

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.

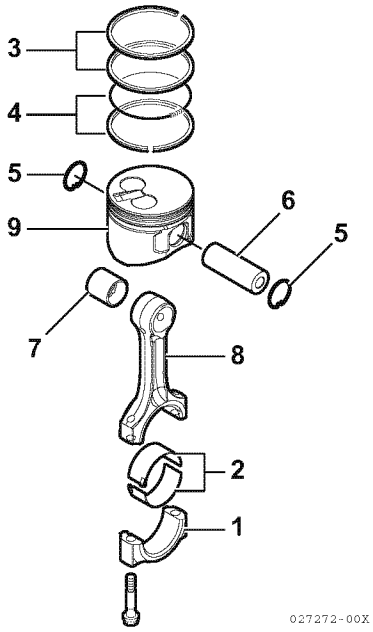


Figure 6-83

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.

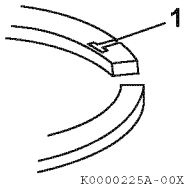


Figure 6-84

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.

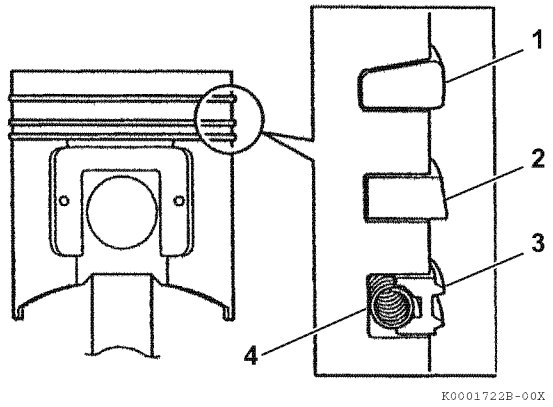
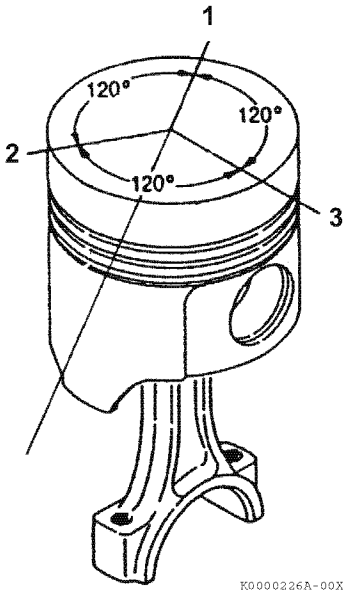


Figure 6-85

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.

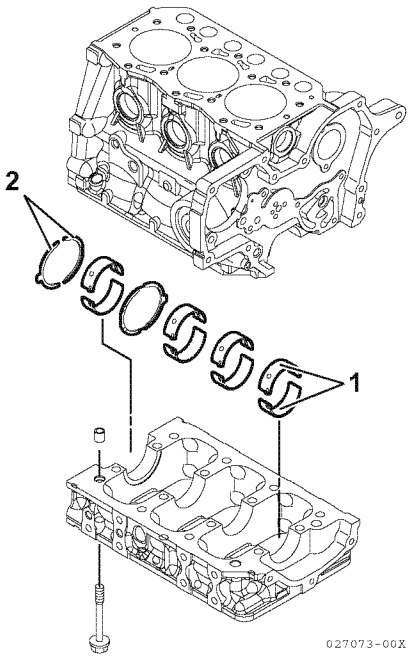


Figure 6-87

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).

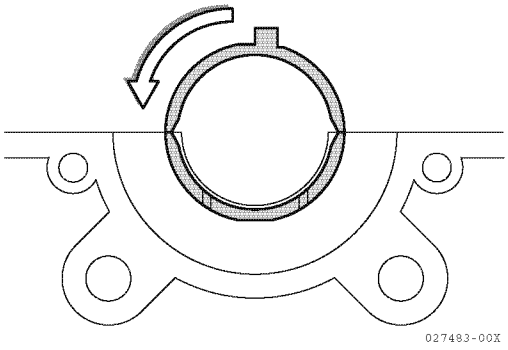


Figure 6-88

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

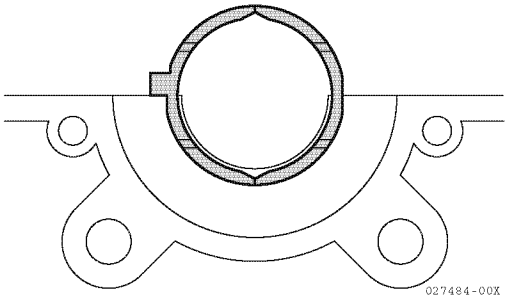


Figure 6-89

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.

