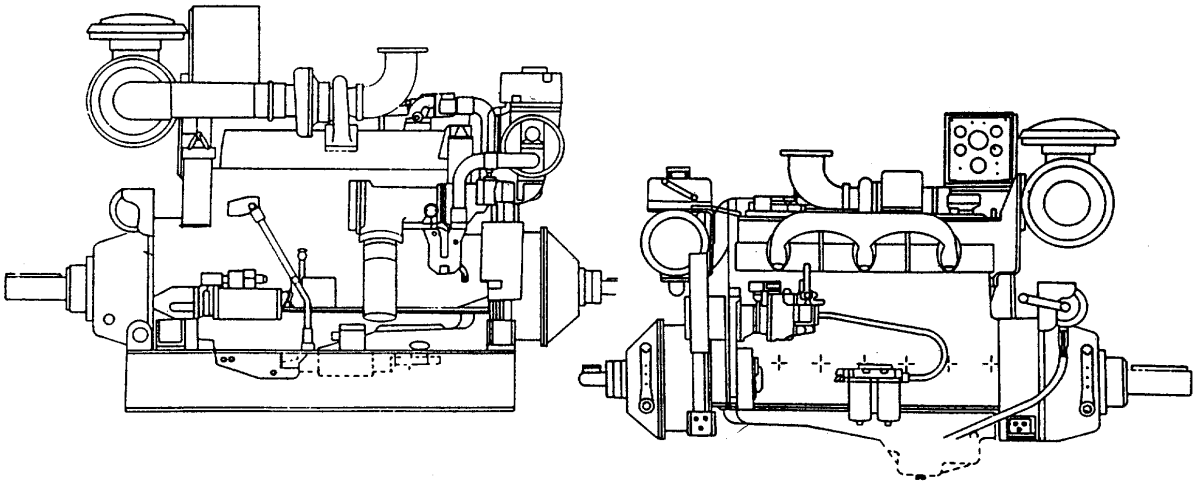
**TECHNICAL MANUAL**

**UNIT, INTERMEDIATE DIRECT SUPPORT**

**AND INTERMEDIATE GENERAL SUPPORT MAINTENANCE INSTRUCTIONS**

**BOWTHRUSTER ENGINE FOR LANDING CRAFT UTILITY (LCU) NSN 1905-01-154-1191**





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**For**
**LANDING CRAFT UTILITY (LCU)**
**NSN 1905-01-154-1191**

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MAINTENANCE INSTRUCTIONS

**BOWTHRUSTER ENGINE**
**for**
**LANDING CRAFT UTILITY (LCU)**
**NSN 1905-01-154-1191**

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Unit, Intermediate Direct Support
and Intermediate General Support
Maintenance Instructions

BOWTHRUSTER ENGINE
for
LANDING CRAFT UTILITY (LCU)
NSN 1905-01-154-1191

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| 4-51 and 4-52 | 4-51 and 4-52 |
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| 4-65 and 4-66 | 4-65 and 4-66 |
| 4-81 through 4-84 | 4-81 through 4-84 |
| 4-97 and 4-98 | 4-97 and 4-98 |
| B-5 through B-18 | B-5 through B-20 |

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**WARNING**

**MODIFICATION HAZARD**

Unauthorized modifications, alterations or installations of or to this equipment are prohibited and are in violation of AR 750-10. Any such unauthorized modifications, alterations or installations could result in death, injury or damage to the equipment.

**HIGH PRESSURE**
**HYDRAULIC SYSTEM HAZARDS**

**Hydraulic systems can cause serious injuries if high pressure lines or equipment fail.**

Never work on hydraulic systems or equipment unless there is another person nearby who is familiar with the operation and hazards of the equipment, and who can give first aid. A second person should stand by controls to turn off hydraulic pumps in an emergency. When the technicians are aided by the operators, the operators must be warned about dangerous areas.

**MOVING MACHINERY HAZARDS**

**Be very careful when operating or working near moving machinery.**

Running engines, rotating shafts, and other moving machinery parts could cause personal injury or death.

**ELECTRICAL HAZARDS**

Whenever possible, the power supply to the equipment must be shut off before beginning work on the equipment. Do not be misled by the term "low voltage." Potentials as low as 50 volts may cause death under adverse conditions.

Be careful not to contact 115-Vac input connections when installing or operating this equipment.

Whenever the nature of the operation permits, keep one hand away from the equipment to reduce the hazard of current flowing through the body.

**For Artificial Respiration, refer to FM 21-11.**

TECHNICAL MANUAL

No.55-1905-223-24-5

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., 17 January 1989

# UNIT, INTERMEDIATE DIRECT SUPPORT, AND INTERMEDIATE GENERAL SUPPORT MAINTENANCE INSTRUCTIONS

BOWTHRUSTER ENGINE
For
LANDING CRAFT UTILITY (LCU)
NSN 1905-01-154-1191

**REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS**

You can help improve this manual. If you find any mistakes or if you know of a way to improve these procedures, please let us know. Mail your letter -or DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in the back of this manual directly to: Commander, US Army Aviation and Troop Command, ATTN: AMSAT-I-MP, 4300 Goodfellow Blvd., St. Louis, MO 63120-1798. A reply will be furnished directly to you.



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# CHAPTER 1

# INTRODUCTION



## SECTION I. GENERAL INFORMATION

1-1. Scope. The scope of this manual is as follows:

a. Type of Manual. Unit, intermediate direct support, and intermediate general support maintenance manual.

b. Model Number and Equipment Name. Bowthruster Engine, Model NT855-M.

c. Purpose of Equipment. Provides drive power to the bowthruster waterjet unit to maneuver the craft and provides power to the auxiliary fire pump.

1-2. Maintenance Forms, Records, and Reports. Department of the Army forms and procedures used for equipment maintenance are those prescribed by DA Pam 738-750, The Army Maintenance Management System.

1-3. Destruction of Material. Refer to TM 750-244-3 for instructions covering the destruction of Army materiel to prevent enemy use.

1-4. Reporting Equipment Improvement Recommendations (EIR). If your equipment needs improvement, let us know. Send us an EIR. You, the user, are the only one who can tell us what you don't like about your equipment. Let us know why you don't like the design. Put it on an SF 368 (Quality Deficiency Report). Mail it to: Commander, U.S. Army Troop Support Command; ATMN: AMSTR-MOF; 4300 Goodfellow Blvd.; St. Louis, Missouri 63120-1798. We'll send you a reply.

1-5. Preparation for Storage or Shipment. Administrative storage of equipment issued to and used by Army activities will have preventive maintenance performed in accordance with the Preventive Maintenance Checks and Services (PMCS) charts before storing. When removing the equipment from administrative storage, the PMCS should be performed to assure operational readiness. Repacking of equipment for shipment or short term storage is covered in paragraph 245.

## SECTION II. EQUIPMENT DESCRIPTION AND DATA

1-6. General Description. The NT855-M is a 300 hp, 6 cylinder, water cooled diesel engine designed for marine use. This engine will furnish drive power to the bowtruster waterjet unit and to the number three fire pump.

1-7. Characteristics, Capabilities, and Features. A very broad view of the bowthruster engine is as follows:

a. Characteristics.

(1) Turbocharger allows more horsepower to be developed

(2) Fuel injectors deliver atomized fuel into the combustion chambers for ignition by heat of compressed air.

(3) Cooling is supplied by: coolant for engine operation heat; a lube oil cooler, which gives off heat to engine coolant; and an aftercooler, which cools (or warms) air before it reaches the turbocharger.

b. Capabilities and Features.

(1) Furnishes 300 hp to drive the waterjet.

(2) Has power takeoff clutch assemblies on each end to drive the waterjet and the auxiliary fire pump.

(3) Has both remote and local control station.

1-8. Location and Description of Major Components. FIGURE 1-1 shows views of each side of the engine with the locations of major components indicated. Refer to FIGURE 1-1 and the reference number key below for the description of these components.

a. Instrument Panel (1) An electrical panel on top of the engine that contains the local display of operational gauges and the switches for local control of the engine.

b. Air Cleaner (2). The filter canister and cover assembly located on the top, rear of the engine.

c. Intake Manifold (3). The intake air distribution piping (assembly) on the left side of the engine.

d. Sump Pump (4). The manually operated oil pump located on the left rear of the engine.

e. Fuel Filters (5). Two spin-on filters located together on the lower left side of the engine.

f. Lube Oil Pump (6). A gear driven pump located on the left front comer of the engine.

g. Fuel Pump (7). A PT (type G) pump and throttle assembly with a 24 volt shutoff valve, located on the left front of the engine.

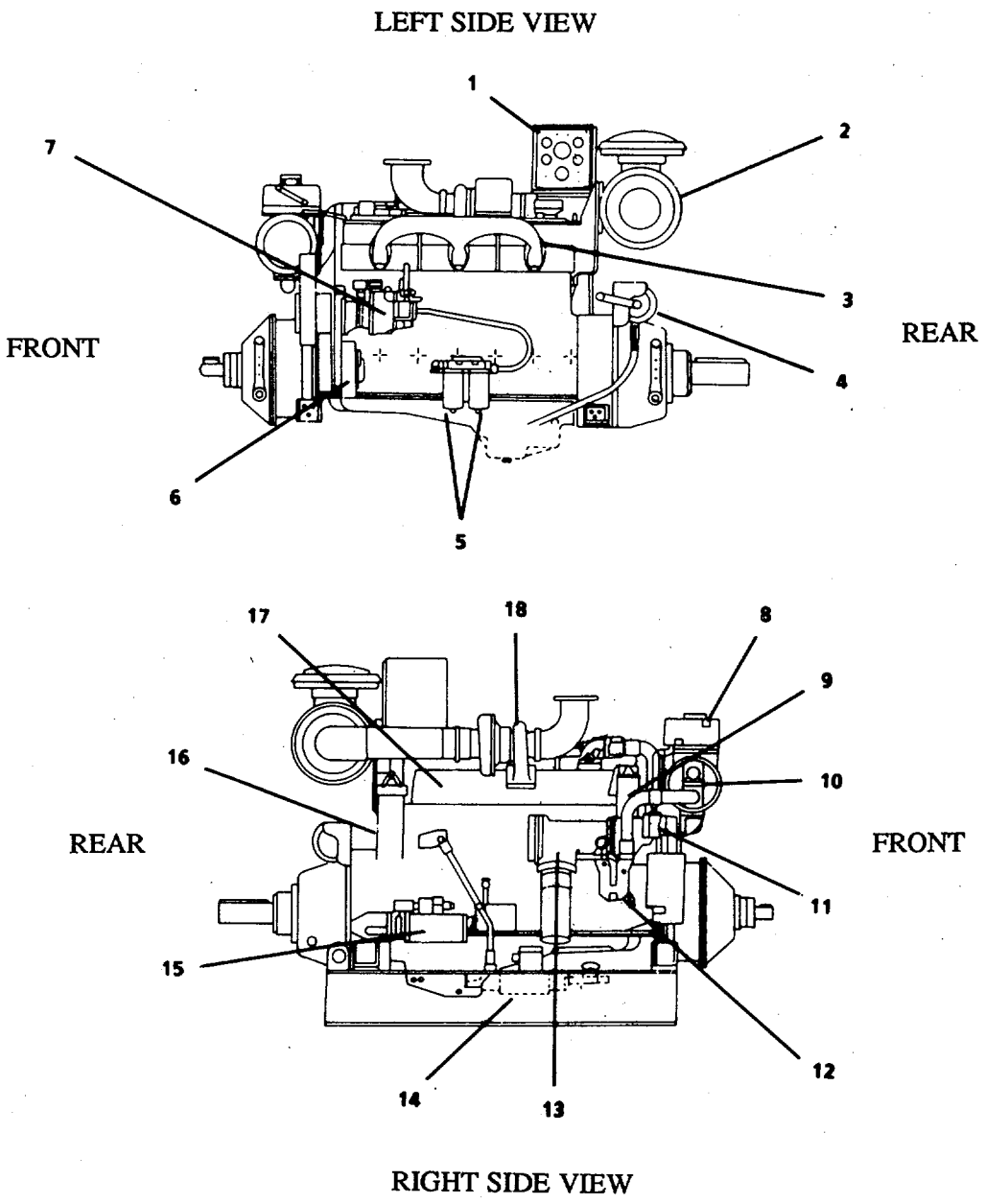


*FIGURE 1-1. Location of Major Components*

h. ExpansionTank(8). The fresh watertank with pressure cap and sight glass located on the top, front of the engine above the heat exchanger.

i. Water Filter (9). A spin-on filter located on the right side near the front of the engine.

j. Heat Exchanger (10). The horizontal, cylindrical tank assembly located on the front of the engine beneath the expansion tank

k. Fresh Water Pump (11). The belt driven pump located on the right front of the engine.

l. Seawater Pump (12). The U-shaped pump assembly on the right side of the engine connected to the heat exchanger seawater inlet piping.

m. Tube Oil Filter/Cooler (13). The spin-on filter and cooling core assembly located on the right side near the front of the engine.

n. Coolant Heater (14). The electric water jacket heater located at the right side of the oil pan.

o. Starter Motor (15). An electric motor, solenoid, and magnetic switch assembly on the right rear comer of the engine. The battery cables are connected to the starter.

p. Bypass Oil Filter (16). A spin-on filter located on the right rear comer near the top of the engine.

q. Exhaust Manifold (17). The water cooled exhaust air assembly on the right side of the engine. The turbocharger is mounted on this manifold.

r. Turbocharger (18). A turbine wheel unit mounted on the exhaust manifold on the right side of the engine.

s. Electrical System. Consists of the batteries, starter and solenoid, and instrument panel Batteries are located remote from the engine assembly. For maintenance information on batteries, refer to TM 55-1905-223-24-1.

1-9. Engine Identification Data. For model identification of an engine, check the data or serial number plate. The following example shows how the engine is identified.

NT 855-M
N = Model Identification
T = Turbocharged
855 = Cubic Inch Displacement
M = Marine Application

a. Engine Dataplate. The engine dataplate (FIGURE 1-2) shows specific information about your engine. The engine serial number and the Control Parts List (CPL) provide information for ordering parts and service needs.

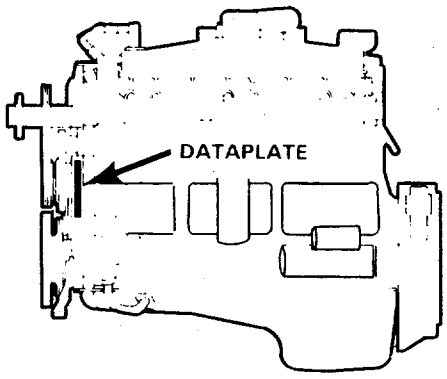


*FIGURE 1-2. Engine Dataplate Location.*

b. Serial Number and Control Parts List. Always record the serial number (1) of the engine, the CPL number (2), and the engine model number (3) on all orders for parts. This information is important for fuel pump calibration and correct identification of parts (FIGURE 1-3).

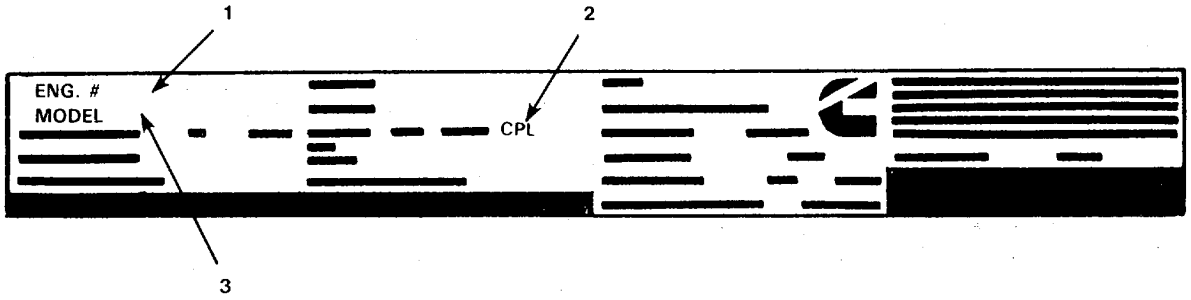


*FIGURE 1-3. Dataplate Information to Record.*

c. Fuel Pump Dataplate (Nameplate). The fuel pump dataplate is located on the top of the fuel pump. It provides information for fuel pump calibration (FIGURE 1-4).

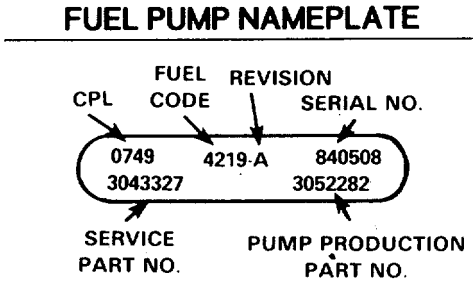


*FIGURE 1-4. Fuel Pump Dataplate.*

1-10. Equipment Data. Characteristics and reference data are provided in Table 1-1. Also see the equipment data given in the operator's manual, TM 55-1905-223-10.

Table 1-1. Equipment Data

| Characteristics | Reference Data |
|---|---|
| **GENERAL ENGINE DATA** | |
| Horsepower | 300 hp |
| Engine Speed at Maximum Output | 1800 rpm |
| Bore and Stroke | 5.5 in (140 mm) X 6.0 in (152 mm) |
| Displacement | 855 $in^3$ (14.0 litres) |
| Compression Ratio | 13.5:1 to 17.2:1 |
| Firing Order | 1-5-3-6-2-4 |
| Engine Weight (With Heat Exchanger and Clutches) | |
| Dry Weight | 3518 lb (1596 kg) |
| Wet Weight | 3757 lb (1704 kg) |
| Dimensions (overall) | |
| Length | 102.8 in (356.3 cm) |
| Width | 36.1 in (91.7 cm) |
| Height | 65.0 in (165.1 cm) |
| **AIR INDUCTION SYSTEM** | |
| Maximum allowable turbocharged intake restriction | 25 in $H_2O$ (64 cm $H_2O$) |
| **LUBRICATION SYSTEM** | |
| Oil pressure at idle (minimum allowable) | 10 psi (70 kPa) minimum |
| At no-load speed | 35-45 psi (240-310 kPa) |
| Oil capacity of engine: | |
| Bypass filter | 0.75 U.S. gl (2.8 liters) |
| Full flow filter | 0.93 U.S. gl (3.5 liters) |
| Oil pan capacity (high-low) | 9 to 7 U.S. gl (26-21 liters) |
| Total system capacity including filters | 11.0 U.S. gl (42 liters) |
| **COOLING SYSTEM** | |
| Coolant capacity (engine only) | 22 U.S. quarts (21 liters) |
| Standard thermostat modulating rang | 180-200°F (82-93°C) |
| Maximum coolant cylinder block pressure (pressure cap removed) | 40 psi (275 kPa) |
| Maximum allowable top tank temperature | 212°F (100°C) |
| Minimum recommended top tank temperature | 158°F (70°C) |
| Minimum recommended pressure cap | 7 psi (50 kPa) |

Table 1-1. Equipment Data - CONT

| Characteristics | Reference Data |
|---|---|
| **EXHAUST SYSTEM** | |
| Maximum allowable back pressure imposed by piping and silencer | 3 in Hg (75 mm Hg) |
| Exhaust pipe size (normally acceptable inside diameter) | 5 in (127 mm) |
| **FUEL SYSTEM** | |
| Engine idle speed | 650 to 750 rpm |
| Maximum allowable restriction to pump: | |
| With clean filter | 4 in Hg (100 mm Hg) |
| With dirty filter | 8 in Hg (200 mm Hg) |
| Maximum allowable fuel return line restriction: | 2.5 in Hg (63 mm Hg) |
| With check valves and/or overhead tanks | 6.5 in Hg (165 mm Hg) |
| Fuel Check Valve between Fuel Filter and Fuel Pump Minimum Opening Pressure | 0.3 psi (2.1 kPa) |
| Fuel Check Valve between Fuel Pump and Cylinder Head Opening Pressure | 3 to- 8 psi (21 to 55 kPa) |
| Fuel Check Valve in Fuel Drain Line Opening Pressure | 1/4 to 1/2 psi (13 to 25 mm Hg) |
| Derate Engine Fuel Rate for Hot Weather | 1% per 10° above 100°F (2% per 11°C above 380C) |
| Shutoff Valve Solenoid Coil Resistance 24 Volts (DC) | 28-32 ohms |
| **NOTE** The number of plates within a given battery size determines reserve capacity. Reserve capacity determines the length of time sustained cranking can occur. | |
| **ELECTRICAL SYSTEM** | |
| Maximum allowable resistance of starting circuit With 24-volt starter | 0.002 ohms |
| Minimum cranking speed without starting aid | 150 rpm |

1-11. Safety, Care, and Handling. Safety precautions must be observed at all times while performing maintenance. General WARNINGS and first-aid data appear in front of this manual. Review all safety information before starting any task. Carefully read through an entire maintenance procedure before performing any maintenance function. Make sure the task can be done safely. All WARNINGS, CAUTIONS, and NOTES are of great importance to your safety and the safety of the equipment.

## SECTION III. PRINCIPLES OF OPERATION

Overview. The principles of operation section will give you an overall description of how the bowthruster engine operates. Keep in mind that proper engine operation depends on two things: 1) Compression for ignition, and 2) that fuel be measured and injected into cylinders in the proper quantity at the proper time.

1-12. Diesel Engine Operation. Diesel engine operation is different from spark ignited engine operation. Compression ratios are higher and the charge taken into combustion chambers during the intake stroke consists of air only, with no fuel mixture. Injectors receive low-pressure fuel from the fuel pump and deliver it into individual combustion chambers at the proper time, in equal quantity, and in an atomized condition for burning. Ignition of fuel is caused by heat of compressed air in the combustion chamber.

a. Diesel Engine Cycles. It is easier to understand the function of engine parts if you know what happens in the combustion chamber during each of the four piston strokes of the cycle. The four strokes happen in this order: intake stroke, compression stroke, power stroke, and exhaust stroke (FIGURE 1-5). In order for the four strokes to function properly, valves and injectors must act in direct relation to each of the four strokes of the piston. The intake valves, exhaust valves, and injectors are camshaft actuated, linked by tappets or cam followers, push rods, rocker levers, and valve crossheads. The camshaft is driven by the crankshaft gear and that means rotation of the crankshaft directs the action of the camshaft, which then controls the opening and closing sequence of the valves and the injection timing (fuel delivery).

(1) Intake Stroke. During intake stroke, the piston travels downward, the intake valve is open, and exhaust valves are closed. The downward travel of the pistons allows air from the intake manifold to enter the cylinders. The intake manifold is pressurized with air from the turbocharger.

(2) Compression Stroke. At the end of the intake stroke, the intake valves close and the pistons starts upward on the compression stroke. The exhaust valves remain closed. At end of compression stroke, air in combustion chambers has been forced by the pistons to occupy a smaller space than it occupied at beginning of stroke, causing the air temperature to rise to a point high enough for ignition of fuel. During last part of compression stroke and early part of power stroke, a small metered charge of fuel is injected into the combustion chamber. Almost immediately after fuel charge is injected into combustion chamber, fuel is ignited by the existing hot compressed air.

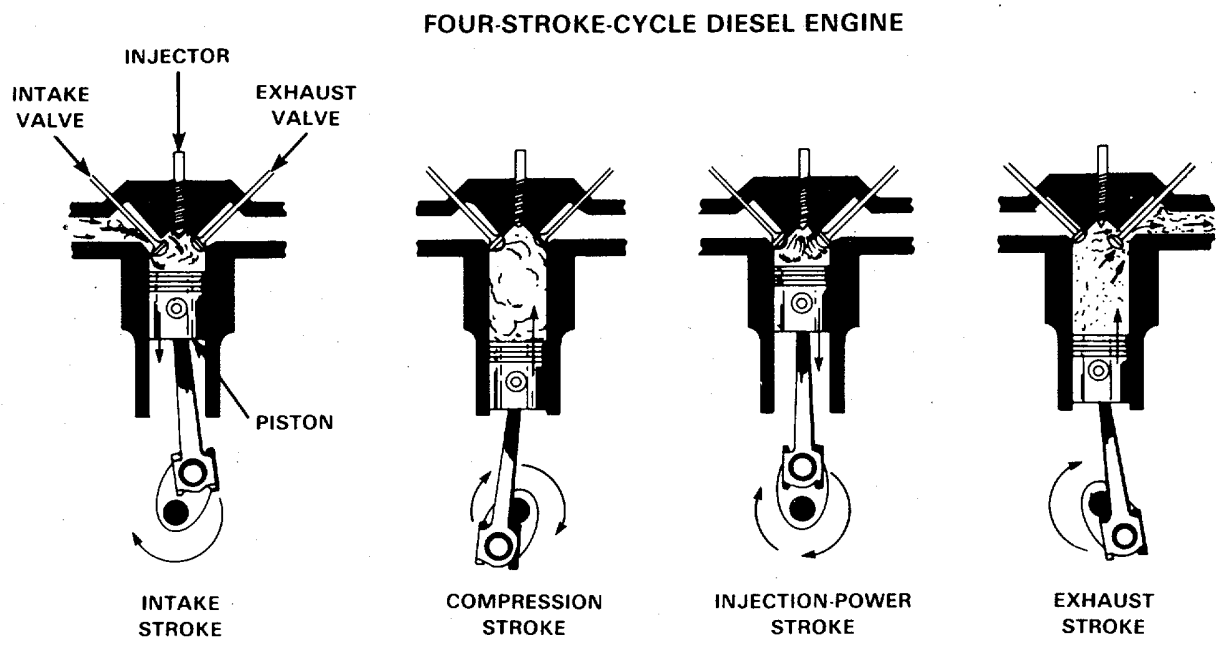


*FIGURE 1-5. Diesel Engine Cycles.*

(3) Power Stroke. During the beginning of the power stroke, the piston is pushed downward by the burning and expanding gases. Both intake and exhaust valves are closed. As more fuel is added and burns, gases get hotter and expand more, to further force the piston downward and add driving force to crankshaft rotation.

(4) Exhaust Stroke. During the exhaust stroke, intake valves are closed, exhaust valves are open, and piston is on the upstroke. Upward travel of the piston forces burned gases out of the combustion chamber through open exhaust valve ports and into the exhaust manifold.

b. Fuel System. The "pressure time" (PT) fuel system consists of the fuel pump, supply lines, drain lines, fuel passages and injectors.

(1) Fuel Pump. The fuel pump is coupled to the fuel pump drive which is driven from the engine gear train. Fuel pump main shaft in turn drives the gear pump, governor, and tachometer shaft assemblies. The PT (type G) fuel pump is made up of three main units: the gear pump, standard governor, and throttle.

(a) Gear Pump and Pulsation Damper. The gear pump is driven by the pump main shaft and contains a single set of gears to pick up and deliver fuel throughout the fuel system. Inlet is at the rear of the gear pump. A pulsation damper mounted to the gear pump contains a steel diaphragm which absorbs pulsations and smooths fuel flow through the fuel system. From gear pump, fuel flows through the filter screen.

(b) Throttle. The throttle provides a means for the operator to manually control engine speed above idle as required by varying operating conditions of speed and load. In the fuel pump, fuel flows to the throttle shaft. At idle speed, fuel flows past the throttle shaft. To operate above idle speed, fuel flows to the throttling hole in the shaft.

(2) PT Injectors. The injector provides a means of introducing fuel into each combustion chamber. It combines the acts of metering, timing, and injection.

(3) Fuel Lines and Connections. Fuel is supplied through lines to cylinder heads. A common drain line returns fuel not injected, to supply tank. Fuel connectors are used between the Inline engine cylinder heads to bridge the gap between each supply and drain passage.

(4) Shutdown Valve. An electric shutdown solenoid valve with a manual override is used on the fuel pump. In case of electrical failure, to start the engine, turn the manual knob clockwise to permit fuel to flow through the valve. To stop the engine, turn the knob fully counterclockwise. For normal operation with the electric valve, the manual control knob must be turned fully counterclockwise to permit the solenoid to open the valve when the switch is turned on.

c. Lubricating System. The bowthruster engine is pressure lubricated. Pressure is supplied by a gear type oil pump located on the side of the engine.

(1) System Operation. Oil is drawn into the pump through an external oil line connected to the oil pan sump. A screen in the sump filters the oil. Oil is drawn from the pan by the pump, out through a full-flow filter, and circulates back into the block.

(2) Lubricating Oil Flow. Oil flows from the pump to the filter/cooler, then flows to an oil header through internal drillings in the gear case. An oil header, drilled full length of block, fuel pump side, delivers oil to moving parts within the engine. Oil pipes carry oil from the camshaft to upper rocker housings and drillings through the block, crankshaft, connecting rods, and rocker levers complete the oil circulating passages.

d. Cooling System. The primary function of the cooling system is to remove the heat created by the engine and its support components. The excess heat energy that is not removed by the cooling system is carried away by exhaust gases and radiated into the atmosphere.

(1) Coolant Flow Path. Water (coolant) is circulated by a centrifugal water pump mounted on front of the engine. The water pump is belt driven. Water circulates around wet-type cylinder liners, through the cylinder heads, and around the injector sleeves. Injector sleeves, in which the injectors are mounted, are designed for fast dissipation of heat. The engine has a thermostat to control
engine operating temperature. FIGURE 1-6 shows the coolant flow path through the
engine.

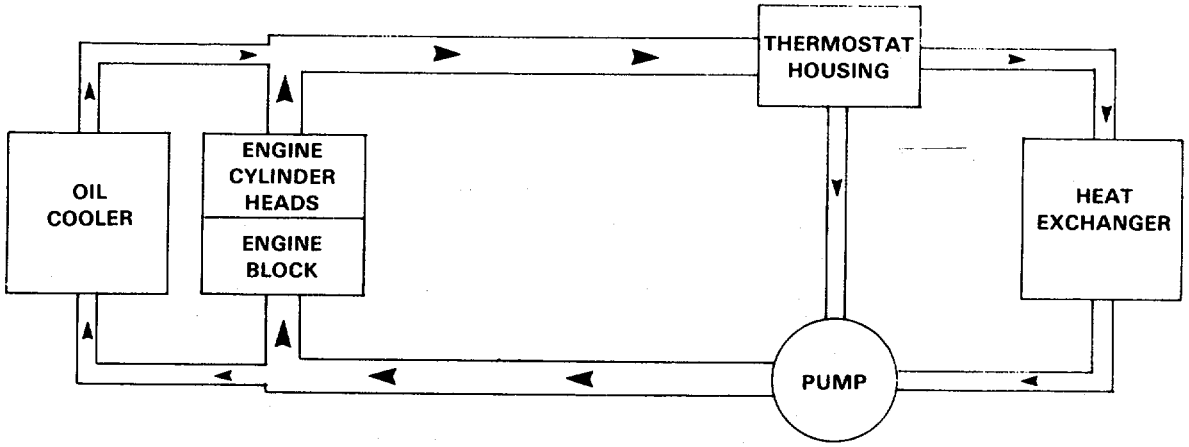


*FIGURE 1-6. Coolant Flow Path.*

(2) Water Filter. A water filter (corrosion resistor) bypasses a small amount of coolant from the system through a filtering and treating element which must be replaced periodically.

(3) Cooling System Venting. The cooling system must be designed to allow air to escape while filling the cooling system. During engine operation, coolant will continuously flow through the engine vent line to remove air. The cooling system vent line on traditional engines is plumbed from a one-eighth inch pipe trapped hole in the front water manifold to the heat exchanger tank above the coolant level.

(4) Coolant Cooling. The engine coolant is cooled in a heat exchanger. Sea water is circulated through the heat exchanger outlet connections.

(5) Coolant. Use ethylene glycol antifreeze year-round to provide freeze point and boil-over protection and always use good quality soft water in the cooling system. Refer to Army Technical Bulletin TB 55-1905-207-24, Treatment of Cooling Water, for antifreeze and additive requirements.

(a) Antifreeze. Too much antifreeze reduces freeze protection. Do not use more than 68 percent antifreeze or overheating may result. A mixture of 50 percent water and 50 percent antifreeze is sufficient for freeze protection to -34°F (-37°C).

(b) Sealing Additives. Sealing additives are not to be used in the cooling system. They will build up in the low flow areas and clog the cooling system.

(c) Soluble Oils. Do not use soluble oils in the cooling system. They may cause cylinder liner pitting and damage heat transfer surfaces, seals, and hoses.

(d) Coolant Additives and Filters. Diesel coolant additives are required to protect the cooling system from fouling and corrosion. The coolant filter is required to protect the coolant system from abrasive materials, debris, and precipitated coolant additives.

(6) Coolant Heating. The engine is equipped with a coolant heater that operates on the principle of thermosiphon when the engine is shut down. An oil pressure switch automatically turns the heater on and off. The heater comes on when the engine is shut down. Heated coolant expands and forces a flow check valve on the water inlet closed. The heated coolant is forced up the outlet to the top of the engine. When pressure drops in the tank, cold coolant enters the tank and the cycle is repeated. A flow through thermostat installed in the inlet line of the engine heater measures the coolant at its coldest point and keeps the coolant within the preset temperature range.

e. Air System. The diesel engine requires hundreds of gallons of air for every gallon of fuel that burns. For the engine to operate efficiently, it must breathe freely. Intake and exhaust systems must not be restricted. The intake air is routed through an air cleaner. The cleaner is mounted on the engine. Air is routed from air cleaner directly to intake air manifolds or turbocharger. The turbocharger forces additional air into combustion chambers, so that engine can burn more fuel and develop more horsepower than if it were naturally aspirated. The turbocharger consists of a turbine wheel and a centrifugal blower, or compressor wheel separately encased but mounted on and rotating with a common shaft. The power to drive turbine wheel - which in turn drives the compressor - is obtained from energy of the engine exhaust gases. Rotating speed of the turbine changes as the energy level of gas changes; therefore, the engine is supplied with enough air to burn fuel for its load requirements. The turbocharger is lubricated and cooled by engine lubricating oil.

f. Electrical System. The electrical power to the engine is a 24 volt circuit coming from the batteries to a magnetic switch, instrument panel, and starter motor and solenoid. Operational gauges and switches-for local control of the engine are mounted on the instrument panel on top of the engine.

# CHAPTER 2

# UNIT MAINTENANCE INSTRUCTIONS

Page



## SECTION I. REPAIR PARTS, SPECIAL TOOLS; TEST, MEASUREMENT, AND DIAGNOSTIC EQUIPMENT (TMDE); AND SUPPORT EQUIPMENT

2-1. Common Tools and Equipment. For authorized common tools and equipment refer to the Modified Table of Organization and Equipment (MTOE) applicable to your organization.

2-2. Special Tools, TMDE, and Support Equipment. Special tools; test, measurement, and diagnostic equipment; and support equipment requirements are listed and illustrated in the Repair Parts and Special Tools List (RPSTL), TM 55-1905-223-24P. These items are also listed in the Maintenance Allocation Chart (MAC), Appendix B of this manual.

2-3. Repair Parts. Repair parts are listed and illustrated in the Repair Parts and Special Tools List (RPSTL), TM 55-1905-223-24P.

## SECTION II. SERVICE UPON RECEIPT

2-4. Checking and Deprocessing Unpacked Equipment.

a. Inspect the equipment for damage incurred during shipment. If the equipment has been damaged, report the damage in accordance with the instructions of DA Pam 738-750.

b. Check the equipment against the packing slip to see if the shipment is complete. Report all discrepancies in accordance with the instructions of DA Pam 738-750.

c. Check to see whether the equipment has been modified.

d. Remove protective caps, plugs, inserts, wrappings and tape when inspection/inventory is completed. Inspect piping openings for damage. Wipe off dirt, grease, or protective films at time of installation.

e. Remove chocks from resilient mounted components.

2-5. Engine Break-in. The way a new engine is operated during the first 100 hours of service will have an important effect on the life of the engine and its parts. Even though all engines are run on a dynamometer for several hours before they leave the factory, an additional period of careful operation is required.

a. Engine Speeds. Avoid operation for long periods at engine idle speeds, or at maximum horsepower levels in excess of 5 minutes.

b. Engine Instruments. Develop the habit of watching engine instruments closely during operation and reduce speed if oil temperature reaches 250°F (121°C) or coolant temperature exceeds 190°F (88°C).

c. Oil Level. Check oil level every 10 hours during break-in period.

2-6. Preliminary Servicing and Adjustment. Follow these procedures when starting a new or rebuilt engine for the first time.

a. Priming the Engine. Prime the fuel and lubricating oil systems before attempting to start the engine.

(1) Fill fuel filter with clean, No. 2 diesel fuel oil.

(2) Remove suction line from fuel pump (paragraph 2-33) and prelubricate gear pump with 2 to 3 oz. (50 to 60 cc) of clean lubricating oil, Item 1, Appendix C. Reconnect the suction line.

(3) Check Fuel Tanks. There must be an adequate supply of clean, No. 2 diesel fuel in the tanks.

(4) If injector and valve or other adjustments have been disturbed by any maintenance work, check to be sure they have been properly adjusted before starting the engine.

CAUTION

Remove oil inlet line from the turbocharger (paragraph 2-26) and prelubricate bearing with 2 to 3 oz (50 to 60 cc) of clean lubricating oil, Item 1, Appendix C. Reconnect oil supply line.

(5) Fill crankcase until oil appears on dipstick.

(6) Remove plug from lubricating oil filter head and use this opening as the oil priming point.

CAUTION

Do not prime engine lubricating system from bypass filter.

(7) Connect a hand or motor-driven priming pump hose from source of clean lubricating oil to priming point.

(8) Prime until a 30 psi (207 kPa) pressure is obtained. Crank engine at least 15 seconds (with fuel shutoff valve closed or disconnected to prevent starting), while maintaining external oil pressure at a minimum of 15 psi (103 kPa). Remove priming hose and replace plug removed in step (6).

b. Oil Dipstick Gauge. All marine engines are shipped with unmarked lubricating oil dipstick gauges. The reason for this is the engine mounting angle is determined at installation; and even though a given amount of oil is required, the dipstick must be marked so the oil level is correct at the engine mounting angle. Should it be necessary to mark a new dipstick, use the following procedure.

(1) Remove the oil pan drain plug or use suction pump to be sure all oil is drained. Replace plug or close sump pump valve.

CAUTION

Any oil left in oil pan will cause error in marking; the oil sometimes accumulates as the oil drains from upper portions and oil passages within the engine.

(2) A tag is attached to new engines indicating high and low capacities of the oil pan. The capacity of the NTA 855 GC engine is 7 gallons (low) to 9 gallons (high).

(3) Fill engine with amount of oil listed as low-level oil pan capacity.

(4) Allow 5 minutes or more for oil to drain to the oil pan. If engine and/or oil temperature is below 40°F (4°C), a longer period may be required for full drain.

(5) Insert dipstick into gauge tube until fully seated; hold for 5 to 10 seconds, then withdraw slowly.

(6) Mark oil level indicated on dipstick with an electric etch. Depth of mark must not exceed 0.010 inch (0.24 mm). Etch "L" above mark.

(7) Add enough additional oil to fill engine to listed high-level capacity.

(8) Repeat Steps 4, 5, and 6. Etch letter "H" directly above the second or high level mark.

NOTE

The above procedure determines dipstick gauge marking for oil pan capacity only. Do not confuse with complete oil capacity, which also includes drilled passages, lines, and filters.

c. Air Connectors. Check air connections for loose clamps or connections, cracks, punctures, or tears in hose or tubing, collapsing hose, or other damage. Tighten clamps or replace parts as necessary to ensure an airtight air intake system. Make sure that all air goes through air silencer or air cleaner.

d. Engine Coolant. Remove expansion tank cap and check engine coolant supply. Add coolant and check water filter. Check for evidence of coolant leakage around tubing, hose connections, etc., and correct as necessary. Inspect water pump for leakage.

e. Fuel Connections. Visually check for any sign of leakage at fuel connections and tighten as necessary.

WARNING

Fuel spills or leaks create a fire hazard.

2-7. Starting the Engine. Starting requires that clean air and fuel be supplied to the combustion chamber in proper quantities at the correct time.

CAUTION

Protect the engine and engine components during startup by idling until normal idle oil pressure is obtained.

a. Starting Procedure.

(1) Open sea cocks to permit raw water flow through heat exchanger and marine gear cooler.

(2) Set throttle for idle speed.

(3) Disengage clutches to driven equipment.

NOTE

A manual override knob provided on the forward end of the manual electric shutdown valve on the fuel pump allows the valve to be opened in case of electric power failure. To use, open by turning full clockwise.

(4) Set the instrument panel run/start toggle switch to "START" and press starter button.

NOTE

To prevent permanent cracking motor damage, do not crank engine for more than 30 seconds continuously. If engine does not start within first 30 seconds, wait 1 to 2 minutes before cranking.

(5) Run engine for 5 minutes and turn engine off.

(6) Wait 5 minutes and check oil level. Add as required.

CAUTION

Never operate the engine with oil level below the low level mark (L), or above the high level mark (H).

b. External Leaks. Check for evidence of external oil leakage. Secure capscrews, fittings and connections, and replace gaskets and O-rings as necessary to correct. Check oil dipstick and filler tube caps; see that they are secure.

2-8. Engine Run-In. After each run-in step has been completed, carefully inspect the engine for fuel, oil, water, air, or exhaust leaks and correct as necessary.

a. Engine Dynamometer Run-In Schedule.

(1) 1200 RPM and 25% of rated load until water temperature reaches 160°F (71°C).

(2) 1200 RPM and 40% of rated load for 2 minutes.

(3) 1600 RPM and 65% of rated load for 5 minutes.

(4) Nominal torque peak RPM (100 below torque peak RPM) and full load for 4 minutes.

(5) Rated speed and full load for 4 minutes.

CAUTION

Do not stop the engine immediately after the last run-in step is completed. Serious engine damage can result.

b. Checks During Run-In. During engine run-in, make the following checks frequently.

(1) Oil Pressure. Pressure must not change while the engine is operating at a given RPM.

(a) Oil pressure should be 15 psi at idle speed.

(b) Oil pressure should be 50-70 psi at rated speed.

(c) Check the oil temperature. If the oil temperature rises above 225°F (107°C), stop the engine, locate the problem, and make the necessary corrections. Refer to Table 2-2.

NOTE

Check the oil pressure when the temperature of the oil in the oil pan is at 200 to 225°F (93 to 107°C).

(2) Engine Coolant. Temperature of engine coolant must be between 160°F (71°C) and 200°F (93°C) during engine operation.

2-9. Initial Setup Procedure. Includes operational checks and inspections that are not performed for a routine startup. Perform initial setup in accordance with the operator's manual, TM 55-1905-223-10.

2-10. Normal Startup. Refer to the operator's manual, TM 55-1905-223-10.

2-11. Shutdown Procedure (Usual and Unusual). Refer to the operator's manual, TM 55-1905-223-10.

## SECTION III. UNIT PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

2-12. Explanation of PMCS Table. PMCS is designed to keep the equipment in good working condition. This is accomplished by performing certain test, inspections, and services. Table 2-1 lists items to be serviced and the procedures needed to accomplish the PMCS. The "Interval" column tells you when to perform a check or service. If needed, PMCS may be performed more frequently than the indicated interval. The "Procedures" column tells you how to perform the required checks and services. If your equipment does not perform as required, see Table 2-2, Troubleshooting. Report any malfunctions or failures on DA Form 2404. In the "TM" Number column on DA Form 2404, record the appropriate Item Number from the PMCS table.

2-13. Intervals. Each PMCS time interval, except for daily and monthly, has a corresponding hours interval. These intervals, along with the repeat check requirements, are as follows:

a. Daily. Every 24 hours.

b. Monthly. Every 30 days.

c. Quarterly. Every 3 months or 250 operating hours (whichever occurs first). Repeat all daily and quarterly checks.

d. Annually. Every 12 months or 1000 operating hours (whichever occurs first). Repeat all daily and quarterly checks.

e. Biennially. Every 24 months or 2000 operating hours (whichever occurs first). Repeat all daily, quarterly, and annual checks.

f. Items which require PMCS according to operating hours only appear at the end of Table 2-1.

## Table 2-1. Preventive Maintenance Checks and Services (PMCS)

D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 1 | • | | | | | Belts | Visually inspect the engine. Look for glazed, loose, frayed, cracked, or misaligned belts.<br><br>Tighten, align, or replace belts as necessary (paragraph 2-29).<br><br>If the water pump belt and pulley can not be aligned, replace the water pump (paragraph 2-29).<br><br>Check for bent pulley, replace pulley (paragraph 2-29). |
| 2 | • | | | | | Hoses | CAUTION<br><br>Do not bend or deform the hoses during inspection. This can cause the hoses to crack.<br><br>Visually inspect all hoses for cracks or cuts and check for any signs of ballooning or collapsing. Replace as necessary.<br><br>Check for loose fittings and clamps, and signs of leakage. Tighten or replace as necessary.<br><br>For replacement, refer to paragraph 2-32.<br><br>Add coolant as necessary, refer to TB 55-1900-207-24 for antifreeze and other additives required. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)-CONT**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 3 | • | | | | | Batteries (remote from engine) | Remove the cell caps and check the electrolyte level in each cell. Add distilled water as required to bring the level to the split ring in each cell. Refer to TM 55-1905-223-24-18.<br><br>Visually inspect the terminals for loose, broken, or corroded connections.<br><br>a. Repair or replace broken cables or terminals.<br><br>b. On corroded terminals, remove the cables and clean with a battery brush. Connect the cables and tighten. |
| 4 | • | | | | | Oil Level | NOTE<br><br>Allow time for the oil to settle in the pan after engine shutdown.<br><br>Check the engine oil level. The oil level should be at, or near, the “H” (high) mark on the dipstick.<br><br>Add oil as necessary. Refer to LO 55-1905-223-12 for oil specifications. |

## Table 2-1. Preventive Maintenance Checks and Services (PMCS)-CONT

D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 5 | • | | | | | Coolant Level | WARNING<br>Check the coolant level only when the engine is stopped. Wait until the temperature is below 120°F.<br>(50°F) before removing the pressure cap. Failure to do so can cause personal injury from hot coolant spray.<br>Check the coolant level. The sight gauge should be 3/4 full or level, it should be at or near, the bottom of the fill neck on the expansion<br>Add coolant as necessary. Refer to TB 55-1900-207-24 for antifreeze and other additive requirements on make-up required. |
| 6 | • | | | | | Intake Air System | Check all air connections for loose clamps or connections, and tighten as required.<br>Check all hoses and tubing for cracks, punctures and tears, and replace as required.<br>Check for collapsing hoses or tubing and other damage, and replace as required. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)-CONT**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 7 | • | | | | | Throttle Linkage | Check for binding, loose fittings, and other obstructions/hat affect the smooth operation of the throttle throughout its range.<br>Adjust as necessary:<br>a. Remove the throttle linkage from the throttle lever.<br>b. Hold the lever in the idle position. Move the linkage to the idle position.<br>c. If the lever and linkage are not aligned, adjust the linkage.<br>d. Move the lever and linkage to the maximum speed position.<br>e. If the lever and linkage are not aligned, adjust the linkage.<br>f. Install the linkage on the lever.<br>NOTE<br>The throttle linkage must be able to reach minimum and maximum stops during remote operation. |
| 8 | • | | | | | Exhaust System | Check for exhaust leaks and correct as required.<br>Check for corrosion and clean as required. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)-CONT**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 9 | • | | | | | Engine (General) | Visually check for air, water, fuel, or oil leaks.<br><br>Tighten any loose connections, fittings or capscrews. |
| 10 | | • | | | | Cooling System | Check for rust and scale formation in the system.<br><br>If rust or scale is found, the system must be cleaned and flushed. Refer to TB 55-1900-207-24.<br><br>NOTE<br><br>Install a new Pre-Charge (DCA) type fitter element before filling the system. Refer to paragraph 2-23. |
| 11 | | | • | | | Fuel Filters | Remove the fuel filters by turning them counterclockwise with a filter wrench.<br><br>Clean the filter head gasket surface with a clean rag (Item 2, Appendix C).<br><br>Apply a light film of clean engine oil to the gasket surface on the filter.<br><br>Fill the new filters with clean fuel. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)-CONT**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 11 | | | | | | Fuel Filters - continued | Install the new filters on the filter head.<br>a. Tighten the fitter until it contacts the filter head surface.<br>b. Tighten an additional one-half to three quarter turn. |
| 12 | | | • | | | Engine Oil | Remove the engine oil after 250 hours operation. Sample engine oil and send to the Army Oil Analysis Program.<br>a. Run the engine until it reaches operating temperature and then shut it off.<br>b. Allow time for the oil to settle in the pan.<br>c. Drain the oil.<br>(1) Open the suction valve in the sump pump line into the oil pan.<br>(2) Manually pump the old oil into the waste oil tank.<br>(3) Close the sump pump valve.<br>NOTE<br>Replace the full-flow and bypass oil filters before adding clean oil. Refer to Item No. 13 of this table. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)-CONT**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 12 | | | | | | Engine Oil - continued | Add clean oil until the level is et the “H” (high) mark on the dipstick. Refer to LO 55-1905-223-12 for oil specifications.<br><br>Operate the engine and check for oil leaks. Correct as necessary. |
| 13 | | | • | | | Oil Filters (Full-Flow and Bypass) | Replace oil filters quarterly or after 250 hours of operation (whichever comes first).<br><br>a. Remove the full-flow and bypass filters.<br><br>b Clean the filter heads with a clean rag (Item 2, Appendix C)<br><br>c. Apply a light film of clean engine oil to the gasket surface of the filters.<br><br>d. Fill the filters with clean oil.<br><br>e. Install the new filters onto their filter heads.<br><br>f. Tighten until the filter contacts the filter head surface.<br><br>g. Tighten an additional three-quarter to one turn. a: |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)-CONT**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 13 | | | | | | Oil Filters - continued | Operate the engine and check for leaks.<br>NOTE<br>The old filter should be cut open with a filter cutter and inspected. Inspect the element for metal particles. If metal particles are found in the element, direct support maintenance is required. |
| 14 | | | • | | | Air Filter | a. Remove the air cleaner housing cover and remove the filter element (paragraph 2-25).<br>NOTE<br>The air filter element may be cleaned several times by using compressed air, or by washing with a non-sudsing detergent and hot water, then drying with compressed air.<br>b. Install a cleaned or new element, making sure that it seats properly on the gasket end, and put the cover back on the housing. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 15 | | | • | | | Crankcase/Breather/Tube | Remove the breather and tube assembly. Refer to paragraph 2-34.<br><br>NOTE<br><br>Foam-type elements must be replaced.<br><br>Clean the wire mesh element and the inside of the tube with a clean rag and cleaning solvent (Item 2 and 5, Appendix C). Visually inspect all parts of the assembly for cracks or other damage and make replacement as necessary.<br><br>Assemble and install the assembly on the engine (paragraph 2-34).<br><br>WARNING<br><br>Wait until the water temperature is below 120°F (50°C) before removing the coolant system pressure cap or removing filters. |
| 16 | | | • | | | Coolant Filter (Corrosion Resistor) | Close the shutoff valve(s).<br><br>Remove the filter by turning counter clockwise.<br><br>Discard the filter.<br><br>Clean the filter head with a clean rag (Item 2, Appendix C). |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 16 | | | | | | Coolant Filter (Corrosion Resistor) - continued | Apply a light film of lubricating oil to the gasket surface of a new filter.<br><br>Install the new filter. Refer to paragraph 2-23.<br><br>a. Tighten until the filter contacts the head gasket surface.<br><br>b. Tighten an additional one-half to three-quarter turn.<br><br>Open the shutoff valves. |
| 17 | | | • | | | Zinc Plugs (Anodes) | Remove and check the zinc plug in the Heat Exchanger.<br><br>Replace the plug if it has deteriorated to one half of its original size. |
| 18 | | | • | | | Engine (Exterior) | CAUTION<br><br>Be sure that all access covers, filters, oils dipstick and filter caps are in place before cleaning engine. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)-CONT**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 18 | | | | | | Engine (Exterior)-continued | NOTE<br>Protect surrounding areas with tarpaulins, plastic sheeting, or similar material before cleaning the engine.<br>Clean the engine exterior. Be sure to clean areas hidden by external components. Use a dry cleaning brush (Item 23, Appendix C), and detergent (Item 35, Appendix C).<br>The engine may be wiped down and dried thoroughly. |
| 19 | | | | • | | Engine Mounts | Check the tightness of mounting capscrews.<br>Using torque wrench kit (P/N 3377216) torque as required (135 ft-lb).<br>Replace any broken or missing bolts, nuts, and washers. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 20 | | | | • | | Coolant Heater | Inspect the beater assembly for corrosion.<br>Refer to paragraph 2-32. |
| 21 | | | | • | | Safety Controls | NOTE<br>Engine safety controls should be hooked up to a horn or other warning device.<br>Check the High Water Temperature Control<br>a. Remove the sensing unit and check the closing of the circuit against a thermometer immersed in water.<br>b. Heat the water to activate the temperature control The horn or warning device should sound at, or near, 200°F (93°C).<br>c. Replace sensing unit if necessary.<br>Check the Lubricating Oil Pressure Sending Device.<br>a Check for broken electrical wiring.<br>b. Check for loose or broken sending device. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 21 | | | | | | Safety controls continued | c. Disconnect the sending device from the main oil rifle on the fuel pump side of the engine and use a sending device of known accuracy to verify the reading of the suspect unit. |
| 22 | | | | | • | Injectors | Replace injectors (paragraph 2-35). |
| 23 | | | | | • | Water Pump | Replace the water pump (paragraph 2-29). |
| 24 | | | | | • | Turbocharger Bearing | Check the bearing radial and axial clearances.<br><br>Remove the shield and piping from the turbocharger.<br><br>Measure the axial (erg-to-end) clearance of the shaft with a dial indicator. Clearance should be not greater than 0.018 inch (0.46 mm).<br><br>Use a wire feeler gauge and measure the radial (side-to-side) clearance. Hold the shaft toward the feeler gauge to check. The clearance should be no greater than 0.033 inch (0.84 mm).<br><br>Replace the turbocharger if either measurement exceeds specifications above, Refer to paragraph 2-26.<br><br>NOTE<br>This procedure is to be performed after every 50 hours of operation. |

## Table 2-1. Preventive Maintenance Checks and Services (PMCS)

D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 25 | | | | | | Friction Clutch Assembly, PTO Main Shaft Bearing (POT-214 only) | Apply 4-6 strokes from a hand operated grease gun through the fitting located at the housing hub (paragraph 2-42).<br><br>NOTE<br>The next two procedures are to be performed after every 100 hours of operation. |
| 26 | | | | | | PTO Clutch Shaft Bearing (SL-111 and SP214) | Apply 2 strokes from a hand operated grease gun to fittings on clutch shafts (paragraph 2-41 and 2-42). |
| 27 | | | | | | Friction Clutch Assembly PTO Throwout Collar | Apply 1 stroke from a hand operated grease gun to fittings on the tapered part of the housings (paragraph 2-42). |
| 28 | | | | | • | Cooling System | WARNING<br>Do not remove expansion tank from a hot engine. Hot steam will cause serious personal injury.<br><br>Drain cooling system.<br><br>a. Open draincock. |

**Table 2-1. Preventive Maintenance Checks and Services (PMCS)**

**D-Daily M-Monthly Q-Quarterly A-Annually B-Biennially**

| Item No. | Interval D | M | Q | A | B | Items To Be Inspected/Serviced | Procedures |
|---|---|---|---|---|---|---|---|
| 28 | | | | | | Cooling System-continued | b. Remove lower expansion tank hose.<br>c. Remove pipe plug and water pump body<br>NOTE<br>If engine has one or more tank type coolant heaters, remove pipe plug from bottom of each. |
| | | | | | | Fill cooling system. | a. Close radiator draincock.<br>b. Install lower expansion tank hose.<br>c. Install pipe plug in water pump body.<br>NOTE<br>If engine has one or more tank type coolant heaters, remove pipe plug from bottom of each.<br>d. Add coolant, refer to TB 55-1900-207-24 for antifreeze and other additives required.<br>e. Install expansion tank cap.<br>f. Operate engine and check for leaks. |
| 29 | | | | • | | Valves and Injectors | Adjust valves and injectors every 1500 hours or annually whichever occurs first. Refer to page 3-32 para (5)-0. |

## SECTION IV. UNIT MAINTENANCE TROUBLESHOOTING

**2-14. Procedures and Techniques.** A thorough analysis of the problem is the key to successful troubleshooting. The more information known about a problem, the faster and easier it can be solved.

a. Troubleshooting Charts. Table 2-2, Troubleshooting, is organized so that a problem can be located and corrected by doing the easiest and most logical things first. Complete all steps in the sequence shown from top to bottom.

b. Troubleshooting Steps. Follow these basic troubleshooting steps:

(1) Get all the facts concerning the complaint.

(2) Analyze the problem thoroughly.

(3) Relate the symptoms to the basic engine systems and components.

(4) Consider any recent maintenance or repair action that may relate to the problem.

(5) Double-check before beginning any disassembly.

(6) Solve the problem by using the logic charts and doing the easiest things first.

(7) Determine the cause of the problem and make a thorough repair.

(8) After repairs have been made, operate the engine to make sure the cause of the problem has been corrected.

**2-15. General Engine Noise Diagnostic Procedures**. When diagnosing engine noise problems, make sure that noises caused by accessories, such as the air compressor and power takeoff, are not mistaken for engine noises. Remove the accessory drive belts to eliminate noise caused by these units. Noise will also travel to other metal parts not involved in the problem. The use of a stethoscope can help locate an engine noise.

a. Frequency of Engine Noise. Engine noises heard at the crankshaft speed (engine rpm) are noises related to the crankshaft, rods, pistons, and piston pins. Noises heard at the camshaft speed (one-half of the engine rpm) are related to the valve train. A hand-held digital tachometer can help to determine if the noise is related to components operating at the crankshaft or camshaft speed.

b. Isolating Engine Noise. Engine noise can sometimes be isolated by holding down the injector plungers one at a time (refer to Table 2-2, Item 21, Step 3). If the volume of the noise decreases or the noise disappears, it is related to that particular engine cylinder.

c. Accessory Noise. Engine driven components and accessories, such as geardriven fan clutches, hydraulic pumps, belt-driven alternators, and turbochargers can contribute to engine noise. Use the following information as a guide to diagnosing engine noise.

d. Main gearing Noise (refer to Table 2-2. Item No. 37). The noise caused by a loose or worn main bearing is aloud, dull knock heard when the engine is pulling a load. If all main bearings are loose or worn, a loud clatter will be heard. The knock is heard regularly every other revolution. The noise is loudest when the engine is "lugging" or under a heavy load. The knock is duller than a connecting rod noise. Low oil pressure can also accompany this condition. If the bearing is not loose or worn enough to produce a knock by itself, the bearing can knock if the oil is too thin, or if there is no oil at the bearing. An intermittent sharp knock can indicate wom crankshaft thrust bearings resulting in excessive crankshaft end clearance. Clutch disengagements can cause a change in the noise.

e. Connecting Rod Bearing Noise (refer to Table 2-2. Item No. 35). Connecting rods with excessive clearance knock at all engine speeds and under both idle and load conditions. When the bearings begin to come loose or worn, the noise can be confused with piston slap or loose piston pins. The noise increases in volume with engine speed. Low oil pressure can also accompany this condition.

f. Piston Noise (refer to Table 2-2. Item No. 36). It is difficult to tell the difference between piston pin, connecting rod, and piston noise. A loose piston pin causes aloud double knock which is usually heard when the engine is idling. When the injector to this cylinder is held down, a noticeable change will be heard in the sound of the knocking noise. However, on some engines, the knock becomes more noticeable when the engine is operated at a steady speed.

**2-16. White Smoke-General Information.** White smoke is the result of incomplete combustion and is generally associated with engine startup at low ambient temperatures. This condition is more predominant on high horsepower fixed injection timing engines because the fuel and combustion systems are optimized for maximum performance and for reliability and durability under high load operating conditions.

a. Starting at Low Ambient Temperatures. These engines can have two or three cylinders that misfire or have incomplete combustion when the engine is started at low ambient temperatures. The fuel that is injected into the cylinders that are misfiring is exhausted into the atmosphere as unburned hydrocarbons which cool, condense, and appear as white smoke. As the cylinder temperature and subsequently the coolant temperature rise, the misfiring cylinders begin to sustain combustion which decreases the hydrocarbon level in the exhaust, resulting in less white smoke being produced.

b. Level of White Smoke. Since white smoke is a normal characteristic of high horsepower, heavy-duty diesel engines during startup at low ambient temperatures, it is extremely important to determine if the level of white smoke is significantly higher than normal for a particular engine model before making any attempt to correct a complaint. This can be accomplished by comparing the level of white smoke from one unit to another which has the same chassis configuration and engine model. If a significant difference in the level of white smoke between the two units is noted under the same operating conditions, refer to Table 2-2, Item No. 34, “excessive White Smoke at Idle” for corrective action.

**2-17. Symptom Index.** Both a symptom index and a troubleshooting table are provided. The symptom index will help you locate the information you need for troubleshooting.

SYMPTOM INDEX

SYMPTOM INDEX - CONT



**2-18. Troubleshooting Table.** Table 2-2 lists the common fault conditions that may be found during operation or maintenance of the equipment. Look for causes and do corrective actions in the order listed. This manual cannot list every symptom that may show up, and it cannot list all of the possible causes and corrective actions. If a symptom is not listed, or if it keeps up after you have performed the corrective actions, notify your supervisor.

**2-19. How to Use the Troubleshooting Table.**

a. Locate the Item Number malfunction, and aligned with the top word in the Table 2-2 heading.

b. The middle item in the table heading refers to a test or inspection you should perform, labeled as steps, and starting at the top with the easiest to repair, and continuing downward to the most difficult.

c. The last item in the Table 2-2 heading column provides a brief description of the corrective action with a paragraph number reference for the repair procedure, where applicable.

## Table 2-2. Troubleshooting

**MALFUNCTION**
**TEST OR INSPECTION**
**CORRECTIVE ACTION**

WARNING

Make sure engine is cooled to below 120°F (50°C) to avoid burn injury.

1. Coolant temperature above normal.

STEP 1. Check for low coolant level.
Add coolant as required (refer to PMCS Table 2-1, Item 5).

STEP 2. Check for collapsed or restricted hoses.
Replace hoses as needed (paras. 2-23, 2-29, and 2-32).

STEP 3. Check for loose water pump belt.
Check belt tension and tighten if necessary (para. 2-29).

STEP 4. Check for incorrect oil level.
Add or drain engine oil (refer to PMCS Table 2-1, Item 4).

STEP 5. Check for malfunctioning temperature gauge.
a. Test the gauge as follows:
(1) Check for a tripped circuit breaker on the instrument panel (para. 2-22).
(2) Check the wiring from the gauge to the sending unit for a broken connection.
(3) Check the temperature sending unit in the front upper water manifold (para. 2-24).
(4) Use a temperature gauge of known accuracy to check system.
(5) Replace faulty gauge (para. 2-22).

STEP 6. Check for incorrect or malfunctioning pressure cap.
Check the gasket on expansion tank fill cap (para. 2-35).

STEP 7. Check for air in the cooling system.
a. Remove pressure cap from the expansion tank.
b. Install a pressure cap which has had the spring and relief valve removed to allow free flow from the overflow tube.
c. Attach a hose to the overflow connection.
d. Put the hose end into a container of water.
e. Operate the engine until water temperature reaches 180°F (80°C).
f. Check for a continuous flow of bubbles coming from the end of the hose submerged in water.;
g. A continuous flow of air bubbles indicates the following:
(1) Aftercooler core leaks.
(2) Cylinder liner protrusion incorrect.
(3) Cracked cylinder liner.
(4) Cylinder head or gasket leakage.

## Table 2-2. Troubleshooting-CONT

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

h. If no bubbles are present, do the following:
(1) Remove the test equipment.
(2) Check coolant level and fill if necessary.
(3) Install the expansion tank pressure cap.
(4) Operate the engine until it reaches a temperature of 180°F (80°C) and check for coolant leaks.

STEP 8. Check for over concentration of antifreeze and/or supplemental coolant additives.
Check coolant concentration (TB 55-1900-207-24).

STEP 9. Check for incorrect or malfunctioning thermostat, do the following:
a. Remove the upper radiator hose from the thermostat housing.
b. Install a hose of the same size on the thermostat housing outlet long enough to reach a remote dry container used to collect coolant.
c. Install and tighten a hose clamp on the housing outlet.
d. Install the end of the hose in a dry container.
e. Operate the engine at idle for one (1) minute.
f. Shut the engine off, and measure the amount of coolant collected in the container.
g. The amount of coolant collected must not be more than 3.3 fluid ounces (100 cc).
h. If more than 3.3 fluid ounces (100 cc) of coolant is collected, the thermostat seal is leaking.
i. Remove the thermostat and inspect thermostat and thermostat seal (para. 2-24).

STEP 10. Water pump malfunctioning.
Replace water pump (para. 2-29).

STEP 11. Check for obstructed or damaged oil cooler.
Replace oil cooler (para. 2-30).

2. Coolant temperature below normal.

STEP 1. Check for malfunctioning temperature gauge.
a. Test the gauge as follows:
(1) Check for a tripped circuit breaker on the instrument panel (para. 2-22).
(2) Check the wiring from the gauge to the sending unit for a broken connection.
(3) Check the temperature sending.unit in the front upper water manifold for proper operating temperature (para. 2-24).
(4) Use a temperature gauge of known accuracy to check system. -
(5) Replace faulty gauge (para. 2-22).

## Table 2-2. Troubleshooting-CONT

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 2. Check for incorrect or malfunctioning thermostat, do the following:

a. Remove the upper heat exchanger hose from the thermostat housing.
b. Install a hose of the same size on the thermostat housing outlet long enough to reach a remote dry container used to collect coolant.
c. Install and tighten a hose clamp on the housing outlet.
d. Install the end of the hose in a dry container.
e. Operate the engine operated RPM for one (1) minute.
f. Shut the engine off, and measure the amount of coolant collected in the container.
g. The amount of coolant collected must not be more than 3.3 fluid ounces (100 cc).
h. If more than 3.3 fluid ounces (100 cc) of coolant is collected, the thermostat or the thermostat seal is leaking.
i. Remove the thermostat and inspect thermostat and thermostat seal (para. 2-24).

3. Loss of engine coolant (overflow).

STEP 1. Check for overfilled cooling system.
Drain coolant to proper level.

STEP 2. Check for dirt, scale or sludge in the cooling system.
Clean cooling system (TB 55-1900-207-24).

STEP 3. Check for frozen coolant due to incorrect antifreeze concentration.
Check coolant antifreeze concentration (TB 55-1900-207-24).

STEP 4. Check for overheating engine.
Refer to Malfunction 1 of this table.

4. Loss of engine coolant (external leakage).

STEP 1. Check for incorrect or malfunctioning expansion tank fill cap.
Check the gasket on expansion tank fill cap (para. 2-35).

STEP 2. Check for loose hose clamp.
Tighten clamp to 40 in-lb. torque.

STEP 3. Check for leaking hoses.
Inspect hoses. Replace if necessary.

STEP 4. Check for leaking coolant draincocks.
Check, tighten or replace if necessary.

STEP 5. Check for leaking coolant expansion plugs, pipe plugs, or fittings.
Tighten or replace if necessary.

## Table 2-2. Troubleshooting-CONT

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 6. Check for incorrectly installed or leaking, cylinder head, water pump, oil cooler, and thermostat housing gaskets.
Install new gaskets as required (paras. 2-40, 2-29, 2-30, and 2-24, respectively).

STEP 7. Check for leaking lubricating oil cooler.
a. Tighten capscrews (para. 2-30).
b. Replace oil cooler (para. 2-30).

STEP 8. Check for leaking water pump seal. Replace water pump (para. 2-29).

5. Loss of engine coolant (internal leakage).

STEP 1. Check fresh water for oil contamination. Replace damaged coolant hoses and tubings.

STEP 2. Check for leaking lubricating oil cooler core. Replace oil cooler core (para. 3-14).

6. Low lubricating oil pressure.

STEP 1. Check for incorrect oil level. Add engine oil to proper level.

STEP 2. Check oil pressure gauge for malfunction. Replace oil pressure gauge (para. 2-22).

STEP 3. Check for fuel diluted oil. Refer to Malfunction 13.

STEP 4. Check for incorrect oil specifications. Change oil (LO 55-1905-223-12).

STEP 5. Check for oil temperature above normal 250°F. Refer to Malfunction 8.

STEP 6. Check for broken oil transfer or suction tube. Replace tubes and fittings (para. 2-44).

STEP 7. Check for plugged oil cooler core.
a. Visually inspect the cooler core for plugged or damaged tubes.
b. Replace oil cooler core (para. 2-30).

7. High lubricating oil pressure.

STEP 1. Check for incorrect oil.
Change oil (LO 55-1905-223-12).

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 2. Check oil pressure gauge for malfunction. V
- a. Check for broken electrical wiring between gauge and sending unit.
- b. Check for loose or broken gauge or loose electrical wiring connection to gauge.
- c. Replace oil pressure gauge (para. 2-22).

STEP 3. Check for low oil temperature.
- a. Check oil cooler bypass valve operation (FIGURE 2-1).

WARNING

The flash point of new lubricating oil is approximately 430°F (220°C). Do not allow oil temperature in the container to exceed 300°F (150°C). Do not allow water droplets to enter the container of hot oil. Water droplets will cause a violent reaction which can cause personal injury.

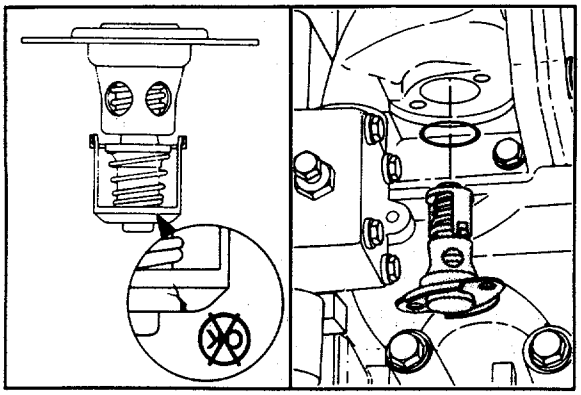

*FIGURE 2-1. Oil Cooler Bypass Valve.*

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

b. Suspend the valve and a 240°F (115°C) thermometer in a container of new lubricating oil. Do not allow the valve or the thermometer to touch the sides of the container.
c. Heat the lubricating oil.
d. Note the temperature at which the valve is fully extended. The valve must be fully extended to at least 2.770 inches (70.36 mm) when the temperature reaches 234°F (112°C) (FIGURE 2-2).
e. Replace the valve if it does not operate as described.

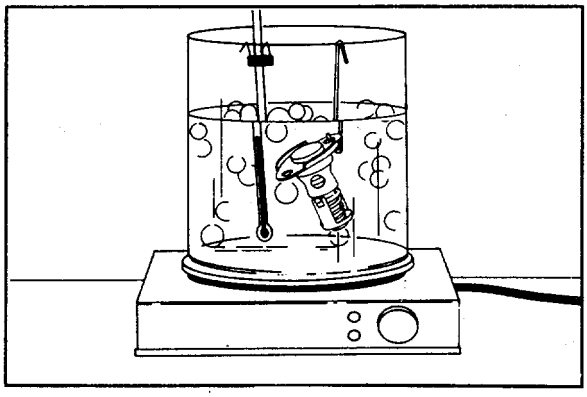

*FIGURE 2-2. Oil Cooler Bypass Valve Temperature Check.*

STEP 4. Check for defective oil filter/cooler.

WARNING

Carefully cut the lubricating oil filter open. The filter element spring is under compression and can cause personal injury.

.

a. Cut the top off the oil filter, remove the-filter element, and inspect the filter element for evidence of moisture or metal particles (FIGURE 2-3). '

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

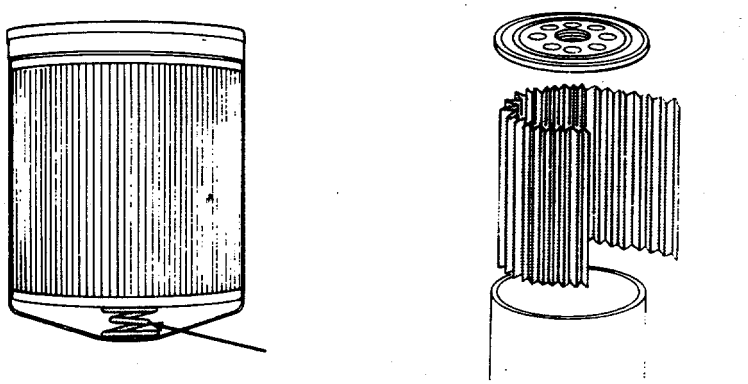

*FIGURE 2-3. Oil Filter/Cooler.*

| Metal | Probable Source | Reference |
|---|---|---|
| Copper | Bearings and Bushings | |
| Chromium | Piston Rings | |
| Iron | Cylinder Liners | |
| Lead | Bearing Overlay Material | |
| Aluminum | Piston Wear or Scuffing | |

NOTE

Sample engine oil and send to the Army Oil Analysis Program to determine metal type.

b. Check for plugged oil cooler by visually inspecting the cooler core for plugged or damaged tubes. Replace oil cooler core (para. 2-30).
c. Check for leaking oil cooler core. Replace oil cooler core (para. 3-14).

8. Lubricating oil temperature above normal.

STEP 1. Check for incorrect oil level.
Add or drain oil as necessary (Table 2-1, Item 4).

STEP 2. Check for high engine coolant temperature.
a. Check thermostat operation (para. 2-24).
b. Check for damaged coolant hoses and tubings.
c. Tighten loose water pump belt (para. 2-29).
d. Replace water pump (para. 2-29).

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 3. Check oil temperature gauge for malfunction.

a. Check the electrical wiring between the gauge and sending unit for breaks or grounded circuit.

b. Check for loose or broken sending unit.

c. Drain engine oil, refer to LO 55-1905-223-12.

d. Remove oil temperature sending unit and substitute an oil temperature gauge of known accuracy to verify reading of suspect gauge and/or sending unit.

e. Fill engine with oil, refer to LO 55-1905-223-12.

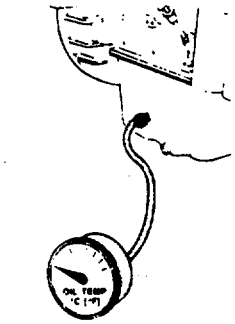

*FIGURE 24. Oil Temperature Gauge.*

f. Run engine until engine is at normal operating temperature.

g. Replace oil temperature gauge and sending unit if readings differ.

h. Drain oil (refer to LO 55-1905-223-1V and reinstall sending unit.

i. fill engine with oil, refer to LO 55-1905-223-12.

STEP 4. Check oil cooler bypass valve for malfunction. Refer to Item 7, Step 3.

9. Lubricating oil in coolant.

STEP 1. Check for malfunctioning lubricating oil cooler.

a. Remove oil cooler core (para. 3-14) and check for leakage.

b. Replace oil cooler core (para. 3-14).

## Table 2-2. Troubleshooting-CONT

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 2. Check cylinder head gasket for leaks.
Replace head gasket (para. 2-41).

STEP 3. Check for cracked or porous cylinder head.
Pressure test the cylinder head (para. 4-12).
Replace the cylinder head (para. 2-41).

10. Excessive lubricating oil loss.

STEP 1. Check for external oil leaks.
Tighten capecrews, pipe plugs and fittings.

STEP 2. Incorrect dipstick calibration.
Check dipstick calibration and guide tube (para. 2-6b).

STEP 3. Check for incorrect oil
Change oil (LO 55-1905-223-12).

STEP 4. Check for fuel contaminated oil.
Refer to Malfunction 13.

STEP 5. Check for incorrect (extended) oil change internals.
Refer to LO 55-1905-223-12.

STEP 6. Check for high oil temperature above 205°F (96°C).
Check engine oil and coolant levels.

STEP 7. Check for malfunctioning turbocharger seat

a. Add one unit of fluorescent tracer to each 10 gallons of engine lubricating oil.

b. Operate the engine at low idle for 10 minutes.

c. Shut off the engine.

d. Allow the Charger to cool and remove the exhaust pipe from the turbine housing (para. 2-26).

e. Use a high intensity black light to inspect the turbine outlet for oil.

**NOTE**

A dark blue glow indicates fuel and yellow glow indicates oil.

f. Replace turbocharger (para. 2-26).

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 8. Check for internal leaks.

a. Measure the blowby by installing a plug in the crankcase breather vent (FIGURE 2-5).

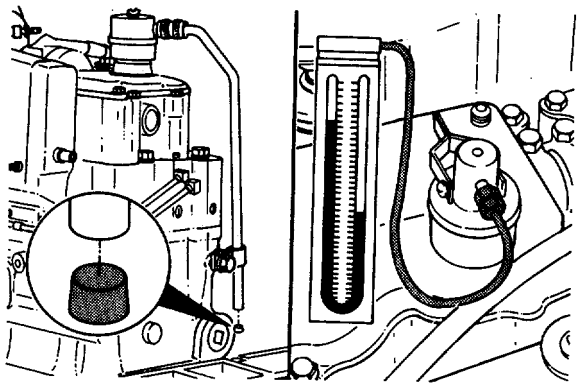

*FIGURE 2-5. Blowby Check.*

b. Remove the oil filler cap and replace with blowby checking tool. Connect the blowby checking tool to a manometer. Run engine at 1500 RPM.

NOTE

Excessive blowby is indicated by a manometer reading over 12.0 in. $H_2O$ (305 cm $H_2O$) for an engine, with less than 3,600 hours and a manometer reading over 18.0 in. $H_2O$ (460 cm H2O) for an engine with more than 3,600 hours. Excessive blowby indicates an internal leak. Normally internal leaks are caused by leaking intake valve guides, piston rings not seating properly, worn or broken piston rings, worn piston ring grooves, and scored or damaged cylinder liners. Refer to Table 3-1, Direct Support Troubleshooting, and Table 4-1, General Support Troubleshooting.

## Table 2-2. Troubleshooting

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 9. Check for excessive blue smoke under load.

a Compare the level of blue smoke with that from another vessel with the same configuration.

b. Excessive blue smoke indicates piston rings not sealing, refer to para. 3-25.

11. Excessive lubricating oil sludge in the crankcase.

STEP 1. Check for incorrect lubricating oil, and/or incorrect (extended) oil change intervals.
Change oil (refer to LO 55-1905-223-12).

STEP 2. Check for incorrect fuel grade.
Change fuel (MIL-F-16884 (grade DFM) military marine diesel fuel).

STEP 3. Check for dirty oil filter(s).
Replace oil filter(s) (refer to PMCS Table 2-3, Item 13).

STEP 4. Check oil cooler bypass valve for malfunction.
Refer to Malfunction 7, Step 3.

STEP 5. Check for low coolant temperature below 140°F (60°C).
Replace thermostat (para. 2-24);

STEP 6. Check for internal coolant leaks.
Refer to Malfunction 12.

12. Coolant in lubricating oil

WARNING

Make sure engine is cool below 120°F (50°C). Bring coolant to proper level. install, a plug in overflow tube.

CAUTION

Do not apply more than 20 psi air pressure to the tester.

STEP 1. Check cylinder liner, crevice seal, or cylinder block for leaks.

a Drain the engine lubricating oil. (LO 55-1905-223-12.)

b. Remove the lubricating oil pan (para. 2-44).

c. Use 20 psi (140 kPa) air pressure to pressurize the engine cooling system (para. 2-36).

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

**NOTE**

Apply the air pressure 15 minutes before inspecting the cylinder liner, the crevice seal, or the cylinder block for coolant leaks.

d. Inspect the visible areas of the cylinder liners and also the area of the cylinder block around the crevice seals and the push tube cavity for coolant leaks.

e. If a leak is found, remove the pressure test equipment. Remove the cylinder head gasket, and inspect for coolant leaks.

f. Remove and inspect the cylinder liner(s) for cracks, porosity, or crevice seal damage (refer to Chapter 4).

g. Visually inspect the cylinder block for cracks or porosity in the crevice seal area.

h. Install a new gasket and the lubricating oil pan (para. 2-44).

i. Fill the engine with clean lubricating oil (LO 55-1905-223-12).

**NOTE**

Make sure the oil drain plug is tight.

j. Operate the engine until it reaches a temperature of 180°F (80°C), and check for coolant or lubricating oil leaks.

13. Fuel in lubricating oil.

STEP 1. Check for low oil and coolant temperature caused by long periods of engine idling.

a. Turn engine OFF (TM 55-1905-223-10) rather than idling for long periods. If long idle necessary, increase idle speed.

b. With engine running, use a tachometer to check the idle speed. It should be between 650 and 725 rpm.

c. Stop the engine (TM 55-1905-223-10).

d. Remove the cover plug for the idle speed adjusting screw (para. 2-33).

e. Operate the engine at high idle for 30 seconds.

f. Adjust the idle speed with the adjusting screw.

g. Install the cover plug to the adjusting screw.

STEP 2. Check for defective top injector o-ring.
Replace top injector o-ring.

STEP 3. Check for defective injector plunger.
Replace injector plunger (para. 2-34).

STEP 4. Check for leakage through the inside of the injector adapter (FIGURE 2-6). Replace injector (para. 2-34).

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

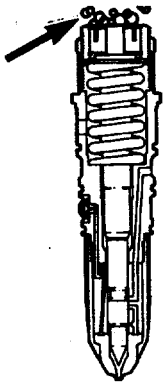

*FIGURE 2-6. Injector Adapter Check.*

STEP 5. Check for damaged fuel pump main shaft seals. Replace fuel pump (para. 2-33).

14. Turbocharger noise.

STEP 1. Check for incorrect turbocharger installed. Install correct equipment (para. 2-26). Refer to TM 55-1905-223-24P.

STEP 2. Check for intake or exhaust air leaks. Secure or repair loose or damaged piping (para. 2-41).

STEP 3. Check for excessive intake air restriction as follows:

a. Install a vacuum gauge or water manometer in the intake air piping (FIGURE 2-7).

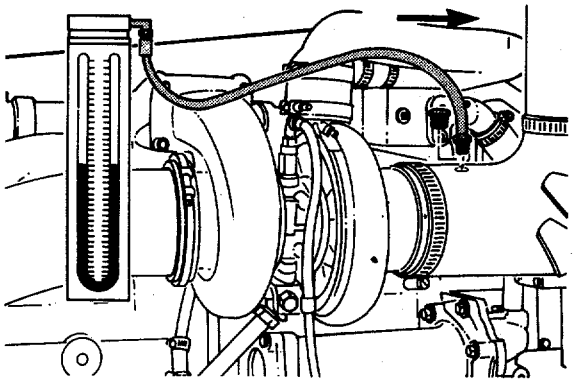

*FIGURE 2-7. Vacuum Gauge or Manometer Installation.*

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

**NOTE**

The gauge adapter must be installed at a 90-degree angle to the air flow in a straight section of pipe, one pipe 4" before the turbocharger.

b. Operate the engine at full throttle and rated RPM with maximum load.

c. Record the reading on the gauge or manometer.

**NOTE**

Restriction must not exceed 25.0 inches H20 (635 cm H20).

d. If the restriction exceeds specifications, do the following:
   (1) Replace or clean the air filter element (para. 2-25).
   (2) Visually inspect the intake air piping for damage.

e. Remove the test equipment.

STEP 4. Check for excessive exhaust restriction as follows:

a. Install a mercury manometer in the exhaust piping (FIGURE 2-8).

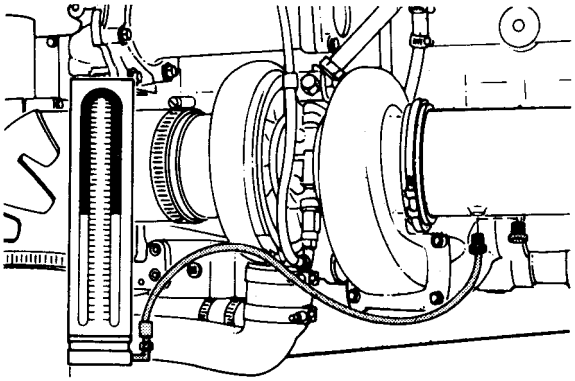

*FIGURE 2-8. Mercury Manometer Installation.*

**NOTE**

The mercury manometer must be installed near the turbocharger or exhaust manifold in a straight section of pipe.

b. Operate the engine at 1500 RPM and record the manometer reading.

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

**NOTE**
Exhaust pressure must not exceed 3.0 inches Hg (7.5 cm).

c. If exhaust pressure exceeds the specifications, visually inspect the exhaust piping for damage and/or restrictions.
d Remove the test equipment.

STEP 5. Check for defective turbocharger compressor impeller or turbine wheel as follows:
a Remove the intake and exhaust pipes from the turbocharger (para. 2-26).
b. Visually inspect the turbocharger compressor impeller blades for damage.
c. If damage is found, replace turbocharger (para. 2-26).

STEP 6. Check for turbocharger bearings damage.
a Refer to PMCS Table 2-1, Item 27.
b. Replace turbocharger (para. 2-26).

15. Low power or excessive smoke (low intake manifold pressure).

STEP 11. Check for incorrect turbocharger installed. Install correct equipment (par. 2-26). Refer to TM 55-1905-223-24P.

STEP 2. Check for dirty air filter element. Refer to PMCS Table 2-1, Item 14.

STEP 3. Check for intake or exhaust air leaks. Secure loose or replace damaged piping (paras. 2-39, 2-40).

STEP 4. Check for excessive exhaust restriction. Refer to Malfunction 14, STEP 4.

STEP 5. Check for intake air restriction. Refer to Malfunction 14, STEP 3.

STEP 6. Check for defective turbocharger bearings.
a Refer to PMCS Table 2-1, Item 27.
b. Replace turbocharger (para. 2-26).

STEP 7. Check for malfunction in fuel system. Refer to Malfunction 25.

16. Turbocharger leaks engine oil or fuel

STEP 1. Check for defective turbocharger turbine seal.
a Refer to Item 10, STEP 7.
b. Replace turbocharger (para. 2-26).

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 2. Check turbocharger for oil leaks.
- a. Remove the air intake and air cross-over piping from the turbocharger (para. 2-26).
- b. Examine the compressor intake and discharge for oil. If oil is present, check the axial motion and radial clearance (Table 2-1, Item 26).
- c. Replace turbocharger (para. 2-26).

STEP 3. Check for excessive engine crankcase gases (blowby).

**NOTE**

Excessive blowby indicates a turbocharger or internal engine malfunction. Do not run engine for more than 10 minutes.

a. Install a plug in the crankcase breather vent (para. 2-34).
b. Remove the oil filler cap and replace it with a blowby checking tool.
c. Connect a pressure manometer to blowby checking tool.
d. Run engine at 1500 RPM. Pressure manometer reading should be no more than 18.0 in. H20 (45.7 cm H20).

**NOTE**

Reading should be no more than 12.0 in. H20 (30.5 cm H20) on engines with less than 3600 operating hours.

e. Check for incorrect oil pressure and any fuel, oil, water, or air leaks.
f. Replace turbocharger (para. 2-26).

17. Engine cranks but will not start (no smoke from exhaust).

STEP 1. Check to see if fuel shutoff valve is closed or defective.
- a. Use manual override.
- b. Check solenoid valve and clean terminals as follows:
  - (1) Make sure all of the wire connection nuts are tight, whether a wire is attached or not.
  - (2) Use a wire brush to clean the corroded solenoid terminals.
  - (3) Make sure the shutoff valve solenoid is the correct voltage.

**NOTE**

The solenoid voltage and a part number are cast into the terminal connection end of the solenoid.

  - (4) Check the voltage (24 Vdc) to the solenoid with a volt-ohm meter. Table 2-2. Troubleshooting-CONT

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION | |
|---|---|
| | **NOTE**<br>Make sure the coil wires are not connected before checking the solenoid resistance. |
| (5) | Check the solenoid resistance with a volt-ohm meter. |
| (6) | The solenoid resistance at 24 Vdc should be 28-32 Ohms. |
| (7) | If resistance is not 28-32 Ohms, replace solenoid (para. 2-33). |
| STEP 2. | Check fuel flow to injectors. Loosen fuel line between fuel pump and cylinder head while cranking engine, check for fuel. |
| STEP 3. | Check for loose fuel connections on suction side of fuel pump. Secure all fuel filter fittings and connections from fuel tank to fuel pump. |
| STEP 4. | Check for plugged fuel filter or suction line restriction. |
| a | Replace fuel filter, refer to PMCS Table 2-1, Item 11. |
| b. | Remove fuel supply hose to fuel pump and install a vacuum tester between the pump and supply line. |
| c. | Hold tester at the same level as the gear pump (para. 2-33). |
| d. | Run the engine and observe the reading on the tester. |
| e. | Maximum reading should be 4 in. Hg clean filter, 8 in. Hg dirty filter. |
| f. | Remove gauge and connect supply line. |
| g. | Check fuel drain line restriction; maximum restriction is 6.5 in Hg. Replace drain line (para. 2-33). |
| STEP 5. | Check for fuel in pump as follows: |
| | **NOTE**<br>Loosen the fuel line at the solenoid shutoff valve while the engine is cranking. If fuel does not come out of the connection, the pump must be primed.<br><br>If fuel pump is dirty, clean the outside of the pump. |
| a | Remove the priming plug (FIGURE 2-9) from the top of the housing. |

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

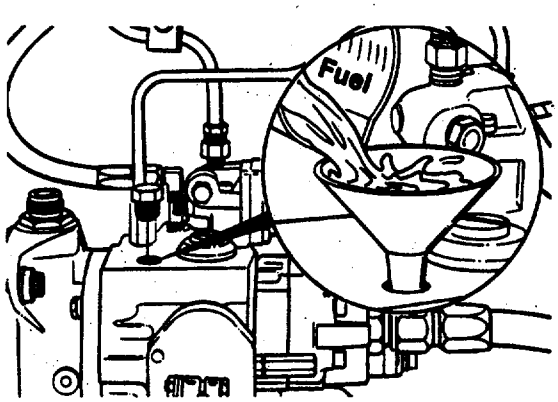


*Figure 2-9. Priming Plug*

b. Fill the housing with clean fuel oil.
c. Tighten the plug to 20 ft-lb. (30 N•m) torque.
d. If the priming plug is hard to remove, remove the fuel supply hose to the gear pump.
e. Fill the gear pump with clean engine lubricating oil.
f. If fuel does not come out of the connection now, replace the pump (para. 2-38).
g. Install the supply hose to the gear pump.

STEP 6. Check for excessive intake air restriction.
Refer to Malfunction 14, Step 3.

STEP 7. Check for excessive exhaust restriction.
Refer to Malfunction 14, Step 4.

STEP 8. Check to see if fuel pump is turning.
a. Make sure tachometer shaft is rotating while cranking.
b. If tachometer shaft is not turning, remove fuel pump to see if accessory drive shaft is turning (para. 2-33).
c. If turning, replace fuel pump (para. 2-33).

STEP 9. Check for broken gear pump shaft.
a Refer to Malfunction 17, Step 5.
b. Refer to Malfunction 17, Step 8.
c. Replace fuel pump (para. 2-33).

STEP 10. Check for defective or worn pump gear.
a. Remove the tachometer drive cable from the fuel pump.
b. Crank the engine and make sure the tachometer drive shaft is turning.
c. Remove the fuel supply hose at the gear pump.
d. Look into the gear pump and crank the engine. The gear pump gears must turn.

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

e. If the gear pump gears do not turn, replace the fuel pump (para. 2-33).

STEP 11. Check for gear pump check valves stuck open. Replace Check valves (para. 2-33).

18. Engine hard to start or will not start (exhaust smoke present).

STEP 1. Check to see if engine cranking speed low (below 150 rpm). Make sure engine cranking rpm's are correct (above 150 rpm).

STEP 2. Check to see if engine driven units engaged. Disengage engine driven units from crankshaft.

STEP 3. Check coolant heater (para. 2-32). Repair coolant heater (para. 2-32).

STEP 4. Check to see if fuel filter plugged. Replace fuel filter. Refer to PMCS Table 2-1, Item 11.

STEP 5. Check for air in the fuel system.
- a. Tighten all fuel line connections.
- b. Tighten fuel filters.
- c. Bleed air from lines at fuel pump:
  - (1) Crank the engine.
  - (2) Loosen the fuel outlet line at the solenoid shutoff valve.
  - (3) If air bubbles continue after initial release of air, replace the fuel pump (para. 2-33).

STEP 6. Check to see if fuel suction line is restricted. Inspect fuel lines for restrictions or damage. Correct as required. Refer to Malfunction 17, STEP 4.

STEP 7. Check air intake system for restriction. Refer to Malfunction 14, STEP 3.

STEP 8. Check for contaminated fuel.
- a. Take a fuel sample and visually inspect for contamination.
- b. If fuel is contaminated, drain and clean fuel tank.
- c. Replace fuel in fuel tank.

19. Engine starts but will not keep running.

STEP 1. Check for air in the fuel system. Refer to Malfunction 18, STEP 5.

STEP 2. Check to see if engine driven units engaged. Disengage engine drive units.

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION | |
|---|---|
| STEP 3. | Check to see if fuel filter is plugged or fuel waxing due to cold weather. Replace fuel filter (para. 2-27). |
| STEP 4. | Check to see if fuel suction line restricted. Refer to Malfunction 17, STEP 4. |
| STEP 5. | Check to see if fuel is contaminated. Drain and clean fuel tank. Replenish fuel. |
| STEP 6. | Check for low idle speed. Refer to Malfunction 24, STEP 10. |
| STEP 7. | Check to see if intake or exhaust system restricted |
| a | Refer to Malfunction 14, STEP 3 for intake. |
| b. | Refer to Malfunction 14, STEP 4 for exhaust. |
| STEP 8. | Check to see if injector cup spray holes plugged. |
| a. | Remove injectors and clean. |
| b. | Make injector Check (para. 2-34). |
| c. | Install injector and attempt to start engine. |
| d. | If engine runs rough, Refer to Malfunction 21, STEP 3. |
| STEP 9. | Check injection timing. Adjust timing (para. 2-34). |
| 20. Warm engine runs rough or misfires in operating range. | |
| STEP 1. | Check for air in fuel. Refer to Malfunction 18, STEP 5. |
| STEP 2. | Check to see if fuel is contaminated. Drain and clean fuel tank. Replenish fuel. |
| STEP 3. | Check for defective injectors as follows: |
| a | Remove the poppet covers (para. 2-34). |
| b. | Operate the engine until it is up to 160°F (70°C). |
| c. | Install Rocker Lever Actuator, P/N ST-1193 on an injector rocker lever. |
| d. | Hold the injector plunger down while the engine is running at low idle. This will stop the fuel flow to that injector. |
| e. | If the engine RPM decreases and/or engine misfires when an injector plunger is held down, the injector is good. |
| f. | If the engine RPM does not decrease, replace the defective injector (para. 2-34). |
| STEP 4. | Check valve and injector adjustments. Adjust valves or injectors (para. 2-34). |

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION | |
|---|---|
| STEP 5. | Check injection timing. Adjust timing (para. 2-34). |
| 21. Rough idle. | |
| STEP 1. | Check for low engine idle speed. Adjust low idle speed. Refer to Malfunction 24, STEP 10. |
| STEP 2. | Check for air in fuel. Refer to Malfunction 18, STEP 5. |
| STEP 3. | Check for defective injector as follows:<br>a. Remove the poppet covers (para. 2-34).<br>b. Operate the engine until it is up to 160°F (70°C).<br>c. Install Rocker Lever Actuator, P/N ST-1193 on an injector rocker lever.<br>d. Hold the injector plunger down while the engine is running at low idle. This will stop the fuel flow to that injector.<br>e. If the engine RPM decreases and/or engine misfires when an injector plunger is held down, the injector is good.<br>f. If the engine RPM does not decrease, replace the defective injector (para. 2-34). |
| STEP 4. | Check for defective fuel pump. Refer to Malfunction 17, Steps 5 and 8. |
| STEP 5. | Check valve and injector adjustments. Adjust valves or injectors (pa. 2-34). |
| STEP 6. | Check injection timing. Adjust timing (para. 2-34). |
| STEP 7. | Check for defective engine mounts. Refer to PMCS Table 2-3, Item 19. |
| 22. Engine surges at low idle. | |
| STEP 1. | Check for air in fuel system. Refer to Malfunction 18, STEP 5. |
| STEP 2. | Check for low engine idle speed. Refer to Malfunction 13, STEP 1. |
| STEP 3. | Check for fuel return line restriction.<br>a Disconnect fuel return line and install a vacuum gauge between the line and the fuel pump return line fitting.<br>(1) Use hose adapters to connect gauge.<br>(2) Operate the engine at rpm and full load. |

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

**NOTE**

Make sure the return line does not have any loops or is not crimped.

(3) Maximum reading should be 6.5 in Hg (165 mm Hg) with check valves.

b. If restriction is above maximum, Check lines or tank vents for obstructions.

STEP 4. Check to see if throttle linkage is adjusted wrong.
a. Adjust linkage (PMCS Table 2-1, Item No. 7).
b. Replace fuel pump (para. 2-33).

23. Engine will not reach rated speed when loaded.

STEP 1. Check for defective tachometer. Replace tachometer (para. 2-22).

STEP 2. Check to see if throttle linkage is set wrong. Adjust throttle linkage (PMCS Table 2-1, Item No. 7).

STEP 3. Check to see if fuel suction line is restricted. Refer to Malfunction 17, STEP 4.

STEP 4. Check for defective fuel pump. Refer to Malfunction 17, Steps 5 and 8.

24. Low power.

STEP 1. Check air filter. Replace air filter (para. 2-25).

STEP 2. Check to see if fuel suction line or fuel filter is restricted. Refer to Malfunction 17, STEP 4.

STEP 3. Check to see if lubricating oil level is too high. Drain oil to proper level.

STEP 4. Check to see if throttle linkage adjustment is wrong. Refer to PMCS Table 2-1, Item No. 7.

STEP 5. Check to see if intake or exhaust system is restricted.
a. Refer to Malfunction 14, STEP 3 for intake.
b. Refer to Malfunction 14, STEP 4 for exhaust.

STEP 6. Check for air in fuel. Refer to Malfunction 18, STEP 5.

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION | |
|---|---|
| STEP 7. | Check to see if fuel return line is restricted or fuel tank vents are plugged. Refer to Malfunction 22, STEP 3. |
| STEP 8. | Check for fuel contamination. Drain and clean fuel tank. Replenish fuel. |
| STEP 9. | Check for air or exhaust leaks between turbocharger and engine. Refer to Malfunction 14, STEP 2. |
| STEP 10. | Check to see if fuel rate low, fuel pressure low, and turbocharger pressure low. |
| a. | Stop the engine. |
| b. | Remove the plug (FIGURE 2-10) from the spring pack cover. |

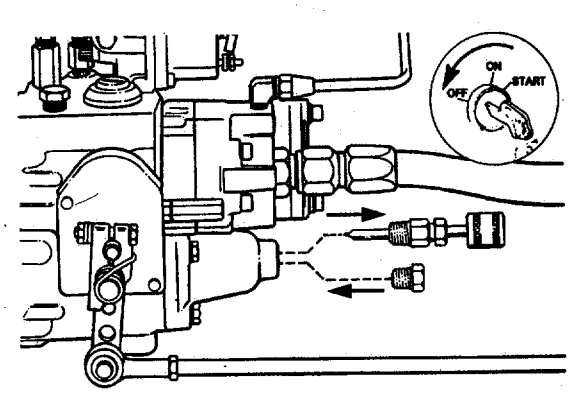


*FIGURE 2-10 Plug Removal.*

| | |
|---|---|
| c. | Install the fuel pump idle adjusting tool, P/N 3375981, in the plug hole. |
| d. | Operate the engine for 30 seconds at high idle to remove the air from the fuel system. |
| e. | Make sure the engine is at or above 160°F (70°C). |
| f. | Adjust low idle speed between 650 and 725 rpm. |
| g. | Remove the fuel pump idle adjusting tool and install the plug. |
| h. | Operate the engine until the rpm is constant and all air is out of the fuel system. |
| i. | Recheck the idle speed. |
| STEP 11. | Fuel rate high, fuel pressure high, and turbocharger pressure high. |
| a. | Lower fuel rate. |
| b. | Refer to Malfunction 24, STEP 10. |
| STEP 12. | Check to see if fuel rate OK, fuel pressure high, and turbocharger pressure OK. |
| a. | Check for defective injector. |

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

b. Refer to Malfunction 21, STEP 3.

STEP 13. Check to see if fuel rate low, fuel pressure high, and turbocharger pressure OK or low.
a. Check for defective injector.
b. Refer to Malfunction 21, STEP 3.

STEP 14. Check to see if fuel rate low, fuel pressure OK, and turbocharger pressure high. Replace turbocharger (para. 2-26).

STEP 15. Check to see if fuel rate low, fuel pressure OK and turbocharger pressure low.
a. Check for defective injector.
b. Refer to Malfunction 21, STEP 3.

STEP 16. Check to see if fuel rate OK, fuel pressure OK, and turbocharger pressure low.
a. Check intake air restrictions (Refer to Malfunction 14, STEP 3).
b. Replace turbocharger (para. 2-26).

STEP 17. Check to see if fuel rate OK, fuel pressure high, and turbocharger pressure OK. Check for restrictions in fuel pressure lines.

STEP 18. Check to see if injectors are seated. Secure holddown capscrews (para. 2-34).

STEP 19. Check to see if injectors are carboned. Replace injectors (para. 2-34).

STEP 20. Check to see if injectors(s) are stuck. Make-sure rocker lever, injector link action is correct (para. 2-34).

STEP 21. Check for defective fuel pump. Refer to Malfunction 17, Steps 5, 8.

25. Exhaust smoke excessive under load.

STEP 1. Check intake air system for restrictions. Refer to Malfunction 14, STEP 3.

STEP 2. Check to see if turbocharger wheel is rubbing. Replace turbocharger (para. 2-26).

STEP 3. Check for intake air leaks between turbocharger and cylinder head. Clear air leaks (para. 2-26).

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION | |
|---|---|
| STEP 4. | Check to see if fuel return line is restricted. Refer to Malfunction 22, STEP 3. |
| STEP 5. | Check for loose injector and incorrectly adjusted valve. Secure or replace injector (para. 2-34). |
| STEP 6. | Check to see if engine is receiving too much fuel.<br>a. Check fuel pressure and rate.<br>b. Refer to Malfunction 24, STEP 10. |
| STEP 7. | Check for turbocharger turbine seal leakage. Replace turbocharger (para. 2-26). |
| STEP 8. | Check to see if injector cups are damaged. Replace injector (para. 2-35). |
| 26. Engine will not shut off. | |
| STEP 1. | Check to see if fuel pump manual override is open. Make sure manual override shutoff screw is turned fully counterclockwise (para. 2-33). |
| STEP 2. | Check to see if fuel pump shutdown valve disk is stuck. Replace shutdown valve (para. 2-33). |
| STEP 3. | Check to see if fuel tank vents are plugged. Remove, clean, or replace. (Refer to TM 55-1905-223-24-18). |
| STEP 4. | Check to see if fuel return line is restricted. Refer to Item No. 22 of this table). |
| STEP 5. | Check to see if engine running on fumes drawn into air intake. Locate and isolate the source of fumes. |
| STEP 6. | Check to see if injector. Check balls not seating or missing. Replace injector (para. 2-34). |
| 27. Poor deceleration. | |
| STEP 1. | Check to see if throttle return spring in linkage is binding. Adjust if necessary. (Refer to PMCS Table 2-1, Item No. 7.) |
| STEP 2. | Check to see if fuel drain lines are restricted. Refer to Malfunction 22, STEP 3. |
| STEP 3. | Check to see if fuel tank vents are plugged. Remove and clean. Replace as necessary (TM 55-1905-223-24-18) |

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 4. Check for throttle leakage.
- a. Clean fuel pump and surrounding area.
- b. Ensure all fluid line fittings are tight.
- c. Replace fuel pump, if required (para. 2-33).

STEP 5. Check to see if injector check ball not seating or missing. Remove injector(s), replace (para. 2-34).

28. Engine surges under load at rated speed throttle wide open.

STEP 1. Check to see if fuel pump assembled or adjusted wrong. Replace fuel pump (para. 2-33).

29. Engine surges at high idle.

STEP 1. Check for air leak in fuel lines. Refer to Malfunction 18, STEP 5.

STEP 2. Check to see if fuel pump assembled or adjusted wrong. Replace fuel pump (para. 2-33).

30. Engine will not crank or cranks slowly.

STEP 1. Check to see if external or internal conditions are affecting engine crankshaft rotation. Check engine for ease of crankshaft rotation. Correct as required.

STEP 2. Check to see if battery connections broken, loose, or corroded. Clean, tighten or replace wiring as required.

STEP 3. Check to see if battery charge is low.
- a. Make sure battery charger is on line.
- b. Remove battery cell covers and check electrolyte level. Add water if electrolyte is low.
- c. Use a hydrometer to measure the specific gravity of each cell. If the specific gravity of any cell is below 1.200, the battery must be charged.
- d. Determine the battery state of charge as follows:

| Battery State of Charge | Specific Gravity at 80°F (27°C) |
|---|---|
| 100% | 1.260-1.280 |
| 75% | 1.230-1.250 |
| 50% | 1.200-1.220 |
| 25% | 1.170-1.190 |
| Discharged | 1.110-1.130 |

- e. Refer to PMCS Table 2-1, Item No. 3.

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION | |
|---|---|
| STEP 4. | Check to see if starting circuit component is malfunctioning. Refer to para. 2-21. Replace starter motor as required. |
| 31. Excessive crankcase gases (blowby). | |
| STEP 1. | Check for restricted crankcase breather vent tube. Clear breather tube restriction (para. 2-33). |
| STEP 2. | Check to see if turbocharger seals are leaking. Replace turbocharger (para. 2-26). |
| 32. Excessive engine vibration. | |
| STEP 1.<br>a.<br>b. | Check to see if engine idle speed too low.<br>Adjust engine idle speed. (Refer to PMCS Table 2-1, Item 7.)<br>Secure driveline to bowthruster waterjet and fire pump and couplings. |
| STEP 2. | Check for loose mountings. Secure mounting capscrews. Torque to 135 ft-lbs. |
| 33. Excessive engine noise. | |
| STEP 1. | Check for accessory noise. Make sure that engine accessories are not the cause of the noise first. Secure accessories and brackets. |
| STEP 2. | Check for excessive valve or injector clearance. Adjust valve and/or injectors (para. 2-34). |
| 34. Excessive white smoke at idle. | |
| STEP 1. | Check for defective engine coolant heater. Replace heater (para. 2-32). |
| STEP 2. | Check for low coolant temperature. Refer to "Coolant Temperature Below Normal," Malfunction 2, Steps 1 and 2. |
| STEP 3. | Check for poor fuel quality. Drain and clean fuel tank. Replenish fuel. |
| STEP 4. | Check for raw fuel in intake manifold. |
| STEP 5. | Check valve or injector adjustment. Adjust valves and/or injectors (para. 2-34). |
| STEP 6. | Check to see if injector cups are damaged or cracked. Replace injector (Refer to para. 2-35). |

**Table 2-2. Troubleshooting-CONT**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION | |
|---|---|
| STEP 7. | Check injector timing. Adjusting timing (para. 2-35). |
| 35. Connecting rod bearing noise. | |
| STEP 1. | Check for insufficient oil supply or low oil pressure. Refer to "Lubricating Oil Pressure Low," Malfunction 6. |
| STEP 2. | Check for thin or diluted lubricating oil. Change lube oil (L) 55-1905-223-12). |
| 36. Piston noise. | |
| STEP 1. | Check for contaminated or poor quality fuel. Drain and clean fuel tank. Replenish fuel. |
| 37. Main bearing noise. | |
| STEP 1. | Check for insufficient oil supply or low oil pressure. Refer to "Lubricating Oil Pressure Low," Malfunction 6. |
| STEP 2. | Check for thin or diluted lubricating oil. Change lube oil (LO 55-1905-223-12). |
| 38. Excessive fuel consumption. | |
| STEP 1. | Check for restricted air intake. Refer to Malfunction 14, STEP 3. |
| STEP 2. | Check for exhaust restriction. Refer to Malfunction 14, STEP 4. |
| STEP 3. | Check for fuel line restriction. Refer to Malfunction 17. |
| STEP 4.<br>a.<br>b. | Check for external or internal leaks.<br>Secure all lines and fittings.<br>Refer to Malfunctions 5 and 13. |
| STEP 5. | Check for defective injectors. Refer to Malfunction 21, STEP 3. |
| STEP 6. | Check for contaminated fuel. Drain and clean fuel tank Replenish fuel. |

## SECTION V. UNIT MAINTENANCE PROCEDURES

2-20. General. This section contains unit maintenance information for the NT 855 M Bowthruster Diesel Engine. Step-by-step actions are provided with illustrations when applicable.

a. Equipment Condition

**WARNING**

Clearly display a tag marked "Out of Service" on the ship's electrical service circuit breaker panel to prevent accidental re-energizing of the circuits that could result in injury or death.

(1) While performing maintenance on the Bowthruster Engine place a tag marked "Out of Service" on the ship's electrical service circuit breaker panel.

(2) When removing components from the engine, ensure that openings are capped/plugged/covered to prevent foreign matter or contamination from entering the engine.

(3) Exercise caution when working with engine or component gasket surfaces.

(4) Clean engine and components with authorized solvents, acids, and solutions only.

(5) Use only authorized tools while working on the engine or engine components.

(6) Use proper safety equipment when required.

b. Work Area

(1) Maintain clean environment for engine or engine component work areas. Contamination will cause premature wear.

(2) Use caution when working with solvents and acids.

**MAINTENANCE OF BOWTHRUSTER DIESEL ENGINE**

## 2-21. Replace/Repair Electric Starter Motor and Magnetic Switch Group. (FIGURE 2-11)

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's-rail and diesel engines, 5180-00-629-9783
Multimeter, 6625-01-139-2512
Torque wrench (30-300 ft-lb), 5120-01-125-5190

Equipment Condition

Engine shut down and cooled to below 120°F (50°C), TM 55-1905-223-10.
Engine tagged "Out of Service, Do Not Operate."

Materials/Parts

Electrical engine starter P/N 3021036
Magnetic switch P/N 3050692
Warning tag, Item 25, Appendix C

REMOVAL

a. Disconnect cables from battery pack.

b. Tag and remove the electrical wiring (1,3) from the engine electrical starter (11) and solenoid (2).

c. Tag and remove the wiring (3) from the magnetic switch (8).

d. Remove three capscrews (10) and remove starting motor (11) and magnetic switch (8).

e. When replacing the magnetic switch (8) only, remove the bolts (7), nuts (4), spacers (6) and washers (5) and remove the switch (8) from the mounting bracket (9).

REPAIR

Repair at unit level consists of replacing the starting motor (11) and magnetic switch (8).

REPLACEMENT

CAUTION

Be sure to use the same thickness of starter motor spacer (if used) as the one removed to install the starting motor to prevent engine or starter motor damage.

a. Install the magnetic switch (8) (if removed) onto the mounting bracket (9) with nuts (4), spacers (6), washers (5), and bolts (7). Connect the electrical leads to the switch (8) terminal lugs.

b. Install starting motor (11) and secure with three capscrews (10).

c. Tighten capscrews (10) to 130 ft-lb (175 N•m) torque.

d. Install cables (1 and 3) and tighten the cable connections (13 and 12) to the starting motor (11) and solenoid (2).

e. Remove "Out of Service-Do Not Operate" tag.

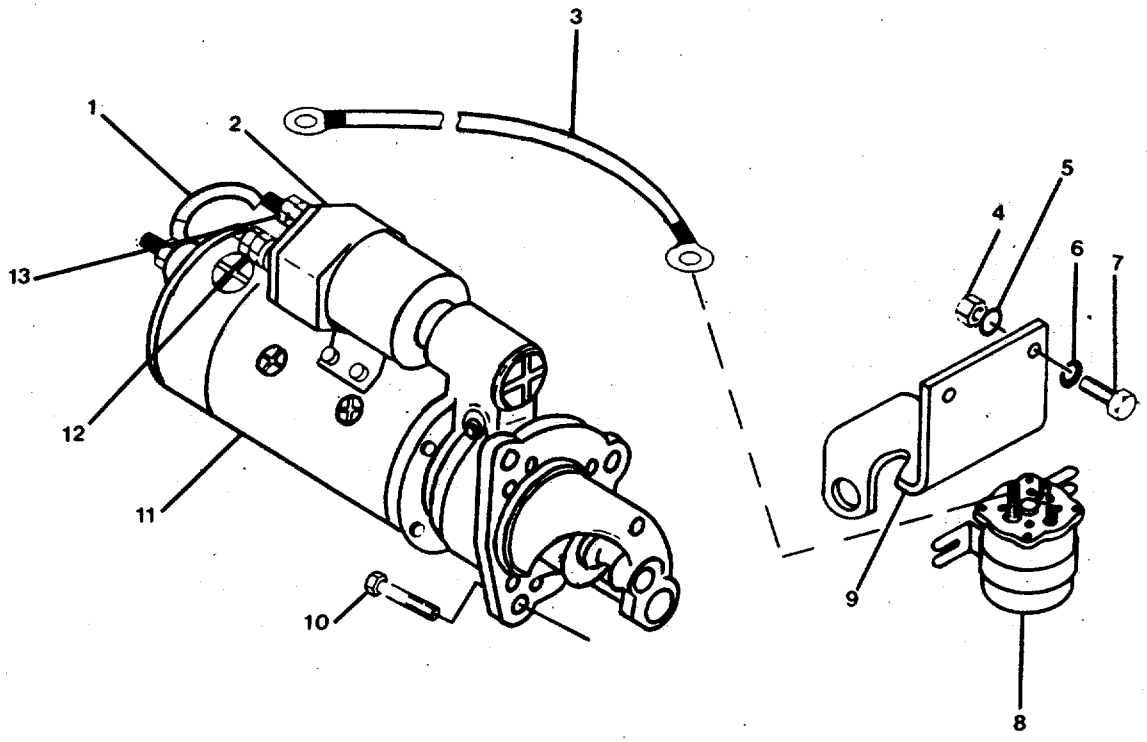


*FIGURE 2-11. Electric Starter and Magnetic Switch.*

## 2-21. Replace/Repair Instrument Panel Group. (FIGURE 2-12)

**This task covers:**

**a. Inspection b. Removal c. Repair d. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's rail and marine diesel engines, 5180-00-629-9783
Multimeter, 6625-01-139-2512

Equipment Condition

Electrical power OFF at primary junction box for removal procedures.
Engine tagged “Out of Service-Do Not Operate.”

Materials/Parts

Wiring harness P/N 3035720, 3035719, 3035718
Thermocouple P/N 3036575
Indicator light P/N 3022279
Circuit Breaker P/N 3034953
Pressure switch P/N 3034985
Voltmeter P/N 3015235
Push switch P/N 3035150
Toggle switch P/N 113527
Indicating pyrometer P/N 3036576
Toggle switch P/N MS35058-22
Hourmeter Tachometer P/N 3049555
Pressure switch P/N 3010649
Pressure switch P/N 3010647
Warning tag, Item 25, Appendix C

### INSPECTION

a. Inspect gauges for loose mounting and cracked or missing glass.

b. Inspect wiring harnesses for frayed, cracked, melted or missing insulation.

c. Check lights and switches for loose mounting.

### REMOVAL

**NOTE**

If only defective gauges, meters, or switches are being replaced, follow the repair instructions of these procedures.

a. Make sure all electrical circuits to the engine are OFF.

b. Loosen two pinhead screws (3) in the upper corners of the instrument panel (19) and swing the panel down for access to inside wiring connections. Tag and disconnect all wiring harness connections to the instrument panel, meters, switches, and light. Disconnect the thermocouple connection (7).

c. Remove mounting nuts and washers (8) to remove the panel box (12). Remove nuts, bolts, and washers (10) if removing mounting bracket (9).

d. Tag, disconnect, and record, the wiring connections from engine.

**NOTE**

Make sure to record the locations on each harness wire disconnected. This will ensure that all harness connections are returned to their proper locations on the engine when installing a new harness.

REPAIR

**NOTE**

Repair to the instrument panel assembly will be only the replacement of defective gauges, switches, circuit breaker, and unit light.

a. Tag and remove all electrical wiring at terminal block (13).

b. Disconnect and remove wiring harnesses (14, 15, 16).

c. Remove gear oil pressure gauge (5).

d. Remove circuit breaker (6).

e. Remove push button switch start (17).

f. Remove run/off toggle switch (18).

g. Remove voltmeter battery (20).

h. Remove pyrometer (21).

i. Remove shutoff toggle switch (22).

j. Remove tachometer and hourmeter (23).

k. Remove water temperature gauge (1).

l. Remove engine oil pressure gauge (2).

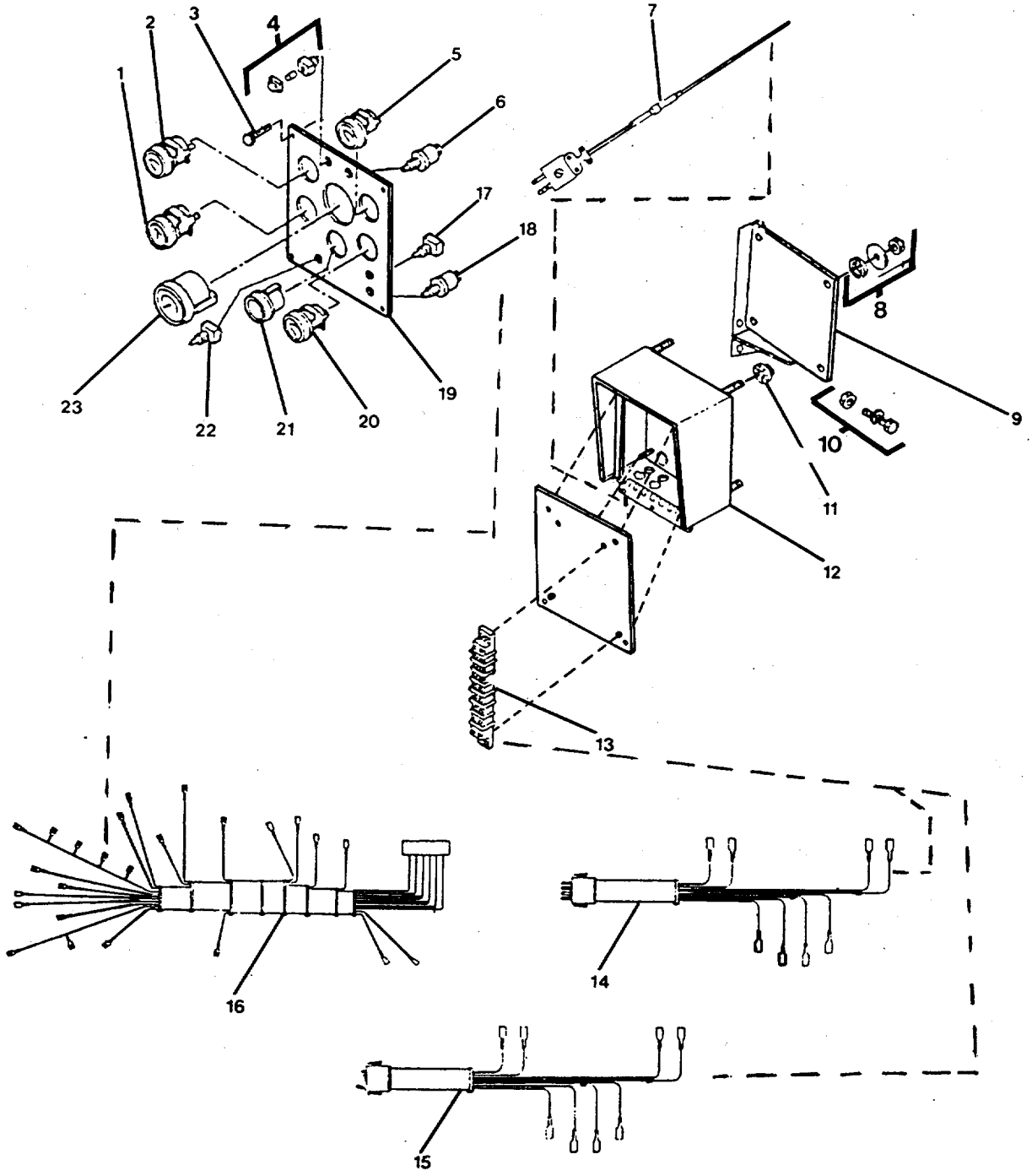


*FIGURE 2-12. Instrument Panel Group.*

m. Remove panel light assembly (4).

n. Replace gauges which are defective, damaged, or not working.

o. Replace damaged or frayed wiring harnesses (14, 15, 16).

REPLACEMENT

a. If a defective gauge (5, 1, 2), switch (17, 18, 22), meter (20, 21, 23), or light (4) unit is being replaced, do the following:

(1) Position the new part in the panel and install the mounting hardware that holds it to the panel.

(2) Connect electrical wiring harnesses (14, 15, 16).

(3) Install mounting bracket (9) if it was removed, using mounting bolts, washers, and nuts (10).

b. To replace the instrument panel assembly:

(1) Install wiring harnesses (14, 15, 16) that were removed. Make sure all wires are connected to proper locations.

(2) Position panel box (12) in the mounting bracket (9) and install the washers and nuts (8) on each corner of the panel box (12). Secure the screws.

(3) Plug in harnesses (14, 15, 16), to the panel box (12).

(4) Connect all electrical wiring to engine.

(5) Connect thermocouple (7). Close panel front and secure the two pinhead screws (3).

c. Check and secure the electrical connections to the starter motor.

d. Remove "Out of Service-Do Not Operate" tags.

## 2-23. Replace/Repair Water Filter Group. (FIGURE 2-13)

**This task covers:**

**a. Inspection b. Removal c. Repair d. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's rail and marine diesel engines, 5180-00-629-9783
Filter wrench, 5120-01-262-7306
Torque wrench (30-300 in-lb), 5120-01-092-3278
Torque wrench (30-300 ft-lb), 5120-01-125-5190

Equipment Condition

Engine shut down and cooled to below 120° F (50°C) (TM 55-1905-223-10).
Engine tagged “Out of Service-Do Not Operate.”

Materials/Parts

Lubrication oil, Item 1, Appendix C
Water filter assembly P/N 3827107
Fluid filter P/N 3318319
Nonmetallic hose P/N 179930, 179918
Angle valve P/N 179901
Wiping rag, Item 2, Appendix C
Warning tag, Item 25, Appendix C

INSPECTION

**WARNING**

Be sure coolant is below 120°F (50°C) before removing filters or replacing parts and fittings.

a. Visually inspect the filter (13) and head (12) assembly for signs of leakage and corrosion.

b. If the filter is leaking around the gasket sealing surface, do the following:

(1) Close the water inlet and outlet valves (10) on each side of the filter head (12) assembly.

(2) Using the filter wrench, unscrew and remove the spin-on filter (13).

(3) Clean the gasket sealing surfaces of the filter (13) and head (12) with a clean rag.

(4) Apply a light coat of oil on the filter gasket. Install the filter (13) and hand-tighten.

(5) Open the water inlet and outlet valves (10).

(6) If leakage is still present, install a new filter element (13) and recheck.

(7) If the new filter (13) element still leaks, replace the head (12) assembly. Refer to removal and replacement steps of this procedure.

c. Check connection fittings (3, 4, 1) for signs of leaks and corrosion.

(1) Tighten fittings (3, 4, 1) and hose clamps (9).

(2) If fittings are corroded.

(a) Close inlet and outlet valves (10).

(b) Remove fittings and clean and inspect. Replace the fittings as necessary.

(c) Install the fittings and re-check.

**NOTE**

For coolant inspection and test procedures, refer to TB 55-1900-207-24.

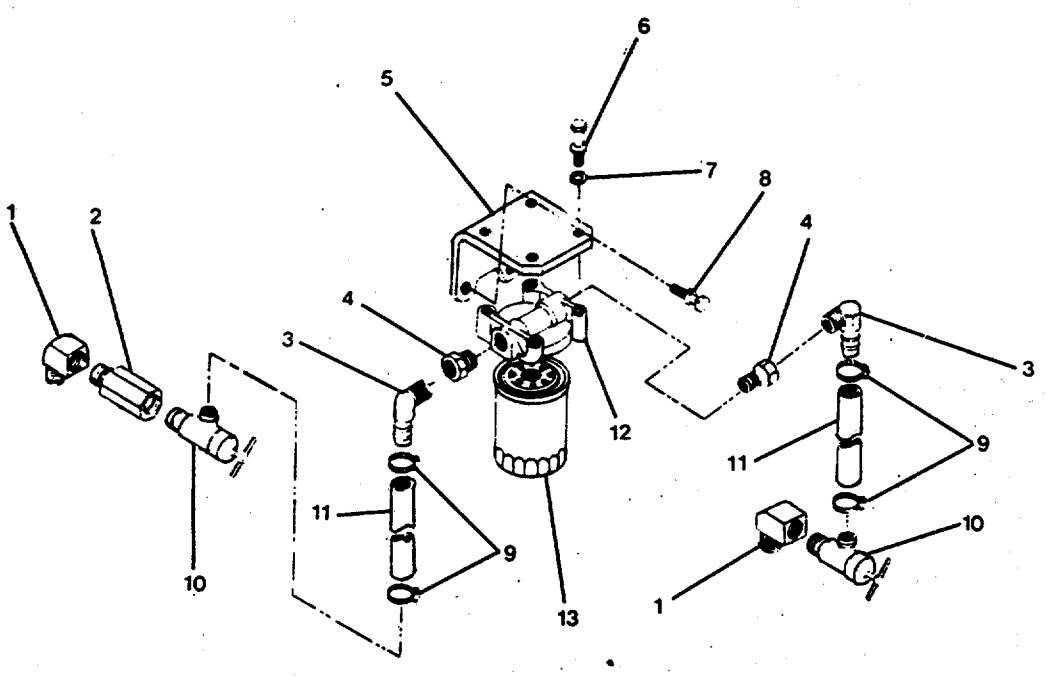


*FIGURE 2-13. Water Filter Group.*

REMOVAL

**WARNING**

Be sure coolant temperature is below 120°F (50°C) before releasing pressure on the cooling system.

a. Release pressure on the cooling system by opening the system relief/dump valves (TM 55-1905-223-24-18).

b. Close shutoff valves (10) on the water filter inlet and outlet lines.

c. Remove and discard the water filter element (13).

d. Disconnect the inlet line and the outlet line from the head (12) of the water filter at hose clamps (9).

e. Remove capscrews (6) and washers (7) that hold the head (12) of the filter to the mounting bracket (5).

f. To remove bracket (5) from the cylinder block, remove capscrews and washers (8).

REPAIR

Repair to the water filter assembly is by replacing the hoses (11), valves (10), water filter assembly, composed of the filter (13) and filter head (12). Refer to disassembly and assembly steps of this paragraph.

REPLACEMENT

a. Install bracket (5) into the cylinder block. Install the filter head (12) with capscrews (6) and washers (7). Tighten the capscrews to 30 to 35 ft-lb torque.

b. Install valves (10) and hoses (11) to the filter head elbows (3) with the hose clamps (9). Tighten clamps to 35-40 in-lb torque.

c. Apply a light coat of oil to the sealing gasket of filter cartridge (13).

CAUTION

Do not use a wrench to tighten the cartridge. Tighten by hand; overtightening can damage the threads and the seal.

d. Install filter (13) cartridge onto the filter head (12). Tighten the cartridge (13) by hand until the sealing gasket touches the filter head (12). Then, tighten the cartridge (13) an additional one-half to three-fourth turns.

e. Open the water inlet and outlet valves (10) on each side of the filter assembly.

f. Remove "Out of Service-Do Not Operate" tag.

**NOTE**

If coolant is added between drain intervals, additional coolant additive (DCA or equivalent) could be required.

g. Before adding coolant the coolant additive concentration must be checked using the DCA test kit and TB 55-1900-207-24.

h. Add coolant as required using a minimum concentration of one DCA unit for each U.S. gallon (3.8 litre) of cooling system capacity.

**NOTE**

One DCA unit equals 1.5 dry ounces (42 grams) or 4.0 fluid ounces (118 millilitres).

CAUTION

Do not use more than two DCA units per U.S. gallon (3.8 litre) as overconcentration will cause sludge in cooling system.

i. Ensure the proper coolant filter is installed to maintain the correct DCA concentration in the system.

**NOTE**

Service filters are satisfactory for use with maintenance intervals from 250 to 600 hours.

DCA is compatible with all permanent type antifreeze except Methoxy Propanol. If using Methoxy Propanol antifreeze reduce the amount of DCA by 1/3 to prevent inhibitor loss.

## 2-24. Replace/Repair Thermostat Housing Group. (FIGURE 2-14)

**This task covers:**

**a. Removal** **b. Inspection** **c. Repair** **d. Replacement**

**INITIAL SETUP:**

Tools

Thermostat seal mandrel
P/N ST-1225, ST-1226
Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Torque wrench (30-300 in-lb),
5120-01-092-3278
Torque wrench (30-300 ft-lb),
5120-01-125-5190

Equipment Condition

Engine shut down, cooled to below 120°F (50°C) (TM 55-1905-223-10).
Engine tagged “Out of Service-Do Not Operate”

Materials/Parts

Nonmetallic hose P/N 3056139
Gasket P/N 3009457, 208128 and 3019158
Thermostat housing seal P/N 186780
Flow control thermostat P/N 201737
Preformed packing P/N 43463-A
Cleaning solvent, Item 5, Appendix C
Wiping rag, Item 2, Appendix C
Warning tag, Item 25, Appendix C

### REMOVAL

**WARNING**

Wait until the water temperature is below 120°F (50°C) before removing the cooling system pressure cap. Failure to do so can cause personal injury from the hot coolant.

a. Removal of Thermostat Only.

(1) Drain the cooling system. Refer to PMCS Table 2-1, Item 21.

(2) Remove pipe plug (24) located on the thermostat housing (19), to drain the excess water.

(3) Disconnect hose clamp (2) on the water outlet connection (4).

(4) Loosen hose clamps (20) and disconnect hose (21).

(5) Loosen the four capscrews (25) and remove the thermostat housing (19) and thermostat (8). Discard the gasket (6) and seal (7).

b. Removal of Housing and Support Assembly.

(1) Remove cooling system pressure cap, located on the external expansion tank.

(2) Drain cooling system. Refer to PMCS Table 2-1, Item 21.

(3) Loosen hose clamp (20) and disconnect the water bypass tube (22).

(4) Loosen hose clamp (2) and disconnect the outlet hose (1).

(5) Loosen hose clamp (10). Disconnect hose (9) from the elbow (11) on the thermostat housing support (17). Remove the elbow (11) from the support (17).

(6) Loosen four capscrews (15) holding the thermostat housing support (17).

(7) Remove capscrews (15), the support (17), and housing (19) assembly. Discard the gasket (18).

(8) Remove two capscrews (3) holding the water outlet connection (4) and remove the connection (4) and gasket (5).

(9) Loosen four capscrews (25) holding the thermostat housing (19).

(10) Remove thermostat (8) from housing (19). Discard gasket (6).

(11) Remove seal (7) from thermostat housing (19).

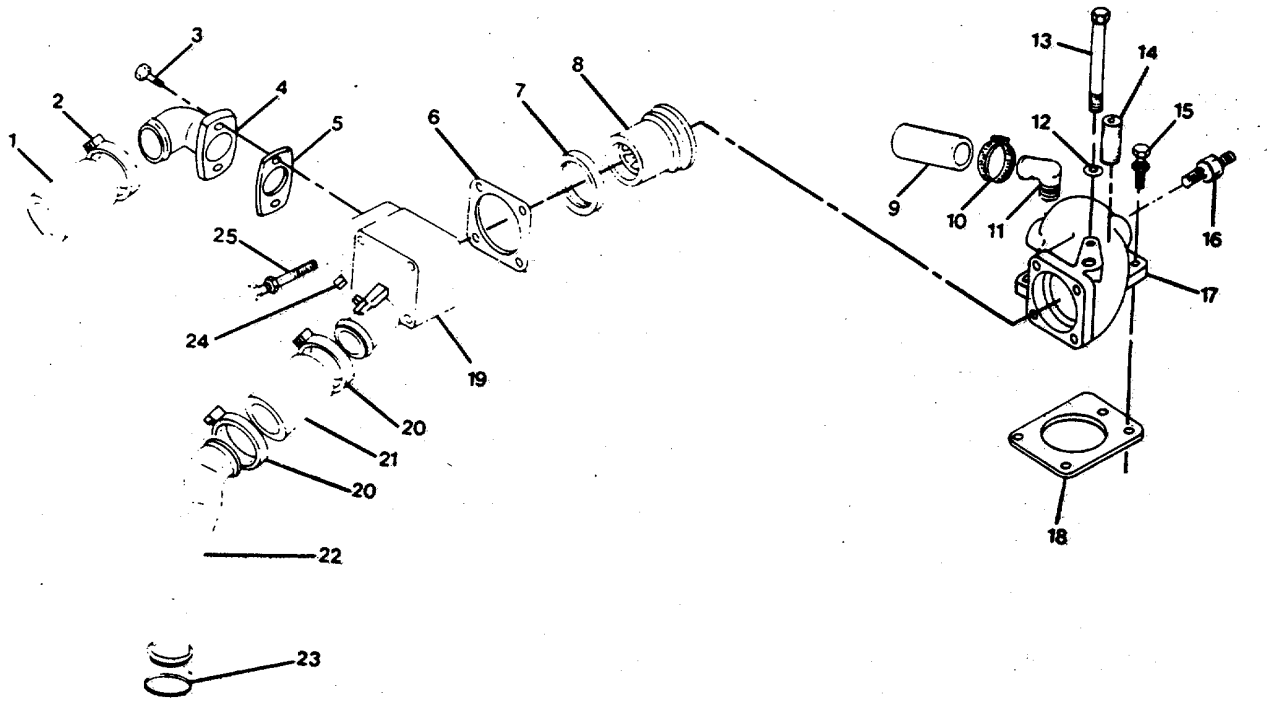


*FIGURE 2-14. Thermostat Housing Group.*

(12) Remove nipple (14), temperature sending unit (16), and bolt and washer (13, 12) from housing support (17).

(13) Remove water bypass tube (22) and preformed packing (23). Discard the preformed packing (23). Clean and inspect the assembly as follows:

INSPECTION

a. Clean the gasket material from the sealing surfaces of the housing (19), support (17), and water outlet connection (4).

b. Clean all parts with cleaning solvent.

c. Inspect all parts for cracks and other damage.

d. Inspect the inlet and outlet hoses (1, 9, 21) for deterioration. Replace if necessary.

e. If damage is discovered, replace the assembly.

f. Visually inspect the thermostat for cracks or corrosion.

g. Suspend the thermostat and a 212°F (100°C) thermometer in a container of water. Do not allow the thermostat or the thermometer to touch the sides of the container.

h. Heat the water.

NOTES

- Write down the temperatures at which the thermostat begins to open and when it is fully open.
- The nominal operating temperature is stamped on the thermostat.
- The thermostat must begin to open between 178°F (81°C) and 182°F (83°C).
- The thermostat must be fully open to at least 9.5 mm (0.375 inch) by the time it reaches 202°F (94°C).

i. Replace the thermostat if it does not operate as described.

j. Visually inspect the thermostat seal for cracks or corrosion. Replace if necessary.

REPAIR

Repair to the thermostat housing is by replacing the water bypass hose (22), nonmetallic hose (21), gaskets (5, 6, 18), thermostat housing seal (7), thermostat flow control (8), and preformed packing (23).

REPLACEMENT

a. Replacement of the thermostat housing assembly. Refer to FIGURE 2-4.

(1) Install nipple (14), temperature sending unit (16), bolt and washer (13, 12) on the housing support (17).

(2) Use a mandrel to install a new seal (7) into the thermostat housing (10).

NOTE

Be sure the part number or metal side (flat side) of the seal is against the mandrel as you install the seal.

(3) Install thermostat (8) into the housing. Slide the sleeve of the thermostat through seal (7).

(4) Use gasket (6) and install the thermostat housing (19) to the thermostat support (17). Tighten capscrews (25) to 35 ft-lb torque.

(5) Use gasket (5) and install water outlet connection (4) to thermostat housing (19). Tighten capscrews (3) to 35 ft-lb torque.

(6) Use gasket (18) and install thermostat housing and support assembly (17) to engine. Tighten capscrews to 35 ft-lb torque.

(7) Install tube (22) and O-ring (23).

(8) Install water bypass tube (22) to water bypass hose (21) using hose clamp (20) and attach to thermostat housing (19).

(9) Connect water outlet connection hose (1) to water outlet connection (4). Tighten the hose clamps (2) to 40 in-lb torque.

(10) Install elbow (11) into thermostat support (17).

(11) Connect hose (9) to elbow (11) with hose clamp (10). Torque to 40 in-lb torque.

(12) Fill the cooling system. Refer to PMCS Table 2-1, Item 21. Run engine. Refer to TM 55-1905-223-10. Check for coolant leaks. Check for correct engine operating temperature.

b. Installation of thermostat only.

(1) Install thermostat (8) and seal (7). Use thermostat gasket (6).

(2) Hold the thermostat housing in position and install the four capscrews (25).

(3) Tighten the capscrews (25) to 35 ft-lb torque.

(4) Install hose (21) with clamps (20) to thermostat housing (19).

(5) Tighten hose clamps (20) to 40 in-lb torque.

(6) Refill the cooling system. Refer to PMCS Table 2-1, Item 21.

(7) Run the engine. Refer to TM 55-1905-223-10. Check for correct operating temperature. Check for coolant leaks.

## 2-25. Replace/Repair Air Cleaner Group. (FIGURE 2-15)

**This task covers:**

**a. Inspection b. Removal c. Repair d. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's rail and marine diesel engines, 5180-00-629-9783

Equipment Condition

Engine shut down (TM 55-1905-223-10).
Engine tagged, "Out of Service - Do Not Operate."

Materials/Parts

Wiping rags, Item 2, Appendix C
Intake filter element P/N 3022209
Preformed hose P/N 3030790
Filter warning indicator P/N 178957
Warning tag, Item 25, Appendix C

INSPECTION

NOTE

Wipe dirt from caps and upper portion of air cleaner before removing caps and filter.

a. Visually check the air cleaner housing (5), caps (4, 6) and elbow (2) for cracks, dents and corrosion.

b. Filter Element Inspection and Replacement:

(1) Remove bolt (9), nut (7), and washer (8) holding the air cleaner strap (3) and filter cap (6).

(2) Remove the air filter element (10). Check the accumulation of dirt and debris on the element. Replace as necessary.

**CAUTION**

Holes, loose end seal, dented sealing surfaces, and other forms of damage render cleaner inoperative and require immediate element replacement.

(3) Check the air indicator (14) for intake air restriction. The indicator will change from green to red when restricted.

c. Replace or clean the air filter (10), using compressed air.

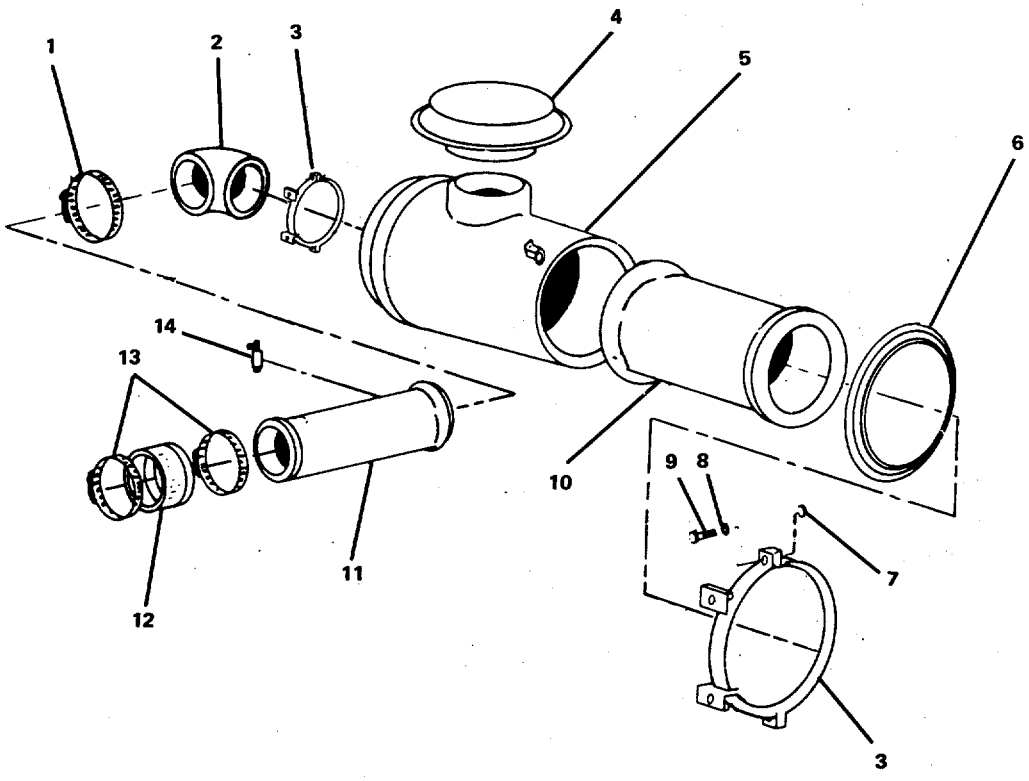


*FIGURE 2-15. Air Cleaner Group.*

d. Inspect the air intake piping for obstructions, corrosion, and dents.

REMOVAL

a. Remove hose clamps (1, 13) at the air inlet metallic tube (11) and preformed hose (12).

b. Remove nonmetallic elbow (2) and metallic tube (11).

c. Remove bolts (9), nuts (7) and washers (8) in the air cleaner straps (3) on each side of the assembly.

d. Remove air cleaner (5).

e. Remove air cleaner inlet cap (4) and filter cap (6).

f. Remove air filter element (10).

g. Unscrew and remove filter warning indicator (14).

REPAIR

Repair to the air cleaner is by replacement of the intake filter element (10), preformed hose (12), and filter warning indicator (14).

REPLACEMENT

a. Insert the clean or new element (10) into the air cleaner (5), making sure that it seats properly on the gasket end.

b. Install the air cleaner inlet and filter caps (4, 6).

c. Install metallic tube (11) and nonmetallic elbow (2).

d. Mount air cleaner unit with air cleaner straps (3) and install bolts (9), nuts (7), and washers (8).

e. Connect the air cleaner (5), nonmetallic elbow (2) and air inlet metallic tube (11) and preformed hose (12) with hose clamps (1, 13).

f. Install filter warning indicator (14).

## 2-26. Replace/Repair Turbocharger Group. (FIGURE 2-16)

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set, metric
10mm to 24mm
5120-01-046-4979
Torque wrench (30-300 in-lb),
5120-01-092-3278
Torque wrench (30-300 ft-lb),
5120-01-125-5190

Equipment Condition

Engine shut down, cooled to below 120°F (50°C), TM 55-1905-223-10.
Engine tagged, "Out of Service - Do Not Operate."
Air cleaner group disassembled (para. 2-25).

Materials/Parts

Insulating turbocharger cover
P/N 3002138
Nonmetallic hose P/N AM1601806MC
Metallic bent tube P/N 3044929
Gasket P/N 3202117, P/N 190849
Thermocouple P/N 3036575
Non-aircraft turbocharger P/N 3801614
Anti-seize. compound, Item 8, Appendix C
Cleaning solvent, Item 5, Appendix C
Nonmetallic hose assembly P/N 209956
Warning tag, Item 25, Appendix C

NOTE

Non-aircraft turbosupercharger seal kit, P/N 3801522, is needed for complete repair.

REMOVAL

a. Remove insulating cover (17).

b. Remove oil supply nonmetallic hose assembly (9), pipe to tube elbow (8) and pipe to hose elbow (16).

c. Remove oil drain tube loop clamps (23 ands24) by removing hexhead capscrew (27), flat washer (26), lockwasher (25), and hex nut (18).

d. Loosen hose clamps (20 and 22) and remove nonmetallic hose (21) and pipe elbow (19).

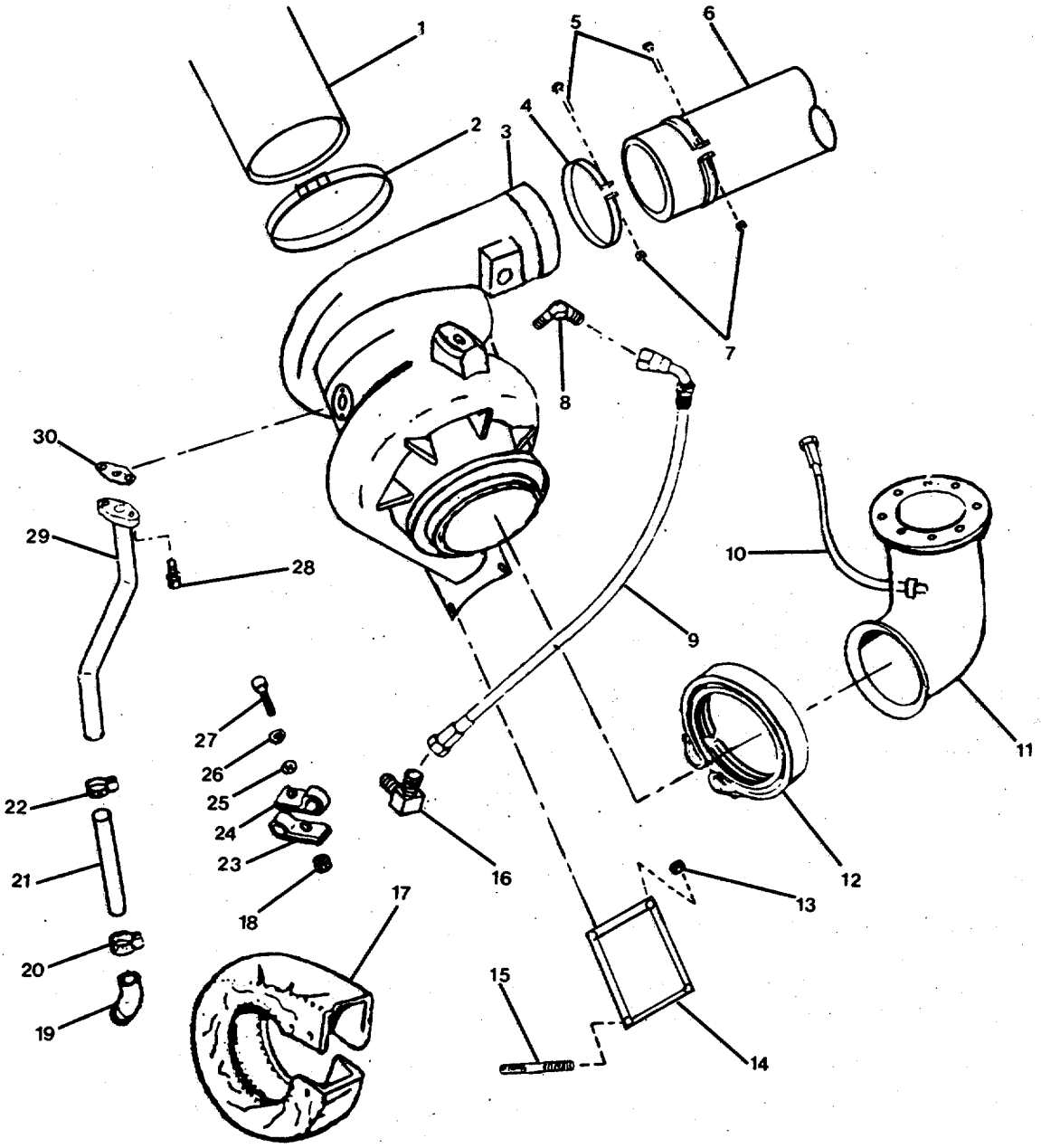


*FIGURE 2-16. Turbocharger Group.*

e. Remove two assembled washer screws (28) and remove oil drain bent metallic tube (29) and gasket (30).

f. Loosen clamp (2) and remove engine air intake pipe (1) from turbocharger (3).

g. Remove thermocouple (10) from exhaust connection (11).

h. Loosen V-clamp (12) and remove exhaust piping (11) from turbocharger (3).

i. Loosen bolts (5) and nuts (7) securing air crossover hose (6), clamps (4) to turbocharger (3) and remove air crossover hose (6).

j. Remove four sleeve nuts (13) from turbocharger mounting studs (15) and remove turbocharger (3) and gasket (14).

k. Tape over engine air inlet (1) and exhaust (11) connections.

REPAIR

Repair of the turbocharger is by replacement of the insulating cover (17), nonmetallic hose (21), nonmetallic hose assembly (9), thermocouple (10), bent metallic tube (29), gaskets (14 and 30), and/or turbocharger (3).

a. Clean turbocharger gasket surface (1, FIGURE 2-17) and exhaust manifold gasket surface (3) with solvent and rag.

b. Check for cracks on turbocharger mounting flange (4 or 5). If cracks are longer than .6 inch (15 mm), replace turbocharger (3) flange.

c. Check for cracks on turbocharger mounting flange (4 or 5) must not reach mounting holes. If cracks reach mounting holes, replace turbocharger flange.

d. Two cracks on turbocharger mounting flange (4 or 5) cannot be closer together than .25 inch (6.4 mm). If closer, replace turbocharger flange.

e. Inspect exhaust manifold gasket surface (3) and mounting studs (2) for cracks or thread damage. If surface is cracked, replace manifold (para. 2-39). If studs are damaged, replace studs.

REPLACEMENT

a. Remove tape covering engine air inlet (1, FIGURE 2-16) and exhaust outlet (11) to turbocharger (3).

b. Apply a coat of anti-seize compound to the threads (FIGURE 2-18) of the turbocharger mounting studs (15, FIGURE 2-16).

c. Install turbocharger gasket (14) onto exhaust manifold. The raised bead on the gasket surface must be toward the turbocharger (3).

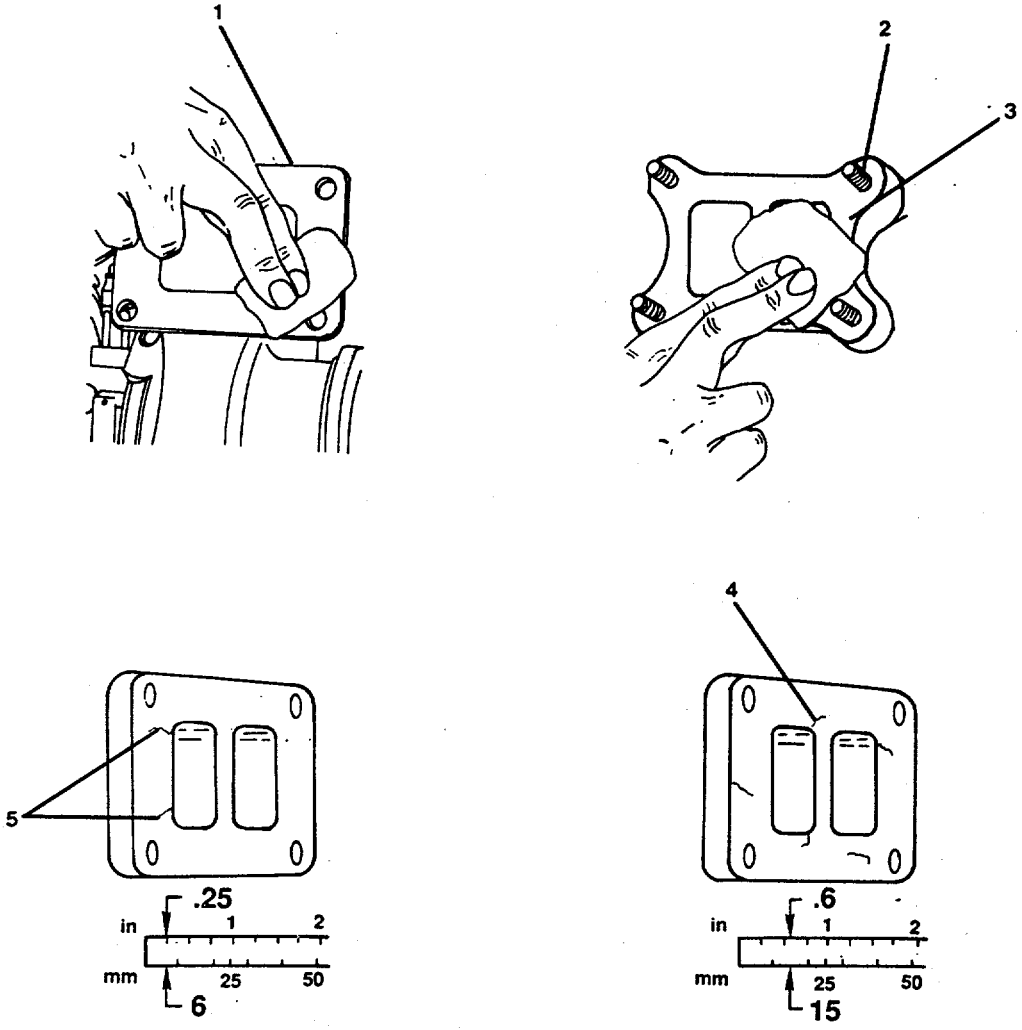


*FIGURE 2-17. Turbocharger Repair.*

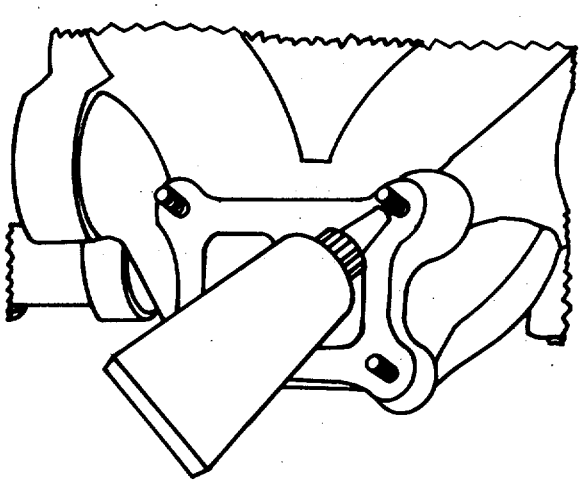

*FIGURE 2-18. Anti-Seize Application.*

NOTE

The centerline of the oil drain hole must be within 30 degrees of vertical when the turbocharger is installed onto the engine.

d. Install turbocharger (3) on mounting studs (15) and replace sleeve nuts (13), but do not tighten at this time.

e. Install air crossover hose (6) with clamps (4), bolts (5) and nuts (7). Tighten bolts (7) to 70 in-lb (8 N•m) torque.

f. Install exhaust piping (11) with V-clamp (12) and secure.

g. Install thermocouple (10) in exhaust pipe connection (11).

h. Install engine air intake pipe (1) with clamp (2). Tighten clamp (2) to 32 ft-lb (44 N•m) torque.

i. Tighten sleeve nuts (13) securing turbocharger (3) mounting flange to exhaust manifold to 32 ft-lb (44 N•m) torque.

j. Install gasket (30), oil drain bent metallic tube (29) and secure with two assembled washer screws to 32 ft-lb (44 N•m) torque.

k. Install nonmetallic hose (21), hose clamps (20 and 22) and pipe elbow (19). Tighten hose clamps to 32 in-lb (4 N•m) torque.

l. Install oil drain loop clamps (23 and 24) and secure with hex nut (18), lockwasher (25), flat washer (26) and hexhead capscrew (27).

m. Install pipe to hose elbow (16) and pipe to tube elbow (8).

n. Connect oil supply nonmetallic hose (9) to pipe to hose elbow (16).

o. Pour 2 to 3 ounces of clean engine oil into oil supply nonmetallic hose assembly (9) and connect hose assembly to pipe to tube elbow (8).

p. Tighten swivel nut of nonmetallic hose assembly (9) at pipe to tube elbow (8) to 22 ft-lb (30 N•m) torque.

q. Startup engine. Refer to TM 55-1905-223-10.

r. Listen for air leaks at inlet (1), air crossover (6) and exhaust (11) connections. Repair as necessary.

s. Remove "Out of Service - Do Not Operate" tag.

## 2-27. Replace/Repair Fuel Filter Group. (FIGURE 2-19)

**This task covers:**

**a. Removal b. Inspection c. Repair d. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Filter wrench, 5120-01-262-7306

Equipment Condition

Engine shut down (TM 55-1905-223-10).
Engine tagged, "Out of Service - Do Not Operate."

Materials/Parts

Teflon pipe thread lubricant,
Item 9, Appendix C
Nonmetallic hose assembly
P/N AM1002200SS
Fuel cartridge P/N 3315847
Lubricating oil, Item 1, Appendix C
Warning tag, Item 25, Appendix C

### REMOVAL

a. Close fuel supply valve to the filter assembly in accordance with the procedure in TM 55-1905-223-10.

b. Using filter wrench, remove two fuel cartridges (4) from fluid filter head (3) by turning counterclockwise. Discard the filters.

c. Disconnect nonmetallic hose assembly (1) from fuel pump and tube to boss elbow (2).

### INSPECTION

Inspect nonmetallic hose (1) for restrictions, cracks, or deterioration. Replace as necessary.

### REPAIR

Repair of the fuel filter group is by replacement of nonmetallic hose (1) and fuel cartridges (4).

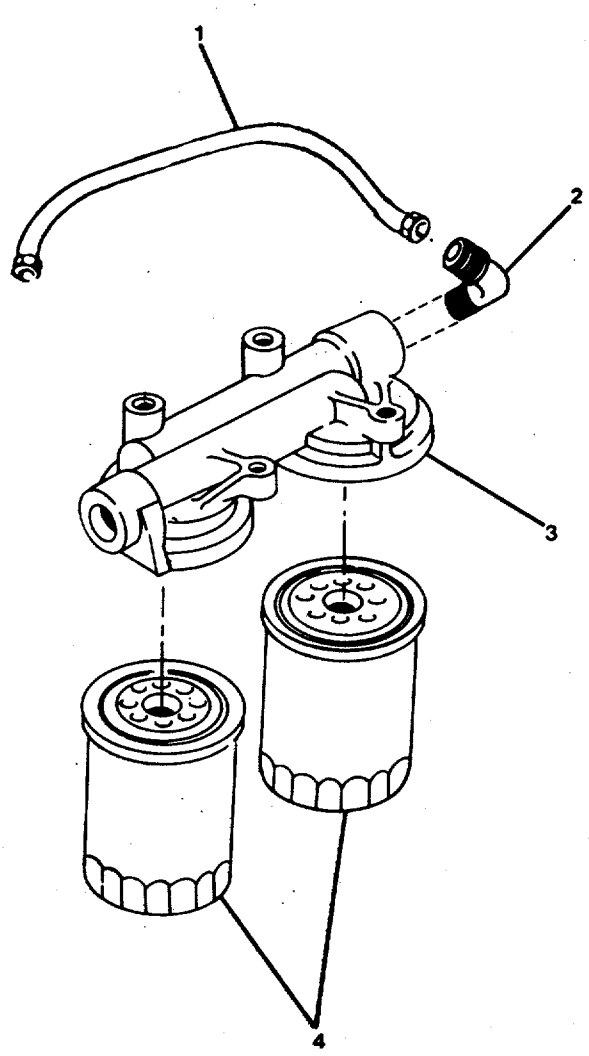


*FIGURE 2-19. Fuel Filter Group.*

REPLACEMENT

a. Connect nonmetallic hose (1) to tube to boss elbow (2).

b. Connect nonmetallic hose assembly (1) to the fuel pump.

c. Install two new fuel cartridges (4) on the fluid filter head (3) as follows:

(1) Apply a light coat of lubricating oil to the gaskets on the filters.

**CAUTION**

Hand-tighten fuel filter cartridges. Do not use a filter wrench or other tool. This may result in damage to the filter element or threads on the filter head.

(2) Turn the fuel filter cartridges (4) clockwise by hand until the gasket on the filter contacts the gasket surface on the head. Then tighten another 1/2 to 3/4 turn.

d. Open the fuel supply valve. Refer to TM 55-1905-223-10.

e. Startup engine. Refer to TM 55-1905-223-10.

f. Observe fuel filter cartridges (4), fluid filter head (3) and nonmetallic hose assembly (1) for fuel leaks. Repair as necessary.

g. Remove "Out of Service - Do Not Operate" tag.

## 2-28. Replace/Repair Sump Pump Group. (FIGURE 2-20)

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783

Equipment Condition

Engine shut down
(TM 55-1905-223-10).
Engine tagged, "Out of Service - Do Not Operate."

Materials/Parts

Nonmetallic hose assembly
P/N AM1005400SS
Shutoff valve P/N 3200802
Rotary pump P/N 123822
Teflon pipe thread lubricant,
Item 9, Appendix C
Warning tag, Item 25, Appendix C

REMOVAL

a. Disconnect loop clamp (16) by removing hexhead capscrew (13) and lockwasher (14) and flat washer (15).

b. Remove pipe bushing (18) and male adapter elbow (17).

c. Disconnect nonmetallic hose assembly (12) from male adapter elbow (11).

d. Disconnect outlet pipe (4) at the top of rotary pump (5).

e. Disconnect piping from shutoff valve (9).

f. Remove mounting screws (1), lockwashers (2), and plain washers (3) and remove rotary pump (5) from the mounting bracket (19).

g. Remove shutoff valves (9 and 10) by unscrewing and removing from pipe nipples (7). Remove elbow (11) from shutoff valve (10).

h. Remove pipe nipples (7) from pipe tee (8).

i. Remove pipe tee (8) from pipe nipple (7).

j. Remove pipe nipple (7) and pipe bushing (6) from rotary pump (5).

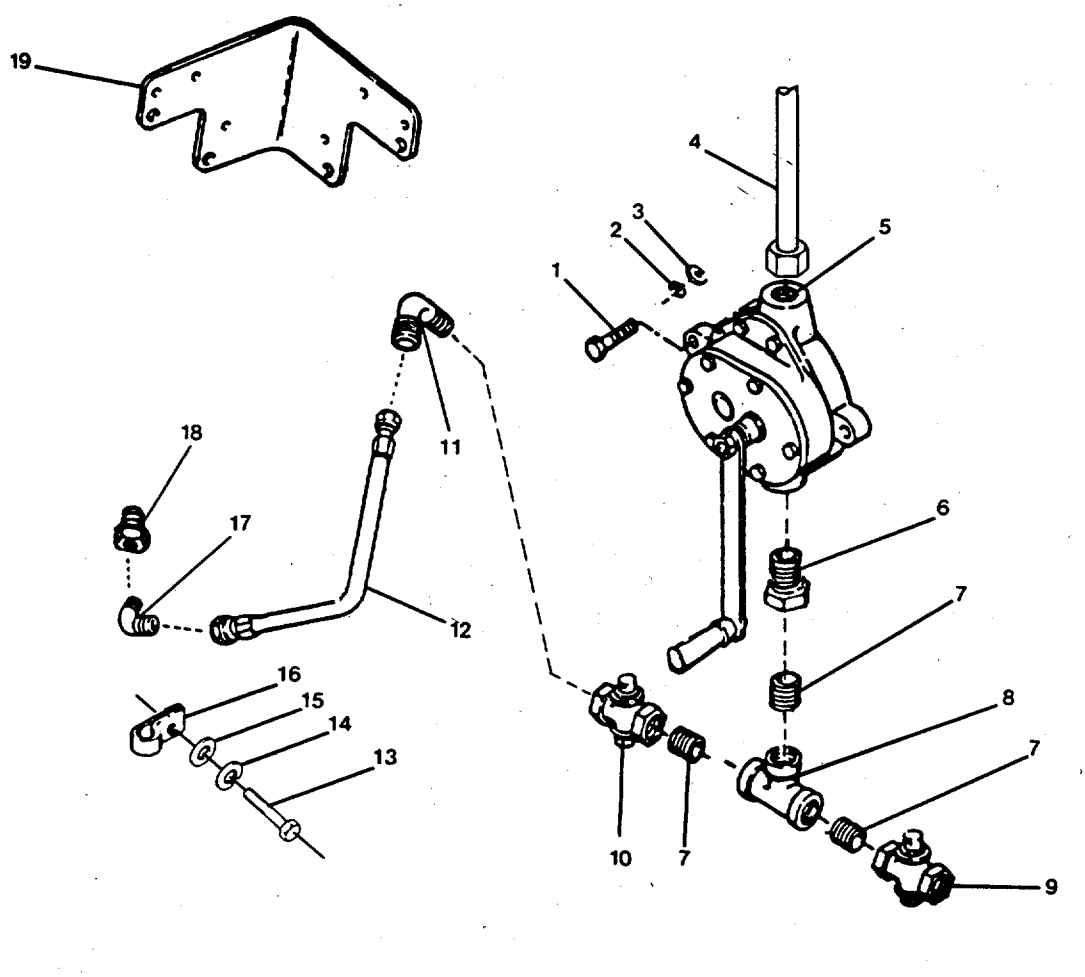


*FIGURE 2-20. Sump Pump Group.*

REPAIR

Repair to the sump pump is by replacement of rotary pump (5), nonmetallic hose assembly (9) and shutoff valves (7).

REPLACEMENT

NOTE

Apply teflon pipe thread lubricant to threaded fittings.

a. Install pipe bushing (6) and pipe nipple (7) on rotary pump (5).

b. Install pipe tee (8) on pipe nipple (7) and pipe nipples (7) on pipe tee (8).

c. Install shutoff (9 and 10) on pipe tee (8)

d. Install pipe elbow (11) on shutoff valve (10) and connect pipe to shutoff valve (9).

e. Mount the pump (5) with mounting screws (1), and lock washers (2), washers (3) to mounting bracket (19).

f. Connect nonmetallic hose assembly (12) to elbow (11) and secure.

g. Connect loop clamp (16) with bolt (13), lockwasher (14), and flat washer (15).

h. Install pipe bushing (18) and male adapter elbow (17).

i. Connect nonmetallic hose assembly (12) to male adapter elbow (17).

j. Install outlet piping (4) to pump (5).

k. Startup engine. Refer to TM 55-1905-223-10.

l. Observe rotary pump (5) for leaks. Repair as necessary.

m. Remove "Out of Service - Do Not Operate" tag.

## 2-29. Replace/Repair of Water Pump and Idler/Belt Guard Group.

**This task covers:**

**a. Inspection b. Adjustment c. Removal d. Repair e. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Belt tension gauge P/N ST-1293
Standard puller P/N ST-647
Bearing disassembly fixture
P/N 3376637
Torque wrench (30-300 ft-lb),
5120-01-125-5190
Mandrel kit, P/N ST-1325

Materials/Parts

Gasket P/N 3024960
Preformed packing P/N 43463-A
V-belt P/N 217638
Belt-chain tension adjusting device
P/N 3050398
Engine cooling system pump P/N 3810708
Bearing retaining ring P/N S-16255
Annular ball bearing P/N 115519
Spacer P/N 196844
Centrifugal pump impeller
P/N 3000888
Packing with retainer P/N 3033677
Shouldered shaft P/N 3050394
Gasket P/N 3002385
Cleaning solvent, Item 5, Appendix C
Warning tag, Item 25, Appendix C
Loctite, Item 37, Appendix C

Equipment Condition

Engine shut down and cooled to 120°F
(TM 55-1905-223-10).
Engine tagged, "Out of Service - Do Not
Operate."

NOTE

Engine water pump (major) parts
kit, P/N 3801712, need for
complete repair of water pump.

INSPECTION

a. Remove belt guard (5, FIGURE 2-21, Sheet 1) by removing two hexhead capscrews (2), lockwashers (3), and flat washers (4).

b. Turn idler groove pulley (18, FIGURE 2-21, Sheet 1) by hand to check ease of rotation. If pulley does not turn easily, replace the idler pulley assembly (32, FIGURE 2-21, Sheet 3). Refer to REMOVAL steps of this procedure.

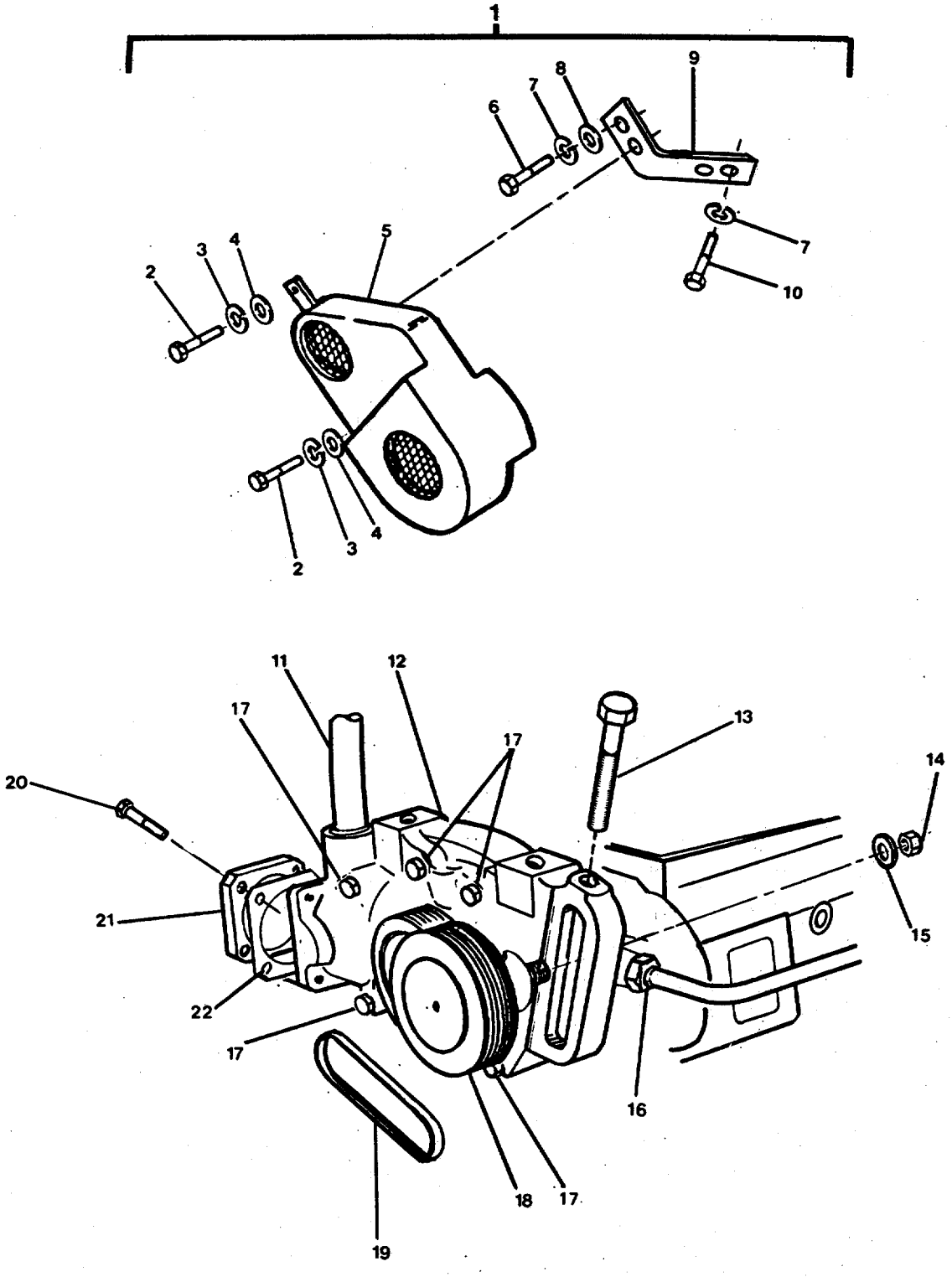


*FIGURE 2-21. Water Pump and Idler (Sheet 1 of 3).*

c. Inspect pulley alignment. Misalignment must not exceed 1/16 inch per foot (0.5mm per cm) of distance between pulley centers. If misaligned, replace the idler pulley assembly (32, FIGURE 2-21, Sheet 3). Refer to REMOVAL steps of this procedure.

ADJUSTMENT

a. Remove belt guard (5, FIGURE 2-21, Sheet 1) by removing two hexhead capscrews (2), lockwashers (3) and flat washers (4).

b. Use belt tension gauge (3, FIGURE 2-21, Sheet 2) to measure V-belt (2) tension.

(1) New belt tension should be 150 to 160 ft-lbs (200 to 220 N•m).

(2) Used belt tension should be 70 to 120 ft-lbs (95 to 165 N•m).

c. Loosen idler pulley assembly locking nut (14, FIGURE 2-21, Sheet 1).

d. Turn adjusting screw (1) counterclockwise to decrease tension on V-belt (2).

e. Turn adjusting screw (1) clockwise to increase tension on V-belt (2).

f. Tighten idler pulley assembly locking nut (14) to 50 ft-lbs (70 N•m).

g. Replace belt guard (5, FIGURE 2-21, Sheet 1) and secure with two flat washers (4), lockwashers (3) and hexhead capscrews (2).

REMOVAL

a. Drain the engine coolant.

b. Remove water pump belt guard (5, FIGURE 2-21, Sheet 1) by removing two hexhead capscrews (2), lockwashers (3) and flat washers (4).

c. Remove mounting bracket (9) and hardware (6, 7, 8, and 10).

d. Loosen the idler pulley shaft locknut (14).

e. Turn adjusting screw (13) counterclockwise to release belt tension and remove water pump V-belt (19). Remove adjusting screw (13). Remove locknut (14) and washer (15) to remove idler pulley assembly (18).

f. Remove water bypass pipe (11), capscrew and retaining clamp (25, 26, FIGURE 2-21, Sheet 3), and preformed packing (24, FIGURE 2-21, Sheet 3).

g. Disconnect water filter hose (16, FIGURE 2-21, Sheet 1).

h. Remove water transfer connection capscrews (20), plate (21) and gasket (22). Discard gasket.

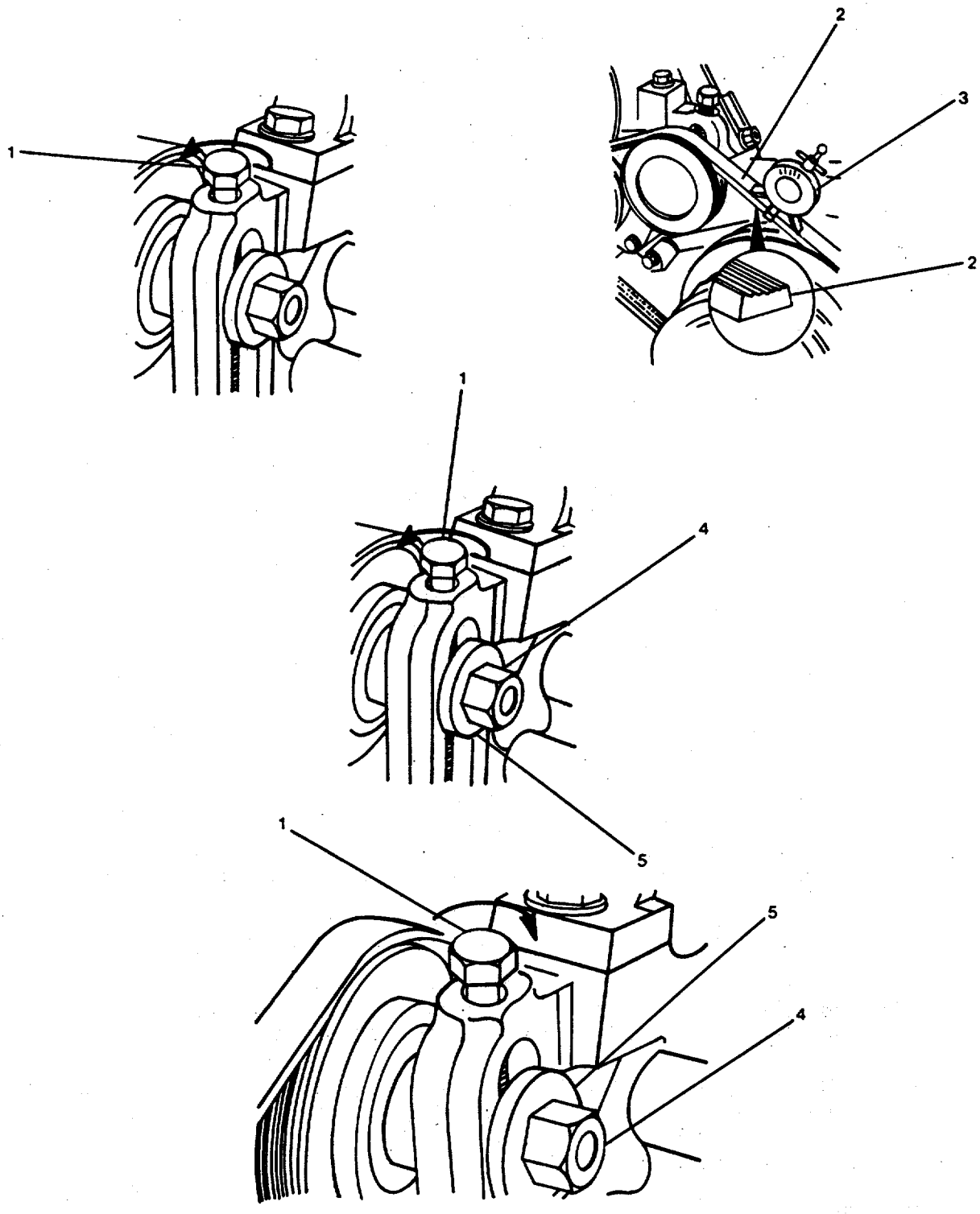


*FIGURE 2-21. Water Pump and Idler (Sheet 2 of 3).*

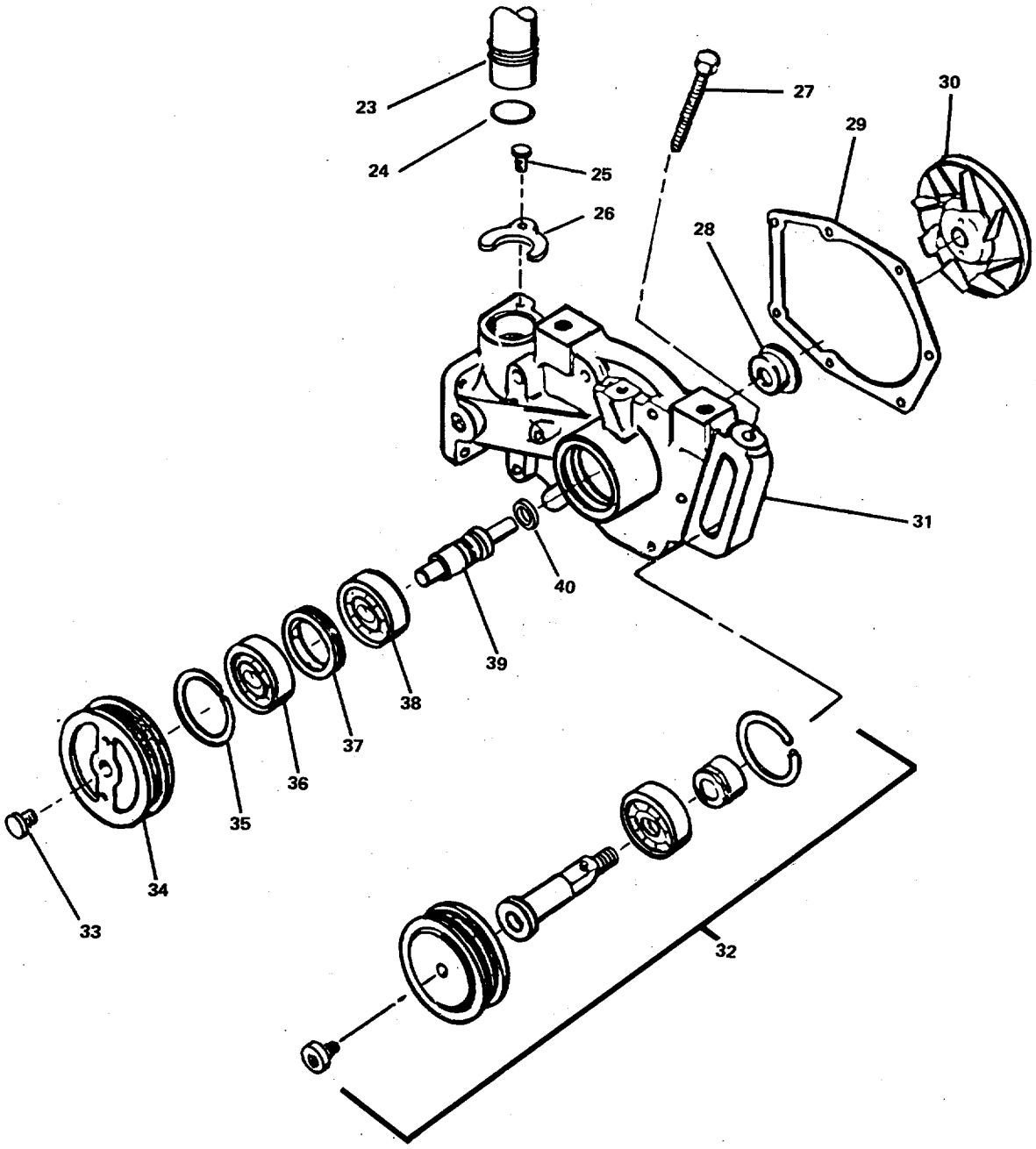


*FIGURE 2-21. Water Pump and Idler (Sheet 3 of 3).*

**CAUTION**

Water pump must be removed carefully to avoid damage to impeller.

i. Remove six mounting screws (17) from water pump (12) and remove the water pump from the engine.

j. Remove the plug (33, FIGURE 2-21, Sheet 3) from the water pump pulley.

k. Using standard puller, remove drive pulley (34, FIGURE 2-21, Sheet 3) and impeller (30) from the shaft (39).

1. Remove the larger retaining ring (35) that holds the bearings (36, 38) and shaft (39) in the water pump (31).

m. Support the pulley side of the housing (31). Push on the impeller (30) end of the shaft (39) to remove the bearings (36, 38), and shaft (39) from the housing.

n. Remove the cupseat (28), grease seal (40), and gasket (29). Discard grease seal and gasket.

o. Use the bearing disassembly fixture to support the outer bearing (36). Push the shaft (34) from the bearing (36, 38) and spacer (37).

REPAIR

a. Clean the parts with cleaning solvent and dry with compressed air.

b. Check the bearings (36, 38) for scoring. If the bearing races are damaged, be sure to check the outside diameter of the shaft (39) and the bearing bores. Discard the bearings (36, 38) after inspection.

c. Check the impeller (30) for cracks, nicks, and corrosion. Replace impeller (30) if damage is found.

d. Measure the bore in the impeller (30). Measure the outside diameter of the shaft (39) at the impeller end of the shaft. There must be at least 0.001 inch (0.03 mm) press-fit between the impeller bore and outside diameter of the shaft.

e. Check the shaft (39) to make sure it is straight. Replace shaft, if bent.

f. Check the water pump housing (31) for cracks and corrosion. Replace water pump, if required.

g. Measure the housing bore. Replace the pump if the bearing bore is larger than 2.4494 inches (62.515 mm). Make sure the weep hole in the housing is open.

h. Replace preformed packing (24, FIGURE 2-21, Sheet 3), grease seal (40), face seal and cup seat (28), spacer (37), and V-belt (19, FIGURE 2-21, Sheet 1).

REPLACEMENT

a. Install the idler pulley assembly (32, FIGURE 2-21, Sheet 3) to the water pump housing (31). Install and tighten idler pulley locknut (14, FIGURE 2-21, Sheet 1) and washer (15).

b. Support the impeller side of the water pump housing.

c. Apply a light coat of clean lubricating oil on the shaft (39). Use the mandrel to support the new inner bearing (38). Push the pulley end of the shaft (39) through the bearing (38) until the bearing is against the larger diameter (shoulder) of the shaft (39).

d. Use the mandrel to support the new outer bearing (36). Install the bearing spacer (37) onto the shaft (39). Push the shaft (39) and spacer (37) through the bearing (36) until the bearing (36) is against the spacer (37). Make sure the bearings (36, 38) turn freely.

**CAUTION**

To prevent damage to the bearing, make sure the inner race of the bearing is not overloaded from contact with the spacer.

e. Apply a thin coat of Loctite to the outside diameter of the bearings (36, 38). Install the bearings (36, 38) and shaft (39) assembly into the bore of the housing. Use the mandrel to push the bearings (36, 38) and shaft (39) assembly into the housing.

f. Install the large retaining ring (35), with the flat side toward the bearing, into the groove in the "housings

g. Install a clean grease fitting into the housing. Install grease into the housing, through the fitting, until you can see the grease through the outer bearing.

NOTE

Use grease that meets the specifications of MIL-G-3545. Do not use grease that has thickeners of sodium or soda soap.

**CAUTION**

Do not install too much grease. This can cause damage to the bearings.

Do not apply more than one drop of Loctite. More than one drop will cause seal and cup seat to fasten together.

h. Install the cup seat (25) and gasket (26). Use the mandrel to install the cup seat.

i. Apply one drop of Loctite to the cup seat (28). Put the drop between the shaft (39) and cup seat (28).

j. Apply a light coat of Loctite to the bore in the drive pulley (34). Push the water pump shaft (39) into the bore until the pulley (34) is against the larger diameter (shoulder) of the shaft (39).

k. Apply a light coat of Loctite to the bore in the impeller (30). Support the pulley end of the shaft (39). Push the impeller (30) onto the shaft (39). The clearance between the vanes of the case iron impeller (30) and the housing must be 0.020 to 0.040 inch (0.51 mm to 1.02 mm), if not, pump must be replaced.

1. Install water pump with six capscrews (17, FIGURE 2-21, Sheet 1). Tighten in stages in 10 ft-lbs, and 20 ft-lbs and 35 ft-lbs in the sequence shown in FIGURE 2-22.

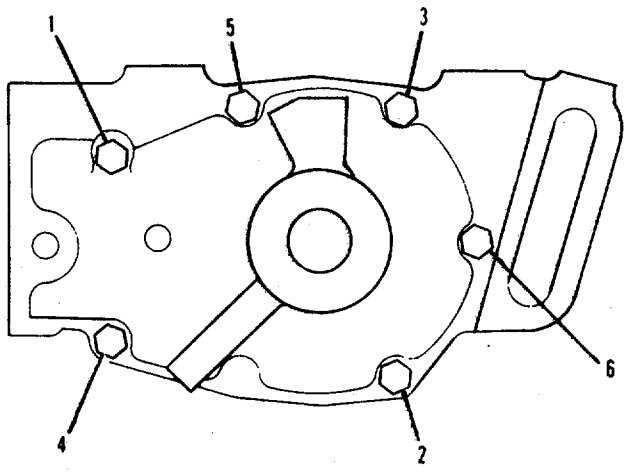


*FIGURE 2-22. Bolt-Tightening Sequence.*

m. Install gasket (22), plate (21) and capscrews (20) to cylinder block. Torque to 35 ft-lb.

n. Install preformed packing (24, FIGURE 2-21, Sheet 3) and, connect water bypass pipe (23). Install pipe retaining clamp (26) and tighten with capscrew (25).

o. Connect water filter hose (16).

p. Install water pump V-belt (19) on the pulley (18).

q. Loosen idler pulling locknut (14). Install adjusting screw (13, FIGURE 2-21, Sheet 1) and increase tension by turning clockwise.

r. Tighten idler pulley locknut (14) and washer (15) to 50 ft-lbs torque.

s. Turn adjusting screw 1/2 turn counterclockwise to prevent breakage.

t. Mount bracket (9) to pump and secure with capscrews (6, 10) and washers (7, 8).

u. Install belt guard (5), and hexhead capscrew bolts (2), lockwashers (3) and flatwashers (4).

v. Add coolant to engine and test.

## 2-30. Replace/Repair Lubricating Oil Cooler/Filter Group.

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Torque wrench kit P/N 3377216

Equipment Condition

Engine shut down and cooled to below 120°F (50°C) (TM 55-1905-223-10).
Engine tagged, "Out of Service - Do Not Operate."
Engine coolant drained (TM 55-1905-223-10).

Materials/Parts

Oil cooler assembly P/N 3003814
Gasket P/N 70089-1, 3008017, 3308958
Preformed packing P/N 3302630
Nonmetallic hose P/N 3051560
Fluid filter element P/N 313279
Engine oil, Item 26, Appendix C
Cleaning solvent, Item 5, Appendix C
Warning tag, Item 25, Appendix C
Vegetable oil, Item 27, Appendix C
Guide studs, oil cooler, Item 36,
Appendix C

REMOVAL

a. Remove turbocharger oil supply tube (4, FIGURE 2-23) and bypass filter return tube (13).

b. Loosen hose clamp (27) and remove nonmetallic hose (26) from flange to hose elbow (2).

c. Loosen hose clamp (25) and hose clamp (23) and remove transfer tube (24).

d. Loosen hose clamp (21) and remove nonmetallic hose (22) and hose clamps (23 and 21) from oil cooler (9).

e. Remove six assembled washer screws (1) and remove flange to hose elbow (2) and gasket (3). Discard gasket.

f. Using filter wrench, remove oil fluid filter element (20) by turning counterclockwise. Discard fluid filter element.

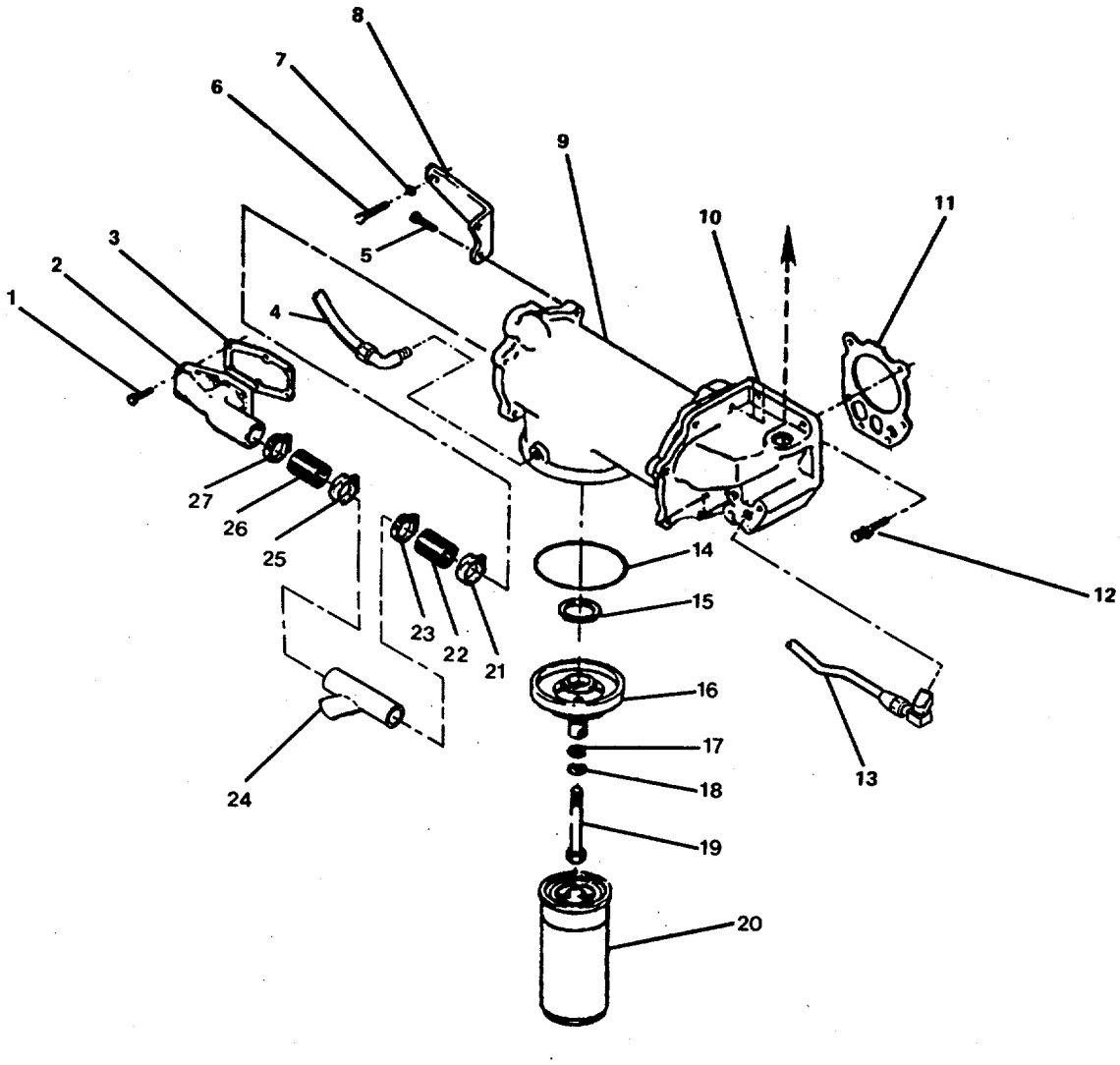


*FIGURE 2-23. Lube Oil Cooler/Filter Group.*

g. Remove assembled washerscrew (19), lockwasher (18), flat washer (17) and fluid filter head (16) with gasket (15) and preformed packing (14). Discard gasket (15) and preformed packing (14).

h. Remove hexhead capscrew (6) and lockwasher (7) holding angle bracket (8) to cylinder block.

i. Remove two assembled washerscrews (5) and remove angle bracket (8) from oil cooler (9).

j. Remove one of the six machine screws (12) holding oil cooler support (10) to the cylinder block. Install guide stud in this hole to support oil cooler.

k. Remove remaining five machine screws (12) and remove oil cooler (9), gasket (11) and guide stud.

REPAIR

Repair of the lubricating oil cooler/filter group consists of replacing gaskets (3, 11 and 15), nonmetallic hoses (22 and 26), preformed packing (14) and fluid filter element (20). The oil cooler assembly (9) is repaired by Intermediate Direct Support Maintenance, Chapter 3.

a. Clean gasket material from cooler support (10) and gaskets (3) and (11) mounting surfaces on the cylinder block.

b. After removing gasket material, clean with cleaning solvent and dry with compressed air.

REPLACEMENT

a. Install two guide studs in cylinder block mountings holes for cooler support (10).

b. Install new cooler support (10) gasket (11) over guide studs.

c. Position oil cooler assembly (9) over guide studs and push it against the cylinder block.

d. Install angle bracket (8) and two assembled washerscrews (5) to oil cooler assembly (9), but do not tighten at this time.

e. Install four of the remaining machine screws (12) and remove guide studs supporting oil cooler assembly (9) support (10).

f. Install the two remaining machine screws (12) and tighten all six machine - screws (12) to 35 ft-lbs (45 N•m) torque.

g. Tighten the two angle bracket (8) assembled washerscrews (5) to 8 ft-lbs (10 N•m) torque.

h. Install hexhead capscrew (6), lockwasher (7) and secure angle bracket (8) to cylinder block.

i. Install new gasket (3), flange to hose elbow (2) and secure with six assembled washerscrews (1).

j. Install new nonmetallic hose (22) with hose clamps (23) and (21) on oil cooler assembly (9). Secure hose clamp (21).

k. Install transfer tube (24) on nonmetallic hose (22) and secure hose clamp (23).

l. Install new nonmetallic hose (26) with hose clamps (25) and (27) on transfer tube (24). Secure hose clamp (25).

m. Install nonmetallic hose (26) and hose clamp (27) on flange to hose elbow (2) and secure hose clamp (27).

n. Connect turbocharger oil supply tube (4) and bypass filter return tube (13).

NOTE

Ensure there is a minimum of 0.250 inch (6.3 mm) clearance between the filter and the oil pan flange of the cylinder block.

o. Install new preformed packing (14) and gasket (15) on fluid filter head (16) and install fluid filter head (16) on oil cooler assembly (9) with flat washer (17), lockwasher (18) and assembled washerscrew (19).

p. Fill new fluid filter element (20) with clean lubricating oil. Coat filter gasket sealing surface with clean vegetable oil.

q. Install fluid filter element (20) by screwing clockwise by hand until snug.

**CAUTION**

Mechanical overtightening may distort the threads or damage the filter element seal.

r. Using oil filter wrench, tighten filter element (20) an additional three-fourths to one (3/4 to 1) turn.

s. Fill cooling system. Refer to TM 55-1905-223-10.

t. Startup engine. Refer to TM 55-1905-223-10.

u. Allow engine to run until water temperature reaches 180°F (80°C).

v. Check for oil and coolant leaks. Repair as necessary.

w. Remove "Out of Service - Do Not Operate" tag.

## 2-31. Replace/Repair Lubricating Oil By-Pass Filter Group.

This task covers: a. Inspection b. Removal c. Repair d. Replacement e. Installation.

INITIAL SETUP:

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Oil filter wrench, 5120-01-160-8863
Filter cutter P/N 3376579

Equipment Condition

Engine shut down and cooled to below 120°F (50°C) (TM 55-1905-223-10).
Engine tagged, "Out of Service - Do Not Operate."

Materials/Parts

Lubricating oil, Item 1, Appendix C
Fluid filter element P/N 3313289
Nonmetallic hose assembly
P/N AM0603600SS, AM0603400SS
Cleaning solvent, Item 5, Appendix C
Warning tag, Item 25, Appendix C
Vegetable oil, Item 27, Appendix C

INSPECTION

a. Inspect hoses (11, FIGURE 2-24) for cracks, holes, secure attachment of hose ends and damaged (stripped, crossed) threads in hose ends.

b. Inspect fluid filter element (14) for holes, dents, clogging and leaks in sealing gasket.

REMOVAL

a. Disconnect and remove capscrew (6), lockwasher (7), flat washer (8), and hose clamps (9).

b. Remove pipe elbows (12) from nonmetallic hose assemblies (11).

c. Remove nonmetallic hose assemblies (11) from pipe elbows (10).

d. Remove and discard fluid filter element (14).

e. Remove capscrews (5), nuts (2), lockwashers (3), and flat washers (4).

f. Remove fluid filter head (13) from angle bracket (1).

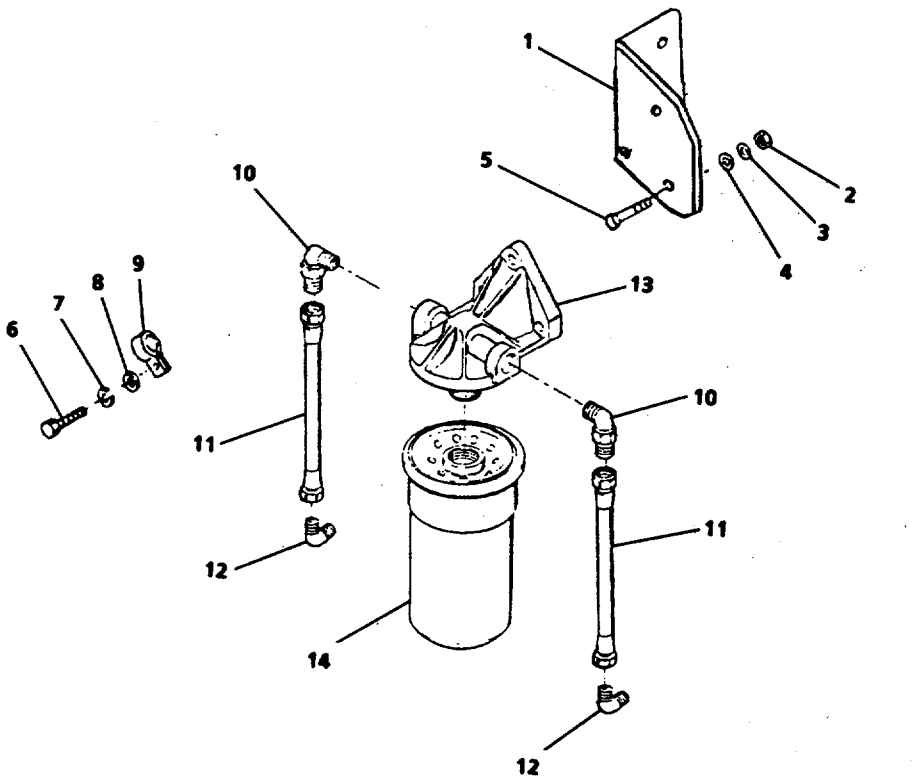


*FIGURE 2-24. Lubricating Oil Bypass Filter Group.*

REPAIR

Repair to the oil bypass group is by replacing the fluid filter element (14) and nonmetallic hose assemblies (11).

REPLACEMENT

a. Install fluid filter head (13) on angle bracket (1) and secure with capscrews (5), flat washers (4), lockwashers (3), and nuts (2).

b. Clean oil filter head surface with cleaning solvent.

c. Use clean vegetable oil to lubricate the gasket surface and fill filter with clean lubricating oil.

d. Install fluid filter element (14) into fluid filter head (13) by turning clockwise. Use oil filter wrench to tighten the filter an additional 3/4 to one turn.

e. Screw nonmetallic hose assemblies (11) into pipe elbows (10).

f. Screw pipe elbows (12) onto ends of nonmetallic hose assemblies (11).

g. Place hose clamps (9) on nonmetallic hose assemblies (11) and secure with capscrews (6), flat washers (8), and lock washers (7).

## 2-32. Replace/Repair Coolant Heater Group.

**This task covers: a. Removal, b. Repair, c. Replacement.**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
DCA Test Kit P/N 3300846S

Equipment Condition.

Engine shut down and cooled to below 120°F (50°C) (TM 55-1905-223-10).
Cooling system drained (refer to PMCS, Item 30).
Engine tagged "Out of Service - Do Not Operate."

Materials/Parts

Preformed hose P/N 3000270
Nonmetallic hose P/N 155789
Nonmetallic hose assembly
P/N AS0403000SS
Pressure switch P/N 196074
Engine coolant heater P/N 212024
Warning tag, Item 25, Appendix C
Cleaning solvent, Item 5, Appendix C

WARNING

Make sure the coolant temperature is below 120°F (50°C) before disconnecting lines.

CAUTION

Operation of the heater without coolant in the heater will cause the element to fail. Coolant mixtures containing excessive amounts of antifreeze can damage element. Refer to TB 55-1900-207-24 for additive and antifreeze requirements.

REMOVAL

WARNING

Make sure electrical power is OFF to the engine coolant heater. Refer to TM 55-1905-223-10.

a. Loosen hose clamps (12 and 17, FIGURE 2-25) and remove two nonmetallic hoses (16) and heater tube (14) with hose clamps (12, 13, 15, and 17) attached.

b. Loosen hose clamps (13 and 15) and remove two nonmetallic hoses (16) from heater tube (14).

c. Remove pipe to hose straight adapter (18) from engine coolant heater (21).

d. Remove capscrew (8), lockwasher (9), and loop clamp (10) from heater tube (27).

e. Loosen hose clamps (24 and 30) and remove two nonmetallic hoses (29 and 25) with hose clamps (30, 28, 26 and 24), nonmetallic hoses (25 and 29) and heater tube (27) attached.

f. Loosen hose clamps (28 and 26) and remove nonmetallic hoses (25 and 29).

g. Remove pipe to hose straight adapter (23) from engine coolant heater (21).

h. Disconnect and tag electrical wiring to the pressure switch (4).

i. Disconnect and remove nonmetallic hose assembly (7) from tube to hose elbows (2 and 11).

j. Remove tube to hose elbow (2) and pipe to tube straight adapter (3) from pressure switch (4).

k. Remove tube to hose elbow adapter (11).

1. Remove two capscrews (6) and lockwashers (5) and remove pressure switch (4).

m. Remove six capscrews (19) and plain washers (20) securing coolant heater to engine heater bracket (22) and remove engine coolant heater. Electrical boxes are removed with the engine coolant heater (see FIGURE 2-26).

REPAIR

Repair of the coolant heater group consists of replacing the engine coolant heater (21), nonmetallic hoses (29, 25 and 26), pressure switch (4) and nonmetallic hose assembly (7).

REPLACEMENT

a. Install engine coolant heater (21, FIGURE 2-25) on engine coolant heater bracket (22) and secure with six capscrews (19) and plain washers (20).

b. Install pressure switch (4) and secure with two capscrews (6) and lockwashers (5).

c. Install tube to hose elbow adapter (11).

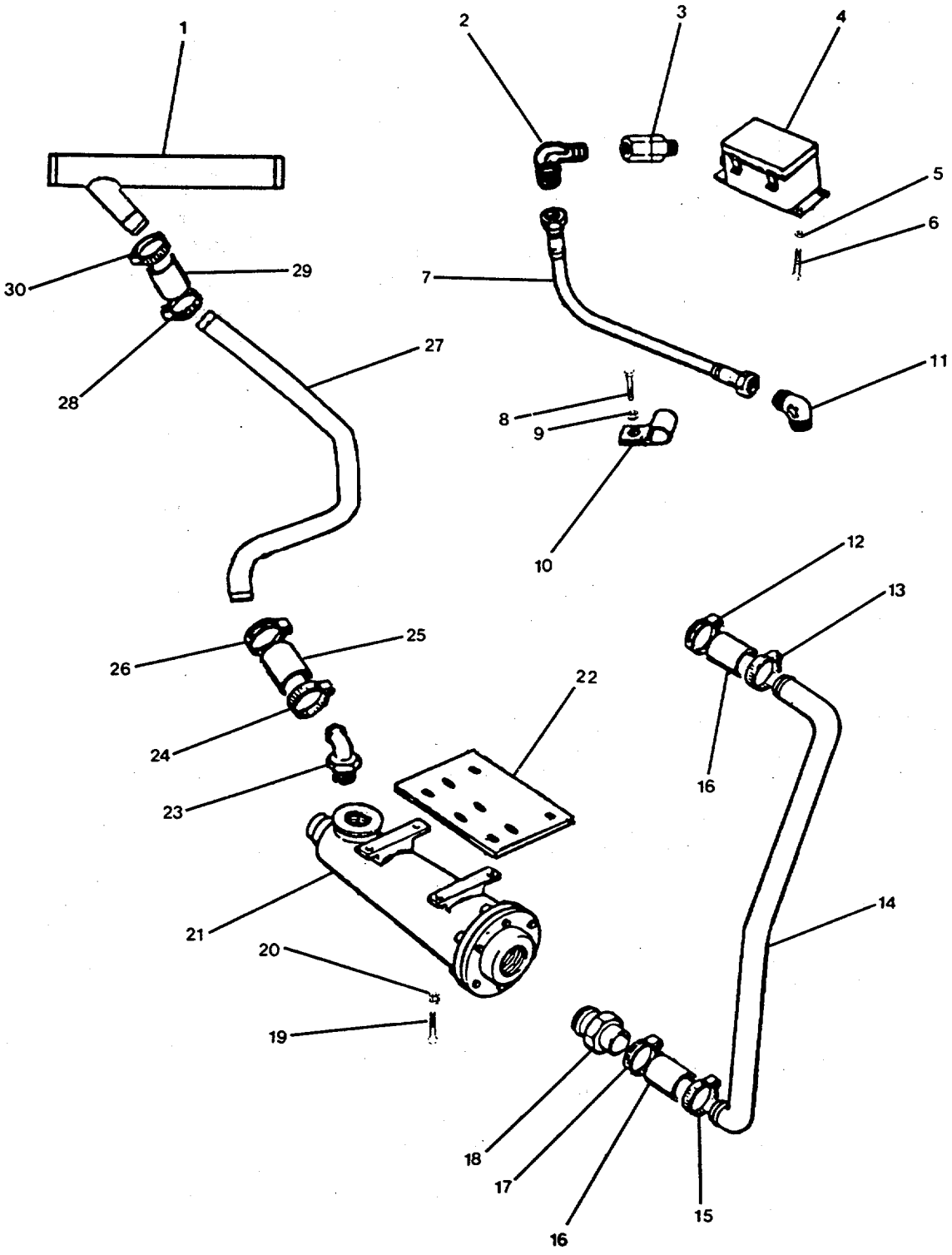


*FIGURE 2-25. Coolant Heater Group.*

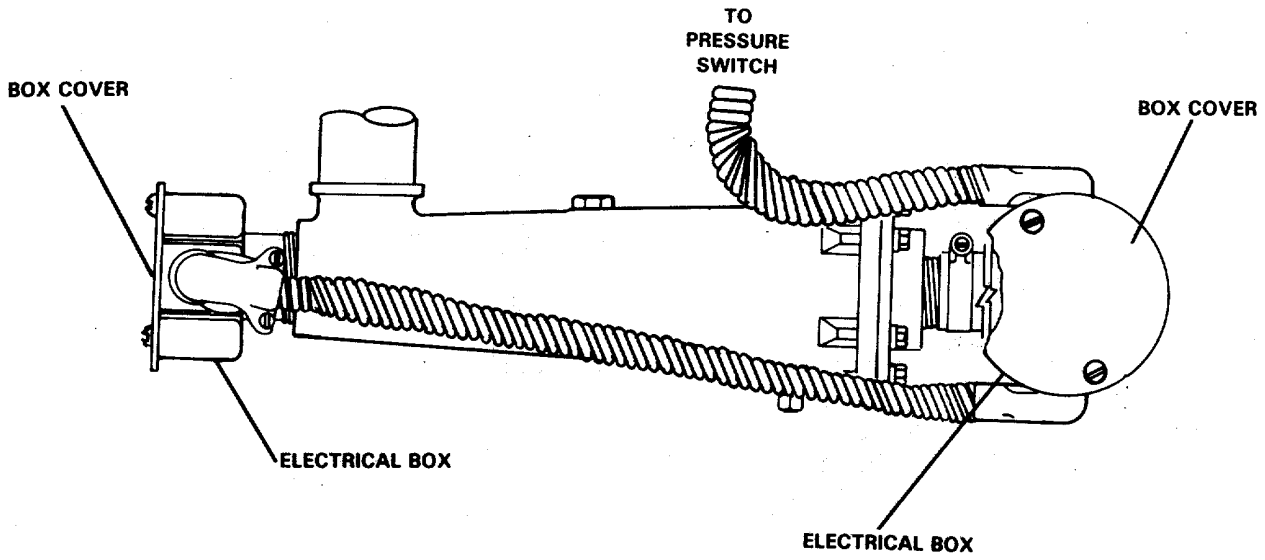


*FIGURE 2-26. Location of Electrical Boxes on Coolant Heater.*

d. Install pipe to tube straight adapter (3) and tube to hose elbow (2) on pressure switch (4).

e. Connect nonmetallic hose assembly (7) to tube to hose elbows (2 and 11).

f. Connect electrical wiring to pressure switch (4).

g. Install pipe to hose straight adapter (23) on engine coolant heater (21).

h. Assembly nonmetallic hoses (25 and 29), heater tube (27) and hose clamps (30, 28, 26 and 24) and heater tube (27). Install this assembly on pipe to hose straight adapter (23) and transfer tube (1). Tighten hose clamps to 35-45 in-lb torque.

i. Install loop clamp (10) on heater tube (27) and secure with capscrew (8) and lockwasher(9).

j. Install pipe to hose straight adapter (18) on engine coolant heater (21).

k. Assemble two nonmetallic hoses (16), heater tube (14), and hose clamps (17, 15, 13, and 12). Install this assembly on pipe to hose straight adapter (18) and engine outlet. Tighten hose clamps to 35-45 in-lb torque.

1. Fill the engine cooling system. Refer to TB 55-1900-207-24.

**NOTE**

Refill the engine heater outlet line disconnected at the engine until outlet line is full of coolant. This eliminates airlocks in the heater and hoses. Connect outlet line to engine and finish filling engine.

m. Startup engine. Refer to TM 55-1905-223-10.

n. Observe engine coolant heater group for leaks. Repair as necessary.

o. Remove "Out of Service - Do Not Operate" tag.

## 2-33. Replace/Repair Fuel Tubing, Shutdown Valve and Fuel Pump Group.

**This task covers: a. Removal b. Repair c. Replacement**

### INITIAL SETUP:

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Torque wrench kit P/N 3375044
Torque wrench, 5120-01-092-3278

Equipment Condition

Engine shutdown (TM 55-1905-223-10).
Fuel supply closed at the fuel filter outlet valve.
Electrical power OFF at primary breaker to the engine. (TM 55-1905-223-10).
Engine tagged "Out of Service - Do Not Operate."

Materials/Parts

Check valves P/N 178079 and P/N 3028325
Solenoid valve P/N 3035346
Metering and distributing fuel pump P/N 3058505
Gasket P/N 154087
Gasket P/N 3053805

### REMOVAL

a. Clean the fuel pump and the surrounding area before removing it from the engine.

b. Secure power to battery charger and then disconnect battery cables.

c. Remove nuts (9, FIGURE 2-27) and wires (8) to the fuel shutoff solenoid valve.

d. Remove the linkage (11) by removing bolt (13) and washer (12) from the throttle lever (10).

e. Disconnect the following:

(1) Tachometer cable (1).

(2) Air supply hose (3).

(3) Fuel supply to injectors (4).

(4) Fuel return hose (2).

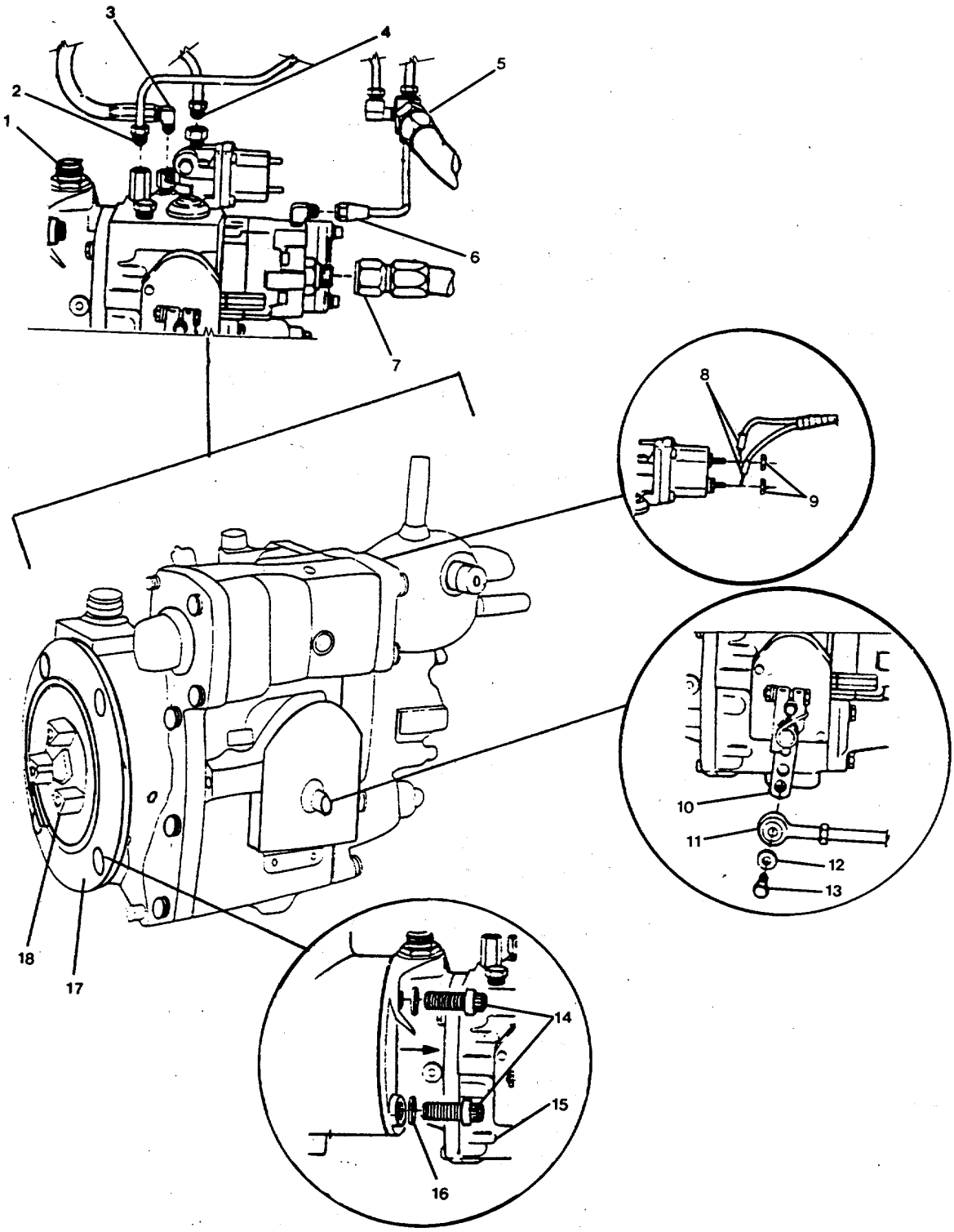


*FIGURE 2-27. Fuel Pump.*

(5) Gear pump cooling drain (6).

(6) Gear pump suction line (7).

(7) Fuel return from cylinder head (5).

f. Remove the four capscrews (14) and washers (16), and the fuel pump (15) and gasket (17).

g. Remove capscrews (2, FIGURE 2-28), lockwashers (3) and flat washers (4).

h. Remove solenoid valve (1) and gasket (5) from top of fuel pump (6).

i. If check valves are to be removed, refer to FIGURE 2-29 and do the following:

(1) Remove the support bracket capscrews (2) and remove the support clips (3).

(2) Disconnect the check valves (4) at hex connections (1) and remove the check valves.

REPAIR

Repair consists of replacing check valves (3, FIGURE 2-29), fuel pump (15, FIGURE 2-27) and gasket (17, FIGURE 2-27), shutdown solenoid valve (1, FIGURE 2-28) and gasket (5).

a. Clean gasket surface of the fuel pump (15, FIGURE 2-27) and accessory drive.

b. Inspect spider coupling (18), if damaged, replace fuel pump (15).

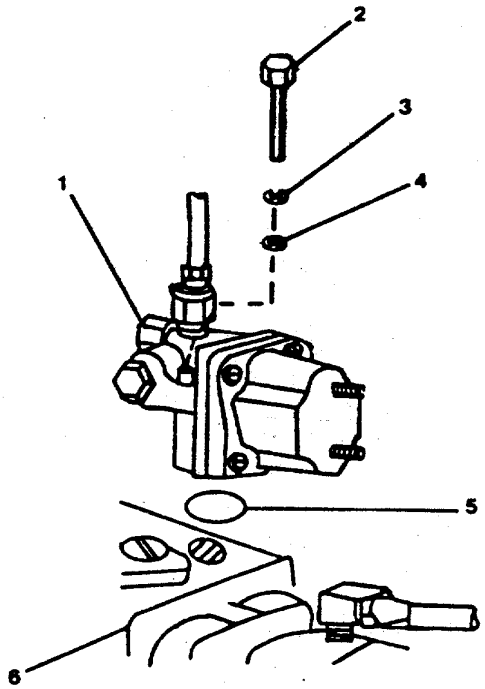


*FIGURE 2-28. Solenoid Valve Replacement.*

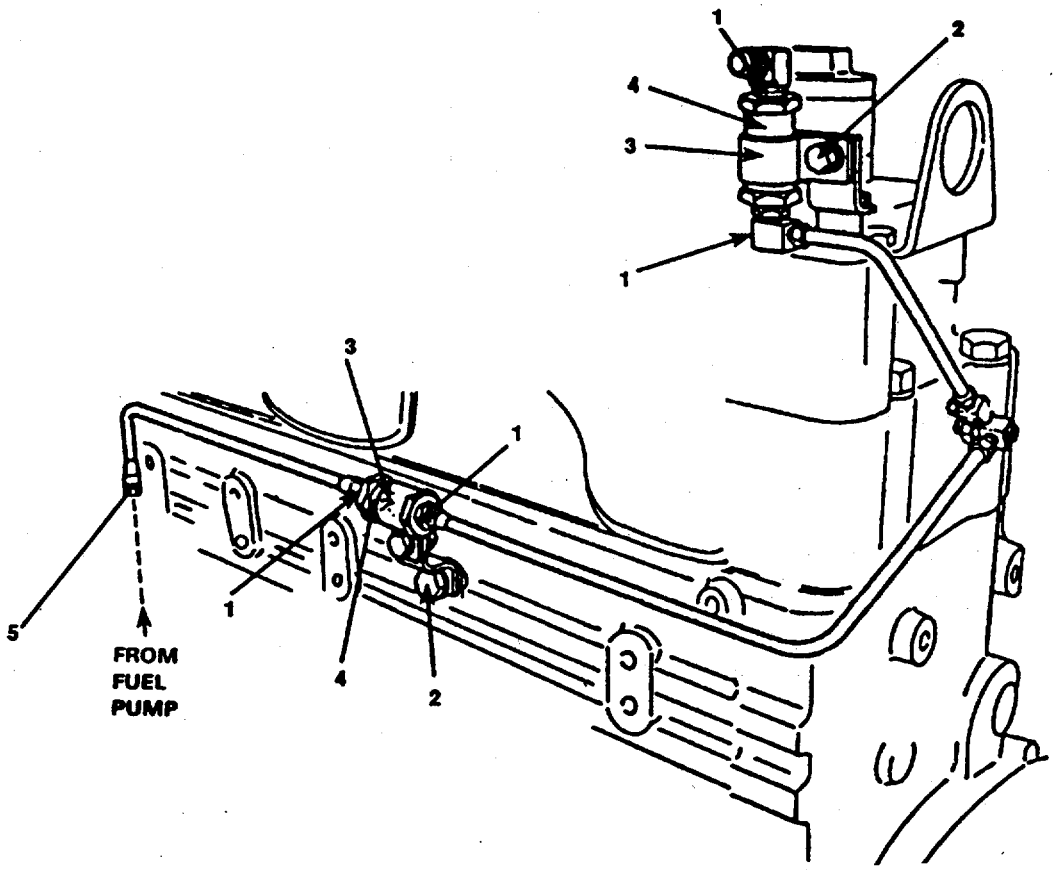


*FIGURE 2-29. Fuel Line Check Valves.*

REPLACEMENT

**CAUTION**

Make sure of proper flow direction when installing check valves.

a. If check valves were removed, connect new valves with hex connections (1, FIGURE 2-29).

b. Install the support clips (3) onto the valves with capscrews (2).

c. Install new gasket (17, FIGURE 2-27) on fuel pump (15).