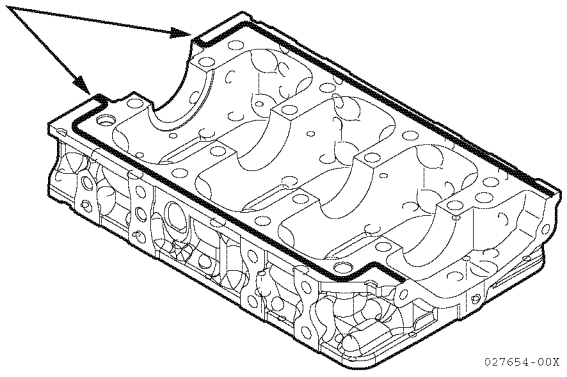
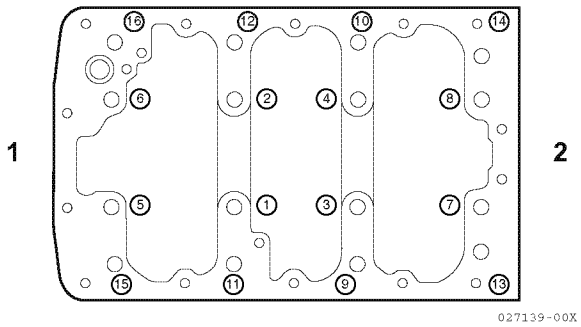


Figure 6-90

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.*

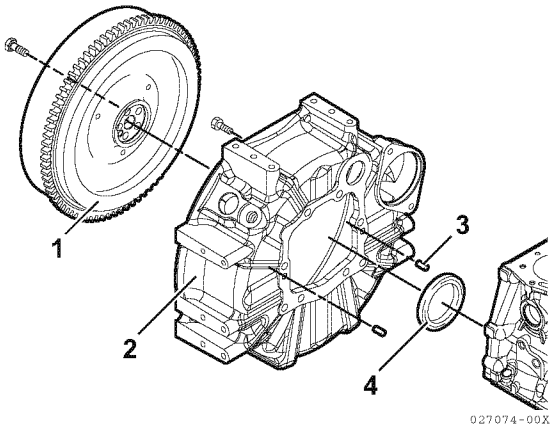


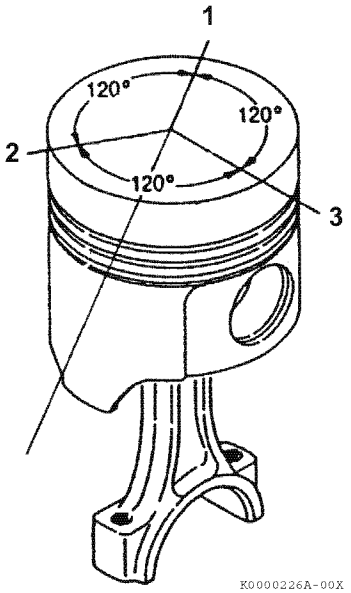
Figure 6-92

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

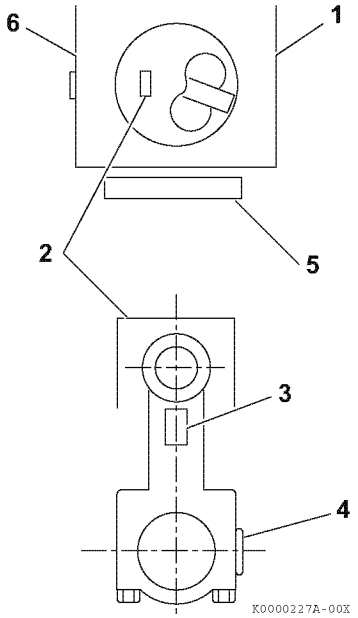
Ensure piston ring gaps are located correctly **(Figure 6-93)**.

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.*

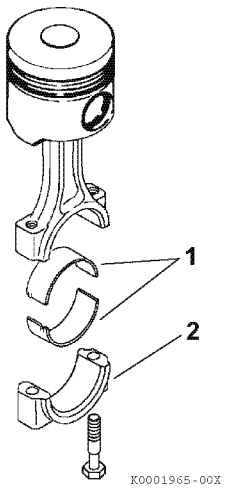


Figure 6-95

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))**.

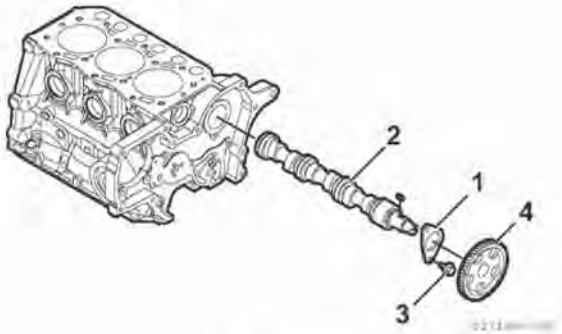


Figure 6-96

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. **3** 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.