**CAUTION**

The spider coupling (18, FIGURE 2-27) must be aligned with accessory drive coupling.

d. Install fuel pump (15) ensuring spider coupling (18) is aligned with necessary drive coupling.

e. Install four capscrews (14) and washers (16) to secure the pump (15). Tighten the capscrews to 35 ft-lb torque.

f. Connect the following:

(1) Fuel drain from cylinder head (5).

(2) Gear pump suction line (7).

(3) Gear pump cooling drain (6).

(4) Fuel drain hose (2).

(5) Fuel supply to injectors (4).

(6) Air supply hose (3).

(7) Tachometer cable (1).

g. Install shutoff solenoid valve wires (8) and secure with nuts (9).

h. Install linkage (11) to throttle lever (10) with bolt (13) and washer (12).

i. Open the fuel supply valve at the fuel filter outlet.

j. Restore electrical power to the engine.

k. Operate the engine (TM 55-1905-223-10) and check for leaks. Repair as necessary.

l. Remove "Out of Service - Do Not Operate" tag.

## 2-34. Replace Rocker Lever Housing/Cover Group.

**This task covers: a. Removal b. Replacement**

INITIAL SETUP:

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Torque wrench kit P/N 3377216
Injector adjustment kit,
P/N 3375842

Equipment Condition

Engine shut down and cooled to below 120°F (50°C) (TM 55-1905-223-10).
Instrument panel removed (para. 2-22).
Intake air crossover pipe removed (para. 2-39).
Upper fuel line check valve removed (para. 2-33).

Materials/Parts

Cleaning solvent, Item 5, Appendix C
Gaskets, P/N 3054841 and P/N 3017750
Nonmetallic hose P/N 64775

### REMOVAL

a. Remove the crankcase breather and tube (FIGURE 2-30) as follows:

(1) Loosen the hose clamp (2) at the breather vent tube (3).

(2) Remove the nonmetallic hose (1).

(3) Pull crankcase breather (3) from the rocker housing cover (5).

b. Remove the five capscrews (4) from each rocker housing cover (5, 6, 7).

c. Remove covers (5, 6, 7) and gaskets (8) from rocker lever housing (14).

d. Remove capscrews (9) from rocker lever housing (14).

e. Remove the two lifting brackets (11, 10).

f. Remove the rocker lever housing (14) as follows:

(1) Loosen the rocker lever adjusting screw locks nuts (12).

(2) Turn adjustment screws (13) counterclockwise two full turns.

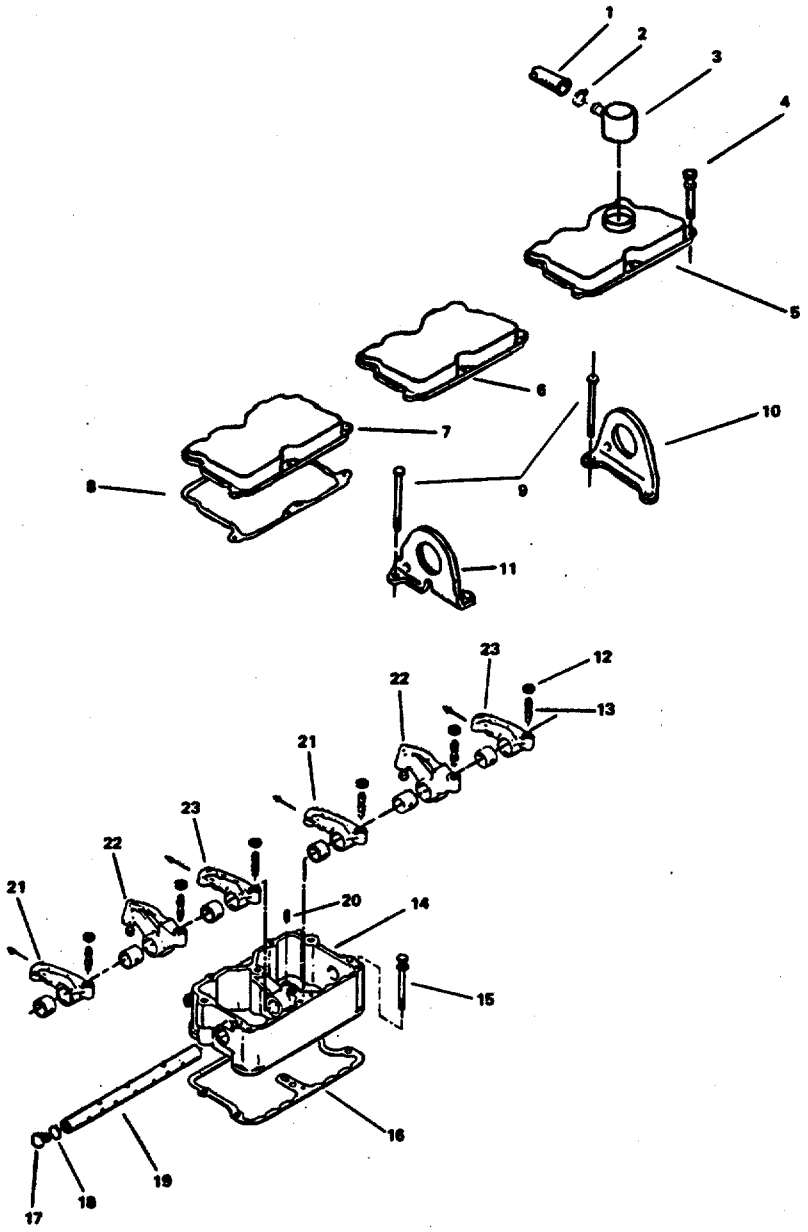


*FIGURE 2-30. Rocker Lever Housing/Cover Group .*

**NOTE**

To prevent increased wear, mark each rocker lever housing as it is removed, and install each in its original location.

(3) Remove the rocker lever housing mounting capscrews (15).

(4) Remove rocker lever housing assembly (14).

(5) Remove gasket (16) and discard.

REPLACEMENT

**NOTE**

Make sure that the covers and gasket surfaces on the housings and cylinder block are clean before installing.

Return each rocker lever housing to its original location on the engine.

a. Install new rocker lever housing gaskets on the cylinder heads (FIGURE 2-31).

b. Install two guide studs in each cylinder head.

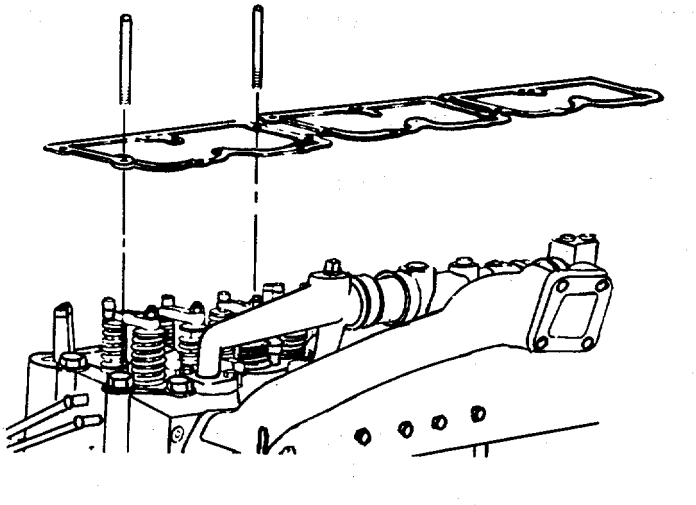

*FIGURE 2-31. Rocker Lever Housing Gaskets.*

**CAUTION**

If the adjusting screws protrude beyond the maximum of 1.2540 inches from the top surface of the lever and the ball end of the adjusting screws, the push rods can be damaged when the housing capscrews are tightened.

c. Loosen the rocker lever adjusting screws so there is a maximum of 1.2540 inches (32.0 mm) from the top surface of the lever and the ball end of the adjusting screw (FIGURE 2-32).

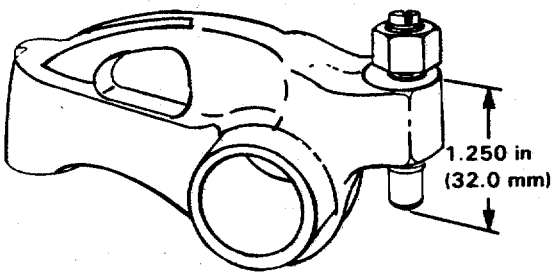


*FIGURE 2-32. Rocker Lever Adjusting Screw.*

d. Install the rocker lever housing as follows:

(1) Hold the rocker levers in position (21, 22, 23, FIGURE 2-30).

(2) Install the ball end of the adjusting screws (15) in the push rod sockets.

(3) Install gaskets (16).

(4) Remove guide studs (FIGURE 2-31).

(5) Install rocker lever housing capscrews (15, FIGURE 2-30).

(6) Install engine lifting brackets (10, 11).

(7) Install capscrews (9) in rocker lever housing (14).

**NOTE**

The longer capscrews are used to secure the engine lifting brackets.

(8) Tighten the rocker lever housing and lifting bracket capscrews to 60 ft-lb torque. Use the sequence shown in FIGURE 2-33 when tightening the housing capscrews.

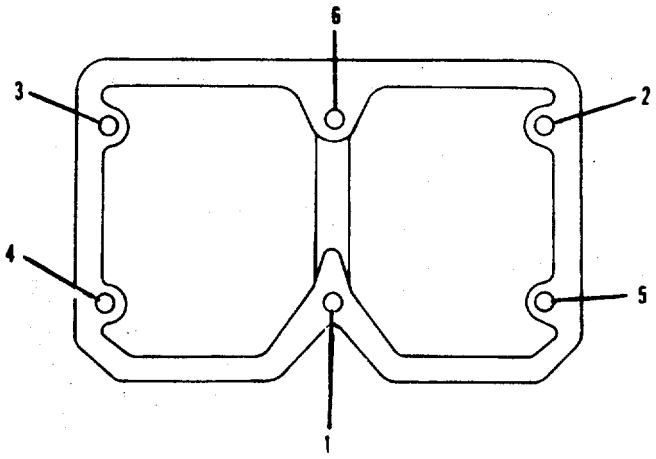


*FIGURE 2-33. Rocker Lever Housing Torque Sequence.*

e. Install gasket (8, FIGURE 2-30) on each rocker lever housing.

**NOTE**

Stamped steel valve covers are designed and manufactured with 0.030 inch (0.75 mm) bow located in the shaded areas as shown in FIGURE 2-34) to provide better sealing qualities. This built-in bow on the valve covers must not be mistaken for warpage. Also, do not attempt to increase or remove the bow from the sealing surface.

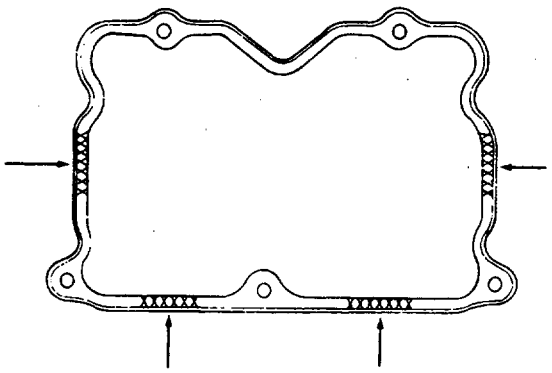

*FIGURE 2-34. Manufactured Bow Areas in Rocker Covers.*

f. Install rocker housing covers (5, 6, 7, FIGURE 2-30) on the rocker lever housing (16).

g. Install the five capscrews (4) in each cover (5, 6, 7).

h. Tighten the capscrews in each cover in the sequence shown (FIGURE 2-35) to 15 ft-lb torque.

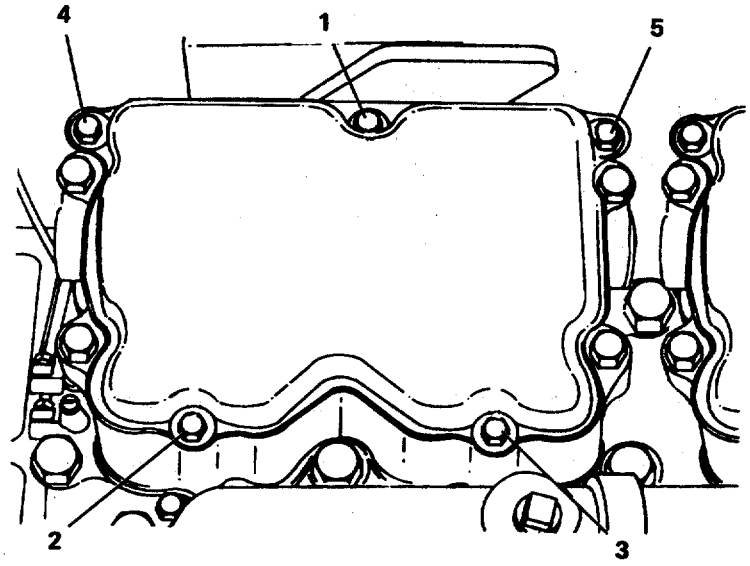


*FIGURE 2-35. Rocker Cover Torque Sequence.*

i. Install the crankcase breather vent tube (3, FIGURE 2-30) on rocker housing cover (5).

j. Install nonmetallic hose (1) on breather (3) and install clamps (2).

k. Tighten hose clamps (3) to 40 in-lb torque.

## 2-35. Replace/Repair Injector Group.

**This task covers: a. Removal, b. Inspection, c. Repair.**

**INITIAL SETUP:**

Tools

Tool kit general mechanic's
rail and marine diesel engines
5180-00-629-9783
Injector adjustment kit P/N 3375842
Injector puller P/N 3376000
Torque wrench,
5120-01-092-3278 (in-lb)
Rocker lever actuator P/N ST-1193

Equipment Condition

Engine shut down and cooled to below 120°F (50°C) (TM 55-1905-223-10).
Instrument panel removed (para. 2-22).
Intake air crossover pipe removed (para. 2-39).
Upper fuel line check valve removed (para. 2-33).
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Materials/Parts

Fuel injection nozzle P/N 3054218
Detent plunger P/N 191916
Lockwasher P/N 180626
Cleaning solvent, Item 5, Appendix C

### REMOVAL

a. Loosen hose clamp (2, FIGURE 2-36) from nonmetallic hose (1).

b. Remove nonmetallic hose (1).

c. Remove four hexhead capscrews (9) and remove engine lifting brackets (8).

d. Remove assembled washer screws (4) from engine poppet covers (5).

e. Remove engine poppet covers (5) and gaskets (6) from rocker lever housing (7). Discard gaskets.

f. Remove breather (3) from engine poppet cover (5).

g. Loosen the adjusting screw locknut (2, FIGURE 2-37) on each injector rocker lever.

h. Turn out the adjusting screw (1) on each injector rocker lever.

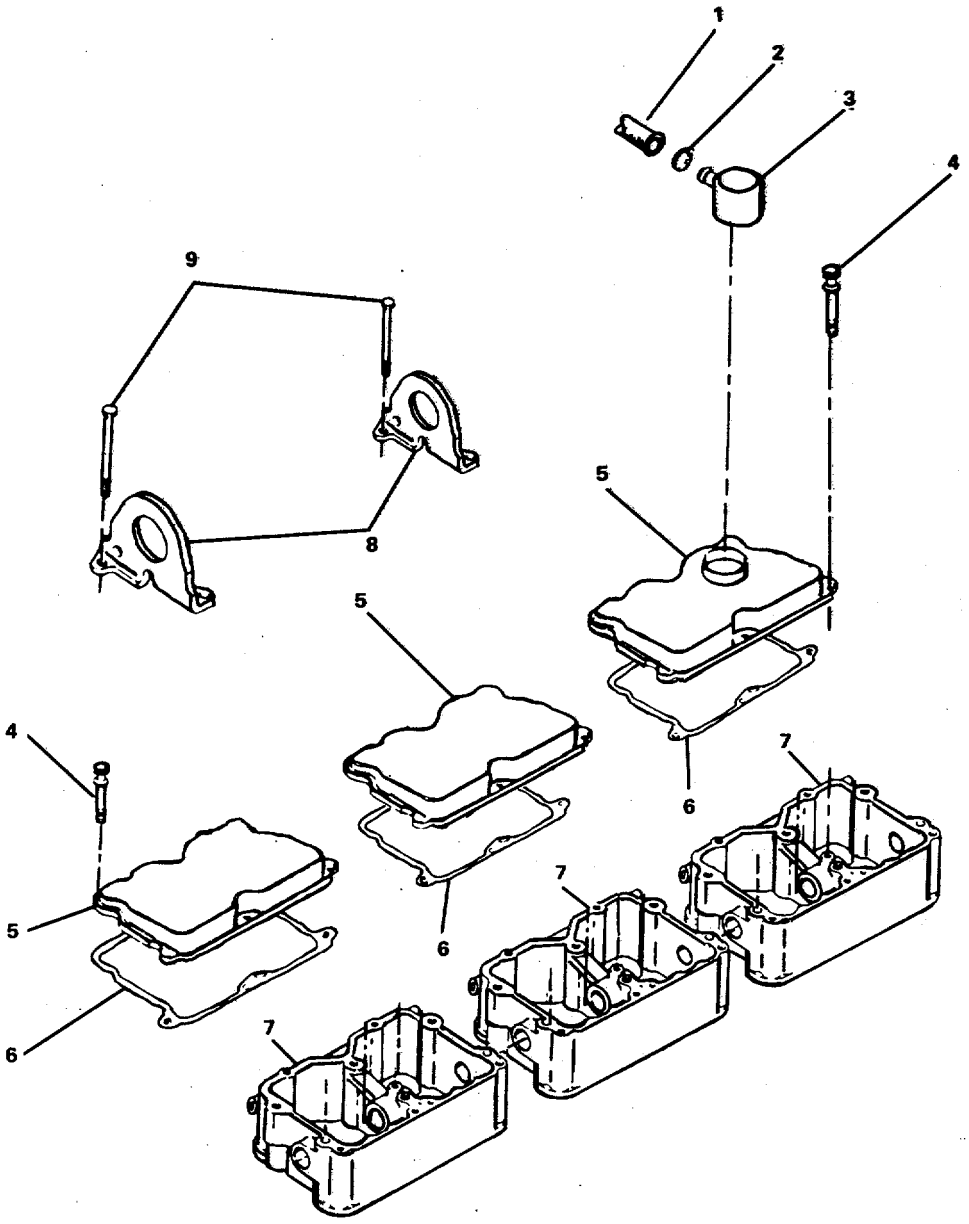


*FIGURE 2-36. Rocker Lever Covers.*

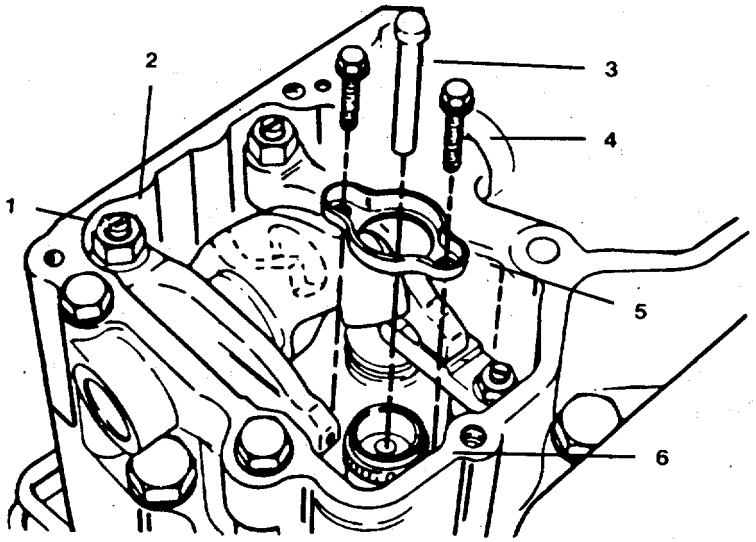


*FIGURE 2-37. Removing Injector.*

i. Move the injector push rod to the side. The push rod is located under the adjusting screw.

j. Rotate the rocker lever up on each cylinder.

k. Remove detent plunger (3).

l. Remove two hexhead capscrews (4) and the injector clamp (5).

m. Use the injector puller to remove the fuel injection nozzle (6).

INSPECTION

a. Clean the injectors with solvent.

**CAUTION**

Do not use anything metal to scrape the injector copper sleeves.

b. Check the injector copper sleeves to make sure they are clean. Use a clean wooden stick with a clean cloth wrapped around the end to remove all of the carbon from the injector copper sleeves in the cylinder head.

REPAIR

a. Lubricate the injector "O" rings with clean lubricating oil just before installing.

b. Install the fuel injector in the cylinder head injector bore.

**CAUTION**

Be sure to place the blunt instrument (mallet or hammer handle) on the body of the injector, not on the detent plunger or link.

c. Seat the injector in the bore with a blunt instrument (mallet or hammer handle). A distinct "snap" will be felt and heard as the injector is seated.

d. Install clamp (5) and capscrews (4) over the injector body.

e. Tighten capscrews alternately and evenly, 50 in-lb (6 N•m) torque at a time, to a final torque of 144 to 168 in-lb (16 to 19 N•m).

f. Install detent plunger (3) in each injector.

g. Align the push rod with the injector rocker lever.

h. Turn adjusting screw (1) for the injector rocker lever in until it is properly seated in the push rod socket.

i. Adjust crossheads, valves, and injectors.

**NOTE**

- The crossheads, valves, and injectors must be adjusted at the same time. Use the following procedure for adjustment.
- After rebuilding the engine or doing any major repair in which the injector setting is disturbed, set all of the valves and injectors. When the adjustment has been completed, continue through the crankshaft rotation and check the injector adjustment on cylinders No. 2, No. 3, and No. 6. Adjust if necessary. This takes care of any camshaft and/or rocker lever shaft deflection that might have occurred during the initial adjustment.
- All overhead (crosshead, valve, and injector) adjustments must be made when the engine is cold. Stabilized coolant temperature must be at or below 140°F (60°C).

(1) General adjustment information:

(a) The valve set marks are located on the accessory drive pulley. The marks align with a pointer on the gear cover.

(b) Use the accessory drive shaft to rotate the crankshaft.

(c) The crankshaft rotation is clockwise when viewed from the front of the engine.

(d) The cylinders are numbered from the front gear cover end of the engine.

(e) The engine firing order is 1-5-3-6-2-4.

(f) Each cylinder has three rocker levers. The rocker lever nearest the center of the housing is the intake lever (3, FIGURE 2-38). The exhaust lever is reference (1) and the injector lever is (2).

(g) The valves and the injectors on the same cylinder are not adjusted at the same index mark on the accessory drive pulley (see Table 2-3).

(h) One pair of valves and one injector are adjusted at each pulley index mark before rotating the accessory drive to the next index mark.

(i) Two crankshaft revolutions are required to adjust all the valves and the injectors.

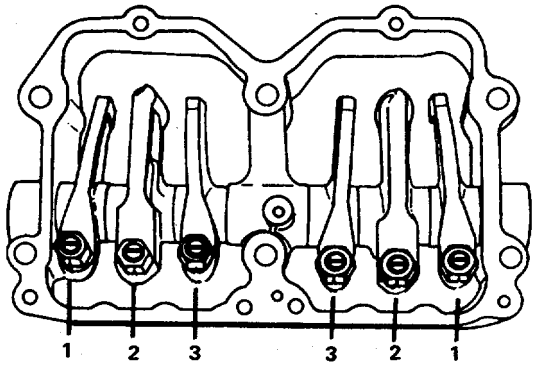


*FIGURE 2-38. Identifying Rocker Levels.*

## Table 2-3. Injector and Valve Adjustment Sequence

| 1. Bar Engine in Direction of Rotation | Pulley Position | Set Cylinder Injector | Set Cylinder Valve |
|---|---|---|---|
| 2. Start | A | 3 | 5 |
| Advance to | B | 6 | 3 |
| Advance to | C | 2 | 6 |
| Advance to | A | 4 | 2 |
| Advance to | B | 1 | 4 |
| Firing Order: 1-5-3-6-2-4 | C | 5 | 1 |

(3) Injector Adjustment, Dial Indicator Method (Non Top-Stop Injector Only).

(a) Rotate the accessory drive until the "A" valve set mark on the accessory drive pulley is aligned with the pointer on the gear cover (FIGURE 2-39).

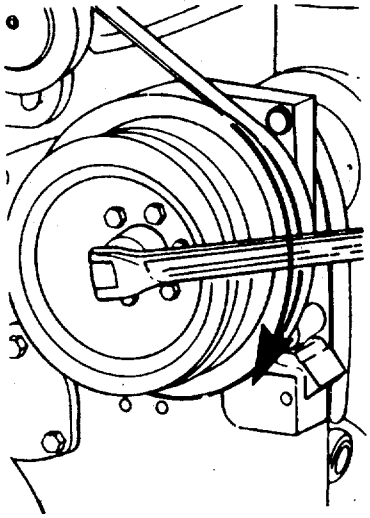

*FIGURE 2-39. Rotating Accessory Drive.*

(b) Check the valve rocker levers on cylinder No. 5 to see if both valves are closed.

**NOTE**

Both valves are closed when both rocker levers are loose and can be moved from side to side. If both valves are not closed, rotate the accessory drive one complete revolution; align the "A" mark with the pointer again.

**CAUTION**

To prevent damage to the indicator and to avoid getting an incorrect reading, install the dial indicator extension so that it clears the rocker lever.

(c) Install the dial indicator (6, FIGURE 2-40) and the support (4) from the injector adjustment kit so that the extension (5) for the dial indicator (6) is on top of the injector plunger flange on cylinder No. 3.

(d) Secure the thumbscrew (1) and capscrew (2).

(e) Loosen the thumbscrew (3) and lower the indicator (6) against the injector plunger flange until the stem is fully compressed.

(f) Raise the indicator (6) approximately 0.025 inch (0.653 mm) and secure the thumbscrew (3) to hold the indicator (6) in position.

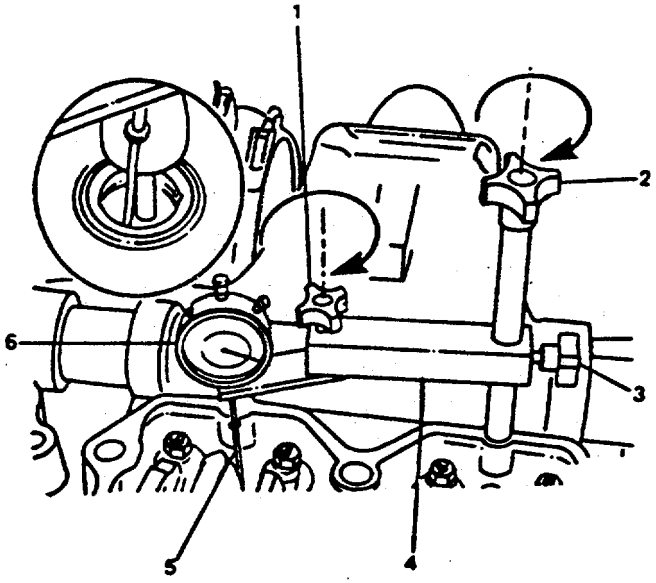


*FIGURE 2-40. Installing Dial Indicator and Support.*

**WARNING**

The injector plunger is under spring tension. Do not allow the rocker lever actuator (P/N ST-1193) to slip. Personal injury can result.

(g) Use the rocker lever actuator to depress the injector plunger three or four times to make sure all the oil and fuel have been removed from the injector assembly. Allow the lever to return slowly to prevent damage to the dial indicator.

(h) Actuate the lever again, and set the dial indicator at "0" (zero) while holding the injector plunger to the bottom of its travel.

(i) Slowly release the actuator and check the indicator travel.

(j) The indicator travel must be 0.228 inch (5.79 mm). If not, go to step (k).

(k) Loosen the locknut (1, FIGURE 2-41) on the injector adjusting screw.

(l) Turn the adjusting screw (2) clockwise or counterclockwise to adjust the injector plunger to 0.228 inches on the dial indicator reading.

(m) Hold the adjusting screw (2) in this position. The adjusting screw (2) must not turn when the locknut (1) is secured. Tighten the locknut (1) to 40 ft-lb torque without adapter, 35 ft-lbs with torque wrench adapter P/N ST-669 (1).

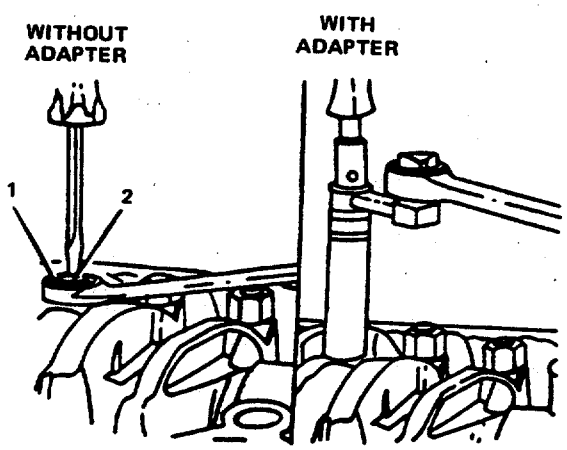


*FIGURE 2-41. Holding the Adjusting Screw.*

WARNING

The injector plunger is under spring tension. Do not allow the rocker lever actuator to slip. Personal injury can result.

(n) Actuate the injector rocker lever several times. Allow the lever to return slowly to prevent damage to the dial indicator. Hold the injector plunger to the bottom of its travel, and confirm the "0" (zero) reading on the dial indicator.

(o) Allow the injector rocker lever to return slowly. Check the reading on the dial indicator. Repeat the adjustment process if the reading is not within specifications.

(p) Adjust the crossheads and the valves on cylinder No. 5 before rotating the accessory drive to the next valve set mark. Refer to "Crosshead Adjustment" and "Valve Adjustment" in this procedure.

(q) After adjusting the crossheads and the valves on cylinder No. 5, rotate the accessory drive; align the next valve set mark on the accessory drive pulley with the pointer on the gear cover (FIGURE 2-42).

(r) Adjust the appropriate injector, the crossheads, and the valves. Follow the valve and injector adjustment sequence chart, Table 2-3.

(s) Repeat the process to adjust all the injectors, the crossheads, and the valves.

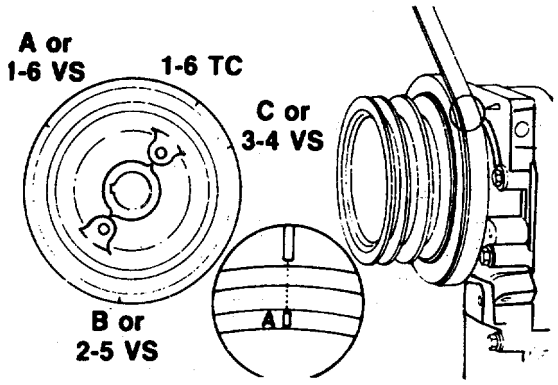


*FIGURE 2-42. Aligning Pulley and Gear Pointer.*

(4) Injector preload adjustment procedures (top-stop injectors only).

**CAUTION**

Top-stop injector plunger travel can be adjusted only when the injectors are removed from the engine. Use the injector adjusting tool to set the injectors.

(a) The top-stop injector preload setting is made at the same injector adjustment position on the accessory drive pulley that is used for the dial indicator method.

(b) Rotate the accessory drive clockwise until the "A" valve set mark on the accessory drive pulley is aligned with the pointer.

(c) Loosen the locknut on the injector adjusting screw on cylinder No. 3. Secure the adjusting screw until all the clearance is removed from the injector train.

(d) Tighten the adjusting screw one additional turn to correctly seat the link.

(e) Loosen the injector adjusting screw until the injector spring retainer washer touches the top-stop screw (FIGURE 2-43).

**CAUTION**

An overtightened setting on the injector adjusting screw will produce increased stress on the injector train and on the camshaft injector lobe, which can result in engine damage.

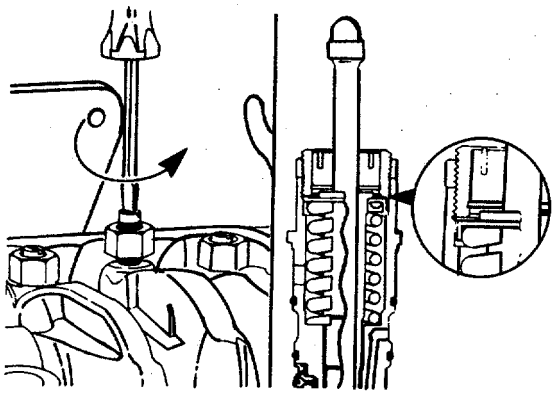

*FIGURE 2-43. Injector Adjusting Screw.*

(f) Tighten the adjusting screw to 5 to 6 in-lb torque using torque wrench.

(g) Hold the adjusting screw in position. The adjusting screw must not turn when the locknut is tightened. Tighten the locknut to the following torque values:

1 With torque wrench adapter - 35 ft lb.

2 Without torque wrench adapter - 45 ft-lb.

(h) Adjust the crossheads and the valves on cylinder No. 5 before rotating the accessory drive to the next valves set mark. Refer to "Crosshead Adjustment" and "Valve Adjustment" in this procedure.

(i) After adjusting the crossheads and the valves on cylinder No. 5, rotate the accessory drive and align the next valve set mark on the accessory drive pulley with the pointer on the gear cover.

(j) Adjust the appropriate injector, the crossheads, and the valves following the Injector and Valve Adjustment Sequence Chart (Table 2-3).

(5) Crosshead Adjustment.

**NOTE**

Crosshead adjustment must always be made before attempting to adjust the valves.

(a) With the "A" valve set mark aligned with the pointer on the gear cover and both valves closed on cylinder No. 5, loosen the crosshead adjusting screw locknuts (1, FIGURE 2-44) on the intake and the exhaust valve crossheads for cylinder No. 5.

**NOTE**

The same procedure is used to adjust the intake and exhaust crossheads.

(b) Turn the adjusting screw (2) out at least one turn.

(c) Hold the crosshead down against its mating valve stems.

(d) Turn the adjusting screw (3) in until it touches the top of the valve stem (5), but do not raise the crosshead (3).

(e) Hold the adjusting screw (3) in this position. The adjusting screw (3) must not turn when the locknut (1) is tightened to its torque value. Tighten the locknut (1) to 25 ft-lb with adapter, 30 ft-lb without adapter.

(f) Adjust the intake and the exhaust valves on No. 5 cylinder before rotating accessory drive to the next valve set mark.

(6) Valve Adjustment.

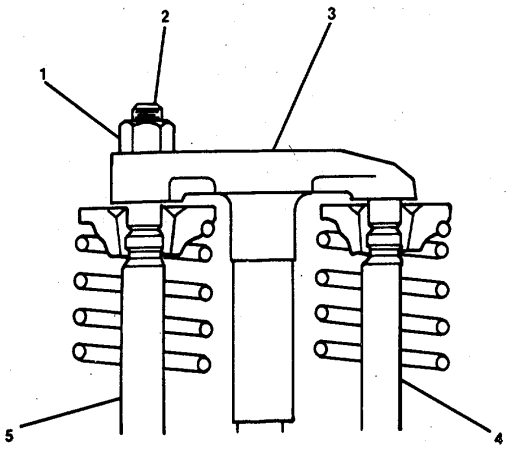


*FIGURE 2-44. Crosshead.*

**NOTE**

- Two methods for establishing valve lash clearance are described below. Either method can be used; however, the torque wrench method has proven to be the most consistent. It eliminates the need to feel the drag on the feeler gauge.
- Torque Wrench Method: Use an inch-pound torque wrench (normally used to set preload on top-stop injectors), and tighten the adjusting screw to 6 in-lb torque.
- Feel Method: Tighten the adjusting screw until a slight drag is felt on the feeler gauge.

(a) With the "A" valve set mark aligned with the pointer on the gear cover and both valves closed on cylinder No. 5, loosen the locknuts on the intake and the exhaust valve adjusting screw.

(b) If the torque wrench method is used, make adjustment as described in the NOTE above.

(c) If the feeler gauge method is used, select a gauge for the correct valve lash specification.

Valve Lash Specification

| Intake | Exhaust |
|---|---|
| 0.028 mm (0.011 inch) | 0.058 mm (0.023 inch) |

(d) Insert the feeler gauge between the top of the crosshead and the rocker lever pad.

(e) Hold the adjusting screw in this position. The adjusting screw must not turn as the locknut is tightened. Tighten the locknut to 35 ft-lbs with adapter, 45 ft-lbs without adapter.

(f) After tightening the locknut to the correct torque value, make sure that the feeler gauge will slide backward and forward between the crosshead and the rocker lever with only a slight drag.

(g) If using the feel method, attempt to insert a feeler gauge that is 0.001 inch (0.03 mm) thicker between the crosshead and the rocker lever pad. The valve lash is not correct when a thicker feeler gauge will fit.

(h) After adjusting the injector on cylinder No. 3 and the crossheads and valves on cylinder No. 5, rotate the accessory drive and align the next valve set mark with the pointer.

(i) Adjust the appropriate injector,. the crossheads, and the valves. Refer to the Injector and Valve Adjustment Sequence Chart, Table 2-3.

(j) Repeat the process to correctly adjust all injectors, crossheads, and valves.

**NOTE**

Stamped steel valve covers are designed and manufactured with 0.030 inch (0.75mm) bow (see shaded areas, FIGURE 2-45) to provide better sealing qualities. This built-in bow on the valve covers must not be mistaken for warpage. Do not attempt to increase or remove the bow from the sealing surface.

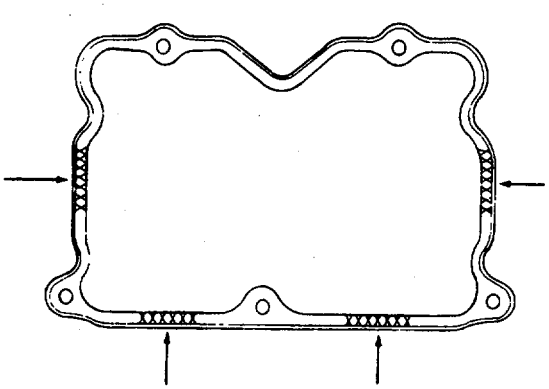

*FIGURE 2-45. Manufactured Bow Areas in Rocker Covers.*

(k). Install breather (3, FIGURE 2-36) on cover (5).

(l) Install gaskets (6) and covers (5) on rocker lever housings (7).

(m) Install assembled washer screws (4) in each cover (5).

(n) Tighten each assembled washer screws (4) in the sequence shown (FIGURE 2-46) to 15 ft-lb torque.

(o) Install engine lifting brackets (8) and four hexhead capscrews (9). Torque cap screws to 60 ft-lb (80 N•m).

(p) Install nonmetallic hose (1) on breather (3) with hose clamp (2).

(q) Replace upper fuel line check valve. Refer to paragraph 2-33.

(r) Replace intake air crossover pipe. Refer to paragraph 2-39.

(s) Replace instrument panel. Refer to paragraph 2-22.

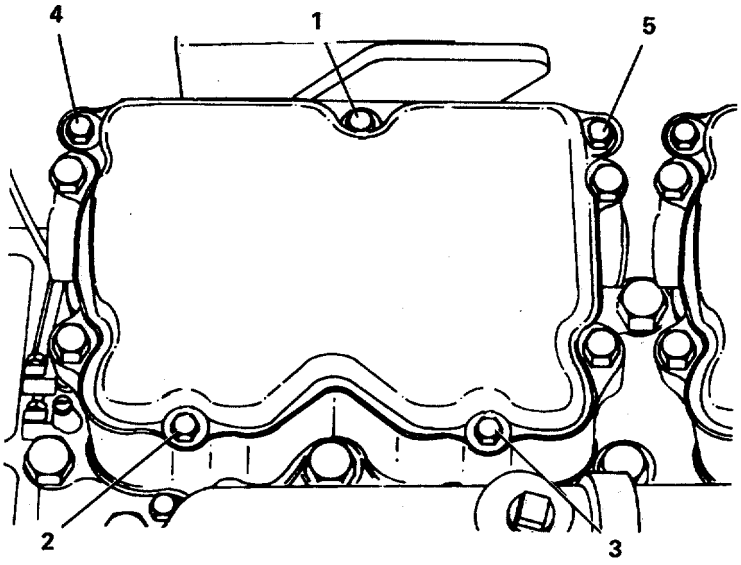


*FIGURE 2-46. Engine Poppet Cover Torque Sequence.*

## 2-36. Replace/Repair Expansion Tank Group. (FIGURE 2-47)

**This task covers:**

**a. Removal b. Inspection c. Repair d. Replacement**

**INITIAL SETUP:**

Tools

Tool kit general mechanic's
rail and marine diesel engines,
5180-00-629-9783

Materials/Parts

Dial indicating pressure gauge
P/N 3008837.
Nonmetallic hose P/N 200517
Nonmetallic hose assembly (2)
P/N AS40120MS
Gasket P/N 7274
Cloth, Item 4, Appendix C

Equipment Condition

Engine shut down (TM 55-1905-223-10.).
Cooling system drained (TB 55-1900-207-24).
Engine tagged "Out of Service-Do Not Operate."

REMOVAL

a. Remove pipe nipple (18), pipe coupling (17), and pipe bushing (16) from pipe elbow (15).

b. Remove pipe elbow (15) from nonmetallic hose assembly (14).

c. Disconnect nonmetallic hose assembly (14) from pipe to tube elbow (13).

d. Disconnect bottom hose clamp (10) and remove from bottom expansion tube (11). Remove nonmetallic hose (12).

e. Disconnect top hose clamp (10) and remove from top expansion tube (11). Remove preformed hose (9).

f. Remove pipe elbow (8) from bottom end of nonmetallic hose assembly (7).

g. Remove nonmetallic hose assembly (7) from straight adapter (6).

h. Remove liquid sight gauge (19).

i. Remove hexhead capscrews (1, 4), flat washers (2, 5).

j. Remove expansion tank (20).

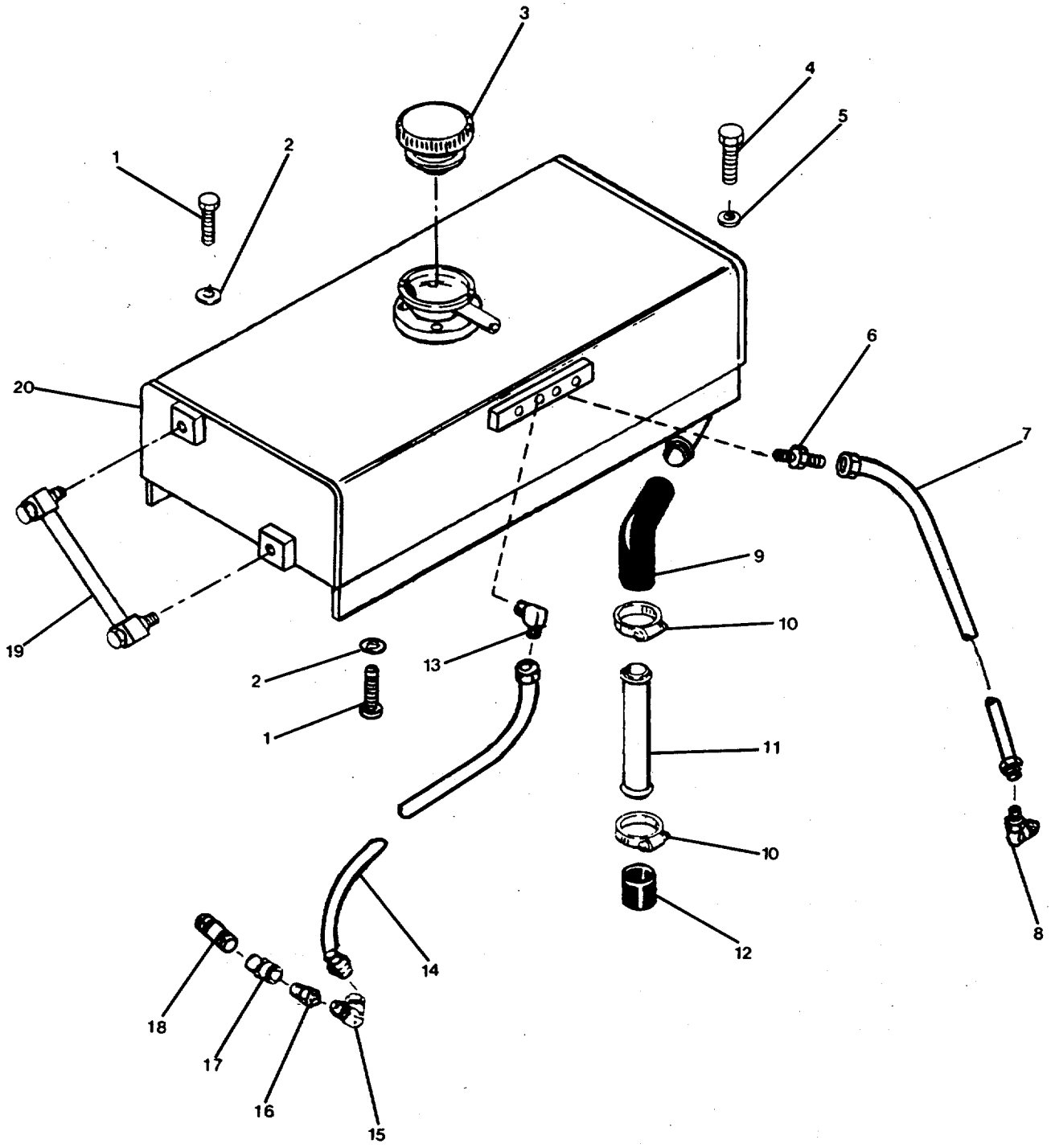


*FIGURE 2-47. Expansion Tank Group.*

INSPECTION

a. Remove pressure cap (3).

b. Inspect rubber seal inside pressure cap for deterioration. Replace if necessary.

c. Inspect fill neck for cracks and corrosion. Clean with solvent and cloth or replace as necessary.

d. Replace pressure cap (3).

REPAIR

Repair at this level of-maintenance is by replacing gaskets (5), nonmetallic hose assembly (7, 14), dial indicating pressure gauge (19), and nonmetallic hose (12).

REPLACEMENT

a. Position expansion tank (20) on mounting bracket.

b. Install new gaskets (5) and flat washers (2). Secure expansion tank (19) to mounting bracket with hexhead capscrews (1, 4).

c. Install sight glass gauge (19).

d. Install nonmetallic hose assembly (7) on straight adapter (6).

e. Install pipe elbow (8) on bottom end of nonmetallic hose assembly (7).

f. Install preformed hose (9) on expansion tank (20).

g. Insert expansion tube (11) into end of preformed hose (9) and secure with top hose clamp (10).

h. Insert nonmetallic hose (12) on bottom end of expansion tube (11) and secure with bottom hose clamp (10).

i. Install nonmetallic hose assembly (14) onto pipe to tube elbow (13).

j. Install pipe elbow (15) onto lower end of nonmetallic hose assembly (14).

k. Install pipe bushing (16), pipe coupling (17), and pipe nipple (18) onto pipe elbow (15).

1. Fill cooling system. Refer to PMCS Table 2-1, -Item 5.

m. Start up engine. Refer to TM 55-1905-223-10.

n. Check for leaks. Repair as necessary.

o. Remove "Out of Service-“Do Not Operate" tag.

## 2-37. Replace/Repair Seawater Pump/Belt Guard Group. (FIGURE 2-48)

**This task covers:**

**a. Inspection b. Adjustment c. Removal d. Repair e. Replacement**

**INITIAL SETUP:**

INITIAL SETUP

Tools

Tool kit general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5720-01-046-4979
Belt tension gauge, P/N ST-1293
Torque wrench, 5120-01-125-5190 (ft-lb)

Materials/Parts

Nonmetallic hose P/N 67185
Vee belt P/N 178691
Engine cooling system pump P/N 3010328

Equipment Condition

Engine shut down (TM 55-1905-223-10).
External seawater inlet and outlet
valves closed (TM 55-1905-223-24-18).
Power take-off assembly removed
(para. 3-20).

INSPECTION

Use a belt tension gauge to visually inspect the seawater pump and connections for signs of loose fittings, corrosion, and leaks. Inspect for belt alignment, pulleys should not exceed 1/6 inch per foot (0.5 mm per cm) of distance between pulley centers.

ADJUSTMENT

a. Remove mechanical guard (8) by removing hexhead capscrew (5), lockwasher (6) and flatwasher (7).

b. Loosen capscrews (9) holding the pump (13) to the seawater bracket (10).

c. Use a pry bar between the pump (13) and the engine to hold tension on the belt (3).

d. Tighten capscrews (9) to secure the pump (13) in position. Torque to 35 ft-lb.

e. Test belt tension with belt tension gauge. It should read 150 to 160 ft-lbs for new belts and 70 to 120 ft-lbs for used belts. Adjust if necessary.

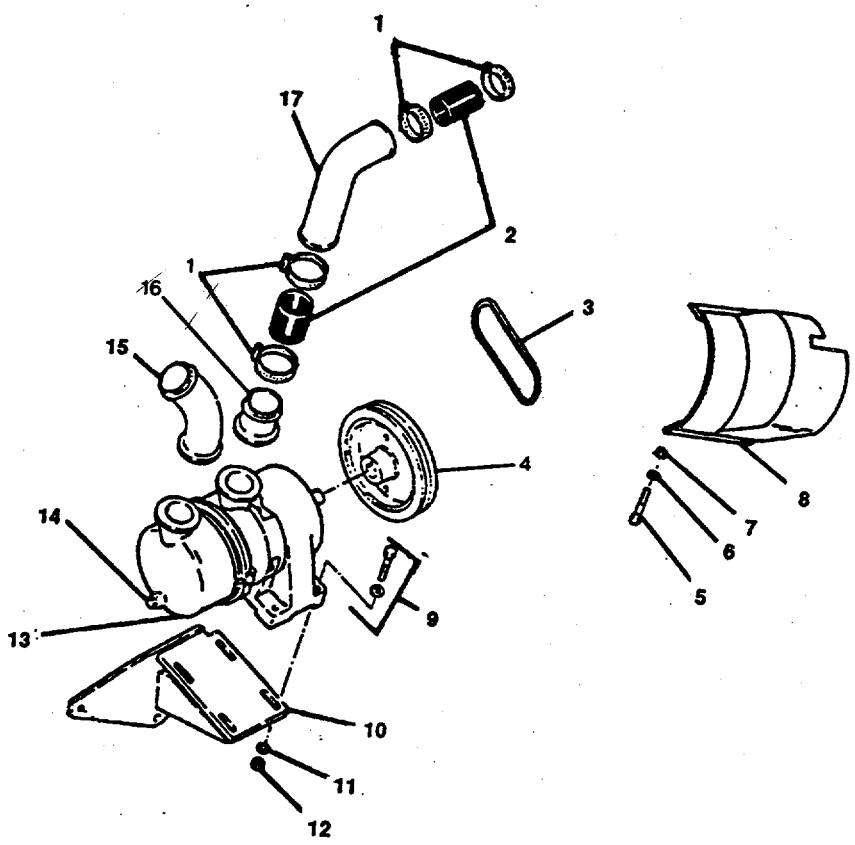


*FIGURE 2-48. Seawater Pump Group.*

f. Install mechanical guard (8) and install hexhead capscrew (5), lockwasher (6) and flatwasher (7).

REMOVAL

a. Drain the seawater cooling system at the seawater pump drain plug (14).

b. Remove mechanical guard (8) by removing hexhead capscrew (5), lockwasher (6) and flat washer (7).

c. Loosen hose clamps (1) from seawater connection (16), nonmetallic hose (2), and water transfer tube (17).

d. Disconnect water inlet connection (15).

e. Loosen capscrews (9) holding the water pump to the bracket (12).

f. Push pump toward the engine to release tension on the drive belt and remove the belt (3).

g. Remove capscrews (9), lockwashers (12), and nuts (11) holding the pump to the bracket (12) and remove the pump (13).

REPAIR

Repair consists of replacement of hoses (2), vee belt (3) and pump (13).

REPLACEMENT

a. Position the seawater pump (13) on the bracket (10) and install the capscrews (9), lockwashers (11), and nuts (12). Do not tighten.

b. Install drive belt (3) onto the pulley (4).

c. Use a pry bar between the seawater pump (13) and engine to hold tension on drive belt (3).

d. Tighten nuts (12) to secure pump (13) in position.

e. Connect water inlet (15) and outlet tube (17). Secure with clamps (1).

f. Tighten water pump mounting capscrews (9) and locknuts (12) to 35 ft-lb torque.

g. Install mechanical guard (8) by installing capscrew (5), lockwasher (6) and nut (7).

h. Open the external seawater inlet and outlet valves. Refer to TM 55-1905-223-24-18.

i. Run the engine until it reaches a temperature at 180F (80°C) and check for leaks. Repair as necessary.

j. Remove "Out of Service-Do Not Operate" tag.

## 2-38. Replace/Repair Heat Exchanger and Heat Exchanger Group. (FIGURE 2-49)

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit general mechanic's
rail and marine diesel engines
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5720-01-046-4579
Torque wrench (30-300 ft-lb),
5120-01-125-5190
Torque wrench (30-300 in-lb),
5120-01-092-3278

Equipment Condition

External seawater inlet and outlet valves closed (TM 55-1905-223-24-18).
Cooling system drained (refer to PMCS, Item 30).
Expansion tank removed (para. 2-36).
Engine tagged "Out of Service-Do Not Operate."

Materials/Parts

Nonmetallic hose P/N 67185 (2)
P/N 104296
Gaskets P/N 3008832 (2)
P/N 3055769 (2)

REMOVAL

a. Drain seawater cooling system at the seawater pump drain plug.

b. Disconnect hose clamps (24 and 26) and remove nonmetallic hose (25) from engine water outlets (19 and 27).

c. Disconnect hose clamps (28, 30, 36 and 38) and remove nonmetallic hoses (29, 37) from metallic tube (35) and water inlet connection (31).

d. Disconnect hose clamp (17) and remove hose (18) from water outlet connection (14).

e. Remove four hexhead capscrews (10) and lockwashers (9) securing water outlet connection (8) and welded pipe (11) and remove outlet connection (8) and pipe (11). Remove gasket (7) and discard.

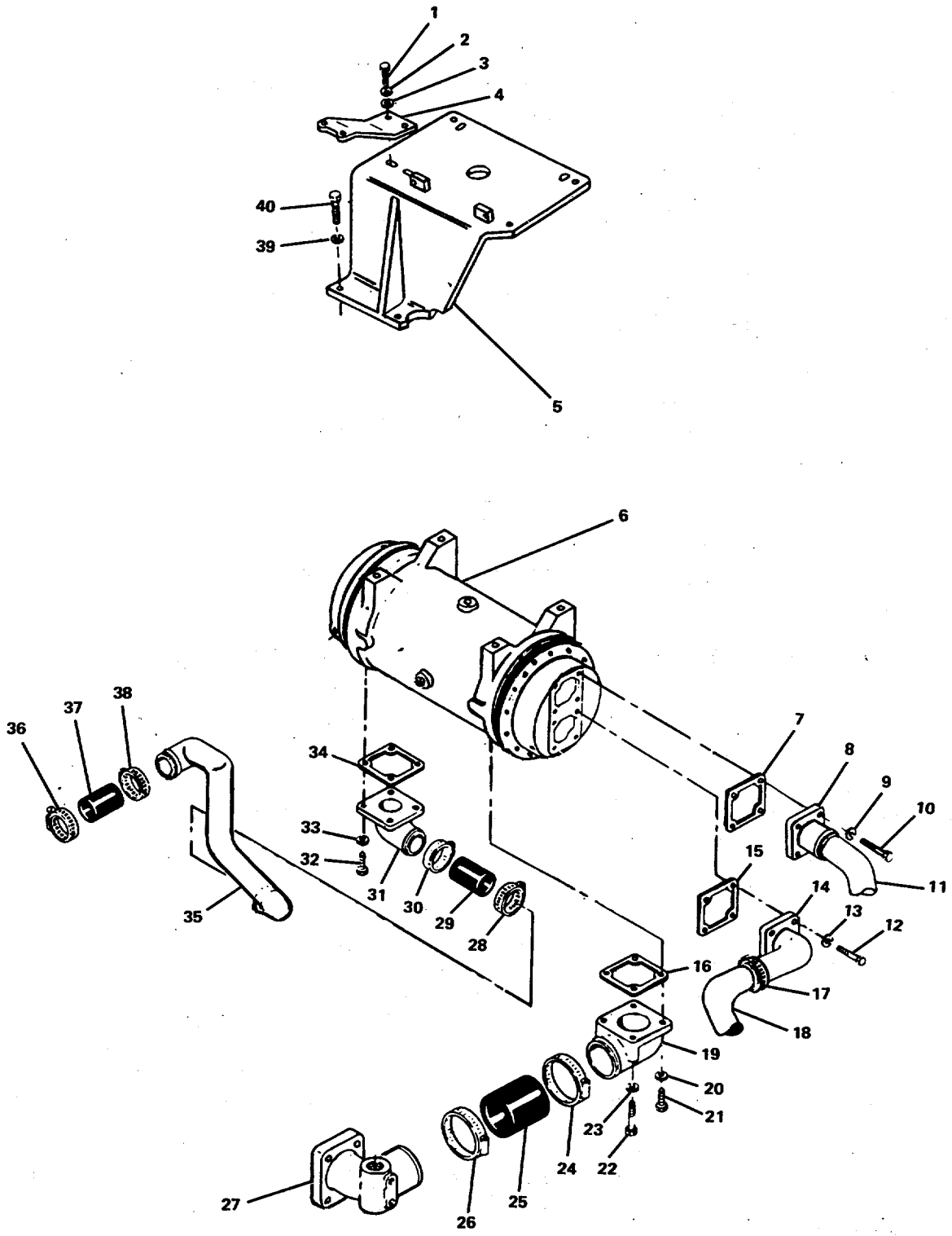


*FIGURE 2-49. Heat Exchanger Group.*

WARNING

A hoist must be used to support and lift the assembly when removing it from the engine. It must be firmly in place before removing the mounting screws. This will prevent personal injury.

f. Attach engine lifting fixture to heat exchanger (6) and support heat exchanger.

g. Remove hexhead capscrews (1), lockwashers (2), and flat washers (3) that secure heat exchanger brace (4) to heat exchanger brace (5).

h. Remove hexhead capscrews (40) and flat washers (39) that secure heat exchanger (6) to engine.

i. Remove heat exchanger (6). Place on the deck or on a suitable workbench.

j. Remove four hexhead capscrews (12) and lockwashers (13). Remove water outlet connection (14) and gasket (15). Discard gasket.

k. Remove four hexhead capscrews (21, 22) and lockwashers (20, 23). Remove outlet connection (19) and gasket (16). Discard gasket.

l. Remove four hexhead capscrews (32) and lockwashers (33). Remove water inlet connection (31) and gasket (34). Discard gasket.

REPAIR

Repair of the heat exchanger consists of replacing gaskets (7, 15, 16 and 34) and hoses (25, 29 and 37). Complete repair of the heat exchanger is accomplished by Intermediate Direct Support Maintenance Chapter 3.

REPLACEMENT

a. Clean all water connections and gasket mounting-surfaces with solvent. Allow to dry.

b. Install new gasket (34) and position water outlet connection (31) and secure with four hexhead capscrews (32) and lockwashers (33). Tighten capscrews to 40 ft-lb torque.

c. Install new gasket (15) and position water outlet connection (14) and secure with four hexhead capscrews (12) and lockwashers (13). Tighten capscrews to 40 ft-lb torque.

d. Install new gasket (16) and outlet connection (19) and secure with capscrews (21 and 22) and lockwashers (20, 23). Tighten capscrews to 40 ft-lb torque.

WARNING

A hoist must be used to support and lift the heat exchanger when replacing it on the engine. It must be firmly in place. This will prevent serious injury to personnel.

e. Lift the heat exchanger (6) and position on the engine and heat exchanger brace (5).

f. Install hexhead capscrews (40) and lockwashers (39), securing brace (5) and heat exchanger (6) to engine.

g. Install heat exchanger brace (4) and secure brace (5) to heat exchanger (6). Secure with hexhead-capscrews (1), flat washers (3), and lockwashers (2).

h. Install gasket (7), water outlet connection (8) with welded pipe (11) attached, and secure with four hexhead capscrews (10) and lockwashers (9).

i. Install hose (18) and hose clamp (17) on water outlet connection (14). Tighten hose clamp to 35-40 in-lb torque.

J. Install nonmetallic hose (25) to engine water outlet (27) and outlet (19). Secure with hose clamps (24, 26). Tighten hose clamps to 35-40 in-lb torque.

k. Install nonmetallic hoses (29, 37) to water inlet connection (31) and metallic tube (35). Secure with hose clamps (28, 30, 36 and 38). Tighten hose clamps to 35-40 in-lb torque.

1. Install expansion tank. Refer to paragraph 2-36 .

m. Open the external seawater inlet and outlet valve. Refer to TM 55-1905-223-24-18.

n. Fill the fresh water cooling system. Refer to TB 1900-207-24.

o. Check coolant level. Refer to PMCS, Item 7.

p. Start up engine. Refer to TM 55-1905-223-10.

q. Check for leaks. Repair as necessary.

r. Remove "Out of Service-Do Not Operate" tag.

## 2-39. Replace/Repair Air Intake Manifold Group. (FIGURE 2-50)

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Lifting sling, P/N 3375958
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Torque wrench, 5120-00-242-3264 (ft-lb)
Torque wrench (30-300 in-lb),
5120-01-092-3278

Materials/Parts

Gaskets P/N 3008591
P/N 3019227 (2)
Nonmetallic hose P/N 3020996
Warning tag, Item 25, Appendix C

Equipment Condition

Engine shutdown (TM 55-1905-223-10).
Engine tagged "Out of Service-Do Not Operate."

REMOVAL

**WARNING**

A hoist must be used to support and lift the assembly when removing it from the engine to prevent injury to personnel. It must be firmly in place before removing the mounting capscrews.

a. Attach lifting sling to air intake manifold (5). Remove hose clamps (1) from air crossover connection (2). Remove nonmetallic hose (15).

b. Remove assembled washer screws (6, 7).

c. Remove sockethead capscrew (8), lockwasher (9), and flat washer (10).

d. Lift the manifold (5) off cylinder head gasket (11) and remove. Discard gasket.

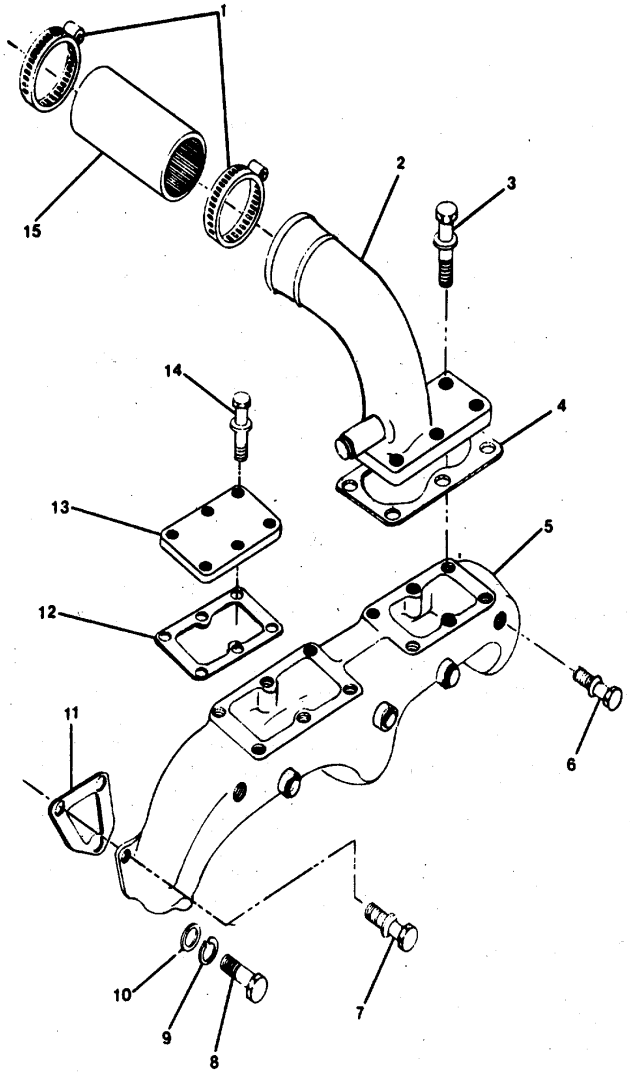


*FIGURE 2-50. Air Intake Manifold Group.*

e. Place air intake manifold on deck or suitable workbench.

f. Remove assembled washer screws (3), air crossover connection (2), and gasket (4). Discard gasket.

g. Remove assembled washer screws (14), plate (13), and gasket (12). Discard gasket.

REPAIR

Repair at this level of maintenance is by replacing: gaskets (4, 11, and 12) and nonmetallic hose (15).

REPLACEMENT

a. Install gasket (12) and plate (13) on air intake manifold (5). Secure with assembled washer screws (14). Torque to 20-25 ft-lb.

b. Install gasket (14) and air crossover connection (2) on air intake manifold (2). Secure with assembled washer screws (3). Torque to 20-25 ft-lb.

c. Install gasket (11) on cylinder head.

WARNING

A hoist must be used to support and lift the assembly when replacing it on the engine. It must be firmly in place.

d. Lift air intake manifold (5) assembly in position to mount to cylinder head.

e. Secure air intake manifold (5) to cylinder head with socket head capscrews (8), lockwashers (9), and flat washers (10). Torque to 20-25 ft lb.

f. Install assembled washer screws (6, 7). Torque to 20-25 ft-lb.

g. Secure nonmetallic hose (15) to air crossover connection (2) with hose clamps (1). Torque hose clamps (1) to 40 in-lb.

h. Remove lifting sling.

i. Start up engine. Refer to TM 55-1905-223-10.

j. Check for leaks. Repair as necessary.

k. Remove "Out of Service-Do Not Operate" tag.

## 2-40. Replace/Repair Exhaust Manifold Group. (FIGURE 2-51)

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's rail and marine diesel engines, 5180-00-629-9783
Combination wrench set, metric 10mm to 24mm, 5720-01-046-4979
Lifting sling P/N 3375958
Torque wrench, 5120-01-125-5190

Materials/Parts

Preformed packing P/N 178937 and P/N 212161
Gaskets P/N 3020943
Warning tag, Item 25, Appendix C

Equipment Condition

Engine shut down (TM 55-1905-223-10).
Engine tagged "Out of Service-Do Not Operate."
Cooling system drained (refer to PMCS, Item 30).
Turbocharger removed (para. 2-26).
Thermostat housing removed (para. 2-24).
Water filter assembly removed (para. 2-23).
Lube oil bypass filter assembly removed (para. 2-31).

### REMOVAL

WARNING

Because this assembly weighs more than 50 lbs. (23 kg), two soldiers or a hoist will be required to lift the exhaust manifold assembly to avoid personal injury.

a. Attach lifting sling to exhaust manifold (7) and support manifold.

b. Disconnect water transfer connection (3) from engine. Remove and discard preformed packing (4).

c. Remove twelve capscrews (5), lockwashers (6), and exhaust manifold (7). Remove manifold gaskets (2) and preformed packing (1). Discard both.

d. Remove drain cock (8).

### REPAIR

Repair is by replacement of gasket (2) and preformed packing (1, 4).

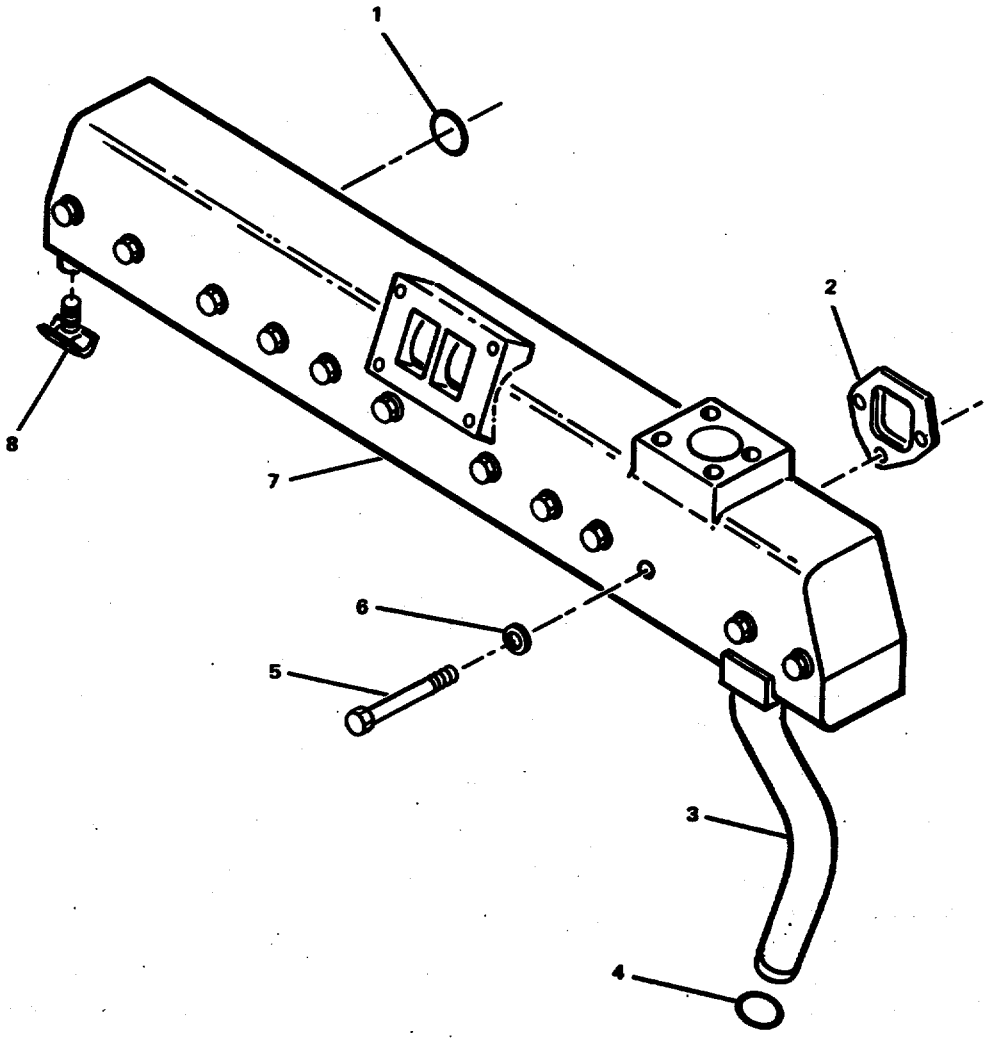


*FIGURE 2-51. Exhaust Manifold.*

REPLACEMENT

a. Install drain cock (8).

b. Position preformed packing (1) and gaskets (2) on manifold (7).

c. Install exhaust manifold (7) and secure with twelve capscrews (5) and lockwashers (6).

d. Tighten the capscrews in two stages in the sequence shown (FIGURE 2-52) to the following torque values:

(1) Tighten to 35 ft-lb.

(2) Tighten to 60 ft-lb.

e. Remove lifting sling.

f. Install a new turbocharger mounting gasket on the turbocharger. Refer to paragraph 2-24 .

g. Replace preformed packing (4, FIGURE 2-51) and connect water transfer connection (3) to engine.

h. Replace oil bypass filter assembly. Refer to paragraph 2-31 .

i. Replace water filter assembly. Refer to paragraph 2-23 .

j. Replace thermostat housing. Refer to paragraph 2-24 .

k. Replace turbocharger. Refer to paragraph 2-26 .

l. Fill system with coolant. Refer to TB 55-1900-207-24.

m. Operate the engine to check for leaks and engine operation.

n. Remove "Out of Service-Do Not Operate" tag.

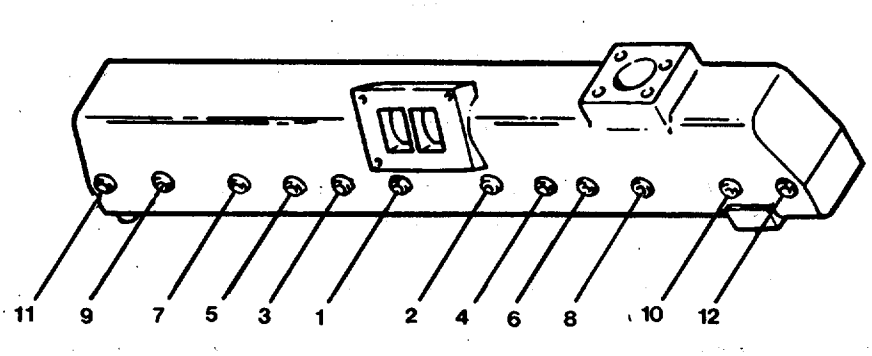


*FIGURE 2-52. Exhaust Manifold Torque Sequence.*

## 2-41. Replace/Repair Cylinder Head Group. (FIGURE 2-53)

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Torque wrench kit P/N 3377216

Materials/Parts

Preformed packing P/N 131026
Head gaskets P/N 3047402
Wood blocks (for laying the heads
on when they are removed), Item 7, Appendix C
Lubricating oil, 15W-40, Item 30, Appendix C

Equipment Condition

Cooling system drained (refer to
PMCS, Item 30).
Air crossover connection and turbocharger
removed (para. 2-26).
Rocker lever housing/cover group
removed (para. 2-34).
Intake manifold removed (para. 2-39).
Exhaust manifold removed (para. 2-40).
Injectors removed (para. 2-34).

REMOVAL

a. Remove bolts (2) holding fuel crossover connections (1).

b. Remove fuel crossover connections (1).

c. Remove preformed packing (7) and discard.

**CAUTION**

Do not damage capscrews.

**NOTE**

Capscrews should be removed in opposite sequence
of installation. (See FIGURE 2-54)

d. Remove capscrews (3) and washers (4).

e. Remove cylinder head (5).

f. Remove head gasket (6) and discard.

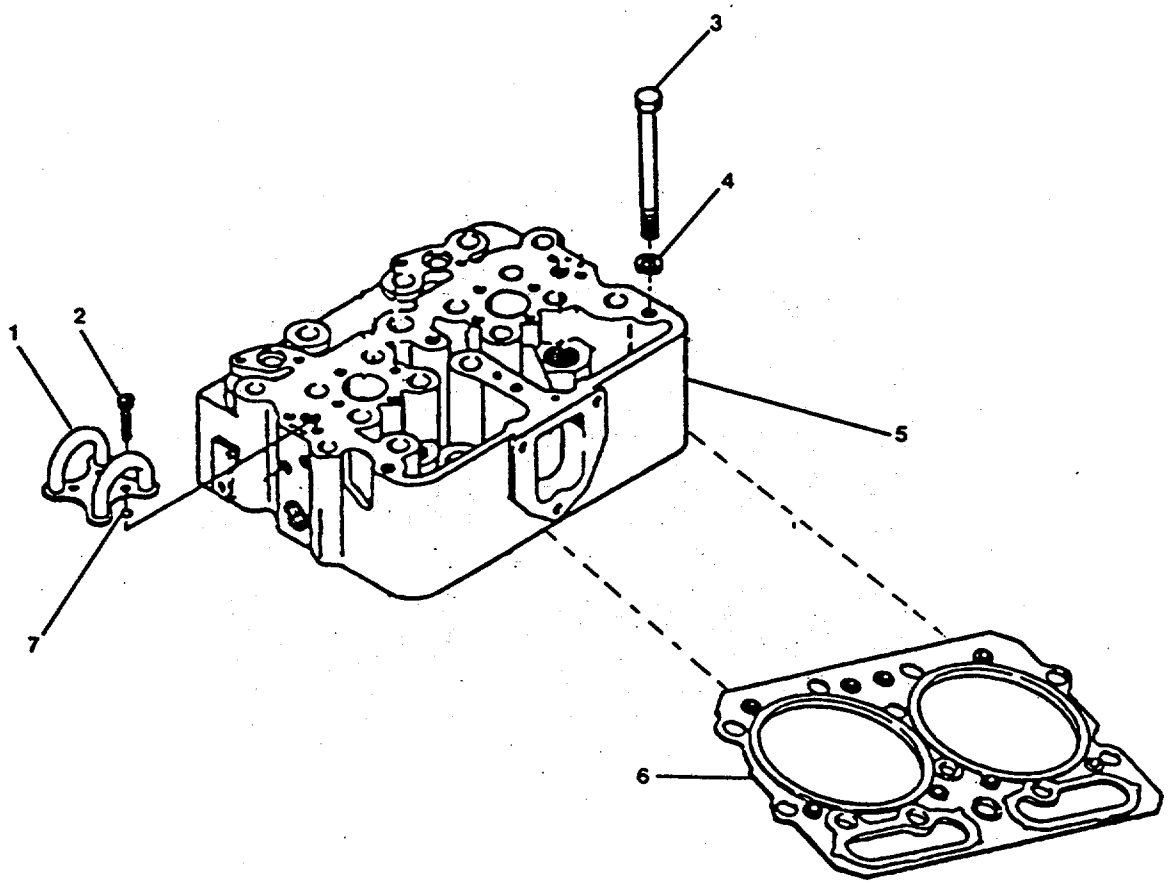


*FIGURE 2-53. Cylinder Head Group.*

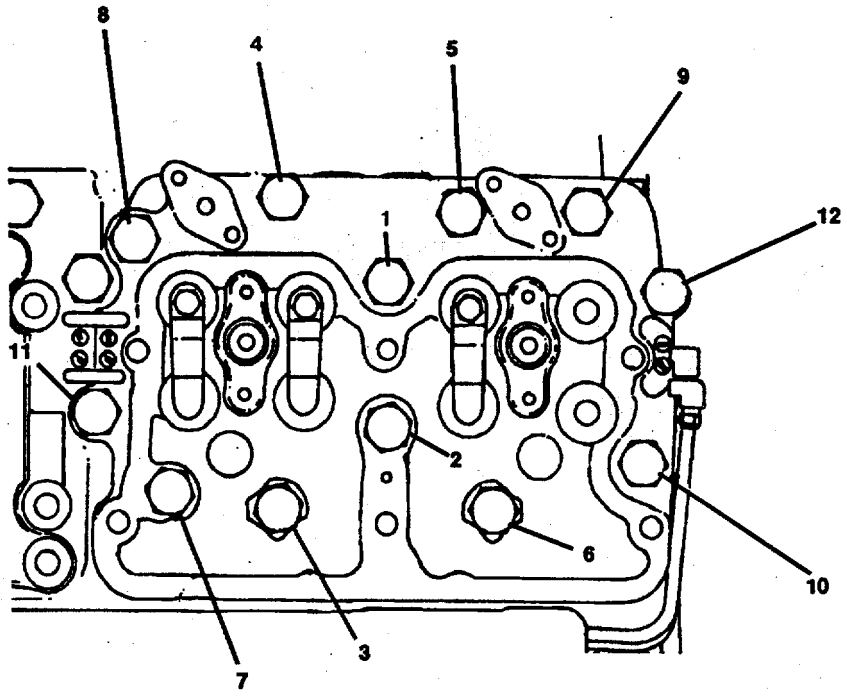


*FIGURE 2-54. Cylinder Head Torque Sequence.*

REPAIR

Repair consists of replacing preformed packing (7) and head gaskets (6).

REPLACEMENT

**CAUTION**

Ensure the gasket side marked TOP is up.

a. Install head gasket (6) on dowel pins (located in the block).

b. Place cylinder head (5) on engine block and align bolt holes with head gasket (6).

c. Install two guide studs in the cylinder block for each cylinder head (5).

d. Install cylinder head (5) over the guide studs and dowel pins.

e. Remove guide studs.

f. Use clean oil and lubricate capscrews (3) and both sides of washers (4). Allow excess oil to drain from capscrew threads.

g. Install capscrews (3) and washer (4); torque in the sequence shown in FIGURE 2-54 .

h. Tighten capscrews in stages to torque values below:

(1) Tighten to 25 ft-lb. torque.

(2) Tighten to 100 ft-lb. torque.

(3) Tighten to 285 ft-lb. torque.

i. Install preformed packing (7).

j. Install fuel crossover connection (1).

k. Install fuel crossover bolts (2). Tighten to 35 in-lb torque.

## 2-42 Replace/Repair Power Take-Off Assembly. (FIGURE 2-55)

**This task covers:**

**a. Removal b. Inspection c. Repair d. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24 mm,
5120-01-046-4979
Standard bearing puller P/N ST-647

Equipment Condition

Engine shut down and cooled to 120°F or lower (TM 55-1905-223-10).
Power take-off assembly removed (para. 3-21).

Materials/Parts

Nonmetallic hose assembly P/N A1663

REMOVAL

a. Support clutch housing (38, FIGURE 2-55) on work bench with wooden blocks with INPUT END facing upwards.

b. Using a standard bearing puller, remove pilot annular ball bearing (2) from the clutch shaft (33).

c. Remove hexhead nut (29) and lockwasher (28) at point (39), securing tube elbow (27) with grease lubrication fitting (30) attached. Push the tube elbow (27) with nonmetallic hose assembly (24) attached into clutch housing (38).

d. Straighten bent portion of lockwasher (4) from hub nut (3).

e. Remove hub nut (3) and lockwasher (4) from clutch shaft (33). Discard hub nut and lockwasher.

f. Remove two hexhead capscrews (36) securing instruction plate (35) and gasket (37) to clutch housing and remove plate and gasket.

g. By reaching through clutch housing (38) instruction plate (35) opening, remove two of the eight machine bolts (31) and helical compression springs (32) (180° apart) from the floating plate (9) and hub and back plate (6).

h. Using a conventional gear puller with threaded legs for 5/8-11 tapped holes, pull the clutch assembly (6 through 23) from the clutch shaft (33).

(1) Install the puller so the threaded legs screw into the 5/8-11 holes from which machine bolts (31) were removed in step g, above.

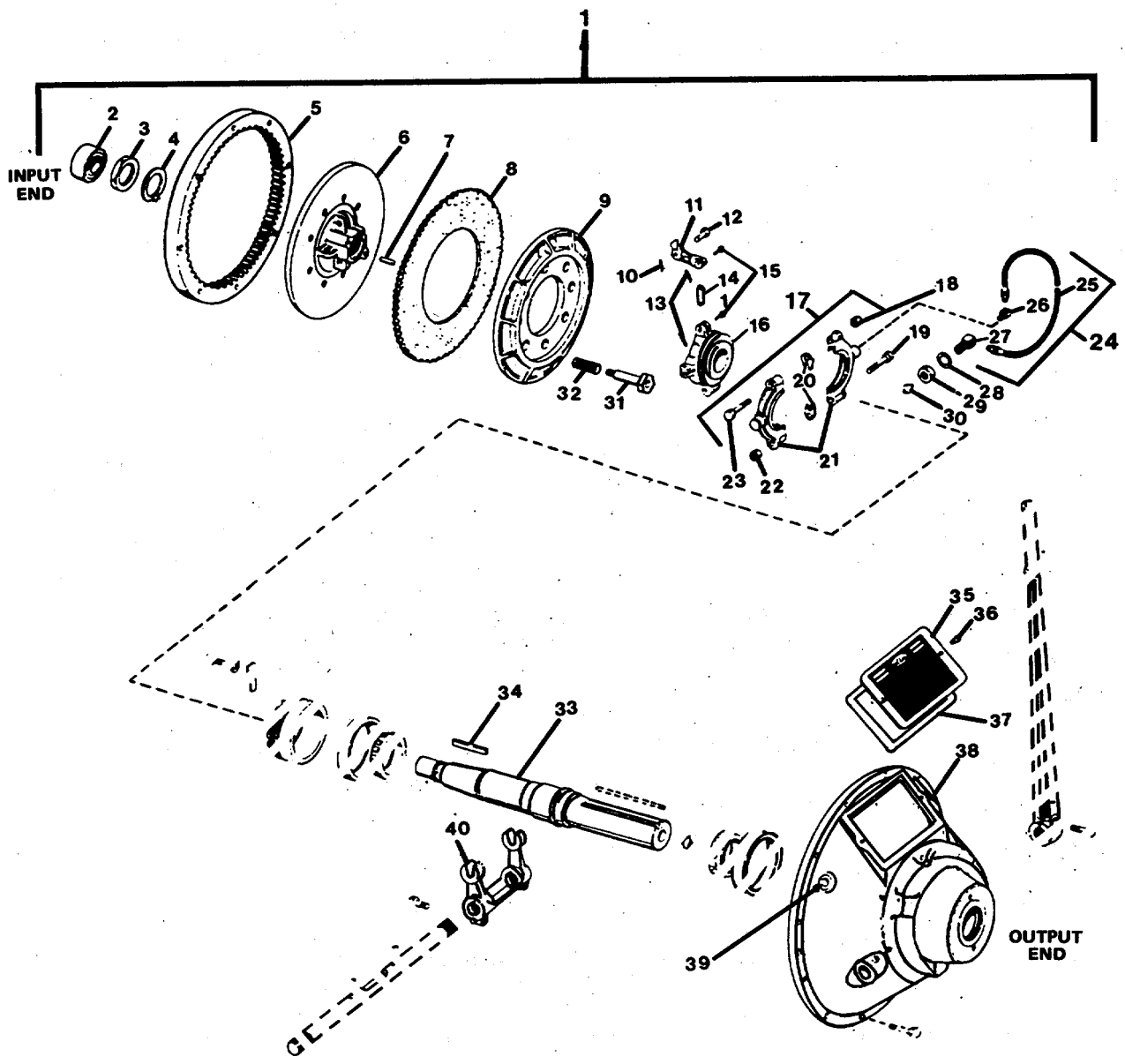


*FIGURE 2-55. Power Take-Off Assembly Repair.*

(2) Use the puller jack screw to exert force on the INPUT END of clutch shaft (33); remove clutch assembly (6 through 23) from clutch shaft (33). Remove machine key (34).

i. Place clutch assembly (6 through 23), with nonmetallic hose assembly (24) attached, on work bench with sliding sleeve assembly (16) facing up.

j. Install the two helical compression springs (32) and machine bolts (31) removed in step g. Tighten machine bolts until their shoulders contact the hub and back plate (6); then tighten to 160-175 ft-lb torque.

k. Remove lubrication fitting (30) from tube elbow (27).

l. Remove tube elbow (27) from nonmetallic hose assembly (25).

m. Remove nonmetallic hose assembly (25) from pipe to tube elbow (26) on the collar (21).

n. Remove pipe to tube elbow (26) from collar (21).

## INSPECTION

a. Inspect nonmetallic hose assembly (24) and nonmetallic hose assembly (25) for cuts, cracks, or swollen hose.

b. Inspect nonmetallic hose assembly (24) for loose or leaking fittings (26 and 27).

c. Replace nonmetallic hose assembly (24) if damaged.

## REPAIR

Repair of the power take-off assembly (1) consists of replacing nonmetallic hose assembly (24).

## REPLACEMENT

a. Install pipe to tube elbow (26) on collar (21).

b. Connect nonmetallic hose assembly (25) to pipe to tube elbow (26) on collar (21).

c. Connect tube elbow (27) to other end of nonmetallic hose assembly (25).

d. Partially install machine key (34) into clutch shaft (33) keyway.

e. Pick up clutch assembly (6 through 23) with nonmetallic hose assembly (24) attached, and carefully slide the clutch assembly over the clutch shaft (33) until sliding sleeve assembly (16) clears machine key (34). Lower clutch assembly (6 through 23), tapping machine key (34) down into position and engaging the collar (21) trunions with the yoke (40) and routing nonmetallic hose assembly (24) clear of moving parts to the hole (39) on clutch housing (38) side.

f. Push nonmetallic hose assembly (24) tube elbow (27) through the hole (39) and secure it with lockwasher (28) and hexhead nut (29).

g. Install lubrication fitting (3) in tube elbow (27).

h. Install lockwasher (4) onto clutch shaft (33), indexing its lower tab in the spot drilling provided on the hub and back plate (6).

i. Install hexhead nut (3) and tighten to remove all clearance, using 30 ft-lb torque. Tighten an additional 60° to 90° further.

j. Bend the tabs on the lockwasher (4) against flats on the hexhead nut (3).

k. Solidly supporting the OUTPUT END of the clutch shaft (33), install the pilot annular ball bearing (2) as follows:

**NOTE**

Do not press the pilot annular ball bearing all the way onto the shaft; room must be left between the front face of the bearing inner race and the end of the clutch shaft.

(1) Press the pilot annular ball bearing (2) onto the clutch shaft (33) by .applying pressure to the inner race of the bearing.

(2) Leave a distance of 0.06 inch between the front face of the pilot annular ball bearing (1, FIGURE 2-56) and the end of the clutch shaft (2).

l. Install new instruction plate gasket (37) and instruction plate (35), and secure with two hexhead capscrews (36). Tighten capscrews to 11-13 ft-lb torque.

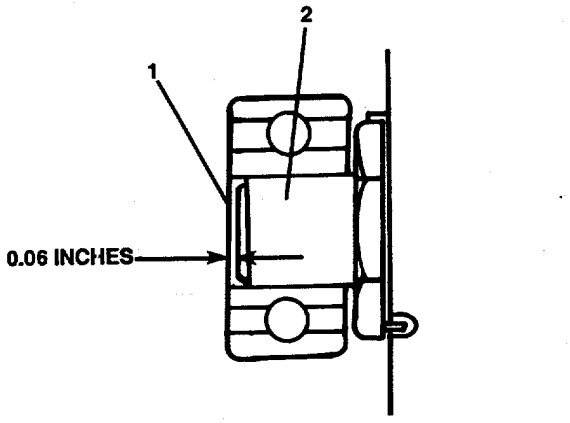


*FIGURE 2-56. Bearing End Clearance.*

## 2-43. Replace Friction Clutch Assembly

**This task covers:**

**b. Removal** **a. Inspection** **c. Repair** **d. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-02-046-4979
Standard puller P/N ST-647
Torque wrench (0-50 ft-lb),
5120-00-242-3264
Arbor press, 4920-00-373-9376

Equipment Condition

Friction clutch assembly removed
(para. 3-22).

Materials/Parts

Nonmetallic hose assembly P/N A1663A
Nonmetallic hose P/N M1292B
Clutch assembly P/N X9586B
Sleeve assembly P/N S-598

REMOVAL

a. Place friction clutch assembly (FIGURE 2-57, Sheets 1 and 2) on workbench and support clutch housing (16, Sheet 1) on wooden blocks with INPUT END facing upward.

b. Using a standard bearing puller, remove pilot annular ball bearing (1) from the clutch shaft (18).

c. Remove the plain hex jam nut (10) and lockwasher (9) securing tube elbow (8) at location (17) on clutch housing (16).

d. Push tube elbow (8) and connected nonmetallic hose assembly (5) into the clutch housing (16).

e. Straighten the bent portion of the hub nut lockwasher (3) from the hex hub nut (2).

f. Remove hex hub nut (2) and lockwasher (3) from clutch shaft (18). Discard lockwasher.

g. Use a conventional gear puller with threaded legs for 5/8-11 tapped holes to pull clutch assembly (4) from the clutch shaft (18).

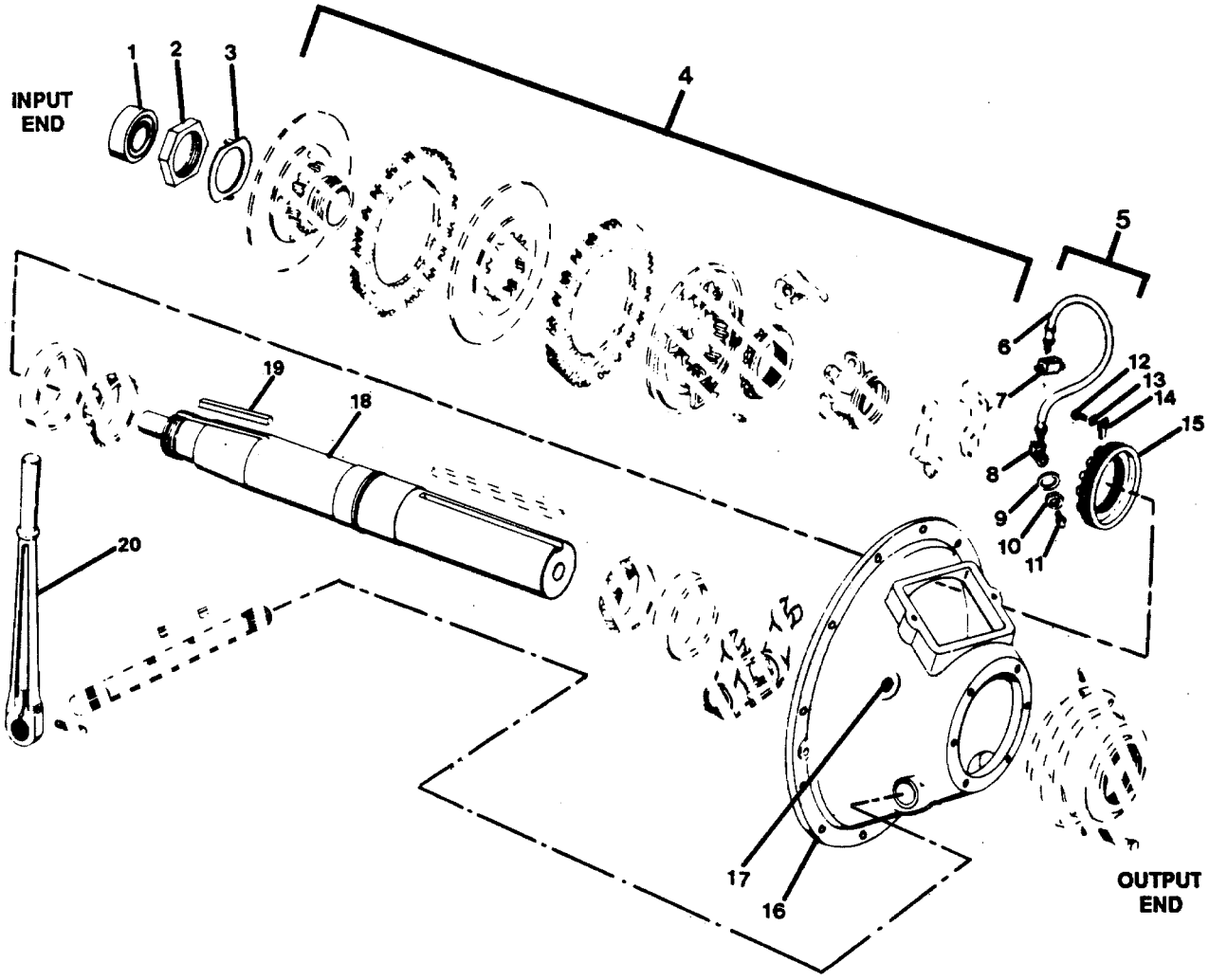


*FIGURE 2-57. Friction Clutch Assembly Repair (Sheet 1 of 2).*

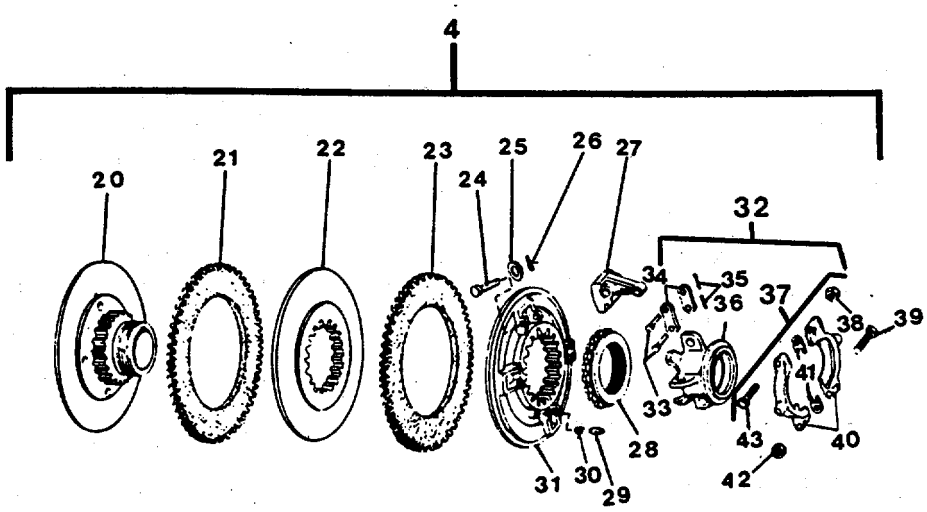


*FIGURE 2-57. Friction Clutch Assembly Repair (Sheet 2 of 2).*

(1) Install puller so the threaded legs screw into the holes provided in the hub and back plate (20, Sheet 2) and the puller jack screw exerts force on the end of the clutch shaft.

(2) Remove the clutch assembly (4, Sheet 1), shaft key (19) and puller and set clutch assembly (4) on workbench with sliding sleeve assembly (32, Sheet 2) facing up.

h. Remove lubrication fitting (11, Sheet 1) from tube elbow (8).

i. Remove tube elbow (8) from nonmetallic hose (6).

j. Remove nonmetallic hose (6) from pipe to tube elbow (7).

k. Remove pipe to tube elbow (7) from split collar (40, Sheet 2).

l. Straighten and remove four cotter pins (26) from four headless straight pins (24).

m. Remove four headless straight pins (24) from four levers (27) and floating plate (31). Remove two spring washers (25) at each lever (27) location and remove the levers (27), sliding sleeve (36) and collar assembly (37) from the floating plate (31) and adjusting ring (28) as an assembly.

n. Straighten and remove eight cotter pins (35) from the lever link pins (33). Remove the lever link pins (33), lever chain link plates (34), and levers (27) from the sliding sleeve assembly (32).

o. Remove two hex self-locking nuts (38 and 42) from two hex capscrews (39 and 43) retaining the split collar (40) to the sliding sleeve (36). Remove the hex capscrews (39 and 43), two shims (41), and split collar (40) halves from the sliding sleeve (36).

**INSPECTION**

a. Inspect nonmetallic hose assembly (5, Sheet 1) for cracks, cuts, swellings, or loose fittings (7 and 8). Replace nonmetallic hose assembly, if damaged.

b. Inspect sleeve assembly (32, Sheet 2) for bent, distorted or broken parts. Replace sleeve assembly, if damaged.

**REPAIR**

Repair of the friction clutch assembly consists of repairing or replacing nonmetallic hose assembly (5, Sheet 1) and replacing sleeve assembly (32, Sheet 2).

**REPLACEMENT**

a. Install the four levers (27, Sheet 2) and eight lever chain link plates (34) to the lugs on the sliding sleeve (36) with eight lever link pins (33) and eight cotter pins (35). Spread the cotter pins (35) so their ends do not exceed a 0.47-inch radius for operating clearance.

b. Install the split collar (40) halves and two shims (41) to the flange provided on the sliding sleeve (36). Secure the collar assembly (37) to the sleeve (36) with two hexhead capscrews (39 and 43) and two hex self-locking nuts (38 and 42). Tighten the hex self-locking nut (38 and 42) to 30 ft-lb torque.

c Install the four levers (27), sliding sleeve (36) and collar (37) group as an assembly onto the adjusting ring (28) and floating plate (31). Secure the levers (27) to the floating plate (31) with eight spring washers (25), one on each side of each lever (27), four headless straight pins (24), and four cotter pins (26). Spread the ends of the cotter pins.

d. Install pipe to tube elbow (7, Sheet 1) onto split collar (40, Sheet 2).

e. Install nonmetallic hose (6, Sheet 1) to pipe to tube elbow (7).

f. Install tube elbow (8) on nonmetallic hose (6).

g. Install lubrication fitting (11) onto tube elbow (8).

h. Pick up clutch assembly (4, Sheet 2) and lower over clutch shaft (18, Sheet 1) and into clutch housing (16) engaging the trunions on the split collar (40, Sheet 2) with the throw yoke (15, Sheet 1), aligning shaft (18) keyway with the keyway in the hub and back plate (20, Sheet 2). Install key (19).

i. Install the hub nut lockwasher (3) onto clutch shaft (18), indexing the washer lower tab in the spot drilling provided on the hub and back plate (20, Sheet 2).

j. Install the hex hub nut (2, Sheet 1). Tighten hex hub nut to 30 ft-lb torque to seat tapers and remove any clearances, then tighten hex hub nut an additional 150°-180° rotation. Bend the hub nut lockwasher (3) against a flat on the hex hub nut (2).

k. Route the nonmetallic hose assembly (5) free of moving parts, and push tube elbow (8) fitting through hole (17) in clutch housing (16).

l. Install lockwasher (9) and plain hex jam nut (10) over tube elbow (8) fitting and secure tube elbow (8) to clutch housing (16).

m. Solidly supporting the OUTPUT END of the clutch shaft (18), install the pilot annular ball bearing (1) as follows:

**NOTE**

Do not press the pilot annular ball bearing (1) all the way onto the shaft. Room must be left between the front face of the bearing inner race and the end of the clutch shaft.

(1) Press the pilot annular ball bearing (1) onto the clutch shaft (18) by applying pressure to the inner race of the bearing.

(2) Leave a distance of 0.12 inch between the front face of the bearing (1, FIGURE 2-58) inner race and the end of the clutch shaft (2).

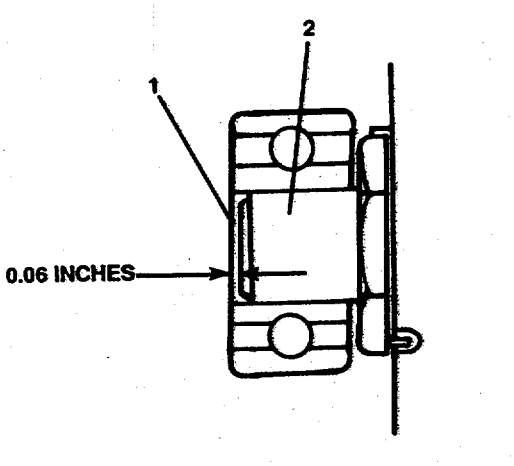


*FIGURE 2-58. Bearing End Clearance.*

n. Adjust clutch assembly as follows:

(1) Install the friction, clutch assembly. Refer to para. 3-21.

(2) With clutch disengaged, turn the clutch by turning the clutch shaft (18, FIGURE 2-57, Sheet 1) until adjusting lock pin (29, Sheet 2) can be reached through a hand hole.

(3) Depress lock pin (29) with a screwdriver and screw the adjusting ring (28) clockwise one or two notches or until a distinct pressure is felt with the hand lever (20, Sheet 1).

(4) Release adjusting pin (29, Sheet 2) and turn adjusting ring (28) to engage the nearest notch with lock pin (29).

(5) Engage and disengage the clutch a number of times with lever (20, Sheet 1) to check operation. If a distinct pressure is not felt by lever (20) when operating, repeat steps (1) through (4) until a distinct pressure is felt with hand lever (20, Sheet 1) when engaging clutch.

## 2-44. Repair Oil Pan Group. (FIGURE 2-59)

**This task covers:**

**a. Removal b. Inspection/Repair . c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979

Equipment Condition

Engine shut down (TM 55-1905-223-10).
Engine tagged, "Out of Service - Do Not Operate."
Lubricating oil drained (PMCS Table 2-1, Item 12).

Materials/Parts

Sediment strainer element P/N 20622
Gasket, P/N 3032861 P/N 65274, P/N 157551
Nonmetallic hose assembly P/N 3017963
Cleaning solvent, Item 5, Appendix C

REMOVAL

a. Remove dipstick (gauge) (21) from the oil gauge tube (20). Turn the T-handle (22) on the dipstick counterclockwise to loosen it for removal.

b. Remove support clip (15) from nonmetallic hose assembly (14).

c. Remove capscrews (16) and lockwashers (17) from the handhole cover bracket (18) and remove the gauge tube, cover, and gasket (19) from the cylinder block.

d. Disconnect nonmetallic hose assembly (14) from the oil pan and lubricating oil pump flange to tube elbow (11). Remove nonmetallic hose assembly.

e. Remove flange to tube elbow connection (11) and suction gasket (12) from the oil pan. Discard the gasket (12).

f. Remove captive washer capscrews (23, 24) that hold the oil pan to the cylinder block and gear cover.

g. Remove capscrews (2) and washers (3) that hold the oil pan to the rear cover.

h. Remove oil pan and discard the gasket (1).

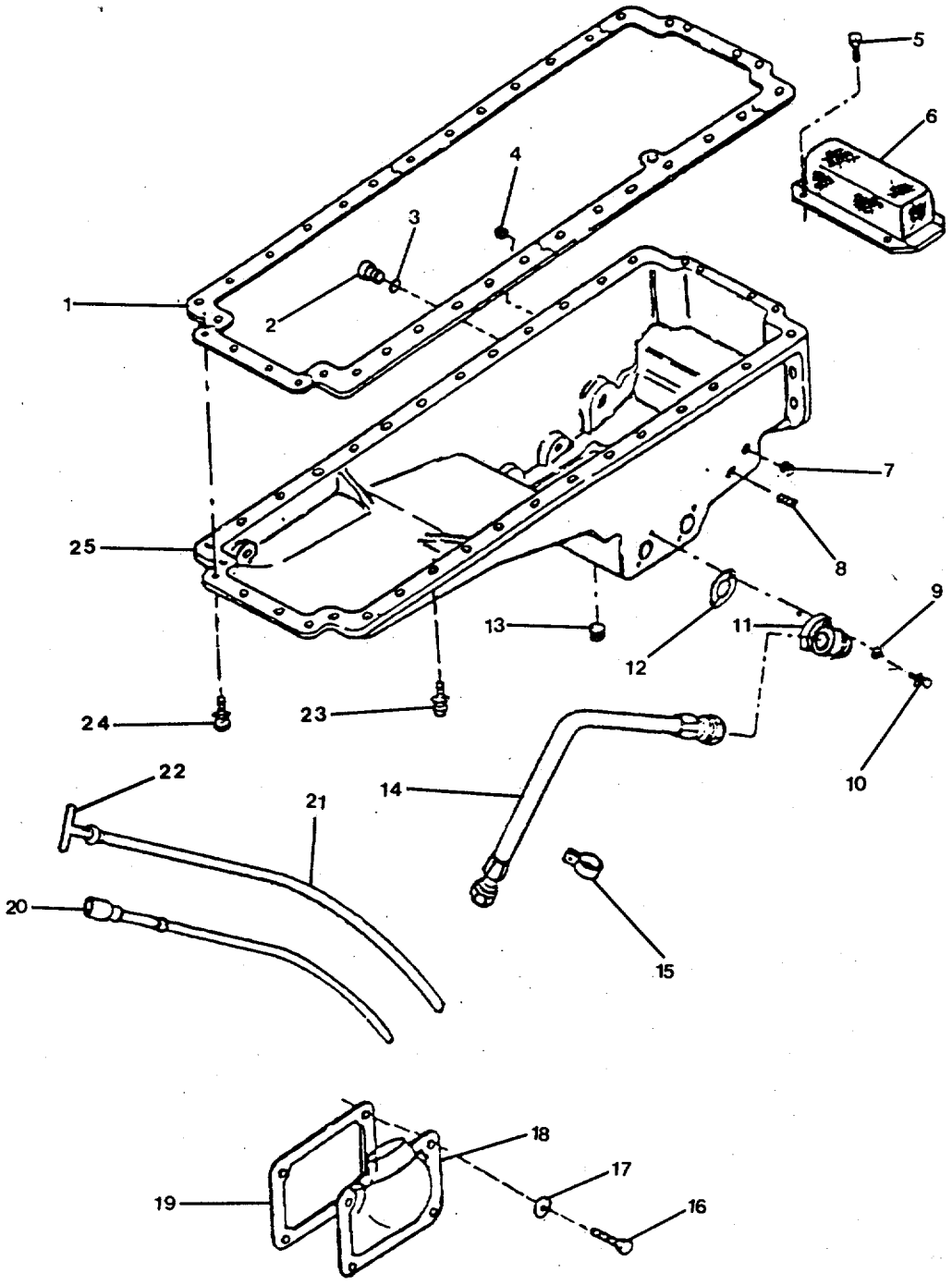


*FIGURE 2-59. Oil Pan Group.*

**INSPECTION/REPAIR**

a. Visually inspect the oil pan and nonmetallic hose assembly for cracks or holes.

b. Remove threaded tapping screws (5) and remove sediment strainer element (6).

c. Replace sediment strainer element (6), gaskets (1, 12, 19), and nonmetallic hose assembly (14).

d. Clean parts with solvent (Item 5, Appendix C).

**REPLACEMENT**

**NOTE**

Ensure the gasket surfaces are clean before installing oil pan.

a. Install sediment strainer element (6) with threaded tapping screws (5).

b. Position the oil pan and new gasket (1). Use your hand to install the captive washer capscrews (23, 24).

c. Use the following sequence to tighten the capscrews. This will prevent damage to the oil pan or flywheel housing.

(1) Install and tighten the middle capscrew in each of the two buttresses on the flywheel housing (FIGURE 2-60).

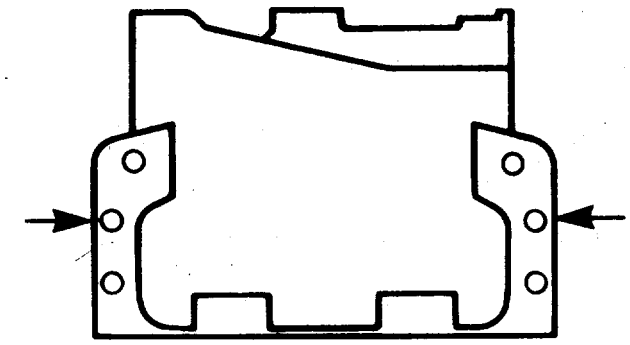

*FIGURE 2-60. Flywheel Housing Buttresses.*

(2) Tighten two 7/16 inch capscrews on each side of the oil pan flange halfway between the front and the rear of the oil pan.

(3) Remove the capscrews that were installed in step c.(l) of this procedure. This is necessary to provide the clearance to perform the following step.

(4) Install and tighten four 5/16 inch capscrews in the rear of the oil pan

(5) Install and tighten 28 7/16 inch capscrews in the remaining oil pan capscrew holes.

(6) Torque the 5/16 inch capscrews to 20 ft-lb and the 7/16 inch capscrews to 50 ft-lb in the sequence shown in FIGURE 2-61 .

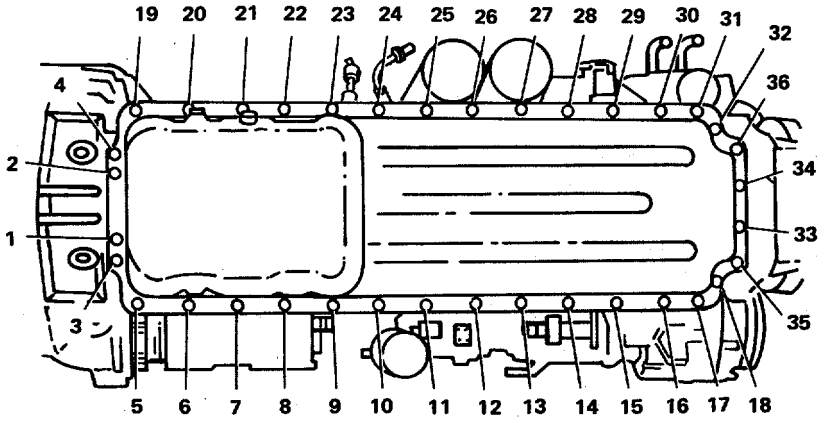


*FIGURE 2-61. Oil Pan Capscrews Torque Sequence.*

(7) Tighten the capscrews that hold the oil pan buttress to the flywheel housing the 70-80 ft-lb torque.

d. Install the flange to tube elbow connection (11) and gasket (12) in the oil pan.

e. Connect nonmetallic hose assembly (14) to the oil pan and lubricating oil pump flange to tube elbow (11) and tighten.

f. Use a gasket (19) and install the hand hold cover (18) and oil gauge (dipstick) tube (20). Tighten the capscrews (16) to 30 to 35 ft-lb torque.

g. Install the support clip (15) to the nonmetallic hose assembly (14).

h. Place dipstick (21) into the oil gauge tube (20).

i. Fill the engine with clean oil (PMCS Table 2-1, Item 12).

j. Operate the engine (TM 55-1905-223-10) until the water temperature reaches 180ºF (80ºC), and check for oil leaks. Repair as necessary.

k. Remove "Out of Service - Do Not Operate" tag.

## SECTION VI. PREPARATION FOR STORAGE OR SHIPMENT

2**-45. General**. If an engine will be out of service for an extended period of time (3 weeks or longer), or reshipped to another location, certain actions must be-taken to protect it against the corrosive effects of the elements. All surfaces of an engine will rust or corrode if they are not protected. The procedures in this paragraph must be taken prior to placing an engine in storage or prior to reshipment to another location. Also see TB 740-97-4, "Preservation of Vessels for Storage."

a. Temporary Engine Storage. If an engine remains out of service for 3 weeks to 3 months, take steps to prevent rust. The following procedures are required to prevent damage to engine in temporary storage.

(1) The engine must be started and the speed gradually increased to 1200 rpm with no load. Operate the engine until the water temperature is at least 160°F (71°C).

(2) Disconnect both fuel lines at the fuel supply tank. Fill two portable containers, one with diesel fuel and a second with preservative oil U.S. Military Specification MIL-L-644 Type P-9.

(3) Start the engine with the fuel inlet line pulling fuel from the can with the diesel fuel. Let the drain line flow into the container with the diesel fuel. After the engine is started and is running at idle, move the fuel line to the container with the preservative oil. Operate the engine five to ten minutes on the preservative oil. Stop the engine and reconnect the fuel lines to the supply tank.

(4) The oil sump fuel filters and fuel tank must be drained, and the drain plugs must be installed. New oil can be added.

(5) Remove the intake hose from between the air cleaner and the intake manifolds.

(6) Disconnect the electrical wiring. Turn the shutoff valve on the fuel pump counterclockwise so that the engine will not start. Rotate the crankshaft of the engine while applying a spray of 10W oil into the intake manifold.

(7) Put tape over all the intake manifold openings to keep out dirt and moisture.

(8) Put tape over all the engine openings, including the coolant inlets, cylinder block, oil breather and crankcase.

(9) Drain the coolant from the cooling system, unless it is a permanent antifreeze with a rust inhibitor added.

(10) Put the engine in a place protected from the weather where the air is dry and the temperature is even.

(11) Rotate the engine crankshaft two or three revolutions every 3 weeks.

b. Long Term Storage. When an engine is to be stored for 6 months or more, the following procedures must be performed.

(1) The engine must be started and the speed gradually increased to 1200 rpm with no load. Operate the engine until the water temperature reaches 160°F (71°C). Stop the engine and drain the old oil.

(2) Fill the crankcase to the full mark on the dipstick with preservative oil, U.S. Military Specification MIL-L-21260, Type P-10, Grade 2, SAE 30.

(3) Disconnect both fuel lines at the fuel supply tank. Fill two portable containers, one with diesel fuel and the second with preservative oil U.S. Military Specification MIL-L-644, Type P-9.

(4) Start the engine with the fuel inlet line pulling fuel from the can with the diesel fuel. The injector drain line can flow into the container with the diesel fuel. After the engine is started and is running at idle, move the fuel inlet line to the container with the preservative oil. Stop the engine and reconnect the fuel lines to the supply tank.

(5) The fuel tank must be drained and the drain plug installed. Make a cover for the filler vent with tape.

(6) Drain all the pumps, compressors, coolers, filters and the crankcase. Replace all the plugs after draining.

(7) Remove the intake and exhaust manifolds. Apply the preservative oil in a spray into the intake and exhaust parts of the engine. Install the intake and exhaust manifolds.

(8) Inspect the coolant in the cooling system. If the coolant contains rust, drain and flush the system. Then fill it with a rust preventing compound. Drain the system while it is hot and then replace the plug. Use an oil which has rust inhibitors that will mix with the water. Flush the cooling system before returning it to service.

(9) Make sure all outside surfaces of the engine are painted. If painting is necessary, refer to step c.

(10) Remove the valve covers and apply preservative oil to the rocker levers, valve stems, springs, guides, crossheads and push tubes. Install the covers.

(11) All engine openings must have a cover of heavy paper and tape.

(12) Put a tag on the engine to show the following:

(a) The engine has been prepared for storage.

(b) The coolant has been removed.

(c) The crankshaft must not be rotated.

(d) The date of the engine was prepared for storage.

(e) The compound used for storage must be removed before running the engine.

(13) Put the engine in a place protected from the weather and where the air is dry and the temperature is even.

**NOTE**

After the engine has been in storage for 24 months, flush it with solvent and repeat the preparation for storage.

c. Painting the Engine.

(1) Make sure all engine surfaces are clean and dry before painting them.

(2) Put tape over all openings that must not be painted.

(3) Put tape over all belts or remove them.

(4) Protect the fuel pump dataplate, engine dataplate and other dataplates on the engine from paint.

(5) Exposed threads, wire terminals, and hose fittings must be protected with tape. Pipe openings, fuel pump drain, fuel manifold drain, and cooler openings must have a cap installed.

(6) Protect the clutch contact surface of the flywheel with a rust preventing compound if the engine is not going into immediate service.

(7) Apply a coat of primer to the outside surfaces of the engine.

(8) Apply enamel paint to the outside surfaces of the engine after the primer is dry.

2-46. **Preparing an Engine From Storage to Service**. When an engine is removed from storage and put into service, the operations listed below must be completed.

a. Cleaning the Engine.

(1) Remove all dirt from the outside of the engine.

(2) Remove all the paper covers and tape.

(3) Use solvent to remove rust preventing compound from the surfaces of the engine.

(4) Fill the crankcase with clean oil.

(5) Flush the cooling system.

b. Inspecting the Engine.

(1) Engines in storage 6 months or less must have the adjustment of the injectors, valves, and the belts checked. Also check the oil filters, air filters, connections, and the torque of the cylinder head capscrews.

(2) When an engine has been in storage for 6 months or more, the following inspection procedure must be followed:

(a) Flush the fuel system with fuel oil until the fuel system is clean.

(b) Remove the plug from the oil filter head and run hot, light mineral oil through the oil passages. Rotate the engine three or four times during the flushing operation.

(c) Remove all screens and make sure they are clean before the engine is started.

c. Precautions Before Starting.

(1) Too much oil in the combustion chamber can cause a hydraulic lock. Damage to the engine will occur if it is started before the oil is removed.

(2) When returning an engine to service from storage, make sure all foreign matter is removed from the screens and strainers.

(3) Apply oil under pressure to the lubricating system before starting the engine.

(4) The engine is now ready to start.

d. Starting the Engine.

(1) After inspecting the engine and parts, make sure all the preservative oil has been flushed away.

(2) Start the engine. Refer to paragraphs 2-7 and 2-8.

(3) Perform Engine Run-In. Refer to paragraph 2-9.

# CHAPTER 3

# INTERMEDIATE DIRECT SUPPORT MAINTENANCE INSTRUCTIONS



## SECTION I. REPAIR PARTS, SPECIAL TOOLS; TEST, MEASUREMENT, AND DIAGNOSTIC EQUIPMENT (TMDE); AND SUPPORT EQUIPMENT

3-1. **Common Tools and Equipment**. For authorized common tools and equipment, refer to the Modified Table of Organization and Equipment (MTOE) applicable to your organization.

3-2. **Special Tools; TMDE, and Support Equipment**. For special tools, test, measurement, and diagnostic equipment; and support equipment requirements are listed and illustrated in the Repair Parts and Special Tools list (RPSTL), TM 55-1905-223-24P. These items are also listed in the Maintenance Allocation Chart (MAC), Appendix B of this manual.

3-3. **Repair Parts.** Repair parts are listed and illustrated in the Repair Parts and Special Tools List (RPSTL) TM 55-1905-223-24P.

## SECTION II. SERVICE UPON RECEIPT

3-4. **Checking and Deprocessing Unpacked Equipment.**

a. Inspect the equipment for damage incurred during shipment. If the equipment has been damaged, report the damage in accordance with the instructions of DA Pam 738-750.

b. Check the equipment against the packing slip to see if the shipment is complete. Report all discrepancies in accordance with the instructions of DA Pam 738-750.

c. Check to see whether the equipment has been modified.

d. Remove protective caps, plugs, inserts, wrappings, and tape when inspection/inventory is completed. Inspect piping openings for damage. Wipe off dirt, grease, or protective films at time of installation.

e. Remove chocks from resilient mounted components.

3-5. **Initial Setup Procedure**. Includes operational checks and inspections that are not performed for a routing startup. Direct support maintenance personnel will perform initial setup in accordance with the operator's manual, TM 55-1905-223-10.

3-6. **Normal Startup**. Refer to the operator's manual, TM 55-1905-223-10.

3-7. **Shutdown Procedure (Usual or Unusual).** Refer to the operator's manual, TM 55-1905-223-10.

## SECTION III. INTERMEDIATE DIRECT SUPPORT PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

3-8. **General**. There is no PMCS at the direct support level. See Chapter 2, Section III.

## SECTION IV. INTERMEDIATE DIRECT SUPPORT TROUBLESHOOTING PROCEDURES

3-9. **General Engine Noise Diagnostic Procedures**. When diagnosing engine noise problems, make sure that noises caused by accessories, such as the air compressor and power takeoff, are not mistaken for engine noises. Remove the accessory drive belts to eliminate noise caused by these units. Noise will also travel to other metal parts not involved in the problem. The use of a stethoscope can help locate an engine noise. For further information concerning engine noise, refer to paragraph 2-15.

3-10. **White Smoke** - General Information. White smoke is the result of incomplete combustion and is generally associated with engine startup at low ambient temperatures. This condition is more predominant on high horsepower fixed injection timing engines because the fuel and combustion systems are optimized for maximum performance and for reliability and durability under high load operating conditions. For further information concerning white smoke, refer to paragraph 2-16.

3-11. **Troubleshooting**. Both a symptom index and a troubleshooting table are provided. The symptom index will help you locate the information you need for troubleshooting.

SYMPTOM INDEX



Table 3-1 lists the common fault conditions that may be found during operation or maintenance of the equipment. Look for causes and do corrective actions in the order listed. This manual cannot list every symptom that may show up, and it cannot list all of the possible causes and corrective actions. If a symptom is not listed, or if it keeps up after you have performed the corrective actions, notify your supervisor.

**Table 3-1. Troubleshooting**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

1. Coolant temperature above normal.

   STEP 1. Check for obstructed or damaged oil cooler.
   Clean oil cooler (para. 3-14).

2. Low lubricating oil pressure.

   STEP 1. Check for malfunctioning main oil pressure regulator.
   Inspect main oil pressure regulator assembly (para. 3-14).

   STEP 2. Check for restricted or plugged lubricating oil pump signal orifice.
   Clean the signal line orifice (para. 3-23).

   STEP 3. Check lubricating oil pump for malfunction.
   Replace lubricating oil pump (para. 3-23).

3. High lubricating oil pressure.

   STEP 1. Check for malfunctioning main oil pressure regulator.
   Check mail oil pressure regulator assembly (para. 3-14). Replace as required.

4. Engine cranks, but will not start (no smoke from exhaust).

   STEP 1. Check for broken camshaft.
   Replace the camshaft (para. 3-24).

   STEP 2. Check to see if fuel pump is turning while cranking engine with starter.
   Repair accessory drive (para. 3-19).

5. Warm engine runs rough or misfires in operating range.

   STEP 1. Check for damaged camshaft.
   Replace camshaft (para. 3-24).

   STEP 2. Check wrong adjustment on valves or injectors.
   Adjust valves/injectors (para. 3-16).

6. Rough idle.

   STEP 1. Check for wrong adjustment on injectors.
   Adjust injectors (para. 3-16).

**Table 3-1. Troubleshooting**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

7. Low power.

   STEP 1. Check for wrong adjustment on valves or injectors.
   Adjust valves/injectors (para. 3-16).

8. Exhaust smoke excessive under load (blue smoke).

   STEP 1. Check if piston rings are sealing.
   Replace piston and ring assembly (refer to para. 3-25).

9. Excessive engine vibration.

   STEP 1. Check for loose or damaged flywheel.
   Replace flywheel (para. 3-26).

   STEP 2. Check for misaligned fire pump or bow thruster unit.
   Refer to TM 55-1905-223-24-12 or TM 55-1905-223-24-6.

   STEP 3. Check for loose or broken engine mount.
   Replace engine mount (para. 3-13).

10. Excessive engine noise.

    STEP 1. Check for damaged push rod or cam follower.
    Check push rods and cam followers (para. 3-16). Replace as required.

    STEP 2. Check for excessive gear train backlash or damaged gear teeth.
    Replace camshaft (para. 3-24).

11. Main bearing noise.

    STEP 1. Check for loose flywheel.
    Check flywheel mounting capscrews (para. 3-26). Replace flywheel if required.

12. Connecting rod bearing noise.

    STEP 1. Check if connecting rod capscrews are loose or not tightened correctly.
    Inspect the connecting rod capscrews (para. 3-25).

    STEP 2. Check if connecting rod bearings are not assembled correctly, damaged, worn or wrong bearings installed.
    Replace the connecting rod bearings (para. 3-25).

**Table 3-1. Unit MaintenanceTroubleshooting-Cont.**

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 3. Check if connecting rods are bent or out of alignment.
Replace the connecting rod assembly (para. 3-25).

13. Piston noise.

STEP 1. Check if piston pin or bushing is loose, worn, or not installed correctly.
Replace piston and ring assembly (para. 3-25).

STEP 2. Check for cracked or broken piston.
Replace piston and ring assembly (para. 3-25).

STEP 3. Check if connecting rod(s) is bent or out of alignment.
Replace connecting rod(s) (para. 3-25).

STEP 4. Check is piston rings are worn or out of alignment.
Replace connecting rod(s) and piston assembly (para. 3-25).

STEP 5. Check for worn or broken piston rings.
Replace piston and ring assembly (para. 3-25).

14. PTO clutch does not pull, heats, or operating lever jumps out.

STEP 1. Check for worn clutch plates.
Replace the clutch plates (paras. 3-21 and 3-22).

STEP 2. Check bearing end play.
Check and adjust bearing end play. For PTO-Sh-111 refer to para. 3-21.
For PTO SP-214 refer to para. 3-22.

## SECTION V. INTERMEDIATE DIRECT SUPPORT MAINTENANCE PROCEDURES

3-12. **General.** This section contains direct support maintenance procedures for the NT 855M Bowthruster Diesel Engine. Step-by-step actions are provided with illustrations when applicable.

MAINTENANCE OF BOWTHRUSTER ENGINE

### 3-13. Replace Bowthruster Engine Assembly. (FIGURE 3-1)

**This task covers:**

**a. Removal** **b. Replacement**

**INITIAL SETUP:**

**Tools**

Tool kit, general mechanic's,
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Engine lifting fixture P/N 3822512
Filter wrench P/N 3375049, 3376807
Torque wrench kit P/N 3377216

**Materials/Parts**

Engine assembly, NT 855-M

**Equipment Condition**

Engine shut down
(TM 55-1905-223-24-10).
Primary circuit breakers OFF
(TM 55-1905-223-10).
Cooling system and lubricating oil
drained (Table 2-1).
Bowthruster Waterjet coupling removed
(TM 55-1905-223-24-6).
Fire pump coupling removed
(TM 55-1905-223-24-12).
Electric starter motor disconnected
(para. 2-21).
Instrument panel disconnected,
(para. 2-22).
All external fuel, seawater valves
closed (TM 55-1905-223-24-18).
Seawater pump drained and disconnected
(para. 2-37).
Fuel pump connections removed
(para. 2-33).
Fuel filter connections removed and
drained (para. 2-27).
Coolant heater disconnected
(para. 2-32).
Exhaust piping disconnected
(para. 2-40).
Fuel supply lines disconnected
(para. 2-33).
Lubrication oil drain line disconnected
(para. 2-31).
Seawater inlet valves disconnected
(para. 2-37).
Seawater outlet valves disconnected
(TM 55-1905-223-24-18).

**REMOVAL**

**WARNING**

- Ensure that all electrical power to the engine assembly has been turned off and tagged in order to prevent injury to personnel.
- Make sure the engine is properly attached to, and supported by, the lifting fixture before removing engine mounting capscrews.

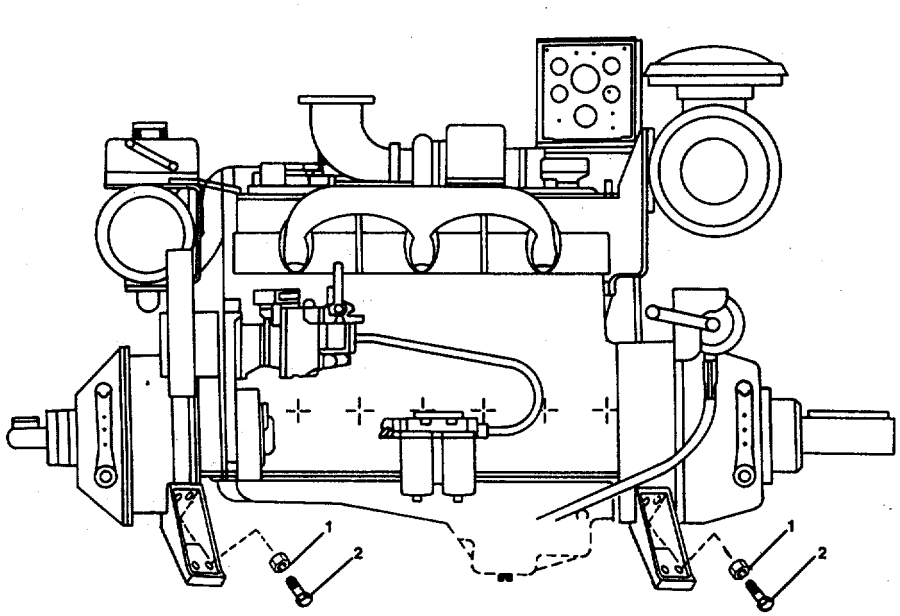


*FIGURE 3-1. Bowthruster Engine.*

**NOTE**

- Place a tag on all hoses, lines, linkage and electrical wiring connections as they are removed. This will identify their locations on installation of new engine.
- Cover all engine openings as they are disconnected to keep dirt and debris from entering.

a. Attach the lifting fixture P/N ST-125 (FIGURE 3-2) to the two lifting brackets on top of the engine.

b. Remove two capscrews (2, FIGURE 3-1) and bolts (1) holding the front and rear engine mounts to the frame support.

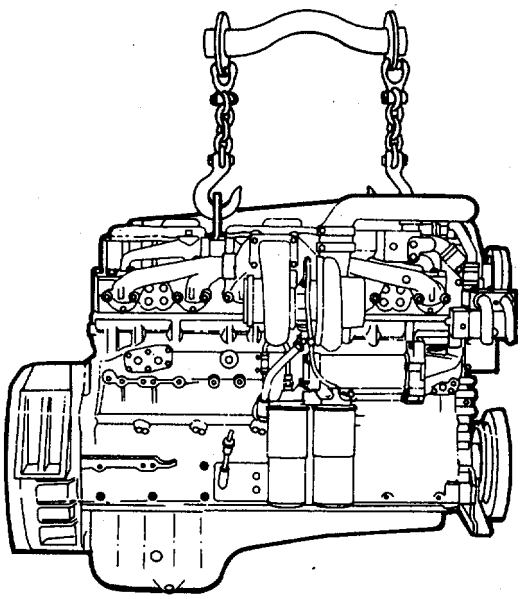

*FIGURE 3-2. Lifting Fixture P/N ST-125.*

**WARNING**

Personnel stand clear during hoisting operation.

c. Lift the engine slowly, ensuring that the lifting device is holding properly.

d. Remove the engine.

**NOTE**

It may be necessary to move, or remove, other external components or fixtures to provide necessary clearance for removing engine.

**REPLACEMENT**

a. Hoist the new engine into place on the frame support and install the mounting capscrews (2) and bolts (1). Torque to 135 ft-lbs.

b. Remove the lifting fixture.

c. Connect all lines and install all couplings listed in equipment conditions.

**NOTE**

Replace any external components or fixtures that were moved, or removed, to facilitate removing the old engine.

d. Conduct break-in, pre-servicing, start-up, and engine run-in in accordance with paragraphs 2-5 through 2-9.

## 3-14. Repair Lubricating Oil Cooler/Filter Group.

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

**Tools**

Tool kit, general mechanic's,
rail and marine diesel engines,
5180-00-629-9783
Valve spring compressor tester,
4910-01-142-4929
Tube bundle tester P/N 3375253
Mandrel kit P/N ST-1325
Torque wrench (30-300 ft-lb)
5120-01-125-5190

**Equipment Condition**

Oil Cooler/Filter group removed
(para. 2-30).
Filter removed from assembly.

**Materials/Parts**

Metal cleaning solvent, Item 5,
Appendix C
Alkaline solution, Item 31, Appendix C
Muriatic acid, Item 19, Appendix C
Oxalic acid, Item 32, Appendix C
Pyridene, Item 20, Appendix C
A 5% sodium carbonate and water
solution, Item 21, Appendix C
Gasket, P/N 218245
Helical compression spring, P/N 68274
Oil pump regulator plunger P/N 127558
Gasket P/N 3010030
Valve disk P/N 3018673
Helical compression spring P/N 202128
Retaining rings P/N 3006745
Preformed packing P/N 3007713
Fluid filter element P/N 3021581
Air nozzle
Container, Item 38, Appendix C

**REMOVAL**

**WARNING**

Carefully remove the capscrew. The pressure regulator spring is under compression.

**NOTE**

The Full Flow Cooling (FFC) engine has an oil pressure regulator that is part of the oil cooler and is located in the front support of the cooler (FIGURE 3-3). The regulator controls the oil pressure before the oil flows through the oil filter.

a. Remove the regulator machine thread plug (5), spacer ring (4), and helical compression spring (3).

b. Remove the regulator plunger (2) from the cooler support (1).

c. Remove the cooler support (5, FIGURE 3-4) and cover (14) from the housing (9) by removing lockwashers (6), hexagon head capscrews (7), and assembled washer screws (15).

d. Remove the lube oil circle cover gaskets (8, 13) and retaining rings (1). Discard the gaskets.

e. Remove and discard the preformed packings (2, 4). Be careful not to damage the fluid filter element (3) when removing packing.

f. Remove the element (3) cooler core from housing (12). Remove retainer plug (9), valve disk (10), and helical compression spring (11) from the housing (12).

**REPAIR**

a. Check the regulator plunger (2, FIGURE 3-3).

(1) Inspect the plunger (2) for scratches or other damage.

(2) If scratch is deep enough to be felt with a fingernail, replace the plunger.

(3) Inspect helical compression spring (3) for damaged or broken coils. Replace if damaged.

(4) Use a valve spring compressor to compress the helical compression spring (3) to 1.820 inches (46.23 mm). The force required must be between 22 and 26 pounds. Replace if necessary.

b. Clean and inspect the cooler element (fluid transmission center) (3, FIGURE 3-4) as follows:

**WARNING**

The fumes from the cleaning solution are dangerous. Use the solution in open air or in a room that has proper ventilation. Wear safety glasses and gloves.

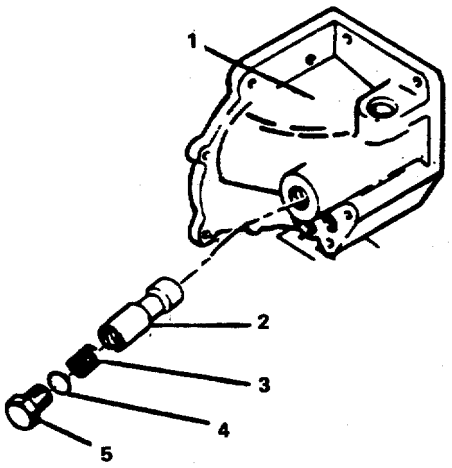


*FIGURE 3-3. Oil Cooler Pressure Regulator.*

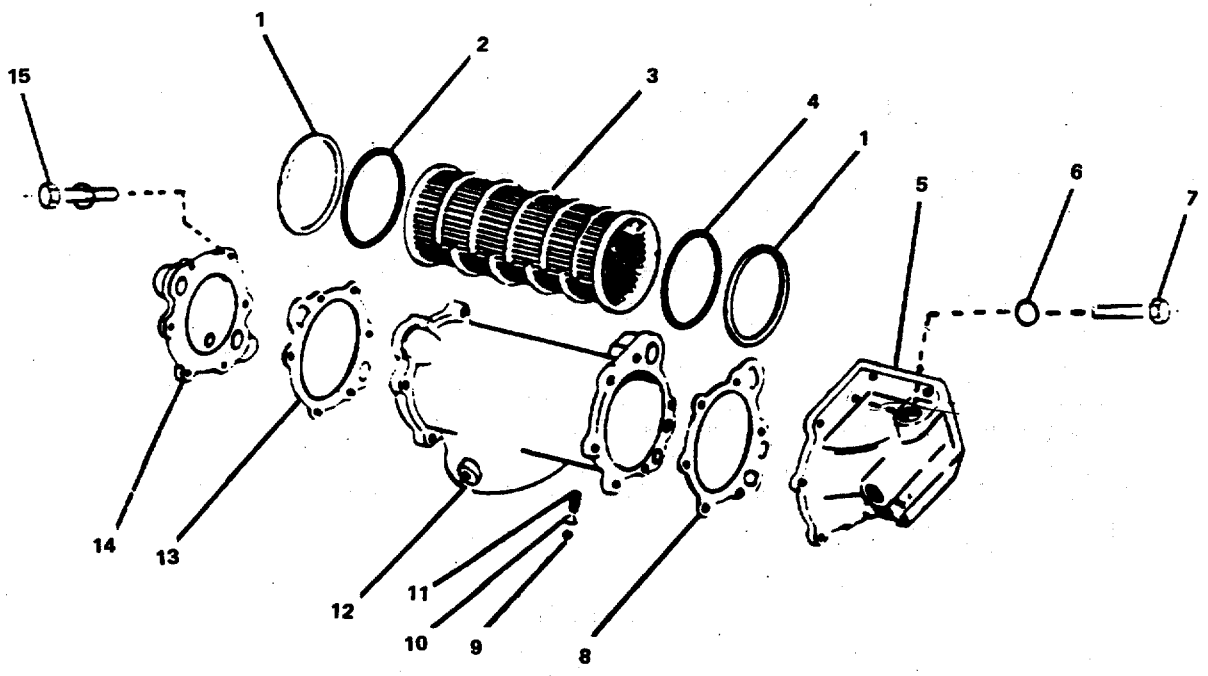


*FIGURE 3-4. Oil Cooler/Filter - Filter Element Removed.*

(1) Put the element (3) into a container of an approved cleaning solvent. Keep the element in the solution for several minutes. Flush the solution around and through the tubes in the element.

(2) Flush the tubes in the element with a solution of alkaline. After cleaning, flush several times with hot water.

**WARNING**

The fumes from the cleaning solution are dangerous. Use the solution in open air or in a room that has proper ventilation. Wear safety glasses and gloves.

(3) Put the element into a container of solution made up of the following: One part muriatic acid, nine parts water, one pound (0.5 kg) oxalic acid, and 0.01 gallon (0.038 L) of pyridene added to each 5 gallons (18.9 L) of muriatic acid.

(4) Remove the element when there are no foam or bubbles in the solution. The foam and bubbles normally stop in 30 to 60 seconds.

(5) Put the element into a container that has a 5 percent solution of sodium carbonate. Remove the element when there are no bubbles coming from the solution.

(6) Flush the element with clean, warm water.

(7) Visually inspect the element for damage. Replace if damaged.

c. Clean the housing (12), support (5); and cover (14) with cleaning solvent.

d. Visually inspect the following:

(1) Check the cooler housing (12, FIGURE 3-4) for cracks, damage and corrosion.

(2) Check the support (5) and cover (14) for cracks, damage, and corrosion.

(3) Replace housing (12), support (5), or cover (15) if damaged.

e. Using the tube bundle tester (FIGURE 3-5), test the cooler element for leaks as follows:

(1) Install the end plate to each end of element.

(2) Position the sliding plate of the fixture so that the fixture will fit over the element and end plates (FIGURE 3-5) .

(3) Position the element into the fixture. Position the fixture so that the air connection fitting goes through the notch in the fixture plate. Install locking clips into the bars of the fixture.

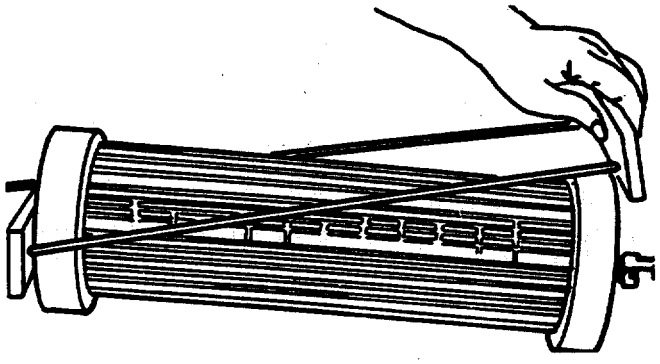

*FIGURE 3-5. Tube Bundle Tester.*

(4) Connect an air supply line that has a quick disconnect fitting to the air connection fitting.

(5) Use an air pressure regulator and a three way air discharge valve to control the pressure.

(6) Apply 60 psi (414 kPa) air pressure to the element.

(7) Place the element and tube bundle tester assembly into a container of water. Ensure the water completely covers the element. Check the element for air leaks.

(8) Remove the element and tube bundle tester assembly from the container of water.

(9) Using the air discharge valve, release air pressure from the element.

(10) Remove the tube bundle tester from the element.

**REPLACEMENT**

**CAUTION**

Never install a used cooler element. Engine damage can occur.

a. Place element (3, FIGURE 3-4) into housing (12). Place housing (12) with the element on flat workbench.

b. Align the index mark on the element with the index mark on the housing (FIGURE 3-6 or 3-7).

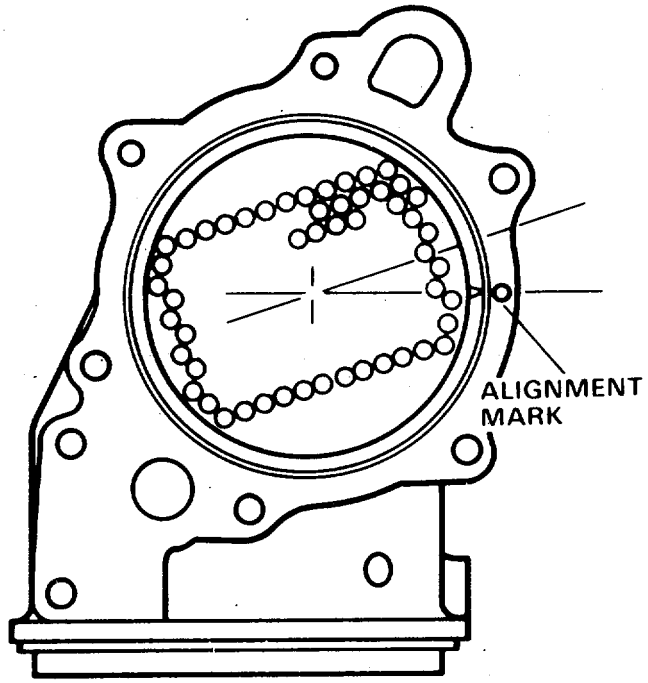


*FIGURE 3-6. Aligning Index Marks.*

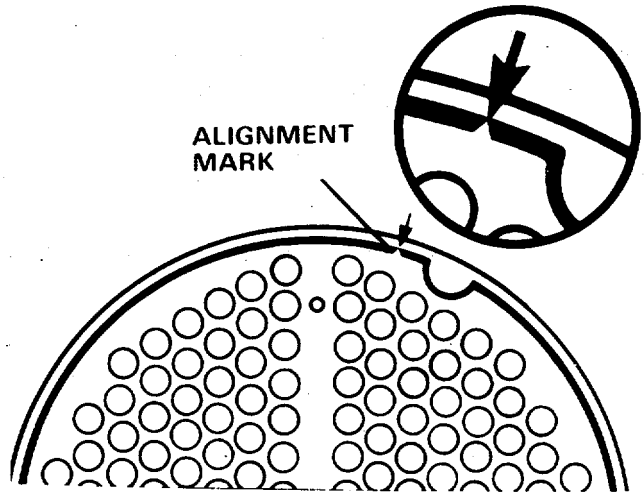


*FIGURE 3-7. Notch Type Index Marks.*

**NOTE**

Some elements have two index marks. They can have an "O" on the tube end plate (FIGURE 3-6) or notch cut into the inside diameter of the rim (FIGURE 3-7) . Use the notch to align the element in the housing.

c. Using a valve spring compressor, compress helical compression spring (11, FIGURE 3-4) to 1.820 inches (46.23 mm). The force required must be between 22 and 26 pounds. Replace if necessary.

d. Install valve disk (10) and helical compression spring (11) and secure with retainer plug (9).

e. Apply a coat of clean lubricating oil to new preformed packing (2). Use cooler "O" ring mandrel (ST-1218 for 5.0 inch element diameter or ST-1223 for 4.0 inch element diameter) to push the preformed packing (2) into the housing. Hit the mandrel with a plastic hammer until the mandrel is against the element and housing.

**NOTE**

The packing must be installed less than 1 hour after the oil is applied.

f. Install retaining ring (1). Ensure that the part number on the ring faces out.

g. Install a new gasket (13) and the cover (14) to the housing (12). Tighten the assembled washer screws (15) to 30 to 35 ft-lb (40.06 to 47.4 N•m) torque.

h. Slide the housing to the edge of the work bench until you can hold the element in position with your hand. Ensure that the element does not move in the housing. Place the housing with the cover end down onto the workbench.

i. Repeat Steps (d), (e), and (f) to install the packing (4, FIGURE 3-4) and retaining ring (1).

j. Install a new gasket (8) and the support (5) to the housing (12). Tighten the hexagon capscrews (7) and lockwashers (6) to 30 to 35 ft-lb (40.6 to 47.4 N•m) torque.

k. Install any pipe plugs that were removed.

l. Tighten the 1/4 inch pipe plug to 25 ft-lb (33.8 N•m) torque.

m. Tighten the 1/8 inch pipe plug to 7 ft-lb (9.4 N•m) torque.

n. Install the plunger (2, FIGURE 3-3), compression spring (3), spacer (4), and machine thread plug (5) into the support housing (1) and tighten the plug to 20 ft-lb torque.

## 3-15. Repair Fuel Tubing, Shut-Down Valve, and Fuel Pump Group

**This task covers:**

**a. Disassembly, b. Repair, c. Assembly.**

**INITIAL SETUP:**

**Tools**

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Multimeter 6625-01-139-2512
Torque wrench kit P/N 3377216

**Equipment Condition**

Fuel tubing, shutdown valve and
fuel pump group removed
(para. 2-33).

**Materials/Parts**

Gasket P/N 154087
Solenoid valve, P/N 3035346
Lubriplate, Item 11, Appendix C
Emery cloth, 240 grit, Item 33, Appendix C
Metal cleaning solvent, Item 5,
Appendix C

**DISASSEMBLY**

**NOTE**

Disassembly in this procedure consists of removing the fluid pressure dampener, gear pump assembly, shutoff valve assembly, electric governor actuator, and fluid filter element from the fuel pump body.

a. Remove solenoid valve (2, FIGURE 3-8) .

(1) Remove the two hexagon capscrews (2, FIGURE 3-9), lockwashers (3), and flat washers (4), securing the solenoid valve to the fuel pump (6).

(2 Remove solenoid valve body and preformed packing (5) from the fuel pump. Discard preformed packing.

b. Remove the fluid pressure dampener (4, FIGURE 3-8) .

(1) Remove two capscrews, lockwashers (1, FIGURE 3-10) and two capscrews and lockwashers and flat washers (5).

(2) Remove the cover access (4), preformed packing, solid plain disk, and spacer ring (3), and the fuel pump dampener housing (2).

(3) Remove packing (6) from the back of housing (2).

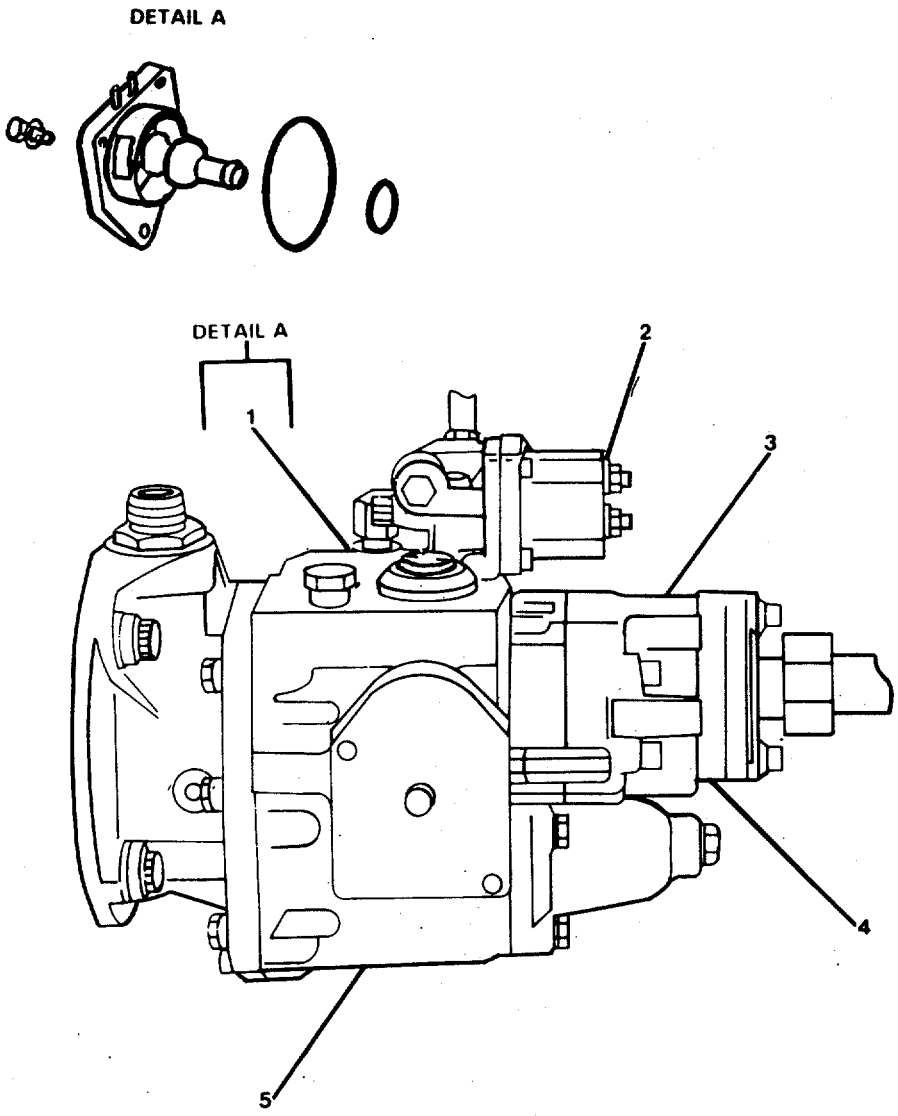


*FIGURE 3-8. Fuel Pump.*

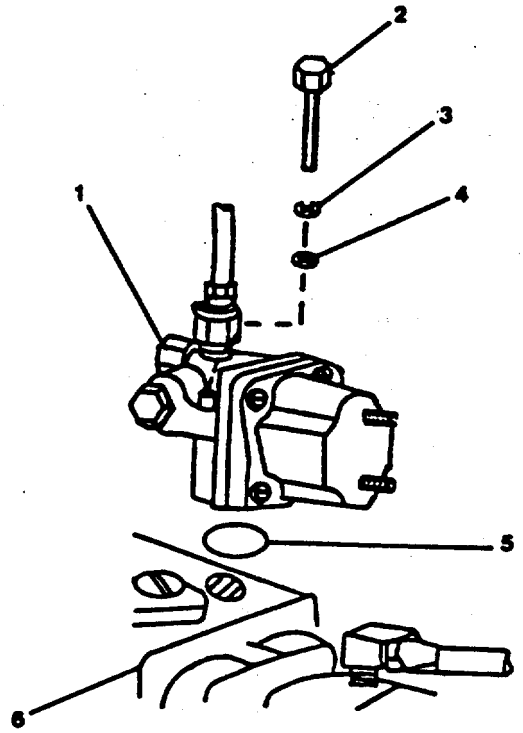


*FIGURE 3-9. Solenoid Valve Assembly.*

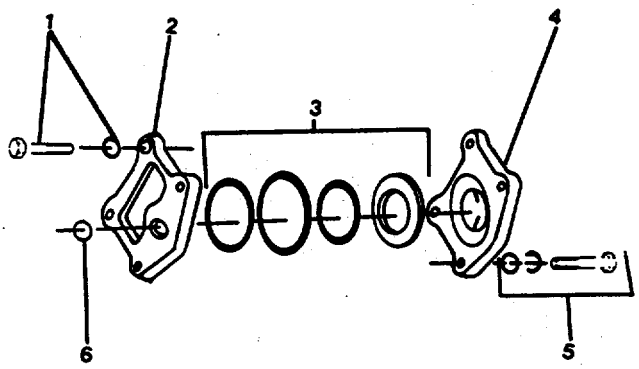


*FIGURE 3-10. Fuel Pump Fluid Pressure Dampener .*

c. Remove the fuel pump gear assembly (3, FIGURE 3-8).

**NOTE**

If only the pump gear assembly is to be replaced on the fuel pump, the dampener must be removed first (step (b) of this procedure).

(1) Remove the two machine bolts, lockwashers and flat washers (3, FIGURE 3-11).

(2) Remove the pump gear assembly.

d. Remove the electric governor actuator (1, FIGURE 3-8).

(1) Remove the three capscrews (1, FIGURE 3-12).

(2) Pull the actuator (2) from the fuel pump (9) body while twisting slowly in a clockwise direction.

(3) Remove the preformed packing (3, 4).

(4) Remove the machine thread plug (5) and remove the seal (6), helical compression spring (7), and fluid filter element (8) from the top of the fuel pump body (9).

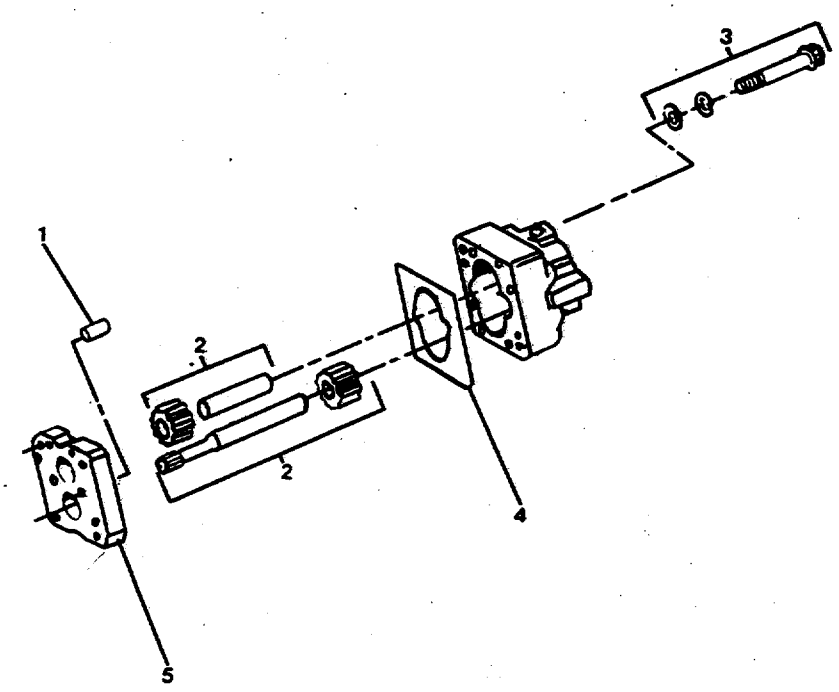


*FIGURE 3-11. Fuel Pump Gear Assembly.*

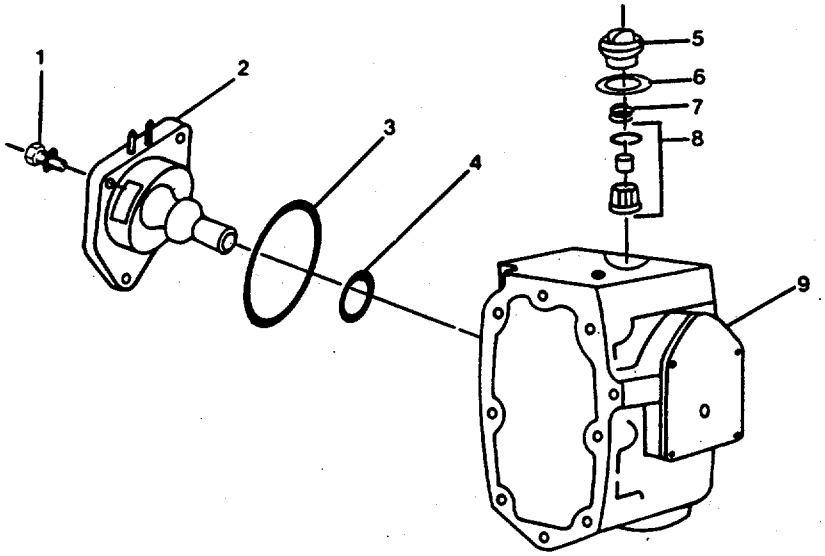


*FIGURE 3-12. Fuel Pump Electric Governor Actuator and Fluid Filter Element Assembly .*

**REPAIR**

a. Check the solenoid valve assembly (FIGURE 3-9).

(1) Check the coil assembly with an ohmmeter. Replace the shutoff valve assembly if the resistance reading is not between 28 and 32 ohms.

(2) Operate the manual control knob (1, FIGURE 3-9) and check for proper operation. With the control knob rotated fully counterclockwise, the fuel passage through the valve should be closed (with no electricity being applied to the coil). With the knob rotated fully clockwise, the fuel passage should be open.

(3) Visually check for dirt, corrosion, or damage. Replace the shutoff valve assembly if any damage is found.

(4) Replace valve assembly (FIGURE 3-9) as required.

b. Inspect the fluid pressure dampener (FIGURE 3-10).

(1) Visually check the body and plate for signs of damage.

(2) Replace the fluid pressure dampener if damaged.

c. Inspect the fuel pump gear (FIGURE 3-11).

(1) Visually inspect the shafts and spur gears (2). Replace the pump gear assembly if excessive wear, or burrs, cracks, or broken-,gear teeth are found.

(2) Check the installed depth of the regulating fluid pressure valve (1) in the cover (5) faced The valve must be even to 0.015 inch (0.38 mm) below the cover face. Seat the pressure valve as required.

d. Inspect the fluid filter element assembly (8, FIGURE 3-12).

**NOTE**

The filter element contains a magnet to hold any steel particles that may have entered the fuel pump.

(1) Clean the metal parts of the fluid filter element (8) in solvent.

(2) After cleaning, visually inspect for metal particles in the mesh. Replace screen as necessary.

(3) Clean the machine thread plug(s) (5) and helical compression spring (7) in fuel oil and inspect for signs of damage. Replace parts as necessary.

e. Check the governor actuator (2, FIGURE 3-12):

(1) Visually check for signs of damage and replace actuator as necessary.

(2) Discard old preformed packing (3, 4).

f. Check the fuel pump body for signs of damage. If damaged, replace the fuel pump assembly.

g. Check fuel tubing for signs for damage, replace if damaged.

**ASSEMBLY**

**CAUTION**

Handle aluminum parts with care to avoid damage.

Do not use a lockwasher next to aluminum. Always use a flat washer between the lockwasher and the aluminum part.

a. Install the fluid filter element assembly (8, FIGURE 3-12) into the top of the pump body. The hole in the screen goes down.

(1) Install the threaded plug (5) and tighten to 10 ft-lb. (13.5 N•m) torque.

b. Install the fuel pump gear assembly (FIGURE 3-11) and pressure dampener (FIGURE 3-10).

(1) Use a new gasket (4, FIGURE 3-11) and install the pump gear assembly to the pump body (5, FIGURE 3-8).

**NOTE**

Align the notches on the top corner of the plate and cover.

(2) Ensure the gasket (4, FIGURE 3-11) is positioned properly and that the housing (body) fuel holes align with the holes in the pump gear assembly.

(3) Install capscrews, lockwashers, and flat washers (3, FIGURE 3-11) and tighten to 12 ft-lb. (16.5 N•m) torque. Turn the drive shaft to ensure the gear pump rotates freely. If gears do not rotate freely, disassemble gear pump and correct as required.

(4) Use new preformed packing (6, FIGURE 3-10) and install the dampener to the gear pump. Tighten mounting capscrews (1, 5) to 12 ft-lb. (16.5 N•m) torque.

c. Use lubriplate to hold new preformed packing (5, FIGURE 3-3) to the bottom of valve. Install valve on the pump body. Tighten the capscrews (2) to 10 ft- lb. (13.5 N•m) torque.

d. Install the fuel pump electric governor actuator (2, FIGURE 3-12) in the pump body.

**CAUTION**

Do not use any gasket adhesive or sealant on the governor actuator preformed packing.

(1) Install the preformed packing (3, 4, FIGURE 3-12) on the actuator. Check that all mounting holes are aligned.

(2) Lubricate the governor actuator preformed packing with clean engine oil and insert the actuator in the cavity of the fuel pump body. The actuator flange will stop approximately 3/8 inch from the pump body.

(3) Using palm of the hand, firmly push and rotate the actuator approximately 30 degrees clockwise until the actuator flange contacts the fuel pump body.

(4) Rotate the actuator counterclockwise until the mounting holes are aligned.

(5) Install the capscrews (1, FIGURE 3-12). These capscrews have captive spring washers and do not require lockwashers. Tighten the capscrews until they are finger tight.

(6) Tighten the actuator capscrews as follows:

(a) Starting with the bottom capscrew, tighten each capscrew 1/8 of a turn until it is seated.

(b) Tighten the capscrews in a clockwise sequence to 25 in-lb. (2.8 N•m) torque.

(c) Tighten in sequence to 50 in-lb. (5.6 N•m) torque.

(d) Now, loosen all three capscrews completely.

(e) Tighten the capscrews again using the same procedure described above. This procedure should keep the actuator from binding.

**CAUTION**

This test will only verify that the actuator will go from the full open to the full closed position. A slight binding of the actuator shaft can cause a governor stability problem. This test may not detect a slight binding.

(7) A final check is to apply and remove battery voltage across the two actuator terminals. You should hear the actuator as it opens and closes. If the actuator sounds as if it is not operating, or is operating too slowly, loosen all capscrews and tighten them again as described in step (6) of this procedure.

e. Install the fuel pump on the engine (paragraph 2-33).

## 3-16. Replace/Repair Rocker Lever Housing/Cover Group.

**This task covers:**

**a. Removal** **b. Repair** **c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's, rail and marine diesel engines 5180-00-629-9783
Injector adjustment kit P/N 3375842
Torque wrench (30-300 ft-lb.) 5120-01-125-5190
Torque wrench (30-300 in-lb.) 5120-01-092-3278
Dial indicator 5210-00-277-8840
Rocker lever actuator P/N ST-1193

Equipment Condition

Engine shut down and cooled below 120°F (50°C) (TM 55-1905-223-10).
Instrument panel removed (para. 2-22).
Intake air cross over pipe removed (para. 2-39).
Upper fuel line check valve removed (para. 2-33).

Materials/Parts

Cleaning solvent, Item 5, Appendix C
Rocker lever housing P/N 3044788
Valve cover gaskets P/N 3054841
Rocker lever housing gaskets P/N 3017750
Rocker lever housing guide studs, Item 24, Appendix C
Engine poppet valve rocker arm P/N BM-95161
Engine poppet valve rocker arm P/N BM-95162
Injector rocker lever P/N AR-2308
Vegetable oil, Item 27, Appendix C
Nonmetallic hose P/N 64775

REMOVAL

a. Remove the crankcase breather and tube as follows:

(1) Loosen the hose clamp (2, FIGURE 3-13) on nonmetallic hose (1).

(2) Pull the breather (3) from the engine poppet valve rocker arm cover (5).

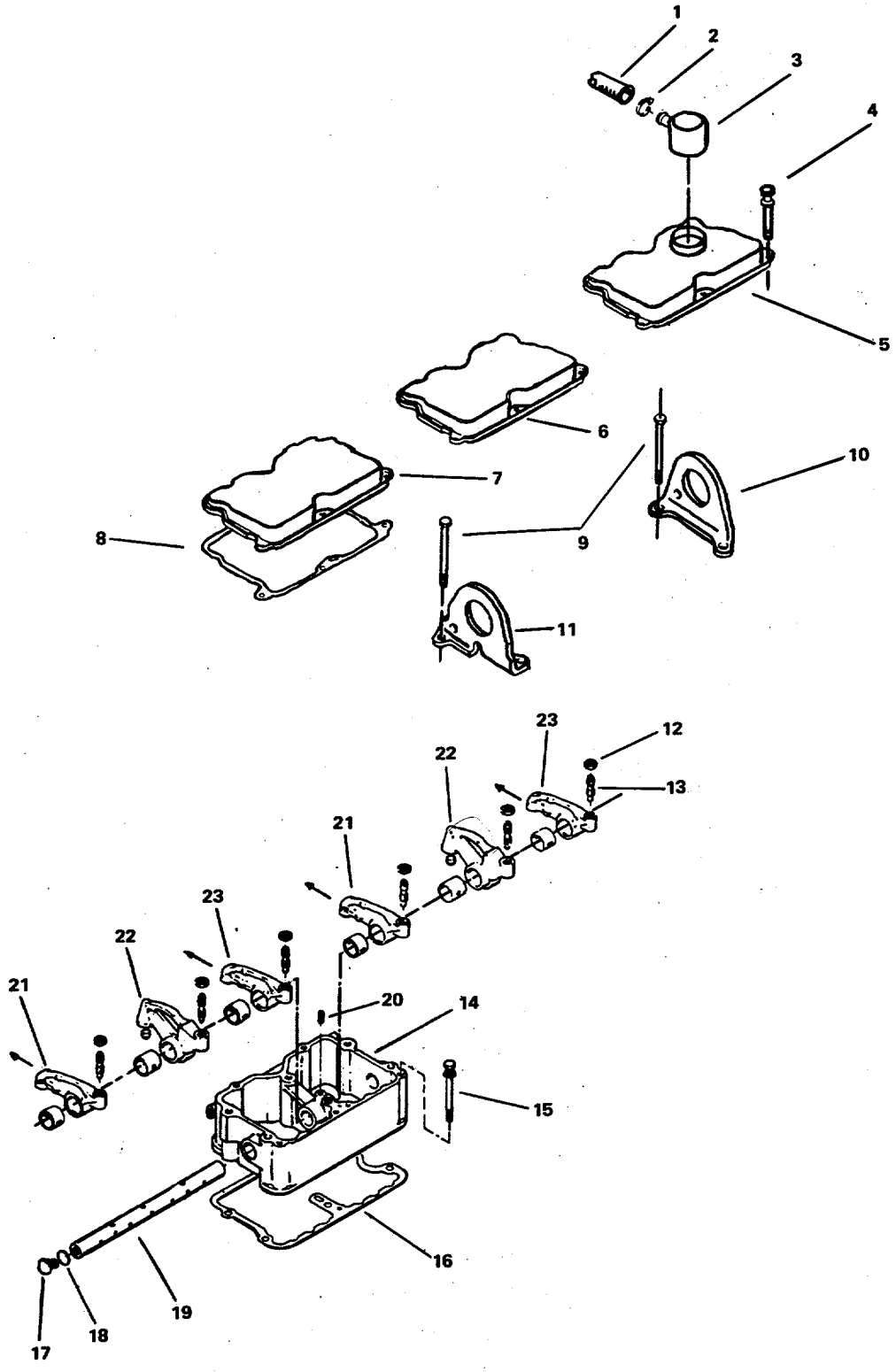


*FIGURE 3-13. Rocker Lever Housing Group.*

b. Remove five assembled washer screws (4) from each engine poppet valve rocker arm cover (5, 6, 7).

c. Remove the three covers (5, 6, 7) and valve cover gaskets (8). Discard gaskets.

d. Remove two hexagon head capscrews (9) in each engine lifting bracket (10, 11).

e. Remove the two engine lifting brackets (10, 11).

f. Remove the rocker lever housing (14) as follows:

(1) Loosen the six plain hexagon nuts (12).

(2) Turn each of the six setscrews (13) counterclockwise two full turns.

**NOTE**

To prevent increased wear, mark each rocker lever housing (14) as it is removed, and install each housing in its original location.

(3) Remove the six assembled washer screws (15) from the rocker lever housing (14).

(4) Remove the rocker lever housing (14).

(5) Remove rocker lever housing gasket (16). Discard gasket.

g. Remove the setscrew (20) from the housing (14).

**NOTE**

To prevent increased wear, mark each rocker arm (21, 23) and rocker lever (22) as it is removed, and install each in its original location.

h. Lightly tap the end of the straight shaft (19) with a drift punch and hammer and remove the shaft (19). Remove the engine poppet valve rocker arms (21, 23) and injector rocker levers (22) from the housing (14).

i. Remove the plain hexagon nuts (12) and the setscrews (13) from the engine poppet valve rocker arms (21, 23) and injector rocker levers (22).

**NOTE**

Machine thread plugs must be removed with an Allen wrench.

j. Remove machine thread plugs (17) from each end of straight shaft (19).

k. Remove preform packing (18) from each end of straight shaft (19). Save the preform packing.

**REPAIR**

a. Clean all parts with solvent or steam before installation.

**WARNING**

High pressure compressed air tanks, piping systems, and air operated equipment have a potential for serious injury to eyes and exposed areas of skin due to escaping air pressure.

b. Dry all parts with compressed air.

**NOTE**

Visually inspect all parts and housing for cracks, burrs, or damage. Replace, if necessary, rocker lever housing (14), engine poppet valve rocker arms (21, 23), injector rocker levers (22), and nonmetallic hose (1).

**REPLACEMENT**

a. Install the set screw (13) and plain hexagon nut (12) in each engine poppet valve rocker arm (21, 23) and injector rocker lever (22). Do not tighten the nuts (12).

**NOTE**

Hold one machine thread plug with an Allen wrench while tightening the other plug to 70 ft-lb. (94.9 N•m) torque. Repeat so that both plugs are tightened to 70 ft-lb. (94.9 N•m) torque.

b. Install machine thread plugs (17) in the straight shaft (19).

**CAUTION**

The setscrew hole (4, FIGURE 3-14) must be to the top and the seven oil passage holes (5) toward the flat side of the housing for correct assembly.

c. Install, in their original location, the exhaust rocker arm (1, FIGURE 3-14), injector rocker lever (2), and intake rocker arm (3) as the shaft is pushed through the rocker lever housing.

d. Install, in their original position, the intake rocker arm (1, FIGURE 3-15), injector lever (2), and exhaust rocker arm (3) as the shaft continues through the rocker lever housing.

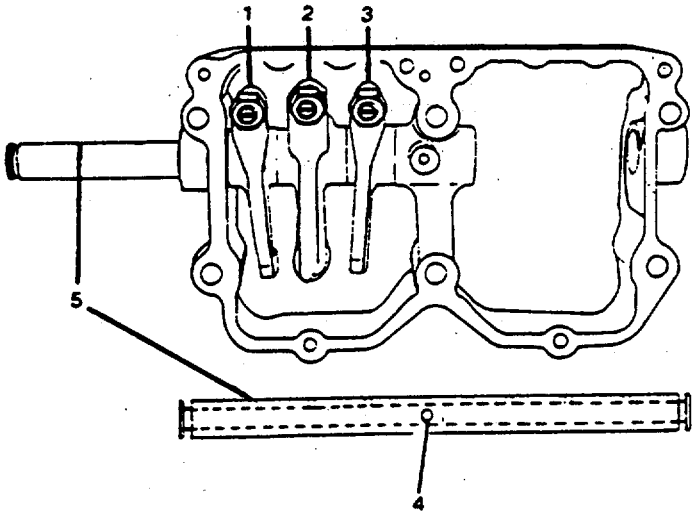


*FIGURE 3-14. Set Screw and Oil Passage Holes.*

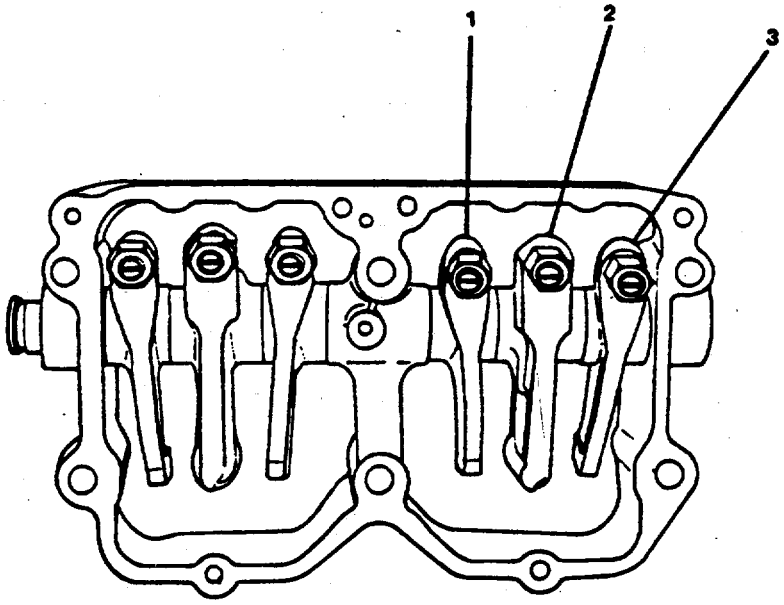


*FIGURE 3-15. Installing the Arms and Levers on Shaft.*

e. Install the preformed packing (18, FIGURE 3-13) as follows:

(1) Push the straight shaft (19) until 0.50 inch (12.7 mm) extends from the rocker lever housing (14).

(2) Lubricate the preformed packing (18) with vegetable oil.

(3) Install the lubricated preformed packing.

(4) Push the straight shaft (19) until the other end extends 0.50 inch (12.7 mm) from the rocker lever housing (14, FIGURE 3-13).

(5) Install the lubricated preformed packing.

f. Align the straight shaft (19) and the rocker lever housing setscrew holes. See (4) and (5), FIGURE 3-14.

g. Install the setscrew (20, FIGURE 3-13).

h. Repeat disassembly steps f through l and assembly steps a through h for the two remaining rocker lever housings (14).

**NOTE**

Ensure covers, housing, and cylinder head surfaces are clean before installing gaskets (8 and 16).

i. Install two rocker lever housing guide studs (1) in each cylinder head.

j. Install new rocker lever housing gaskets (2, FIGURE 3-16) on the cylinder heads.

**NOTE**

Return each housing to its original position on the engine.

k. Install each rocker lever housing (14, FIGURE 3-13).

**CAUTION**

If the adjusting screws protrude beyond the maximum of 1.259 inches from the top surface of the lever and the ball end of the adjusting screws, the push rods can be damaged when the housing capscrews are tightened.

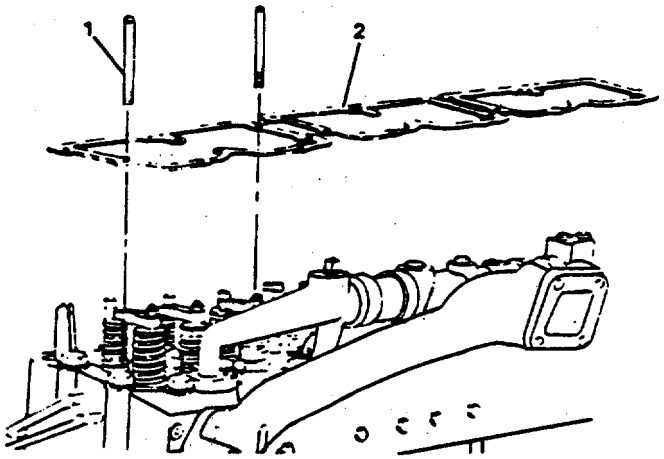


*FIGURE 3-16. Rocker Housing Gaskets and Guide Studs.*

l. Loosen the rocker lever setscrews so there is a maximum of 1.259 inches (32 mm) from the top surface of the lever and the ball end of the adjusting screw (FIGURE 3-17).

m. Hold the rocker levers in position.

(1) Install the ball end of the setscrews (13, FIGURE 3-13) in the push rod sockets.

(2) Remove the guide studs (1, FIGURE 3-16).

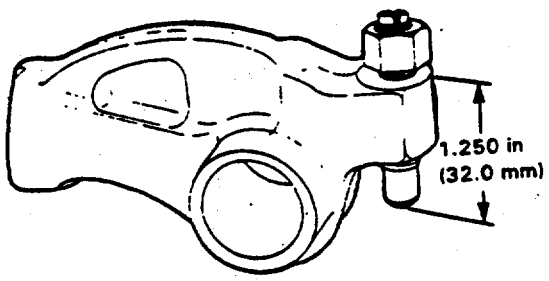


*FIGURE 3-17. Rocker Lever Adjusting Screw.*

(3) Install the assembled washer screws (15, FIGURE 3-13).

**NOTE**

The longer capscrews are used to secure the engine lifting brackets.

(4) Install the engine lifting brackets (10, 11) with hexagon head capscrews (9).

(5) Tighten the housing and bracket screws (9 and 15) to 60 ft-lb. (81.3 N•m) torque. Use the sequence shown in FIGURE 3-18 when tightening the housing assembled washer screws.

n. Repeat steps k through m for the two remaining rocker lever housings (14, FIGURE 3-13).

o. Adjust crossheads, valves, and injectors as follows:

**NOTE**

The crossheads, valves, and injectors must be adjusting at the same time. Use the following procedure for adjusting.

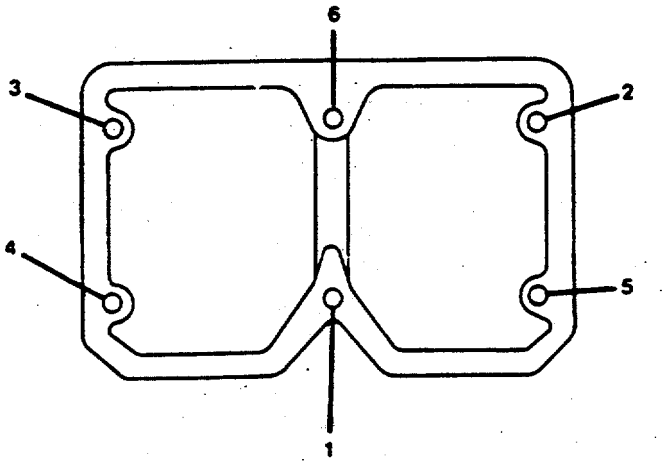


*FIGURE 3-18. Rocker Housing Torque Sequence.*

**NOTE**

- After any repair where the injector setting is disturbed, all of the valves and injectors must be set. Once the adjustment procedure has been completed, continue through the crankshaft rotation and check (adjust if necessary) the injector adjustment on cylinders No. 2, No. 3, and No. 6. This takes care of any camshaft and rocker lever shaft deflection which may have occurred during the initial adjustment.

- All overhead (crosshead, valve, and injector) adjustments must be made when the engine is cold (any stabilized coolant temperature at 140°F (60°C) or below).

(1) With the rocker lever covers removed and rocker housing capscrews tightened to 60 ft-lb. torque, alternately tighten the injector holddown clamp capscrews to 156 in-lb. torque. Refer to paragraph 2-34.

(2) General adjustment information:

(a) The valve set marks are located on the accessory drive pulley. The marks align with a pointer on the gear cover.

(b) Use the accessory drive shaft to rotate the crankshaft. See FIGURE 3-19 .

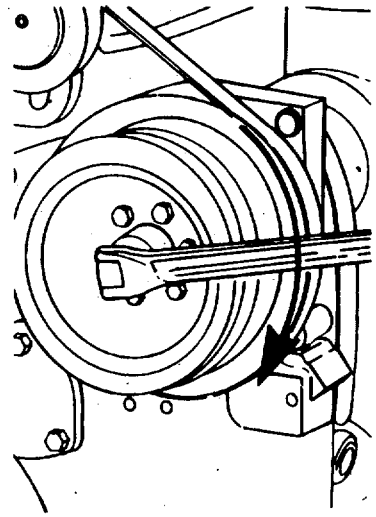

*FIGURE 3-19. Rotating Accessory Drive.*

(c) The crankshaft rotation is clockwise when viewed from the front of the engine.

(d) The cylinders are numbered from the gear cover end of the engine.

(e) The engine firing order is 1-5-3-6-2-4.

(f) Each cylinder has three rocker levers. The rocker lever nearest to the center of the housing is the intake lever (3, FIGURE 3-20), the exhaust lever is (1), and the injector lever is (2).

(g) The valves and the injectors on the same cylinder are not adjusted at the same index mark on the accessory drive pulley (see Table 2-4).

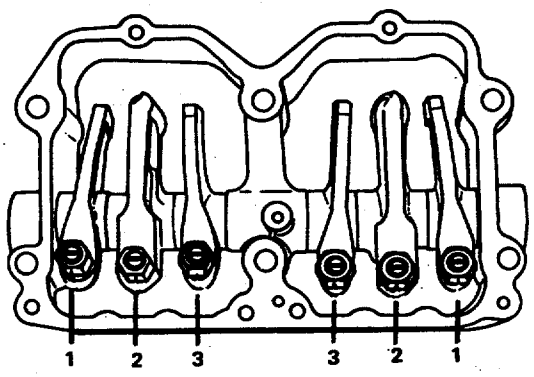


*FIGURE 3-20. Identifying Rocker Levers.*

**Table 2-4. Injector and Valve Adjustment Sequence**

| Bar Engine in Direction of Rotation | Pulley Position | Set Injector | Cylinder Valve |
|---|---|---|---|
| Start | A | 3 | 5 |
| Advance to | B | 6 | 3 |
| Advance to | C | 2 | 6 |
| Advance to | A | 4 | 2 |
| Advance to | B | 1 | 4 |
| Firing Order: 1-5-3-6-2-4 | C | 5 | 1 |

(h) One pair of valves and one injector are adjusted at each pulley index mark before rotating the accessory drive to the next mark.

(i) Two crankshaft revolutions are required to adjust all the valves and the injectors.

(3) Injector Adjustment, Dial Indicator Method (Nonstop Injector Only).

(a) Rotate the accessory drive clockwise until the "A" valve set mark on the accessory drive pulley is aligned with the point on the gear cover (FIGURE 3-21).

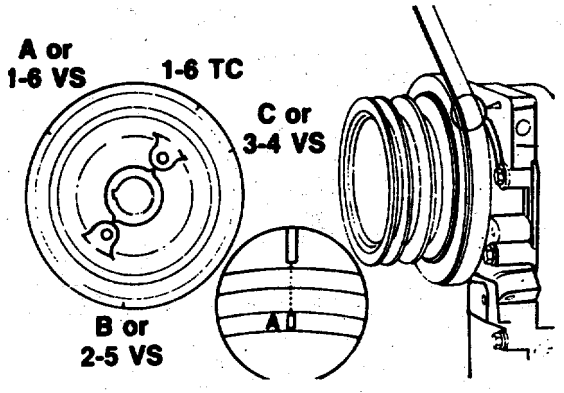


*FIGURE 3-21. Aligning Pulley and Gear Pointer.*

(b) Check the valve rocker levers on cylinder No. 5 to see if both valves are closed.

**CAUTION**

To prevent damage to the indicator or to avoid getting an incorrect reading, install the dial indicator extension so that it clears the rocker lever. See FIGURE 3-22 .

**NOTE**

Both valves are closed when rocker levers are loose and can be moved from side to side. If both valves are not closed, rotate the accessory drive one complete revolution; align the "A" mark with the pointer again.

(c) Install the dial indicator (6, FIGURE 3-22) and the support (4) from the Injector Adjustment Kit so that the stem (5) of the dial indicator is on top of the injector plunger flange on cylinder No. 3.

(d) Securely tighten the thumbscrew (1) and the hold down screw (2) in place.

(e) Loosen the thumbscrew (3) and lower the indicator against the injector plunger flange until the stem (5) is fully compressed.

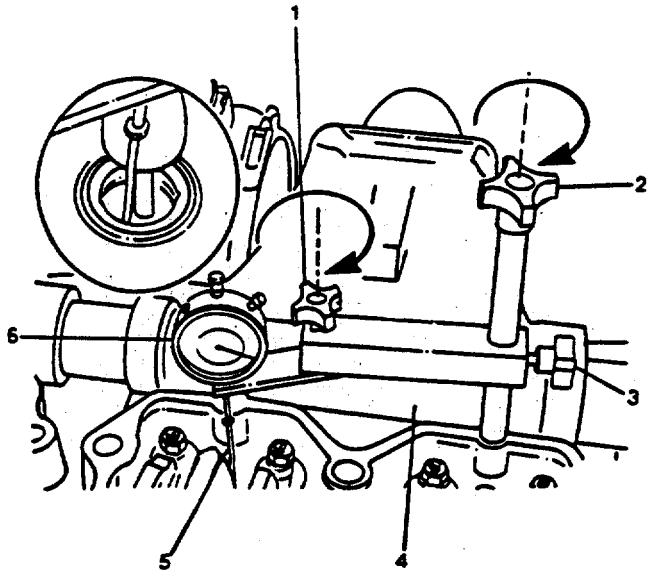


*FIGURE 3-22. Installing Dial Indicator and Support .*

(f) Raise the indicator (6) approximately 0.025 inch (0.653 mm), and tighten the thumbscrew (3) to hold the indicator in position.

**WARNING**

The injector plunger is under spring tension. Do not allow the tool to slip. Personal injury can result.

(g) Use the rocker lever actuator (1, FIGURE 3-23) to depress the injector plunger three or four times to make sure all the oil and fuel have been removed from the injector assembly. Allow the lever to return slowly to prevent damage to the dial indicator.

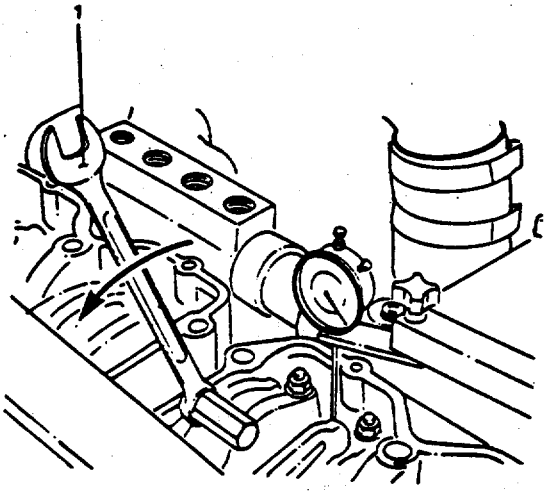

*FIGURE 3-23. Rocker Lever Actuator.*

(h) Actuate the lever again, and set the dial indicator at "0" (zero) while holding the injector plunger to the bottom of its travel.

(i) Slowly release the actuator and check the indicator travel.

(j) The indicator travel should be between 0.226 inch and 0.230 inch. If not within those limits, go to step (k).

(k) Loosen the locknut on the injector adjusting screw.

(1) Turn the adjusting screw clockwise or counterclockwise to adjust the injector plunger to 0.228 inches.

(m) Hold the adjusting screw in this position. See FIGURE 3-24 . The adjusting screw must not turn when the lock nut is tightened. Tighten the lock nut to the following value:

| | |
|---|---|
| With adapter | - 35 ft-lbs (45 N•m) torque. |
| Without adapter | - 45 ft-lbs (60 N•m) torque. |

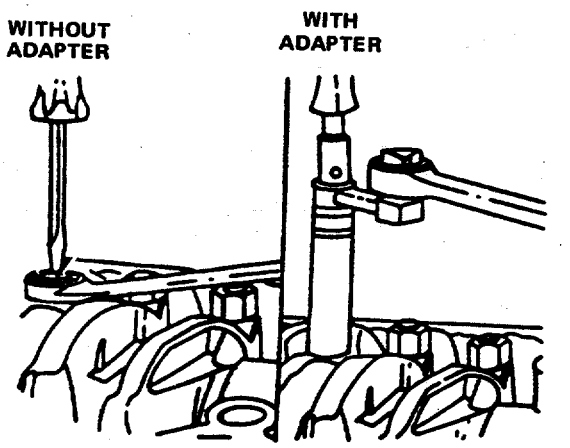


*FIGURE 3-24. Torque Methods.*

**WARNING**

The injector plunger is under spring tension. Do not allow the tool to slip. Personal injury can result.

(n) Actuate the injector rocker level several times. Allow the lever to return slowly to prevent damage to the dial indicator. Hold the injector plunger to the bottom of its travel, and confirm the "O" (zero) reading on the dial indicator.

(o) Allow the injector rocker level to return slowly. Check the reading on the dial indicator. Repeat the adjustment process if the reading is not within specifications.

(p) Adjust the crossheads and the valves on cylinder No. 5 before rotating the accessory drive to the next valve set mark. Refer to Cross head Adjustment and Valve Adjustment in this procedure.

(q) After adjusting the crossheads and the valves on cylinder No. 5, rotate the accessory drive; align the next valve set mark on the accessory drive pulley with the pointer on the gear cover.

(r) Adjust the appropriate injector, the cross heads, and the valves. Follow Table 2-4, Valve and Injector Adjustment Sequence Chart.

(s) Repeat the process to adjust all the injectors, the cross heads, and the valves correctly.

(4) Injector Preload Adjustment Procedures (Top-stop Injectors Only).

**CAUTION**

Top-stop injector plunger travel can be adjusted only when the injectors are removed from the engine. Use the injector adjusting tool to set the injectors.

(a) The top-stop injector preload setting is made at the same injector adjustment position on the accessory drive pulley which is used for the dial indicator method.

(b) Rotate the accessory drive clockwise until the "A" valve set mark on the accessory drive pulley is aligned with the pointer (FIGURE 2-21).

(c) Loosen the lock nut on the injector adjusting screw (FIGURE 3-26) on cylinder No. 3. Tighten the adjusting screw until all the clearance is removed from the injector train.

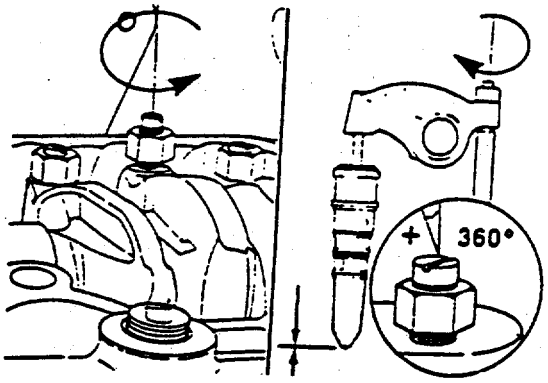


*FIGURE 3-25. Injector Adjusting Screw.*

(d) Tighten the adjusting screw one additional turn to correctly seat the link.

(e) Loosen the injector adjusting screw until the injector spring retainer washer touches the top-stop screw (FIGURE 3-26).

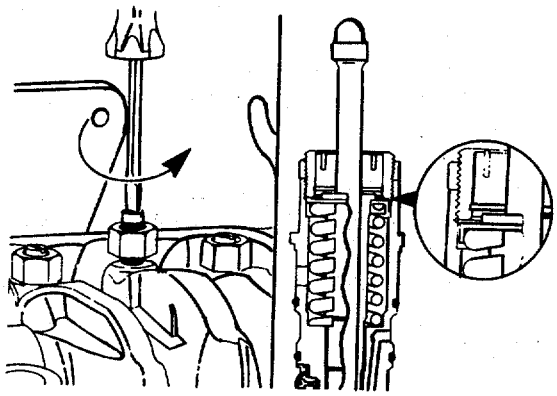

*FIGURE 3-26. Loosening Injector Adjusting Screw.*

**CAUTION**

An overtight setting on the injector adjusting screw will produce increased stress on the injector train and the camshaft injector lobe which can result in engine damage.

(f) Tighten the adjusting-screw to 5 to 6 in-lbs (0.56 to 0.68 N•m) torque.

(g) Hold the adjusting screw in position. The adjusting screw must not turn when the locknut. is tightened. Tighten locknut to the following value:

| | |
|---|---|
| With adapter | - 35 ft-lb. (45.4 N•m) torque. |
| Without adapter | - 45 ft-lb. (60 N N•m) torque. |

(h) Adjust the crossheads and the valves on cylinder No. 5 before rotating the accessory drive to the next valve set mark. Refer to Crosshead Adjustment and Valve Adjustment in this procedure.

(i) After adjusting the crossheads and the valves on cylinder No. 5, rotate the accessory drive and align the next valve set mark on the accessory drive pulley with the pointer on the gear cover.

(j) Adjust the appropriate injector, the crossheads, and the valves following the Injector and Valve Adjustment Sequence Chart (Table 2-4).

(k) Repeat the process to adjust all injectors, crossheads, and valves correctly.

(5) Crosshead Adjustment.

**NOTE**

Crosshead adjustment must always be made before attempting to adjust the valves.

(a) With the "A" valve set mark aligned with the pointer on the gear cover (FIGURE 3-21) and both valves closed on cylinder No. 5, loosen the crosshead adjusting screw locknuts on the intake and the exhaust valve crossheads for cylinder No. 5.

**NOTE**

The same procedure is used to adjust the intake and exhaust crossheads.

(b) Turn the adjusting screw out at least one turn.

(c) Hold the crosshead down against its mating valve stems.

(d) Turn the adjusting screw in until it touches the top of the valve stem, ,but does not raise the crosshead.

(e) Hold the adjusting screw in this position. The adjusting screw must not turn when the locknut is tightened to its torque value (FIGURE 3-24). Tighten the locknut to the following value:

| | |
|---|---|
| With adapter | 25 ft-lb. (35 N•m) torque. |
| Without adapter | 30 ft-lb. (40 N•m) torque. |

(f) Adjust the intake and the exhaust valve on No. 5 cylinder before rotating accessory drive to the next valve set mark. Refer to Valve Adjustment, item (6) in this procedure.

(6) Valve Adjustment.

(a) With the "A" valve set mark aligned with the pointer on the gear cover (FIGURE 3-21) and both valves closed on cylinder No. 5, loosen the lock nuts on the intake and the exhaust valve adjusting screws.

(b) Select a feeler gauge for the correct valve lash specification.

Valve Lash Specification

| INTAKE | EXHAUST |
|---|---|
| (0.028 mm) | (0.058 mm) |
| 0.011-inch | 0.023-inch |

(c) Insert the feeler gauge between the top of the crosshead and the rocker lever pad. (Refer to FIGURE 3-27 .)

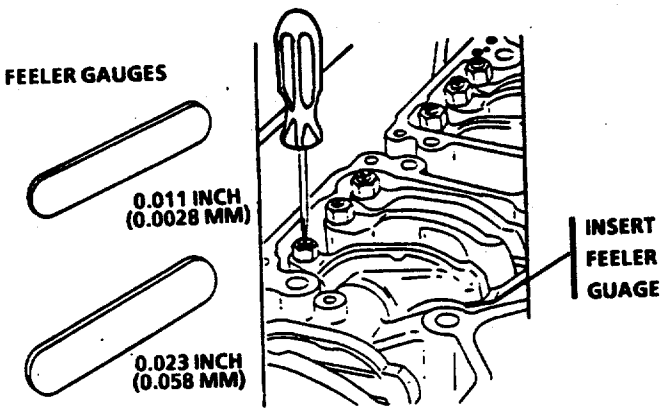


*FIGURE 3-27. Checking Valve Lash (Feeler Method).*

**NOTE**

Two different methods for establishing valve lash clearance are described. Either method can be used; however, the torque wrench method has proved to be the most consistent. It eliminates the need to feel the drag on the feeler gauge.

Torque Wrench Method: Use an inch-pound torque wrench (normally used to set preload on top-stop injectors), and tighten the adjusting screw (1, FIGURE 3-28) to 6 in-lb. (0.68 N•m) torque.

Feel Method: Tighten the adjusting screw (2, FIGURE 3-28) until a slight drag is felt on the feeler gauge.

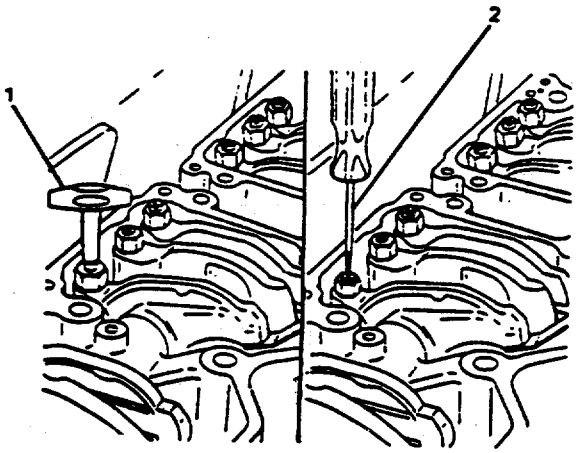


*FIGURE 3-28. Tightening Adjusting Screw.*

(d) Hold the adjusting screw in this position. The adjusting screw must not turn when the locknut is tightened (refer to FIGURE 3-26). Tighten the locknut to the following value:

| | |
|---|---|
| With adapter | - 35 ft-lbs (45 N•m) torque. |
| Without adapter | - 45 ft-lbs (60 N•m) torque. |

(e) After tightening the locknut to the insert a feeler gauge that is 0.001 inch (0.03 mm) thicker between the crosshead and the rocker lever pad. The valve lash is not correct when a thicker feeler gauge will fit.

(f) If using the feel method, attempt to insert a feeler gauge that is 0.001 inch (0.03 mm) thicker between the crosshead and the rocker lever pad. The valve lash is not correct when a thicker feeler gauge will fit.

(g) After adjusting the injector on cylinder No. 3 and the crossheads and the valves on cylinder No. 5, rotate the accessory drive and align the next valve set mark with the pointer.

(h) Adjust the appropriate injector, the crossheads, and the valves following the Injector and Valve Adjustment Sequence Chart, Table 2-4.

(i) Repeat the process to adjust all indicators, crossheads, and valves correctly.

p. Install a new valve cover gasket (8, FIGURE 3-13) on each rocker level housing (14).

**NOTE**

Stamped steel valve covers are designed and manufactured with 0.030 inch (0.75 mm) bow located in the shaded areas as shown in FIGURE 3-29 to provide better sealing qualities. This built in bow on the valve covers must not be mistaken for warpage. Also, do not attempt to increase or remove the bow from the sealing surface.

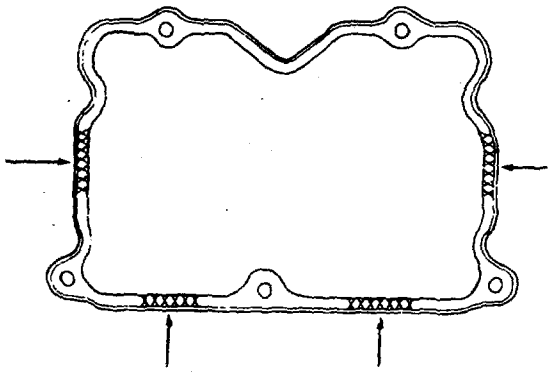

*FIGURE 3-29. Cover Manufactured Bow Areas.*

q. Install the covers (5, 6, 7) on the rocker lever housings (14).

r. Install the five assembled washerscrews (4) in each cover.

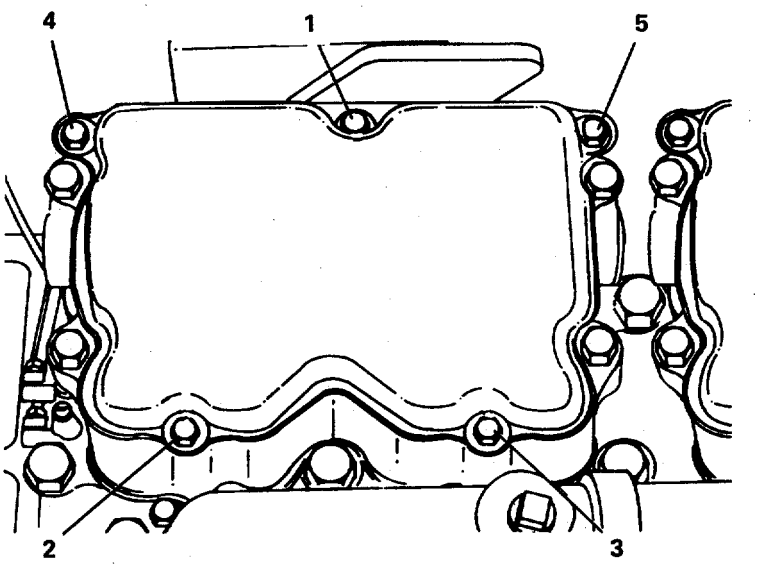


*FIGURE 3-30. Rocker Arm Cover Torque Sequence.*

s. Tighten the assembled washerscrews in each cover in the sequence shown to 15 ft-lb. (20.3 N•m) torque (FIGURE 3-30).

t. Insert the crankcase breather (3, FIGURE 3-31) in the cover (4).

u. Install the nonmetallic hose (1) on the breather (3) with clamp (2). Tighten clamp (2).

v. Install the upper fuel line check valve (paragraph 2-33).

w. Install the intake air crossover pipe (paragraph 2-39).

x. Install the instrument panel (paragraph 2-22).

y. Prepare engine for run operation. Remove tags.

z. Start the engine and check for proper operation (TM 55-1905-223-10).

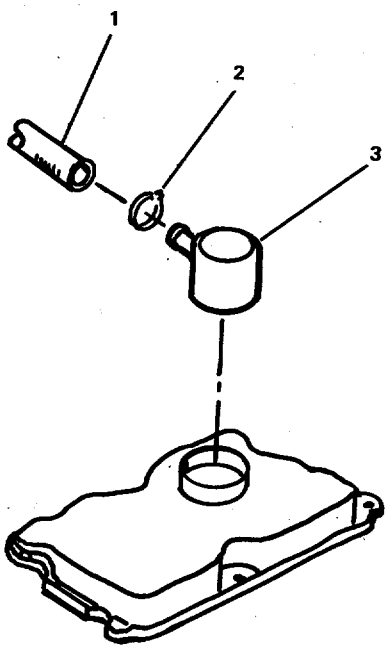


*FIGURE 3-31. Crankcase Breather and Tube.*

## 3-17. Repair Heat Exchanger Group. (FIGURE 3-32)

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's, rail and marine diesel engines, 5180-00-629-9783
Combination wrench set, metric 10mm to 24mm, 5120-01-046-4979

Equipment Condition

Heat exchanger removed (para. 2-38).

Material/Parts

Teflon pipe thread lubricant, Item 9, Appendix C
Cleaning solvent, Item 5, Appendix C
Electrode plug P/N 68241
Preformed packing P/N 3011337
Gaskets P/N 3011325
Gasket P/N 3011332
Cooler core P/N 3011327

REMOVAL

a. Remove the socket head capscrews (2) and lockwashers (3) securing end cover (1). Remove cover (1), preformed packing (14), and gasket (4). Discard preformed packing and gasket.

b. Remove socket head capscrews (11) and lockwashers (10) securing cover (9) and remove cover (9) and gasket (8). Discard gasket.

c. Pull cooler core (7) from housing (5). Remove gasket (6) from cooler core (7) and discard.

d. Remove six zinc plugs (15) from cover (1).

e. Remove four pipe plugs (13) from housing (5).

f. Remove pipe plug (12) from cover (9).

REPAIR

a. Clean the housing (5) and end covers (1 and 9) with cleaning solvent.

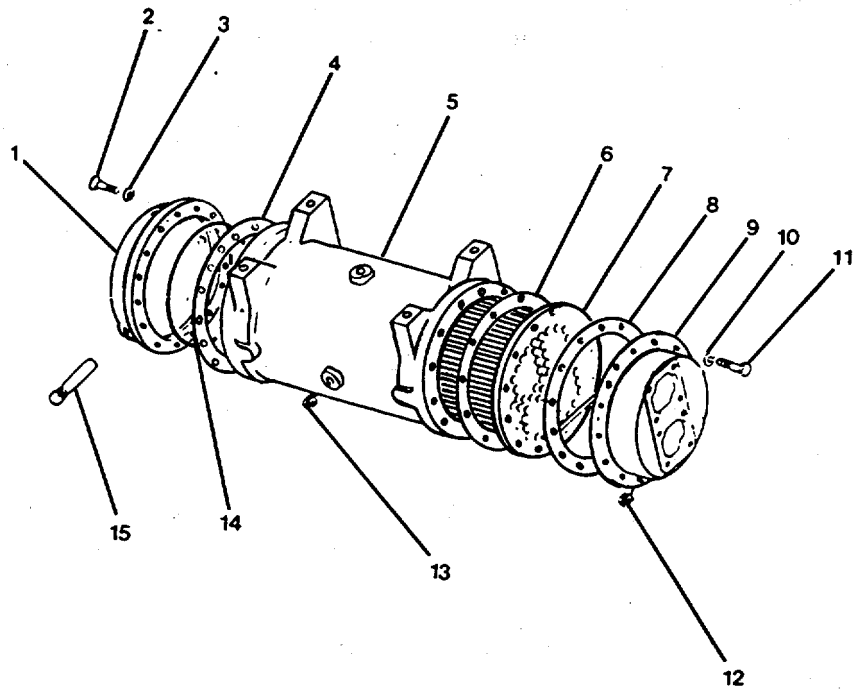


*FIGURE 3-32. Heat Exchanger Group.*

b. Visually inspect housing (5) and end covers (1 and 9) for cracks. Replace if damaged.

c. Clean all plugs (12, 13, and 15) and capscrews (2 and 11) for thread damage. Replace if necessary.

d. Visually inspect the cooler core for plugged or damaged tubes.

REPLACEMENT

a. Apply Teflon tape lubricant to all pipe plugs threads (12 and 13) and install them into housing (5) and end covers (1 and 9). Tighten pipe plugs in accordance with Appendix D.

b. Slip a new gasket (6) onto a new cooler core (7) and slide the core into the housing (5).

c. Install new gasket (8) and end cover (9). Secure with lockwashers (10) and socket head capscrews (11). Tighten 3/8-16 x 1-1/8 inch capscrews alternately.

**CAUTION**

Ensure new preformed packing is properly sealed when installing cover.

d. Use a new gasket (4) and new preformed packing (14) and install end cover (1). Secure with lockwashers (3) and socket head capscrews (2). Tighten capscrews alternately.

e. Apply Teflon lubricant tape to the threads of new electrode plugs (15). Install plugs into end cover (1) and tighten.

## 3-18. Replace/Repair Cam Follower Housing Group.

**This task covers:**

**a. Removal b. Repair c. Replacement**

INITIAL SETUP:

Tools

Tool kit, general mechanic's,
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-00-046-4979
Injection timing fixture
4910-00-999-1269
Torque wrench, (30-300 in-lb)
5120-01-092-3278
Torque wrench, (30-300 ft-lb)
5120-01-125-5190

Equipment Condition

Fuel pump removed (para. 2-33)
Rocker lever housings removed
(para. 3-16).

Materials/Parts

Cam follower housing, P/N 3036939
Gaskets, P/N 3020000, 3020002, 3020003
Cleaning solvent, Item 5, Appendix C

REMOVAL (FIGURE 3-33)

a. Remove the cam follower housing assemblies as follows:

(1) Lift the push rods (3, 5) from their sockets (12) from the top of the engine.

(2) Remove accessory drive. Refer to paragraph 3-19;

(3) Remove the six capscrews (17) from each cam follower housing.

(4) Remove the cam follower assemblies (20) and gaskets (2, 4, 6).

**NOTE**

To prevent increased wear, mark the cam follower housing assemblies as they are removed so they can be installed back in their original location on the block (if they are to be reused).

b. Measure and record the thickness of the gaskets (2, 4, 6) used between each cam follower housing and the block.

**NOTE**

The thickness of the gaskets controls the injection timing.

c. Discard the gaskets (2, 4, 6).

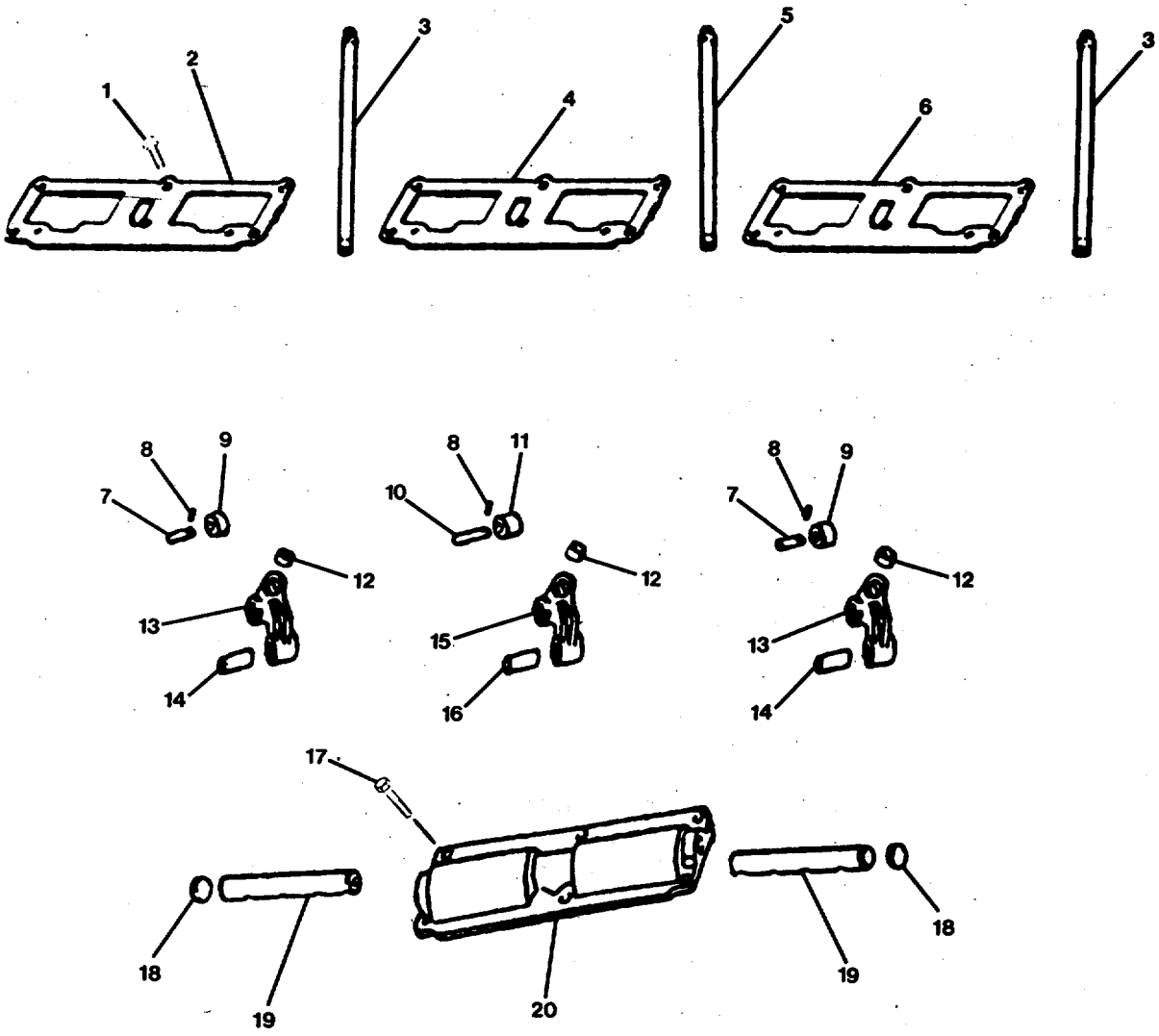


*FIGURE 3-33. Cam Follower Housing Group.*

REPAIR

Repair consists of replacement of gaskets (2, 4, 6) and housing (20).

REPLACEMENT

CAUTION
Ensure gasket sealing surfaces are clean.

a. Clean cam follower parts with cleaning solvent, and dry with compressed air.

b. Install the new cam follower gaskets-(2, 4, 6) to the block as follows:

(1) One gasket is required for each cam follower housing.

(2) The gasket must be installed against the block with the sealing bead toward the cam follower housing.

(3) Measure the gasket (2, 4, 6) thickness. The replacement gaskets must be the same thickness as the gaskets which were removed.

(4) Install the gaskets (2, 4, 6) on the block.

c. Install the cam follower (20) in the block as follows:

(1) Install six capscrews (17) in each cam follower housing.

(2) Tighten the capscrews in the alternating sequence shown to the following torque values (FIGURE 3-34).

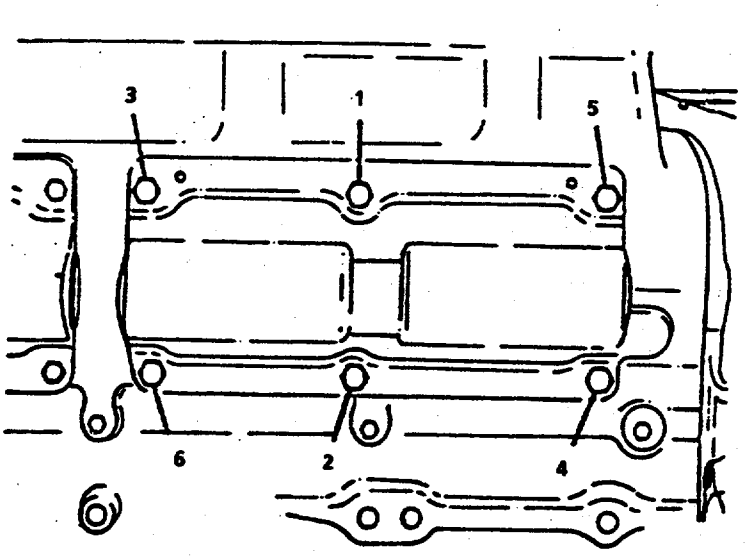


*Figure 3-34. Cam Follower Housing Torque Sequence.*

(a) Tighten to 180 in-lb torque.

(b) Tighten to 35 ft-lb torque.

d. Check the injection timing:

(1) Injection Timing Code. The injection timing code appears on the engine data plate. Codes are alphabetic letters that relate to a numerical specification.

(2) Advanced and Retarded Timing. Advanced timing (1, FIGURE 3-30) means the fuel is injected earlier into the cylinder during the compression stroke. Retarded timing (2) means the fuel injection occurs closer to top dead center (TDC) in the cylinder.

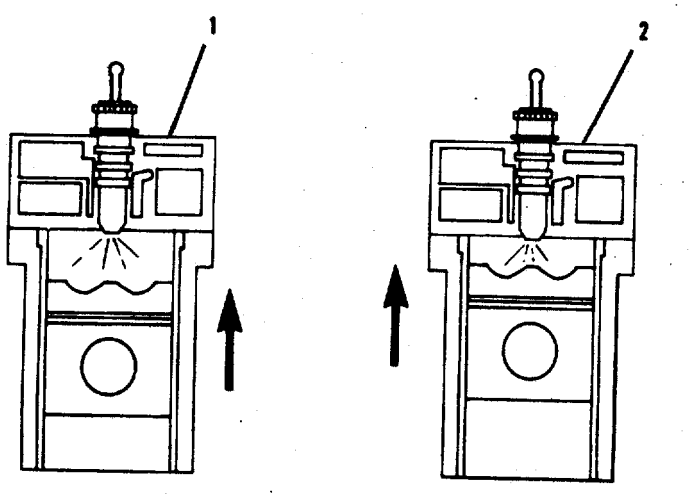


*FIGURE 3,-35. Advanced and Retarded Timing.*

(3) Injection Timing Changes. Injection timing changes are accomplished by advancing (1) or retarding (2) the cam follower action in relation to the piston position (FIGURE 3-36). This is accomplished by changing the orientation of the camshaft lobe to the cam follower using different cam follower gasket thicknesses or offset camshaft gear keys.

**NOTE**

Gear train timing (index mark alignment) always remains the same.

(4) Injection Timing Check. The injection timing check is a measurement which determines the injector push rod travel in relation to the piston travel. Due to normal parts tolerances, it is necessary to check one cylinder for each cam follower housing.

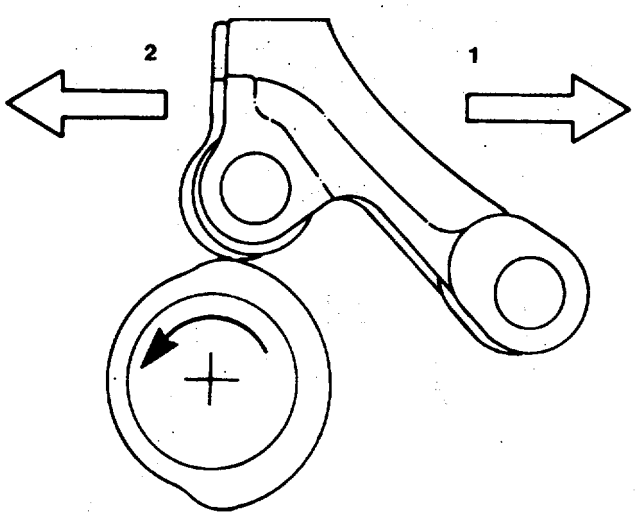


*FIGURE 3-36. Timing Changes.*

(5) Measure Injector Timing.

(a). Remove the rocker housing covers (paragraph 3-16).

(b) Remove the injectors from cylinders No. 1, No. 3, and No. 5 (paragraph 2-34).

**NOTE**

- It is not necessary to remove all of the injectors; however, engine rotation will be easier with all of the injectors removed.
- Injector timing tool can be installed without removing the rocker levers.

CAUTION

Pivot the dial indicator stems away from their respective plunger rods before installing the timing fixture to prevent damage to the indicators.

(c) Install the support bracket (7, FIGURE 3-37) for the push rod adapter (8) into the slot (10) nearest the clamp handle (1).

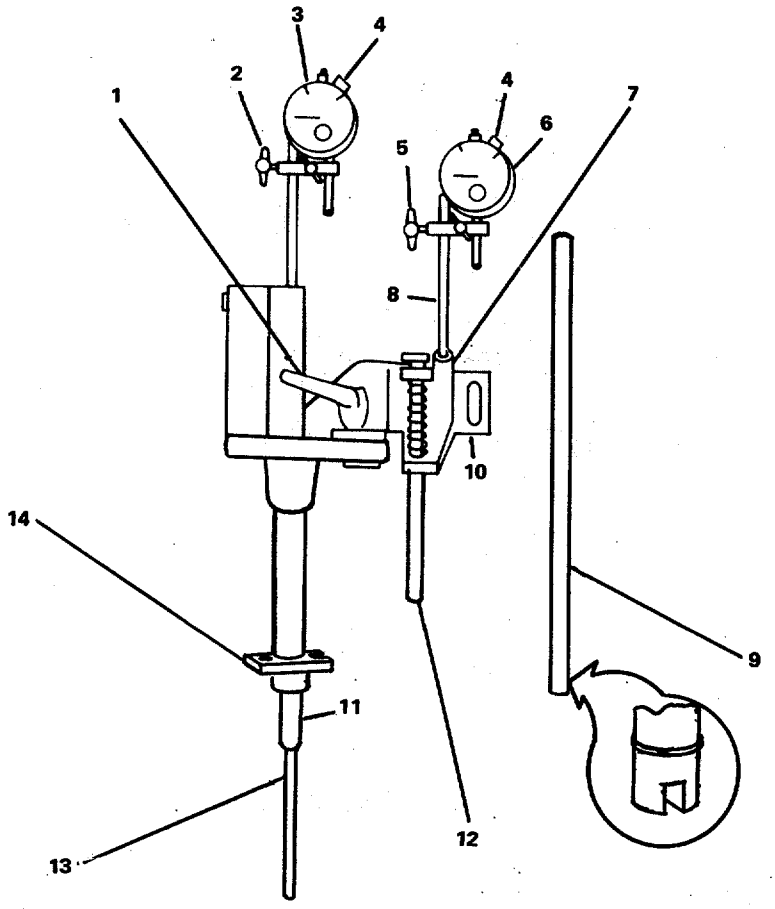


*FIGURE 3-37. Injection Timing Tool.*

(d) Install. the piston plunger rod (13) into the injector sleeve of the No. 1 cylinder.