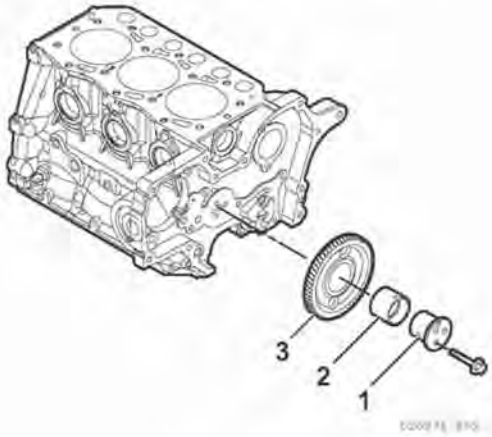
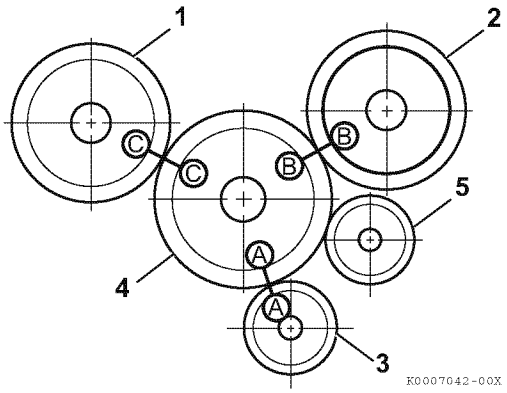


Figure 6-97

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.

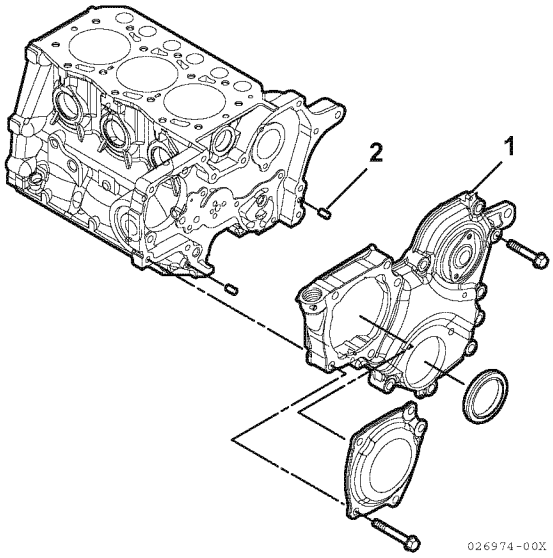


Figure 6-99

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))**.

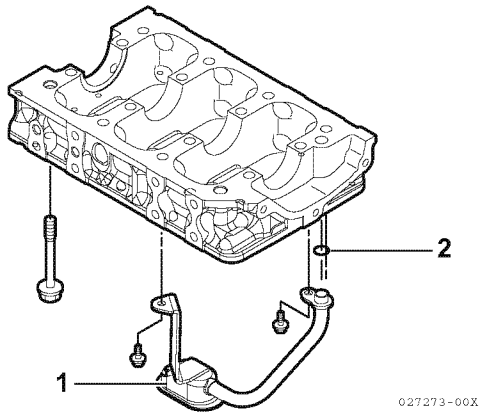


Figure 6-100

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.

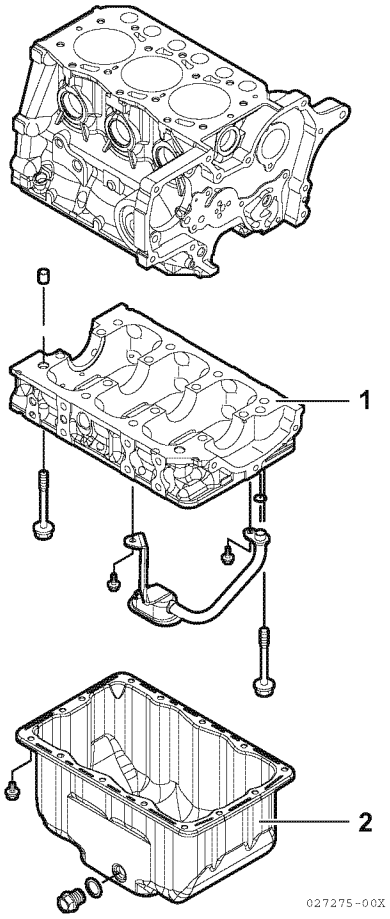


Figure 6-101

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.