(e) To fasten the timing tool to the cylinder head, install the adapter screws (11) through the mounting foot (14) and into the holes for the injector holddown plate.

(f) Use the tightening rod (9) to secure the adapter screws.

(g) Loosen the clamp handle (1) and align the push rod adapter.

(h) Secure the clamp handle (1). Loosen the bolt in support bracket (10).

(i) Slide the bracket down until the adapter (12) engages the push rod. Then, compress the tension spring for the adapter approximately 0.50 inch (12.7 mm).

(j) Secure the bolt in support bracket (10). Make sure the support bracket is aligned with the vertical line located on the clamp handle bracket.

(k) Using a socket on the end of the accessory drive, rotate the crankshaft in the direction of engine rotation to the Top Dead Center (TDC) position of the compression stroke for the No. 1 cylinder (1, FIGURE 3-38).

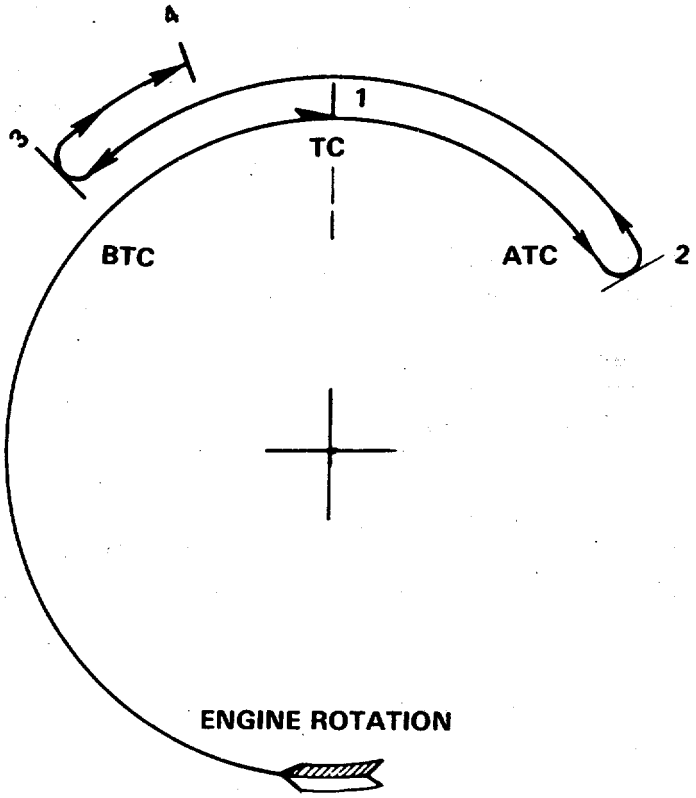


*Figure 3-38. Crankshaft Rotation for Timing.*

(1) Loosen the thumbscrew for the piston travel gauge. Move the gauge so that the stem of the gauge is in the center of the piston plunger rod.

CAUTION

Both indicators must have a travel range of at least 0.250 inch or the indicators will be damaged.

(m) Lower the gauge against the piston plunger rod until the stem is fully compressed, then raise the gauge approximately 0.250 inch.

(n) Secure the thumbscrew to hold the gauge in position.

(o) Rotate the crankshaft 2 or 3 degrees clockwise and counterclockwise to make sure the piston is at TDC.

(p) Loosen the setscrew (4, FIGURE 3-37) for the gauge dial and turn the dial so that the indicator is at zero. Secure the setscrew.

**NOTE**

Each gauge for the timing tool has a total travel of 1.0 inch. One revolution of the indicator needle equals 0.1 inch travel of the indicator stem. When the stem of the gauge is compressed, the indicator turns clockwise and the revolution counter turns counterclockwise. Be sure to note the reading on the revolution counter at TDC. This will help you find 0.2032 inch Before Top Dead Center (BTDC).

(q) Rotate the crankshaft in the direction of engine rotation (clockwise) to 90 degrees after Top Dead Center (ATDC), (2, FIGURE 3-38). The piston travel plunger will be at the NH/NT 90 degree mark on the timing tool.

(r) Loosen the thumbscrew (5, FIGURE 3-37) for the push rod travel gauge.

(s) Move the gauge so that the stem of the gauge is in the center of the push rod adapter.

(t) Lower the gauge against the adapter until the stem is fully compressed. Then raise the gauge approximately 0.025. inch.

(u) Secure the thumbscrew (5) to hold the gauge in position.

(v) Loosen the setscrew (4) for the gauge dial, turn the dial so that the indicator is zero and secure the setscrew.

(w) Rotate the crankshaft in the opposite direction of engine rotation, until you reach TDC.

**NOTE**

Always rotate the crankshaft slowly. Watch the piston travel indicator as you rotate the crankshaft.

(x) Continue to rotate-the crankshaft past TDC until the indicator shows 0.225 inch (two and one-fourth revolutions of the indicator needle past TDC) (3, FIGURE 3-38.) This step is necessary to take up the gear lash in the engine.

(y) Rotate the crankshaft in the direction of engine rotation until the piston travel gauge is at 0.2032 inch BTDC (4, FIGURE 3-38.)

**NOTE**

The engine must be on the compression stroke. When the crankshaft is rotated to TDC on the compression stroke, the indicators on both gauges will move in the same direction. If they do not, rotate the crankshaft one complete revolution and repeat step (e).

(z) Read the push rod travel gauge. The push rod travel must be within the limits given in Table 3-3.

Table 3-3. Injection Timing Codes and Push Rod Travel.

| Timing (1) Code | Push Rod Travel (2) (Inches) Fast (3) | Slow (3) |
|---|---|---|
| A | -0.0395 | -0.0435 |
| C | -0.0315 | -0.0355 |
| D | -0.034 | -0.038 |
| E | -0.028 | -0.030 |
| Z | -0.024 | -0.028 |
| AA | -0.030 | -0.032 |
| AC | -0.027 | -0.029 |
| AF | -0.044 | -0.046 |
| AH | -0.034 | -0.036 |
| AK | -0.040 | -0.042 |
| AN | -0.045 | -0.047 |
| AQ | -0.041 | -0.043 |
| AS | -0.035 | -0.037 |
| AU | -0.048 | -0.050 |
| AV | -0.049 | -0.051 |
| AW | -0.059 | -0.061 |
| AX | -0.054 | -0.056 |
| AY | -0.039 | -0.041 |
| AZ | -0.058 | -0.060 |

Table 3-3. Injection Timing Codes and Push Rod Travel - CONT

| Timing (1) Code | Push Rod Travel (2) (Inches) Fast (3) | Slow (3) |
|---|---|---|
| BA | -0.027 | -0.029 |
| BC | -0.023 | -0.025 |
| BH | -0.051 | -0.053 |
| BM | -0.052 | -0.054 |
| BS | -0.071 | -0.073 |
| BT | -0.080 | -0.082 |
| BU | -0.064 | -0.066 |
| BV | -0.061 | -0.063 |
| BW | -0.066 | -0.068 |
| BY | -0.069 | -0.071 |
| CD | -0.073 | -0.075 |
| CE | -0.025 | -0.027 |
| CF | -0.037 | -0.039 |
| CH | -0.051 | -0.053 |
| CO | -0.0625 | -0.0645 |

(1) Check the engine dataplate to find the Timing Guide.
(2) Measure the push rod travel when the piston is at 0.2032 inch Before Top Dead Center (BTDC).
(3) Engine rotation speed. Reading differ when engine is turned fast/slow.

(6) Correcting Injector Timing. If the reading on the push rod travel gauge is not within the limits given in Table 3-3, increase or decrease the thickness of the cam follower gaskets to correct the injection timing. See Table 3-4.

**NOTE**

Never change the cam follower gaskets to correct the injection timing until you check the following:

That the timing tool is correctly installed.

That the gauges are correctly adjusted.

That the crankshaft has been rotated in the correct direction.

That the capscrews for the cam follower housing are tightened to 30 to 35 ft-lb torque.

(a) If the indicator reading is higher than the specification, the timing is retarded. Increase the gasket thickness to advance the injection timing (right hand rotation engine).

(b) If the timing indicator reading is lower than specification, the timing is advanced. Decrease the gasket thickness to advance the injection timing (right hand rotation engine).

(c) Table 3-4 lists the different cam follower housing gaskets, the gasket thickness, and approximate change in push rod travel at 19 TDC (0.2032 inch piston travel).

Table 3-4. Change in Push Rod Travel Due to Gasket Thickness

| Gasket Thickness mm (inch) | Change In Push Rod Travel At 19° BTDC mm (inch) |
|---|---|
| 0.15 to 0.20 (0.006 to 0.008) | 0.04 to 0.05 (0.0015 to 0.002) |
| 0.36 to 0.51 (0.014 to 0.020) | 0.09 to 0.13 (0.0035 to 0.005) |
| 0.51 to 0.61 (0.020 to 0.024) | 0.013 to 0.15 (0.005 to 0.006) |
| 0.69 to 0.84 (0.027 to 0.033) | 0.18 to 0.20 (0.007 to 0.008) |

(d) The gasket (1, FIGURE 3-39) must be against the cylinder block with the sealing bead toward the cam follower housing. The minimum amount of gasket stack-up thickness which may be used is 0.017 inch (0.43 mm). The maximum gasket stack-up thickness allowed is 0.080 inch (2.03 mm).

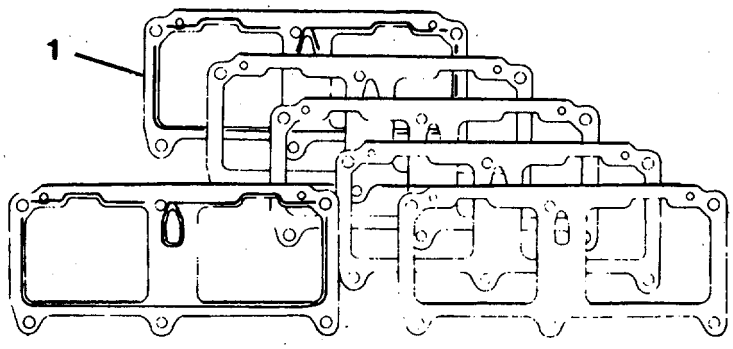


*FIGURE 3-39. Gasket Stack-Up Thickness.*

(e) If you can not correct the injection timing by increasing or decreasing the thickness of the cam follower housing gaskets, an offset camshaft key must be installed (General Support (GS) maintenance required).

(f) After completing the injection timing check on cylinders No. 1, 3, and 5, remove the test equipment.

(7) Install accessory drive. Refer to paragraph 3-19.

(8) Install the injectors (paragraph 2-34).

(9) Install the fuel pump (paragraph 2-33).

(10) Install the push rods.

(11) Install the rocker lever housings (paragraph 3-16).

(12) Adjust the valves and injectors (paragraph 2-34).

(13) Install the rocker housing covers (paragraph 3-16).

(14) Run the engine (TM 55-1905-223-10) and check for leaks and engine operation.

## 3-19. Replace/Repair Accessory Drive and Pulley Group.

**This task covers:**

**a. Removal b. Repair c. Replacement**

INITIAL SETUP**:**

Tools

Tool kit, general mechanic's, rail and marine diesel engines, 5180-00-629-9783
Combination wrench set, metric 10mm to 24mm, 5120-01-046-4979
Torque wrench kit P/N 3377216
Arbor Press, 4920-00-373-9376
Standard puller P/N ST-647

Equipment Condition

Water pump belt removed (para. 2-29)
Fuel pump removed (para. 2-33).

Materials/Parts

Pump pulley sleeve, P/N 190397
Gasket, P/N 200809
Power takeoff transmission, P/N 3005131
Drive pulley coupling, P/N 3000175
Thrust bearing washer, P/N 3026557
Straight headless pin, P/N 3034438
Shaft, P/N 3000171
Thrust bearing washer, P/N 3026556
Helical gear, P/N 142689
Constant speed drive, P/N AR-45728
Sleeve bearing, P/N 116391
Crocus cloth, Item 14, Appendix C
Clean cloth, Item 4, Appendix C

REMOVAL

a. Remove the pulley retainer nut (12, FIGURE 3-40) and washer (11).

CAUTION

The timing marks on the accessory drive gear and the camshaft gear must be aligned so that the valve and the injector set marks on the accessory drive pulley show the correct adjustment position.

b. Rotate the crankshaft until the "A" mark (1, FIGURE 3-41) on the accessory drive is aligned with the pointer (2) on the gear cover.

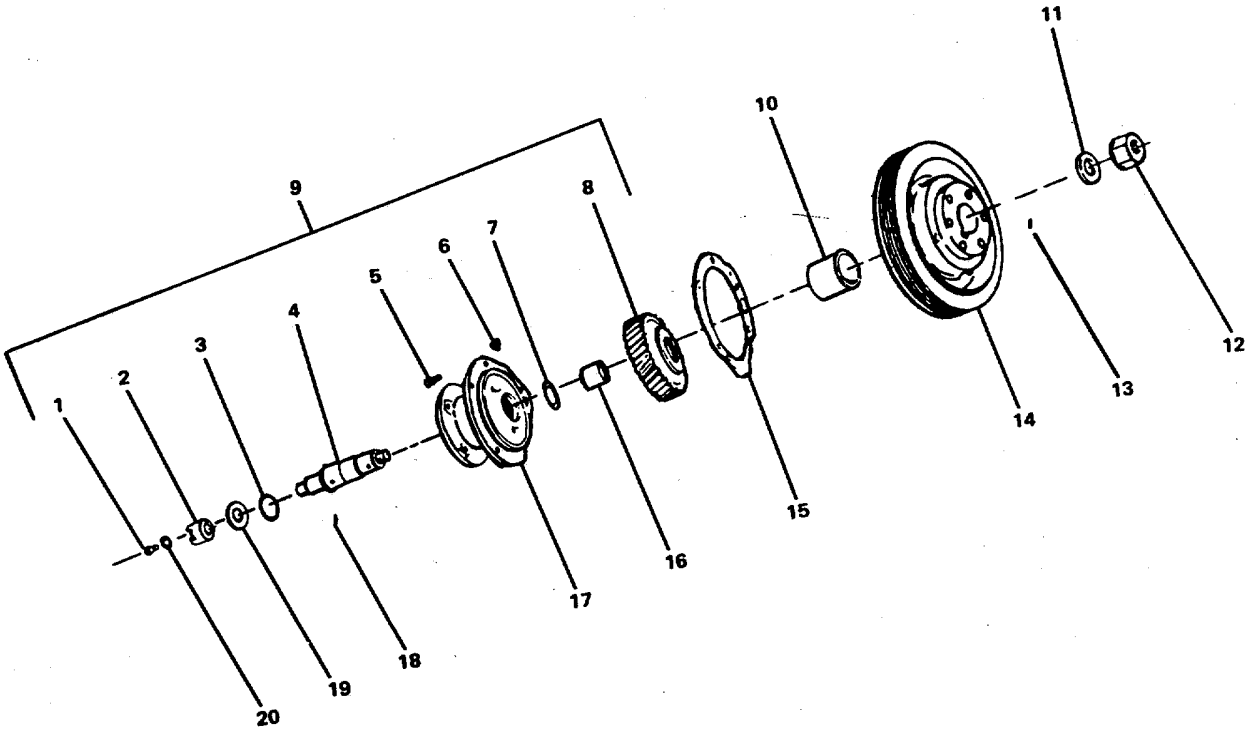


*FIGURE 3-40. Power Take Off, Accessory Drive and Pulley Group.*

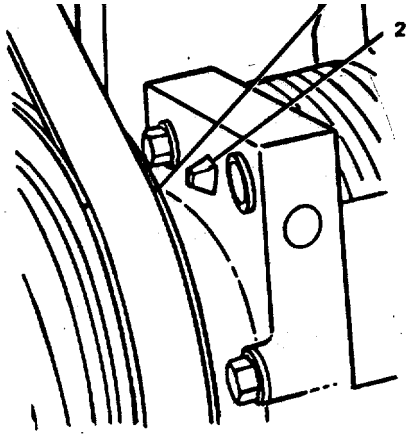


FIGURE 3-41. Gear Pointer.

*FIGURE 3-41. Gear Pointer.*

CAUTION

The gear cover will be damaged if the puller capscrews extend beyond the rear face of the accessory drive pulley.

c. Use a puller and remove the accessory drive pulley (14).

d. Remove the inspection hole plug (1, FIGURE 3-42) in the gear cover.

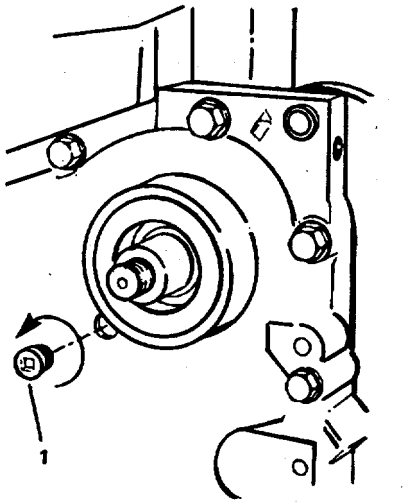


*FIGURE 3-42. Inspection Hole.*

e. Check to make sure the timing marks on the camshaft gear and the accessory drive gear are aligned with each other (FIGURE 3-43). If only one timing mark is visible through inspection hole, rotate crankshaft one complete revolution in direction of rotation and recheck.

CAUTION

If the accessory drive dowel pin has been incorrectly installed, the dowel pin must be removed before attempting to remove the accessory drive to prevent damage to the accessory drive bushing (FIGURE 3-44).

f. Remove five capscrews (1, FIGURE 3-45) and transmission power takeoff assembly (2) from rear of gear housing.

g. Remove all of the old gasket material (3) from sealing surface.

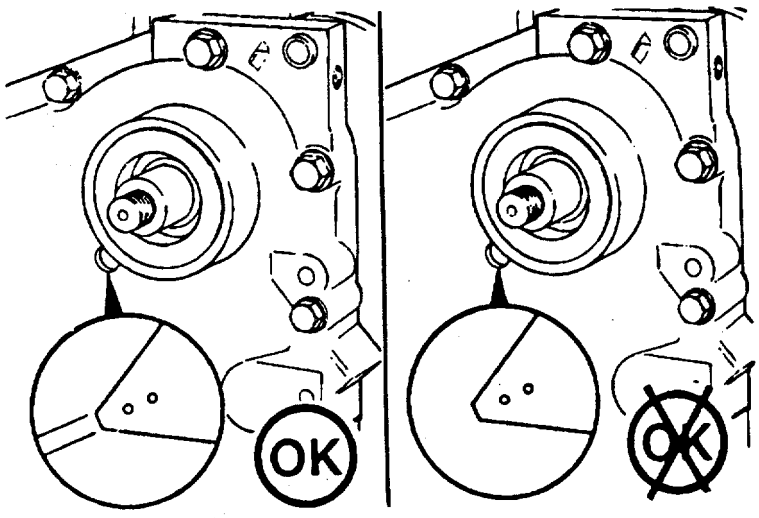


*FIGURE 3-43. Gear Alignment.*

h. Remove self locking capscrew (1, FIGURE 3-40) from shaft (4) and washer (20).

i. Remove gear (8), bushing (16) and thrust bearing (7) from shaft (4).

j. Remove coupling (2), washer (19) and thrust bearing (3) from shaft (4).

k. Pull shaft (4) with groove pin (18) from pulley end of accessory drive housing (17).

l. Remove groove pin (18) from shaft (4).

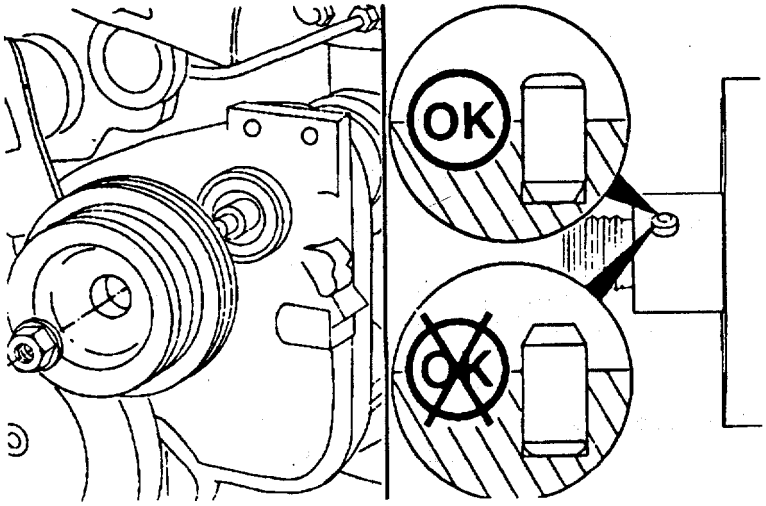


*FIGURE 3-44. Accessory Drive Dowel Pin.*

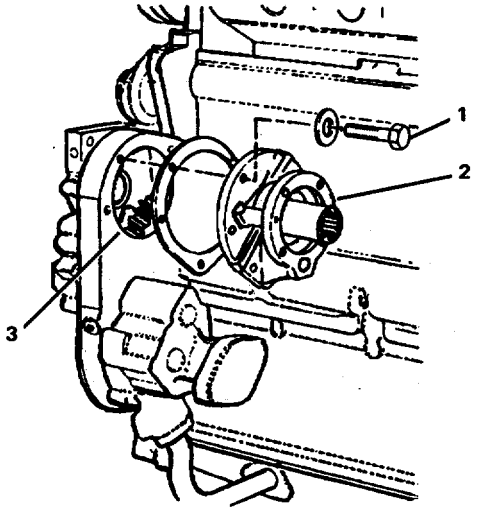


*FIGURE 3-45. Removing Accessory Drive.*

m. Remove the pulley wear sleeve (10) from the pulley (14), as follows:

CAUTION

The jaws of the vise must have copper plates to prevent damage to the pulley.

(1) Put the accessory drive pulley (14) in a vise.

(2) Grind a 0.062 inch (1.57 mm) radius on the cutting edge of a 0.75 inch (19.05 mm) chisel.

(3) Put the chisel against the pulley wear sleeve (10). Use a hammer to strike the chisel at four points on the outside diameter of the pulley wear sleeve (9) to relieve the press fit (FIGURE 3-46).

(4) After the press fit has been relieved, remove the pulley wear sleeve (10) by hand.

REPAIR

Repair by replacing the gasket (15, FIGURE 3-40), and accessory drive assembly components, which include coupling (2), thrust bearing (3), headless straight pin (18), accessory drive shaft (4),thrust bearing (7), helical gear (8), accessory drive housing (17), sleeve bearing (16), and pulley wear sleeve (10).

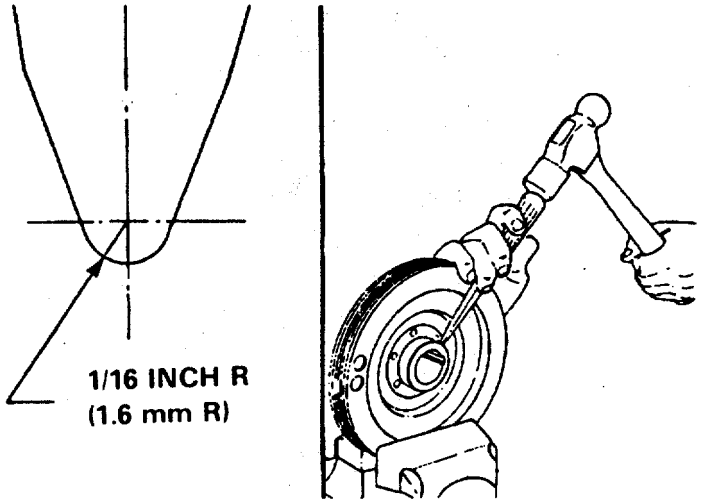


*FIGURE 3-46. Relieving Press Fit.*

a. Use a crocus cloth to remove any deposits from the seal area of the pulley.

b. Clean the seal area of the pulley with a clean cloth.

c. Inspect the seal wear area of the pulley for cracks. If cracked, replaced with new one.

REPLACEMENT

a. Install the pulley wear sleeve:

(1) Support the accessory drive pulley (14) in an arbor press.

(2) Install pulley wear sleeve (10) on the pulley seal wear surface with the chamfer on the outside diameter of pulley pump sleeve facing up (away from the pulley).

(3) Place a flat steel plate on top of the wear sleeve (10). Press the sleeve (10) on the pulley (14) until the steel plate contacts the pulley.

(4) Inspect pulley wear sleeve (10) for corrosion, nicks or burrs.

b. Assemble parts onto the shaft, as follows:

(1) Insert the shaft (4) into the accessory drive housing (17) from the gear side. Insert the groove pin (18).

(2) Place the thrust bearing (3), washer (19), and coupling hub (2) onto the shaft (4). Install the washer (20) and screw (1) and tighten in accordance with Appendix D.

(3) Place the thrust bearing (7), bushing (16), and gear (8) onto the shaft.

CAUTION

If the crankshaft was rotated after the accessory drive was removed, rotate the crankshaft until the timing mark on the camshaft gear is visible in the inspection hold before installing the accessory drive assembly. See FIGURE 3-41.

**NOTE**

Make sure mounting surfaces are clean of dirt and debris before installing the accessory drive.

c. Install a gasket (15, FIGURE 3-40) on the accessory drive housing (17).

CAUTION

Make sure the dowel pin has been inserted correctly before installing the accessory drive. See FIGURE 3-44.

d. Put the accessory drive shaft dowel pin (13, FIGURE 3-40) at approximately the 11:30 o'clock position when facing the shaft from the pulley end.

e. Install the accessory drive assembly in the gear housing accessory drive mounting hole.

f. Check the alignment of the camshaft gear and the accessory drive gear timing marks through the inspection hole in the gear cover (FIGURE 3-43).

**NOTE**

The accessory drive shaft dowel pin will be at the 12 o'clock position after the accessory drive is installed.

g. Install and tighten the five accessory drive mounting capscrews (5, FIGURE 3-40) to 45 ft-lb torque.

h. Apply pipe sealant to the 3/8 inch inspection hole pipe plug.

i. Install and tighten the plug (FIGURE 3-42) to 20 ft-lb torque.

j. Install a new accessory drive seal in the gear cover. Refer to paragraph 3-20.

CAUTION

Do not use any kind of lubricant to install the seal. The oil seal must be installed with the lip of the seal and seal wear area of the accessory drive pulley clean and dry. Use of lubricant will result in oil leakage at the seal.

k. Install the accessory drive pulley:

(1) Apply a film of Lubriplate 105 or equivalent to the accessory drive shaft.

(2) Align the keyway in the pulley (14, FIGURE 3-40) with the dowel pin (13) in the shaft (4). Use your hand to push the pulley (14) part way on the shaft (4).

(3) Install the washer (11) and the retaining nut (12) on the accessory drive shaft (4). Tighten the nut to 310 ft-lb torque.

l. Install the fuel pump (paragraph 2-33).

m. Install the water pump belt (paragraph 2-29).

n. Run the engine'(TM 55-1905-223-10) and check for leaks.

## 3-20. Replace/Repair Gear Cover Group.

**This task covers:**

**a. Removal b. Repair c. Replacement**

INITIAL SETUP:

Tools

Tool kit, general mechanic's, rail and marine diesel engines, 5180-00-629-9783
Combination wrench set, metric 10mm to 24mm, 5120-01-046-4979
Lifting sling, P/N 3375958
Injector adjustment kit, P/N 3375842
Dial indicator, 5120-00-277-8840
Torque wrench kit P/N 3377216
Special puller/driver P/N ST 12591

Equipment Condition

Seawater Pump removed (para. 2-37)
Oil drained (PMCS Table 2-1, Item 12).
PTO (SL 111 HP2) to fire pump removed (para. 3-21).
Water pump belt removed (para. 2-29).
Accessory drive pulley removed (para. 3-19).

Materials/Parts

Lube plate, 105, Item 11, Appendix C
Cleaning solvent, Item 5, Appendix C
Cover gasket, P/N 3021704
Seals, P/N 3020183 and P/N 3020185
Thrust shims P/N AR-1176
Preformed packing P/N 215705
Gear cover P/N 3036125
Vegetable oil, Item 27, Appendix C

REMOVAL

WARNING

A hoist must be used to support and lift the engine when removing the gear housing assembly. It must be firmly in place before removing the mounting capscrews.

CAUTION

Apply just enough lift to the hoist so that the housing (2, FIGURE 3-47) can be removed.

a. Remove the capscrews (4) and lockwasher (3) from the engine supports (1).

b. Remove the housing (2).

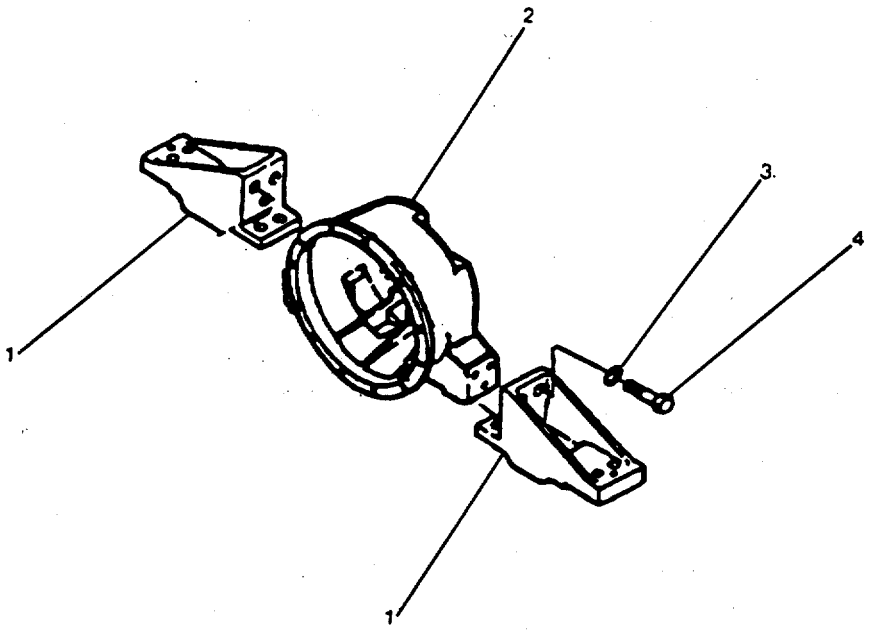


*FIGURE 3-47. PTO Housing and Mounts.*

c. Remove the camshaft support and the thrust bearing:

(1) Remove the three capscrews (3, FIGURE 3-48) and lockwashers (1) from the support (2).

(2) Use a rubber or plastic hammer to rotate the bearing support (2) approximately 60 degrees.

(3) Use a suitable pry bar to remove the bearing support (2) from the gear cover.

CAUTION

If the accessory drive dowel pin has been incorrectly installed, the dowel pin must be removed before attempting to remove the gear cover to prevent damage to the accessory drive bushing (FIGURE 3-49).

(4) Remove the preformed packing and the shims from the bearing support. Do not dispose of the shims (2, FIGURE 3-50).

d. Remove the four capscrews which hold the oil pan to the gear cover.

e. Loosen all remaining oil pan mounting capscrews four to five turns.

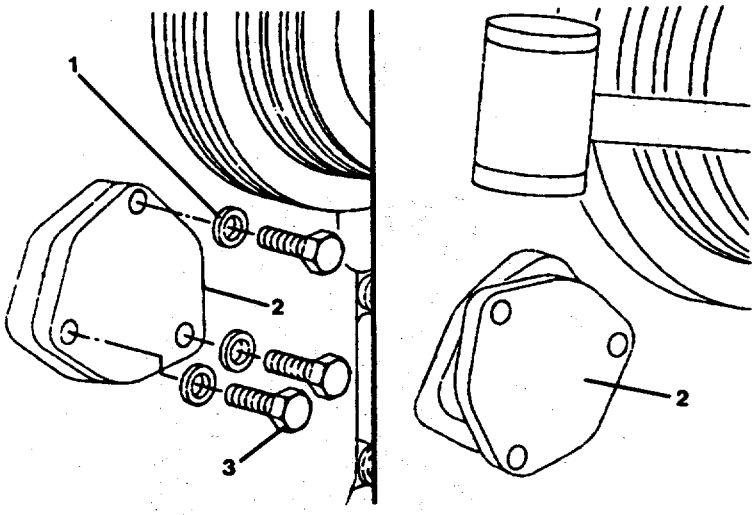


*FIGURE 3-48. Bearing Support.*

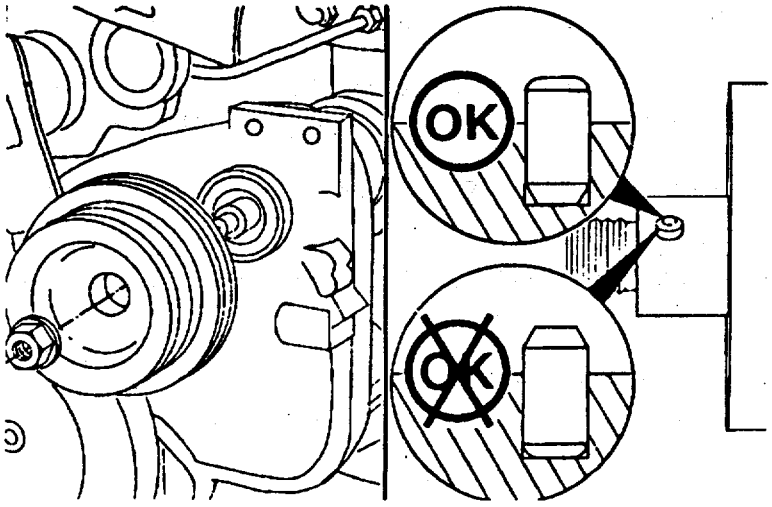


*FIGURE 3-49. Checking Dowel Pin.*

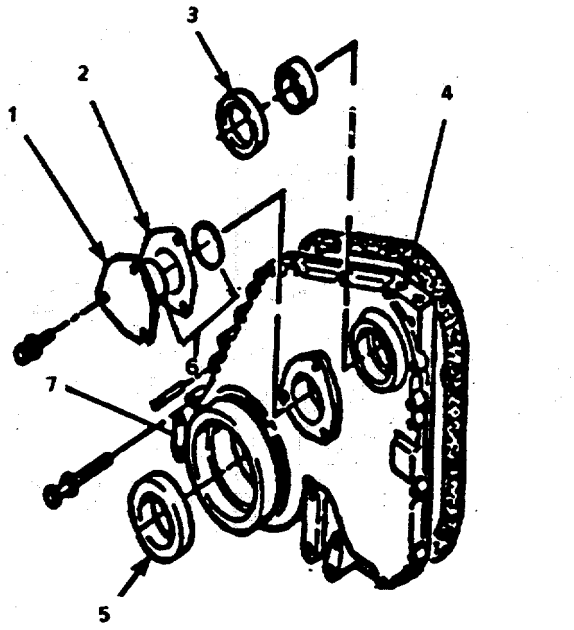


*FIGURE 3-50. Gear Housing (Cover).*

f. Insert a feeler gauge or a shim stock between the gear cover and the oil pan gasket. Move the feeler gauge or the shim stock back and forth to separate the gasket from the lower edge of the gear cover.

g. Remove one capscrew on each side of the gear cover, and install a 7/16-20 x 4 inch guide stud in each location to support the cover during removal.

h. Remove the remaining gear cover capscrews. Remove the gear cover and guide studs.

i. Remove the front crankshaft seal (5) and the accessory drive seal (3) from the cover.

j. Remove the gear cover gasket (4).

REPAIR

Repair is by replacement of the seals (5, 3), gasket (4), shim (2), preformed packing (6), and gear cover (7).

a. Clean the bearing support and the shims (2) with solvent. Dry with compressed air.

b. Inspect bearing supports, for cracks to the thrust surface. Replace if damaged.

c. Scrape the gasket surfaces on the gear cover and steam clean the cylinder block before installing the cover assembly.

REPLACEMENT

a. Install one 7/16-20 x 4 inch guide stud in each side of the gear cover mounting flange to align the cover.

b. Install the gear cover gasket over the guide studs and the dowel pins.

**NOTE**

Use a film of Lubriplate 105 or its equivalent or grease to hold the gear cover gasket in place, if necessary.

c. Install the gear cover and the mounting capscrews. Tighten the capscrews to 50 ft-lb torque.

d. Cut the ends of the gasket off even with the oil pan mounting flange.

e. Mount a dial indicator on the front face of the crankshaft. Put the indicator plunger (FIGURE 3-51) against the oil seal bore, and set the dial indicator at "0" (zero).

f. Rotate the crankshaft one complete revolution while monitoring the indicator. The tool indicator reading must not exceed 0.010 inch (0.25 mm).

g. If the total indicator reading exceeds 0.010 inch (0.25 mm), remove the gear cover. Check the cover and the housing for nicks or burrs; remove with file.

h. Scrape the gasket surfaces and clean the gear cover and the housing thoroughly with steam.

i. Repeat the gear cover installation procedure, and check the total indicator reading again.

j. Install the camshaft bearing support as follows:

(1) Install the support bearing in the bore of the gear cover. Do not install the preformed packing on the support at this time.

(2) Push the support against the camshaft so the camshaft gear rests against the camshaft thrust washer.

(3) Hold the support against the camshaft, and use a feeler gauge to measure the space between the gear cover flange and the support bearing (FIGURE 3-52).

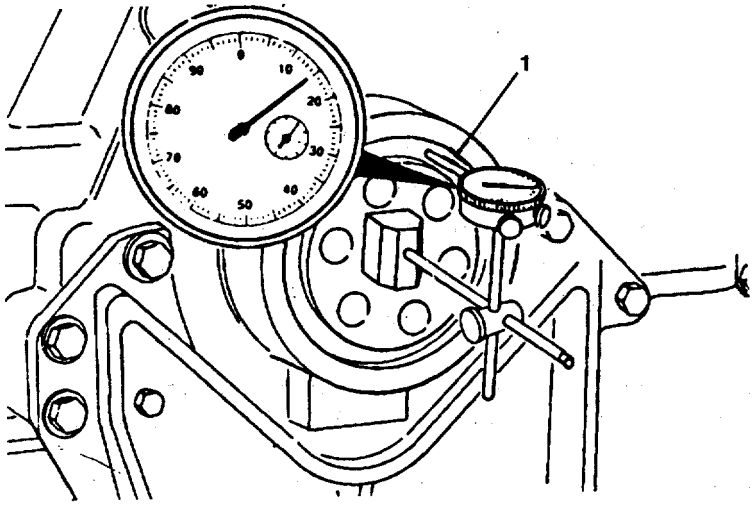


*FIGURE 3-51. Dial Indicating Crankshaft Face.*

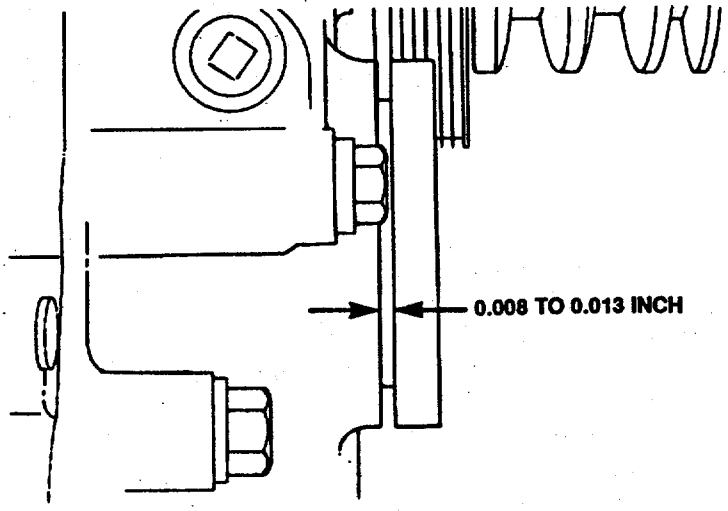


*FIGURE 3-52. Gear Cover/Flange Clearance.*

(4) The clearance between the bearing support and the camshaft gear must be 0.008 to 0.013 inch (0.20 mm to 0.33 mm). After measuring the space between the bearing support and the gear cover flange, add an additional 0.008 to 0.013 inch (0.20 mm to 0.33 mm) to that number to determine the thickness of the shims required. Example: Space of 0.060 inch (11.52 mm), measured with a feeler gauge, plus 0.010 inch (0.25 mm) for clearance would require 0.070 inch (1.77 mm) shims.

(5) Use a micrometer to measure the thrust shims removed from the support at the time of disassembly. Add or remove the shims as required to obtain the correct clearance between the bearing support and the camshaft gear. Shims are available in the following thickness:

| Shim Thickness | |
|---|---|
| mm | in |
| 0.05 | 0.002 |
| 0.13 | 0.005 |
| 0.25 | 0.010 |
| 0.63 | 0.025 |

(6) Install the required number of thrust shims as determined in paragraphs (4) and (5) above and new preformed packing on the support bearing.

(7) Lubricate the preformed packing with vegetable oil and install the support bearing into the gear cover.

(8) Tighten the capscrews to 20 ft-lb torque.

k. Install the front crankshaft seal.(5, FIGURE 3-50).

**NOTE**

Lay-down Lip, Teflon (LDL TFE) oil seals for service replacement have an assembly tool which protects the seal lip during shipment and installation. The "LDL TFE" oil seal must be installed with the lip of the seal and the crankshaft clean and dry. Do not use any kind of lubricant. The use of lubricant will result in oil leakage at the seal.

(1) Use hand pressure to push the oil seal from the assembly tool onto the crankshaft as far as possible. Remove the assembly tool.

(2) Install the top plate (from oil seal puller/driver) on the crankshaft, and use three vibration damper mounting capscrews and flat washers.

(3) Tighten the three capscrews alternately in 1/2-turn increments until top plate seals against the crankshaft nose.

(4) Remove the top plate and capscrews.

l. Install the PTO housing (2, FIGURE 3-43) onto the gear cover.

m. Relieve tension on the hoist to set the housing (2) on the engine supports (1). Install the support capscrews (4) and lockwashers (3). Tighten the capscrews to 50 ft-lb torque.

n. Install the crankshaft pulley (paragraph 3-19).

o. Install the accessory drive seal (paragraph 3-19).

p. Install the dowel pin in the accessory drive shaft (if removed) (FIGURE 3-49).

q. Install the accessory drive pulley (paragraph 3-19).

r. Install the water pump belt (paragraph 2-29).

s. Install the four capscrews that hold the oil pan to the gear cover.

t. Tighten one of the 7/16 inch oil pan mounting capscrews on each side of the oil pan, halfway between the front and the rear of the oil pan, 15 ft-lb torque.

u. Tighten the four 5/16 inch capscrews in the rear of the oil pan to 20 ft-lb torque in the sequence shown (FIGURE 3-53).

v. Tighten the thirty-two 7/16 inch capscrews to 50 ft-lb torque in the sequence shown (FIGURE 3-53).

w. Install the seawater pump belt and belt/guard (paragraph 2-37).

x. Install the Power Takeoff (paragraph 3-20).

y. Fill the lubricating oil system (PMCS Table 2-1, Item 12).

z. Run the engine (TM 55-1905-223-10) until it reaches a temperature of 180°F (80°C) and check for leaks.

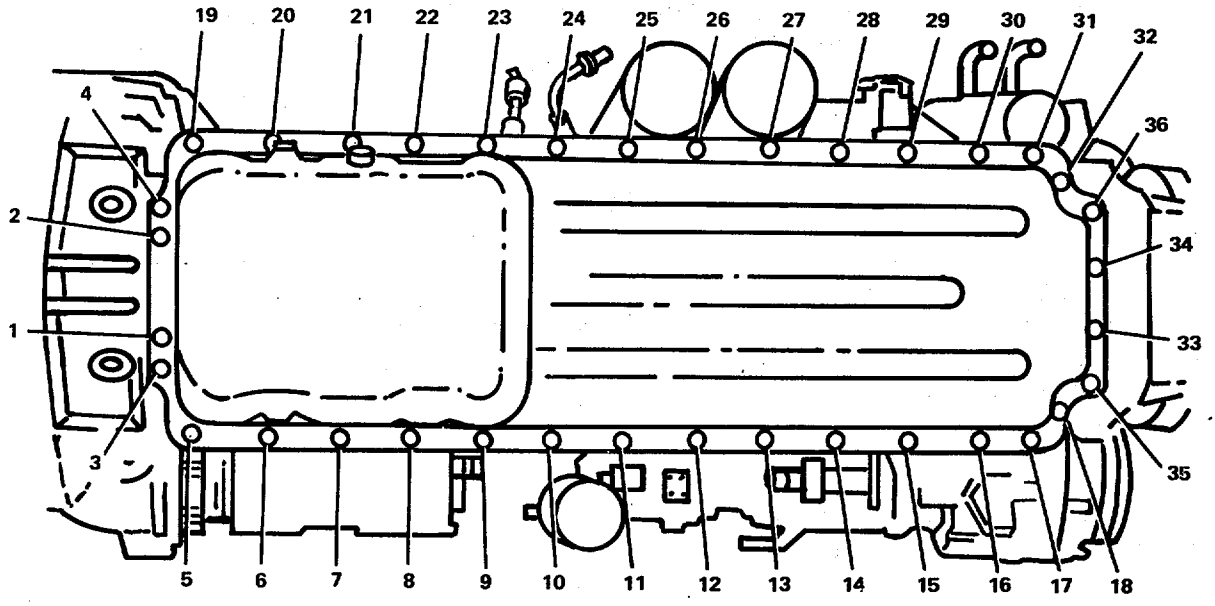


*FIGURE 3-53. Oil Pan Capscrew Torque Sequence.*

## 3-21. Replace/Repair Power Takeoff Assembly.

**This task covers:**

**a. Removal b. Disassembly c. Repair d. Assembly e. Replacement**

INITIAL SETUP:

Tools

Tool kit, general mechanic's, rail and marine diesel engines, 5180-00-629-9783
Engine lifting sling, P/N 3375958
Combination wrench set, metric 10mm to 24mm, 5120-01-046-4979
Pusher screws 3/8-16
Dial indicator, 5210-00-277-8840
Torque wrench kit P/N 3377216

Equipment Condition

Fire pump coupling removed from shaft (TM 55-1905-223-24-18).
Seawater pump belt guard removed from PTO housing (para. 2-37).

Materials/Parts

Hub nut lockwasher
Wood blocks, Item 7, Appendix C
PTO assembly P/N SL-111 HP2
Helical compression spring P/N A2709N
Tapered roller bearing P/N M207

REMOVAL

WARNING

A hoist must be used to support and lift the assembly when removing it from the engine. It must be firmly in place before removing the mounting capscrews.

a. Remove the shaft key (3, FIGURE 3-54).

b. Attach a suitable hoist to the PTO. Remove the 12 hex-head capscrews (2) that secure the clutch housing (4) to the engine. Use two pusher screws (3/8-16) in the tapped holes provided in the clutch housing flange and swing the PTO from the engine.

**NOTE**

Do not remove the driving ring (1) from the PTO adapter plate unless it is necessary to replace engine parts.

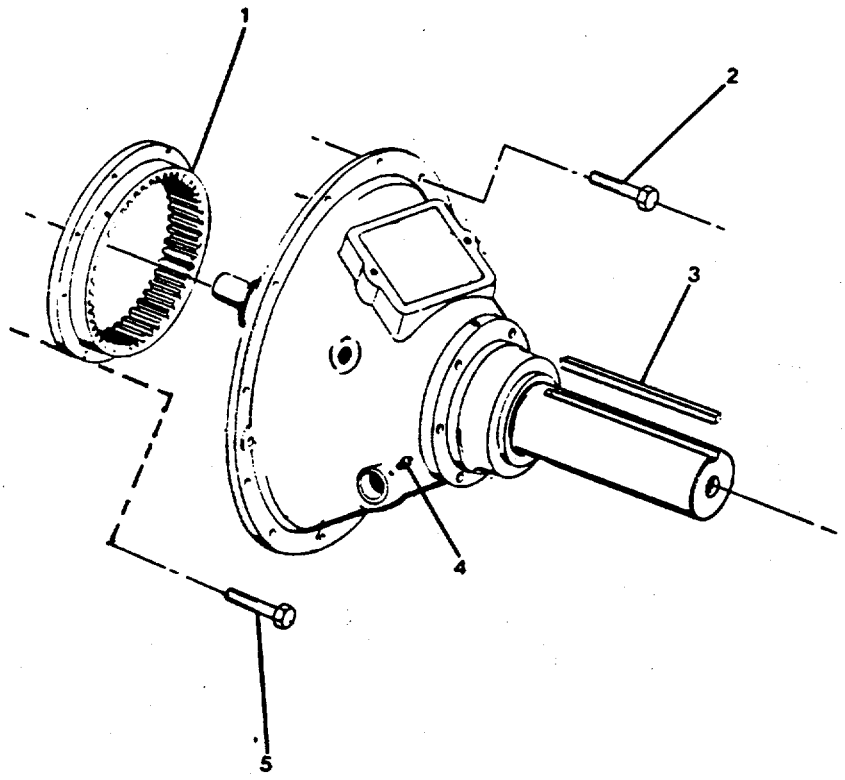


*FIGURE 3-54. Power Takeoff Assembly (SL-111 HP2).*

c. Remove the eight hex-head capscrews (5) that secure the driving ring (1) to the PTO adapter. Remove the driving ring (1).

d. Support the clutch housing on a work bench with wooden blocks. Have the clutch end facing upward.

DISASSEMBLY

**NOTE**

On PTO units which have been disassembled, steps (a) through (i) of the Assembly Procedures must be accomplished in order to reach a starting point for bearing adjustment. For field adjustment of bearing only, go to assembly step (i) of this procedure.

a. Support the power take-off housing (44, FIGURE 3-55) on a work bench with wooden blocks. Have the PTO end facing upward.

b. Remove the pilot bearing (1) from the clutch shaft (34).

c. Remove the jam nut (26) and lockwasher (25) from the hose fitting (23) located in the PTO housing (44). Push the fitting (23) and hose (24) into the PTO housing (44).

d. Straighten the bent portion of the hub nut lockwasher (3) from the hub nut (2). Remove the hub nut (2) and the lockwasher (3) from the clutch shaft (34). Discard the hub nut lockwasher (3).

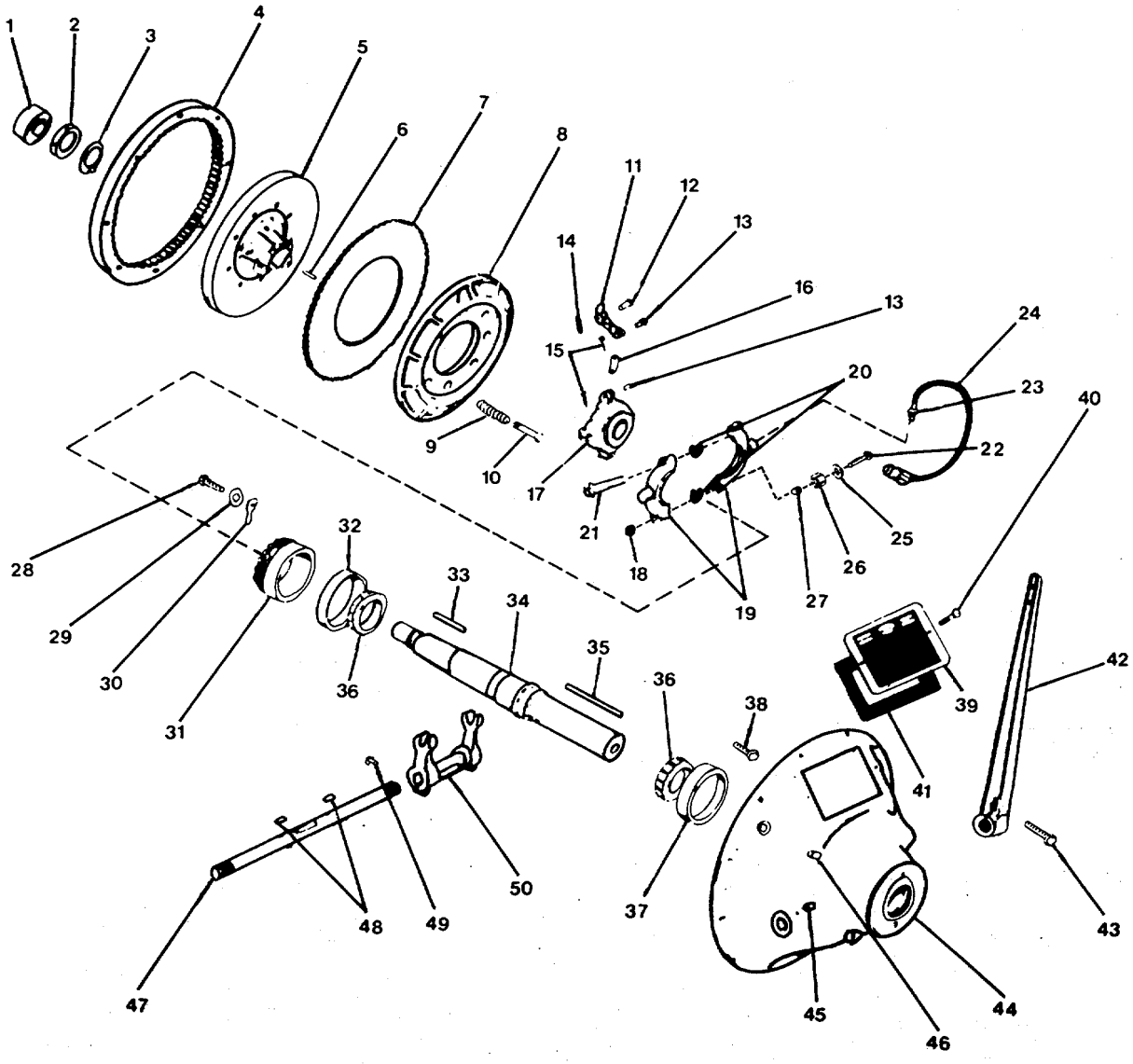


*FIGURE 3-55. Power Takeoff Assembly (SL-111 HP2).*

e. Remove the two-round head screws (40) which secure the instruction cover plate (39) and gasket (41) to the PTO housing (44) and remove the plate and gasket.

f. By reaching through the cover plate opening, remove two of the spring bolts (10) and pressure springs (9) from the hub and back plate (5). Remove the second spring bolt 180ºF from the first.

g. Use a gear puller with threaded legs for 5/8-11 tapped holes to pull the clutch assembly (5) from the clutch shaft (34). Install the puller so the threaded legs screw into the 5/8-11 holes from which the spring bolts were removed in step above. Use the jack screw to exert force on the input end of the clutch shaft (34). Remove the puller and clutch assembly from the clutch shaft (34). Remove the shaft hub key (33).

h. Set the clutch assembly on a bench with the sliding sleeve assembly end facing up. Remove the lubrication fitting (27) from the hose fitting (23). Remove the hose from the fitting on the collar (19). Remove the fitting from the collar (19).

i. Straighten and remove four of eight cotter pins (15) from four of eight lever link pins (13). Remove four lever link pins (13) from the lever links (16) and sliding sleeve (17).

j. Remove the sliding sleeve (17) and collar (19) assembly from the hub and back plate. Remove the hex-nuts (18) from the capscrews (22) and remove the collar halves (19) and shims (20) from the sliding sleever (19). Remove the two guide pins (6) from the sliding sleeve (17) only if replacement of the parts is necessary.

k. Remove the six remaining spring bolts (10) and pressure springs (9) from the hub and back plate.

l. Remove the floating plate (8) and driving plate (7) from the hub and back plate.

m. Remove the remaining four cotter pins (15) from the remaining lever link pins (13) and remove the lever links (16) from the levers (11) after removing the link pins (13). Straighten the four cotter pins (14) which secure the finger lever pins (12) to the finger levers and the hub and back plate and remove the finger levers (11) from the hub and back plate.

n. Remove the hex-head capscrew (28), lockwasher (29), and lock (30) which secure the bearing retainer (31) in position from the PTO housing. Remove the bearing retainer (31) from the PTO housing.

o. Remove the clutch shaft (34) with attached parts from the PTO housing by carefully tapping on the output end of the shaft. The forward bearing cup (32), and both roller bearings (36) will remain with the shaft.

p. Pull bearing cup (32) from shaft (34).

q. Use a bearing puller to remove bearing (36) from the clutch shaft.

r. Remove the two dust protector caps from the PTO housing and with a long, straight, shank blunt punch, tap the rear bearing cup (37) from the PTO housing.

s. Remove the hexhead capscrew (43) that secures the hand operating lever (42) to the operating shaft (47) and remove the hand lever (42). Set the PTO housing (44) on the bench with the clutch end facing up.

t. Remove the two hexhead capscrews (49) which secure the throwout yoke (50) to the operating shaft (47). Gently tap one end of the operating shaft (47), and roll out the exposed Woodruff key (48). Repeat this procedure and roll out the remaining Woodruff key (48). Remove the operating shaft (47) and throwout yoke (50) from the PTO housing (44).

u. Remove the lubrication fittings (45, 46) from the PTO housing. Remove the plug (38) only if cleaning of the drilling is necessary.

REPAIR

Repair consists of replacing compression springs (9) and bearings (36) with bearing cups (32, 37).

ASSEMBLY

**NOTE**

Torque values given in these procedures are for clean, oiled thread conditions. See Torque Value Tables 3-5 for Capscrews, Bolts, and Nuts; 3-6 for Tapered Plugs; and 3-7 for Tube and Hose Fittings.

a. Install the lubrication fittings (45) and (46) in the PTO housing (44) if removed during disassembly.

b. Install the bearing and cup (37) into its bore in the PTO housing (44). Press or tap the bearing cup (37) squarely into its bore to bottom on its back face.

c. Install the two dust protectors in their holes at the rear of the PTO housing.

d. Install the passage plug in the PTO housing (44) if removed during disassembly.

e. With the PTO housing setting on the bench with the clutch end facing up, install the operating shaft (47) and throwout yoke (50). Push the operating shaft halfway into the PTO housing (44). Slip the throwout yoke (50) onto the operating shaft (47) and then push the shaft (47) the rest of the way through the PTO housing (44) to its normal position. Be sure the throwout yoke (50) is installed so the capscrews (49) enter from the clutch side toward the rear. Slide the yoke (50) to one side to expose Woodruff key slot in the shaft (34) and install the key (48). Slide the yoke (50) to the other side and install the remaining key (48). Center the yoke (50) over the keys (48) and secure the yoke (50) to the shaft (34) with the two hexhead capscrews (49). Tighten the capscrews (49) to 30-42 ft-lb torque.

f. Using an arbor press and steel tubing, press the two bearings onto the clutch shaft (34), one from each end, with their back faces butting against the stop shoulder on the shaft (34).

g. Install and secure the hand lever (42) to the operating shaft (47) with the hexhead capscrew (43). Tighten the capscrew to 86-95 ft-lb torque.

h. Install the clutch shaft (34) bearings attached into the shaft bore and bearing cup (37) in the PTO housing (44); install the output end of the shaft (34) first. Slide the bearing cup (32) over the shaft and into its bore in the PTO housing. Squarely press the bearing cup (32) in place against the bearing. Install the bearing retainer (31) over the shaft (34).

i. Adjust the bearing end play to 0.004-0.007 inch on the SP111 HP2 (0.006-0.010 inch on the SP 214 P1).

**NOTE**

- The only approved method of field adjustment is by the use of a dial indicator to read actual end play. The adjustment procedures are the same for both PTOs (except for end play measurements).

- On PTO units which have been disassembled, steps (a) through (i) of the Assembly Procedures must be accomplished in order to reach a starting point for bearing adjustment on the SP 111 HP2.

(1) Use the bearing retainer nut for adjusting the tapered roller bearings. Refer to FIGURE 3-56.

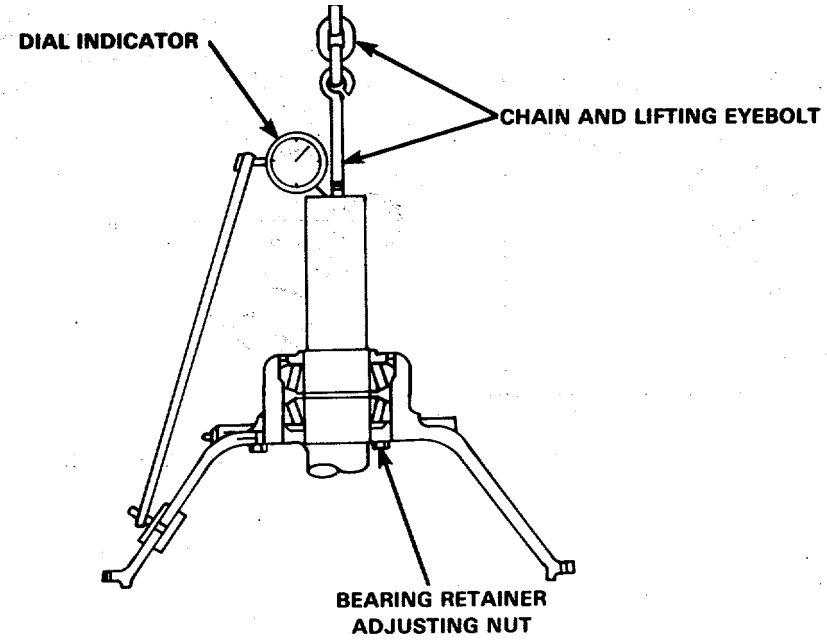


*FIGURE 3-56. Adjusting Roller Bearings..*

(a) Tighten the retainer nut until the shaft requires 60 in-lb of force to turn.

(b) Back off the retainer nut 3-1/4 - 4-1/4 notches. See FIGURE 3-57.

(2) Dial indicate the end play as follows:

(a) Set PTO on supporting blocks with the clutch shaft in a vertical position with the input end down.

(b) Attach an eyebolt in the 1/4 PTF thread at the output end of the shaft. (Models which do not have this hole will have to be inverted with the input end up, and clearance at the output end below, for dial indicator mounting. An extra hub nut with a loop shaped strap welded to it can be used to apply the pushing and pulling forces required during end play check.) See FIGURE 4-19 .

**CAUTION**

Select lifting eyebolts to obtain maximum thread engagement with bolt shoulder tight against housing. Bolts should be near but should not contact bottom of bolt hole.

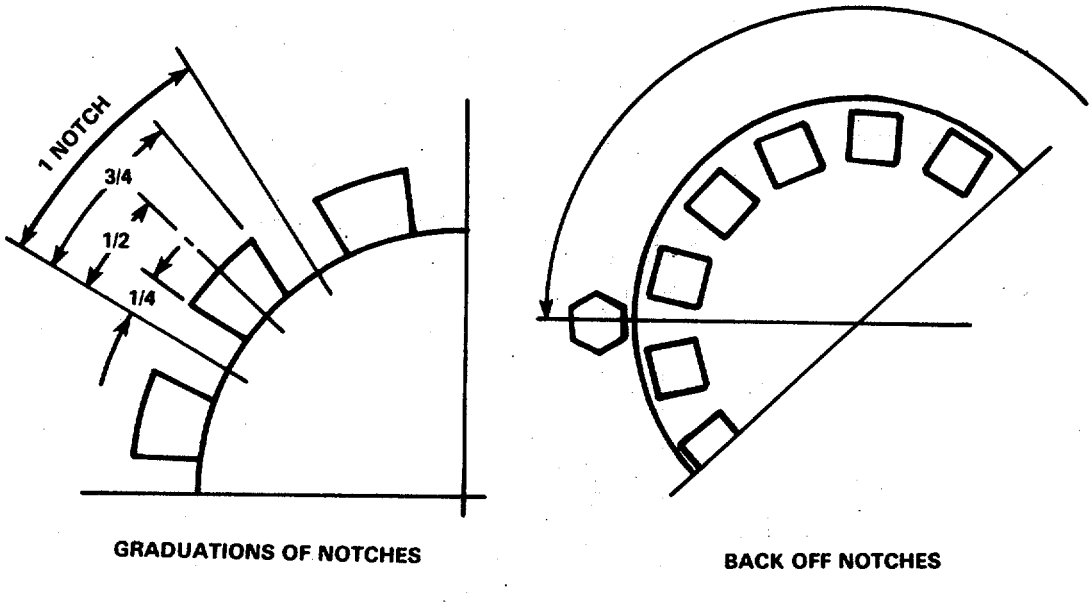


*FIGURE 3-57. Adjusting Retainer Nut.*

(c) Attach a dial indicator to the housing and locate the stem or plunger, from the indicator, on the outer machined area of the end of the clutch shaft. Mark a spot next to the indicator stem.

(d) Apply a pushing force of 200 pounds while turning the shaft two complete revolutions in each direction (the weight of the shaft can be counted as part of the 200 pounds). With the pushing force applied, stop the plunger or stem next to the mark and zero the dial indicator.

(e) Apply a pulling force of 200 pounds (compensate for shaft weight) to the shaft and rotate, with force applied two complete revolutions in each direction. Stop with force applied and mark next to plunger or stem of the dial indicator. The indicator reads the actual end play.

(f) Adjust nut to obtain the desired end play. Recheck final end play with the dial indicator as described. Lock nut when play adjustment is between 0.004 and 0.007 inch on the SL111 HP2.

j. After adjustment, install the retainer lock (30, FIGURE 3-55) and secure the lock (30) to the clutch housing (44) with a capscrew (28) and lockwasher (29). Tighten the capscrew to 21-24 ft-lb torque. Be sure to lubricate the main bearings through the housing fitting near the shaft exit.

k. Install the lubrication fitting (38) in the rear (output) end of the clutch shaft (if used).

l. Set the clutch hub and back plate assembly on the bench with the hub section facing up.

m. Install four levers (11) and pins (12) in the hub and back plate (8). Secure the levers (11) and pins (12) to the plate (8) with four cotter pins (14). Spread the cotter pins.

n. Install the driving plate (7) onto the hub and back plate.

o. Install the floating plate (8) onto the hub and back plate (5) against the driving plate (7).

p. Use four pins (13) and cotter pins (15) to attach eight links (16) to the finger levers (11). Spread the cotter pins. When the cotter pins are spread, the radius of the pin ends must not be greater than 0.31 inch. This is necessary to prevent operating interference.

q. Install the eight spring bolts (10) and pressure springs (9) through the floating plate and into the hub and back plate. Tighten the spring bolts until their shoulders contact the hub and back plate; then, tighten them to 160-175 ft-lb torque.

r. Assemble the collar (19) halves and shims (20) to the sliding sleeve (17) with the two capscrews (22) and two hex-nuts (18). Tighten the hex-nuts to 38-42 ft-lb torque. Install the two guide pins (6) with flats into the sliding sleeve (17) if they were removed during disassembly.

s. Install the sliding sleeve (17) with attached parts entering the guide pins (6) into the hub of the hub and back plate.

**CAUTION**

When the cotter pins are spread, the radius of the pin ends must not be greater than 0.31 inch. This is necessary to prevent operating interference.

t. Attach the loose ends of the eight links (16) to the sliding sleeve (17) with four pins (13) and four cotter pins (15). Spread the cotter pins.

u. Install the hose fitting (23) into the collar (19) and attach the flexible hose to the fitting.

v. Attach the fitting (22) to the end of the flexible hose (24).

w. Partially install key (33) into the shaft keyway.

x. Carefully slide the PTO assembly, (5) onto the clutch shaft, until sleeve (17) clears key (33). Lower PTO assembly, tapping key (33) down into position and engaging the trunnions of the collar (17) with the yoke (19) and routing the flexible hose (24) clear of the moving parts to the hole on the inside of the PTO housing (44).

y. Push the fitting (23) through the hole in the PTO housing (44) and secure it in place with the lockwasher (25) and nut (26). Install the lubrication fitting (27) into the hose fitting.

z. Install the hub nut lockwasher (3) onto the clutch shaft (34), locating its lower tab in the spot drilling provided on the hub and back plate. Install the hub nut (2). Tighten the nut (2) to remove all clearance, applying 30 ft-lb torque. Then tighten the nut 60-90° further. Bend the lockwasher (3) against a flat spot on the nut.

**CAUTION**

The pilot roller bearing has an inner race that is removable from the outer race roller and seal assembly. Due to this construction, axial alignment of the inner and outer races is most important.

aa. Press the pilot bearing (1) on the clutch shaft (34). Solidly support the output end of the clutch shaft (34) during installation of the pilot bearing (1). Also, apply the force to the inner race of the pilot bearing during installation. Don't press the pilot bearing all the way onto the shaft. Leave a distance of 0.06 inch between the front face of the bearing inner race and the end of the clutch shaft. Refer to FIGURE 3-58 .

ab. Place the instruction cover plate gasket (41, FIGURE 3-55) and install the cover plate (39) on the PTO housing with two round-head screws (40). Tighten the screws to 11-13 ft-lb torque.

ac. If the driving ring (4) was removed, position the driving ring (4) against the engine flywheel and secure it with eight hex-head capscrews. Torque capscrews. Refer to Table 3-5.

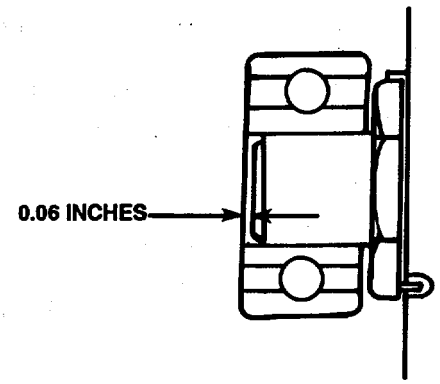


*FIGURE 3-58. Pilot Bearing (PTO/SL-111).*

REPLACEMENT

a. If the driving ring (1) was removed, install it to the PTO adapter plate with the eight hex-head capscrews and lockplates. Tighten the capscrews to 80 ft-lb torque.

**NOTE**

It is recommended after a new Power Takeoff has been assembled to an engine or the bearings have been adjusted, to tap the shaft on the end with a lead hammer to relieve any preloading that may result due to the resistance of the pilot bearing when being pressed into the flywheel.

b. Position the PTO clutch housing (4) against the engine housing carefully aligning the pilot bearing in its bore and engaging the teeth of the clutch driving plate with the internal teeth on the driving ring.

c. Secure the clutch housing (4) to the engine housing with 12 hex-head capscrews (2). Torque to 80 ft-lbs. Tap the output end of the shaft with a soft hammer to relieve any preloading on the bearings.

**CAUTION**

It is possible, due to mismatch of components or other reasons, to have flywheel to driven component interference. As a result, it is necessary that the crankshaft end play be measured before and after the driven component is installed. Both measurements should be the same. If they are not, the driven component should be removed and the source of the interference found and corrected.

d. Install the key (35) on the output end of the shaft.

e. Install the coupling to the Firepump (TM 55-1905-223-24-18).

## 3-22. Replace/Repair Friction Clutch Assembly

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Lifting sling P/N 3375958
Combination wrench set,
metric 10mm to 24mm,
5120-02-046-4979
Arbor press, 4920-00-373-9376
Pusher screws, 7/16-4
Standard puller P/N ST-647
Conventional gear puller P/N 3375840

Materials/Parts

Friction clutch assembly P/N SP214-P1
Lockwasher P/N B1511L
Tapered roller bearings P/N M215
Adjusting spring P/N A2702BE

Equipment Condition

Bowthruster water jet coupling removed from the shaft (TM 55-1905-223-24-18).

REMOVAL

**WARNING**

A hoist must be used to support and lift the assembly when removing it from the engine. It must be firmly in place before removing the mounting capscrews.

a. Remove the shaft key (3, FIGURE 3-59) and hydraulic grease fitting (4) from OUTPUT END of clutch shaft (5).

b. Remove twelve hex-head capscrews (2) securing clutch housing (6) to the engine.

c. Use two 7/16-14 pusher screws (7) in the tapped holes provided in the clutch housing (6) flange and remove the friction clutch assembly.

**NOTE**

It is not necessary to remove driving ring (1) unless replacing engine parts.

d. Remove eight hex head capscrews securing driving ring (1) to engine flywheel. Remove driving ring (1)

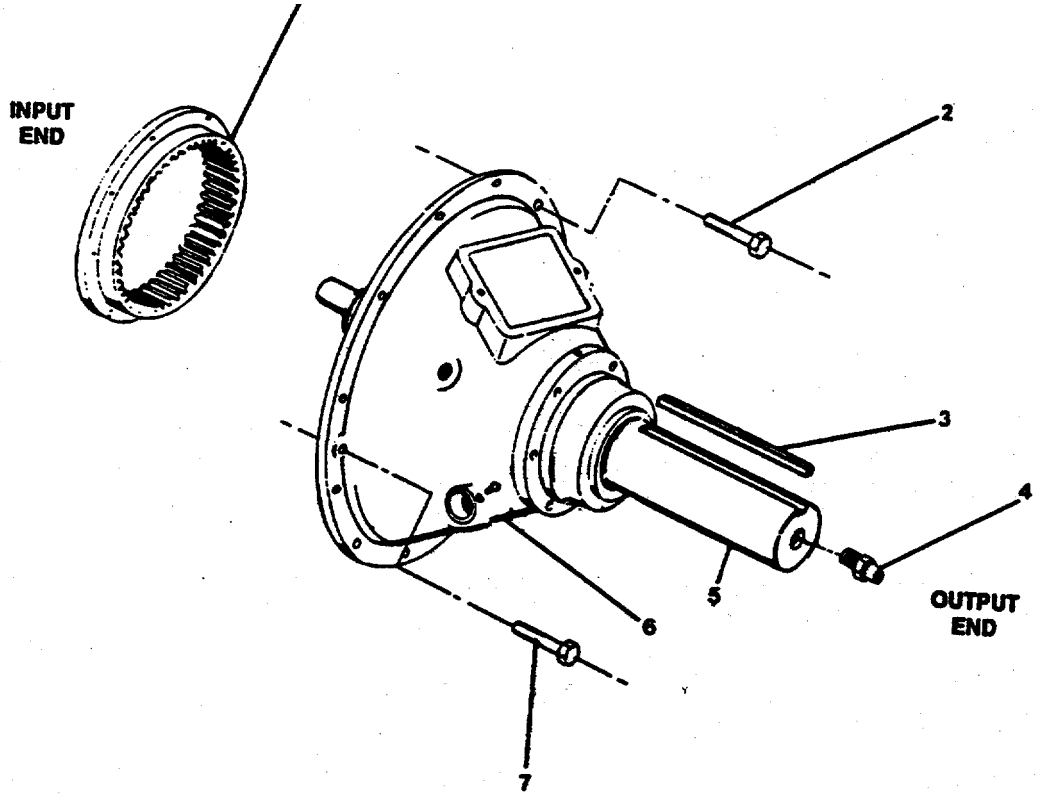


*FIGURE 3-59. Friction Clutch Assembly (SP-214-P1).*

e. Support clutch housing (6) on a workbench with wooden blocks, clutch (INPUT END) facing upward.

REPAIR

a. Using a standard puller, remove pilot annular ball bearing (2, FIGURE 3-60, Sheet 1) from the clutch shaft (35).

b. Remove hex hub nut (3) and lock washer (4) securing tube elbow (9) located in clutch housing (23) opening at point (22). Push tube elbow (9) and nonmetallic hose assembly (6) nonmetallic hose (7) into clutch housing (23).

c. Straighten the bent portion of the hex hub nut lock washer (4) from hex hub nut (3). Remove hex hub nut (3) and lock washer (4) from clutch shaft (35). Discard hub nut lock washer (4).

d. Use a conventional gear puller with threaded legs for 5/8-11 tapped holes to pull the clutch assembly (5, Sheet 2) from the clutch shaft.

(1) Install conventional puller so that the threaded legs screw into holes provided in the hub and back plate (38).

(2) Screw down on puller jack screw so that force is applied to the clutch shaft, pulling the clutch assembly (5) from the shaft.

e. Remove shaft key, (36, Sheet 1) and remove puller and clutch assembly (5) from the clutch shaft (35).

f. Set the clutch assembly (5, Sheet 2) on workbench with sliding sleeve assembly (50) facing upward.

g. Remove nonmetallic hose assembly (6, Sheet 1) by remaining nonmetallic hose (7) from tube elbow (8) on split collar (32, Sheet 2).

h. Straighten and remove four cotter pins (44) from the four headed straight pins (42).

I Remove four headed pins (42), eight spring washers (43) and remove the four levers (45) and sleeve assembly (50) from floating plate (49).

j. Depress adjusting lock pin (47) with a screwdriver and unscrew adjusting ring (46), removing it from the hub of the back plate (38).

k. Remove adjusting ring lock pin (47) and adjusting spring (48) from floating plate (49). Inspect adjusting spring (48) for broken or bent coils. Replace as necessary.

l. Install adjusting spring (48) into the bore provided in the floating plate (49).

m. Install the adjusting lock pin (47) and depress the lock pin (47) and spring (48) with screwdriver while installing the adjusting ring (46) on the hub and back plate (38) hub.

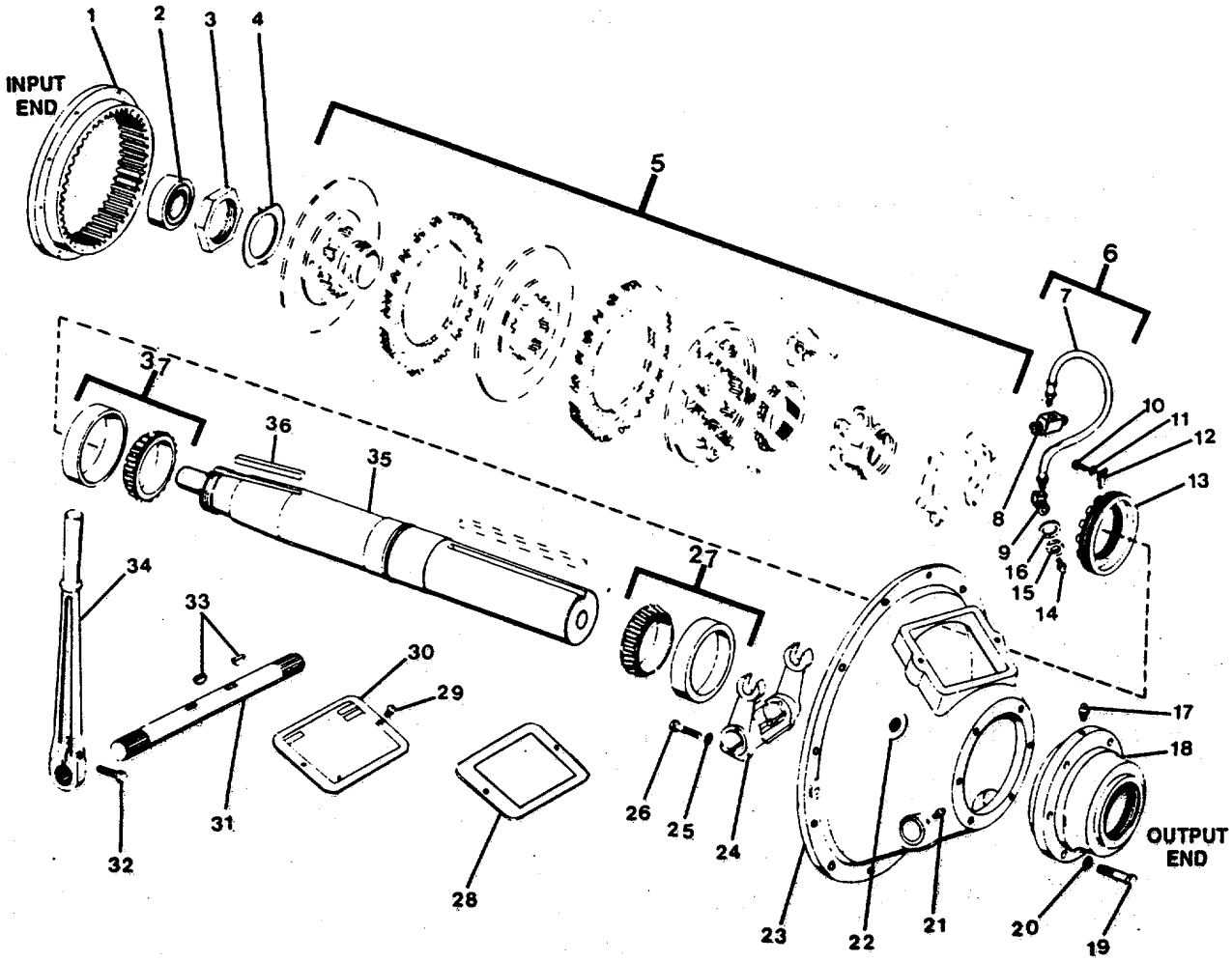


*FIGURE 3-60. Friction Clutch Assembly Repair (Sheet 1 of 2).*

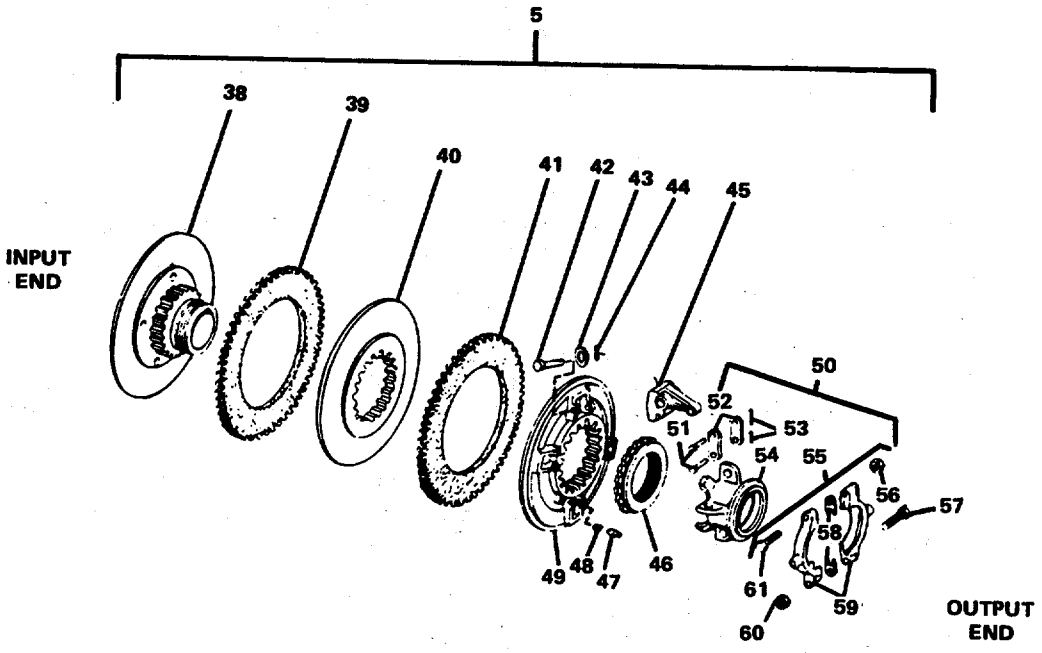


*FIGURE 3-60. Friction Clutch Assembly Repair (Sheet 2 of 2).*

n. Install levers (45) and sliding sleeve (50) as an assembly onto the adjusting ring (46) and floating plate (49).

(1) Secure levers (45) to floating plate with eight spring washers (43) (two at each lever (45) location) with four headed straight pins (42) and four cotter pins (44).

(2) Spread the ends of the cotter pins (44).

o. Turn clutch housing (23, Sheet 1) with attached parts over on the workbench with OUTPUT END facing up. Support housing with wooden blocks.

p. Remove six hex head capscrews (19) and lock washers (20) securing bearing carrier (18) to clutch housing (23).

q. Remove bearing carrier (18) and clutch shaft (35) with attaching parts from housing (23). Set clutch shaft (35) in a large vise with INPUT END of shaft facing upward, and gripping the rear cast section of bearing carrier (18) with vice.

r. Remove hex head capscrews (10), lockwashers (11) and bearing retainer lock (12) from bearing carrier (18).

s. Remove bearing retainer (13) from bearing carrier (18). Lift clutch shaft (35) separating it with attached parts from bearing carrier (18). The INPUT END tapered roller bearing (37) and OUTPUT END tapered roller bearing (27) will remove with clutch shaft (35).

t. Use a standard puller and remove tapered roller bearings (27 and 37) from clutch shaft (35). The tapered roller bearings (27 and 37) remove in opposite directions from the shoulder machined on the clutch shaft. Inspect tapered roller bearings (27 and 37) for scratches or deterioration of bearing vise. If damaged, replace with new ones.

u. Use arbor press and install tapered roller bearings (27 and 37) on clutch shaft (35), one from each end, with their back faces butting against the stop shoulder on the shaft.

v. Use a piece of steel tubing slightly smaller in diameter than the outside diameter of the tapered roller bearing cup to press the cup onto the bearing carrier, back face of cup rearward. Press cup to bottom of bore.

w. Set bearing carrier (18) in bench vise, INPUT END upward, gripping the casting with vise jaws below mounting flange.

x. Install clutch shaft (35) with tapered roller bearings (27 and 36) into bearing carrier (18) OUTPUT END down. Use a piece of steel tubing, 18 inches long, and slightly smaller than the outside diameter of bearing cup and install the bearing cup over clutch shaft and into the bearing carrier. Tap or press the cup into position.

y. Install bearing retainer (13) into bearing carrier (18) against tapered roller bearing (27) cup.

z. Adjust the bearing end play to 0.006-0.010 inch.

**NOTE**

The only approved method of field adjustment is by the use of a dial indicator to read actual end play. The adjustment procedures are the same for both PTO's (except for end play measurements).

aa. Use the bearing retainer nut (13) for adjusting the tapered roller bearings. Refer to FIGURE 3-61 .

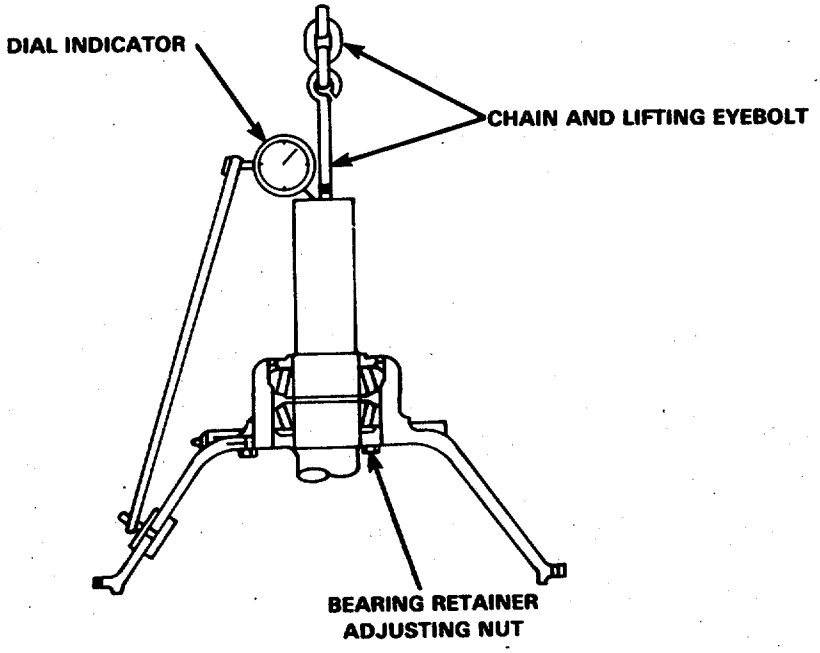


*FIGURE 3-61. Adjusting Roller Bearings.*

(1) Tighten the retainer nut until the shaft requires 60 in-lb of force to turn.

(2) Back off the retainer nut 3-1/4 - 4-1/4 notches. See FIGURE 3-62 .

ab. Dial indicate the end play as follows:

(1) Set clutch housing on supporting blocks with the clutch shaft in a vertical position with the INPUIT END down.

**CAUTION**

Select lifting eyebolts to obtain maximum thread engagement with bolt shoulder tight against housing. Bolts should be near but should not contact bottom of bolt hole.

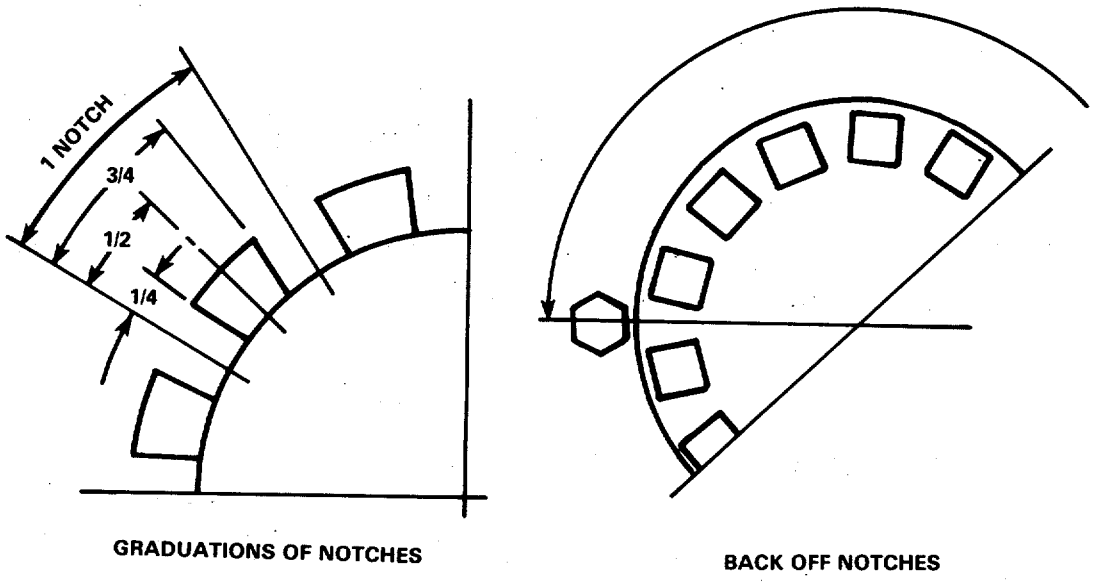


*FIGURE 3-62. Adjusting Retainer Nut.*

(2) Attach an eyebolt in the 1/4 PTF thread at the output end of the shaft. (Models which do not have this hole will have to inverted with the input end up, and clearance at the output end below, for dial indicator mounting. An extra hub nut with a loop shaped strap welded to it can be used to apply the pushing and pulling forces required during end play check.) See FIGURE 3-61 .

(3) Attach a dial indicator to the housing and locate the stem or plunger, from the indicator, on the outer machined area of the end of the clutch .shaft. Mark a spot next to the indicator stem.

(4) Apply a pushing force of 200 pounds while turning the shaft two complete revolutions in each direction (the weight of the shaft can be counted as part of the 200 pounds). With the pushing force applied, stop the plunger or stem next to the mark and zero the dial indicator.

(5) Apply a pulling force of 200 pounds (compensate for shaft weight) to the shaft and rotate, with force applied two complete revolutions in each direction. Stop with force applied and mark next to plunger or stem of the dial indicator. The indicator reads the actual end play.

(6) Adjust nut to obtain the desired end play. Recheck final end play with the dial indicator as described. Lock nut when end play adjustment is between 0.004 and 0.007 inch on the SL11 HP2 (0.006 to 0.010 on the SP 214 P2).

ac. After adjustment, install the retainer lock (12, FIGURE 3-60, Sheet 1) and secure lock to the clutch housing with a capscrew (10) and lock washer (11). Tighten the capscrew to 21-24 ft-lb torque. Be sure to lubricate the main bearings through the housings fitting near the shaft exit.

ad. Set clutch housing (23, FIGURE 3-60, Sheet 1) on workbench. Raise and support housing with wooden blocks about five inches from the bench, so the OUTPUT END of the housing faces upward.

ae. Install clutch shaft (35) with attached parts into cloth housing (23). Secure bearing carrier (18) to housing with six hex head capscrews (19) and lock washers (20). Tighten capscrews to 85 ft-lbs torque.

af. On clutch assembly (5) sitting on bench, install nonmetallic hose assembly (6) nonmetallic hose (7) on tube elbow in split collar (59, sheet 2).

ag. Set clutch housing (23, sheet 1) with attached parts on bench with INPUT END facing up and supported with wooden blocks.

ah. Pick up and lower clutch assembly (5) over clutch shaft (35) and into clutch housing, engaging the trunnions on split collar (59, Sheet 2) with throwout yoke (24, Sheet 1).

ai. Align shaft (35) keyway with the keyway in hub and back plate (38, Sheet 2). Install key (36, Sheet 1) in shaft (35).

aj. Install hub nut lock washer (4) onto clutch shaft (35), indexing its lower tab in the spot drilling provided on the hub and back plate (38, Sheet 2).

ak. Install hub nut (2, Sheet 1) on shaft (35). Tighten nut to 30 ft-lb torque to seat washer tapers and remove any clearance, then tighten nut an additional 150° - 180° rotation. Bend the lock washer (4) against a flat on the hub nut (3).

al. Route nonmetallic hose assembly (6) free of moving parts and push tube elbow (9) through hole in housing (23) at point (22). Install lock washer (12) and hex nut (15) to retain.

am. Solidly support the shaft OUTPUT END with a block of wood, and install pilot annular bearing (2) as follows:

(1) Apply force to inner race of bearing by tapping with mallet and force the bearing down onto shaft.

**CAUTION**

Do not press bearing completely onto shaft.

(2) Leave a distance of 0.12 inch between front face of bearing (1, FIGURE 3-63) inner race and the end of clutch shaft (2).

an. Adjust clutch assembly (5, FIGURE 3-60, Sheet 2) as follows:

(1) Remove two capscrews (30, Sheet 1) and remove instruction plate (29) and gasket (28) from clutch housing (23).

(2) With clutch disengaged, turn clutch assembly by turning shaft until adjusting lock pin (47, Sheet 2) can be reached through instruction plate opening in housing.

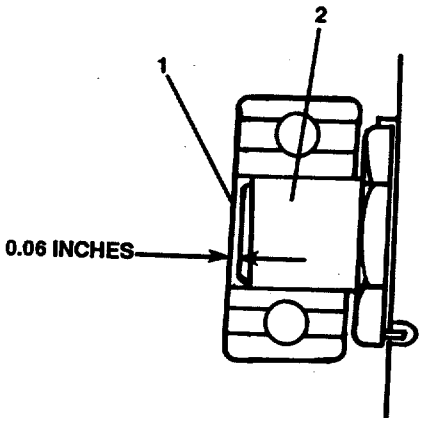


*FIGURE 3-63. Bearing End Clearance.*

(3) Depress lock pin (47) with screwdriver and screw adjusting ring (46) clockwise one or two notches or until a distinct pressure is felt when operating hand lever (34, Sheet 1).

(4) Release adjust lock pin (47, Sheet 2) and turn adjusting ring (46) to engage nearest notch with the pin (47).

(5) Operate lever (34, Sheet 1) to disengage and engage the clutch a number of times to check operation. If a distinct pressure is not felt by use of hand lever, repeat steps (3) and (4).

ao. Position instruction plate gasket (28) and instruction plate (30) and secure with two capscrews. Tighten capscrews to 11 ft-lb torque.

REPLACEMENT

a. If the driving ring (1, FIGURE 3-59) was removed, install it to the flywheel with the eight capscrews. Tighten the capscrews to 80 ft-lb torque.

**NOTE**

It is recommended after a new power takeoff has been assembled to an engine or the bearings have been adjusted, to rap the shaft on the end to relieve any preloading that may result due to the resistance of the pilot bearing when being pressed into the flywheel.

b. Position the clutch housing (6) against the engine flywheel housing, carefully aligning the pilot bearing (2, FIGURE 3-60, Sheet 1) with the flywheel pilot and the clutch driving plates with the driving ring (1, FIGURE 3-59).

c. Secure the clutch housing (6) to the flywheel housing with 12 hex-head capscrews (2). Tighten to 80 ft-lb torque. Rap the output end of the shaft with a soft hammer to relieve any preloading on the bearings.

d. Install the shaft key (3) in the clutch shaft.

e. Install the coupling to the bowthruster water jet drive coupling (TM 55-1905-223-24-6).

**CAUTION**

It is possible, due to mismatch of components or other reasons, to have flywheel to driven component interference. As a result, it is necessary that the crankshaft end play be measured before and after the driven component is installed. Both measurements should be the same. If they are not, the driven component should be removed and the source of the interference found and corrected.

## 3-23. Replace/Repair Lubricating Oil Pump Group

**This task covers:**

**a. Removal** **b. Disassembly** **c. Repair** **d. Assembly**

**e. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Torque wrench kit P/N 3377216
Depth vernier P/N ST-537
Gear puller P/N 3375082
Gear puller P/N 3375083
Dowel puller P/N ST-1134
Bushing mandrel P/N ST-1158
Lubricating oil pump boring tool
P/N 3375206

Equipment Condition

Engine shut down (TM 55-1905-223-10) and cooled to below 120°F (50°C).

Materials/Parts

Lubricating oil pump P/N AR-10172
Gasket P/N 3004242
Sleeve bearing P/N 69521
Gasket P/N 203145, 3031434
Spur gear P/N 3014965
Sleeve bushing P/N 68365
Helical compression spring P/N 21939
Pressure regulator plunger P/N 109333
Lubricating Oil, Item 1, Appendix C

REMOVAL

a. Disconnect oil lines to the inlet and outlet of the oil pump.

b. Remove capscrews (19, FIGURE 3-64), machine bolts (20) and lockwashers (18) securing oil pump to the cylinder block.

**CAUTION**

Do not pry on oil pump mounting flange when removing oil pump. This will cause damage to the oil pump.

c. Remove the oil pump and gasket from the gear case. Discard gasket (32).

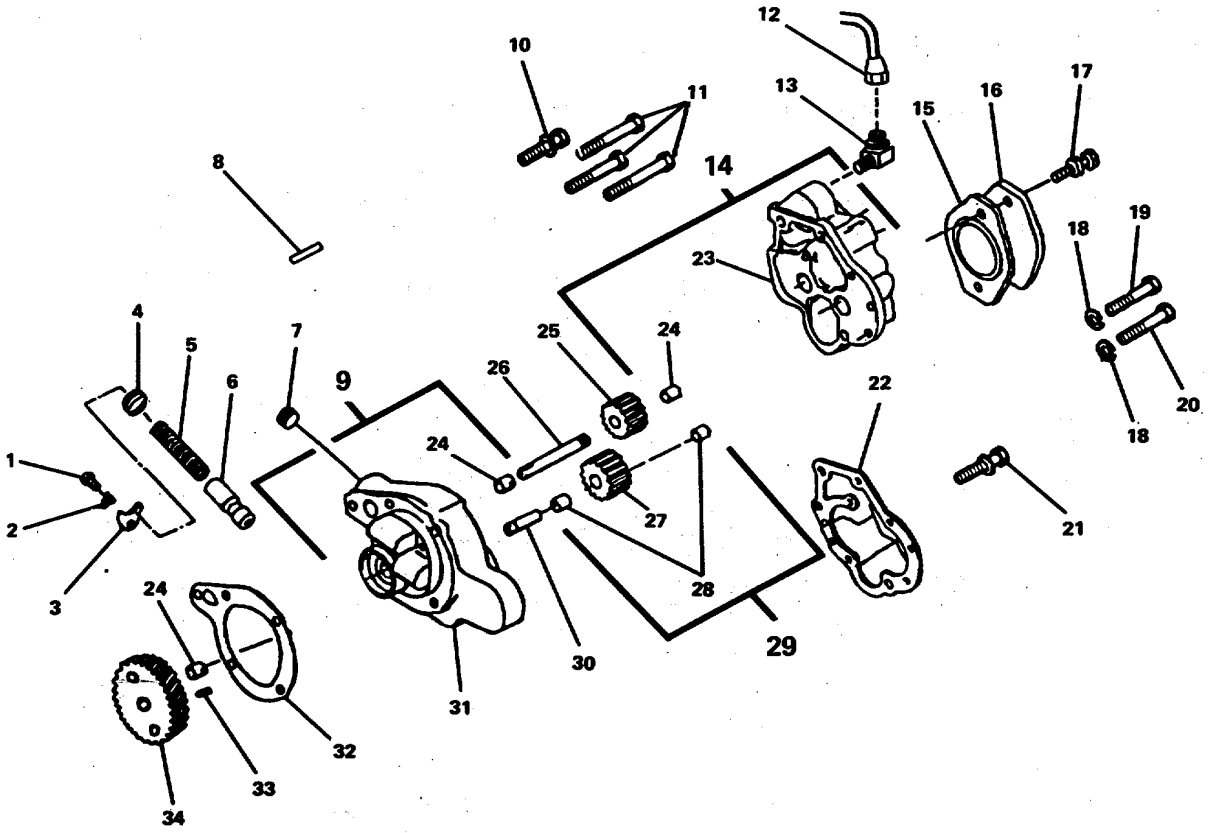


*FIGURE 3-64. Lubricating Oil Pump Group.*

**CAUTION**

Do not allow dirt or gasket material to enter oil passages on the pump. Bearing damage will result.

d. Remove two assembled washer machine screws (17) and remove access cover (16) and gasket (15). Discard gasket.

e. Using solvent, clean pump and cylinder block gasket surfaces. Dry with compressed air.

f. Inspect gears (25, 27 and 34) for freedom of rotation.

g. Inspect gears (25, 27 and 34) for cracked or broken teeth. Replace in REPAIR procedure if cracked or broken teeth are observed.

h. Inspect bushings (28 and 24) for excessive wear or discoloration due to overheating or seizure to the shafts. Replace if necessary in REPAIR procedure.

i. Use depth verniers to measure drive shaft (30) end clearance (FIGURE 3-65) in two locations 90° apart. Drive shaft end clearance should be as follows:

Minimum - 0.002 inch (0.05 mm)
Maximum - 0.005 inch (0.13 mm)

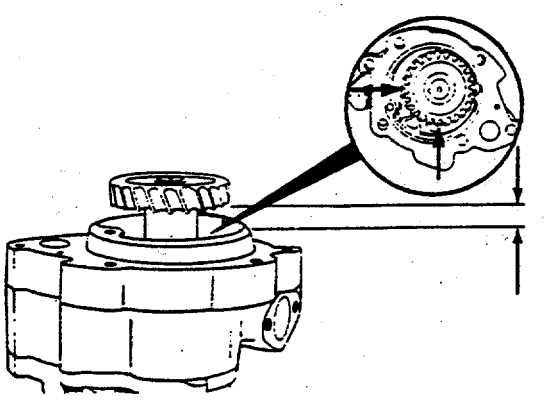

*FIGURE 3-65. Drive Shaft End Clearance.*

DISASSEMBLY

a. Remove assembled washer capscrews (21, FIGURE 3-64) securing cover (23) to pump body (31). Tap cover (23) lightly with rubber hammer to help remove cover (23) from dowels (8) in the body (31). Remove cover.

b. Remove the idler gear (25) from shaft (26).

c. Using gear puller P/N 3375082 to remove drive gear P/N 143190 or gear puller P/N 3375083 to remove drive gear P/N 125988, remove drive gear (27) from drive shaft (30) and drive gear (34).

**NOTE**

Some double lubricating oil pumps have a scavenger pump body that must be removed after the drive shaft is pushed through the driven gear. After removing scavenger pump body, repeat step b. and c.

d. If the oil pump has a tube for piston cooling and the tube is damaged, push the tube from the inside part of pump body to remove

e. Push idler shaft (26) from pump body (31).

**WARNING**

Carefully remove the capscrew. The pressure regulator spring is under compression.

f. Remove capscrew (1), lock plate (2), clamp (3), vent plug (4), helical compression spring (5) and pressure regulator plunger (6). Ensure plunger (6) moves freely in the bore.

REPAIR

a. Check idler shaft (22) for damage. Replace if damaged.

b. Check dowel pins (8) in the pump body (31) for damage. Use dowel puller P/N ST-1134 to remove damaged pins.

c. Check drive shaft (30) for damage.

d. Check all gears (25, 27 and 34) for worn or broken teeth. Replace with new ones if damaged.

e. Check pump body (31) for cracks, worn bushing threads or scratched gasket surfaces.

f. Use bushing mandrel, P/N ST-1158, and push bushings (24, 28) from pump body (31), cover (23) and gears (25, 27 and 34).

g. Use bushing mandrel, P/N ST-1158, to push new bushings (24, 28) into body (31), cover (23) or gears (25, 27 and 34). Bushings must be even with or 0.020 inch (0.51 mm) below surface of body (31), cover (23) or gears (25, 27 and 34).

h. Use lubricating oil pump boring tool to cut the bore in the new bushings in the pump body (31).

i. Cut the bore in new bushings:

(1) Install the guide bushing (1, FIGURE 3-66) into the gear pocket. Tighten the capscrew (2) against the side of the gear pocket to hold the guide bushing in position.

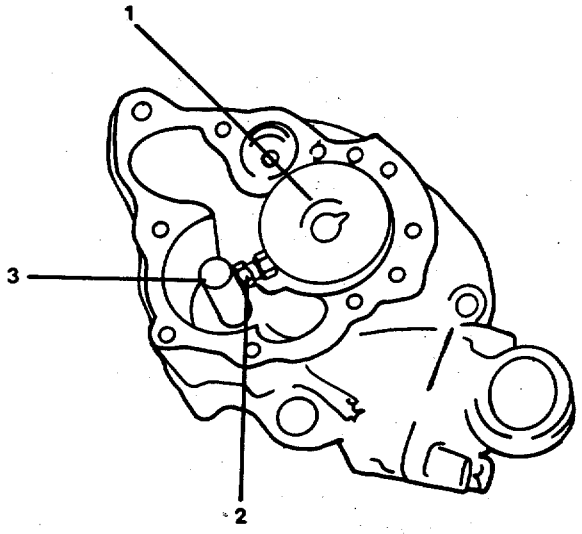


*FIGURE 3-66. Install the Guide Bushing into the Gear Pocket.*

(2) Install the dial indicator (3) into the setting block. Put the setting block on the setting standard with the indicator tip on the diameter size of the bore to be cut. See Table 3-5. Adjust the dial indicator.

(3) Install the tool bit into the boring bar. Do not completely tighten the setscrew. Install the tool bit adjusting knob into the boring bar. Hold the setting block and indicator against the boring bar so the indicator tip will be over the tool bit. Turn the adjusting knob clockwise to push the tool bit against the indicator tip. Adjust the tool bit until the indicator has the same reading as when adjusted on the setting standard. After the tool bit is correctly adjusted, tighten the setscrew and remove the adjusting knob.

(4) Install the boring tool (1, FIGURE 3-67) into the guide bushing. The tool bit must go through the slot in the guide bushing. Do not hit the tool bit against the bushing.

(5) Adjust the travel of the boring bar so the tool bit will go through the guide bushing but not touch the bushing in the pump body.

(6) Fasten the boring tool to the pump body with capscrews (2). Rotate the shaft to make sure it will turn freely.

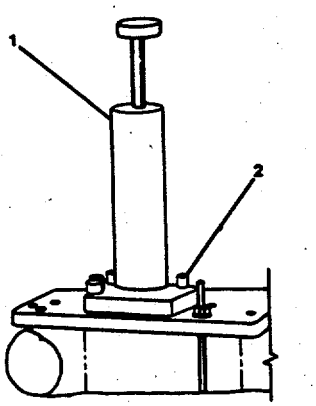


*FIGURE 3-67. Install the Boring Tool.*

(7) Move the feed control lever to the "on" position. This will prevent the drive shaft from moving down. Put the pump and boring tool in a vertical position. Make sure the boring tool can cut completely through the bushing.

(8) Install the drive adapter into a heavy duty 3/8 inch electric drill. Engage the adapter with the drive shaft of the boring tool.

(9) Start the drill and cut the bore in the bushings. Make sure you cut the bore in both bushings. Do not push down on the drill. The feed mechanism in the boring tool will move the boring bar.

(10) Stop the drill. Move the feed control lever to the "off" position. Pull up on the drive shaft to remove the tool bit from the bore.

(11) Remove the boring tool from the pump body. Make sure the tool bit moves through the slot in the guide bushing. Do not hit the tool bit against the guide bushing.

(12) Remove the guide bushing. Clean the metal particles from the pump body.

(13) Measure the bore in the bushings.

j. Cut the bore in the bushings that are in the cover.

(1) Repeat Steps i (1) through (3) for the bushings in the body.

(2) Install the pump cover to the body.

(3) Put the pump on a work bench with the cover down.

(4) Install the boring tool to the pump body. Use the long capscrews and nuts to fasten the tool to the body.

(5) Install the boring bar through the guide bushing. Do not damage the tool bit.

(6) With the feed control lever in the "off" position, move the drive shaft down until the tool bit touches the bushing in the cover.

(7) Hold a new bushing and a 1/16 inch (1.59 mm) feeler gauge against the drive shaft, at the top of the boring tool body. Move the stop collar down against the feeler gauge. Tighten the set screw in the stop collar. Move the feed lever to the "on" position and remove the feeler gauge and bushing.

(8) Start the drill and cut the bore in the bushing.

(9) Stop the drill when the stop collar on the drive shaft is against the body of the boring tool.

(10) Move the feed control lever to the "off" position.

(11) Pull the drive shaft up to remove the tool bit from the bushing. Move the lever to the "on" position.

(12) Remove the boring tool from the pump body. Do not damage the tool bit.

(13) Remove the cover from the body.

(14) Remove the guide bushing. Clean all metal particles from the body and cover.

(15) Measure the inside diameter of the bushing.

| | Worn Limit | New Minimum | New Maximum |
|---|---|---|---|
| Bushing Inside Diameter | 0.6185 in (15.710 mm) | 0.6165 in (15.659 mm) | 0.6175 in (15.684 mm) |
| Idler and Drive Shaft Outside Diameter | 0.6145 in (15.608 mm) | 0.615 in (15.62 mm) | 0.6155 in (15.634 mm) |

(16) Check for restricted or plugged lubricating oil pump signal orifice.

(17) Remove the oil pressure signal line (12, FIGURE 3-65) and the 1/8 inch NPTE adapter (13) from the lubricating oil pump cover (23).

(18) Use a wire that is 0.040 inch (1.0 mm) or less in diameter to clean the signal orifice in the pump cover.

(19) Use solvent and compressed air to wash the debris from the signal orifice and the pressure regulator bore in the lubricating oil pump.

(20) Clean the inside of the signal line (12) and the 1/8 inch NPTE adapter (13) with solvent and compressed air.

(21) Replace the 1/8 inch NPTE adapter (13) and the oil pressure signal line (12).

ASSEMBLY (Refer to FIGURE 3-64).

a. Apply a coat of lubricating oil to the large outside diameter of the idler shaft (26).

b. Install the large outside diameter of the shaft (26), from the gear pocket side of the body (31), into the bore in the pump body.

c. Use gear and spacer mandrel and an arbor press to push the shaft (26) into the bore.

**NOTE**

See Table 3-5 and FIGURE 3-68 for the correct idler shaft protrusion after it is installed in the pump body.

d. Apply a coat of lubricating oil to the inside diameter of the driven gear (27, FIGURE 3-64). Install the gear (27) onto the drive shaft (30). Use an arbor press to push the gear (27) onto the shaft (30). See Table 3-5 and FIGURE 3-68 to find the correct amount of protrusion .the drive shaft must have after the gear is installed.

Table 3-5. Oil Pump Shaft Limits - Inch (mm)

| | Minimum | Maximum | |
|---|---|---|---|
| Single Oil Pump<br>Drive Shaft<br>Protrusion 1 | 0.855<br>(21.72) | 0.875<br>(22.22) | |
| Idler Shaft<br>Protrusion 2 | 0.720<br>(18.29) | 0.740<br>(18.80) | |
| Drive Shaft End<br>3 Movement | 0.0002<br>(0.05) | 0.0005<br>(0.13) | SINGLE |

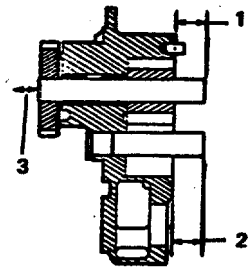


*FIGURE 3-68. Limits.*

e. Install the drive shaft (30) from the gear pocket side of the pump body, into the bore in the pump body (31). Apply a coat of lubricating oil to the inside diameter of the drive gear(s) (34). Put the gear (34) on the shaft (30) on the side of the body opposite to the gear pockets; use an arbor press to push the gear (34) onto the shaft (30). There must not be-more than 0.012 inch (0.030 mm) clearance between the gear (34) and the body (31).

f. Apply lubricating oil to the inside diameter of the idler gear (25). Install the idler gear onto the idler shaft (26).

g. Apply clean lubricating oil to the gears, bushings, and shafts.

h. Install plunger (6), spring (5), plug (4), cap (3), washer (2), and capscrew (1) into the pump body (31). Tighten the capscrew (1) to 30 to 35 ft-lb torque.

i. Install the cover (16) with capscrew (17) and gasket (15) to the pump cover (14). Install cover (14) with capscrews (21). Hit the cover lightly with a rubber hammer to push the cover onto the dowels. Install the capscrews (17) and lockwashers so that the cover is held to the body. Tighten the capscrews to 30-35 ft-lb torque. Turn the gears to make sure they move freely in the pump.

REPLACEMENT

a. Install gasket (32) onto the mounting flange of the oil pump.

b. Position the pump onto the mounting hole in the cylinder block. Make sure that the gear teeth of the pump align with the camshaft gear teeth.

c. Install the capscrews (19, 20) and lockwashers (18) to fasten the pump to the cylinder block. Tighten the capscrews to 35 to 45 ft-lb torque.

d. Connect the oil inlet and outlet lines to the pump.

e. Operate the engine (TM 55-1905-223-10) and check for leaks and for proper oil pressure at operating temperature.

## 3-24. Replace Camshaft Group

**This task covers:**

**a. Removal** **b. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's, rail and marine diesel engines, 5180-00-629-9783
Camshaft installation pilots P/N 3375268
Main bearing cap puller P/N ST-1178
Bushing, Inserter P/N 3376637
Bushing driver kit P/N 3376633
Dial indicator, 5210-00-277-8840

Equipment Condition

Accessory drive pulley removed (para. 3-19).
Cam followers removed (para. 3-18).
Gear cover assembly removed (para. 3-20).

Materials/Parts

Lubriplate 105 or equivalent, Item 11, Appendix C
Rubber bands, Item 29, Appendix C
New camshaft P/N 3049024

### REMOVAL

a. Install four camshaft pilots (1, FIGURE 3-69) over the outer base circle of the valve lobes between the camshaft journals (FIGURE 3-69).

b. Use a rubber band (3) to hold the installation pilots (1) in place. The rubber band must straddle the valve lobe (FIGURE 3-69).

c. Use one hand to slowly rotate and pull the camshaft (2) from the cylinder block and the other hand to balance the camshaft (2) as it is removed.

d. Remove the camshaft thrust bearing (4, FIGURE 3-70) from the camshaft.

### REPLACEMENT

a. Apply a film of Lubriplate 105 or its equivalent to both sides of the camshaft thrust bearing (4, FIGURE 3-70).

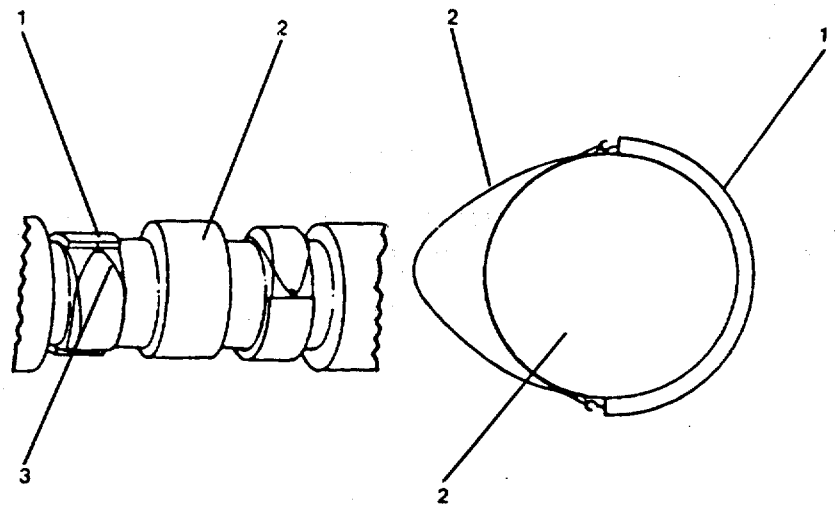


*FIGURE 3-69. Holding Camshaft Pilots in Place.*

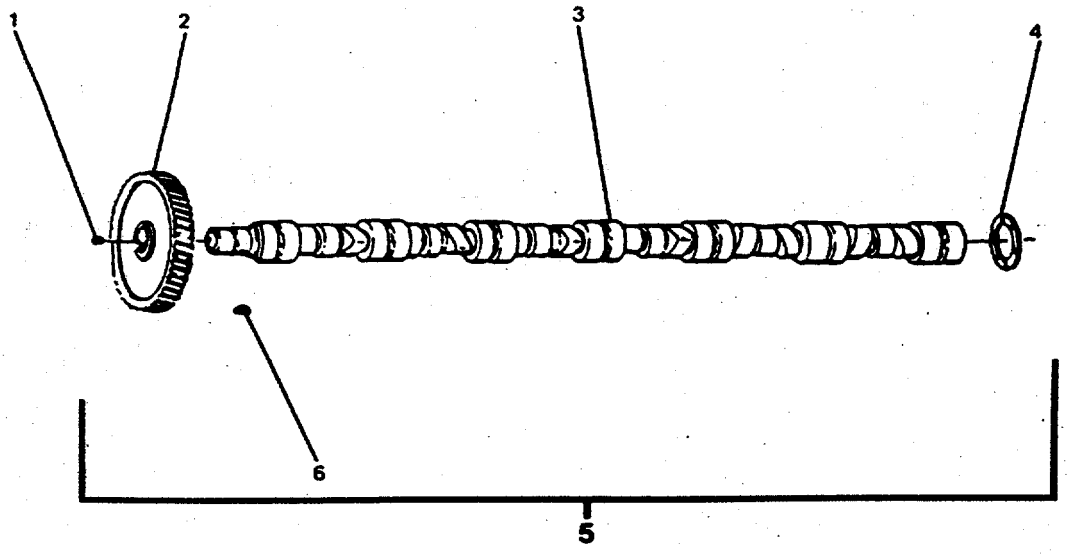


*FIGURE 3-70. Camshaft Group.*

**CAUTION**

The oil grooves on the thrust bearing must be toward the camshaft gear to prevent bearing failure.

b. Install the thrust bearing (4) on the camshaft (3).

c. Install four camshaft pilots (1) over the outer base circle of the valve lobes between the camshaft journals (FIGURE 3-69).

d. Use a rubber band (3) to hold the installation pilots (1) in place. The rubber band (3) must straddle the valve lobes.

e. Apply a film of Lubriplate 105 or its equivalent to the camshaft journals and the camshaft bushings.

f. Rotate the camshaft slowly as it is being installed in the cylinder block.

g. Align the "O" mark on the camshaft gear with the "O" mark on the crankshaft gear (FIGURE 3-70).

h. After aligning the "O" marks, push the camshaft in the bore until the thrust bearing fits against the cylinder block.

**CAUTION**

Do not allow the rubber bands to fall into the crankshaft cavity of the cylinder block when removing the installation pilots.

i. Remove the camshaft installation pilots (1, FIGURE 3-69).

j. Use a dial indicator to check the backlash between the camshaft gear (1, FIGURE 3-71) and the crankshaft gear (2).

(1) Put the tip of the dial indicator (1, FIGURE 3-72) against a tooth on the camshaft gear (2).

(2) Turn the camshaft gear by hand as far as it will freely move, and set the dial indicator at "O" (zero).

(3) Turn the camshaft gear (2) by hand in the opposite direction as far as it will freely move, and read the dial indicator (1). Backlash between the camshaft and the crankshaft gears should be minimum 0.002 inch (0.05 mm); the maximum should be 0.02 inch (0.50 mm).

k. Install the gear cover and PTO housing assembly (paragraph 3-20).

l. Lubricate the valve and the injector lobes with engine lubricating oil, and install the cam follower assemblies (paragraph 3-18).

m. Install the accessory drive pulley (paragraph 3-19).

n. Operate the engine (TM 55-1905-223-10) until it reaches a temperature of 180°F (80°C), and check for coolant or lubricating leaks.

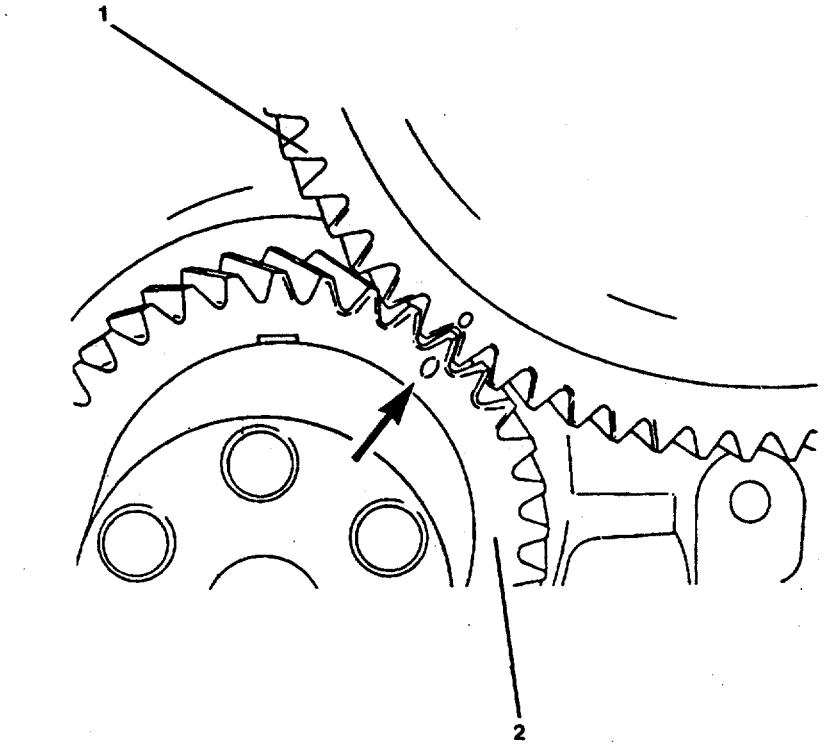


*FIGURE 3-71. Aligning Gear.*

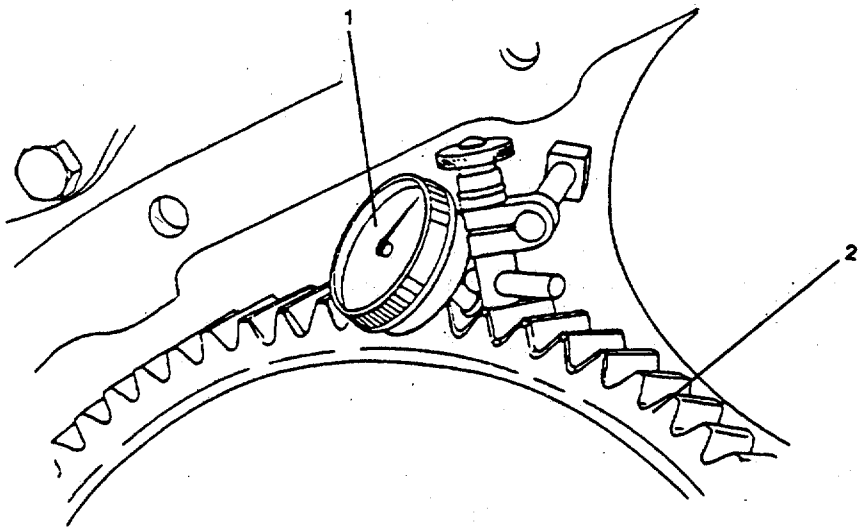


*FIGURE 3-72. Checking Gear Backlash.*

## 3-25. Replace/Repair Connecting Rod and Piston Group.

**This task covers:**

**a. Removal b. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Piston ring compressor P/N 3822736
Piston ring expander P/N ST-763
Connecting rod guide pins P/N 3375601
Torque wrench kit P/N 3377216
Piston ring compressor P/N 3375167

Equipment Condition

Oil pan removed (para. 2-44).
Cylinder heads removed (para. 2-41).

Materials/Parts

Lubricating oil, Item 1, Appendix C
Lubriplate 105 or equivalent,
Item 11, Appendix C
Connecting rod P/N 3013930
Engine piston set P/N 3801770

REMOVAL

a. Rotate the crankshaft to position two connecting rods at bottom dead center (BDC) (FIGURE 3-73) .

b. Loosen, but do not remove, the connecting rod capscrews (5, FIGURE 3-74) .

c. Use a rubber hammer to hit the connecting rod capscrews (5) to loosen the cap (6) from the dowel (4) in the connecting rod (7).

d. Check to see if the connecting rod (7) and the cap ('6) have matching numbers stamped on them and that they are in the correct cylinder location.

e. Remove the connecting rod capscrews (5) and cap (6).

f. Remove the lower rod bearings (3).

g. Mark the cylinder number and the letter "L" in the flat surface of the bearing tang.

h. Push the rod away from the crankshaft, until piston rings are outside cylinder.

i. Remove the piston and rod assembly.

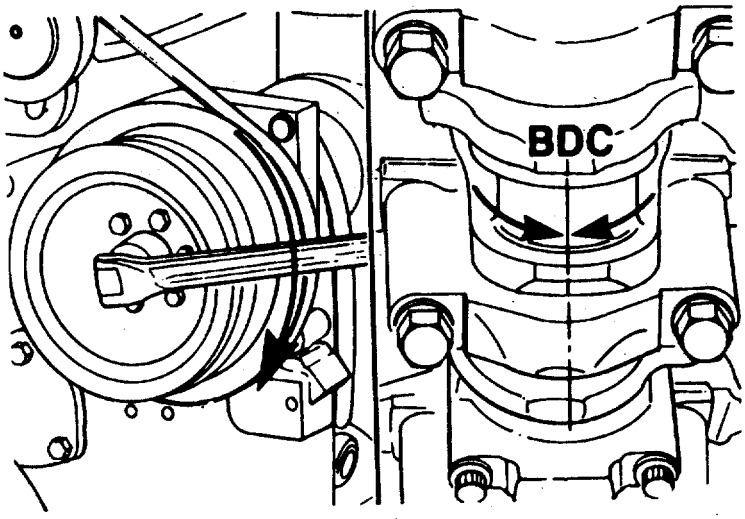


*FIGURE 3-73. Rotating Crankshaft to Bottom Dead Center (BDC).*

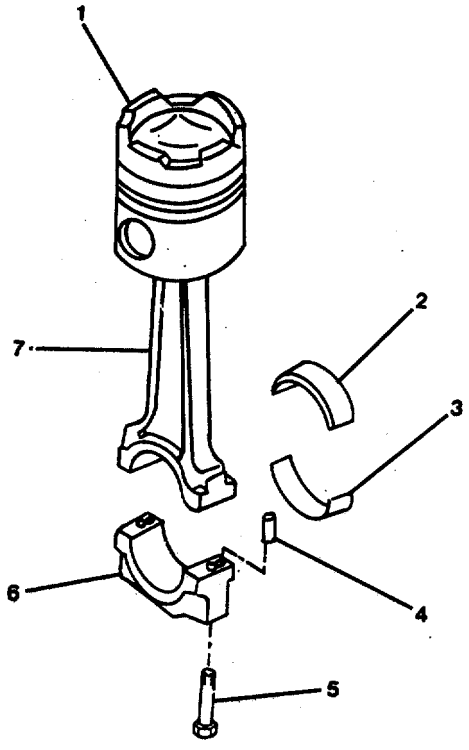


*FIGURE 3-74. Connecting Rod and Piston Group.*

NOTE

- To prevent increased wear, the piston and connecting rod assemblies must be installed in the same cylinder from which they were removed.
- The pistons must have the cylinder numbers stamped on the piston top toward the camshaft side of the engine.

j. If the piston is not previously marked, mark the cylinder number on the top of each piston on the camshaft side as the assembly is removed.

k. Place the rod and piston assemblies in a container of clean lubricating oil to protect them from damage.

NOTE

The cylinder number is stamped on the rod and the cap. When the rods and the caps are installed in the engine, the numbers on the rods and the caps must match and be installed on the same side of the engine.

l. Remove the upper rod bearing (2).

m. Mark the cylinder number and the letter "U" in the flat surface of the bearing tang.

REPLACEMENT

a. Install the upper bearing shell (2) in the connecting rod (7). If used bearing shells are to be installed, each bearing shell must be installed in its original location.

NOTE

The tang of the bearing shell must be in the slot of the rod,

b. Use clean Lubriplate 105 or its equivalent to lubricate the bearing shell (2).

c. Apply a heavy film of clean engine oil to the cylinder liner.

NOTE

The ring gap of each ring must not be aligned with the piston pin or with any other ring.

d. Position the ring gaps as shown in FIGURE 3-75.

(1) (Top) Ring (A)

(2) Second Ring (B)

(3) Third Ring (C)

(4) (Bottom) Oil Ring (D)

(5) Piston Pin (E)

e. Install the connecting rod guide pins (1, FIGURE 3-76) .

f. Use piston ring compressor to compress the rings (FIGURE 3-77) .

g. Using the accessory drive pulley, rotate the crankshaft to position the connecting rod journal at "BDC" (bottom dead center).

**CAUTION**

To avoid piston damage, do not use a metal object to push the piston in the liner.

NOTE

The tang of the connecting rod must be toward the camshaft side of the cylinder block.

**CAUTION**

Do not use a hammer or equivalent to install the piston in the cylinder liner. The piston rings can be damaged.

h. Using piston ring compressor (FIGURE 3-77), install the connecting rod in the cylinder liner, and push the piston down. If the piston does not move freely, remove the piston. Inspect for broken or damaged rings.

i. Use the guide pins (1, FIGURE 3-76) to pull the connecting rod (2) against the crankshaft.

j. Remove the guide pins (1).

**CAUTION**

The rod cap number must match the number on the connecting rod and must be installed with the numbers aligned to prevent damage to the connecting rods and the crankshaft. The slot in the cap and the rod must be toward the camshaft side of the cylinder block.

NOTE

The tang of the bearing must be in the slot of the cap.

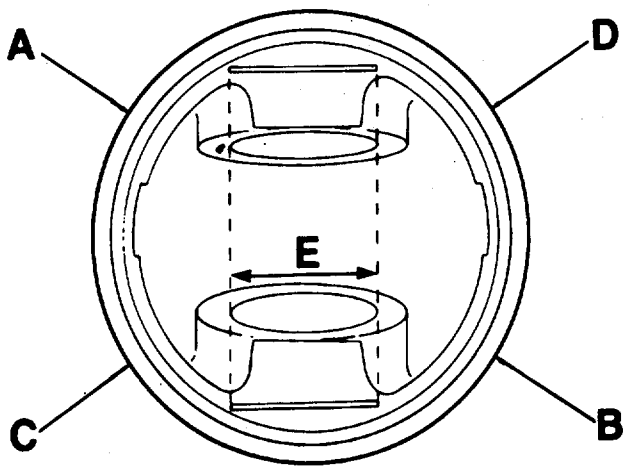


*FIGURE 3-75. Positioning Ring Gaps.*

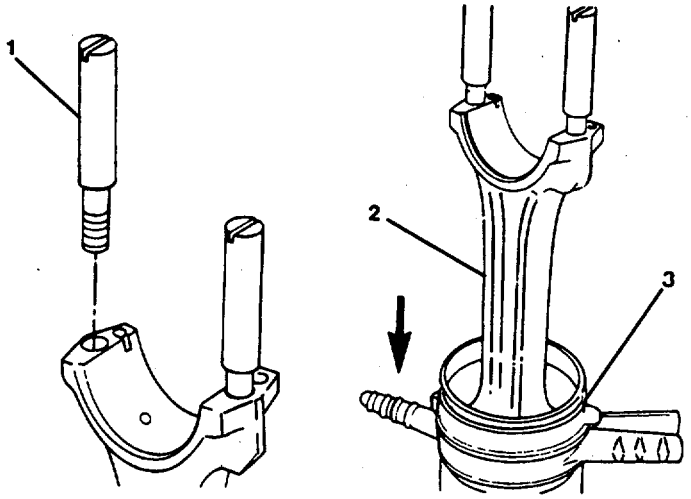


*FIGURE 3-76. Connecting Rod Guide Pins and Piston Ring Compressor.*

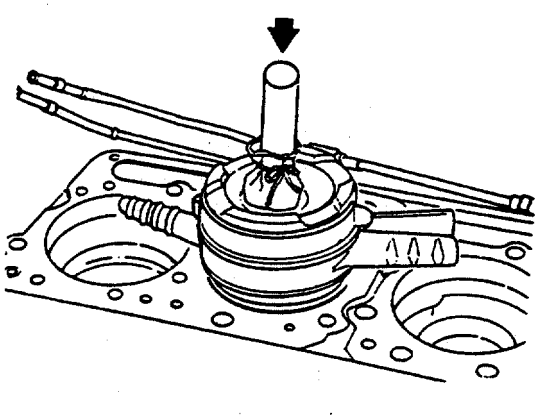

*FIGURE 3-77. Using Piston Ring Compressor.*

k. Install the lower rod bearing (3, FIGURE 3-74) in the connecting rod cap (6).

l. Lubricate the bearing shell (3) with Lubriplate 105 or its equivalent. Lubricate the connecting rod capscrew (5) threads and the washer face with the engine lubricating oil.

**CAUTION**

The connecting rod cap and rod numbers must match (FIGURE 3-78) .

m. Install the connecting rod caps (6, FIGURE 3-74) and the capscrews.

n. Tighten the rod capscrews (5) in alternating sequence to the following torque values:

(1) Tighten to 75 ft-lb torque.

(2) Tighten to 170 ft-lb torque.

o. Measure the connecting rod side clearance. The side clearance must be between 0.0045 inch (0.114 mm) and 0.13 inch (3.30 mm).

NOTE

The connecting rod must move freely from side to side on the crankshaft journal. If the rod does not move freely, remove the rod cap and make sure the bearing shells are the correct size. Check for dirt or damage on the crankshaft and the bearing shells.

p. Install the oil pan (paragraph 2-44).

q. Install the cylinder heads (paragraph 2-41).

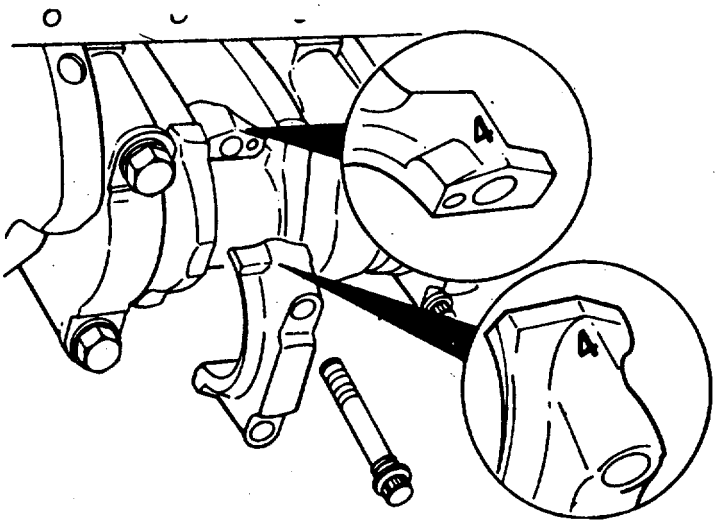


*FIGURE 3-78. Matching Rod Cap Numbers.*

**CAUTION**

The lubricating oil system must be primed before operating the engine after any internal engine repairs to avoid internal component damage. Do not prime the system from the bypass filter; the filter will be damaged.

r. Remove the pipe plug from the lubricating oil pump cover.

s. Install the priming pump oil supply hose. Use clean engine lubricating oil out of a bucket or container. Supply oil to the crossover oil passage.

t. Allow the oil to flow until the oil pressure gauge indicates a maximum pressure of 30 psi (210 kPa) to prime the lubricating oil system. Remove the priming pump hose and replace the pipe plug.

u. Fill the oil pan (PMCS Table 2-1, Item 12).

v. Run the engine (TM 55-1905-223-10) until it reaches a temperature of 180°F (80°C) and check for leaks.

## 3-26. Replace/Repair Flywheel and Flywheel Housing Assembly.

**This task covers:**

**a. Removal b. Repair c. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engines,
5180-00-629-9783
Torque wrench kit
P/N 3377216
Lifting sling
P/N 3375958
Combination wrench set,
metric 10mm to 24mm,
5120-01-046-4979
Capscrew puller, 1/2-13 x 1-1/2
Guide studs, 5/8-15 x 6 inch
and 5/8-18 x 4 inch
Dial indicator gauge and
dial gauge attachment
5210-00-277-8840, ST-1193
Mandrel kit P/N ST-1325

Equipment Conditions

Bowthruster water jet shaft coupling removed (TM 55-1905-223-24-18).
Friction clutch assembly removed (para. 3-22).
Lubricating oil drained (Table 2-1, Item 12).
Starting motor removed if housing is to be removed (para. 2-21).

Materials/Parts

Lubricating oil, Item 26, Appendix C
Flywheel P/N 3023510
Rear crankshaft seal P/N 3006737
Gaskets P/N 3021735 and P/N 40662-A
Electrical coil P/N 3034572
Chalk, Item 3, Appendix C
Wiping rags, Item 2, Appendix C
Crocus cloth, Item 14, Appendix C
240 grid emery cloth, Item 33, Appendix C

REMOVAL

a. Remove the flywheel.

(1) Hold the flywheel to prevent rotation.

(2) Install two 1/2-13 x 1-1/2 puller capscrews (5, FIGURE 3-79) which have a minimum of 1-1/4 inch threaded area at points (1) and (2).

(3) Remove capscrews (7) and install two 5/8-18 x 6 inch guide studs (6).

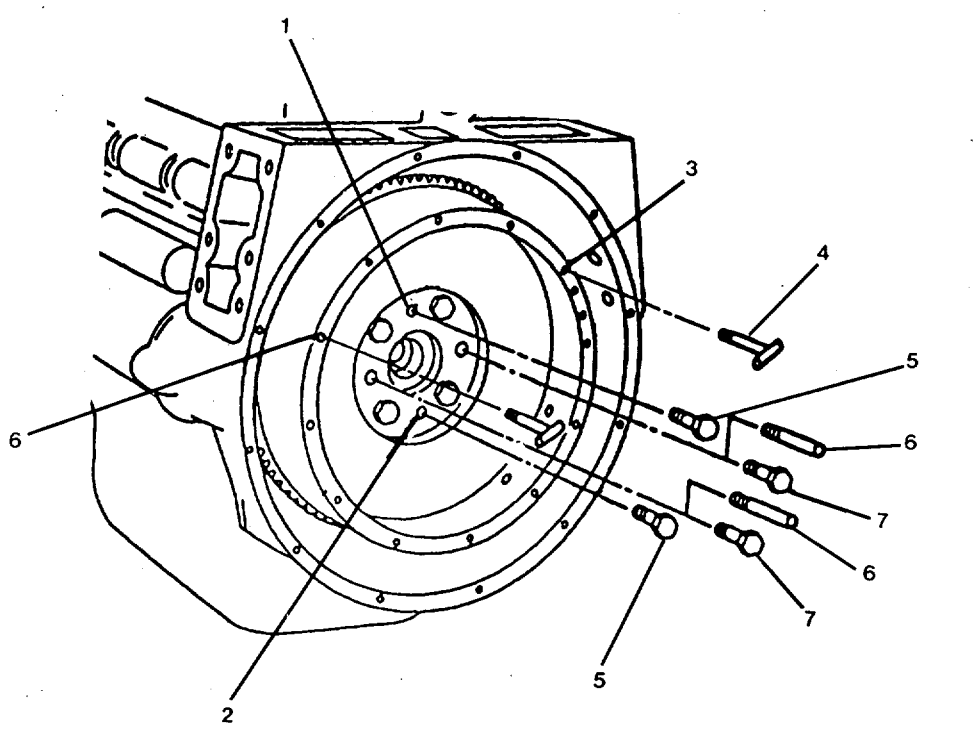


*FIGURE 3-79. Guide Studs and T-Handles.*

(4) Determine the capscrew thread size, and install two T-handles (4) in the flywheel at points (3) and (5).

WARNING

Because the flywheel weighs more than 50 lb (23 kg), two people or a hoist will be required to lift the flywheel to avoid personal injury.

(5) Remove the remaining four flywheel mounting capscrews (7).

(6) Tighten capscrews (5) in alternating sequence to loosen the flywheel (FIGURE 3-80) .

(7) Remove the flywheel (FIGURE 3-81) .

(8) Use a mandrel and a hammer to remove the pilot bearing from the flywheel.

b. Remove the flywheel housing.

(1) Before removing the housing, loosen the lock nut and unscrew the magnetic coil (13, FIGURE 3-80) pickup and wiring from the top of the housing (5).

(2) Loosen the oil pan mounting capscrews four to five turns (FIGURE 3-82) .

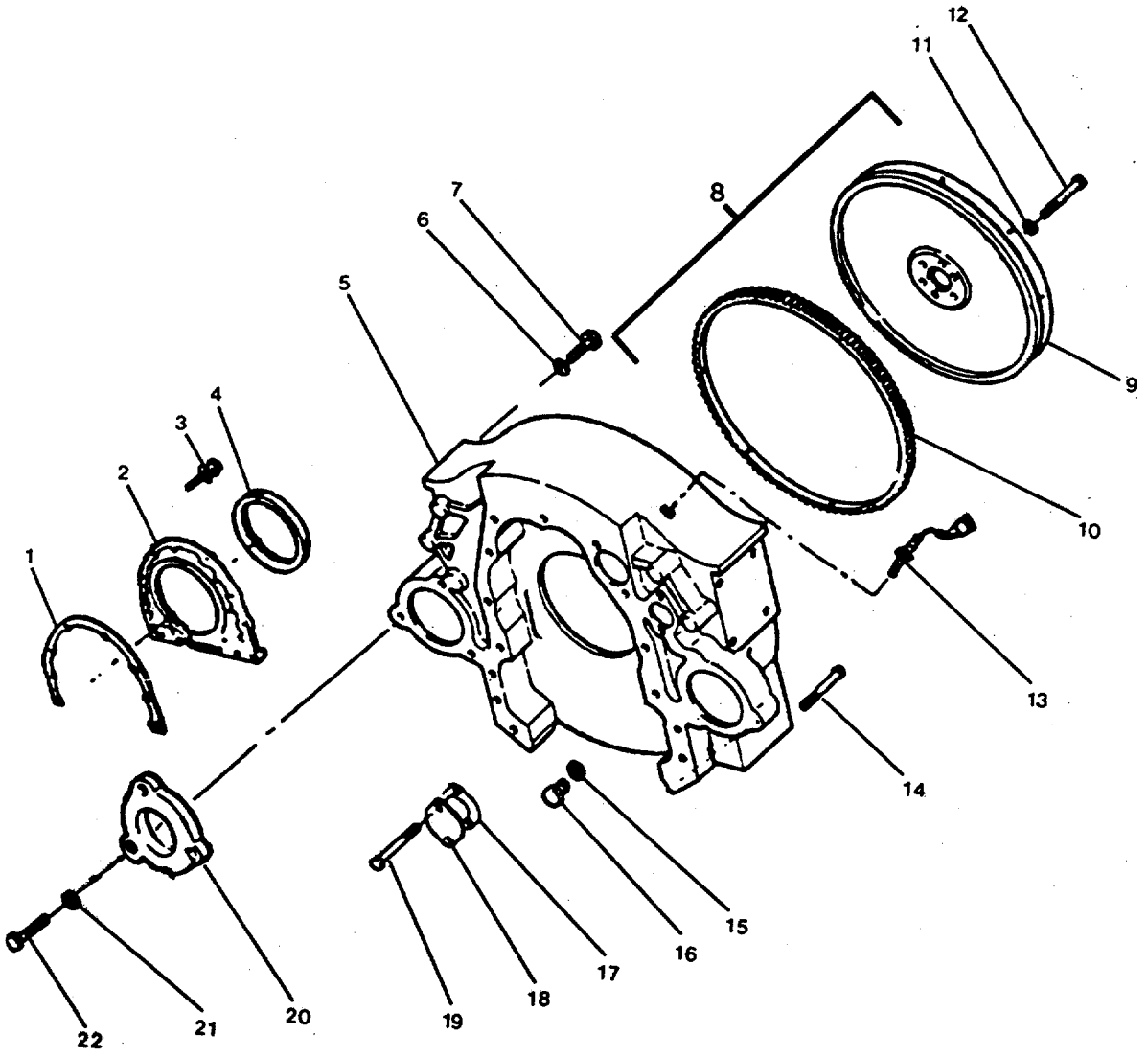


*FIGURE 3-80. Flywheel and Flywheel Housing Group.*

(3) Remove the four oil pan mounting capscrews which secure the oil pan to the rear cover (FIGURE 3-82) .

**CAUTION**

Use extreme care when releasing the oil pan gasket from the rear cover to prevent damage to the gasket. If the gasket is damaged, the oil pan must be removed and the gasket replaced (paragraph 2-44).

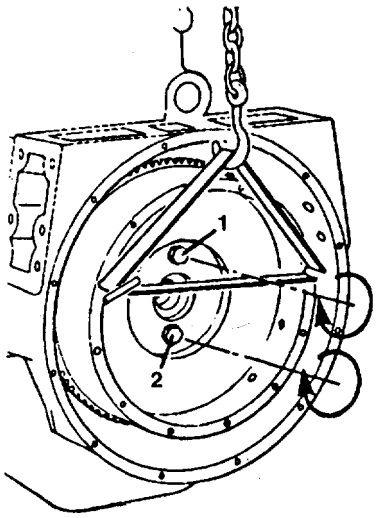


*FIGURE 3-81. Removing Flywheel.*

(4) Insert a feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge or the shim stock back and forth to release the gasket from the rear cover.

(5) Remove the capscrews from the rear cover, and remove the cover from the crankshaft flange (FIGURE 3-83) .

(6) Remove the crankshaft seal from the rear cover.

(7) Use the lifting fixture to support the rear of the engine.

(8) Remove the capscrews and both rear engine mounts (FIGURE 3-84) .

(9) Remove capscrews (1) and (2), install two 5/8-18 x 4 inch guide studs (FIGURE 3-85) .

(10) Remove the remaining capscrews.

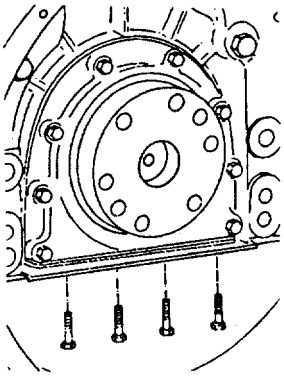

*FIGURE 3-82. Rear Cover Capscrews.*

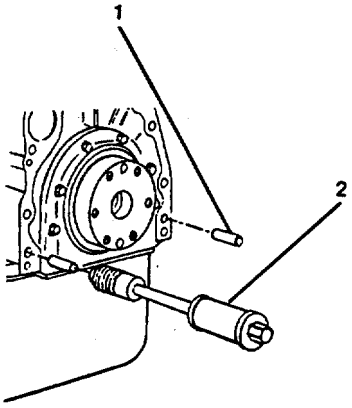


*FIGURE 3-83. Flywheel Housing Redowel.*

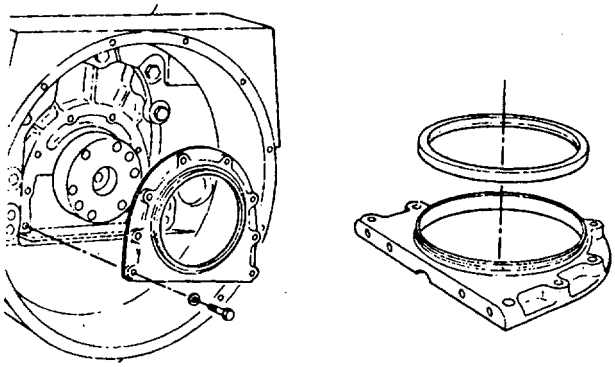

*FIGURE 3-84. Crankshaft Flange Cover.*

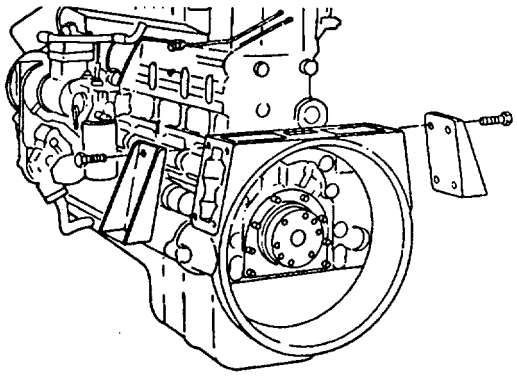

*FIGURE 3-85. Removing Mounts.*

(11) Use a rubber hammer to loosen the housing from the dowels in the cylinder block.

(12) Remove the flywheel housing.

(13) Remove electrical coil from the top at flywheel housing.

REPAIR

Repair is by replacement of flywheel, rear crankshaft seal, gaskets and electrical coil.

REPLACEMENT

a. Flywheel housing redowel to cylinder block.

(1) Use dowel pin extractor (2, FIGURE 3-83) and remove the two dowel pins (1) from cylinder block.

b. Install the flywheel housing, as follows:

**CAUTION**

If a new flywheel housing is being installed, the dowels must be removed from the cylinder block prior to installing the housing to prevent damage to the housing. The housing must be doweled with an oversize dowel after it has been aligned.

NOTE

- If the dowel pins were removed from the cylinder block, use a drill and reaming fixture to ream the dowel holes to the next oversize.
- Install the dowel pins. The dowels must be even with or 0.010 inch (0.25 mm) below the surface of the housing that is closest to the flywheel.

(1) Install two 5/8-18 x 4 inch guide studs (FIGURE 3-86) in the cylinder block to help support and align the housing during installation (FIGURE 3-87) .

(2) Install the flywheel housing over the guide studs.

(3) Install the capscrews, and tighten to 150 ft-lb (205 N•m) torque in the sequence shown (FIGURE 3-88) .

(4) Measure the flywheel housing bore alignment.

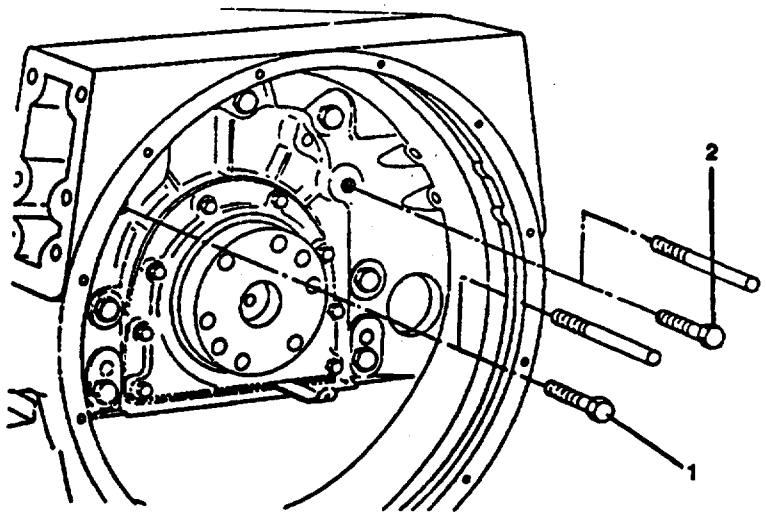


*FIGURE 3-86. Flywheel Housing Guide Studs.*

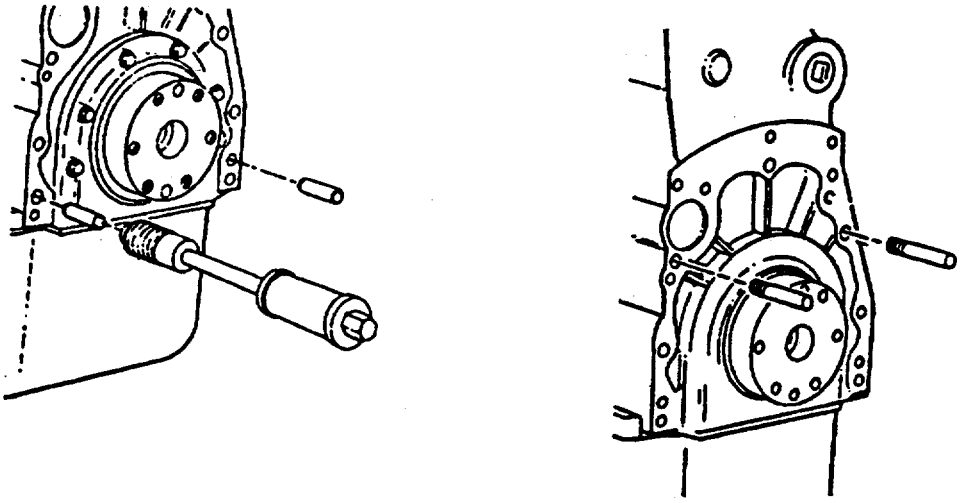

*FIGURE 3-87. Housing Alignment.*

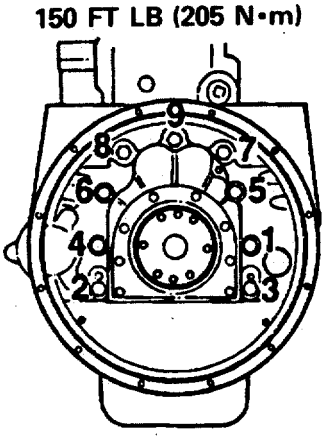


*FIGURE 3-88. Flywheel Housing Torque Sequence.*

**CAUTION**

The flywheel housing bore and the surface must be in alignment with the crankshaft to prevent possible damage to the engine.

(a) Use chalk to mark the housing at the 12 o'clock, 3 o'clock, 6 o'clock, and 9 o'clock positions.

(b) Use the dial gauge indicator and the dial gauge attachment to measure the bore alignment. Attach the dial indicator to the crankshaft as shown (FIGURE 3-89) .

NOTE

The indicator arm must be rigid for an accurate reading. It must not sag.

(c) Put the indicator at the 12 o'clock position. Adjust the dial indicator until the needle points to "0" (zero).

(d) Use the accessory drive shaft to rotate the crankshaft in a clockwise direction (FIGURE 3-90) .

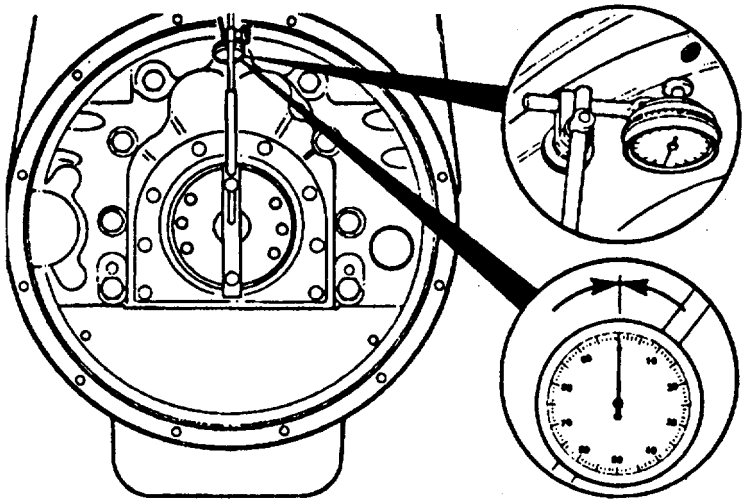

*FIGURE 3-89. Attaching Dial Indicator to Crankshaft.*

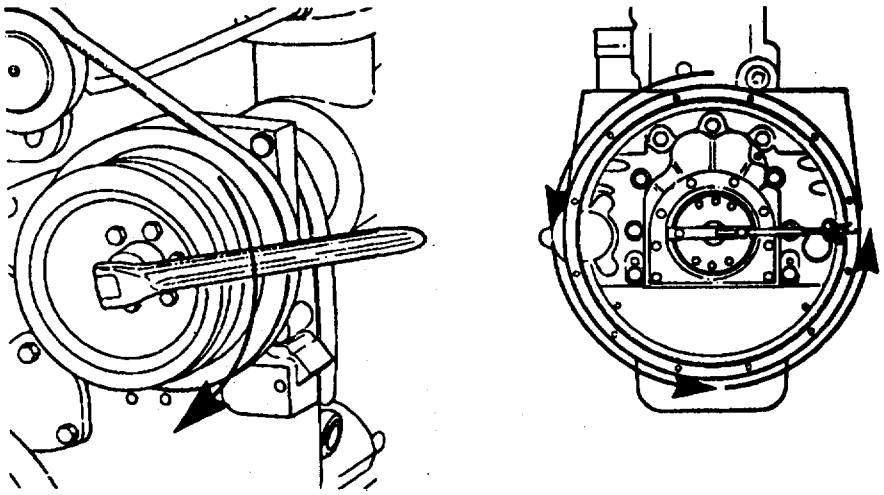

*FIGURE 3-90. Rotating Crankshaft.*

(e) Record the indicator reading at three different points: 3 o'clock, 6 o'clock, and 9 o'clock.

(f) Continue rotating the crankshaft until the dial indicator is at the 12 o'clock position.

(g) Check the dial indicator to make sure the needle still points to "O" (zero).

NOTE

If the dial indicator is not pointing to "O" (zero), check the tightness of the indicator arm and repeat steps (a) through (g) above.

(h) Determine the total indicator run out (TIR) as follows:

| | mm | in |
|---|---|---|
| Example: | | |
| 12 o'clock | ( 0.00) | 0.00 |
| 3 o'clock | (+ 0.08) | + 0.003 |
| 6 o'clock | (- 0.05) | - 0.002 |
| 9 o'clock | (+ 0.08) | + 0.003 |
| Equals TIR | ( 0.13) | 0.005 |

(i) The maximum allowable total indicator reading (TIR) depends on the diameter of the housing bore (FIGURE 3-91) .

(j) Refer to Table 3-10 for allowable total indicator reading (TIR).

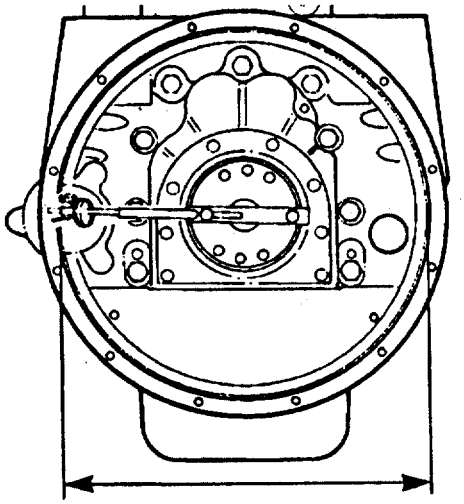

*FIGURE 3-91. Housing Bore Diameter.*

Table 3-10. Allowable Total Indicator Reading (TIR) Flywheel Housing Bore and Face

| SAE No. | Bore Diameter (mm) | Bore Diameter in | Bore Location Tolerance (mm) | Bore Location Tolerance in |
|---|---|---|---|---|
| 00 | (787.40 to 787.64) | 31.000 to 31.010 | (0.30) | 0.012 TIR |
| 0 | (647.70 to 647.95) | 25.500 to 25.510 | (0.25) | 0.010 TIR |
| 1/2 | (584.00 to 584.20) | 23.000 to 23.008 | (0.25) | 0.010 TIR |
| 1 | (534.27 to 534.40) | 20.125 to 20.130 | (0.20) | 0.008 TIR |
| 2 | (447.68 to 447.80) | 17.625 to 17.630 | (0.20) | 0.008 TIR |
| 3 | (409.58 to 409.70) | 16.125 to 16.130 | (0.20) | 0.008 TIR |

(k) If the bore alignment does not meet the specifications, loosen the housing capscrews. Tighten the capscrews again, and measure the bore alignment again.

(l) If the alignment is not within specifications and the bore is round, the housing can be shifted.

(m) If the alignment is not within specifications and the bore is not round, the housing must be replaced.

(5) Measure the flywheel housing face alignment.

(a) Install the dial indicator as shown (FIGURE 3-92) .

**CAUTION**

The tip of the gauge must not enter the capscrew holes or the gauge will be damaged.

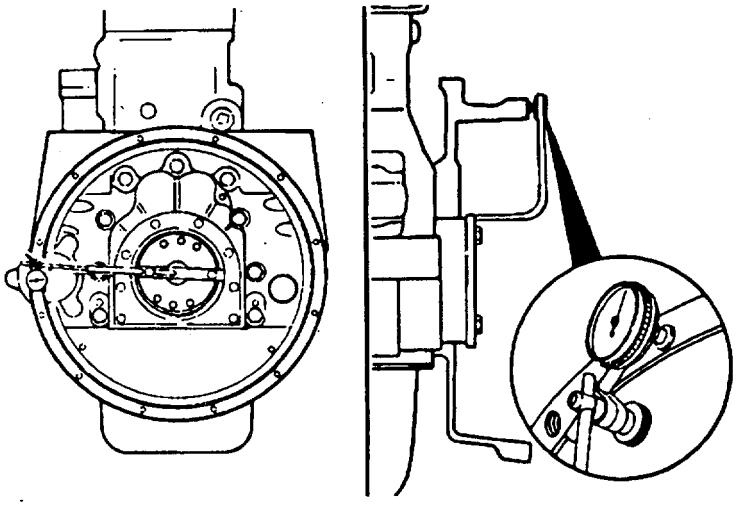

*FIGURE 3-92. Positioning Tip of Dial Indicator.*

(b) Put the tip of the dial indicator gauge against the flywheel housing surface.

(c) Use the accessory drive to rotate the crankshaft until the dial indicator is at the 12 o'clock position.

(d) Push the crankshaft toward the front of the engine. Adjust the dial on the indicator until the needle points to "0" (zero).

NOTE

The crankshaft must be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

(e) Use the accessory drive to rotate the crankshaft in the clockwise direction.

(f) Record the indicator reading at three different points: 3 o'clock, 6 o'clock, and 9 o'clock.

(g) Continue rotating the crankshaft until the dial indicator is at the 12 o'clock position.

(h) Check the dial indicator to make sure the needle still points to "0" (zero).

(i) Determine the total indicator run out (TIR) as follows:

| | mm | in |
|---|---|---|
| Example: | | |
| 12 o'clock | ( 0.00) | 0.00 |
| 3 o'clock | (+ 0.08) | + 0.003 |
| 6 o'clock | (- 0.05) | - 0.002 |
| 9 o'clock | (+ 0.08) | + 0.003 |
| Equals TIR | ( 0.13) | 0.005 |

(j) The maximum allowable total indicator reading (TIR) depends on the diameter of the housing bore. Refer to Table 3-10.

(k) If the alignment is not within specifications, remove the housing. Check for nicks, burrs, or foreign material between the block and the housing.

(l) Check the alignment again. If the alignment is not within specifications, the block or the housing is not machined correctly.

(6) Install the two rear engine mounts. Tighten the capscrews to 158 ft-lb torque.

(7) Remove the lifting fixture used to support the engine.

(8) Install a new rear crankshaft seal.

(a) Clean the gasket surface of the cylinder block and the rear cover.

(b) Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

(c) Use a clean cloth to clean the crankshaft flange.

(d) Install a new gasket on the cylinder block.

(e) Install the rear cover and the eight capscrews and washers. Tighten the capscrews just enough to hold the rear cover in position.

(f) Remove the pins from the crankshaft oil seal driver, and use the driver to align the rear cover with the crankshaft (FIGURE 3-93) .

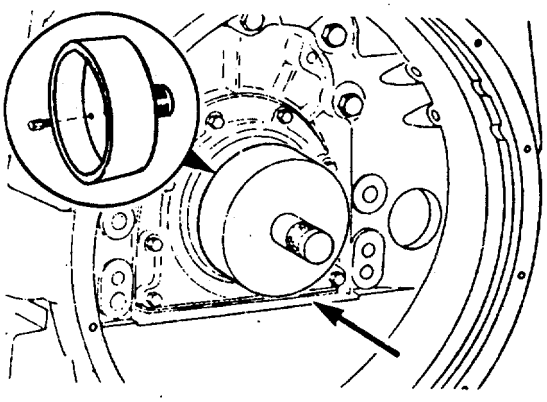

*FIGURE 3-93. Using Seal Driver.*

(g) Install the seal driver on the crankshaft flange and in the bore of the rear cover.

(h) Tighten the rear cover mounting capscrews to 35 ft-lb (45 N•m) torque, and remove the crankshaft oil seal driver (FIGURE 3-94) .

(i) Use a feeler gauge to make sure the rear cover is within 0.004 inch (0.10 mm) of being parallel with the oil pan flange of the cylinder.

(j) Trim the excess gasket material from the ends of the rear cover gasket so the gasket is even or does not extend more than 0.010 inch (0.25 mm) beyond the pan flange.

(k) Use the installation sleeve provided with the seal to install the seal on the crankshaft (FIGURE 3-95) .

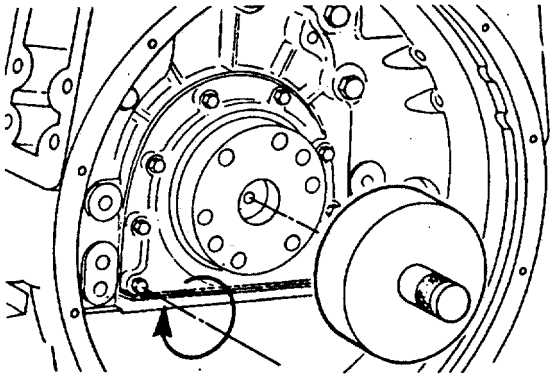

*FIGURE 3-94. Checking Rear Cover and Oil Pan Flange.*

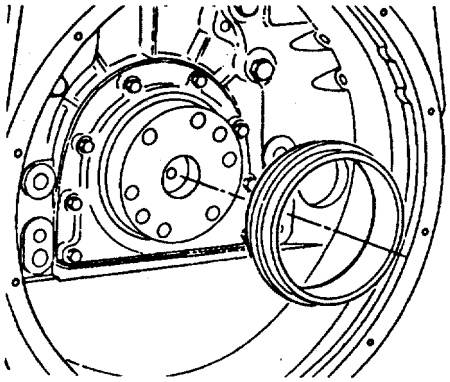

*FIGURE 3-95. Installation Sleeve.*

NOTE

Do not use any kind of lubricant to install the seal. The oil seal must be installed with the lip of the seal and the crankshaft clean and dry.

(l) Push the oil seal over the installation sleeve onto the crankshaft and remove the sleeve (FIGURE 3-95) .

(m) Install the pins in the crankshaft oil seal drive.

(n) Use the crankshaft oil seal driver to install the oil seal in the rear cover (FIGURE 3-96) .

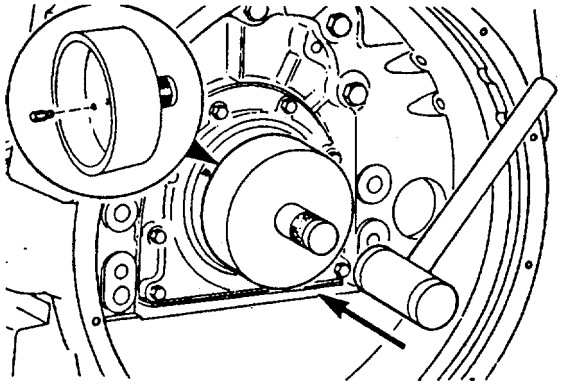

*FIGURE 3-96. Installing Seal With Driver.*

(o) Install the four capscrews which hold the oil pan to the rear cover.

(p) Tighten one of the 7/16-inch oil pan mounting capscrews on each side of the oil pan, halfway between the front and the rear of the oil pan, to 15 ft-lb (20 N•m) torque.

(q) Tighten the four 5/16-inch capscrews in the rear of the oil pan to 20 ft-lb (25 N•m) torque in the sequence shown (FIGURE 3-97) .

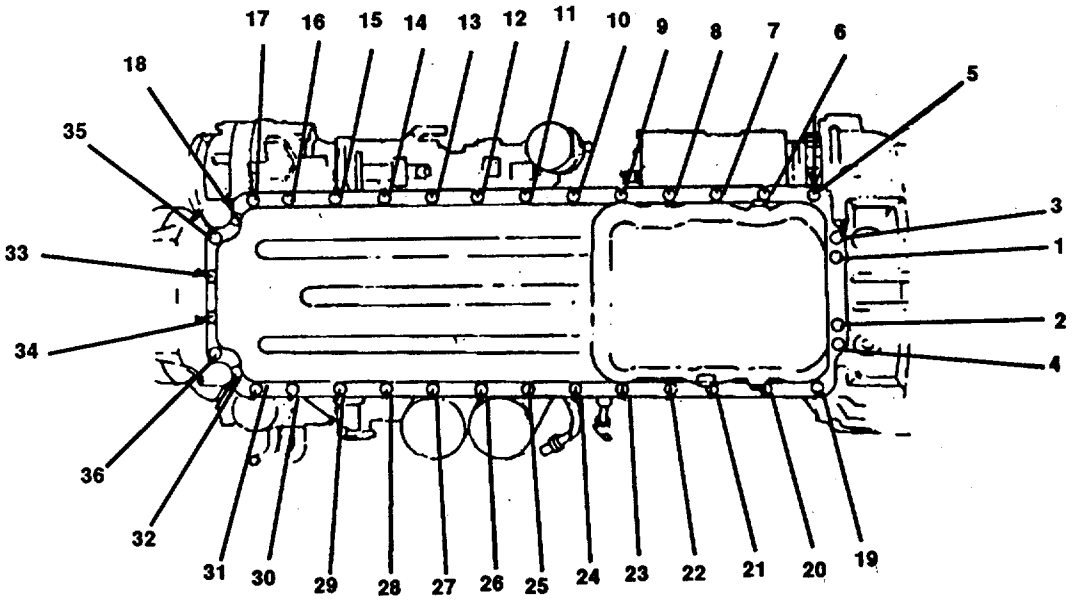


*FIGURE 3-97. Oil Pan Torque Sequence.*

(r) Tighten the thirty (32) 7/16-inch capscrews to 50 ft-lb (70 N•m) torque in the sequence shown.

(9) Install the flywheel.

c. Install the flywheel.

(1) Install the pilot bearing in the flywheel:

(a) Use a 240 grit emery cloth to clean the pilot bore.

(b) Use a mandrel and a hammer to install the pilot bearing.

NOTE

The pilot bearing must be installed flush with the pilot bore surface (FIGURE 3-98) .

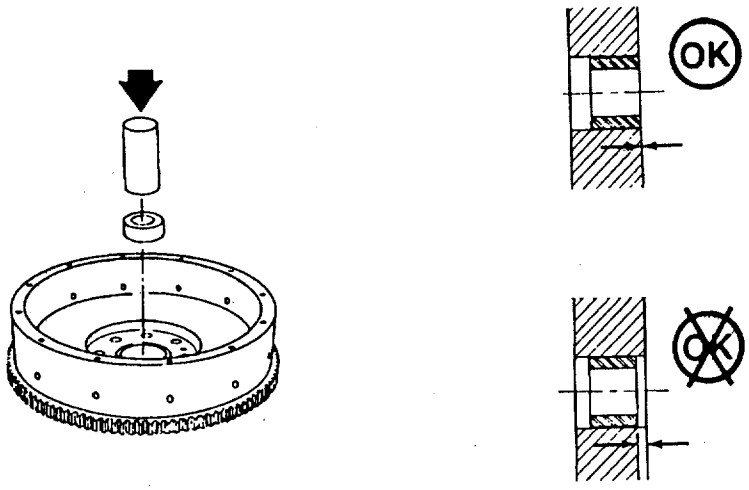


*FIGURE 3-98. Install Pilot Bearing.*

(c) Install two 5/8-18 x 6 inch guide studs in the crankshaft flange.

(d) Install two T-handles in the flywheel for lifting.

WARNING

Because the flywheel weighs more than 50 lb (23 kg), two people or a hoist will be required to lift the part to avoid personal injury.

(e) Install the flywheel on the guide stud.

(f) Lubricate the threads of the capscrews and the surface of the washers with 15W-40 engine lubricating oil.

(g) Install the four capscrews and washers.

(h) Remove the T-handles and the guide studs.

(i) Install the remaining two capscrews in the holes from which the guide studs were removed.

(j) Tighten the capscrews in a star pattern to 200 ft-lb (270 N•m) torque.

(2) Measure the flywheel bore runout.

(a) Install the attachment to the flywheel housing.

(b) Install the gauge on the attachment.

NOTE

Use a dial indicator gauge (1) or its equivalent and a gauge attachment (2) to inspect the flywheel bore (3) and the surface (4) runout (FIGURE 3-99) .

(c) Install the contact tip of the indicator against the inside diameter of the flywheel bore, and set the dial indicator at "0" (zero).

(d) Use the accessory drive shaft to rotate the crankshaft one complete revolution.

NOTE

The total indicator reading (TIR) must not exceed 0.0050 inch (0.127 mm).

(e) If the total indicator reading is greater than the specification, do the following:

1 Remove the flywheel.

2 Inspect the flywheel mounting surface for dirt or damage.

3 Inspect the crankshaft for dirt or damage.

4 Install the flywheel, and inspect the bore runout again (FIGURE 3-99) .

5 Replace the flywheel if the runout does not meet specifications.

(3) Measure the flywheel face runout.

(a) Install the contact tip of the indicator against the flywheel face, as close to the outside diameter as possible, to inspect the face (4) runout (FIGURE 3-100) .

(b) Push the flywheel forward to remove the crankshaft end clearance. Adjust the dial on the indicator until the needle points to "0" (zero).

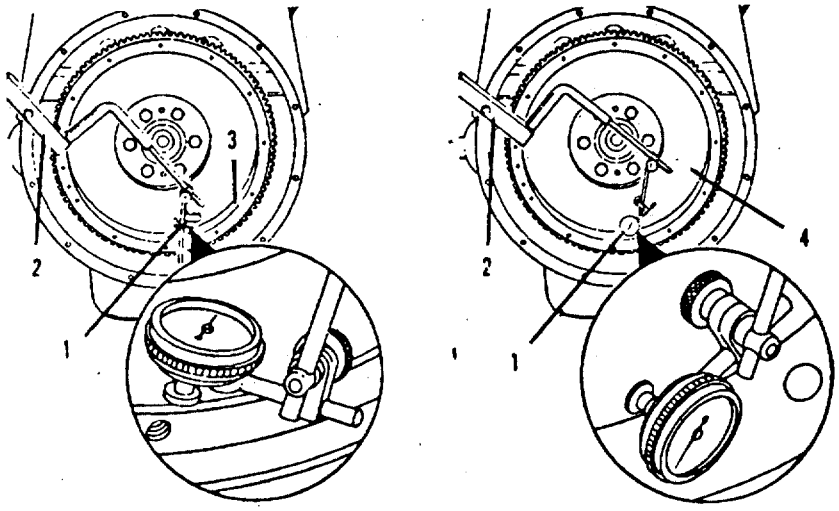


*FIGURE 3-99. Measuring Flywheel Bore Runout.*

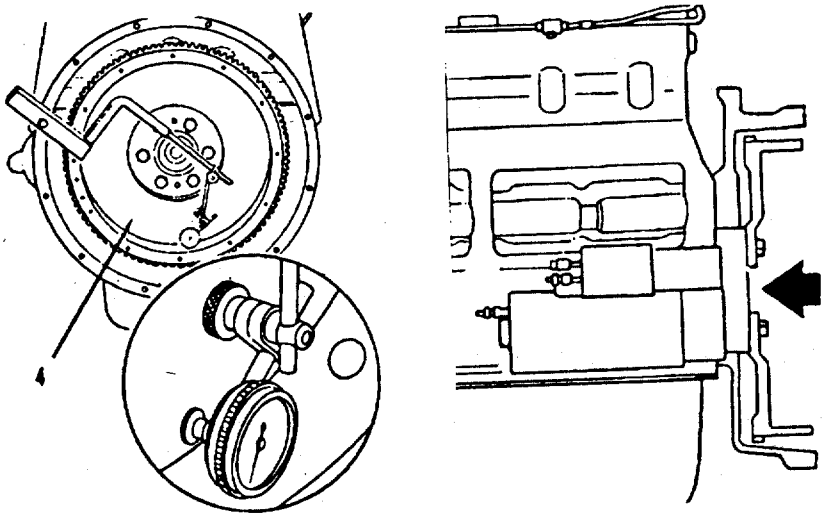


*FIGURE 3-100. Checking Flywheel Face Runout.*

(c) Use the accessory drive shaft to rotate the crankshaft one complete revolution. Measure the flywheel runout at four equal points on the flywheel.

NOTE

The flywheel must be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

(d) The total indicator reading (TIR) of the flywheel face must not exceed the following specifications:

| Flywheel Radius (A) | | Maximum (TIR) of Flywheel Face | |
|---|---|---|---|
| mm | in | mm | in |
| 203 | 8 | 0.203 | 0.008 |
| 254 | 10 | 0.254 | 0.010 |
| 305 | 12 | 0.305 | 0.012 |
| 356 | 14 | 0.356 | 0.014 |
| 406 | 16 | 0.406 | 0.016 |

(e) If the flywheel face runout is not within specifications, remove the flywheel. Check for nicks, burrs, or foreign material between the flywheel mounting surface and the crankshaft flange.

1 Repair or replace as necessary.

2 Measure the face runout again.

d. Install the magnetic pickup in the flywheel housing as follows:

NOTE

The pickup hole is perpendicular to the flywheel gear teeth.

(1) Make sure a gear tooth is centered in the pickup hole. If necessary, rotate the flywheel to center a tooth in the hole.

(2) Screw the magnetic coil (13, FIGURE 3-80) pickup all of the way down until it contacts the flywheel gear tooth. The pickup will screw in very easily; do not use excessive pressure to install the pickup.

NOTE

If the pickup does not screw in with finger pressure, check the hole and the pickup threads. Tap the hole if required.

(3) Back the pickup out 1/2 to 3/4 of a turn.

(a) If you can get a feeler gauge between the magnetic pickup and the flywheel gear tooth, back the pickup out 0.028 to 0.042 inch (0.71 to 1.07 mm) from the flywheel gear tooth.

(b) If the pickup signal is less than 1.5 volts ac, screw the pickup in 1/8 to 1/4 turn. See step (6) below.

(4) Secure the locknut down on the flywheel housing.

(5) Plug the electrical connection into the pickup. The pickup now has the wires attached.

**CAUTION**

Measure the voltage of the panel mounted governor control on the printed circuit board terminal strip. Do not measure the voltage on the control terminal strip.

(6) Check the magnetic pickup voltage at the governor control. If voltage is less than 1.5 volts ac, see stop (3) of this procedure.

e. Install the starter motor (paragraph 2-21).

f. Fill the engine with lubricating oil (Table 2-1, Plan 12).

g. Install the friction clutch assembly (paragraph 3-22).

h. Install the coupling to the bowthruster water jet (TM 55-1905-223-24-6).

i. Operate the engine (TM 55-1905-223-10) until it reaches a temperature of 180°F (80°C) and check for leaks.

## 3-27. Replace Cylinder Block Group

**This procedure covers:** **a. Removal** **b. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's, rail and marine diesel engines, 5180-00-629-9783
Lifting fixture P/N 3375958
Combination wrench set, metric 10mm to 24mm, 5120-01-046-4979
Torque wrench kit P/N 3377216
Gauge block P/N 3376220
Cylinder liner clamp set, P/N 3822503
Cylinder liner driver P/N ST-1229
Cylinder liner puller P/N 3376015

Materials/Parts

Diesel engine cylinder block P/N 3801592

Equipment Condition

Starter motor removed (para. 2-21).
Coolant heater removed (para. 2-32).
Instrument panel and wiring removed (para. 2-22).
Sump pump and bracket removed (para. 2-28).
Air cleaner and piping removed (para. 2-25).
Fuel filter assembly removed (para. 2-27).
Lube oil cooler/filter removed (para. 2-30).
Lube oil cooler/bypass filter removed (para. 2-31).
Water pump and idler assembly removed (para. 2-29).
Seawater pump removed (para. 2-37).
Heat exchanger removed (para. 2-38).
Cylinder head removed (para. 2-41).
Oil pan removed (para. 2-44).
Lube oil pump removed (para. 3-23).
Accessory drive removed (para. 3-19).
Gear cover removed (para. 3-20).
Flywheel and housing removed (para. 3-26).

REMOVAL

a. Unless otherwise directed, remove the following:

   (1) Cam follower assemblies (paragraph 3-18).

   (2) Camshaft (paragraph 3-24).

   (3) Connecting rod and piston group (paragraph 3-25).

b. Through the process of removing the assemblies and components listed in the Equipment Condition and in Step a, the block assembly should now be free from its mounts and supported by the lifting fixture.

NOTE

Other external components or fixtures may have to be moved, or removed, to provide necessary clearance for removing the block assembly.

REPLACEMENT

a. Install the following:

(1) Connecting rod, piston, and ring assemblies (paragraph 3-25).

(2) Camshaft group (paragraph 3-24).

(3) Cam followers (paragraph 3-18).

b. Using the lifting fixture, hoist the block assembly into place.

c. Install the following assemblies:

(1) Flywheel and housing (paragraph 3-26).

(2) Gear cover (paragraph 3-20).

(3) Accessory drive and pulley (paragraph 3-19).

(4) Lube oil pump (paragraph 3-23).

(5) Oil pan (paragraph 2-44).

(6) Cylinder head (paragraph 2-41).

(7) Heat exchanger (paragraph 2-38).

(8) Water pump and idler (paragraph 2-29).

(9) Lube oil cooler/filter (paragraph 2-30).

(10) Lube oil bypass filter assembly (paragraph 2-31).

(11) Fuel filter assembly (paragraph 2-27).

(12) Air cleaner and piping (paragraph 2-25).

(13) Sump pump (paragraph 2-28).

(14) Seawater pump (paragraph 2-38).

(15) Instrument panel and wiring (paragraph 2-22).

(16) Coolant heater (paragraph 2-32).

(17) Starter motor (paragraph 2-21).

### 3-28. Replace Bowthruster Sub-Base Assembly.

**This task covers:** **a. Removal,** **b. Replacement**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's rail and marine diesel engines, 5180-00-629-9783
Combination wrench set, metric 10mm to 24mm, 5120-01-046-4979

Material/Parts

Isolation Pad P/N 44-9500-0100

Equipment Condition

Bowthruster engine assembly removed (para. 3-13).

REMOVAL

a. Remove eight bolts (2, FIGURE 3-101), washer (3), and nuts (1) from sub-base (5).

b. Remove sub-base (5).

REPLACEMENT

a. Install sub-base (5) over isolation pads (4).

b. Install eight bolts (2), washers (3), and nuts (1). Tighten bolts to 35 ft-lb torque.

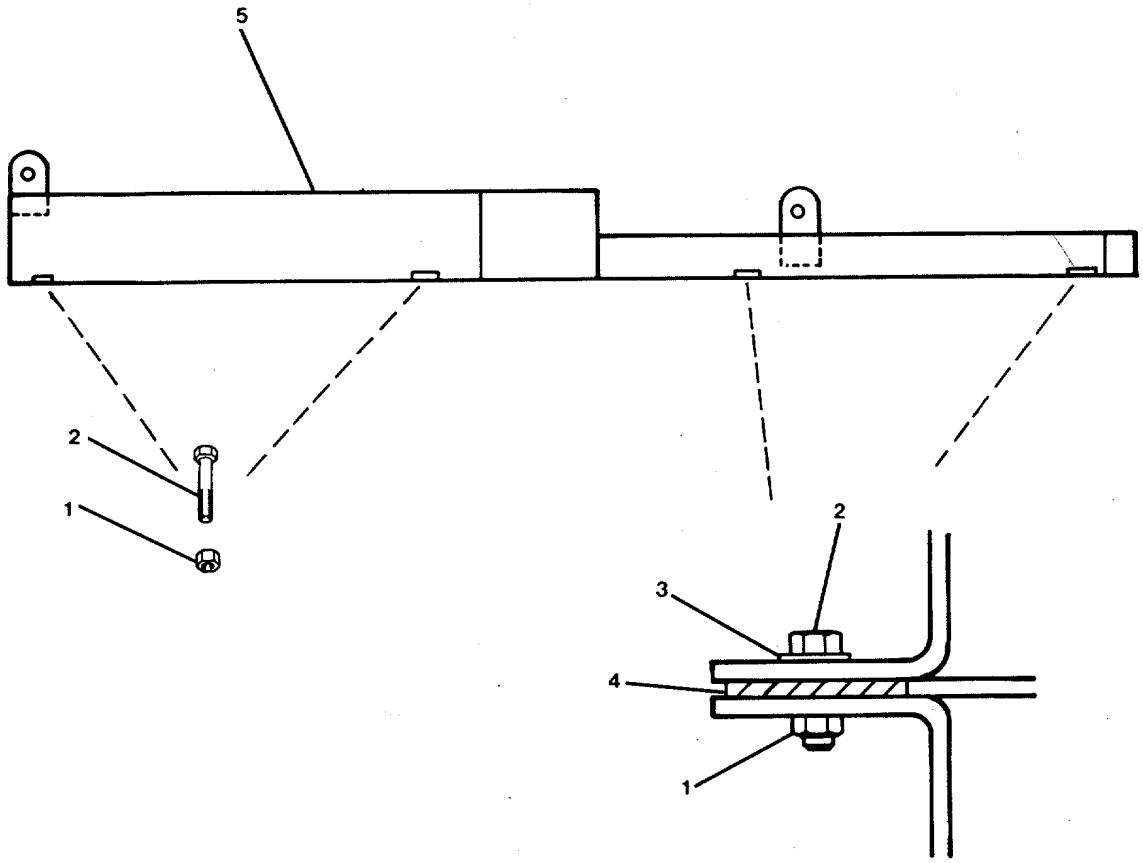


*FIGURE 3-101. Bowthruster Sub-Base Assembly.*

## SECTION VI. PREPARATION FOR STORAGE OR SHIPMENT

3-29. Refer to Chapter 2, Section VI.

# CHAPTER 4

# INTERMEDIATE GENERAL SUPPORT MAINTENANCE INSTRUCTIONS



## SECTION I. REPAIR PARTS, SPECIAL TOOLS; TEST, MEASUREMENT, AND DIAGNOSTIC EQUIPMENT (TMDE); AND SUPPORT EQUIPMENT

4-1. **Common Tools and Equipment**. For authorized common tools and equipment, refer to the Modified Table of Organization and Equipment (MTOE) applicable to your organization.

4-2. **Special Tools, (TMDE), and Support Equipment.** For special tools, test, measurement, and diagnostic equipment; and support equipment, requirements are listed and illustrated in the Repair Parts and Special Tools List (RPSTL), TM 55-1905-223-24P. These items are also listed in the Maintenance Allocation Chart (MAC), Appendix B.

4-3. **Repair Parts.** Repair parts are listed and illustrated in the Repair Parts and Special Tools List (RPSTL), TM 55-1905-223-24P.

## SECTION II. SERVICE UPON RECEIPT

4-4. **Checking and Deprocessing Unpacked Equipment.**

a. Inspect the equipment for damage incurred during shipment. If the equipment has been damaged, report the damage in accordance with the instructions of DA Pam 738-750.

b. Check the equipment against the packing slip to see if the shipment is complete. Report all discrepancies in accordance with the instructions of DA Pam 738-750.

c. Check to see whether the equipment has been modified.

d. Remove protective caps, plugs, inserts, wrappings, and tape when inspection/inventory is completed. Inspect piping openings for damage. Wipe off dirt, grease, or protective films at time of installation.

e. Remove chocks from resilient mounted components.

4-5. **Initial Setup Procedure**. Includes operational checks and inspections that are not performed for a routine startup. Direct support maintenance personnel will perform initial setup in accordance with the operator's manual, TM 55-1905-223-10.

4-6. **Normal Startup.** Refer to the operator's manual, TM 55-1905-223-10.

4-7. **Shutdown Procedure (Usual or Unusual).** Refer to the operator's manual, TM 55-1905-223-10.

## SECTION III. INTERMEDIATE GENERAL SUPPORT PREVENTIVE MAINTENANCE CHECKS AND SERVICES

4-8. **PMCS.** There is no PMCS at the general support level. See Chapter 2, Section III.

## Section IV. INTERMEDIATE GENERAL SUPPORT TROUBLESHOOTING PROCEDURES

4-9. **General Diagnostic Information.** For general information concerning engine noise and white smoke, refer to Chapter 2, paragraphs 2-17 and 2-18, and Chapter 3, paragraphs 3-9 and 3-10.

4-10. **Troubleshooting.** Both a symptom index and a troubleshooting table are provided. The symptom index will help you locate the information you need for troubleshooting.

SYMPTOM INDEX

| | Troubleshooting Procedure (Table 4-1) |
|---|---|
| EXCESSIVE CRANKCASE GASES (BLOWBY) | Item 5 |
| EXCESSIVE ENGINE NOISE | Item 6 |
| EXCESSIVE LUBRICATING OIL CONSUMPTION | Item 9 |
| FUEL IN THE LUBRICATING OIL | Item 2 |
| LOSS OF ENGINE COOLANT (INTERNAL) | Item 8 |
| LUBRICATING OIL IN THE COOLANT | Item 7 |
| LUBRICATING OR HYDRAULIC OIL IN COOLANT | Item 1 |
| ROUGH IDLE | Item 4 |
| WARM ENGINE RUNS ROUGH OR MISFIRES | Item 3 |

Table 4-1 lists the common fault conditions that may be found during operation or maintenance of the equipment. Look for causes and do corrective actions in the order listed. This manual cannot list every symptom that may show up, and it cannot list all the possible causes and corrective actions. If a symptom is not listed, or if it keeps up after you have performed the corrective actions, notify your supervisor.

Table 4-1. Troubleshooting

| **MALFUNCTION**<br>**TEST OR INSPECTION**<br>**CORRECTIVE ACTION** |
|---|

1. Lubricating or hydraulic oil in coolant.

   STEP 1. Check to see if cylinder head is cracked.
   Pressure test cylinder head (para. 4-12).

2. Fuel in the lubricating oil.

   STEP 1. Check to see if cylinder head is cracked.
   Pressure test cylinder head (para. 4-12).

3. Warm engine runs rough or misfires in operating range.

   STEP 1. Check for broken rocker levers, push rods bent, or damaged valves.
   a. Inspect push rods or rocker levers (para. 4-12).
   b. Inspect valves (para. 4-13).

   STEP 2. Check for damaged camshaft.
   Inspect camshaft (para. 4-16).

4. Rough idle.

   STEP 1. Check for worn or damaged valves.
   Pressure test cylinder head (para. 4-12).

5. Excessive crankcase gases (blowby).

   STEP 1. Check for worn or damaged piston rings.
   Inspect pistons and ring (para. 4-17).

   STEP 2. Check for worn or damaged cylinder liners.
   Repair cylinder liners (para. 4-20).

6. Excessive engine noise.

   STEP 1. Check for damaged pushrod or cam follower.
   Inspect pushrods and cam followers (para. 4-12).

   STEP 2. Check for connecting rod or rod bearing noise.
   a. Inspect connecting rod bearings (para. 4-17).
   b. Inspect connecting rod (para. 4-17).
   c. Inspect connecting rod caps and capscrews (para. 4-17).
   d. Inspect crankshaft journals (para. 4-19).

Table 4-1. Troubleshooting - CONT

| MALFUNCTION<br>TEST OR INSPECTION<br>CORRECTIVE ACTION |
|---|

STEP 3. Check for main bearing noise.
- a. Inspect main bearing caps and capscrews (para. 4-19).
- b. Inspect main bearings (para. 4-19).
- c. Inspect crankshaft journals (para. 4-19).

STEP 4. Check for piston noise.
- a. Piston rings worn or broken. Inspect piston rings (para. 4-17).
- b. Piston cracked or broken. Inspect piston (para. 4-17).
- c. Carbon deposits on the top of piston. Clean piston (para. 4-17).
- d. Piston pins or bushings loose, worn or not installed correctly. Inspect the piston pins and bushings (para. 4-17).
- e. Cylinder liners worn or out-of-round. Repair cylinder liners (para. 4-20).

7. Lubricating oil in the coolant.

STEP 1. Check for cracked or porous cylinder block.
Replace cylinder block (para. 4-20).

8. Loss of engine coolant (internal leakage).

STEP 1. Check injector sleeves.
Repair cylinder block (para. 4-20).

STEP 2. Check cylinder block for cracks or porous condition.
Replace cylinder block (para. 4-20).

STEP 3. Check cylinder liners.
Repair cylinder block (para. 4-20).

9. Excessive lubricating oil consumption.

STEP 1. Check for internal leaks.
Test for excessive blowby, refer to Table 2-2, Item 10, step 8.

STEP 2. Check for worn, broken, or not properly seated piston rings.
Repair piston ring assembly (para. 4-17).

STEP 3. Check for worn piston ring grooves.
Repair piston ring assembly (para. 4-17).

STEP 4. Check for scored or damaged cylinder liners.
Replace cylinder block (para. 4-20).

STEP 5. Check intake valve guide for leakage.
Repair cylinder head (para. 4-12).

## SECTION V. INTERMEDIATE GENERAL SUPPORT MAINTENANCE PROCEDURES

4-11. General. This section covers the general support maintenance procedures for the NT-855M bowthruster diesel engine. Step-by-step procedures are provided, supported by illustration, as required.

**MAINTENANCE OF BOWTHRUSTER ENGINE**

### 4-12. Repair Cylinder Head Group.

**This task covers: a. Disassembly b. Repair c. Assembly**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's rail and marine diesel engines, 5180-00-629-9783
Adapter plate P/N 3376686
Drive Unit, counterbore P/N 3376855
Cutter plate P/N 3377235
Gauge block P/N 3376220
Torque wrench kit P/N 3377216
Combination wrench set 5120-01-046-4979
Valve spring compressor stand and plate, P/N ST-1022, ST-1026
Valve seat insert tool kit P/N ST-257
Valve seat insert cutter P/N ST-662
Valve guide arbor P/N ST-663
Valve facing machine P/N 3376256
Valve guide reamer P/N ST-646
Valve head checking tool P/N 3375933
Valve seat grinder P/N ST-685
Valve guide mandrel P/N 3375282
Drill press 5130-00-293-1949
Dial bore gauge P/N 3376619
Head holding fixture P/N ST-583
Engine lifting fixture P/N 3822512
Injector sleeve holding tool P/N ST-1179
Hydrostatic tester P/N ST-1012
Tester adapter plate P/N ST-1013
Staking tool driver P/N ST-1122
Staking tool P/N ST-1124
1/2" Electric drill 4130-889-9002
Valve guide reamer P/N ST-1188
Machinists measuring tool kit 5280-00-278-9919

Equipment Condition

Cylinder head removed (para. 2-41).

Tools - Continued

Valve guide reamer P/N ST-1188
Valve spring tester P/N 3375182
Crosshead guide spacer P/N ST-633
Water hole counter boring tool kit
P/N ST-1010
Injector sleeve puller P/N ST-1244
Bead cutting tool P/N ST-788
Holder and pilot P/N ST-884-1, ST-884-6
Injector sleeve driver P/N ST-1277
Injector sleeve expander P/N ST-880
Injector seat cutter P/N ST-884
Vernier depth gauge P/N ST-537
Valve tester P/N ST-1257
Pressure manometer P/N PVS-2

Materials/Parts

Cleaning solvent
PD-680, Item 5, Appendix C
Teflon pipe thread compound, Item 9, Appendix C
Cup plug sealant, Item 12, Appendix C
Prussian blue compound, Item 13, Appendix C
Preformed packing P/N 131026, 3007759
Gasket P/N 3024709
Crosshead Valve P/N 3030038
Valve spring lock P/N 127554
Helical compression spring seat
P/N 170296
Valve spring P/N 211999
Crosshead guide P/N 161527
Expansion plug sealant P/N 3375068
Helical compression spring P/N 211999
Valve spring guide P/N 3202144
Valve stem guide P/N 3050369
Valve stem guide P/N 3006456
Engine poppet valve P/N 3040830, 135957
Valve seat P/N 3017759
Valve seat P/N 200354
Fuel injection nozzle cooling sleeve
P/N 3011934
Lubricating oil, Item 1, Appendix C
Razor blade scraper

DISASSEMBLY (Refer to FIGURE 4-1)

a. Clean the cylinder head assembly.

b. Put the cylinder head in the head holding fixture or an equivalent tool to hold the cylinder head during disassembly.

c. Use the valve spring compressor stand and the valve spring compressor plate (FIGURE 4-2) to compress the valve springs.

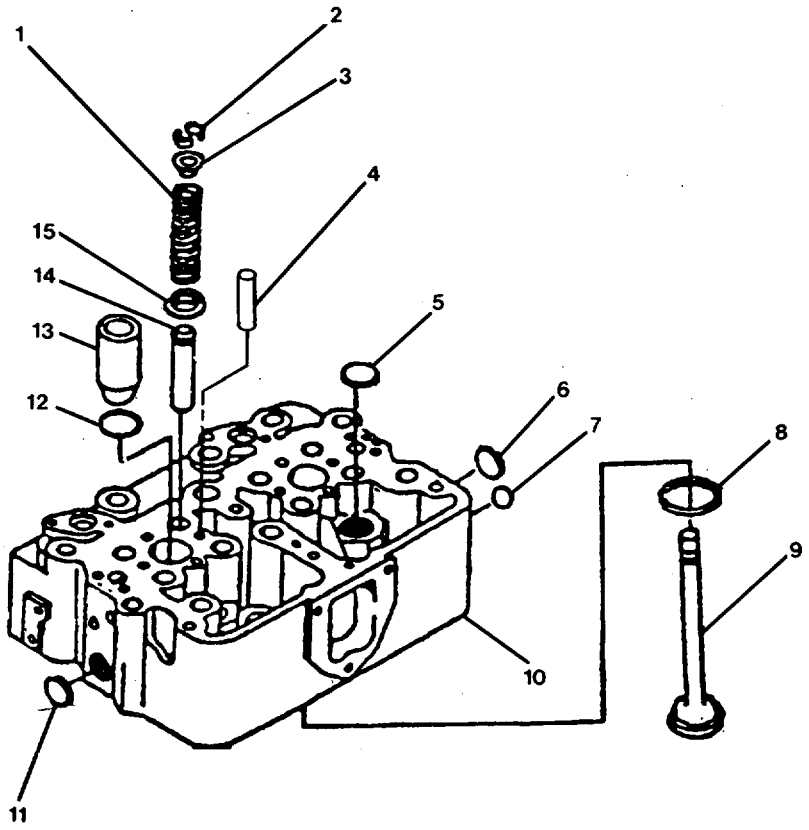


*FIGURE 4-1. Cylinder Head Assembly - Exploded View.*

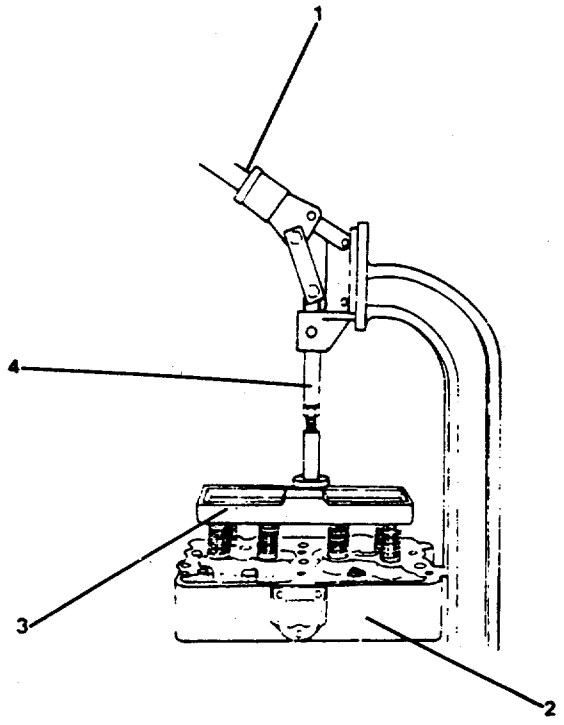


*FIGURE 4-2. Removing Valves.*

(1) Make sure the valve spring compressor stand is fastened to the work bench.

(2) Align the center of the cylinder head with the plunger (4) of the compressor stand.

(3) Position the compressor plate (3) on the cylinder head (2) so that the valve stems will be in the center of the holes in the plate (3).

(4) Pull down on the handle (1) of the stand. Make sure the valve stems stay in the center of the holes.

(5) Bring the handle (1) all the way down so that the locking pin will engage the hole in the plunger (4). The locking pin holds the plunger (4) against the plate (3) that compresses the springs.

(6) Remove the valve spring collects (2, FIGURE 4-1).

(7) Push down on the handle (1, FIGURE 4-2) and disengage the locking pin from the plunger (4). Raise the plunger (4) from the cylinder head (2).

(8) Remove the valve springs (1, FIGURE 4-1), valve springs guides (3, 15), and valves (9) from the cylinder head.

(9) Mark each valve as it is removed to identify its location in the cylinder head.

d. There is a 1/8 inch pipe plug in the cylinder head vent hole. Remove the pipe plug (15).

e. Remove the pipe plugs from the fuel holes in the number 1 and 3 cylinder head.

f. Remove the pipe plugs from the fuel passages in each end of the cylinder head.

g. Remove the expansion plugs (7, 5, and 6, FIGURE 4-1).

(1) Use a hammer and punch to loosen the cup plug. Hold the punch against the plug, near the outside diameter of the plug, and hit the punch with a hammer to cause one side of the plug to move from its correct location.

(2) Use pliers to pull the plug from the hole.

REPAIR. Table 4-3 lists specifications for the cylinder head, valve guides, valve seat inserts, crosshead guides, and injector sleeves. See FIGURE 4-3 for reference numbers in Table 4-3 which is located at the end of this procedure.

a. Clean and inspect the cylinder head and capscrews.

(1) Blow out all capscrew holes, fuel passages, and oil passages.

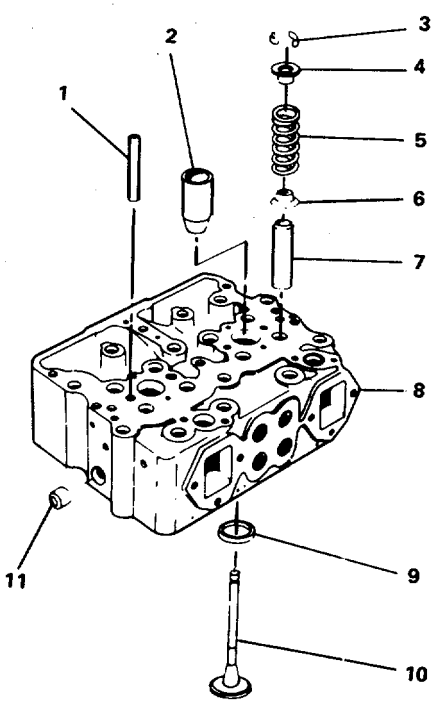


*FIGURE 4-3. Cylinder Head (Table 4-3 Reference).*

(2) Use a gasket scraper to remove heavy dirt and debris from the cylinder head gasket surface.

(3) Use a razor blade scraper and solvent to remove any remaining material from the cylinder head gasket surface.

(4) Clean with solvent and dry with compressed air.

(5) Clean the rocker housing gasket surface on each cylinder head.

(6) Visually inspect the cylinder heads for cracks or damage.

NOTE

If a crack in a cylinder head is suspected, pressure test the cylinder head. Refer to step (b) of this procedure.

(7) Visually inspect the valves for indications of leakage or burning. If indications of leakage or burning are found, the valves and the seats must be resurfaced. Refer to steps (h) and (j) of this procedure.

CAUTION

Do not use caustic or acid solutions to clean the cylinder head capscrews.

(8) Use cleaning solvent to thoroughly clean the capscrews.

(9) Visually inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter (due to capscrew stretching).

NOTE

Do not reuse a capscrew that has damaged threads or a reduced diameter from having been stretched.

(10) Replace damaged, worn, and corroded capscrews.

(11) Immediately after cleaning and inspecting, apply a film of clean engine lubricating oil to capscrews that are to be used again.

(12) Clean the valves, springs, and retainers with solvent.

b. Cylinder head pressure test procedures:

(1) Install two injector sleeve holding tools in each cylinder head, (FIGURE 4-4). Each injector sleeve holding tool consists of 2 hex head capscrews (1, 5), flat washer (2), anvil (3) and mandrel (4).

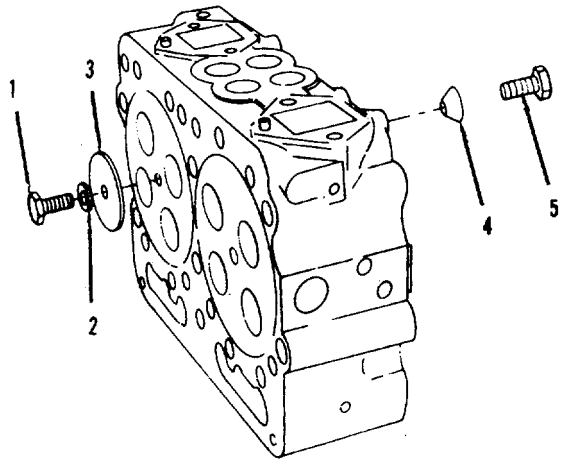


*FIGURE 4-4. Injector Sleeve Holding Tool.*

(2) Tighten the injector sleeve holding tool capscrews to the following torque values:

(a) Tighten to 45 in-lb torque.

(b) Tighten to 90 in-lb torque.

(c) Tighten to 130 in-lb torque.

(3) Install the cylinder head in a hydrostatic tester and hydrostatic tester adapter plate (FIGURE 4-5) as follows:

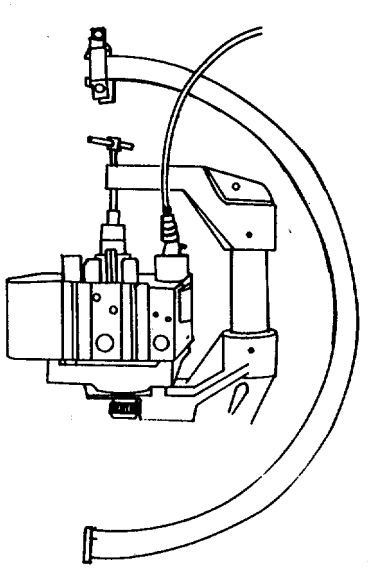

*FIGURE 4-5. Hydrostatic Tester and Plate.*

(a) Install the plates on the cylinder head. Engage the locating pins for the plates with the holes in the cylinder head.

(b) Install the clamping assembly over the plates on the cylinder head. Engage the locating pins for the clamping assembly with the holes in the plate.

(c) Tighten the screw for the clamping assembly. Make sure the drain valve in the adapter plate is in the closed position.

(d) Use the pins that are supplied with the quadrant to fasten the clamping assembly to the quadrant. Fasten the longer bracket of the quadrant to the bottom of the clamping assembly.

(4) Connect a regulated air supply hose to the test fixture plate.

(5) Adjust the air pressure to 30 to 40 psi (207 to 276 kPa).

(6) Use a hoist to place the cylinder head in a tank of warm water heated to 140°F (60°C).

(7) Completely submerge the cylinder head in the water.

(8) Visually inspect for air bubbles rising from the water.

(9) If air bubbles are observed, replace the cylinder head.

(10) Lift the cylinder head from the tank.

(11) Disconnect air supply hose from test fixture plate.

c. Water pressure test the cylinder head:

(1) Install a pressure regulator and gauge into a hose that connects to the water and air supply.

NOTE

The water and air supply must have shut-off valves.

(2) Set the pressure at 35 to 85 psi (241 to 586 kPa).

(3) Heat water temperature to 180° to 200°F (82° to 93°C).

(4) Connect the hose to the fitting in the plate. Open the drain valve to remove the air from the cylinder head.

(5) Open the valve for the water to fill the cylinder head with water.

(6) Close the valves for the water and drain when all the air has been removed from the head.

(7) Open the valve for the air pressure.

(8) Check the cylinder head for leaks. Be sure to check the areas around the valve seats and the injector sleeve for leaks or cracks.

(9) If leaks are observed, replace the cylinder head.

(10) Close the valve for the air pressure.

(11) Open the valve for the water drain to check the water flow through the cylinder head. If the water does not flow freely, remove the plugs and injector sleeves and clean the deposits from the water passages.

(12) Remove test equipment.

d. Valve Seat Inserts. Inspection and replacement procedures. See Table 4-4, at the end of this procedure, for oversize valve seat insert specifications.

NOTE

To find loose valve seat inserts before they are removed, carefully hit the head with a wood or rubber hammer. If the insert is loose enough so that it moves, replace the insert.

(1) Check the seat area width. If the width is more than 0.125 inch (3.18 mm) and cannot be cut narrower, replace the insert.

(2) Use the following tools to cut the counterbore:

Valve seat insert tool kit
Valve seat insert cutter
Valve guide arbor

(a) Install the arbor (1, FIGURE 4-6) into the valve stem guide. Put the adapter sleeve from the tool kit onto the arbor.

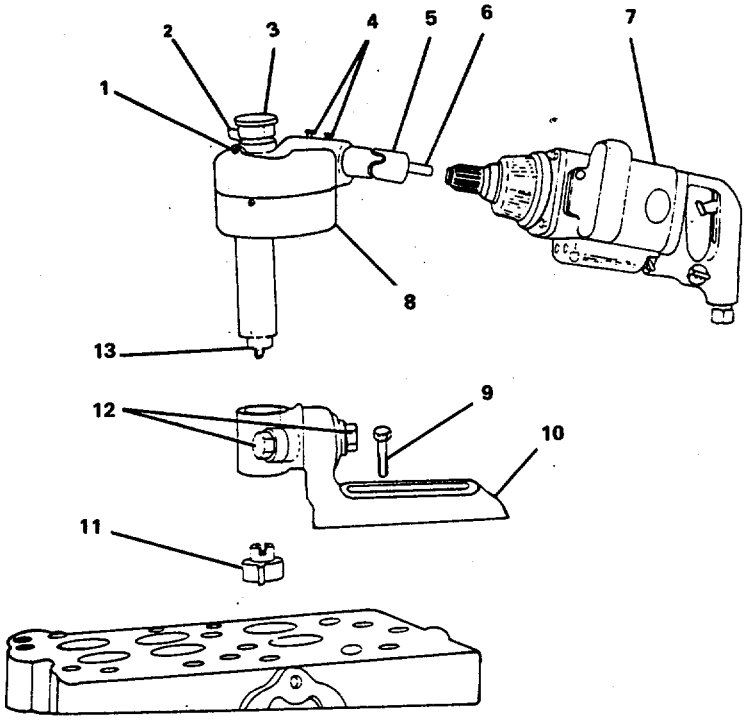


*FIGURE 4-6. Removing the Arbor.*

(b) Loosen the clamp screws (4, FIGURE 4-7) for the swivel (1) and for the gear case.

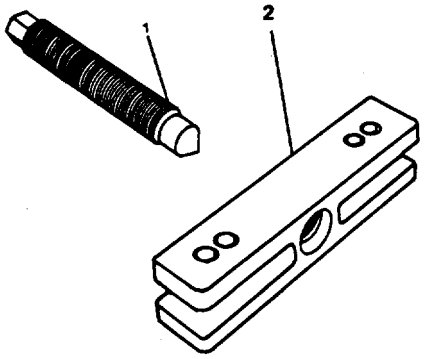


*FIGURE 4-7. Arbor Alignment.*

(c) Remove the gear case (8).

(d) Install the base (10) and swivel onto the arbor and adapter sleeve.

(e) Make sure the base (10) is flat against the cylinder head.

(f) Use capscrew (9) to fasten the base (10) to the cylinder head. Do not tighten the capscrew.

(3) Use a seat driver from the tool kit.

(a) The driver must have the same diameter as the cutter.

(b) Install the driver over the arbor and adapter sleeve and through the swivel (FIGURE 4-7).

(4) Adjust the position of the base (10) and swivel so the driver will move freely on the arbor.

(a) Secure the capscrew (9) to hold the base (10) to the cylinder head.

(b) Secure the clamp screw for the swivel.

(5) Make sure the alignment is correct, then remove the driver. Use the T-handle arbor puller (2, FIGURE 4-6) and remove the arbor (1).

(6) Apply lubricating oil to the arbor and the hole in the adapter sleeve.

(a) Put the cutter (11, FIGURE 4-7) into position over the valve seat.

(b) Install the arbor into the valve guide.

(c) Install the adapter sleeve onto the arbor.

(7) Install the gear case (8) into the swivel.

(a) Engage the bottom of the drive shaft (13) with the top of the cutter (11). Make sure the drive shaft (13) is against the cutter (11).

(b) Secure the clamp screws (12) to hold the gear case (8) and drive shaft (13) in the swivel.

(8) To set the depth of the cutter:

(a) Rotate the feed depth knob (3) counterclockwise four or five complete turns.

(b) Put the new valve seat insert under the knob (3).

(c) Turn the feed depth knob (3) clockwise until it is against the valve seat insert.

(d) Turn the knob (3) counterclockwise until there is 0.006 to 0.010 inch (0.15 to 0.25 mm) clearance between the knob and the insert.

(9) Turn the feed engaging knob (2) clockwise to engage the feed mechanism. Attach the chuck of a 1/2-inch electric drill to the drive shank (6).

(10) Start the drill and cut the counterbore until the feed depth knob (3) is against the gear case (8).

(a) Let the cutter turn two or three more revolutions to make sure the counterbore surface is even.

(b) If the feed engaging knob (2) disengages before the knob is against the gear case, turn the knob with your hand to complete the cut.

(11) Loosen the clamp screw (1) for the gear case. Remove the gear case (8), arbor and cutter (11). Be careful and do not move the base or swivel.

(12) Remove all metal particles and dirt from the counterbore.

(13) Position the valve seat insert in the counterbore.

(14) Make sure the chamber on the insert is against the cylinder head.

(15) Install the driver adapter and valve seat driver through the swivel.

(a) Hit the valve seat driver with a heavy hammer to install the valve seat insert into the counterbore.

(b) Make sure the valve seat goes to the bottom of the counterbore.

(c) Remove the adapter, driver, base, and swivel from the cylinder head.

CAUTION

Be careful not to damage the cylinder head when you stake the valve seat insert.

(16) Use the staking tool driver (1, FIGURE 4-8) and the staking tool (2) to stake the valve seat insert in the cylinder head. If the staking tool (2) and driver (1) are not available, you can use a punch to stake the valve seat insert. Make sure the end of the punch is round.

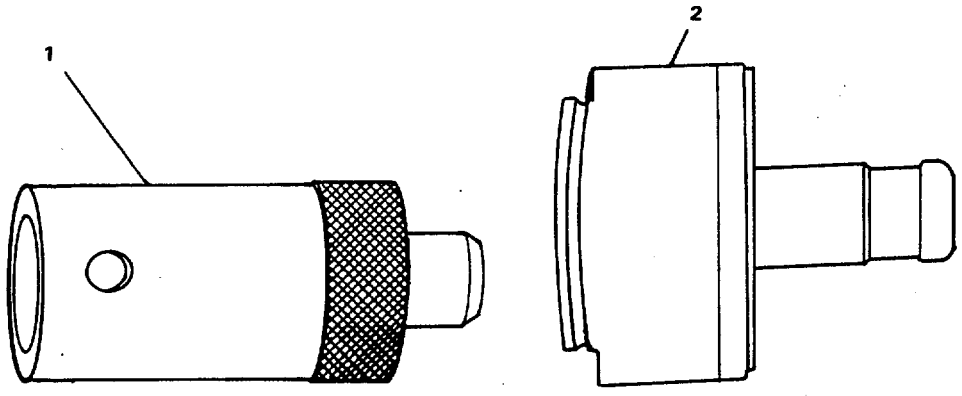


*FIGURE 4-8. Using Staking Tool Driver and Staking.*

e. Valve Guides. Inspection and replacement procedures.

(1) Inspection.

(a) Check the inside diameter of the valve guide. Replace the guide if the bore is worn larger than 0.455 inch (11.56 mm).

(b) Use a bore gauge to check the bore at four points spaced 90 degrees apart to find if the bore is out-of-round. Check the full length of the bore. Replace the guide if it is out-of-round.

(c) Visually check the guides for damage.

(2) Replacement.

(a) Remove the worn valve guides. Use the valve guide mandrel to install the new valve guides.

(b) If the bore for the valve guide is damaged and is to be repaired, use the reamer, ST-1188 to cut the bore to measure 0.760 to 0.761 inch (19.30 to 19.33 mm) inside diameter. Make sure the reamer cuts the entire bore. Remove all sharp edges.

NOTE

If the damage to the valve guide bore is not removed by using the ST-1188 reamer, use the ST-1187 reamer to cut the bore to the next largest size. Repeat steps (a) and (b) to cut the bore to measure 0.765 to 0.766 inch (19.43 to 19.46 mm). Install the oversize valve guide. You can ream the hole in the valve spring guides to measure 0.768 to 0.775 inch (19.51 to 19.63 mm) so the spring guides will fit the oversize valve guides.

(c) Use an arbor press to install the valve guide. Make sure the height of the valve guide is 1.270 to 1.280 inch (32.26 to 32.51 mm) after it is installed.

(d) Use a new valve to check the inside diameter of the guide. Insert the valve into the guide. The valve stem must move freely.

(e) If the valve does not move freely in the guide, use the valve guide reamer ST-646 to ream the guide.

(f) Use a drill press that has a floating tool holder to ream the valve guide. Install the reamer in the drill press.

(g) Apply lubricating oil to the reamer while the guide is being reamed.

(h) Do not ream the inside diameter of the guide larger than 0.4532 inch (11.511 mm).

f. Valves. Inspection, grinding and replacement.

(1) Visually inspect the valves as follows:

(a) Clean the valves and polish with fine crocus cloth.

(b) Check the valve head for damage. Use the valve head checking tool to measure the thickness of the valve head rim (A), FIGURE 4-9. The rim must measure a minimum of 0.105 inch (2.67 mm).

(c) Measure the outside diameter of the valve stem. Discard the valve if the stem is damaged or measures less than 0.449 inch (11.44 mm).

(d) Check the grooves in the valve stem for wear. The valve spring collet must fit tightly in the grooves. Discard the valve if the grooves are worn enough that the collet is loose.

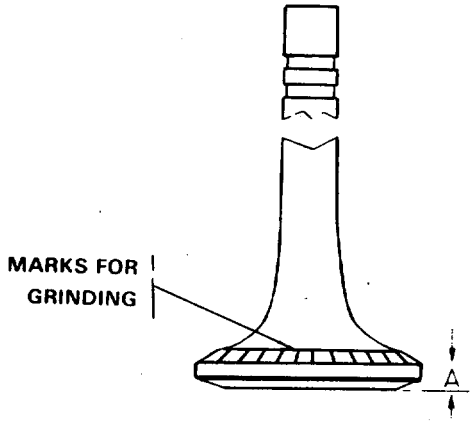


*FIGURE 4-9. Rim Measurements and Grinding Marks.*

(2) Valve grinding.

(a) Use a valve facing machine to grind the face of the valve. Check the setting of the facing machine by using a new valve and an indicator gauge.

(b) Put the valve to be ground in the chuck of the machine. Tighten the chuck on the grind area of the valve stem.

(c) Position the tip of the indicator against the valve face.

(d) Turn the valve. Put a mark on the valve face where the indicator shows the highest reading.

(e) Remove the valve from the chuck.

(f) Turn the valve 180 degrees from the original position in the chuck.

(g) Put the valve in the chuck and tighten the chuck.

(h) Repeat steps (b) and (c).

(i) If the highest indicator reading is the same, and in the same location of the face when the valve is positioned as in steps (a) and (d), the valve is distorted.

(j) If the highest readings are at different locations on the valve face in steps (a) and (d), the chuck is not in alignment.

(k) The indicator must not show more than 0.001 inch (0.02 mm) difference around the circumference of the valve face.

(1) Grind the face of the valve. Make sure the coolant will spray on the valve head, not on the grinding wheel.

(m) Grind the valve face to an angle exactly 30 degrees from the horizontal position of the valve.

(n) Check the thickness of the valve head rim, FIGURE 4-9 to be sure that. the rim thickness is not less than 0.124 inch (3.15 mm). Do not repair any valve with cracks or other damage or any valve whose rim thickness is less than 0.124 inch (3.15 mm).

(o) Make sure the valve face has the correct contact against the valve seat.

(p) Put marks on the valve face as shown in FIGURE 4-9. Use a liquid metal marker.

(q) Install the valve in the valve guide.

(r) Hold the valve against the valve seat and rotate the valve at least 10 degrees. The correct contact against the set will cause the marks on the valve face to be broken.

(s) If the marks are not broken, check the adjustment of the facing machine and the condition of the grinding wheel.

(t) Valves and valve seats that are correctly machined do not require the use of lapping compound to make an airtight seal. If the Valve Seating Test shows leakage, you can use a small amount of lapping compound on the valve and seat to make an airtight seal.

(u) The correct conditions on the valve and valve seats are:

1 No marks or scratches on the valve face or valve seat.

2 No marks or scratches in the valve guide.

3 The angle of the valve face must be exactly 30 degrees.

4 Valve guide to valve stem clearance must be a minimum of 0.0022 inch (0.056 mm).

g. Valve Springs. Inspection and replacement.

NOTE

Weak valve springs can cause wear and damage to the valve and valve seat. Weak springs can also change the valve timing and cause the valve to hit the top of the piston.

(1) Use the valve spring tester to test valve spring.

(2) Compress the spring to the working force shown in Table 4-2.

(3) Check the amount of force required to compress the spring, if not within limits discard the spring.

(4) Use spacers under the valve spring when the valve and valve seat have had a total of 0.030 inch (0.76 mm) material removed. Do not use more than two spacers under a valve spring.

(5) Replace any springs which do not meet the specifications in Table 4-2. See other spring specifications in Table 4-5 at the end of the repair procedures.

Table 4-2. Valve Spring Data -- inch (mm) lb (N)

| | Approximate Working Force to Compress | | |
|---|---|---|---|
| Free Length - in (mm) | Length - in (mm) | Minimum - lb (N) | Maximum - lb (N) |
| 2.685 (68.20) | 1.724 43.79) | 147.25 (655) | 162.75 (724) |

h. Crossheads and guides. Inspection and replacement.

(1) Crossheads (21, FIGURE 4-1).

(a) Check the inside diameter of the bore (3, FIGURE 4-10), replace the crosshead if the bore exceeds 0.440 inch (11.18 mm).

(b) Use a bore gauge to check the bore at two points spaced 90 degrees apart to find if the bore is out-of-round. Replace as required.

(c) Inspect the rocker lever contact surface (1) and the valve stem contact surface (2) for wear. Check the adjusting screw and threads in the crosshead (4) for wear or damage (FIGURE 4-10).

(d) Replace the crosshead if there is damage to the threads in the crosshead.

(2) Crosshead Guides (4, FIGURE 4-1).

(a) Make sure the guide is straight. Replace any guide that is not straight.

(b) Use a micrometer to measure the outside diameter of the crosshead guide. The diameter must not be worn to less than 0.432 inch (10.97 mm). Replace as required.

(c) The guide must be at a right angle to the surface of the cylinder head. Replace the guide if it is not.

(d) Use the crosshead guide spacer to install the crosshead guide.

(e) If guide spacer is not available use a press to install the crosshead guide. Make sure the height of the guide is between 1.860 to 1.880 inch (47.24 to 47.75 mm) after it is installed.

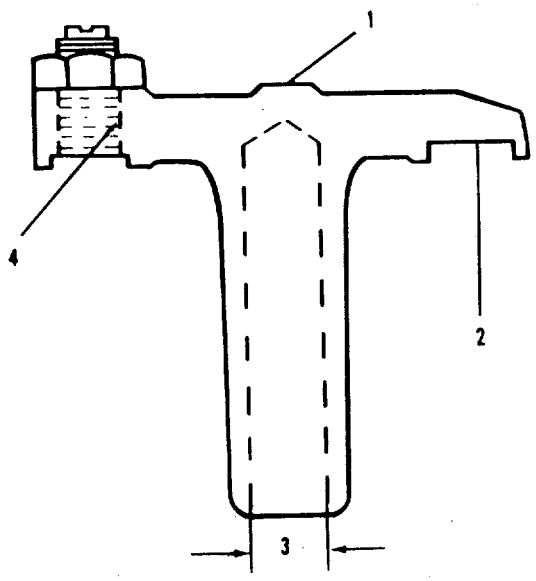


*FIGURE 4-10. Crosshead Inspection Areas.*

(f) If the bore for the crosshead guide is damaged:

1 Use a 29/64 inch drill to cut the guide bore. Cut the oversize bore to the same depth as the original bore.

2 Use a 15/32 reamer to ream the bore. Apply lubricating oil to the reamer as the bore is being reamed.

3 Install the crosshead guide as in steps (e) or (f) of this procedure.

i. Cylinder head water holes. Inspection and repair.

(1) Inspection. The surface of the cylinder head around the water holes must not have any scratches, cracks or corrosion deeper than 0.003 inch (0.08 mm). There must not be any defect which extends more than 3/32 inch
( 2.38 mm) from the edge of the water hold.

(2) Repair.

(a) To repair the water holes, use the following tools from the water hole counterboring tool kit:

| | |
|---|---|
| Bushing plate | Drive adapter |
| Adapter screw | Locating pin |
| Stop collar | Allen wrench |
| Counterbore cutter | Gauge block |

(b) Adjust the depth of the counterbore cutter:

1 Put the bushing plate on a flat surface with the side of the plate marked "Top" away from the surface.

2 Install the counterbore cutter in the 5/8 inch (15.8 mm) bushing. Make sure the cutter is against the flat surface.

3 Slide the stop collar up on the counterbore cutter.

4 Put the gauge block on top of the bushing plate. Hold the curve at the plate against the cutter.

5 Slide the stop collar down against the gauge block (FIGURE 4-11). Tighten the setscrew in the stop collar.

6 Remove the cutter and gauge block from the bushing plate.

(c) Put the bushing plate on the cylinder head with the side of the plate marked "Top" away from the cylinder head.

(d) Fasten the bushing plate to the cylinder head. Insert the adapter screw through an injector hole and through the bushing plate. Install the adapter knob on the end of the adapter screw.

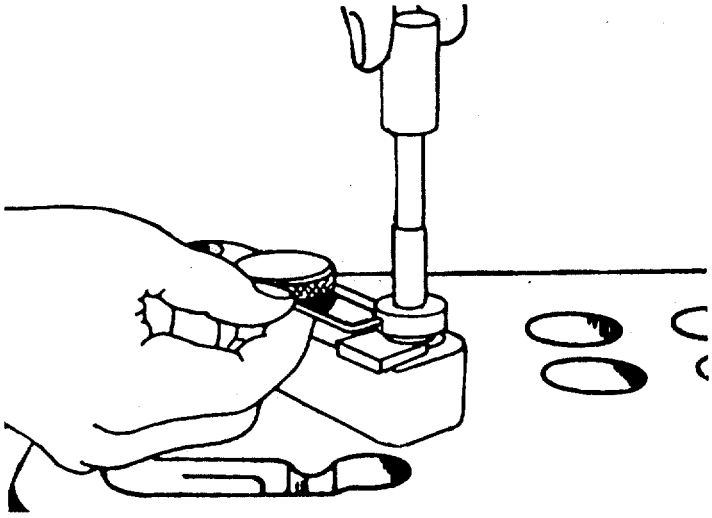

*FIGURE 4-11. Adjusting Counterbore Cutter.*

(e) Insert the locating pin through the 5/8 inch bushing and into the water hole to be repaired. Use your hand to tighten the adapter knob to approximately 50 ft-lb. torque.

(f) Remove the locating pin.

(g) Install the counterbore cutter in the bushing.

(h) Install the drive adapter in an electric drill.

(i) Engage the drill adapter with the counterbore drill.

(j) Start the drill. Apply minimum downward force while cutting the hole.

(k) Remove the counterbore cutter and bushing plate from the cylinder head.

(1) To install the water passage sleeve:

1 Make sure the hole is clean and all metal particles and sharp edger are removed.

2 Slide the sleeve into the end of the bushing driver.

3 Apply a coat of sealant to the sleeve.

4 Align the sleeve with the water hole. Hit the bushing driver with a hammer to install the sleeve into the water hole.

5 Cut the sleeve so that is even with the surface at the cylinder head. Use a flat, wide mill file to cut the sleeve. Be careful not to damage the surface of the cylinder head when you cut the sleeve.

(m) You can use copper tubing if the sleeve is not available:

1 The tubing must have a heavy wall and the outside diameter must be 0.002 to 0.005 inch (0.05 to 0.13 mm) larger than the diameter of the hole.

2 The length must be 0.50 inch (12.7 mm) and the inside diameter must be 0.437 inch (11.11 mm).

j. Injector sleeves (13, FIGURE 4-1). Inspection and replacement.

(1) Inspection and removal of sleeves.

(a) Check the sleeve for scratches and other damages.

(b) Replace the sleeve which leaks or has damage. Use the injector sleeve puller to remove the injector sleeve from the cylinder head.

NOTE

Do not tighten the hexagon nuts on the Injector Puller.

(c) Install the puller into the sleeve so that the legs of the bridge are against the surface of the cylinder head.

(d) Install the driver on the puller. The driver must be against the large hexagon nut. Hit the driver with a large hammer to push the forming collar into the injector sleeve. Remove the driver.

(e) Tighten the small hexagon nut to 50 ft-lb. torque. Make sure you do not tighten the nut more than 60 ft-lb. torque.

(f) Turn the large nut clockwise to pull the injector sleeve from the cylinder head. You can use an impact wrench to turn the nut.

(g) To remove the sleeve from the puller:

1 Loosen the large and small nuts.

2 Hit the small end of the sleeve lightly to loosen it from the puller.

3 Turn the sleeve 120 degrees and slide it from the puller.

(h) Make sure the bead in the bottom on the injector bore is smooth. Use the bead cutting tool with the holder and pilot to cut the bead in the bore.

(2) Installing New Sleeves.

(a) Apply a coat of clean lubricating oil to injector sleeve preformed packing. Install the preformed packing into the groove in the bore for the sleeve (FIGURE 4-12).

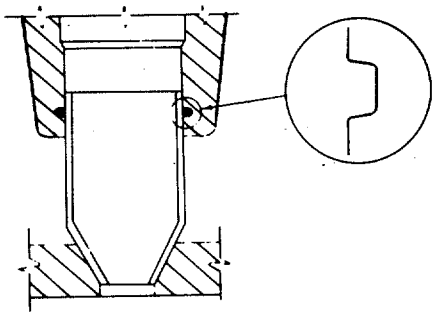

*FIGURE 4-12. Installing Injector Sleeve O-Ring.*

CAUTION

Do not hit the driver with a hammer.

(b) Use the injector Sleeve Driver to push the sleeve into the bore.

(c) Remove the driver from the sleeve.

(d) Install the injector sleeve holding tool into the sleeve. Tighten the capscrew to 35 to 40 ft-lb. torque.

(e) Install the driver in the sleeve.

(f) Hit the driver two times with a hammer to make sure the sleeve is against the bottom of the bore.

(g) Remove the driver and tighten the holding tool capscrew again to 35 to 40 ft-lb. torque.

(h) Use the Injector Sleeve Expander to expand the upper section of the sleeve to cause a seal between the sleeve and the cylinder head.

CAUTION

Be careful when you expand the sleeve. Do not damage the sleeve and O-ring.

1 Install the expander into the sleeve. Use an inch-pound torque wrench to turn the mandrel of the expander.

2 Turn the mandrel until the torque wrench shows 75 in-lb. torque.

(i) Remove the expander and the holding tool from the sleeve.

(j) Use the injector seat cutter to cut the injector seat in the sleeve.

1 Install the injector in the cylinder head, tighten the capscrews to 10 to 12 ft-lb. torque.

2 Use gauge block to measure the protrusion of the injector tip to find the amount to cut from the sleeve (FIGURE 4-13).

3 The protrusion of the injector tip must be 0.060 to 0.070 inch (1.52 to 1.78 mm) (FIGURE 4-14). Remove the injector.

(k) Install the cutter and pilot in a drill press.

(1) Cut the seat for the injector. Be sure to use enough cutting oil while cutting the seat.

(m) The seat must have a smooth surface.

(n) Apply Prussian blue compound to the inside of the sleeve at the area of the injector seat. When the injector is installed, the compound must show completely around the injector and must be a minimum width of 0.060 inch (1.52 mm).

(o) Use the water test method to test the cylinder head for leaks. Refer to step (c).

(3) Protrusion of the injector tip.

**NOTE**

Check the sleeve to ensure the protrusion of the injector tip and the seating pattern is correct.

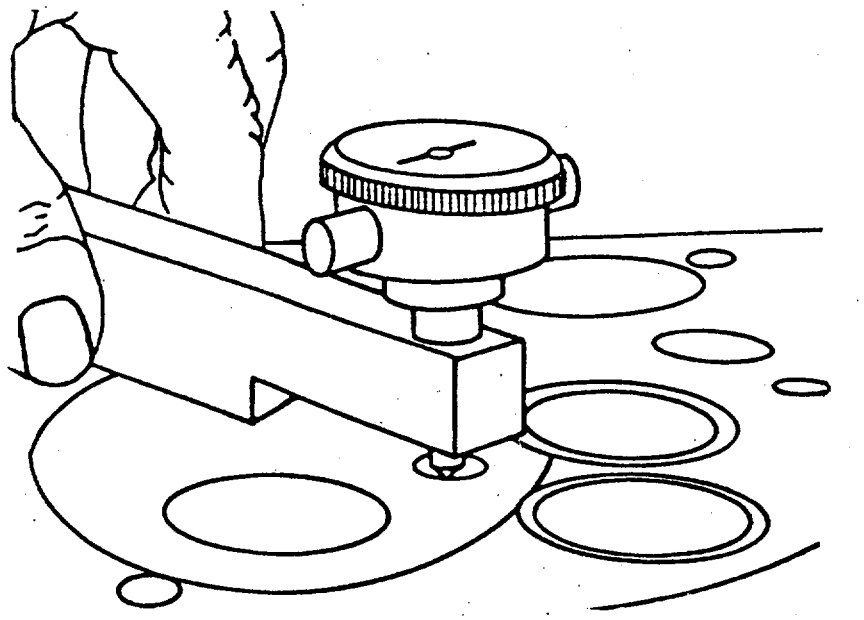

*FIGURE 4-13. Using Gauge Block.*

(a) Apply a light coat of blue compound to the injector cup.

(b) Install the injector assembly into the sleeve.

(c) Tighten the capscrews to 10 to 12 ft-lb. torque.

(d) Remove the injector and check the pattern of the blue compound in the sleeve.

(e) The pattern in the sleeve must be a minimum of 0.060 inch (1.52 mm) wide and 0.469 inch (11.91 mm) from the bottom surface of the cylinder head (FIGURE 4-14).

(f) If the sleeve does not meet those specifications, it must be replaced.

(g) Install the injector assembly into the sleeve.

(h) Install the capscrews to 10 to 12 ft-lb. torque.

(i) Use the gauge block to measure the protrusion of the injector tip (FIGURE 4-13).

(j) The protrusion of the tip must measure 0.060 to 0.070 inch (1.52 to 1.78 mm).

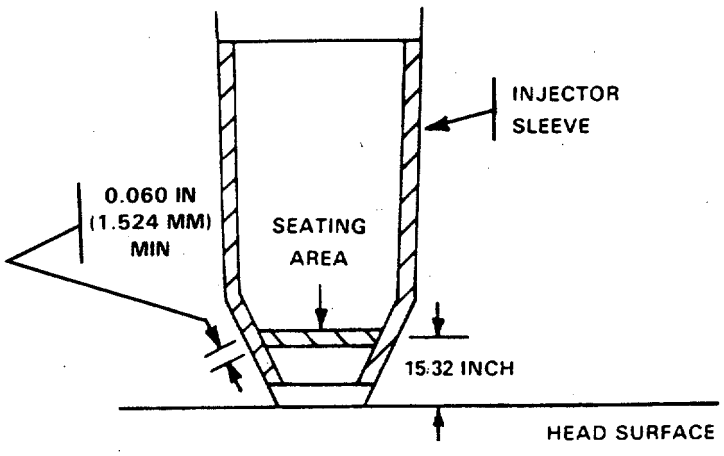


*FIGURE 4-14. Injector Sleeve Measurements.*

Table 4-3. Specifications for Cylinder Head, Valves, Crosshead Guides, and Injector Sleeves-inch (mm) (Reference No. Keyed to FIGURE 4-3).

| Ref. No. | Worn Measurement | New Limit | New Minimum | Maximum |
|---|---|---|---|---|
| 1 | Crosshead Guide Outside Diameter | 0.432 (10.97) | 0.4332 (11.00) | 0.4335 (11.011) |
| | Assembled Height | | 1.860 (47.24) | 1.880 (47.75) |
| | Crosshead Bore | 0.440 (11.18) | 0.434 (11.02) | 0.436 (11.07) |
| 2 | Injector Sleeve Tip Protrusion | | 0.060 (1.52) | 0.070 (1.78) |
| 5 | Valve Spring Assembled Height (refer to Table 4-5 for free length and wear limits) | | 2.250 | (57.15) |
| 7 | Valve Guide Inside Diameter | 0.455 (11.56) | 0.4525 (11.494) | 0.451 (11.511) |
| 8 | Cylinder Head Height | 4.340 (110.24) | 4.370 (111.00) | 4.380 (111.25) |
| 9 | Valve Seat Insert Outside Diameter (refer to Table 4-4 for oversize specifications) | | 2.0025 (50.787) | 2.0035 (50.889) |
| 10 | Valve Stem Outside Diameter | 0.449 (11.41) | 0.450 (11.43) | 0.451 (11.46) |
| | Face Angle | | 30 degree | 30 degree |
| | Assembled Height | | 1.270 (32.26) | 1.280 (32.51) |
| | Cylinder Head Inside Diameter | | 1.9995 (50.787) | 2.00005 (50.813) |

Table 4-3. Specifications for Cylinder Head, Valves, Crosshead Guides, and Injector Sleeves-inch (mm)-CONT

| Ref. No. | Worn Measurement | New Limit | New Minimum | Maximum |
|---|---|---|---|---|
| | Insert Height | | 0.278 (7.06) | 0.282 (7.16) |
| | Run Out in 360 Degrees | 0.002 (0.05) | | |
| | Refaced Seat Width | | 0.063 (1.59) | 0.125 (3.18) |

Table 4-4. Oversize Valve Seat Insert Specifications-inch (mm)

| Oversize Diameter | Oversize Depth | Insert od | Cylinder Head id | Insert Thickness |
|---|---|---|---|---|
| | | **NOTE**<br>Be sure to measure the insert before machining the head or installing the insert | | |
| 0.005 (0.13) | Std. | 2.0075/2.0085 (50.991/51.016) | 2.0045/2.0055 (50.914/50.940) | 0.278/0.282 (7.06/7.16) |
| 0.010 (0.25) | Std. | 2.0125/2.0135 (51.118/51.143) | 2.0095/2.0105 (51.041/51.067) | 0.278/2.282 (7.06/7.16) |
| 0.020 (0.50) | 0.005 (0.013) | 2.0225/2.0235 (51.372/51.397) | 2.0195/2.0205 (51.372/51.397) | 0.238/0.287 (7.19/7.29) |
| 0.030 (0.76) | 0.010 (0.25) | 2.0325/2.0335 (51.626/51.651) | 2.0295/2.0305 (51.549/51.575) | 0.288/0.292 (7.32/7.42) |

Table 4-5. Valve Spring Measurements and Wear Limits-inch (mm)

| Free Length Inch (mm) | No. Coils | Wire Diameter Inch (mm) | Length Inch (mm) | Lb (N) Worn Limit | Lb (N) New Minimum | Lb (N) New Maximum |
|---|---|---|---|---|---|---|
| 2.685 (68.20) | 9 | 0.177 (4.50) | 1.724 (43.79) | 143 (636) | 147.25 (655) | 162.75 (724) |

ASSEMBLY

a. Install the pipe plugs, fuel inlet, and fuel drain fittings into the fuel passage.

(1) Make sure the fittings and plugs are installed in their original location.

(2) Apply teflon tape or liquid lead compound to the threads.

(3) Tighten the pipe plugs to the torque value given in Table 4-6.

Table 4-6. Pipe Plug Torque-ft-lb. (N•m)

| Plug Size Inch | Minimum Torque | Maximum Torque |
|---|---|---|
| 1/16 | 3 (4) | 6 (8) |
| 1/8 | 5 (7) | 10 (14) |
| 3/8 | 35 (47) | 45 (61) |
| 1/2 | 60 (81) | 70 (95) |
| 3/4 | 65 (88) | 75 (102) |
| 1 | 135 (182) | 145 (197) |

(4) Apply a coat of expansion plug sealant to the outside diameter of the expansion (cup) plug. Apply a coat of the sealant to the inside diameter at the water hole.

(5) Use the correct expansion plug driver to install the expansion plug (cup) plug.

**NOTE**

- If you do not have expansion plug drivers, you can use a mandrel of the correct size to install the plug. Install the plug so that it will be even with 0.090 inch (2.29 mm) below the chamber, FIGURE 4-15. Do not push the plug to the bottom of the counterbore.

o Apply clean lubricating oil to the valve stems.

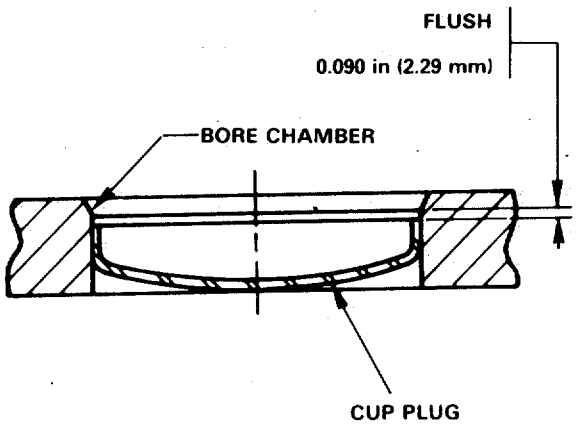


*FIGURE 4-15. Expansion (Cup) Plug Specifications.*

b. Install the valves in their original positions in the cylinder head and the valve springs in the cylinder head as follows: (FIGURE 4-16).

Valve-A

Valve Spring Guide-B

Valve Spring-C

Valve Spring Retainer-D

Valve Spring Collets-E

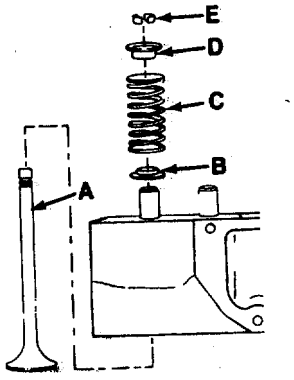


*FIGURE 4-16. Valve and Spring Installation Order.*

CAUTION

Put the cylinder head on a wood surface to prevent damage to the surface of the cylinder head.

**NOTE**

Always use new valve spring collets.

c. Compress the valve springs and install new valve spring collets.

**NOTE**

Cylinder heads that have two valve springs for each exhaust valve require a heavy duty spring guide at the top of the springs, and two spring wear plates at the bottom of the springs.

d. Test the valve seats.

CAUTION

Never vacuum test a cylinder head with the injectors installed. Installing the injectors can cause the valves to be out of alignment and will show leakage during the vacuum test. When the cylinder head is installed to the cylinder block, installing the injectors will not cause the valves to go out of alignment.

(1) Use the valve vacuum tester to check the seal between the valve and the valve seat.

(2) Be sure that the valve and valve seats are clean and dry.

(3) Put the vacuum cup over the valve. The O-ring in the cup must make a seal on the cylinder head around the valve.

(4) Turn the shutoff valve to the open position. Hold down the pushbutton to stop the vacuum pump.

(5) Operate the vacuum pump until the vacuum gauge indicates between 18 to 25 in Hg (457 to 635 mm Hg).

(6) Turn the shutoff valve to the closed position. Release the pushbutton to stop the vacuum pump.

(7) Check the time for the gauge to indicate a decrease in vacuum.

(a) Start timing when the gauge indicates "18".

(b) Stop timing when the gauge indicates "8." The total amount of time must not be less than 10 seconds.

(c) Lightly hit the valve stem with a soft hammer.

(d) Check the connections on the vacuum tester for leaks by starting the pump and holding the cup against a smooth surface. A decrease in vacuum indicates a loose or leaking connection.

(8) If the total time of the vacuum to decrease from "18" to "8" is less than 10 seconds.

(9) If there are no loose or leading connections on the tester, check for leaks between the valve seat insert and counterbore.

(a) Apply a coat of grease to the outside diameter of the insert to make a grease seal between the insert and the counterbore.

(b) Vacuum test and inspect the grease seal. A break in the seal indicates a leak between the insert and counterbore.

(c) Stake the valve seat insert and vacuum test for leaks.

(10) If leaks are indicated in step (9) above, disassemble and grind the valve face and/or the valve seat insert.

(11) Always clean the cylinder head after any grinding or cutting operation.

(12) Reassemble the cylinder head.

e. Install the cylinder head (paragraph 2-40).

## 4-13. Repair Cam Follower Housing Group.

**This task covers:** **a. Disassembly** **b. Repair** **c. Assembly**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Timing tool P/N 3375522
Combination wrench set 5120-01-046-4979
Lever bushing block P/N 3376026
Chamber tool P/N ST-1318
Drill press 5130-00-293-1949
Mandrel and block P/N ST-249
Plug gauge P/N ST-195
Expansion plug driver P/N 3376209
Dial bore gauge P/N 3376619
Machinists measuring tool kit
5280-00-278-9919

Equipment Condition

Cam follower housings and push rods removed (para. 3-18).

Materials/Parts

Cam Follower Housing P/N 3036939
Engine Poppet Valve Rocker Arm
P/N 3036935, 3036937
Sleeve Bearing P/N 4118378, 4118377
Headless Straight Pin P/N 4118939
Headed Straight Pin P/N 3013331, 3013330
Linear-Rotary Motion Roller
P/N 3036933, 3036934
Cam Follower Socket P/N 4213559
Internal Push Rod P/N 3046420
Injector Push Rod P/N 3046430
Cleaning solvent Item 5, Appendix C
Soap, Item 17, Appendix C

DISASSEMBLY

**NOTE**

Push rods should be removed from sockets before disassembling shaft.

a. Remove the lockscrews (1) that hold the shafts in the housing (FIGURE 4-17).

b. Remove the expansion plugs (2) from the ends of the housing.

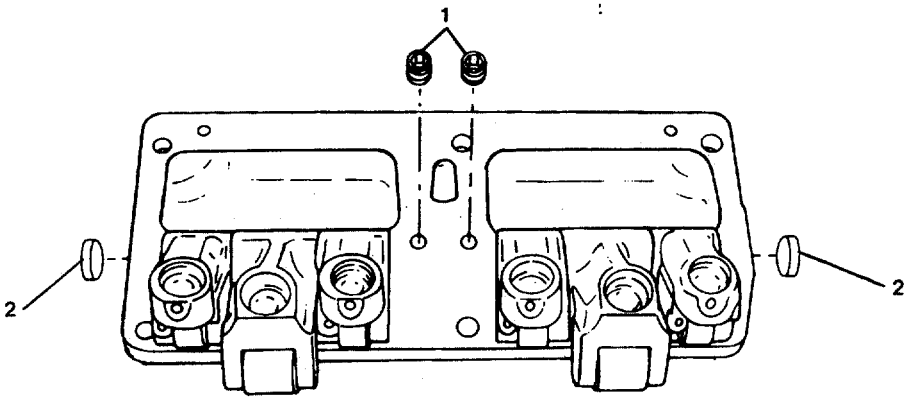


*FIGURE 4-17. Cam Follower Lockscrews.*

(1) Use a punch with a sharp point to make a hole in the center of the plugs (2). Hit one edge of the plug to loosen it.

(2) Use pliers to remove the plug (2).

c. Push against the shafts (5, FIGURE 4-19) in the housing to move the plug out of the hole in the opposite end of the housing.

d. Slide shafts out of housing. This frees the levers which can then be lifted from the housing.

**NOTE**

To prevent increased wear, mark the cam follower shafts and the levers as they are removed so they can be installed back in their original positions in the housing (FIGURE 4-18).

e. Remove the cam follower levers (6, FIGURE 4-19) from the housing.

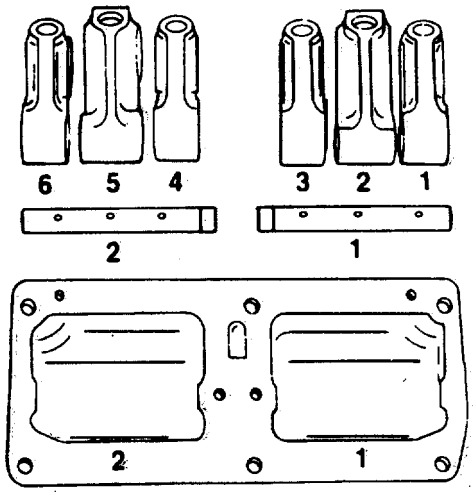


*FIGURE 4-18. Marking Original Location.*

REPAIR

a. Cleaning.

WARNING

High pressure compressed air tanks, piping system, and air operated devices possess potential for serious injury to eyes and exposed areas of skin due to escaping air pressure.

(1) Clean the cam follower shafts in a container of mineral spirits. Use compressed air to dry the shafts.

(2) Clean the other parts with cleaning solvent and dry with compressed air.

CAUTION

Be sure that the oil passages in the levers are clean.

b. Inspecting. Table 4-7 lists specifications for the cam follower assembly. See FIGURE 4-19 for reference numbers in Table 4-7.

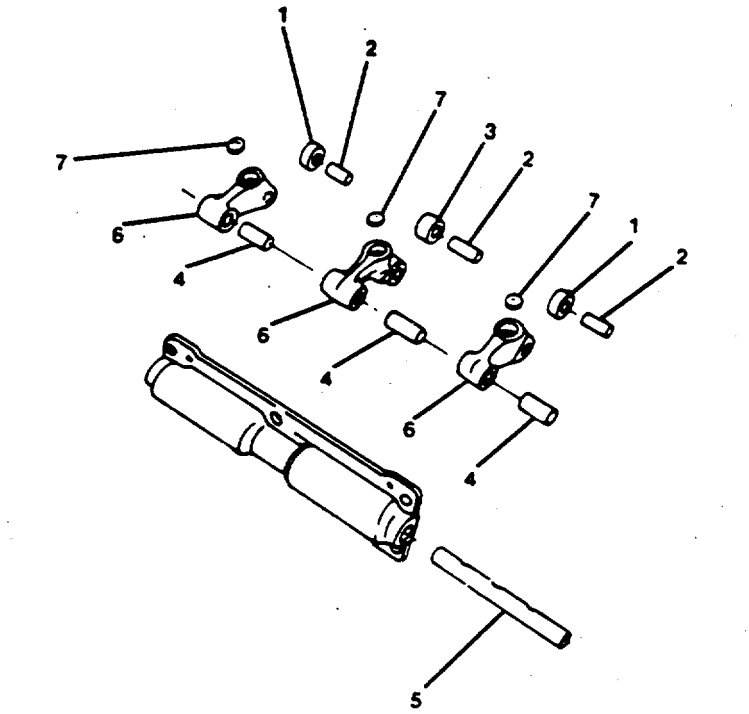


*FIGURE 4-19. Cam Follower Housing. Group (Push Rods Removed) with Callouts for Table 4-7 References.*

Table 4-7. Cam Follower Group Specifications-inch (mm)
(Reference No. Keyed to Figure 4-17 Callouts)

| Ref. No. | Measurement | Worn Limit | New Minimum | New Maximum |
|---|---|---|---|---|
| 1 | Valve Cam Rollers | | | |
| | Inside Diameter | 0.503 (12.78) | 0.5005 (12.773) | 0.5015 (12.708) |
| | Outside Diameter | 1.2485 (31.71) | 1.2495 (31.73) | 1.2505 (31.76) |
| 2 | Roller Pin Diameter | | | |
| | Valve | 0.497 (12.62) | 0.4997 (12.692) | 0.500 (12.70) |
| | Injector | 0.697 (17.70) | 0.6997 (17.772) | 0.7000 (17.780) |
| | Diameter of Bore for the Roller Pin | | | |
| | Valve | | 0.4990 (12.674) | 0.4995 (12.687) |
| | Injector | | 0.6992 (17.759) | 0.6997 (17.772) |
| 3 | Injector Cam Roller | | | |
| | Inside Diameter | 0.705 (17.91) | 0.7030 (17.86) | 0.7040 (17.88) |
| | Outside Diameter | 1.2485 (31.71) | 1.2495 (31.73) | 1.2505 (31.75) |
| 4 | Bushing Inside Diameter | 0.752 (19.10) | 0.7501 (19.053) | 0.7511 (19.078) |
| 5 | Shaft Outside Diameter | 0.748 (19.00) | 0.7485 (19.012) | 0.7490 (19.02) |

(1) Use micrometer to measure the outside diameter of the-shaft.

(a) The shaft must measure 0.7485 to 0.7490 inch (18.012 to 19.01 mm).

(b) Replace the shaft if it is damaged or the outside diameter measures less than 0.748 inch (19.00 mm).

**NOTE**

On the part of the shaft for the lockscrew, ensure that the grooves are clean.

(2) Inspect the cam follower housing for cracks or other damage. Discard if damaged or worn.

(3) Check the bushing in the cam follower lever for scratches or other damage.

(a) Use inside micrometer to measure the inside diameter of the bushing.

(b) The bushing must measure 0.7501 to 0.7511 inch (19.053 to 19.078 mm).

(c Replace the bushing if it measures more than 0.752 inch (19.10 mm).

(4) Use a magnetic inspection method to check the levers for cracks (FIGURE 4-20).

(a) Apply coil magnetization to the lever.

(b) Use 300 to 500 amperes with residual magnaglo.

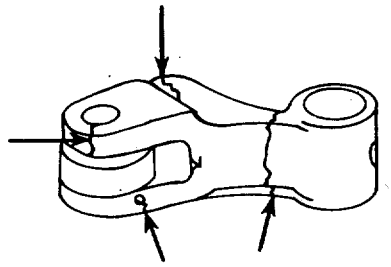

*FIGURE 4-20. Inspecting Levers for Cracks.*

(5) Check the expansion plug holes in the housing for damage or sharp edges.

(a) Use 240 grit aluminum oxide paper to remove any sharp edges.

(b) Put the aluminum paper in a rod that has a slot in the end to hold the paper. Install the rod in an electric drill.

(c) Start the drill and push the paper through the hole.

(d) Make a chamfer on the edge of the hole and remove any sharp edges.

(6) Check the insert in the cam follower lever for wear or damage.

(a) Use a new push rod ball or a 0.625 inch (15.88 mm) checking ball to check the insert.

(b) Apply a Prussian blue compound to the ball. Put the ball into the insert in the lever and rotate the ball 180 degrees.

(c) Replace the insert if it is damaged or has less than 80 percent contact with the ball.

(7) Remove the roll pins, roller pins, and rollers from the cam levers.

(8) Inspect the rollers.

(a) Use a small bore gauge to measure the inside diameter of the rollers.

(b) Check the rollers to be sure they are not out-of-round. See Table 4-7 for the dimensions of the rollers.

(c) Use micrometer to measure the outside diameter at the roller.

(d) The outside diameter of the roller must have a common center within 0.002 inch (0.05 mm).

(9) Use micrometer to measure the outside diameter of the roller pins. See Table 4-7 for dimensions of the roller pins.

(10) Measure the roller pin bore in the cam follower lever. See Table 4-7 for dimensions.

(11) If the rollers are damaged, be sure to inspect the camshaft for damage. Replace any part that is damaged or worn beyond the limits in Table 4-7.

(12) Replace the cam followers if they have any damage or cracks.

(13) Replace the cam followers if they are worn beyond the limit.

(14) Inspect the push rods.

(a) Clean the push rods with cleaning solvent.

(b) Inspect for engine oil in the push rods as follows:

(c) Inspect the straightness of the push rod by rolling it on a level surface. Replace the push rod if it is bent. Do not use a bent push rod.

(d) Visually inspect the ball and the socket ends of the push rods for uneven wear or scratches.

(e) Visually inspect the push rod ball end for excessive wear.

(f) Visually inspect the seating pattern in the push rod socket for excessive wear.

(15) Remove the bushing in the cam follower if the inside diameter of the bushing is more than 0.752 inch (19.10 mm).

(a) Use the lever bushing block and mandrel to remove the bushing.

(b) Use compressed air to clean the oil passage.

(c) Use the bushing block and mandrel to install a new bushing in the lever. Make sure the oil hole in the bushing is aligned with the oil hole in the lever.

(d) Cut a chamfer on each end of the bushing. Use a drill press at a slow speed and a chamfer tool that cuts a 60 degree angle chamfer.

(e) Put soap into the oil hole in the bushing. This will prevent metal particles from entering the oil hole.

(f) Cut the bore in the bushing to measure 0.7501 to 0.7511 inch (19.053 to 19.078 mm).

(g) Use the plug gauge to check the bore.

(h) Use compressed air to remove the soap from the oil holes. Wash the lever in cleaning solvent and dry with compressed air.

(i) If the socket insert in the lever was removed, use a press to install the new insert. Make sure the insert is installed tightly.

CAUTION

If a new cam follower insert is installed in the lever, a new push rod must also be used.

ASSEMBLY

a. Hold a 0.006 inch (0.15 mm) feeler gauge between the cam follower (6, FIGURE 4-19) lever and roller (1).

(1) Install the roller pin (2) through the lever (6) and roller (1).

(2) Install the other rollers and pins into the levers.

b. Assemble the levers (6) and shafts (5) in the housing. Make sure the lever for the injector is in the center position in each assembly.

**NOTE**

Make sure the push rod sockets in the levers and the dowel holes in the housing are to the top when the assembly is mounted on the engine.

c. Install a temporary screw in the shaft (5). This will prevent breakage of the lockscrew when the plug is installed in the housing.

d. Apply a light coat of sealant to the expansion plug hole in each end of the housing.

(1) Use the expansion plug driver to install the expansion plug (2, FIGURE 4-17).

(2) Install the plug (2) so it is at least even with the edge of the hole or not more than 0.010 inch (0.25 mm) below the edge of the hole.

e. Remove the temporary screws and install the lockscrews in the shafts (21).

f. Install the cam follower housing (paragraph 3-31).

## 4-14. Repair Power-Takeoff (PTO) Assembly. (SL111 HP2/with non-adjusting clutch.)

**This task covers:** a. Disassembly b. Repair c. Assembly

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Engine lifting fixture P/N 3822512
Combination wrench set,
5120-01-046-4979
Dial indicator, 5210-00-277-8840
Torque wrench kit P/N 3377216

**Materials/Parts**

Internal gear P/N 6931
Annular ball bearing P/N M224
Nonmetallic hose assembly
P/N A1663, M1292A
Helical compression spring
P/N A2709N
Tapered roller bearing
P/N M207

Equipment Condition

PTO removed (para. 3-21).

**NOTE**

- It is necessary to remove the PTO from the engine first, then the clutch assembly from the clutch shaft in order to replace worn clutch plates.
- The pilot roller bearing may be replaced without removing the PTO clutch assembly from the clutch shaft.
- On PTO units which have been disassembled, steps (a) through (i) of the Assembly Procedures must be accomplished in order to reach a starting point for bearing adjustment. For field adjustment of bearing only, go to assembly step (i) of this procedure.

DISASSEMBLY

(Refer-to FIGURE 4-21 for reference numbers used in this procedure.)

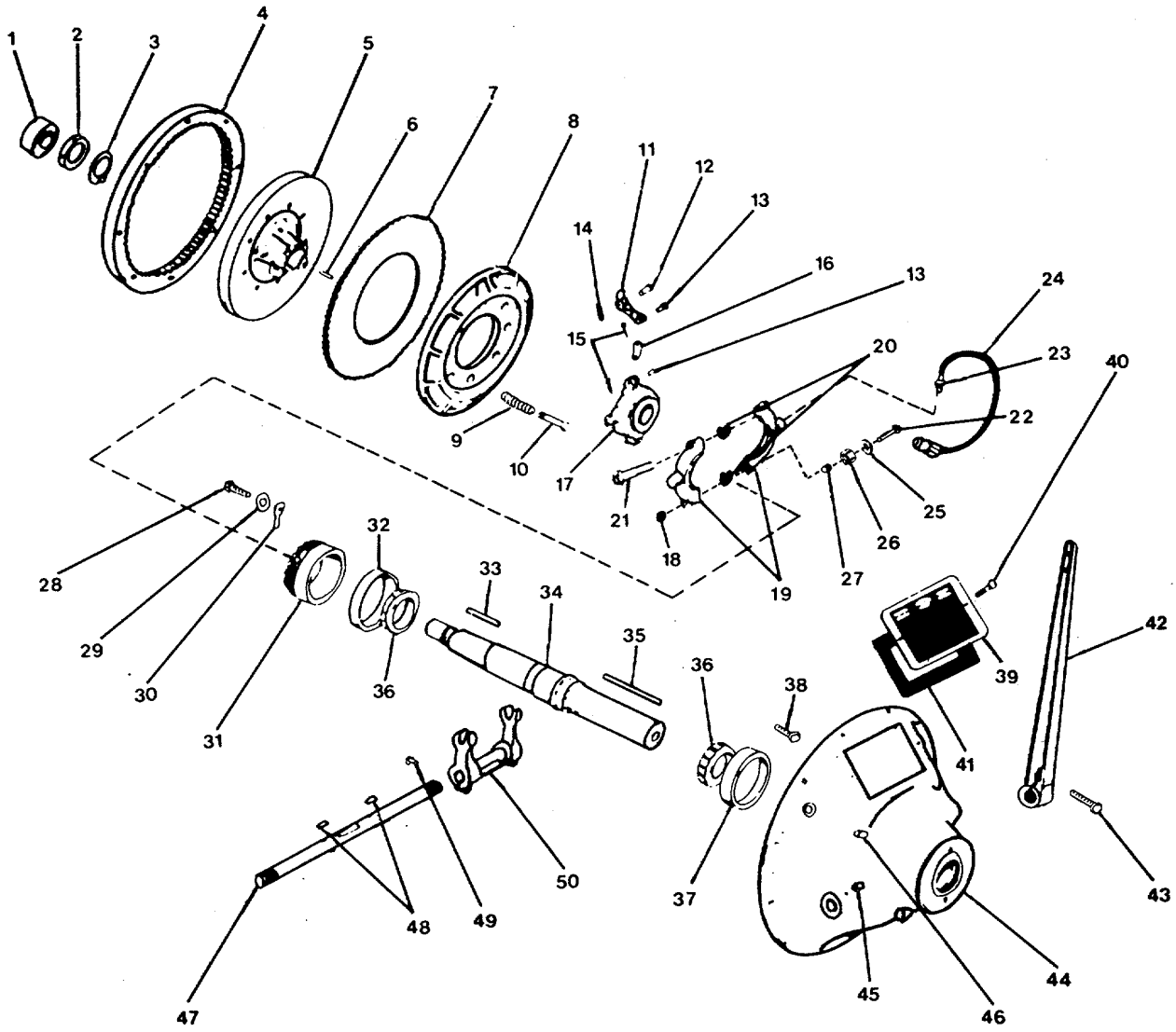


*FIGURE 4-21. Power Takeoff Assembly (SL-111).*

a. Support the Power Takeoff (PTO) housing (44) on a work bench with wooden blocks. Have the clutch end facing upward.

b. Remove the pilot bearing (1) from the clutch shaft (34).

c. Remove the jam nut (26) and lockwasher (25) from the hose fitting (23) located in the PTO housing (44). Push the fitting (23) and hose (24) into the PTO housing (44).

d. Straighten the bent portion of the hub nut lockwasher (3) from the hub nut (2). Remove the hub nut (2) and the lockwasher (3) from the clutch shaft (34). Discard the hub nut lockwasher (3).

e. Remove the two round-head screws (40) which secure the instruction cover plate (39) and gasket (41) to the PTO housing (44) and remove the plate and gasket.

f. By reaching through the cover plate opening, remove two of the spring bolts (10) and pressure springs (9) from the hub and back plate (5). Remove the second spring bolt 180° from the first.

g. Use a gear puller with threaded legs for 5/8-11 tapped holes to pull the PTO assembly, (5) from the clutch shaft (34). Install the puller so the threaded legs screw into the 5/8-11 holes from which the springs bolts were removed in step above. Use the jack screw to exert force on the input end of the clutch shaft (34). Remove the puller and clutch assembly from the clutch shaft (34). Remove the shaft hub key (33).

h. Set the clutch assembly (5) on a bench with the sliding sleeve assembly end facing up. Remove the lubrication fitting (27) from the hose fitting (23). Remove the hose from the fitting on the collar (19). Remove the fitting from the collar (19).

i. Straighten and remove four of eight cotter pins (15) from four of eight lever link pins (13). Remove four lever link pins (13) from the lever links (16) and sliding sleeve (17).

j. Remove the sliding sleeve (17) and collar assembly (19) from the hub (5) and back plate (8). Remove the hex-nuts (18) from the capscrews (22) and remove the collar halves (19) and shims (20) from the sliding sleeve (19). Remove the two guide pins (6) from the sliding sleeve (17) only if replacement of the parts is necessary.

k. Remove the six remaining spring bolts (10) and pressure springs (9) from the hub and back plate.

l. Remove the floating plate (8) and driving plate (7) from the hub and back plate.

m. Remove the remaining four cotter pins (15) from the remaining lever link pins (13) and remove the lever links (16) from the levers (11) after removing the link pins (13). Straighten the four cotter pins (14) which secure the finger lever pins (12) to the finger levers and the hub and back plate and remove the finger levers (11) from the hub and back plate.

n. Remove the hex-head capscrew (28), lockwasher (29), and lock (30) which secure the bearing retainer (31) in position from the PTO housing. Remove the bearing retainer (21) from the PTO housing.

o. Remove the clutch shaft (34) with attached parts from the PTO housing by carefully tapping on the output end of the shaft. The forward bearing cup (32) and both roller bearing (36) will remain with the shaft.

p. Pull bearing cup (32) from shaft (34).

q. Use a bearing puller to remove the bearing (36) from the clutch shaft.

r. Remove the two dust protector caps from the PTO housing and with a long, straight, shank blunt punch, tap the rear bearing cup (37) from the PTO housing.

s. Remove the hex-head capscrew (43) that secures the hand operating lever (42) to the operating shaft (47) and remove the hand lever (42). Set the PTO housing (44) on the bench with the clutch end facing up.

t. Remove the two hex-head capscrews (49) which secure the throwout yoke (50) to the operating shaft (47). Gently tap one end of the operating shaft (47), and roll out the exposed Woodruff key (48). Repeat this procedure and roll out the remaining Woodruff key. Remove the operating shaft (47) and throwout yoke (50) from the PTO housing (44).

u. Remove the lubrication fittings (45, 46) from the PTO housing. Remove the plug (38) only if cleaning of the drilling is necessary.

REPAIR

a. Visually inspect for damage or scrubbing of parts due to misalignment between the engine and the Power Takeoff.

b. Replace roller bearings (36) in the PTO housing. Ensure proper alignment of parts between the engine and the PTO on reinstallation.

c. Check all parts of the PTO unit, clutch assembly and housing for visual signs of cracks or other damage. Replace internal gear (4) and pilot bearing (1).

ASSEMBLY

**NOTE**

Torque values given in these procedures are for clean, oiled thread conditions. See Torque Value Tables 3-5 for Capscrews, Bolts, and Nuts; 3-6 for Tapered Plugs; and 3-7 for Tube and Hose Fittings.

a. Install the lubrication fittings (45) and (46) in the PTO housing (44) if removed during disassembly.

b. Install the bearing and cup (37) into its bore in the PTO housing (44). Press or tap the bearing cup (37) squarely into its bore to bottom on its back face.

c. Install the two dust protectors in their holes at the rear of the PTO housing.

d. Install the passage plug (38) in the PTO housing (44) if removed during disassembly.

e. With the PTO housing setting on the bench with the clutch end facing up, install the operating shaft (47) and throwout yoke (50). Push the operating shaft halfway into the PTO housing (44). Slip the throwout yoke (50) onto the operating shaft (47) and then push the shaft (47) the rest of the way through the PTO housing (44) to its normal position. Be sure the throwout yoke (50) is installed so the capscrews (49) enter from the clutch side toward the rear. Slide the yoke (50) to one side to expose Woodruff key slot in the shaft (34) and install the key (48). Slide the yoke (50) to the other side and install the remaining key (48). Center the yoke (50) over the keys (48) and secure the yoke (50) to the shaft (34) with the two hex-head capscrews (49). Tighten the capscrews (49) to 30-42 ft-lb. torque.

f. Using an arbor press and steel tubing, press the two bearings (36) onto the clutch shaft (34), one from each end, with their back faces butting against the stop shoulder on the shaft (34).

g. Install and secure the hand lever (42) to the operating shaft (47) with the hex-head capscrew (43). Tighten the capscrew to 86-95 ft-lb. torque.

h. Install the clutch shaft (34) with bearings attached into the shaft bore and bearing cup (37) in the PTO housing (44); install the output end of the shaft-(34) first. Slide the bearing cup (32) over the shaft and into its bore in the PTO housing. Squarely press the bearing cup (32) in place against the bearing. Install the bearing retainer (31) over the shaft (34).

i. Adjust the bearing end play to 0.004-0.007 inch on the SP111 HP2 (0.006-0.010 inch on the SP 214 P1).

**NOTE**

- The only approved method of field adjustment is by the use of a dial indicator to read actual end play. The adjustment procedures are the same for both PTOs (except for end play measurements).

- If only bearing adjustment is being made, remove the PTO from the engine (paragraph 3-38).

**NOTE**

On PTO units which have been disassembled, steps (a) through (i) of the Assembly Procedures must be accomplished in order to reach a starting point for bearing adjustment on the SP 111 HP2 (steps (a) through (g) on the SP 214 P1, paragraph 4-15).

(1) Use the bearing retainer nut for adjusting the tapered roller bearings. Refer to FIGURE 4-22.

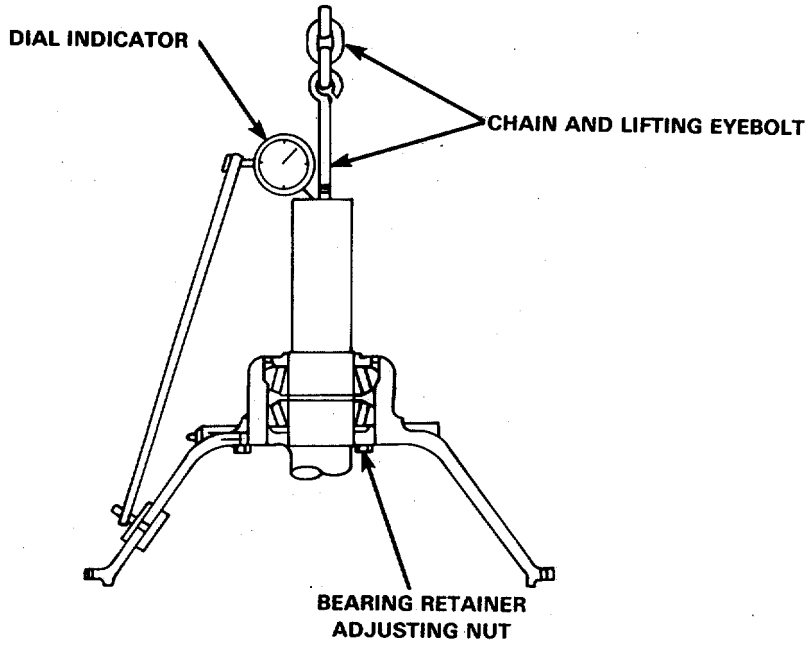


*FIGURE 4-22. Adjusting Roller Bearings.*

(a) Tighten the retainer nut until the shaft requires 60 in-lb. of force to turn.

(b) Back off the retainer nut 3-1/4-4-1/4 notches. See FIGURE 4-23.

(2) Dial indicate the end play as follows:

(a) Set PTO on supporting blocks with the clutch shaft in a vertical position with the input end down.

(b) Attach an eyebolt in the 1/4 PTF thread at the output end of the shaft. (Models which do not have this hole will have to be inverted with the input end up, and clearance-at the output end below, for dial indicator mounting. An extra hub nut with a loop shaped strap welded to it car be used to apply the pushing and pulling forces required-during end play check.) See FIGURE 4-18.

CAUTION

Select lifting eyebolts to obtain maximum thread engagement with bolt shoulder tight against housing. Bolts should be near but should not contact bottom of bolt hole.

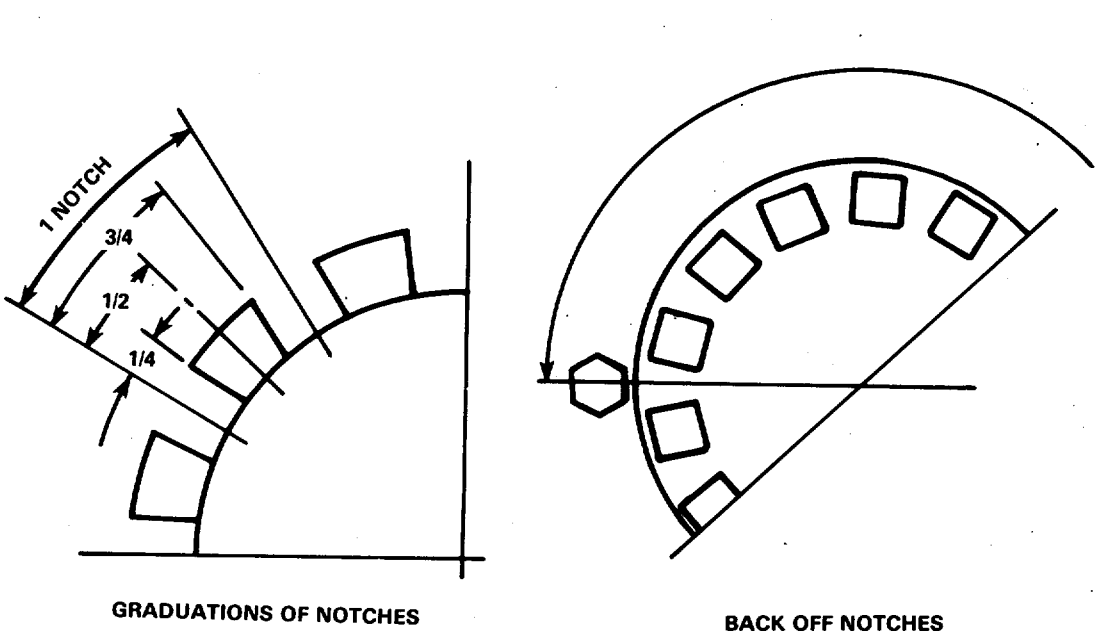


*FIGURE 4-23. Adjusting Retainer Nut.*

(c) Attach a dial indicator to the housing and locate the stem or plunger, from the indicator, on the outer machined area of the end of the clutch shaft. Mark a spot next to the indicator stem.

(d) Apply a pushing force of 200 pounds while turning the shaft two complete revolutions in each direction (the weight of the shaft can be counted as part of the 200 pounds). With the pushing force applied, stop the plunger or stem next to the mark and zero the dial indicator.

(e) Apply a pulling force of 200 pounds (compensate for shaft weight) to the shaft and rotate, with force applied two complete revolutions in each direction. Stop with force applied and mark next to plunger or stem of the dial indicator. The indicator reads the actual end play.

(f) Adjust nut to obtain the desired end play. Recheck final end play with the dial indicator as described. Lock nut when play adjustment is between 0.004 and 0.007 inch on the SL111 HP2 (00.06 to 0.010 on the SP 214 P2).

j. After adjustment, install the retainer lock (30, FIGURE 4-21) and secure the lock (30) to the clutch housing (44) with a capscrew (28) and lockwasher (29). Tighten the capscrew to 21-24 ft-lb. torque. Be sure to lubricate the main bearings through the housing fitting near the shaft exit.

k. Install the lubrication fitting (38) in the rear (output) end of the clutch shaft (if used).

l. Set the clutch hub and back plate assembly on the bench with the hub section facing up.

m. Install four levers (11) and pins (12) in the hub and back plate (8). Secure the levers (11) and pins (12) to the plate (8) with four cotter pins (14). Spread the cotter pins.

n. Install the driving plate (7) onto the hub and back plate.

o. Install the floating plate (5) onto the hub and back plate (8) against the driving plate (7).

p. Use four pins (13) and cotter pins (15) to attach eight links (16) to the finger levers (11). Spread the cotter pins. When the cotter pins are spread, the radius of the pin ends must not be greater than 0.31 inch. This is necessary to prevent operating interference.

q. Install the eight spring bolts (10) and pressure springs (9) through the floating plate and into the hub and back plate. Tighten the spring bolts until their shoulders contact the hub and back plate; then, tighten them to 160-175 ft-lb. torque.

r. Assemble the collar (19) halves and shims (20) to the sliding sleeve (17) with the two capscrews (22) and two hex-nuts (18). Tighten the hex-nuts to 38-42 ft-lb. torque. Install the two guide pins (6) with flats into the sliding sleeve (17) if they were removed during disassembly.

s. Install the sliding sleeve (17) with attached parts entering the guide pins (6) into the hub of the hub and back plate.

CAUTION

When the cotter pins are spread, the radius of the pin ends must not be greater than 0.31 inch. This is necessary to prevent operating interference.

t. Attach the loose ends of the eight links (16) to the sliding sleeve (17) with four pins (13) and four cotter pins (15). Spread the cotter pins.

u. Install the hose fitting (23) into the collar (19) and attach the flexible hose to the fitting.

v. Attach the fitting (22) to the end of the flexible hose (24).

w. Partially install key (33) into the shaft keyway.

x. Carefully slide the PTO assembly (5) onto over the clutch shaft, until sleeve (17) clears key (33). Lower PTO assembly, tapping key (33) down into position and engaging the trunnions of the collar (17) with the yoke (19) and routing the flexible hose (24) clear of the moving parts to the hole on the inside of the PTO housing (44).

y. Push the fitting (23) through the hole in the PTO housing (44) and secure it in place with the lockwasher (25) and nut (26). Install the lubrication fitting (27) into the hose fitting.

z. Install the hub nut lockwasher (3) onto the clutch shaft (34), locating its lower tab in the spot drilling provided on the hub and back plate. Install the hub nut (2). Tighten the nut (2) to remove all clearance, applying 30 ft-lb. torque. Then tighten the nut 60-90° further. Bend the lockwasher (3) against a flat on the nut.

CAUTION

The pilot roller bearing has an inner race that is removable from the outer race roller and seal assembly. Due to this construction, axial alignment of the inner and outer races is most important.

aa Press the pilot bearing (1) on the clutch shaft (34). Solidly support the output end of the clutch shaft (34) during installation of the pilot bearing (1). Also, apply the force to the inner race of the pilot bearing (1) during installation. Don't press the pilot bearing all the way onto the shaft. Leave a distance of 0.06-inch between the front face of the bearing inner race and the end of the clutch shaft. Refer to FIGURE 4-24.

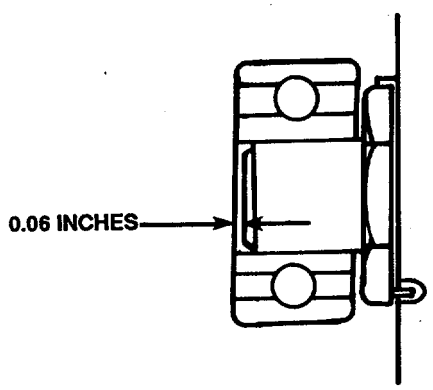


*FIGURE 4-24. Pilot Bearing (PTO/SL-111).*

ab. Place the instruction cover plate gasket (41) and install the cover plate (39) on the PTO housing with two round-head screws (40). Tighten the screws to 11-13 ft-lb. torque (FIGURE 4-21).

ac. If the driving ring (4) was removed, position the driving ring (4) against the engine flywheel and secure it with eight hex-head capscrews. Torque capscrews. Refer to Table 3-5.

ad. Install the PTO, clutch, and housing assembly (paragraph 3-38).

## 4-15. Repair Friction Clutch Power-Takeoff Assembly. (SP 214 Pl/with adjustable clutch.).

**This task covers:** **a. Disassembly** **b. Repair** **c. Assembly**

**INITIAL SETUP:**

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Engine lifting fixture P/N 3822512
Combination wrench set,
5120-01-046-4979
Gear puller P/N 3375016
Searing puller P/N ST-1178
Torque wrench kit P/N 3377216

Materials/Parts

Internal gear P/N 5713
Annular ball bearing P/N M1985A
Wooden blocks, Item 7, Appendix C

Equipment Condition

Friction Clutch Assembly removed
(para. 3-22).

**NOTE**

- It is necessary to remove the friction clutch assembly from the engine first, then the clutch from the clutch shaft in order to replace worn clutch plates.
- The pilot roller bearing may be replaced without removing the clutch from the clutch shaft.

**NOTE**

On friction clutch units which have been disassembled, steps (1) through (9) of the Assembly Procedures must be accomplished in order to reach a starting point for bearing adjustment. For field adjustment of bearing only to step c of this procedure.

DISASSEMBLY. (Refer to FIGURE 4-25 for reference numbers.)

a. Support the clutch housing (32) on a work bench with wooden blocks. Have the clutch end facing upward.

b. Use a standard bearing puller, and remove the pilot bearing (2) from the clutch shaft (54).

c. Remove the jam nut (34) and lockwasher (35) from the hose fitting (25) located in the clutch housing (18). Push fitting (25) and hose (21) into the clutch housing (32).

d. Straighten the bent portion of the hub nut lockwasher (4) from the hub nut (3). Remove the hub nut (3) and the lockwasher (4) from the clutch shaft (54).

e. Use a conventional gear puller with threaded legs for 5/8-11 tapped holes to pull the clutch assembly (9) from the clutch shaft (54). Install the puller so the threaded legs screw into the holes provided in the hub and back plate (5) and the jack screw exerts force on the end of the clutch shaft (54). Remove the shaft key (23). Remove the puller and the clutch assembly (9) from the clutch shaft (54).

f. Set the clutch assembly (9) on a bench with the sliding sleeve assembly (16) end facing upward. Remove the hydraulic (grease) fitting (33) from the hose fitting (25). Remove the hose (21) from the hydraulic (grease) fitting (20). Remove the hydraulic (grease) fitting (20) from the split collar assembly (36).

g. Straighten and remove the four cotter pins (12) from the headed pins (10). Remove the four headed pins (10) from the levers (13) and the floating plate (43). Remove the two spring washers (11) at each lever location, and remove the levers (13), sliding sleeve (16), and collar (36) groups from the floating plate (43) and adjusting ring (40) as an assembly.

h. Straighten and remove the eight cotter pins (51) from the headed pins (39). Remove the headed pins (39), lever links (14), and levers (13), and the collar halves (36) from the sliding sleeve (16). Remove screws (19) and nuts (37) to separate collar halves (36) and to remove shims (17).

i. Depress the adjusting lock pin (41) with a screwdriver, and unscrew the adjusting ring (40), removing it from the hub of the back plate (5). Remove the adjusting ring lock pin and spring (42) from the floating plate (43).

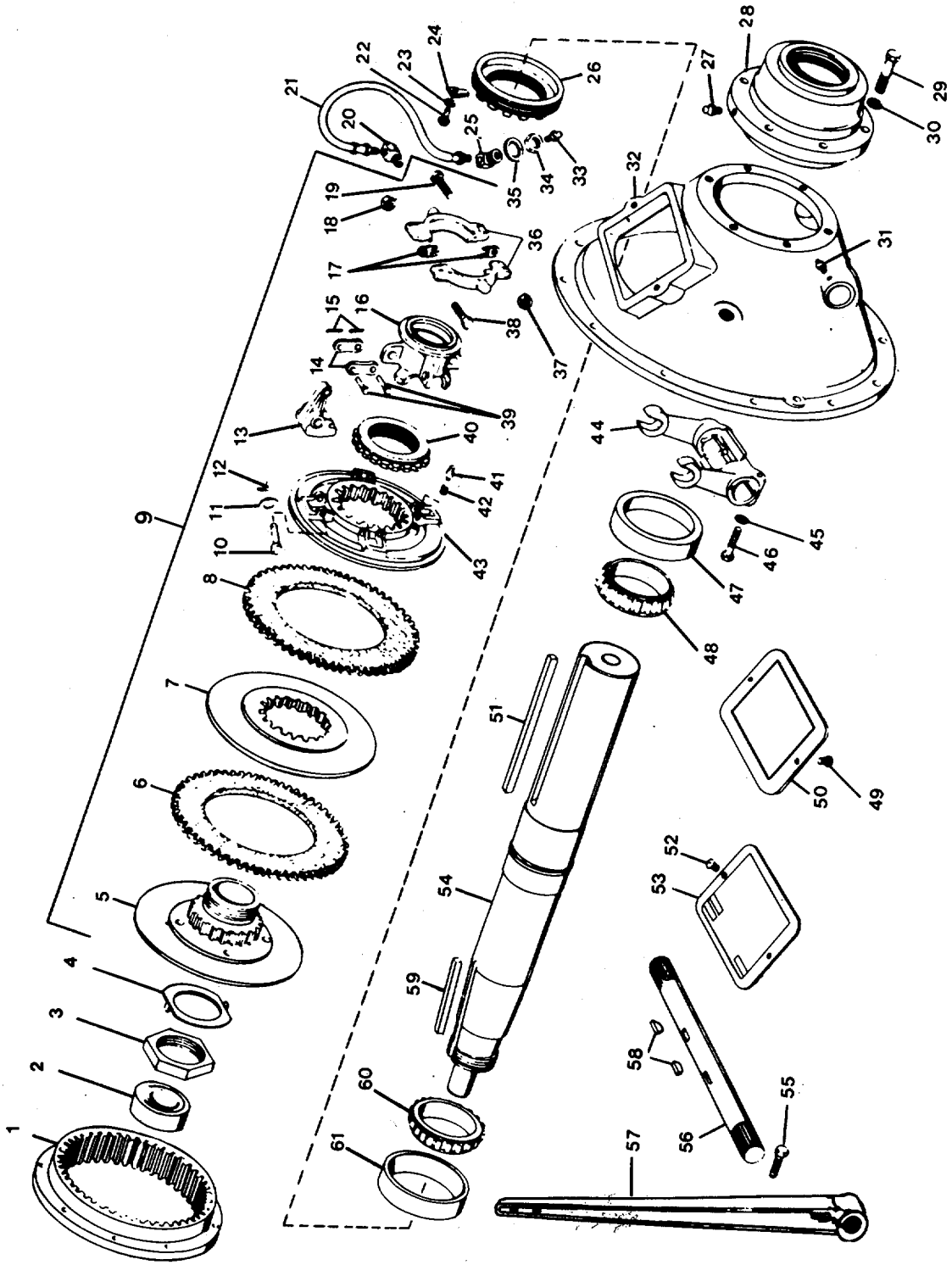

*FIGURE 4-25. Friction Clutch (Power Takeoff) Assembly.(SP-214).*

j. Remove floating plate (5), driving plates (6, 8), and center plate (7).

k. Turn the clutch housing (32) with attached parts over the bench, and support the housing (32) with wooden blocks so the output end of the clutch shaft (54) faces up.

l. Remove shaft key (21), six hex-head capscrews (37) and lockwashers (36) which secure the bearing carrier (16) to the clutch housing (18). Remove bearing carrier.

m. Remove two round-head machine screws (52) which secure the instruction cover plate (53) to the housing (32). Remove the plate (53).

n. Remove two round-head machine screws (49) which secure the bottom cover plate (50) to the housing (32). Remove the plate (50).

o. Remove two hydraulic (grease) fittings (35, 27) from the housing only if replacement of the parts is necessary.

p. Remove the bearing carrier (28) clutch shaft (54) with attached parts from the housing (32). Set the clutch shaft (54) with attached parts in a large vise with the clutch end of the shaft (54) facing up. Grip the rear cast section of the bearing carrier (28) with the vise. Remove hexhead capscrew (22), lockwasher (23), and retainer lock (24) from the bearing carrier (28).

q. Remove the bearing retainer (26) from the bearing carrier (28). Lift the clutch shaft (54), separating it with attached parts from the bearing carrier (28). The bearing cup (61) and bearing cones (48, 60) will be removed with the shaft (54).

r. Pull bearing cup (61) from shaft (54).

s. Use bearing puller and remove the bearing cones (48 and 60) from the clutch shaft (54). The bearing cones (48 and 60) remove in opposite directions from the shoulder machined on the clutch shaft (54).

t. Two small (5/16-inch) holes are provided in the bearing carrier (28) for removal of the bearing cup (47). Use a straight blunt punch through these holes and tap the bearing cup (47) out of its bore. Remove the cup (47) only if replacement of the part is necessary.

u. Remove the hexhead capscrew (55) that secures the hand lever (57) to the operating shaft (56). Remove the hand lever (57) from the operating shaft.

v. Set the clutch housing (32) on the bench with the clutch end facing upward. Remove two hexhead capscrews (46) and lockwashers (45) from the throwout yoke (44). Gently tap one end of the operating shaft (56), and roll out the exposed Woodruff key (58). Repeat this procedure and remove the remaining Woodruff key (58). Remove the operating shaft (56) and throwout yoke (44) from the clutch housing (32).

REPAIR

a. Visually inspect for damage or scrubbing of parts due to misalignment between the engine and the friction clutch assembly.

b. Replace bearings (48, 60) and cups (47, 61) in the housing. Ensure proper alignment of parts between the engine and the friction clutch assembly on reinstallation.

c. Check all parts of the PTO unit. Replace internal gear (1) and annular Ball Bearing (2).

ASSEMBLY (Refer to FIGURE 4-25)

NOTE

Torque values given in these procedures are for clean, oiled thread conditions. See Torque Value Tables 3-5 for Capscrews, Bolts, and Nuts; 3-6 for Tapered Plugs; and 3-7 for Tube and Hose Fittings.

a. Install the two 1/4-inch hydraulic (grease) fittings (31, 27).

b. Set the clutch housing (32) on a bench with the clutch end facing up. Install the operating shaft (56) halfway into the clutch housing (32). Slip the throwout yoke (44) onto the operating shaft (56), and push the shaft (56) through the opening on the other side of the clutch housing (32). Install one woodruff key (58) in the operating shaft (56). Slightly move the throwout yoke (44) on the operating shaft (56) and install the other key (58). Install two hexhead 3/8-16 x 1-1/2 capscrews (46) and the 3/8-inch lockwashers (45) to secure the throwout yoke (44) to the shaft (56). Tighten capscrews (46) to 38 ft-lb. torque.

c. Install and secure the hand lever (57) to the operating shaft (56) with a hexhead 1/2-13 x 1-3/4 capscrew (55). Tighten the capscrew (55) to 85 ft-lb torque.

d. Use an arbor press and install the two bearing cones (48 and 60) on the clutch shaft (54), one from each end with their back faces butting against the stop shoulder on the shaft (54).

e. Press bearing cup (47) into the bearing carrier (28), back face of the cup rearward. Press cup (47) to bottom of bore.

f. Press bearings (48, 60) onto each end of shaft (54).

g. Set the bearing carrier (28) in a large bench vise with the clutch end facing up. Grip the casting with the vise jaws below the mounting flange. Install the clutch shaft (54), with bearing cones (48, 60), into the bearing cup (61) over the clutch shaft (54) and into the bearing carrier. Tap or press the cup (61) into position. Install the bearing retainer (26) into the bearing carrier (28) against the bearing cup (61).

h. Adjust the bearing end play of 0.006-0.10 inch. Refer to assembly i in paragraph.

i. After adjustment, install the retainer lock (24) and secure the lock to the bearing carrier with a lockwasher 23) and hexhead 5/16 - 18 x 3/4 capscrew (22). Tighten the capscrew (22) to 21 ft-lb. torque.

j. Set the clutch housing (32) on a work bench. Raise and support the housing (32) with wooden blocks about 5 inches from the bench, so the output end of the housing faces up. Install the clutch shaft (54) with attached parts into the clutch (32) housing. Secure the bearing carrier (28) to the clutch housing (32) with six hexhead 1/2 - 13 x 2 capscrews (29) and six lockwashers (30). Tighten the capscrews to 85 ft-lb. torque. Grease fitting is at top position when the unit is in normal operating position. Install shaft key (51).

k. Set the clutch hub and back plate assembly (5) on the bench with the hub section facing up.

l. Install a driving plate (6) onto the hub and back plate (5). Install the center plate (7) onto the first driving plate (6). Install the second! driving plate (8). Install the floating plate (43) upon the second driving plate (8).

m. Install the adjusting lock pin spring (42) into the bore provided in the floating plate (43). Install the adjusting lock pin (41) and de-press the pin (41) and spring (42) with a screwdriver while installing the adjusting ring (40). Screw ring about halfway down hub thread.

n. Install the four levers (13) and eight lever links (14) to the lugs on the sliding sleeve (16) with eight headed pins (39) and eight cotter pins (15). Spread the pins (15) so their ends do not exceed a 0.47 inch radius for operating clearance.

o. Install the collar halves (36) and two shims (17) to the flange provided on the sliding sleeve (16). Retain the collar (36) to the sleeve (16) with two hexhead 3/8 - 24 x 2-1/4 capscrews (19) and two hex-nuts (37). Tighten the hex nuts (37) to a 30 ft-lb. torque.

p. Install the levers (13), sliding sleeve (16), and collar (36), as an assembly, onto the adjusting ring (40) and floating plate (43). Retain the levers (13) to the floating plate (43) with eight spring washers (11) (one on each side of each lever), four headed pins (10), and four cotter pins (12). Spread the ends of the cotter pins (12).

q. Install the hose assembly (21). Install the hose fitting (20) into the split: collar (36). Install the hose (21) into the fitting (20). Install the hydraulic (grease) fitting (33) into the hose fitting (25).

r. Set the clutch housing (32) with attached parts on the bench with the clutch end facing up and support firmly with wooden blocks.

s. Lower the clutch assembly (9) over the clutch shaft (54) and into the clutch housing (32), engaging the trunnions on the split collar (36) with the throwout yoke (44). Align the shaft keyway with the keyway in the hub and back plate (5). Install the key (59).

t. Install the hub nut lockwasher (4) onto the clutch shaft (54), indexing its lower tab in the drilling provided on the hub and back plate (5). Install the hub nut (3). Tighten the hub nut (3) to 30 ft-lb. torque to seat tapers and remove clearance, then tighten the nut an additional one-half turn. Bend the lockwasher (4) against a flat on the nut (3).

u. Route the hose assembly (21) free of moving parts and push the fitting (25) through the hole provided in the clutch housing (32). Install the lockwasher (35), and the jam nut (34) to retain the fitting (25) in the housing (32).

v. Tap or press the pilot bearing (2) on. the clutch shaft (54). Solidly support the output end of the clutch shaft (54) during installation of the pilot bearing (2). Also, apply the force to the inner race of the pilot bearing (2) during installation. Don't press the pilot bearing (2) all the way onto the shaft (54). Leave a distance of 0.12 inch between the front face of the bearing (2) inner race and the end of the clutch shaft (54). (See FIGURE 4-26)

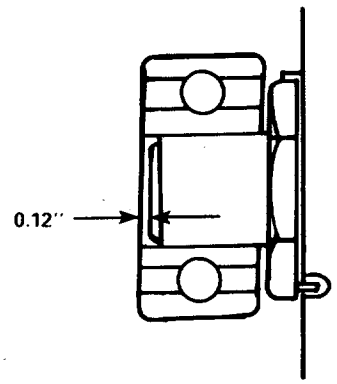


*FIGURE 4-26. Pilot Bearing (PTO/SP-214).*

w. Adjust the clutch assembly by the following procedure:

(1) With the clutch disengaged, turn the clutch until the adjusting lock pin (41) can be reached through a hand hole (40). Depress the pin (41) with a screwdriver and screw the adjusting ring clockwise one or two notches or until a distinct pressure is felt with the hand lever (57).

(2) Release the adjusting pin (41) and turn the adjusting ring (40) to engage the nearest notch with the pin (41).

(3) Engage and disengage the clutch a number of times to check the operation. If proper adjustment has not been accomplished, repeat steps (a) and (b) until proper engagement and disengagement are obtained.

x. Place instruction cover plate (53) in position on the clutch housing (32). Secure the plate (53) with two round-head 1/4-20 x 1/2 machine screws (52). Tighten the screws (52) to 11 ft-lb. torque.

y. Place bottom cover plate (50) in position on the clutch housing (32). Secure the plate (50) to the housing (32) with two round-head 1/4-20 x 1/2 machine screws. Tighten the screws to 11 ft-lb. torque.

z. If the driving ring (1) was removed, position the driving ring (1) against the engine flywheel and secure it with eight hexhead capscrews. Torque the capscrews (Table 3-5).

aa. Install the PTO (paragraph 3-38).

## 4-16. Repair Camshaft Group.

**This task covers:**

**a. Disassembly** **b. Inspection** **c. Repair** **d. Assembly**

INITIAL SETUP

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Main bearing cap puller P/N ST-1178
Cam shaft installation pilots
P/N 3375268
Hydraulic press P/N 2009-15
Machinists measuring tool kit
5280-00-278-9919

Equipment Condition

Camshaft removed (para. 3-24).

Materials/Parts

Crocus cloth (fine), Item 14, Appendix C
Cleaning solvent
Item 5, Appendix C
Lubriplate, Item 11, Appendix C
Wood blocks (to support gear if removed),
Item 7, Appendix C
Camshaft P/N 3049024
Thrust bearing washer P/N 215233
Gear spur P/N 3035195

DISASSEMBLY

a. Remove thrust bearing.

b. Remove the gear, as follows:

CAUTION

Place a wooden block under the camshaft to avoid damage as the camshaft drops free from the cam gear.

(1) Install the camshaft and gear assembly in a hydraulic press. Place V-blocks under the gear. Make sure the V-blocks support the hub area of the gear (FIGURE 4-27) .

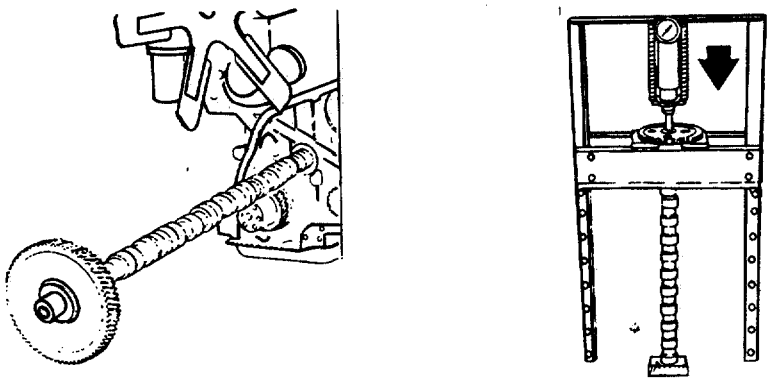

*FIGURE 4-27. Removing Camshaft Gear.*

CAUTION

Do not use a heating torch to remove the gear. If you use a heating torch, a new gear must be installed.

(2) Push the shaft from the gear.

NOTE

If the camshaft key is marked with an arrow, record the direction in which it is pointed.

(3) Use a flat chisel and hammer to remove the camshaft key.

## INSPECTION

CAUTION

If the inside diameter of the gear is damaged in excess of a 0.125 inch (3.175 mm) wide band, do not use the gear. This damage can result in gear movement on the camshaft nose which can cause camshaft nose failure.

a. Inspect the gear, as follows:

(1) Inspect the gear for cracks, chipped or broken teeth.

(2) Inspect the bore of the gear for burrs or other damage.

(3) Inspect the gear keyway for burrs.

(4) Measure the gear bore (FIGURE 4-28).

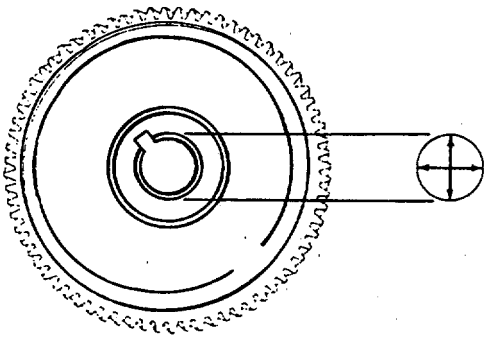

*FIGURE 4-28. Measuring Gear Bore.*

| | Camshaft Gear Bore id mm | | in |
|---|---|---|---|
| Flanged Camshaft | 44.455<br>44.475 | MIN<br>MAX | 1.7052<br>1.7510 |
| Flangeless Camshaft | 45.662<br>45.682 | MIN<br>MAX | 1.7977<br>1.7985 |

b. Inspect camshaft, as follows:

CAUTION

If the area of fretting is longer than a 0.125 inch (3.175 mm) wide band, do not use the camshaft. Fretting or damage can result in gear movement on the camshaft nose and can cause camshaft failure.

(1) Visually inspect the camshaft nose in the gear fit area for burrs or other damage.

(2) Check camshaft for cracks, nicks and chipping.

(3) Measure camshaft bushing journals. They should be between 2.495 inches (63.37 mm) and 2.497 inches (63.42 mm).

(4) Discard the camshaft if the journals measure less than 2.495 inches (63.37 mm).

(5) Measure the camshaft nose in the gear press fit area (FIGURE 4-29).

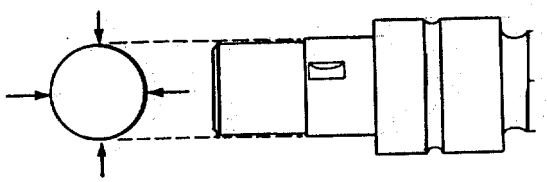

*FIGURE 4-29. Measuring Camshaft Nose.*

| | Camshaft Gear Press Fit OD mm | | in |
|---|---|---|---|
| Flanged Camshaft | 45.526 | MIN | 1.7530 |
| | 44.539 | MAX | 1.7535 |
| Flangeless Camshaft | 45.733 | MIN | 1.8005 |
| | 45.745 | MAX | 1.8010 |

REPAIR

a. Using fine crocus cloth, remove burrs from bore and keyway or spur gear.

b. Remove burrs-from nose of camshaft.

c. Replace spur gear or camshaft if damage cannot-be removed with fine crocus cloth or if gear bore or camshaft diameter is not within tolerances.

d. Replace thrust bearing if it-is damaged, worn or distorted.

e. Replace thrust bearing if it is worn thinner than 0.083 inch (2.11 mm).

ASSEMBLY

a. Install the gear onto the camshaft, as follows:

(1) Use a leather mallet to install the camshaft gear key.

CAMSHAFT KEY DATA

| Offset (mm) | Offset Inch | Timing Change | Change In Push Rod Travel At 19° BTDG (mm) | Change In Push Rod Travel At 19° BTDG Inch |
|---|---|---|---|---|
| (1.30) | 0.0510 | Retard | (0.65) | 0.0255 |

NOTE

If the same camshaft and gear are used again, use the same part number key as the one that was removed. Make sure the arrow on the key is pointing in the same direction as when it was removed.

(2) Put the camshaft in a vertical position with the gear fit area (nose) pointing up.

(3) Apply Lubriplate or its equivalent to the camshaft gear fit area before installing the gear.

WARNING

Wear protective gloves when handling parts that have been heated to prevent personal injury.

(4) Heat the gear in an oven at 500ºF (260ºC) for a minimum of 1 hour.

(5) Remove the gear from the oven.

NOTE

Gear must be installed on the camshaft within 30 seconds after it is removed from the oven.

CAUTION

The timing marks and the gear part number must be facing away from the camshaft.

NOTE

Align the gear keyway with the key in the camshaft, and install the gear.

(6) Keep the camshaft in a vertical position with the gear up until the gear has cooled.

(7) If the gear does not seat against the locating shoulder on the camshaft, use a brass drift and a hammer to drive the gear up against the shoulder (FIGURE 4-30) .

(8) Use a feeler gauge to check the clearance between the camshaft gear and the shoulder. The clearance must not exceed 0.0050 inch (0.13 mm) (FIGURE 4-30) .

(9) Apply a coat of Lubriplate to both sides of the thrust bearing.

(10) Install the thrust bearing onto the camshaft.

NOTE

Make sure that the oil grooves on the thrust bearing are toward the camshaft gear.

b. Install the camshaft (paragraph 3-22).

NOTE

The engine timing should be checked after engine assembly (paragraph 3-32).

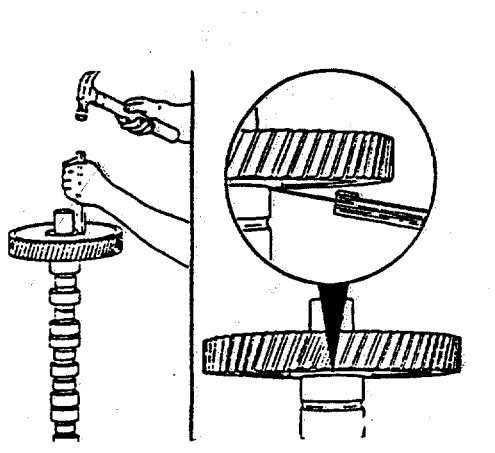

*FIGURE 4-30. Seating the Gear and Checking Clearance.*

## 4-17. Repair Connecting Rod and Piston Group.

**This task covers:**

**a. Disassembly** **b. Inspection** **c. Repair** **d. Assembly**

INITIAL SETUP

Tools

Tool kit, general mechanic's rail and marine diesel engine, 5180-00-629-9783
Piston ring expander P/N ST-763
Piston ring compressor P/N 3822736
Connecting rod guide pins P/N 3375601
Bushing driver P/N ST-1242
Rod checking fixture P/N ST-561
Locating mandrel P/N ST-563
Boring machine P/N 3375115
Arbor press, 4920-00-373-9376
Piston ring groove wear gauge P/N ST-560
Internal snap ring pliers, 5120-00-595-9551
Dial indicator, 5120-00-277-8840
Dial bore gauge P/N 3376619
Machinists measuring tool kit 5280-00-278-9919

Equipment Condition

Piston assembly and connecting rods removed (para. 3-25).

Materials/Parts

Machine bolt P/N 219153
Piston pin P/N 70550
Piston ring bushing P/N 187420
Bearing P/N 214950
Engine Piston Set P/N 3801770
Retaining ring P/N 175755
Piston pin P/N 191970
Lubriplate, Item 11, Appendix C

DISASSEMBLY

a. Disassemble the engine connectings rods as follows (1, FIGURE 4-31):

(1) Remove the machine bolts (10) and separate the connecting rod (1).

(2) Remove the bearings (11).

(3) Mark the cylinder number and the letter "u" in the flat surface of the bearing tang.

(4) Remove the (dowel) pins (12) from the connecting rods (1).

b. Use the piston ring expander to remove the piston rings (FIGURE 4-32) .

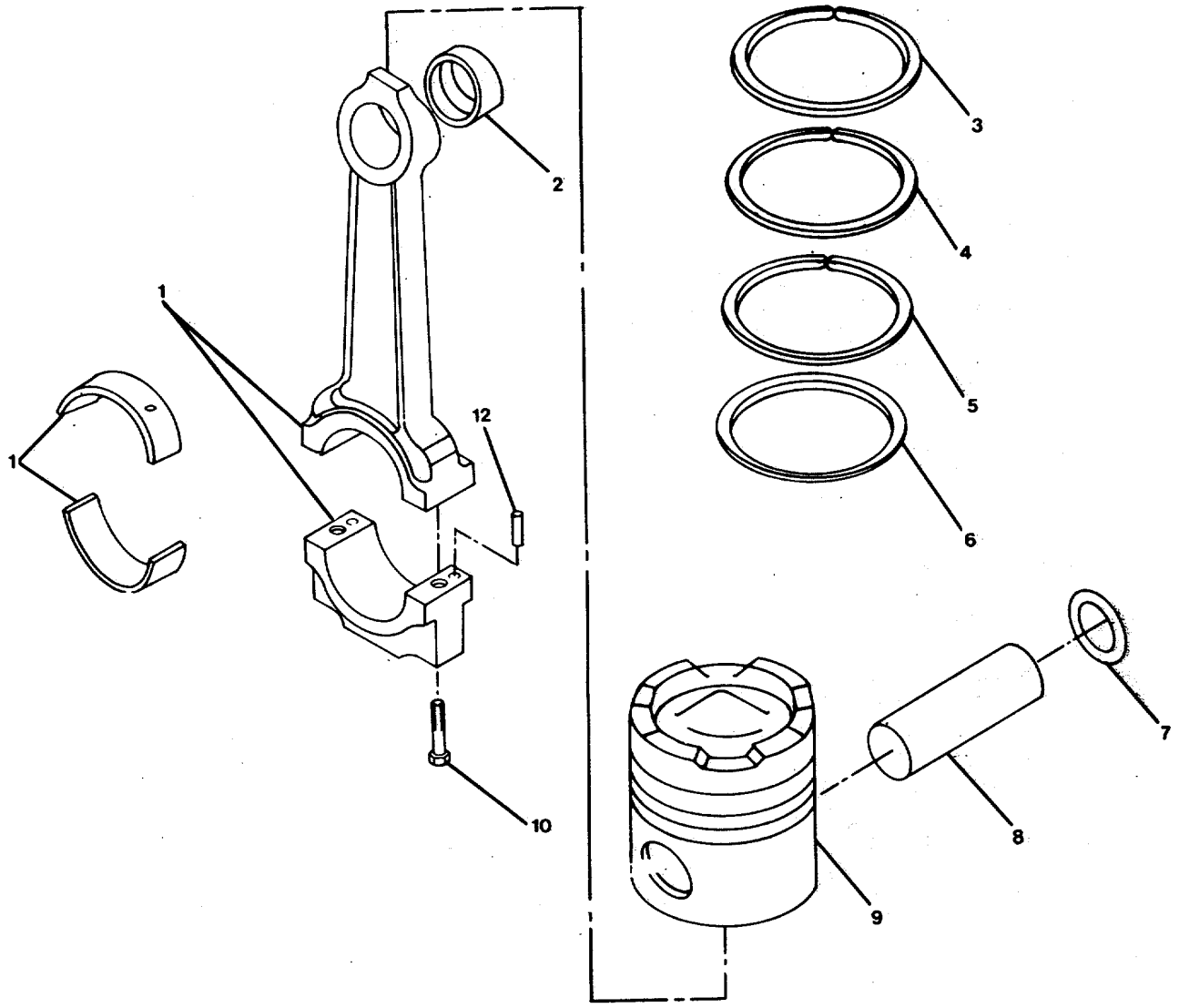


*FIGURE 4-31. Connecting Rod and Piston Group.*

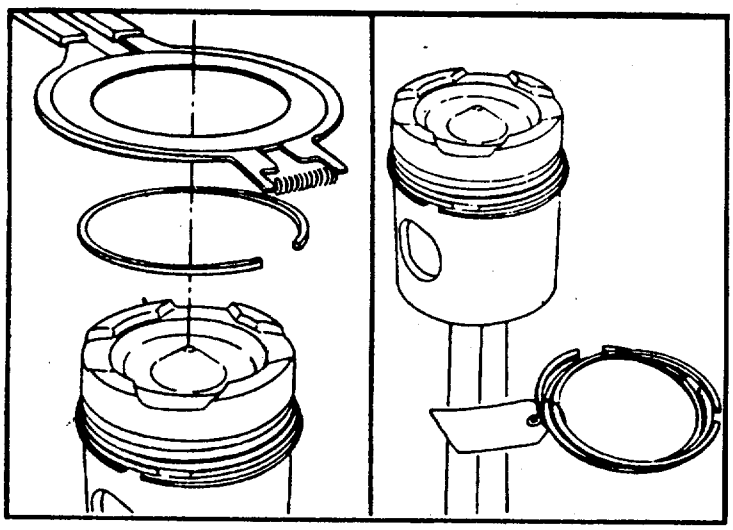

*FIGURE 4-32. Removing Piston Rings.*

c. Place a tag on the rings, and record the cylinder number of the piston on the tag for future reference (if required).

d. Use internal snap ring pliers to remove the snap rings from both sides of the piston.

e. Put the piston rod assembly in a container of water.

WARNING

Use insulated gloves to prevent injury from boiling water or heated piston.

f. Heat the piston in boiling water for 15 minutes.

CAUTION

Do not use a hammer to remove the piston pins. The piston can distort and cause the piston to seize in the liner.

g. Remove the piston from the water, and use a blunt tool to push the piston pin from the piston and rod assembly.

INSPECTION

a. Inspect the connecting rod bearings (11, FIGURE 4-31) .

(1) Clean the bearings (11) with solvent.

(2) Visually inspect the rods (1), the connecting rod bearing saddles, and the machine bolts (10) for nicks, cracks, burrs, scratches, or fretting.

(3) Visually inspect the bearings (11) for damage.

NOTE

- Replace any bearings with lock tang damage or scratches (deep enough to be felt with a fingernail). Also replace any bearings which show pitting, flaking, or corrosion in the copper lining.

- Bearing shells (12) are available for crankshafts which are 0.010 inch (0.25 mm), 0.020 inch (0.51 mm), 0.030 inch (0.76 mm), or 0.040 inch (1.02 mm) undersize. Crankshafts which are ground undersize in the connecting rod or the main bearing journals are marked on the front counter weight. If the crankshaft is marked, check the bearing shell to make sure the correct bearing size is used (FIGURE 4-33) .

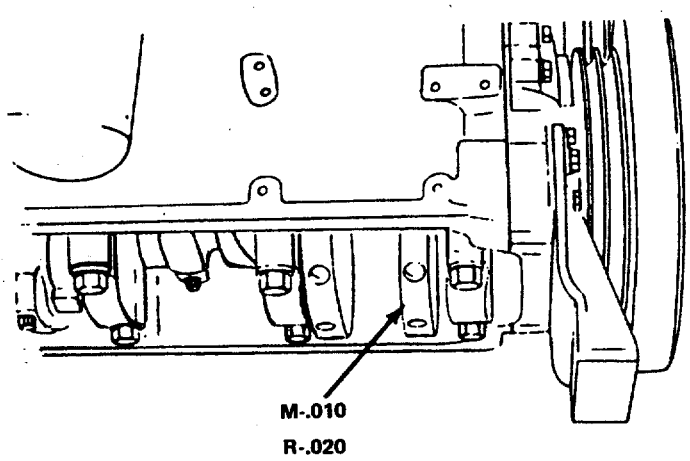


*FIGURE 4-33. Counterweight Markings for Bearing Sizes.*

NOTE

Normal bearing wear produces a smooth finish which will wear into the copper lining. Exposed copper does not always indicate worn bearings. If large areas of copper lining are visible in the bearings before the engine has accumulated 3,750 hours, inspect the engine for contamination from fine dirt particles and correct the problem.

(4) Visually inspect the bearing seating surface for nicks or burrs.

(5) If nicks or burrs cannot be removed with a fine crocus cloth, the bearings (11, FIGURE 4-31) must be replaced.

(6) Measure the rod bearing shell (11) thickness with an outside micrometer that has a ball tip.

(7) The bearing thickness should be between 0.093 inches (2.362 mm) and 0.0947 inches (2.405 mm). Replace bearing shell (11) if it is not within these measurements.

b. Clean and inspect the connecting rods (1).

(1) Use steam or solvent to clean the connecting rods (1).

(2) Use a nylon bristle brush to clean the oil drillings.

(3) Dry with compressed air.

(4) Replace the rod (1) if the "I-Beam" is nicked or damaged.

(5) Inspect the rod pin bore bushing (2) for damage or misalignment of the oil passage and the bushing.

(6) Use the magnetic particle detection kit to find cracks in the connecting rods (1) and machine bolts (10). Discard the part if cracks are found.

NOTE

Some joints in the forging will show as cracks. Make sure to check the rod for the location of these joints. These lines are not an indication of cracks. Do not discard parts with these marks.

(7) Inspect the connecting rod pin bushing bore and crankshaft bore.

(a) Be sure to keep the connecting rod (1) and the cap together.

(b) Assemble the rod (1) and tighten the machine bolts (10) to the correct torque in the correct sequence. FIGURE 4-34 shows the correct sequence, and Table 4-8 gives torque specifications.

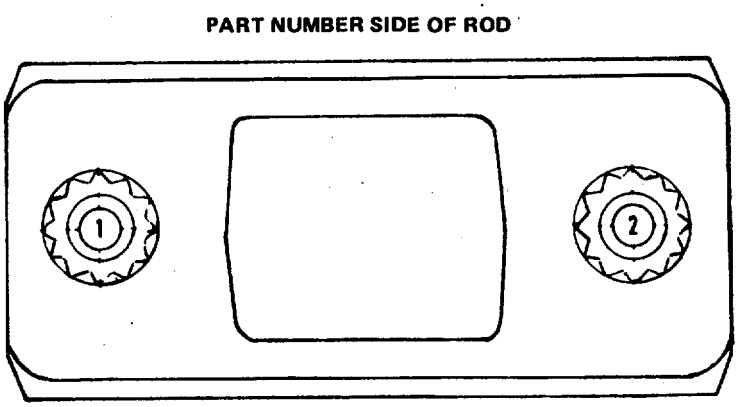


*FIGURE 4-34. Connecting Rod Torque Sequence.*

Table 4-8. Connecting Rod Torque Specifications

| | | Minimum ft-lb. | Maximum ft-lb. |
|---|---|---|---|
| Step 1. | Tighten to | 70 | 75 |
| Step 2. | Tighten to | 140 | 150 |
| Step 3. | Loosen completely | | |
| Step 4. | Tighten to | 25 | 30 |
| Step 5. | Tighten to | 70 | 75 |
| Step 6. | Tighten to | 140 | 150 |

(c) Measure the crankshaft bore in the connecting rod (1, FIGURE 4-31) with a dial bore gauge. The connecting rods must have a crankshaft bore with a diameter between 3.3157 to 3.3167 inches (84.219 to 84.244 mm).

(d) Measure the inside diameter of the piston pin bushing (2). Use a dial bore gauge. The inside diameter must measure between 2.0010 to 2.0022 inch (50.825 to 50.838 mm).

(e) If the crankshaft bore is not correct, the connecting rod (1) must be machined to the correct size or replaced.

(f) Discard all connecting rods (1) that have cuts, scratches or other damage that is deeper than 1/32 inch (0.80 mm) on the "I-Beam."

(8) Calibrate the rod checking fixture, ST-561, and locating mandrel, ST-563, and check the connecting rod length.

(a) Use a new connecting (master) rod that measures 12.000 inches (304.80 mm) between the centers of the crankshaft bore and the piston pin bore to calibrate the fixture.

(b) Select the correct piston pin mandrel from the locating mandrel and install it in the piston pin bore.

(c) Install the arbor in the crankshaft bore and expand the arbor.

(d) Make sure the pin on the arbor is down and locked in position in the center of the connecting rod.

(e) Put the connecting rod (1) in the fixture. Move the dial holder so that the contact points of the indicators are touching the mandrel in the piston pin bore.

(f) Tighten the bracket to hold the indicators and set the indicator dials at zero.

(g) Remove the connecting rod (1) from the fixture.

(h) Turn the rod (1) horizontally 180 degrees and put the rod (1) in the fixture.

(i) If the dial indicators show any change from the first reading, adjust the dials to half of the indicated change.

(j) In either position that the connecting rod (1) is put in the fixture, the dials will show the same reading, but in opposite directions on the dials. At this point the fixture is calibrated.

(9) Check the alignment of the connecting rod (1).

(a) Install the mandrel and arbor in the connecting rod (1) to be checked. See (12) steps (b), (c) and (d) in the calibration procedure above.

(b) Put the connecting rod (1) in the fixture.

(c) Measure the length. The rod (1) must be no longer than the master rod and no more than 0.002 inch (0.05 mm) shorter.

(d) Check the bore alignment by using the difference between the indicator readings. It must not be more than 0.10 inch (0.25 mm) without a bushing installed or 0.004 inch (0.10 mm) with a bushing installed.

(10) Measure the amount of twist in the rod (1).

(a) Measure with a feeler gauge between the mandrel and the dial indicator holding plate.

(b) Without a piston pin bushing (2), the twist must be no more than 0.020 inch (0.51 mm).

(c) With a bushing (2) installed and machined to the correct size, the twist must be no more than 0.010 inch (0.25 mm).

(11) Measure the connecting rod machine bolts (10).

(a) Check the smallest diameter. Discard if the diameter is less than 0.583 inch (14.81 mm), or 0.590 maximum diameter.

(b) Replace any machine bolts (10) that have damaged threads.

(12) Measure the pilot bore in the bolt holes.

(a) If the pilot bore in the rod (1) is larger than 0.6249 inch (15.872 mm), discard the rod.

(b) If the pilot bore in the cap (11) is larger than 0.6252 inch (15.880 mm), discard the cap (11).

(13) Check the radius on the bolt pad.

(a) The pad must have a fillet radius of 0.045 to 0.055 inch (1.14 to 1.40 mm). See FIGURE 4-35 .

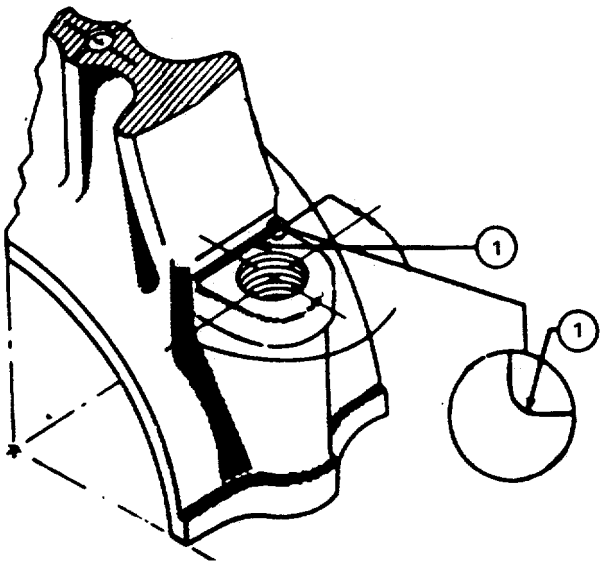


*FIGURE 4-35. Fillet Radius.*

(b) A maximum of 0.0625 inch (1.587 mm) material can be cut from the pad to repair the radius.

(c) Remove any sharp edges from the pad.

c. Clean and inspect the pistons.

CAUTION

To avoid damage to the pistons, make sure the cleaning solvent is approved for aluminum. Refer to Federal Specification PD-680.

(1) Allow the piston to soak for a minimum of 30 minutes in a tank containing an approved cleaning solvent for aluminum.

(2) Use a hot, soapy solution and a nonmetallic brush to remove carbon deposits.

CAUTION

- Do not use a metal brush. A metal brush will damage the piston ring grooves. Do not use glass beads to clean the grooves. Walnut shell blasting may be used on grooves with a ni-resist insert and on the dome of the piston.

- Use the minimum effective pressure and do not concentrate the spray in one area for an extended period of time.

- Do not use walnut shell blasting on the pin bores or aluminum grooves. This can damage pin bore surface finish or prevent the rings from seating correctly in the grooves.

(3) Steam clean the pistons and dry with compressed air.

(4) Visually inspect the piston bowl, pin bore, and skirt for cracks or damage. Replace damaged parts as required.

NOTE

Do not use pistons with dome cracks.

(5) Use the piston ring groove wear gauge ST-560 to inspect the top and second grooves.

NOTE

The widest part (shoulder) of the tool must not come in contact with the piston. Replace the piston if the shoulder touches the piston.

(6) Hold a new ring in the groove. Install a 0.006 inch (0.152 mm) feeler gauge. If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.

(7) Measure the outside diameter of the piston as follows:

(a) Measure at right angles to the piston pin bore.

(b) Piston temperature must be between 70ºF (21ºC) and 90ºF (32ºC).

(c) Replace piston if it measures less than 5.483 inches (139.27 mm) outside diameter.

(8) Measure the piston pin bore inside diameter when the piston temperature is 68ºF (20ºC). It should be between 1.9985 inches (50.762 mm) and 2.0000 inches (58.8 mm).

NOTE

Add 0.0005 inch (0.013 mm) to the bore inside diameter per 10°F (5°C) temperature rise up to 90°F (32°).

(9) Inspect the piston pin for scratches, grooves, or other damage. Replace the pin if damage.

(10) Measure the piston pin outside diameter. It must be between 1.9985 inches (50.762 mm) and 1.9990 inches (50.775 mm).

(11) Discard the piston pin if it is more than 0.001 inches (0.03 mm) out-of-round.

(12) To check the ring gap, install the new piston rings in the cylinder liner in which they will be used.

(13) Use the top part of the piston to position the ring in the liner correctly.

(14) Use a feeler gauge to inspect the ring gap. Replace the ring if it does not meet the following specifications:

Piston Ring Gap

| Position | MIN | MAX |
|---|---|---|
| Top | 0.017-inch (0.43 mm) | 0.027-inch (0.68 mm) |
| Second | 0.020-inch (0.51 mm) | 0.030-inch (0.76 mm) |
| Third | 0.019-inch (0.48 mm) | 0.029-inch (0.74 mm) |
| Oil | 0.010-inch (0.25 mm) | 0.025-inch (0.64 mm) |

NOTE

Add 0.003 inch (0.08 mm) to the maximum limit for each 0.001 inch (0.03 mm) wear in the cylinder inner wall (FIGURE 4-36) .

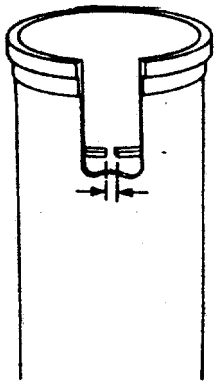

*FIGURE 4-36. Ring Gap.*

REPAIR

a. Repair the crankshaft bore of the connecting rod (1, FIGURE 4-31) if:

(1) The bore is larger than 3.3167 inch (84.244 mm).

(2) The face of the connecting rod (1) is damaged.

b. To make repairs:

(1) Use the bushing driver, ST-1242, to remove the piston pin bushing (2).

(2) Install the cap on the connecting rod (1) and tighten the machine bolts (10) to the torque listed in Table 4-9.

(3) Use the checking fixture, ST-561, to measure the length of the rod (1). Discard the rod if the length is 11.991 inches (304.57 mm) or less.

(4) Remove the cap from the rod (1).

NOTE

- A maximum of 0.009 inch (0.23 mm) can be removed from the rod and cap. Equal amounts of material must be removed from the rod and the cap. The length of the rod must be 12.000 inches (304.80 mm) before you can remove a maximum of 0.009 inch (0.23 mm) from the rod and cap. If the maximum of 0.009 inch (0.23 mm) had to be removed, the rod must measure 11.991 inches (304.57 mm) in length after machining.

- The alignment of the bolt bores in the rod (1) and cap must not change. Hold the rod (1) and cap in a clamp that holds the rod in alignment when cutting material from the surfaces.

- Use lapping compound to polish the surfaces that were machined. Apply a blue compound to the surfaces and check them against a flat plate.

- The area outside the centerline of the bolt bores (the area farthest from the crankshaft bore) must show 100 percent contact. The remaining area must show a minimum of 75 percent contact.

(5) Install the cap on the rod (1) and tighten the machine bolts (10) to the torque listed in Table 4-9.

(6) Cut the crankshaft bore with the boring machine, P/N 3375115, that has a precision fixture to keep the piston pin bore and crankshaft bore in alignment. The surface of the bore must be smooth within 75 micro-inches.

(7) Put the connecting rod (1) in the fixture, P/N ST 561, and check the alignment.

(8) Cut the inside diameter of the bore for rods with bolts and nuts to measure 3.2722 to 3.2732 inches (83.114 to 83.139 mm), or cut the inside diameter of the bore for rods with capscrews to measure 3.3157 to 3.3167 inches (84.219 to 83.139 mm).

c. Install the piston pin bushing (7, FIGURE 4-37).

(1) Put the bushing (7) on the mandrel (1).

(2) Put the sleeve (4) and then the cup (2) on the mandrel (ST-1242).

(3) Fasten the cup (2) on the mandrel (1) with the locking pin (6).

(4) Put the connecting rod (8) on the block (3) and hold it in a horizontal position.

(5) Insert the mandrel (1) into the bore of the connecting rod (8).

(6) Align the sleeve (4) with the middle of the boss on the connecting rod (8).

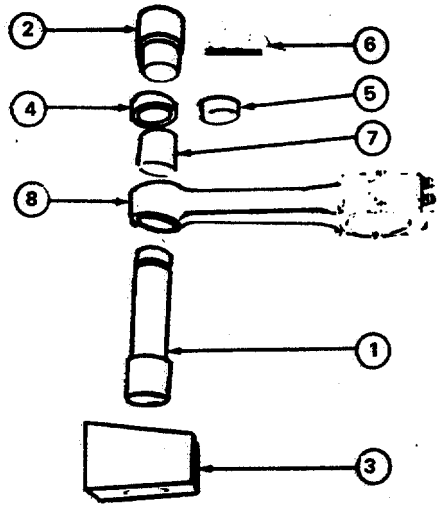


*FIGURE 4-37. Installing Piston Pin Bushing.*

NOTE

Make sure the oil holes are in alignment.

(7) Use an arbor press to push the bushing (7) into the bore until the sleeve (4) is in contact with the connecting rod (8).

(8) Check the alignment of the oil holes. Make sure an 1/8 inch (3.17 mm) diameter rod can move freely through the connecting rod (8) and bushing (7).

d. Cut the bore in the piston pin bushing (7).

(1) Fill the oil holes with soap to prevent metal particles from entering the holes.

(2) Install the connecting rod (8) in the boring machine.

NOTE

To put the connecting rod in the correct position to cut the bore in the bushing, use only the two horizontal blades of the lower mandrel on the machine.

(3) The instructions for the boring machine are included with the machine.

(4) Cut the bushing (2) to 2.0010 to 2.0015 inches (50.825 to 50.838 mm) inside diameter.

(5) Remove the rod (8) from the boring machine and check the bore with a dial bore gauge.

(6) Remove all sharp edges.

(7) Remove any metal particles and the soap from the oil holes.

(8) Wash the bores and holes with mineral spirits and dry with compressed air.

(9) Use the checking fixture ST-561 to check all the dimensions.

## ASSEMBLY

a. Piston pin.

(1) Install a new snap ring (7, FIGURE 4-31) in the snap ring groove of the piston pin bore at each position.

(2) Heat the pistons (9) in boiling water for 15 minutes or in an oven for 30 minutes at 212°F (100°C).

(3) Use clean engine oil to lubricate the connecting rod piston pin bore and the piston pin (8).

WARNING

Use insulated gloves to prevent injury from boiling water or the heated piston.

(4) Remove the piston (9) from the water or the oven.

(5) Align the pin bore of the rod (1) with the pin bore of the piston (9), and install the piston pin (8).

CAUTION

Do not use a hammer to install the piston pin. The piston will be damaged.

NOTE

The cylinder number on the piston top must be toward the bearing tang side of the rod.

(6) Install a new snap ring (7) in the second piston pin bore snap ring groove. The snap ring must be seated completely in the snap ring groove.

b. Piston rings.

(1) Use a piston ring expander to install the piston rings (3, 4, 5, 6) with the part number, mark, or the work "TOP" toward the top of the piston (FIGURE 4-38) .

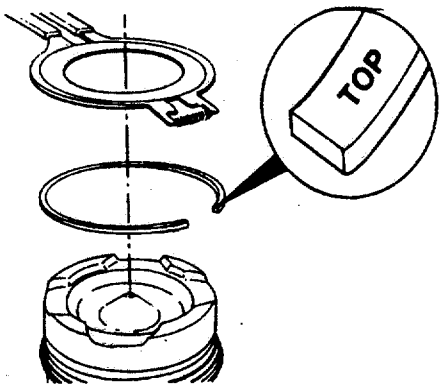


*FIGURE 4-38. Installing Rings.*

(2) A cross-sectioned view of an oil control ring is shown. The two-piece oil control ring must be installed with the expander ring gap 180 degrees from the gap of the oil ring (FIGURE 4-39) .

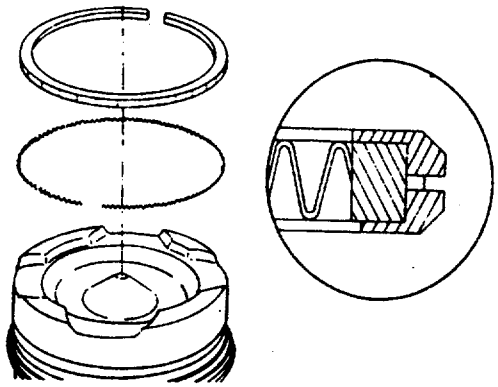

*FIGURE 4-39. Oil Control Ring.*

(3) The piston ring shipping package identifies the location of each piston by ring part number. Install the rings in the position shown (FIGURE.4-40) .

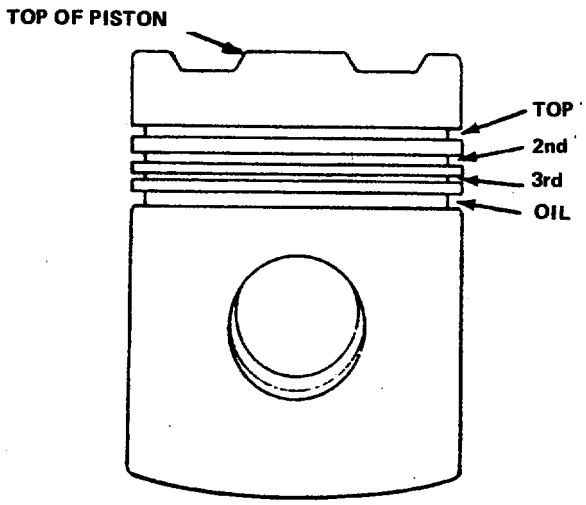


*FIGURE 4-40. Ring Positions.*

c. Rod bearings.

(1) Install the upper and lower bearings in the connecting rod (1, FIGURE 4-31) .

(2) If used bearings are to be installed, each bearing must be installed in its original location.

NOTE

The tang of the bearing must be in the slot of the rod.

(3) Use clean Lubriplate 105 or equivalent to lubricate the bearings.

(4) Apply a heavy film of clean engine oil to the liner.

(5) Install the (dowel) pins (12) in the connecting rod (1).

(6) Join the connecting rod halves (1).

(7) Install machine bolts (10).

d. Install piston assembly and connecting rods (paragraph 3-25).

## 4-18. Repair Flywheel and Flywheel Housing Group.

**This task covers:**

**a. Disassembly** **b. Inspection** **c. Repair** **d. Assembly**

INITIAL SETUP

Tools

Tool kit, general mechanic's rail and marine diesel engine, 5180-00-629-9783
Engine lifting fixture P/N 3822512
Torque wrench kit P/N 3377216
Combination wrench set, 5120-01-046-4979
Heating torch 5433-00-357-8166
Crack detector kit P/N 3375432

Equipment Condition

Flywheel and housing removed, (para. 3-26).

Materials/Parts

Spur Gear P/N 4851

### DISASSEMBLY

a. Remove flywheel spur gear.

(1) Remove the spur gear (2, FIGURE 4-41) from the flywheel (3) as follows. Refer to FIGURE 4-41.

CAUTION

Do not use a cutting torch to heat the spur gear. The flywheel can be damaged.

(a) Heat the outside diameter of the spur gear (2) with a heating torch.

(b) Use a blunt chisel and a hammer to remove gear from the flywheel (3).

### INSPECTION

a. Clean and inspect flywheel (3).

(1) Use a wire brush to clean the crankshaft pilot bore.

(2) Steam clean or use solvent to clean the flywheel.

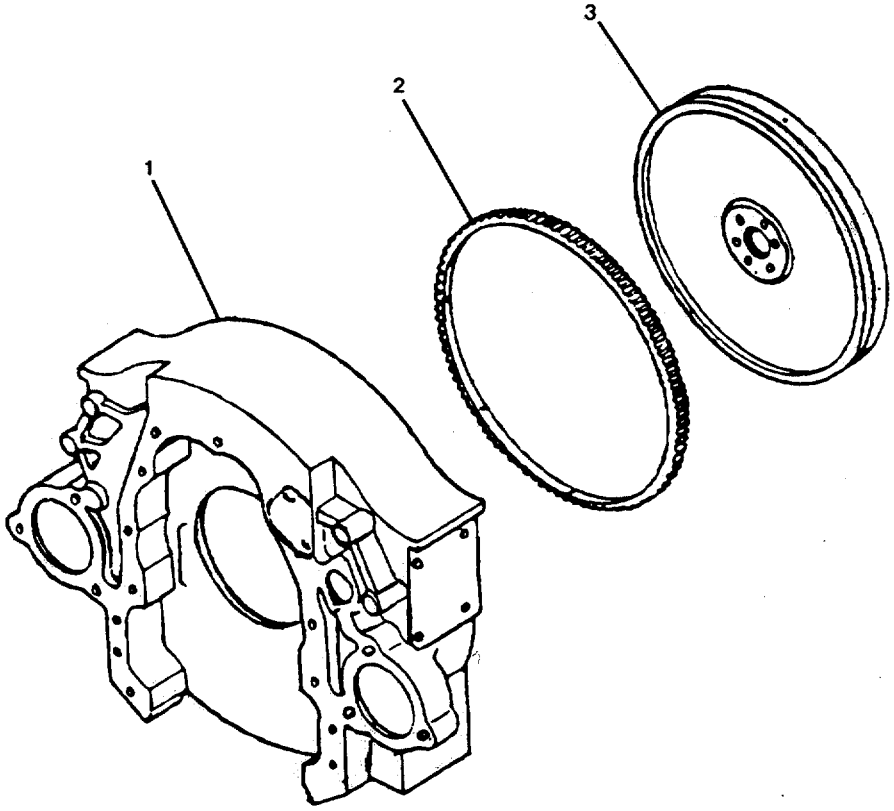


*FIGURE 4-41. Flywheel and Housing Group.*

(3) Dry with compressed air.

(4) Visually inspect for nicks or burrs.

(5) Use fine crocus cloth to remove small nicks and burrs.

WARNING

Do not use a cracked or resurfaced flywheel. These can break, causing serious personal injury or property damage.

(6) Use crack detection kit, P/N 3375432 to check for cracks in the flywheel.

(7) Visually inspect the flywheel spur gear (2) for cracks and chips.

NOTE

If the spur gear teeth are cracked or broken, the spur gear must be replaced.

REPAIR

Repair consists of replacement of spur gear (2).

ASSEMBLY

a. Install spur gear (2) on flywheel (3), as follows:

(1) Heat spur gear (2) in an oven heated to 600°F (316°C) for a minimum of one hour.

NOTE

If an oven is not available, use a heating torch to heat the inside diameter of the spur gear to 600°F (316°C). Use a tempilstick crayon or equivalent to check the gear temperature.

CAUTION

Do not overheat spur gear. Metal hardness will change.

WARNING

Wear protective gloves when handling heated parts to avoid injury.

(2) Remove the gear from the oven, and install it on the flywheel before it cools.

(3) Install spur gear (2) on flywheel (3).

## 4-19. Replace/Repair Crankshaft Group.

**This task covers: a. Removal, b. Repair, c. Replacement.**

INITIAL SETUP

Tools

Tool kit, general mechanic's rail and marine diesel engine, 5180-00-629-9783
Strap wrench, P/N 3376807
Torque wrench kit P/N 3377216
Main bearing cap puller P/N ST-1178
Gear puller P/N 3375840
Engine lifting fixture P/N 3822512
Dial indicator 5120-00-277-8840
Machinists measuring tool kit 5288-00-278-9919

Materials/Parts

Bearing set P/N 3801260
Engine crankshaft P/N 3608833
Lubricating oil, Item 1, Appendix C
Crocus cloth, Item 14, Appendix C
Lubriplate 105, Item 11, Appendix C
Soft bristle brush

Equipment Condition

Water pump belt removed (para. 2-29).
Fuel pump removed (para. 2-33).
Seawater pump removed (para. 2-37).
Oil drained (PMCS Table 2-1, Item 12).
Accessory drive pulley removed (para. 3-19).
Gear cover group removed (para. 3-20).
Oil pan group removed (para. 2-44).
PTO (SL 111 HP2) to firepump removed (para. 3-21).

REMOVAL (Refer to FIGURE 4-42).

NOTE

The gear cover and oil pan assemblies must be removed from the engine before removing the crankshaft assembly (paragraphs 3-42 and 3-26).

a. Remove the engine main bearings (5 thru 10) and thrust bearings (11), as follows:

CAUTION

The main bearing caps are marked for position on the camshaft side and the cylinder block identification on the exhaust side. Mark any caps that are not marked before removing them from the cylinder block.

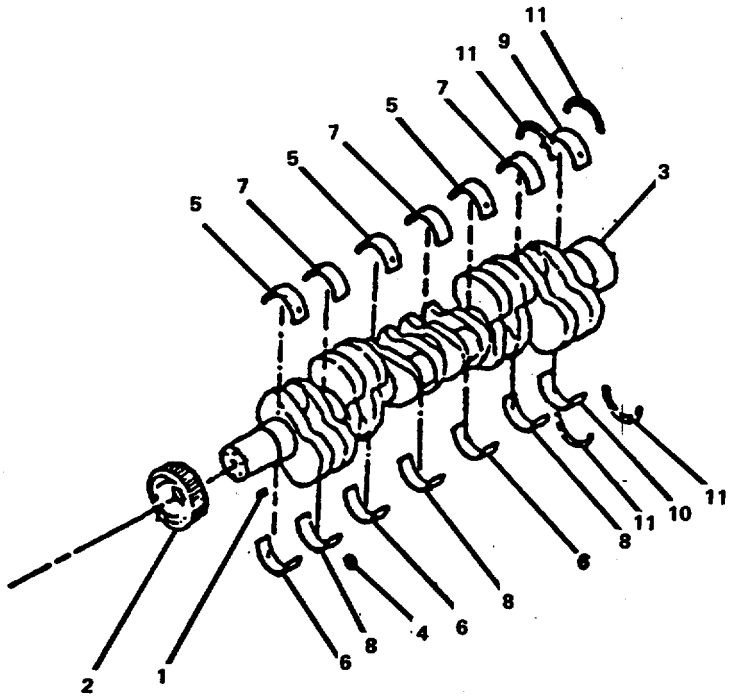


*FIGURE 4-42. Crankshaft Group.*

**CAUTION**

Replace main bearings one at a time.

(1) Remove the No. 7 main bearing cap capscrews and washers.

**NOTE**

The No. 7 main bearing cap has thrust bearings and dowel pins.

**CAUTION**

The main bearing cap puller must be centered on the cap.

(2) Use the main bearing cap puller to remove the cap (FIGURE 4-43) .

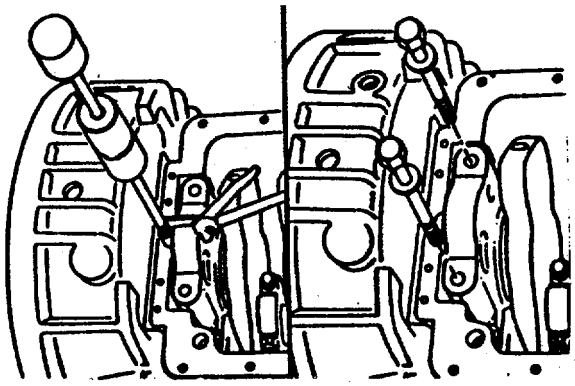

*FIGURE 4-43. Removing Main Bearing Cap.*

(3) Remove the lower main bearing shell from the crankshaft journal.

**NOTE**

Mark the bearing shells with the journal number from which they were removed.

(4) Remove the dowel ring (FIGURE 4-44) .

(5) Remove the thrust bearings from the No. 7 cap.

(6) Mark these bearings from the No. 7 cap.

**CAUTION**

Do not damage the crankshaft when removing the thrust bearings.

(7) Use a blunt tool to remove the upper thrust bearings.

(8) Mark these bearings as the top front and the top rear thrust bearings.

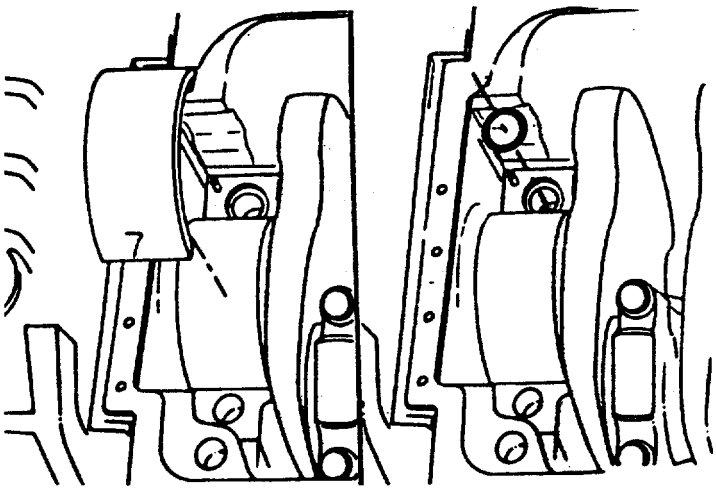


*FIGURE 4-44. Removing Dowel Ring.*

(9) To remove the upper main bearing shell, install a tool similar to the one in the oil hole of the main bearing journal as shown in FIGURE 4-45 .

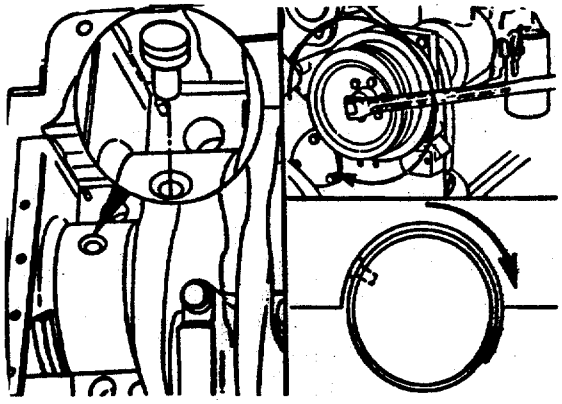

*FIGURE 4-45. Removing Main Bearing Shell.*

(10) Repeat step (2) to remove each bearing cap and bearings.

b. Remove the crankshaft gear (2, FIGURE 4-42), as follows:

**NOTE**

Inspect the crankshaft gear for wear and damage before removal. If it is in good condition, do not remove it.

(1) Use the following tools from the gear puller kit, P/N 3375840 to remove gear:

| | |
|---|---|
| 3375834 | Gear Puller Assembly |
| 3375839 | Jaw |

(2) Install the crankshaft gear puller on the gear.

(3) Turn the pressure screw clockwise to remove the gear.

**CAUTION**

Do not damage the crankshaft when removing the key (1, FIGURE 4-42) .

(4) Use a flat chisel and hammer to remove the key.

**CAUTION**

Be careful not to damage the surface of the crankshaft.

c. Remove the crankshaft as follows:

(1) With the main bearing caps, bearings, and shells removed, use a hoist and a lifting strap to remove the crankshaft.

REPLACE/REPAIR

a. Inspect crankshaft gear:

(1) Visually inspect the crankshaft gear for cracks and broken teeth.

(2) Remove any burrs with fine crocus cloth.

(3) Visually inspect the crankshaft gear fit area for burrs or damage.

(4) Remove any burrs with fine crocus cloth.

(5) Measure the crankshaft bore (FIGURE 4-46). It should be between 3.7557 inches (95.394 mm) and 3.7565 inches (95.415 mm).

(6) Measure the crankshaft gear fit area outside diameter. It should be between 3.7600 inches (95.504 mm) and 3.7607 inches (95.522 mm).

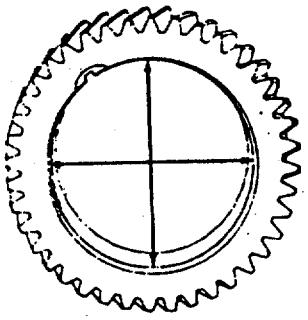

*FIGURE 4-46. Measuring Crankshaft Bore.*

(7) Replace gear if damaged.

b. Inspect bearing cap, bearings and shells:

(1) Use a soft bristle brush and solvent to clean the parts.

(2) Dry with compressed air.

(3) Visually inspect the main cap and capscrews for damage.

(4) Visually inspect the bearing shells and the thrust bearings for nicks, scratches or damage.

**NOTE**

If the main bearings are damaged, inspect the crankshaft main bearing journals.

(5) Use an outside diameter ball tipped micrometer to measure the main bearing shell thickness. It should be between 0.1215 inches (3.086 mm) and 0.1238 inches (3.145 mm).

(6) Discard a main bearing shell if its thickness is below the minimum specification.

**NOTE**

Bearing shells are available for crankshafts which are 0.010 inch (0.25 mm), 0.020 inch (0.51 mm), 0.030 inch (0.76 mm), or 0.040 inch (1.02 mm) undersize. Crankshafts which are ground undersize in the connecting rod and main bearing journals are marked on the front counter weight (FIGURE 4-47) . If the crankshaft is marked, check the bearing shell to make sure the correct size bearing is used.

c. Inspect crankshaft:

(1) Check the crankshaft for wear, cracks, and other damage.

(2) Using micrometer, measure each journal of the crankshaft in three places and take the average of those three measurements.

(3) Grind the crankshaft journals if they are out-of-round more than 0.002 inch (0.05 mm) (or replace the crankshaft) (See Table 4-9 for minimum and maximum diameters.) Follow the instructions provided-with the grinding equipment.

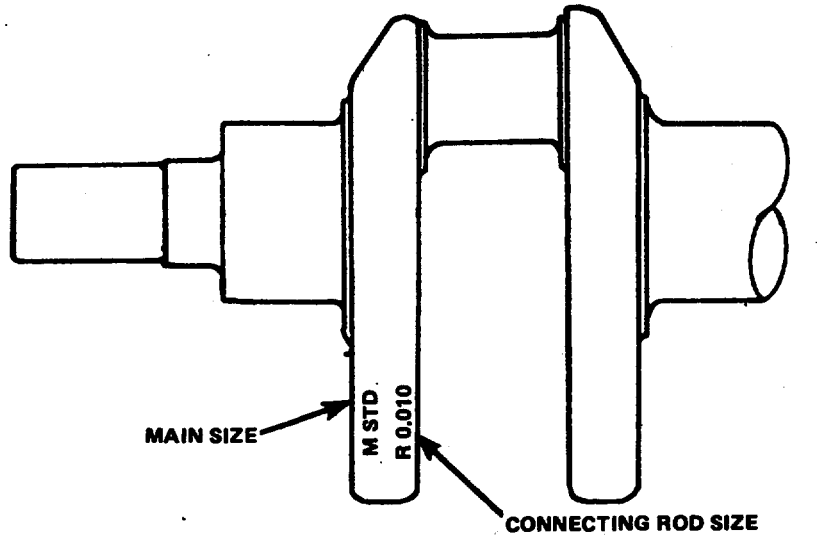


*FIGURE 4-47. Front Counterweight Markings.*

Table 4-9. Crankshaft Journal Diameters

| Journal | Minimum Inch (mm) | Maximum Inch (mm) | Worn Limit Inch (mm) |
|---|---|---|---|
| Connecting Rod | 3.1235 (79.337) | 3.125 (79.375) | 3.122 (79.298) |
| Main Bearing | 4.4985 (114.262) | 4.500 (114.30) | 4.4975 (114.237) |

(4) Carefully inspect the crankshaft journals and the thrust flange at the main bearing journal. If the surfaces have damage or scratches, grind the crankshaft If the crankshaft is ground, oversize main and connecting rod bearings and oversize thrust must be installed.

(5) Put a mark on the crankshaft after grinding. This will show the correct size for the main and connecting rod bearings. Put this mark on the front counterweight. (See FIGURE 4-47) .

(6) Put a mark for the oversize trust bearing on the rear counterweight (FIGURE 4-48) .

(7) Inspect the crankshaft key for damage. Replace as required.

**NOTE**

If grinding of journals is to be done, follow the instructions provided with the grinding equipment.

(8) Replace crankshaft if repair is not possible.

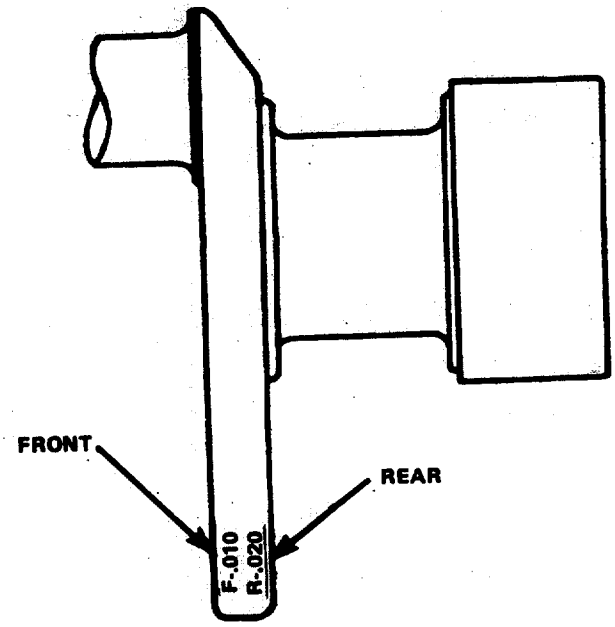


*FIGURE 4-48. Rear Counterweight Markings.*

REPLACEMENT

a. Install the crankshaft gear on the crankshaft.

(1) Use a leather hammer to install the key in the crankshaft keyway.

(2) Heat the gear in an oven for a minimum of 1 hour at 400°F (205°C).

**WARNING**

Wear protective gloves when handling parts that have been heated to prevent personal injury.

(3) Remove the gear from the oven.

**NOTE**

The gear must be installed within 30 seconds after being removed from the oven.

**CAUTION**

The timing mark and the gear part number must be facing away from the crankshaft.

(4) Align the gear keyway and the key, and install the gear firmly on the crankshaft.

**CAUTION**

It will be necessary to align the timing marks of the crankshaft and the camshaft gears when the crankshaft is installed.

b. Install the crankshaft:

**CAUTION**

Be careful not to damage the surface of the crankshaft.

(1) Lift the crankshaft into position using a hoist and lifting strap.

(2) Install bearing shells, main bearings and caps.

c. Install the bearings, shells, and caps as follows:

**NOTE**

The upper main bearing shells have a groove and an oil hole to provide crankshaft lubrication. The lower main bearing shells do not. The groove for the No. 7 shell is not in the center of the shell. The wider part of the No. 7 shell must be installed toward the flywheel end of the cylinder block (FIGURE 4-49) .

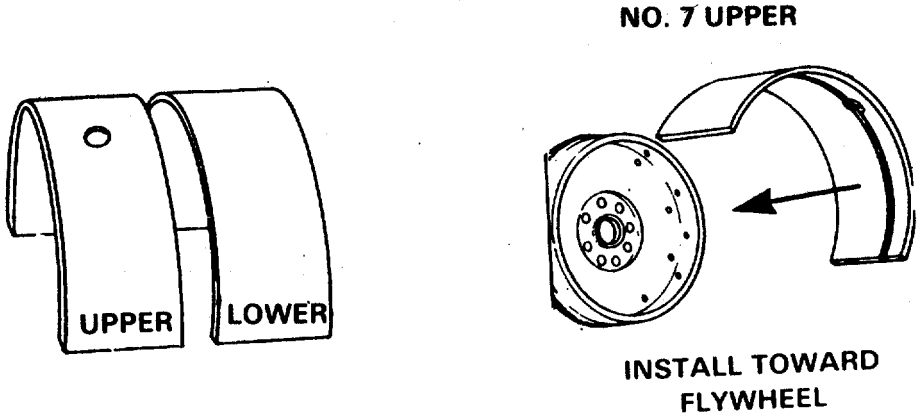


*FIGURE 4-49. Bearing Shell Identification.*

**CAUTION**

The cylinder block saddle and the cap mating surfaces must be clean and dry when the bearing shells are installed. Used bearings must be installed in their original location.

(1) Use clean Lubriplate 105 or its equivalent to lubricate the upper main bearing shell to crankshaft journal mating surface.

(2) Install the upper main bearing shell. Use the same method that was used to remove the shell.

**CAUTION**

The groove for the dowel ring must be next to the dowel ring counterbore in the cylinder block.

(3) Use clean Lubriplate 105 or its equivalent to lubricate the upper thrust bearings.

(4) Install the upper thrust bearings in the No. 7 main bearing saddle.

**CAUTION**

The grooves must be toward the crankshaft (FIGURE 4-50) .

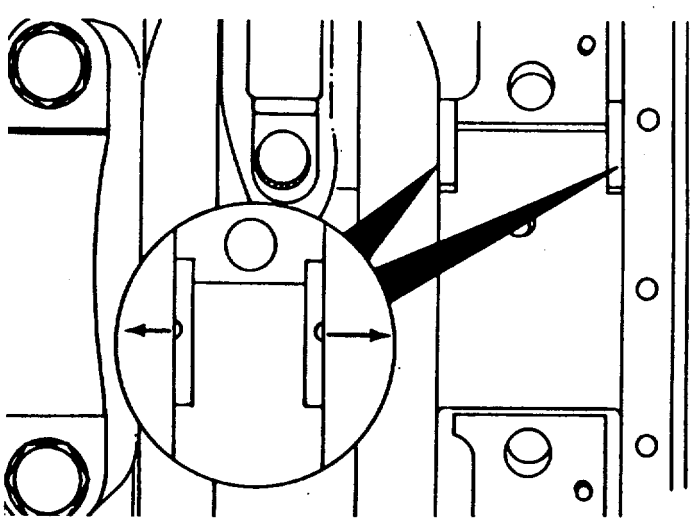

*FIGURE 4-50. Positioning Bearing Grooves.*

**NOTE**

Push the crankshaft toward the rear of the engine to install the front bearing and to the front of the engine to install the rear bearing.

(5) Install the dowel ring counterbore of the cylinder block.

(6) Install the lower main bearing shell as follows:

(a) Use clean Lubricate 105 or its equivalent to lubricate the bearing shell to the crankshaft journal mating surface.

(b) Align the bearing shell with the dowel ring.

(c) Push the side of the bearing shell opposite the dowel ring to install the bearing shell (FIGURE 4-51) .

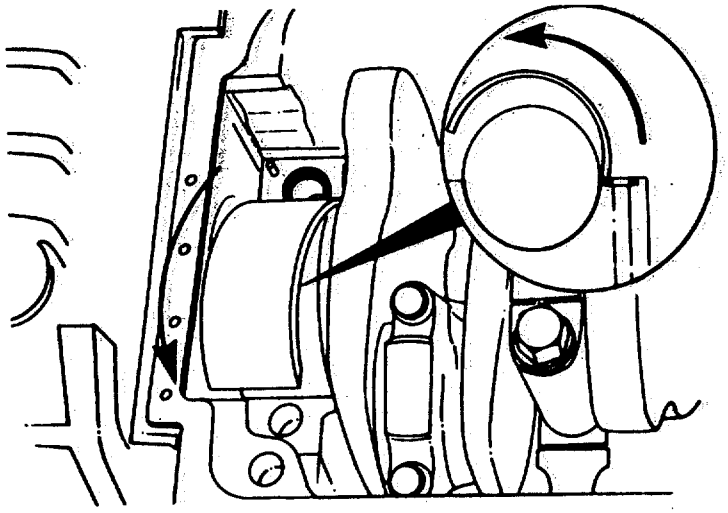

*FIGURE 4-51. Installing the Bearing Shell.*

(7) Use clean Lubriplate 105 or its equivalent to lubricate the lower thrust bearings.

**CAUTION**

The grooves of the thrust bearing must be toward the crankshaft. The locating dowels must not protrude above the thrust bearing surface.

(8) Install the lower thrust bearings in the No. 7 main bearing cap.

(9) Use clean engine oil to lubricate the capscrew threads and the flat washers.

(10) Drain the excess oil from the capscrews before installing them.

**CAUTION**

The main bearing caps are marked for position (1, FIGURE 4-52) on the camshaft side and the cylinder block identification (2) on the exhaust side. The cylinder block identification number (3) is stamped on the pan rail on the camshaft side of the block. Install the caps in the correct position with the position number to the camshaft side and its part number toward the rear of the engine.

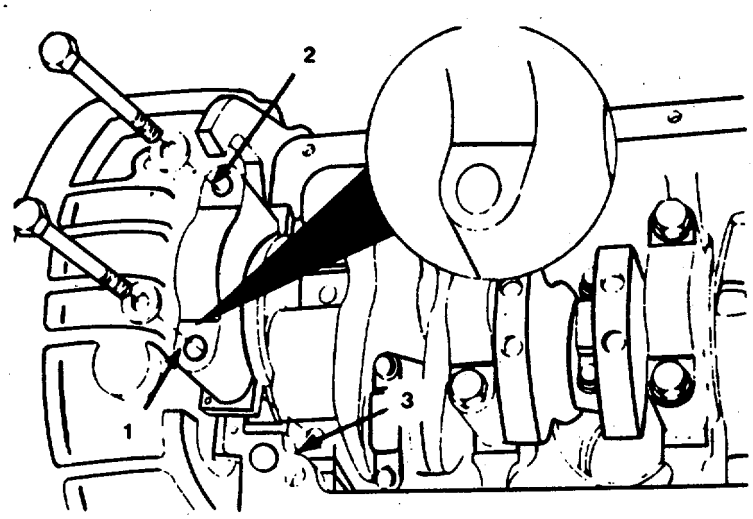


*FIGURE 4-52. Bearing Cap Location Marks.*

(11) Install the main bearing caps as follows:

(a) Align the capscrew holes in the cap with the holes in the cylinder block. Make sure the ring dowel and the lower bearing shell are in position.

(b) Install the capscrews and the washers through the cap and into the cylinder block.

(c) Use your hand to tighten the capscrews two to three threads.

**CAUTION**

When hitting the cap, make sure the bearing shell and dowel ring do not move.

(d) Hit the cap with a rubber mallet to push it into the correct position.

(12) Tighten the capscrews on a main bearing cap on engines built with 1-inch diameter main bearing capscrews to the following torque values:

(a) Tighten both to 110 ft-lb.

(b) Tighten both to 210 ft-lb.

(c) Tighten both to 310 ft-lb.

(d) Loosen both completely.

(e) Tighten again as described above.

(13) Tighten the capscrews on a main bearing cap on engines built with 3/4- diameter main bearing capscrews to the following torque values:

(a) Tighten both to 90 ft-lb.

(b) Tighten both to 170 ft-lb.

(c) Tighten both to 255 ft-lb.

(d) Loosen both completely.

(e) Tighten again as described above.

(14) Replace the main bearing shells No. 1 through No. 6. (Repeat step (3) in this procedure to install each bearing.)

**NOTE**

Main bearings No. 1 through No. 6 do not have thrust bearings.

(15) Measure the end clearance of the crankshaft as follows:

(a) Install a dial indicator to the oil pan flange.

(b) Put the tip of the gauge against the crankshaft counter weight.

(c) Push the crankshaft toward the rear of the cylinder block.

(d) Set the dial indicator at "0" (zero).

(e) Push the crankshaft toward the front of the cylinder block.

(16) If the end clearance is less than 0.007 inch (0.18 mm), do the following:

(a) Loosen the main bearing capscrew one turn.

(b) Push the crankshaft toward the front and then toward the rear of the cylinder block.

(c) Tighten the main bearing capscrews in the sequence shown in FIGURE 4-53 to the torque values listed in step (1) or step (m) of this procedure.

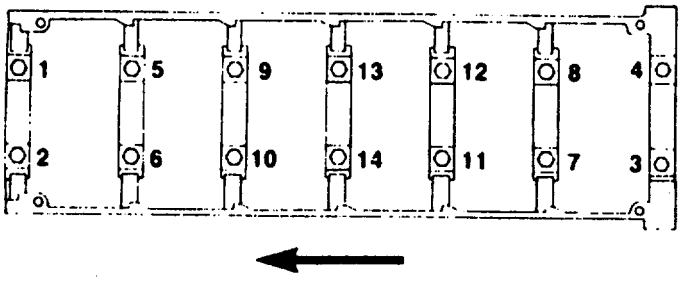


*FIGURE 4-53. Bearing Cap Torque Sequence.*

(d) Measure the crankshaft end clearance. The end clearance specification for a new or reground crankshaft with new thrust bearings is 0.07 inch (0.18 mm) to 0.018 inch (0.45 mm).

**NOTE**

Crankshafts that have been reground on the thrust bearing surfaces are marked for oversize thrust bearings on the rear crankshaft counter weight. If the crankshaft counter weight is marked, check the thrust ring part number to make sure the correct thrust ring size is used (FIGURE 4- 54) .

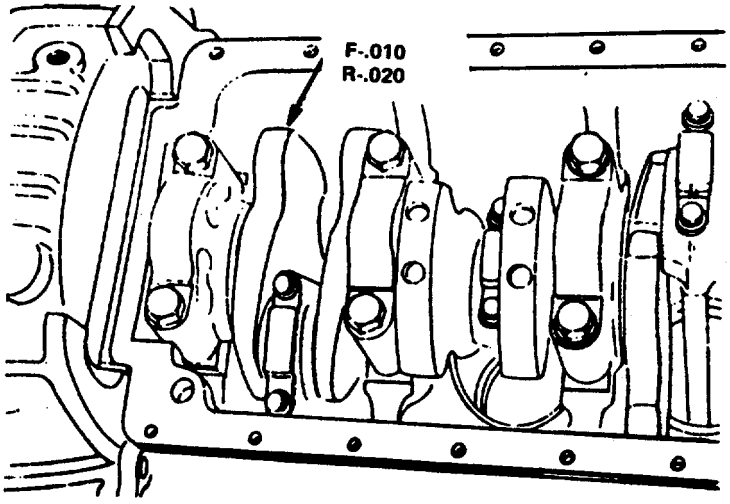


*FIGURE 4-54. Example of Oversize Thrust Bearing Marks.*

## 4-20. Repair Cylinder Block Group.

**This task covers: a. Repair, b. Diassembly, c. Assembly.**

**INITIAL SETUP**

Tools

Tool kit, general mechanic's
rail and marine diesel engine,
5180-00-629-9783
Combination wrench set,
5120-01-046-4979
Torque wrench kit P/N 3377216
Gauge Block P/N 3376220
Main bearing cap puller P/N ST-1178
Cylinder liner clamp set P/N 3822503
Cylinder liner driver P/N ST-1229
Cylinder liner puller P/N 3376015
Camshaft bushing kit P/N 3376633
Drive assembly camshaft bushing
P/N 3376637
Machinists measuring tool kit
5280-00-278-919

Materials/Parts

Marker, metal, liquid,
Item 33, Appendix C
Preformed Packing P/N 3007442, 3032874
Cylinder Sleeve P/N 3801826
Gasket P/N 70089-1
Cap, Dust and Moisture Seal Protective
P/N 3011952
Headless Straight Pin
P/N 67211, 68585
Piston cooling nozzles
P/N 3014404, 3013591
Bearing sleeve P/N 3011951
Bushing sleeve P/N 3028075, 3028269
Vegetable oil, Item 44, Appendix C
RTV sealant, Item 45, Appendix C
Metal cleaning solvent, Item 6, Appendix C
Crocus cloth (fine), Item 26, Appendix C
Straight hexagon pins P/N 202903

Equipment Condition

Starter motor removed (para. 2-21).
Coolant heater removed (para. 2-32).
Instrument panel and wiring removed
(para. 2-22).
Sump pump and bracket removed
(para. 2-28).
Air cleaner and piping removed
(para. 2-25).
Fuel filter assembly removed (para. 2-27).
Lube oil bypass filter assembly removed
(para. 2-31).
Lube oil cooler/filter removed
(para. 2-30).
Water pump and idler/belt guard removed
(para. 2-29).
Seawater pump removed (para. 2-37).
Heat exchanger removed (para. 2-38).
Cylinder head removed (para. 2-41).
Oil pan removed (para. 2-44).
Lube oil pump removed (para. 3-23).
Accessory drive removed (para. 3-19).
Gear cover removed (para. 3-20).
Flywheel and housing removed (para. 3-26).
Crankshaft group removed (para. 4-19).

REPAIR

Repair to the cylinder block group consists of replacing cylinder sleeve assembly (1, FIGURE 4-43), access cover gasket (8), pins (10), bushings (13, 14), bearing (12) and piston cooling nozzles (15).

a. Replace the cylinder sleeve set as follows:

(1) Remove the liner (4, FIGURE 4-55) .

DISASSEMBLY

a. Unless otherwise directed, remove the following:

(1) Cam follower assemblies (paragraph 3-18).

(2) Camshaft (paragraph 3-24).

(3) Connecting rod and piston group (paragraph 3-25).

b. Through the process of removing the assemblies and components listed in the Equipment Conditions in Step (a), the block assembly should now be free from its mounts and supported by the lifting fixture.

**NOTE**

Other external components or fixtures may have to be moved, or. removed, to provide necessary clearance for removing the block assembly.

**CAUTION**

The liner puller must be installed and used as described to avoid damage to the cylinder block.

(1)

(a) Insert the liner puller (FIGURE 4-56) in the top of the cylinder block.

1 The liner puller must be centered on the top of the cylinder block.

2 When using liner puller shown in FIGURE 4-56 the feet on the extension arms must be extended below the bottom of the liner.

3 With liner puller shown in FIGURE 4-56, the puller plate must be parallel to the main bearing saddles and it must not overload the liner outside diameter.

(b) Turn the puller jackscrew clockwise.

(c) Use both hands to remove the liners.

(d) Remove and discard the performed packing (2, FIGURE 4-55) and gasket (3).

**NOTE**

Do not discard the shims (5, FIGURE 4-55) which may be used under the cylinder liner flange.

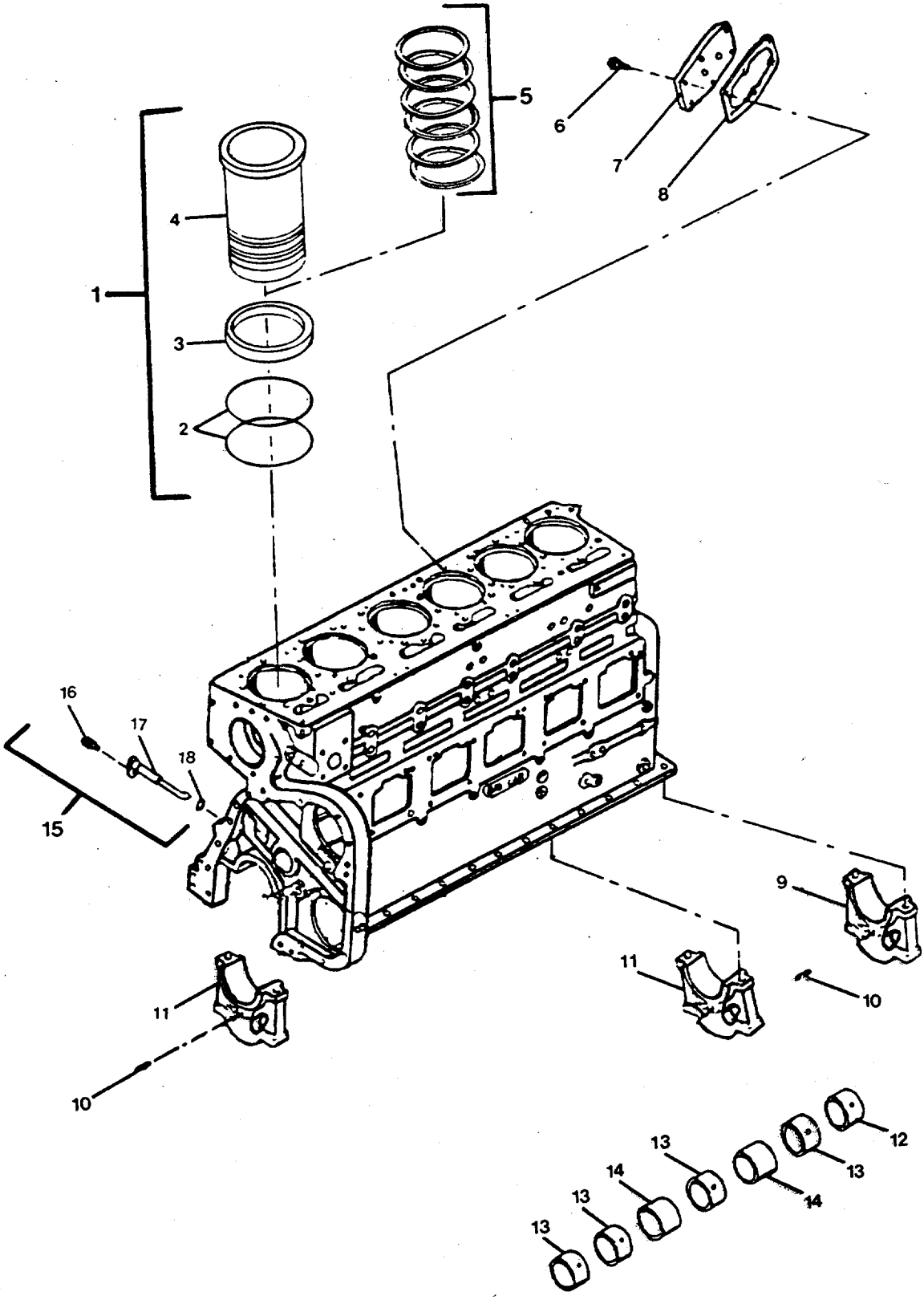


*FIGURE 4-55. Cylinder Block Group.*

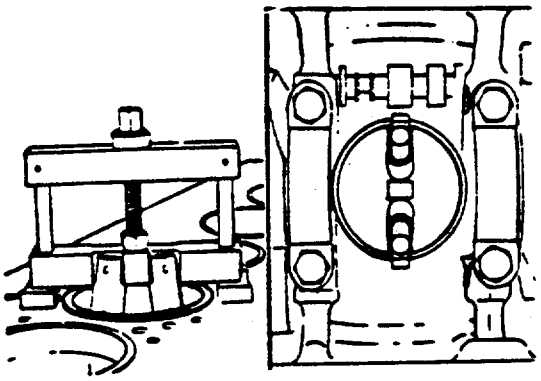

*FIGURE 4-56. Extended Foot Type Puller.*

(e) Use a liquid metal marker to mark the cylinder number on each liner.

(f) If the shims were removed, perform the following:

1 Tag and record cylinder number.

2 Measure and record the thickness of the shims used in each cylinder.

(2) Inspect the liner bore and counterbore as follows:

(a) Clean the cylinder block bore and counterbore with an approved cleaning solvent.

(b) Remove any rough edges with crocus cloth.

(c) Clean the cylinder block deck surface.

**NOTE**

The top of the cylinder block must be flat and without damage or distortion. Use a straight edge and a 0.002 inch (0.05 mm) feeler gauge to check the surface.

(d) Inspect the liner bore and counterbore for cracks. If cracks are present, the cylinder block may be used if:

1 Circumferential cracks do not extend into a cylinder head capscrew hole or water jacket hole.

2 Circumferential cracks do not extend beyond one-half the width of the counterbore ledge from the radius.

**CAUTION**

Do not attempt to reuse the cylinder block if radial cracks extend into the water jacket or the lubricating oil or water passages.

(e) Measure the diameter of the counterbore in the liner press fit area (FIGURE 4-57).

1 Measure the counterbore from the top deck to 0.100 inch (2.54 mm) below the top deck of the cylinder block.

2 If the counterbore diameter does not exceed 6.5635 inches (166.713 mm) standard liners may be used.

3 If the counterbore diameter exceeds 6.5635 inches (166.713 mm) in the press fit area, replace the cylinder block.

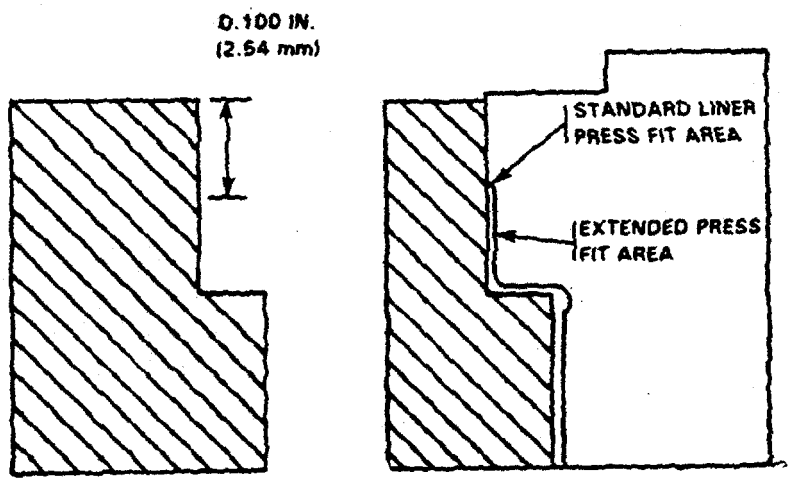


*FIGURE 4-57. Liner Press Fit Area.*

(f) Measure the depth of the counterbore at locations 1 and 2, FIGURE 4-58, at four equally spaced points around the bore.

1 Measure at point 1 as close to the counterbore wall as possible.

2 Measure at point 2 as far from the counterbore wall as possible.

3 There must not be more than a total of 0.001 inches (0.03 mm) difference in the measurements around the circumference of the "counterbore.

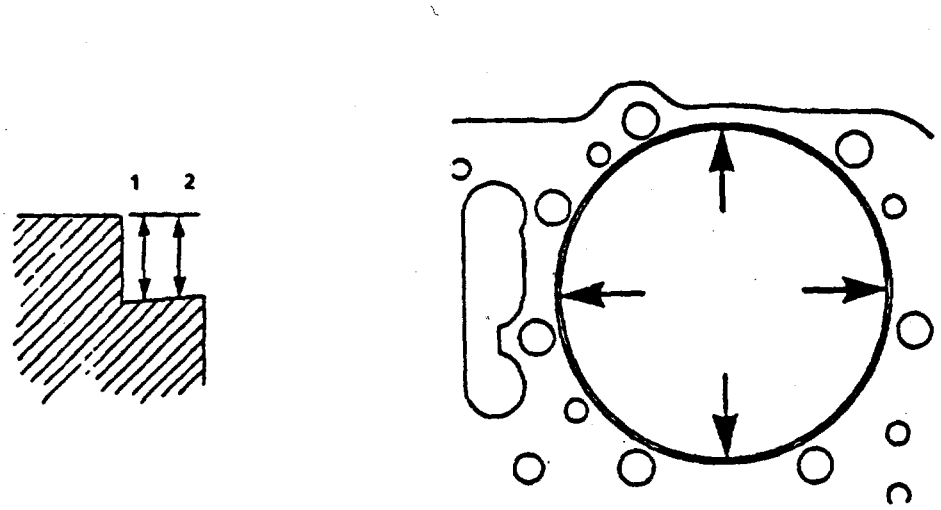


*FIGURE 4-58. Measuring Counterbore.*

**CAUTION**

A concave condition in the counterbore can cause liner breakage.

4 Measurement 2 must never exceed measurement 1 (concave) or be less than measurement 1 (convex) by more than 0.0014 inches (0.036 mm).

(3) Install the cylinder sleeves (liners).

**NOTE**

- Be sure that the cylinder block and all parts are clean before assembly. If used liners are being installed again, any shims (5, FIGURE 4-55) that were removed must be installed.
- Lubricate preformed packing with vegetable oil. Do not use lubricating oil on preformed packing because they will increase in size after they have been lubricated.

(a) Lubricate new liner preformed packings (2, FIGURE 4-55) and gasket (3) with vegetable oil.

(b) Install the preformed packings (2) and the gasket (3) as follows:

1 Install the gasket (3, FIGURE 4-55) in the top groove of the liner (4).

2 Install the preformed packings (2, FIGURE 4-55) in the center and the bottom grooves.

**CAUTION**

Do not use excessive amount of sealant. Excessive sealant can cause problems in the cooling system.

(c) Apply a bead of RTV type sealant on either the cylinder block counterbore or the liner flange. The liner must be installed within 5 minutes after the sealant is applied (FIGURE 4-59) .

**NOTE**

The diameter of the bead must be at least 3/64-inch and not more than 1/16-inch.

(d) Lubricate the gasket and the preformed packing with vegetable oil. Install the liner in the bore with a quick push.

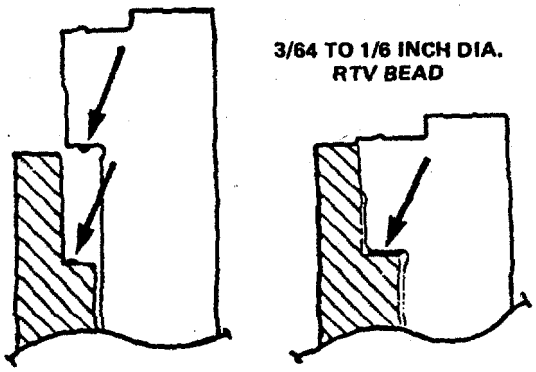


*FIGURE 4-59. Applying Sealant to Liner.*

**NOTE**

Be sure that the oil does not touch the counterbore or the liner flange and that the preformed packing does not move from the grooves.

(e) Use the cylinder liner driver and a leather mallet to drive the flange of the liner against the counterbore ledge.

(f) Check the protrusion of the cylinder liner as follows:

1 Install the cylinder liner clamp set.

2 Tighten the capscrews to 50 ft-lb (67 N•m) torque. Do not damage the liner bead.

3 Use the gauge block to measure the liner protrusion at four points 90 degrees apart (FIGURE 4-60) . The protrusion must be from 0.003 inch to (0.08 mm) to 0.006 inch (0.15 mm).

(g) Use a feeler gauge to measure the clearance between the liner and the lower liner bore (FIGURE 4-61) . The clearance must be from 0.002 inch (0.05 mm) to 0.006 inch (0.15 mm).

**NOTE**

The clamp set uses two cylinder head capscrews. The clamps must be installed 180 degrees from each other to apply equal amounts of pressure on the liner (FIGURE 4-60) .

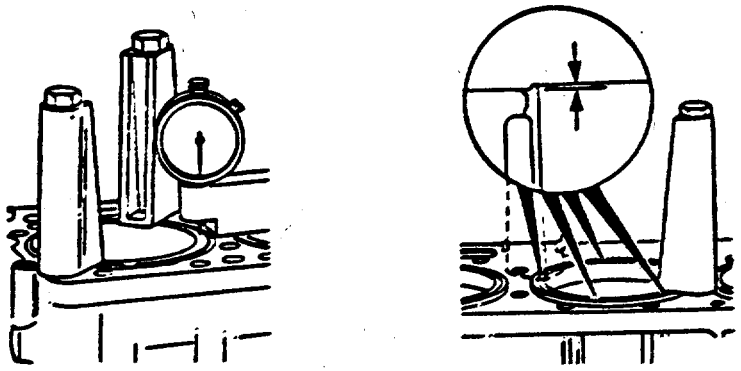

*FIGURE 4-60. Measuring Liner Protrusion.*

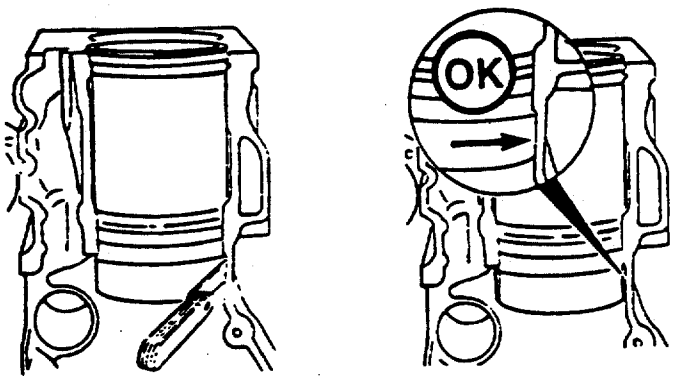


*FIGURE 4-61. Liner and Lower Liner Bore Clearance.*

**NOTE**

If the liner protrusion is below the specifications, liner shims might be required.

(h) Measure the liner bore for out of roundness as follows: (FIGURE 4-62).

1 Measure at points "C", "D", "E", "F", and "G".

2 Measure each point in the direction "AA" and "BB".

3 At point "C", the liner cannot be more than 0.003 inch (0.08 mm) out of round.

4 At points "D", 'E", 'F", and 'G", the liner bore cannot be more than 0.002 inch (0.15 mm).

(i) Check the following and replace liners again as necessary.

1 Liner protrusion.

2 Liner and cylinder block lower liner bore.

3 Liner bore out-of-round.

(j) Check for twisted preformed packing.

(k) Clean the liner flange and the cylinder block liner counterbore.

(1) Inspect the liner flange for burrs.

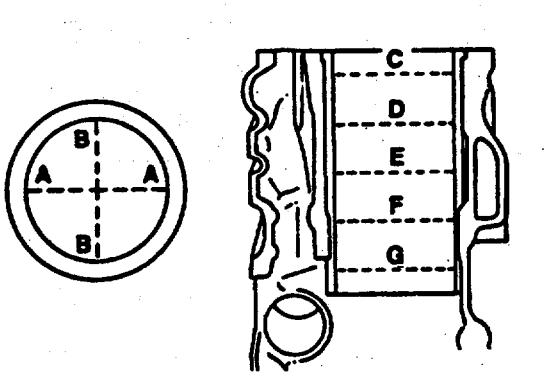


*FIGURE 4-62. Checking Liner Bore.*

(m) Inspect the cylinder block liner counterbore for burs.

(n) Remove the burrs, or replace the damaged parts.

(o) Repeat steps (a) through (h).

c. Remove and inspect the piston cooling nozzles (15, FIGURE 4-55) .

(1) Remove the six self-locking screws (16, FIGURE 4-55) and pull the nozzles (17) from the cylinder block as illustrated in FIGURE 4-63 .

(2) Remove and discard the preformed packing (18, FIGURE 4-55) .

(3) Clean the piston cooling nozzles with an approved solvent.

(4) Blow out the oil passages with compressed air.

(5) Visually inspect the cooling nozzles for cracks or damage.

(6) Visually inspect the screws for damaged threads.

(7) Replace any damaged parts.

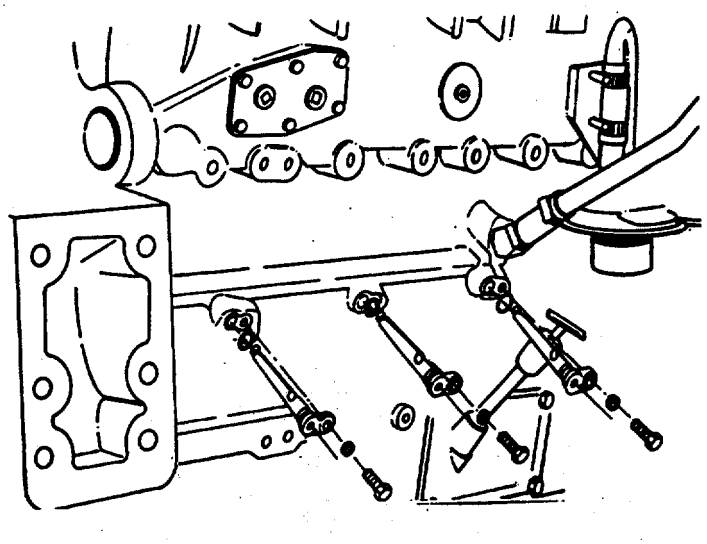

*FIGURE 4-63. Piston Coolin2 Nozzles.*

(8) Lubricate the new preformed packing with vegetable oil.

(9) Install the preformed packing in the groove of the piston cooling nozzle.

**CAUTION**

Be sure that the oil passage opening in the piston cooling nozzle is pointing up toward the piston.

(10) Install the nozzles in the cylinder block.

(11) Install the self-locking screws.

(a) Tighten the capscrews to 140 in-lb (15.8 N•m) torque.

(b) Tighten the slotted head screws to 95 in-lb (10.7 N•m) torque.

d. Replace the camshaft bushings and bearing (13, 14, 12, FIGURE 4-55) as follows:

**NOTE**

The bushings and bearing must be removed in the order shown in FIGURE 4-64 .

(1) Using the camshaft bushing driver kit and driver, remove the No. 1 bushing first and then the remaining six (6) bushings in order from front to rear.

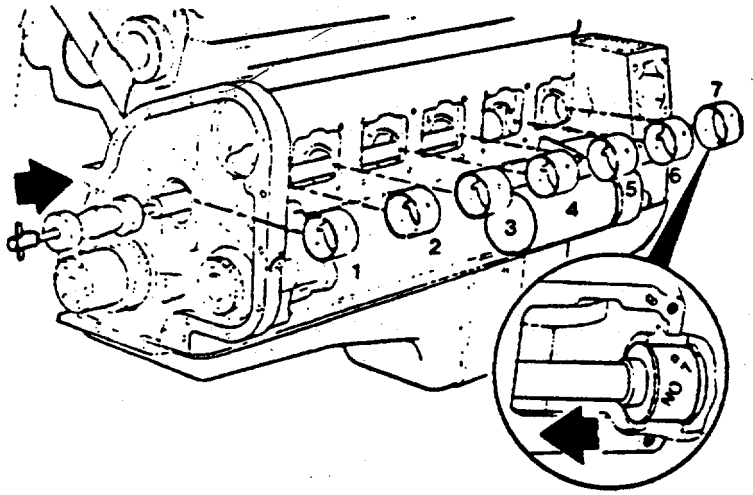


*FIGURE 4-64. Camshaft Bushing/Bearing Removal Sequence.*

(a) To remove bushings No. 1 through No. 6, insert the tools assembly through the camshaft bore until the driver is against the bushing.

(b) Hit the slide hammer against the shaft assembly until the bushing is driven from the bore.

(c) Using the camshaft bushing driver kit and puller, remove the No. 7 bushing. Insert the tool assembly through the bore until the pins of the puller assembly are engaged behind the bushing.

(d) Hit the slide hammer against the T-handle until the bushing is removed from the bore.

**CAUTION**

Incorrect installation will result in severe damage to the engine. Refer to the numbers stamped on the bushings to determine the correct cylinder block cam bore location in which the bushings are to be installed. Install the camshaft bushings in the following order: No. 7, No. 6, No. 5, No. 4, No. 3, No. 2, and No. 1.

(2) Install the tool assembly through the camshaft bore until driver is in the cavity between the No. 6 and No. 7 bores.

(3) Install the camshaft bushing guide in the No. 5 and No. 6 bores.

(4) Install the bushing marked No. 7 on the driver with the location notch to the rear of the engine and at the 6 o'clock position.

(a) Push the bushing in the bore until the oil holes in the bushing are aligned with the drillings in the bore.

(b) Use a 0.094 (2.39 mm) diameter rod to check the position and the location at the oil hole in the bushing and the cylinder block.

(c) The rod must pass through the oil holes in the bushing and into the oil supply drillings in the cylinder block.

**CAUTION**

The locating notch in the No. 2 through No. 6 bushings must face the rear of the engine and be located at the 9 o'clock position when looking at it from the front of the engine.

**NOTE**

• Use bushing driver (1) to install bushings No. 1, No. 2, No. 4, and No. 6. Use bushing driver (2) to install bushings No. 3 and No. 5 (FIGURE 4-65).

• Install the No. 6 through the No. 2 bushings in the same manner as No. 7.

(5) Install the tool assembly through the camshaft bore until the driver is in the cavity between the bores where the bushing is to be installed.

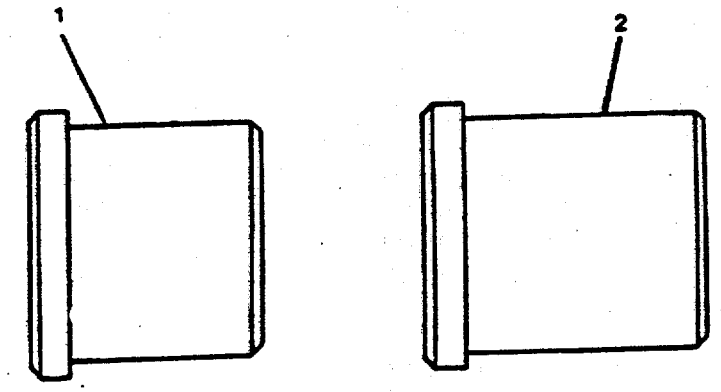


*FIGURE 4-65. Bushing Driver Identification.*

(6) Install the bushing guide in the camshaft bore next to the bore where the bushing is to be installed.

(7) Install the bushing marked for that location on the driver with the locating notch to the rear of the engine and at the 9 o'clock position.

(a) Push the bushing in the bore until the oil holes in the bushings are aligned with the drillings in the bore.

(b) Use a 0.094-inch (2.39 mm) diameter rod to check the position and the location of the oil hole in the bushing and the cylinder block.

(c) he rod must pass through the oil holes in the bushing and into the oil supply drillings in the cylinder block.

**NOTE**

The Camshaft Bushing Guide is not used to install the No. 1 bushing.

(8) Install bushing No. 1 on the driver with the notch to the rear of the engine and at the 9 o'clock position when looking at it from the front of the engine.

(a) Push the bushing in the bore until the oil holes in the bushings are aligned with the drillings in the bore.

(b) Use a 0.094 inch (2.39 mm) diameter rod to check the position and the location of the oil holes in the bushing and the cylinder block.

(c) The rod must pass through the oil holes in the bushing and into the oil supply drillings in the cylinder block.

(9) Measure the camshaft bushings installed inside diameter. The measurement should be between 2.4983 inches (63.457 mm) and 2.5023 inches (63.558 mm).

e. Replace the gasket (8, FIGURE 4-55) as follows:

(1) Remove the six assembled washer screws (6, FIGURE 4-55) and remove the access cover (7).

(2) Remove the gasket (8).

(3) Position a new gasket (8) and install the access cover (7) with capscrews (6).

f. The pillow block (main bearing) caps (9, 11, 17, FIGURE 4-55) were removed with the crankshaft group (paragraph 4-19). The pins (10, FIGURE 4-55) may be removed and replaced in the bearing caps.

ASSEMBLY

a. Install the following:

(1) Connecting rod, piston, and ring assemblies (paragraph 3-23).

(2) Camshaft group (paragraph 3-22).

(3) Cam followers (paragraph 3-16).

b. Using the lifting fixture, hoist the block assembly into place.

c. Install the following assemblies:

(1) Flywheel and housing (paragraph 3-24).

(2) Gear cover (paragraph 3-18).

(3) Accessory drive and pulley (paragraph 3-17).

(4) Lube oil pump (paragraph 3-21).

(5) Oil pan (paragraph 2-45).

(6) Cylinder head (paragraph 2-42).

(7) Heat exchanger (paragraph 2-39).

(8) Water pump and idler (paragraph 2-29).

(9) Lube oil cooler/filter (paragraph 2-30).

(10) Lube oil bypass filter assembly (paragraph 2-31).

(11) Fuel filter assembly (paragraph 2-27).

(12) Air cleaner and piping (paragraph 2-25).

(13) Sump pump (paragraph 2-28).

(14) Seawater pump (paragraph 2-38).

(15) Instrument panel and wiring (paragraph 2-22).

(16) Coolant heater (paragraph 2-32).

(17) Starter motor (paragraph 2-21).

## SECTION VI. PREPARATION FOR STORAGE OR SHIPMENT

4-21. Refer to Chapter 2, Section VI.

# APPENDIX A

# REFERENCES

A-1. Scope. This paragraph lists the manuals, bulletins, specifications, and miscellaneous publications referenced in this manual or required for maintenance activities.

A-2. Field Manuals.

| | |
|---|---|
| FM 21-11 | First Aid for Soldiers |
| FM 31-70 | Basic Cold Weather Manual |
| FM 55-501 | Marine Crewman's Handbook |

A-3. Technical Manuals.

| | |
|---|---|
| TM 43-0139 | Painting Instructions for Field Use |
| TM 55-1905-223-10 | Operator's Manual for Landing Craft, Utility (LCU) |
| TM 55-1905-223-24-2 | Main Reduction Gear |
| TM 55-1905-223-24-18 | LCU 2000 Class Basic Craft Maintenance Manual |
| TM 55-1905-223-24P | Repair Parts and Special Tools List for the LCU 200 Class Watercraft |
| TM 750-244-3 | Destruction of Army Materiel to Prevent Enemy Use |

A-4. Technical Bulletins.

| | |
|---|---|
| TB 43-0144 | Painting of Vessels |
| TB 55-1900-207-24 | Treatment of Cooling Water in Marine Diesel Engines |
| TB 740-97-4 | Preservation of Vessels for Storage. |

A-5. Military Specifications.

| | |
|---|---|
| MIL-C-16173C | Rust Preventive, Type P-1 |
| MIL-L-644 | Preservative Oil, Type P-9 |
| MIL-L-21260 | Preservative Oil, Type P-10 |

A-6. Miscellaneous Publications.

| | |
|---|---|
| DA Pam 738-750 | The Army Maintenance Management System |
| LO 55-1905-223-12 | Lubrication Order for the LCU 2000 Class Watercraft |
| *AMC-R 750-11 | Use of Lubricants, Fluids, and Associated Products |

A-7. Forms.

| | |
|---|---|
| DA Form 2028 and DA Form 2028-2 | Recommended Changes to Publications and Blank Forms |
| DA Form 2404 | Equipment Maintenance and Inspection Worksheet |
| DA Form 2408-16 | Logsheet |
| DA Form 2410 | Logsheet |
| SF Form 368 | Quality Deficiency Report |

*Supersedes Darcom-R 750-11

# APPENDIX B

# MAINTENANCE ALLOCATION CHART

## SECTION I. INTRODUCRION

B-1. General.

a. This section provides a general explanation of all maintenance and repair functions authorized at various maintenance categories (levels).

b. The Maintenance Allocation Chart (MAC) in Section II designates overall authority and responsibility for the performance of maintenance functions on the identified end item or component. The application of the maintenance functions to the end item or component will be consistent with the capacities and capabilities of the designated maintenance categories.

c. Section III lists the tools and test equipment (both special tools and common tool sets) required for each maintenance function as referenced from Section II.

d. Section IV contains supplemental instructions and explanatory notes for a particular maintenance function.

B-2. **Maintenance Functions.** Maintenance functions will be limited to and defined as follows:

a. Inspect. To determine the serviceability of an item by comparing its physical, mechanical, and/or electrical characteristics with established standards through examination (for example, by sight, sound, or feel).

b. Test. To verify serviceability by measuring the mechanical, pneumatic, hydraulic, or electrical characteristics of an item and comparing those characteristics with prescribed standards.

c. Service. Operations required periodically to keep an item in proper operating condition, that is, to clean (includes decontaminate, when required), to preserve, to drain, to paint, or to replenish fuel, lubricants, chemical fluids, or gases.

d. Adjust. To maintain or regulate, within prescribed limits, by bringing into proper or exact position, or by setting the operating characteristics to specified parameters.

e. Align. To adjust specified variable elements of an item to bring about optimum or desired performance.

f. Calibrate. To determine and cause corrections to be made or to be adjusted on instruments or test, measuring, and diagnostic equipments used in precision measurement. Consists of comparisons of two instruments, one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared.

g. Remove/Install. To remove and install the same item when required to perform service or other maintenance functions. Install may be the act of emplacing, seating, or fixing into position a spare, repair part, or module (component or assembly) in a manner to allow the proper functioning of an equipment or system.

h. Replace. To remove an unserviceable item and install a serviceable counterpart in its place. "Replace" is authorized by the MAC and is shown as the third position code of the SMR code.

i. Repair. The application of maintenance services, including fault location/troubleshooting, removal/installation, and disassembly/assembly procedures, and maintenance actions4 to identify troubles and restore serviceability to an item by correcting specific damage, fault, malfunction, or failure in a part, subassembly, module (component or assembly), end item, or system.

j. Overhaul. That maintenance effort (service/action) necessary to restore an item to a completely serviceable/operational condition as required by maintenance standards in appropriate technical publications [i.e., Depot Maintenance Work Requirements (DMWR)]. Overhaul is normally the highest degree of maintenance performed by the Army. Overhaul does not normally return an item to like-new condition.

k. Rebuild. Consists of those services/actions necessary for the restoration of unserviceable equipment to a like-new condition in accordance with original manufacturing standards. Rebuild is the highest degree of materiel maintenance applied to Army equipment. The rebuild operation includes the act of returning to zero those age measurements (hours, miles, etc.) considered in classifying Army equipments/components.

B-3. **Explanation of Columns in the MAC, Section II.**

a. Column 1, Group Number. Column 1 lists functional group code numbers, the purpose of which is to identify maintenance-significant components, assemblies, subassemblies, and modules with the next higher assembly. End item group number shall be "00."

[1]Services-inspect, test, service, adjust, align, calibrate, and/or replace.
[2]Fault locate/troubleshoot-The process of investigating and detecting the cause of equipment malfunctioning; the act of isolating a fault within a system or unit under test (UUT).
[3]Disassemble/assemble-encompasses the step-by-step taking apart (or breakdown) of a spare/functional group coded item to the level of its least componency identified as maintenance significant (that is, assigned an SMR code) for the category of maintenance under consideration.
[4]Actions-welding, grinding, riveting, straightening, facing, remachinery, and/or resurfacing.

b. Column 2, Component/Assembly. Column 2 contains the noun names of components, assemblies, subassemblies, and modules for which maintenance is authorized.

c. Column 3, Maintenance Function. Column 3 lists the functions to be performed on the item listed in Column 2. (For detailed explanation of these C functions, see paragraph B-2.)

d. Column 4, Maintenance Category. Column 4 specifies, by the listing of a work time figure in the appropriate subcolumn(s), the category of maintenance authorized to perform the function listed in Column 3. This figure represents the active time required to perform that maintenance function at the indicated category of maintenance. If the number or complexity of the tasks within the listed maintenance function vary at different maintenance categories, appropriate work time figures will be shown for each category. The work time figure represents the average time required to restore an item (assembly, subassembly, component, module, end item or system) to a serviceable condition under typical field operating conditions. This time includes preparation time (including any necessary disassembly/assembly time), troubleshooting/fault location time, and quality assurance/quality control time in addition to the time required to perform the specific tasks identified for the maintenance functions authorized in the maintenance allocation chart. The symbol designations for the various maintenance categories are as follows:

| | |
|---|---|
| UNIT | C-Operator or Crew<br>O-Organizational Maintenance |
| INTERMEDIATE | F-Direct Support Maintenance<br>H-General Support Maintenance |
| DEPOT | D-Depot |

e. Column 5, Tools and Equipment. Column 5 specifies, by code, those common tool sets (not individual tools) and special tools, TMDE, and support equipment required to perform the designated function.

f. Column 6, Remarks. This column shall, when applicable, contain a letter code, in alphabetic order, which shall be keyed to the remarks contained in Section IV.

B-4. **Explanation of Columns in Tool and Test Equipment Requirements, Section III.**

a. Column 1, Reference Code. The tool and test equipment reference code correlates with a code used in the MAC, Section II, Column 5.

b. Column 2, Maintenance Category. The lowest category of maintenance authorized to use the tool or test equipment.

c. Column 3, Nomenclature. Name or identification of the tool or test equipment.

d. Column 4, National Stock Number. The National stock number of the tool or test equipment.

e. Column 5, Tool Number. The manufacturer's part number.

B-5. **Explanation of Columns in Remarks, Section IV.**

a. Column 1, Reference Code. This code recorded in Column 6, Section II.

b. Column 2, Remarks. This column lists information pertinent to the maintenance function being performed as indicated in the MAC, Section II.

## SECTION II. MAINTENANCE ALLOCATION CHART FOR BOWTHRUSTER ENGINE

| (1) GROUP NUMBER | (2) COMPONENT ASSEMBLY | (3) MAINTENANCE FUNCTION | (4) MAINTENANCE LEVEL | | | | | (5) TOOLS & EQUIPMENT | (6) REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | UNIT | | INTERMED | | DEPOT | | |
| | | | C | O | F | H | D | | |
| 05 | ENGINE, BOWTHRUSTER | INSPECT | 0.5 | | | | | | A |
| | | TEST | 0.8 | | | | | | |
| | | SERVICE | 1.0 | | | | | | |
| | | ADJUST | 0.5 | | | | | | |
| | | REPLACE | | | 30.0 | | | 1,2,3,7, 12 | |
| | | REPAIR | 1.0 | 2.0 | 1.0 | 60.0 | | 1-104 | |
| | | OVERHAUL | | | | | * | 1-32 | A |
| 0501 | STARTING MOTOR/MAGNETIC SWITCH GROUP | REPLACE | 1.0 | | | | | 1,35 | B |
| | | REPAIR | 2.0 | | | | | 1,28 | |
| 0502 | INSTRUMENT PANEL GROUP | INSPECT | 0.1 | | | | | 1,32 | |
| | | REPLACE | | 3.0 | | | | 1 | |
| | | REPAIR | | 1.5 | | | | 1 | |
| 0503 | WATER FILTER GROUP | INSPECT | 0.2 | | | | | 1,33-35 | |
| | | SERVICE | 0.3 | | | | | | |
| | | REPLACE | | 0.5 | | | | 1,33-35 | |
| | | REPAIR | | 2.0 | | | | 1,33-35 | |
| 050301 | WATER FILTER ASSEMBLY | INSPECT | 0.1 | | | | | | |
| | | SERVICE | 0.1 | | | | | | |
| | | REPLACE | | 0.5 | | | | 1,33-35 | |
| | | REPAIR | 0.2 | 0.5 | | | | 1,33-35 | |
| 0504 | THERMOSTAT HOUSING GROUP | INSPECT | 0.1 | | | | | 1,5,6 | |
| | | SERVICE | 0.1 | | | | | | |
| | | REPLACE | 0.5 | | | | | 1,5,6, 34,35 | |
| | | REPAIR | | 0.5 | | | | 1,5,6 34,35 | |
| 0505 | AIR CLEANER GROUP | INSPECT | 0.1 | | | | | | |
| | | SERVICE | 0.3 | | | | | | |
| | | REPLACE | | 0.5 | | | | 1 | |
| | | REPAIR | 0.5 | 1.5 | | | | 1 | |
| 050501 | CLEANER, AIR | REPLACE | 0.2 | | | | | 1 | |
| | | REPAIR | | 0.3 | | | | 1 | |
| 0506 | TURBOCHARGER GROUP | REPLACE | 0.7 | | | | | 1,2,34, 35 | C,B |
| | | REPAIR | | 1.5 | | | | 1,2,34, 35 | |

## SECTION II. MAINTENANCE ALLOCATION CHART FOR BOWTHRUSTER ENGINE

| (1) GROUP NUMBER | (2) COMPONENT ASSEMBLY | (3) MAINTENANCE FUNCTION | (4) MAINTENANCE LEVEL | | | | | (5) TOOLS & EQUIPMENT | (6) REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | UNIT | | INTERMED | | DEPOT | | |
| | | | C | O | F | H | D | | |
| 0507 | FUEL FILTER GROUP | INSPECT | 0.1 | | | | | 1,33 | |
| | | SERVICE | 0.5 | | | | | | |
| | | REPLACE | | 0.7 | | | | 1,33 | |
| | | REPAIR | 0.2 | 0.5 | | | | 1,33 | |
| 0508 | SUMP PUMP GROUP | REPLACE | | 0.7 | | | | 1 | |
| | | REPAIR | | 0.3 | | | | 1 | B |
| 0509 | WATER PUMP AND IDLER/ BELT GUARD GROUP | INSPECT | 0.1 | | | | | | |
| | | SERVICE | 0.2 | | | | | | |
| | | ADJUST | 0.3 | | | | | | |
| | | REPLACE | 1.0 | | | | | 1,2 | |
| | | REPAIR | | 1.5 | | | | 1,2,35-37,57 | |
| 050901 | ADJUSTING DEVICE, BELT-CHAIN TENSION | INSPECT | 0.1 | | | | | 1,2 | |
| | | SERVICE | 0.1 | | | | | 1,2 | |
| | | ADJUST | 0.1 | | | | | | |
| | | REPLACE | 0.1 | | | | | 1,2 | |
| | | REPAIR | | 1.5 | | | | 1,2 | |
| 050902 | PUMP, COOLING SYSTEM, ENGINE | REPLACE | 0.1 | | | | | 1,2 | |
| | | REPAIR | | 1.5 | | | | 1,2 | |
| 0510 | LUBRICATING OIL COOLER/ FILTER GROUP | INSPECT | 0.2 | | | | | | |
| | | SERVICE | 0.2 | | | | | 1,2,12 | |
| | | REPLACE | | 1.0 | | | | 1,2,12 | |
| | | REPAIR | | 1.0 | 1.0 | | | 1,2 12,31,35 57,88 | |
| 051001 | COOLER ASSEMBLY, OIL | REPLACE | | 1.0 | | | | 1,2 | |
| | | REPAIR | | 1.0 | 1.0 | | | | |
| 05100101 | COOLER, FLUID, INDUSTRIAL | REPLACE | | 1.0 | | | | 1,2 | |
| | | REPAIR | | | 1.0 | | | 1,2 | |
| 0511 | LUBRICATING OIL BYPASS FILTER GROUP | INSPECT | 0.1 | | | | | | |
| | | SERVICE | 0.3 | | | | | 1,2,7,9 | |
| | | REPLACE | | 0.5 | | | | 1,2,7,9 | |
| | | REPAIR | | 0.5 | | | | 1,2,7,9 | |
| 0512 | COOLANT HEATER GROUP | REPLACE | | 0.7 | | | | 1,2,32 | B |
| | | REPAIR | | 0.5 | | | | 1,2,32 | |

## SECTION II. MAINTENANCE ALLOCATION CHART FOR BOWTHRUSTER ENGINE

| (1) GROUP NUMBER | (2) COMPONENT ASSEMBLY | (3) MAINTENANCE FUNCTION | (4) MAINTENANCE LEVEL | | | | | (5) TOOLS & EQUIPMENT | (6) REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | UNIT | | INTERMED | | DEPOT | | |
| | | | C | O | F | H | D | | |
| 0513 | FUEL TUBING, SHUT, DOUN | REPLACE | 1.0 | | | | | 1,2 | B |
| | VALVE AND FUEL PUMP | REPAIR | 1.0 | | 1.0 | | | 1,2,12, | |
| | GROUP | | | | | | | 28,34,38 | |
| 051301 | VALVE, SOLENOID | REPLACE | 1.0 | | | | | 1,2 | |
| | | REPAIR | 0.2 | | 2.0 | | | 1,2 | |
| 051302 | PUMP, FUEL, METERING AND | REPLACE | 1.0 | | | | | 1,2 | B |
| | DISTRIBUTING | REPAIR | | | 5.0 | | | 1,2 | |
| 0514 | ROCKER LEVER HOUSING/ | REPLACE | 1.0 | | | | | 1,2,11, | |
| | COVER GROUP | | | | | | | 12 | |
| | | REPAIR | | | 2.0 | | | 1,11,34, | |
| | | | | | | | | 35,40,41 | |
| 051401 | HOUSING, ROCKER LEVER | REPLACE | | | 1.0 | | | 1,2 | |
| | | REPAIR | | | 1.0 | | | 1,2 | |
| 05140101 | ROCKER ARM, ENGINE | REPLACE | | | 1.0 | | | 1,2 | |
| | POPPET VALVE | REPAIR | | | 1.0 | | | | |
| 05140102 | LEVER, INJECTOR, ROCKER | REPLACE | | | 1.0 | | | 1,2 | |
| | | REPAIR | | | 1.0 | | | 1,2 | |
| 05140103 | ROCKER ARM, ENGINE | REPLACE | | | 1.0 | | | 1,2 | |
| | POPPET VALVE | REPAIR | | | 1.0 | | | 1,2 | |
| 0515 | INJECTOR GROUP | INSPECT | 0.5 | | | | | 1,10,11, | |
| | | | | | | | | 34,41 | |
| | | REPLACE | 0.5 | | | | | 1,10,11, | |
| | | | | | | | | 34,41 | |
| | | REPAIR | | 0.5 | | | | 1,10,11, | |
| | | | | | | | | 34,41 | |
| 0516 | EXPANSION TANK GROUP | INSPECT | 0.1 | | | | | | |
| | | SERVICE | 0.2 | | | | | 1 | |
| | | REPLACE | | 0.5 | | | | 1 | |
| | | REPAIR | | 1.0 | | | | 1 | |
| 0517 | SEA WATER PUMP/BELT | INSPECT | 0.1 | | | | | | |
| | GUARD GROUP | SERVICE | 0.5 | | | | | 1,2 | |
| | | ADJUST | 0.3 | | | | | 1,2 | |
| | | REPLACE | | 1.0 | | | | 1,2 | |
| | | REPAIR | | 1.0 | | | | 1,2,35, | |
| | | | | | | | | 36 | |

## SECTION II: MAINTENANCE ALLOCATION CHART FOR BOWTHRUSTER ENGINE

| (1) GROUP NUMBER | (2) COMPONENT ASSEMBLY | (3) MAINTENANCE FUNCTION | (4) MAINTENANCE LEVEL | | | | | (5) TOOLS & EQUIPMENT | (6) REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | UNIT | | INTERMED | | DEPOT | | |
| | | | C | O | F | H | D | | |
| 051701 | PUMP, COOLING SYSTEM, ENGINE | REPLACE | | 1.0 | | | | 1,2 | B,J |
| 0518 | HEAT EXCHANGER GROUP | REPLACE<br>REPAIR | | 0.5<br>1.0 | <br>1.5 | | | 1,2<br>1,2,34, 35 | |
| 051801 | EXCHANGER, HEAT | REPLACE<br>REPAIR | | 1.0<br>0.5 | <br>2.0 | | | 1,2<br>1,2 | |
| 0519 | AIR INTAKE MANIFOLD GROUP | REPLACE<br>REPAIR | | 0.5<br>1.0 | | | | 1,2,4<br>1,2,4,34, 39 | |
| 0520 | EXHAUST MANIFOLD GROUP | REPLACE<br>REPAIR | 0.7 | <br>1.0 | | | | 1,2<br>1,2,4,35 | |
| 0521 | CYLINDER HEAD GROUP | REPLACE<br>REPAIR | 1.0<br>1.0 | | | <br>3.0 | | 1,2,12<br>1,2,3, 12-16, 29-31,48 58-68, 70-75, 77-87, 104 | D |
| 052101 | VALVE, CROSSHEAD ASSEMBLY | REPLACE<br>REPAIR | | | | 1.0<br>2.0 | | 1,2,17<br>1,2,17 | |
| 052102 | CYLINDER HEAD, DIESEL ENGINE | REPLACE<br>REPAIR | 1.0 | | | <br>2.0 | | 1,2<br>1,2,17 | |
| 0522 | CAN FOLLOWER HOUSING GROUP | REPLACE<br>REPAIR | | | 0.5<br>0.5 | <br>1.0 | | 1,2,34, 35,42<br>1,2,17, 34,35,86 89-93, 104 | |
| 052201 | HOUSING, CAM FOLLOWER | REPLACE<br>REPAIR | | | 0.5 | <br>2.0 | | 1,2<br>1,2,17 | |
| 052202 | ROCKER ARM, ENGINE POPPET VALVE | REPLACE<br>REPAIR | | | | 0.5<br>2.0 | | 1,2,17<br>1,2,17 | |

## SECTION II. MAINTENANCE ALLOCATION CHART FOR BOWTHRUSTER ENGINE

| (1) GROUP NUMBER | (2) COMPONENT ASSEMBLY | (3) MAINTENANCE FUNCTION | (4) MAINTENANCE LEVEL | | | | | (5) TOOLS & EQUIPMENT | (6) REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | UNIT | | INTERMED | | DEPOT | | |
| | | | C | O | F | H | D | | |
| 052203 | ROCKET ARM, ENGINE | REPLACE | | | | 0.5 | | 1,2,17 | |
| | POPPET VALVE | REPAIR | | | | 2.0 | | 1,2,17 | |
| 0523 | ACCESSORY DRIVE AND | REPLACE | | | 0.5 | | | 1,2 | E |
| | PULLEY GROUP | REPAIR | | | 0.7 | | | 1,2,12, 37,43 | |
| 052301 | POWER TAKEOFF, | REPLACE | | | 0.5 | | | 1,2 | E |
| | TRANSMISSION | REPAIR | | | 0.7 | | | 1,2 | |
| 0524 | GEAR COVER GROUP | REPLACE | | | 1.0 | | | 1,2,4 | |
| | | REPAIR | | | 1.5 | | | 1,2,4 , 11,12, 40,44 | |
| 052401 | COVER, GEAR | REPLACE | | | 1.0 | | | 1,2,4 | |
| | | REPAIR | | | 1.5 | | | 1,2,4 | |
| 0525 | POWER TAKE-OFF ASSEMBLY | INSPECT | 0.1 | | | | | | |
| | | SERVICE | 0.2 | | | | | 1,2 | |
| | | REPLACE | | | 1.0 | | | 1,2,4 | |
| | | REPAIR | | 0.5 | 1.0 | 3.0 | | 1-4,12, 37,40,45 | |
| 052501 | HOSE ASSEMBLY, NONMETALLIC | REPLACE | | 0.5 | | | | 1,2 | |
| | | REPAIR | | | 1.0 | | | 1,2,4 | |
| 052502 | COLLAR ASSEMBLY | REPLACE | | 0.5 | | | | 1,2 | |
| | | REPAIR | | | 1.0 | | | 1,2,4 | |
| 0526 | CLUTCH ASSEMBLY, FRICTION | INSPECT | 0.1 | | | | | | |
| | | SERVICE | 0.2 | | | | | 1,2 | |
| | | REPLACE | | | 1.0 | | | 1,2,4 | |
| | | REPAIR | | 0.5 | 1.0 | 3.0 | | 1-4,12, 18,37,39 43,46,47 102 | |
| 052601 | HOSE ASSEMBLY, NONMETALLIC | REPLACE | | 0.5 | | | | 1,2 | |
| | | REPAIR | | 1.0 | | | | 1,2 | |
| 052602 | CLUTCH ASSEMBLY | REPLACE | | 0.5 | | | | 1,2 | |
| | | REPAIR | | 0.5 | 1.0 | | | 1,2 | |

## SECTION II. MAINTENANCE ALLOCATION CHART FOR BOWTHRUSTER ENGINE

| (1) GROUP NUMBER | (2) COMPONENT ASSEMBLY | (3) MAINTENANCE FUNCTION | (4) MAINTENANCE LEVEL | | | | | (5) TOOLS & EQUIPMENT | (6) REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | UNIT | | INTERMED | | DEPOT | | |
| | | | C | O | F | H | D | | |
| 05260201 | SLEEVE ASSEMBLY | REPLACE | | 0.5 | | | | 1,2 | |
| | | REPAIR | | 0.5 | 1.0 | | | 1,2,4 | |
| 052602010101 | COLLAR, SHAFT, ASSEMBLY | REPLACE | | 0.5 | | | | 1,2 | |
| | | REPAIR | | | 1.0 | | | 1,2,4 | |
| 0527 | OIL PAN GROUP | REPLACE | | 1.0 | | | | 1,2 | |
| | | REPAIR | | 0.5 | | | | 1,2 | |
| 0528 | LUBRICATING OIL PUMP GROUP | REPLACE | | | 0.5 | | | 1,2,12 | |
| | | REPAIR | | | 0.7 | | | 1,2,12, 48-53 | |
| 052801 | PUMP, OIL LUBRICATING | REPLACE | | | 0.7 | | | 1,2 | |
| | | REPAIR | | | 0.5 | | | 1,2 | |
| 05280101 | HOUSING, HYDRAULIC DRIVE | REPLACE | | | 0.7 | | | 1,2 | |
| | | REPAIR | | | 0.5 | | | 1,2 | |
| 05280102 | GEAR, SPUR | REPLACE | | | 0.7 | | | 1,2 | |
| | | REPAIR | | | 0.5 | | | 1,2 | |
| 05280103 | BODY, LUBE OIL PUMP | REPLACE | | | 0.7 | | | 1,2 | |
| | | REPAIR | | | 0.5 | | | 1,2 | |
| 0529 | CAMSHAFT GROUP | REPLACE | | | 3.0 | | | 1,18-21, 40 | |
| | | REPAIR | | | | 0.5 | | 1,18,19, 68,103 | |
| 052901 | CAMSHAFT | REPLACE | | | | 3.0 | | 1,18-21 | |
| | | REPAIR | | | | 0.5 | | 1,18,19, 68,103 | |
| 0530 | CONNECTING ROD AND PISTON GROUP | REPLACE | | | 1.0 | | | 1,22-24 | F,G |
| | | REPAIR | | | 0.5 | 0.3 | | 1,12,22-24,40,43 68,94-99 104 | |
| 053001 | CONNECTING ROD, PISTON ASSEMBLY | REPLACE | | | 0.5 | | | 1,22 | F |
| | | REPAIR | | | | 0.3 | | 1,22 | |

## SECTION II. MAINTENANCE ALLOCATION CHART FOR BOWTHRUSTER ENGINE

| (1) GROUP NUMBER | (2) COMPONENT ASSEMBLY | (3) MAINTENANCE FUNCTION | (4) MAINTENANCE LEVEL | | | | | (5) TOOLS & EQUIPMENT | (6) REMARKS |
|---|---|---|---|---|---|---|---|---|---|
| | | | UNIT | | INTERMED | | DEPOT | | |
| | | | C | O | F | H | D | | |
| 053002 | PISTON SET, ENGINE | REPLACE | | | 0.5 | | | 1,23,24 | G |
| | | REPAIR | | | | 0.3 | | 1,23,24 | |
| 0531 | FLYWHEEL AND FLYWHEEL HOUSING GROUP | REPLACE | | | 2.5 | | | 1,2,4,12 | |
| | | REPAIR | | | 2.5 | 1.0 | | 1-3,12, 100,101 | |
| 053101 | FLYWHEEL, ENGINE ASSEMBLY | REPLACE | | | 2.5 | | | 1,2,4, 12,40, 55-57 | |
| | | REPAIR | | | 1.0 | 1.0 | | 1,2,4, 12,40, 55-57, 99-100 | |
| 0532 | CRANKSHAFT GROUP | REPLACE | | | | 3.0 | | 1,8 | |
| | | REPAIR | | | | 0.5 | | 1,3,8, 12,18 47,68 | |
| 0533 | CYLINDER BLOCK GROUP | REPLACE | | | 30.0 | | | 1-3,12, 13,25-27 | H, I |
| | | REPAIR | | | | 60.0 | | 1,2,12, 13,18, 20,21, 25-27, 68 | |
| 053301 | NOZZLE, PISTON COOLING | REPLACE | | | | 1.0 | | 1,2 | |
| | | REPAIR | | | | 1.5 | | 1,2 | |
| 053302 | BLOCK, ENGINE, DIESEL CYLINDER | REPLACE | | | | 1.0 | | 1,2,12, 13,18 | I |
| | | REPAIR | | | | 2.5 | | 1,2,12, 13,18 | |
| 0534 | BOWTHRUSTER SUBBASE ASSEMBLY | REPLACE | | | 1.0 | | | 1,2 | J |

## SECTION III. TOOL AND TEST REQUIREMENTS FOR BOWTHRUSTER ENGINE

| TOOL OR TEST EQUIPMENT REF CODE | MAINTENANCE CATEGORY | NOMENCLATURE | NATIONAL/NATO STOCK NUMBER | TOOL NUMBER |
|---|---|---|---|---|
| 1 | O,F,H | Tool kit, general mechanics rail and marine diesel engines | 5180-00-629-9783 | (50980) SC-5180-CL -N55 |
| 2 | O,F,H | Combination wrench set, metric 10mm thru 24 mm | 5120-01-046-4979 | |
| 3 | F,H | Engine Lifting fixture | | (15434) 3822512 |
| 4 | O,F | Engine Lifting sling | 3940-01-183-9412 | (15434) 3375958 |
| 5 | C,O | Thermostat seal mandrel | | (15434) ST-1225 |
| 6 | 0 | Thermostat seat mandrel | | (15434) ST-1226 |
| 7 | C,O,F | Fitter wrench | 5120-01-160-8863 | (15434) 3375049 |
| 8 | H | Strap wrench | | (15434) 3376807 |
| 9 | C,O | Filter cutter | | (15434) 3376579 |
| 10 | O | Injector putter | | (15434) 3376000 |
| 11 | O,F | Injector adjustment kit | | (15434) 3375842 |
| 12 | C,F,H | Torque wrench kit | | (15434) 3377216 |
| 13 | F,H | Gauge block | 5120-01-157-3091 | (15434) 3376220 |
| 14 | H | Counterbore, drive unit | | (15434) 3376855 |
| 15 | H | Adapter plate | | (15434) 3376686 |
| 16 | H | Cutter plate | | (15434) |

## SECTION III. TOOL AND TEST REQUIREMENTS FOR BOWTHRUSTER ENGINE

| TOOL OR TEST EQUIPMENT REF CODE | MAINTENANCE CATEGORY | NOMENCLATURE | NATIONAL/NATO STOCK NUMBER | TOOL NUMBER |
|---|---|---|---|---|
| 17 | H | Timing fixture | | (15434) 3375522 |
| 18 | F,H | Main bearing cap puller | | (15434) ST-1178 |
| 19 | F,H | Camshaft installation pilots | | (15434) 3375268 |
| 20 | F,H | Bearing and bushing inserter | | (15434) 3376637 |
| 21 | F,H | Kit, driver, bushing | | (15434) 3376633 |
| 22 | F,H | Connecting rod guide pins | | (15434) 3375601 |
| 23 | F,H | Piston ring expander | | (15434) ST-763 |
| 24 | F,H | Piston ring compressor | | (15434) 3822736 |
| 25 | F,H | Cylinder Liner clamp set | | (15434) 3822503 |
| 26 | F,H | Cylinder liner driver | | (15434) ST-1229 |
| 27 | F,H | Cylinder Liner puller | 5120-01-143-2032 | (15434) 3376015 |
| 28 | C,F | Digital multimeter | 6625-01-139-2512 | (80058 AN/PSM-45 |
| 29 | H | Pressure manometer | 6685-01-107-6875 | (23582) PVS-2 |
| 30 | H | Valve tester | 4910-01-141-8387 | (15434) ST-1257 |
| 31 | F,H | Valve spring compression tester | 4910-01-142-4929 | (15434) |

## SECTION III. TOOL AND TEST REQUIREMENTS FOR BOWTHRUSTER ENGINE

| TOOL OR TEST EQUIPMENT REF CODE | MAINTENANCE CATEGORY | NOMENCLATURE | NATIONAL/NATO STOCK NUMBER | TOOL NUMBER |
|---|---|---|---|---|
| | | | | 3375182 |
| 32 | N | DCA test kit | | (15434) 330846S |
| 33 | C,O | Filter, wrench | 5120-01-262-7306 | |
| 34 | C,O,F | Torque wrench (30-300 in-tb) | 5120-01-092-3278 | |
| 35 | C,O,F | Torque wrench (30-300 ft-Lb) | 5120-01-125-5190 | |
| 36 | C,O | Belt tension gauge | | (15434) ST-1293 |
| 37 | C,O,F,H | Standard puller | | (15434) ST-647 |
| 38 | C,O | Torque wrench kit | | (15434) 3375044 |
| 39 | C,O | Torque wrench | 5120-00-242-3264 | |
| 40 | F,H | Dial indicator | 5210-00-277-8840 | |
| 41 | O,F | Rocker Lever actuator | | (15434) ST-1193 |
| 42 | F | Injection timing fixture | 4910-00-999-1269 | |
| 43 | O,F,H | Arbor press | 4920-00-373-9376 | |
| 44 | F | Special/puller driver | | (15434) ST-1259 |
| 45 | F | Pusher screws | | (15434) 3/8-16 |
| 46 | F | Pusher screws | | (15434) 7/16-4 |
| 47 | F,H | Gear puller | | (15434) 3375840 |
| 48 | F,H | Depth vernier | | (15434) ST-537 |
| 49 | F | Gear puller | | (15434) 3375082 |
| 50 | F | Gear puller | | (15434) 3375083 |
| 51 | F | Dowel puller | | (15434) |

## SECTION III. TOOL AND TEST REQUIREMENTS FOR BOWTHRUSTER ENGINE

| TOOL OR TEST EQUIPMENT REF CODE | MAINTENANCE CATEGORY | NOMENCLATURE | NATIONAL/NATO STOCK NUMBER | TOOL NUMBER |
|---|---|---|---|---|
| | | | | ST-1134 |
| 52 | F | Bushing mandrel | | (15434) ST-1158 |
| 53 | F | Lubricating oil pump boring toot | | (15434) 3375206 |
| 54 | F | Piston ring compressor | | (15434) 3375167 |
| 55 | F | Capscrew puller | | (15434) 1/2-13x1-1/2 |
| 56 | F | Guide studs | | (15434) 5/8-15x6& 5/8-18x4 |
| 57 | O, F | Mandrel kit | | (15434) ST-1325 |
| 58 | H | Valve spring compressor stand | | (15434) ST-1022 |
| 59 | H | Valve spring compressor plate | | (15434) ST-1026 |
| 60 | H | Valve seat insert tool kit | | (15434) ST-257 |
| 61 | H | Valve seat insert cutter | | (15434) ST-258 |
| 62 | H | Valve guide arbor | | (15434) ST-663 |
| 63 | H | Valve facing machine | | (15434) 3376256 |
| 64 | H | Valve guide reamer | | (15434) ST-646 |
| 65 | H | Valve head checking tool | | (15434) 3375933 |

## SECTION III. TOOL AND TEST REQUIREMENTS FOR BOWTHRUSTER ENGINE

| TOOL OR TEST EQUIPMENT REF CODE | MAINTENANCE CATEGORY | NOMENCLATURE | NATIONAL/NATO STOCK NUMBER | TOOL NUMBER |
|---|---|---|---|---|
| 66 | H | Valve seat grinder | | (15434) ST-685 |
| 67 | H | Valve guide mandrel | | (15434) 3375282 |
| 68 | H | Machinists measuring toot kit | 5280-00-278-9919 | |
| 69 | H | Head holding fixture | | (15434) ST-583 |
| 70 | H | Injector sleeve holding tool | | (15434) ST-1179 |
| 71 | H | Hydrostatic tester | | (15434) ST-1012 |
| 72 | H | Tester adapter plate | | (15434) ST-1013 |
| 73 | H | Staking tool driver | | (15434) ST-1122 |
| 74 | H | Staking toot | | (15434) ST-1124 |
| 75 | H | Valve guide reamer | | (15434) ST-1188 |
| 76 | H | Valve guide reamer | | (15434) ST-1187 |
| 77 | H | Crosshead guide spacer | | (15434) ST-633 |
| 78 | H | Water hole counterbore tool kit | | (15434) ST-1010 |
| 79 | H | Injector sleeve puller | | (1434) ST-1244 |
| 80 | H | Bead cutting toot | | (15434) ST-788 |
| 81 | H | Holder | | (15434) |

## SECTION III. TOOL AND TEST REQUIREMENTS FOR BOWTHRUSTER ENGINE

| TOOL OR TEST EQUIPMENT REF CODE | MAINTENANCE CATEGORY | NOMENCLATURE | NATIONAL/NATO STOCK NUMBER | TOOL NUMBER |
|---|---|---|---|---|
| | | | | ST-884-1 |
| 82 | H | Pilot | | (15434) ST-884-6 |
| 83 | H | Injector sleeve extractor | | (15434) ST-1277 |
| 84 | H | Injector sleeve expander | | (15434) ST-880 |
| 85 | H | Injector seat cutter | | (15434) ST-884 |
| 86 | H | Drill press | 5130-00-293-1949 | |
| 87 | H | 1/2" electric drill | 4130-00-889-9002 | |
| 88 | F | Tube bundle tester | | (15434) 3375253 |
| 89 | H | Lever bushing block | | (15434) 3376026 |
| 90 | H | Chamfer tool | | (15434) ST-1318 |
| 91 | H | Mandrel and block | | (15434) ST-249 |
| 92 | H | Plug gauge | | (15434) ST-195 |
| 93 | H | Expansion plug driver | | (15434) ST-1053 |
| 94 | H | Bushing driver | | (15434) ST-1242 |
| 95 | H | Rod checking fixture | | (15434) ST-561 |
| 96 | H | Locating mandrel | | (15434) ST-563 |
| 97 | H | Boring machine | | (15434) 3375115 |

## SECTION III. TOOLS AND TEST EQUIPMENT REQUIREMENTS FOR BOWTHRUSTER ENGINE

| TOOL OR TEST EQUIPMENT REF CODE | MAINTENANCE CATEGORY | NOMENCLATURE | NATIONAL/NATO STOCK NUMBER | TOOL NUMBER |
|---|---|---|---|---|
| 98 | H | Piston ring groove wear gauge | | (15434) ST-560 |
| 99 | H | Internal snap ring pliers | 5210-00-595-9551 | |
| 100 | H | Torch outfit, cutting and welding | 5433-00-357-8166 | |
| 101 | H | Crack detector kit | | (15434) 3375432 |
| 102 | H | Gear puller | | (15434) 3375016 |
| 103 | H | Hydraulic press | | (15434) 200915 |
| 104 | H | Bore gauge | | (15434) 3376619 |

## SECTION IV. REMARKS BOWTHRUSTER ENGINE

| REFERENCE CODE | REMARKS |
|---|---|
| A | Depot maintenance will be performed on a case by case basis subject to approval and funding by the National Maintenance Point (NMP). |
| B | This item is a candidate for direct exchange with the vendor. |
| C | During disassembly of the engine, put a cover tape over the inset and outlet of the turbocharger. |
| D | Remove the capscrews in the opposite sequence as that used for installing the cylinder heads |
| E | When a flanged locknut is used to hold the pulley on the shaft, you must not let the accessory drive shaft turn when the locknut is removed. When the flanged locknut is installed, it is tightened to 270 to 340 ft. lbs. torque. |
| F | Do not use a hammer or screwdriver to remove the caps from the connecting rods. |
| G | Do not use a hammer or other tools to remove the piston pin. |
| H | You do not need to use shims for the cylinder liner unless the counterbore has been repaired. |
| I | Inspect the cylinder block on a flat surface to prevent distortion. Do not inspect the cylinder block on the engine stand. |
| J | Repair of this item is by replacement. |



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# APPENDIX C

# EXPENDABLE/DURABLE SUPPLIES AND MATERIALS LIST

## SECTION I. INTRODUCTION

C-1. **Scope.** This appendix lists expendable supplies and materials needed to operate and maintain the LCU 2000 Class Watercraft. These items are authorized by CTA 50-970, Expendable/Durable Items (except Medical, Class V, Repair Parts and Heraldic Items), or CTA 8-100, Army Medical Department Expendable Items.

C-2. **Explanation of Columns.**

a. Column (1)-Item Number. This number is assigned to the entry in the listing and is referenced in the narrative instructions to identify the material (for example, "Use cleaning compound, Item 5, App. C").

b. Column (2)-Level. This column identifies the lowest level of maintenance that requires the listed item.

As applicable:

C-Operator/Crew
O-Organizational Maintenance
F-Direct Support Maintenance
H-General Support Maintenance

c. Column (3)-National Stock Number. This is the National stock number assigned to the item; use it to request or requisition the item.

d. Column (4)-Description. Indicates the Federal item name and, if required, a description to identify the item. The last line for each item indicates the Federal Supply Code for Manufacturers (FSCM) in parentheses followed by the part number.

e. Column (5)-Unit of Measure (U/M). Indicates the measure used in performing the actual maintenance function. This measure is expressed by a two-character alphabetical abbreviation (for example, ea, in, pr). If the unit of measure differs from the unit of issue, requisition the lowest unit of issue that will satisfy your requirements.

## SECTION II. EXPENDABLE / DURABLE SUPPLIES AND MATERIAL LIST

| (1) ITEM NO. | (2) LEVEL | (3) NATIONAL STOCK NUMBER | (4) DESCRIPTION | (5) U/M |
|---|---|---|---|---|
| 1 | | | Lubricating oil | |
| 2 | | | Wiping rag | |
| 3 | | | Chalk | |
| 4 | | | Cloth | |
| 5 | | | Cleaning solvent, PD-680 | |
| 6 | | | Lapping compound | |
| 7 | | | Wooden blocks | |
| 8 | | | Anti-seize compound | |
| 9 | | | Teflon pipe thread lubricant | |
| 10 | | | Heat determining crayon | |
| 11 | | | Lubriplate | |
| 12 | | | Cup plug sealant | |
| 13 | | | Prussian blue compound | |
| 14 | | | Crocus cloth (fine) | |
| 15 | | | Loctite (or equivalent) | |
| 16 | | | Liquid metal marker | |
| 17 | | | Soap | |
| 18 | | | Mineral spirits | |
| 19 | | | Muriatic acid | |
| 20 | | | Pyridene | |
| 21 | | | 5% sodium carbonate and water solution | |
| 22 | | | Light machine oil | |

**SECTION II. EXPENDABLE / DURABLE SUPPLIES AND MATERIAL LIST**

| (1) ITEM NO. | (2) LEVEL | (3) NATIONAL STOCK NUMBER | (4) DESCRIPTION | (5) U/M |
|---|---|---|---|---|
| 23 | | | Cleaning brush | |
| 24 | | | Rocker lever housing guide studs | |
| 25 | | | Warning tag | |
| 26 | | | Engine oil | |
| 27 | | | Vegetable oil | |
| 28 | | | Paper abrasive aluminum oxide (240 grit) | |
| 29 | | | Rubber bands | |
| 30 | | | Lubricating oil, 15W-40 | |
| 31 | | | Alkaline solution | |
| 32 | | | Oxalic acid | |
| 33 | | | Emery cloth (240 grit) | |
| 34 | | | Paper towels (lint free) | |
| 35 | | | Detergent | |
| 36 | | | Oil cooler guide studs | |
| 37 | | | Loctite | |
| 38 | | | Container, 3-gallon | |

## APPENDIX D

## TORQUE VALUES

D-1. Scope. SAE capscrews are graded according to the strength of the capscrew. They are marked on the head so the correct strength and torque value are known. The tables in this appendix will list the capscrew markings with correct torque values as well as values for pipe plugs and metric bolts.

**CAUTION**

When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using incorrect capscrews can result in equipment damage. Bolts threaded into aluminum require much less torque.

**NOTE**

Always use torque values listed in the tables when specific torque values are unknown. The torque values listed in the tables are based on the use of lubricated threads.

**Table D-1. Capscrew Markings and Torque Values**

| Capacity Body Size | | SAE Grade #5 Cast Iron or Steel | | | SAE Grade #6 or #7 Cast Iron or Steel | | | SAE Grade #8 Cast Iron or Steel | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Thread | Torque | | | Torque | | | Torque | | |
| Inches- | | ft-lb | kgm | N•m | ft-lb | kgm | N•m | ft-lb | kgm | N•m |
| 1/4 | -20 | 8 | 1.1064 | 10.8465 | 10 | 1.3630 | 13.5582 | 12 | 1.6596 | 16.2698 |
| | -28 | 10 | 1.3830 | 13.5582 | | | | 14 | 1.9362 | 18.9815 |
| 5/16 | -18 | 17 | 2.3511 | 23.0489 | 19 | 2.6277 | 25.7605 | 24 | 3.3192 | 32.5396 |
| | -24 | 19 | 2.6277 | 25.7605 | | | | 27 | 3.7341 | 36.6071 |
| 3/8 | -16 | 31 | 4.2873 | 42.0304 | 34 | 4.7022 | 46.0978 | 44 | 6.0852 | 59.6560 |
| | -24 | 35 | 4.8405 | 47.4536 | | | | 49 | 6.7767 | 66.4351 |
| 7/16 | -14 | 49 | 6.7767 | 66.4351 | 55 | 7.6065 | 74.5700 | 70 | 9.6810 | 94.9073 |
| | -20 | 55 | 7.6065 | 74.5700 | | | | 78 | 10.7874 | 105.7538 |
| 1/2 | -13 | 75 | 10.3725 | 101.6863 | 85 | 11.7555 | 115.2445 | 105 | 14.5215 | 142.3609 |
| | -20 | 85 | 11.7555 | 115.2445 | | | | 120 | 16.5860 | 162.6960 |
| 9/16 | -12 | 110 | 15.2130 | 149.1380 | 120 | 16.5960 | 162.6960 | 155 | 21.4365 | 210.1490 |
| | -18 | 120 | 16.5960 | 162.6960 | | | | 170 | 23.5110 | 230.4860 |
| 5/8 | -11 | 150 | 20.7450 | 203.3700 | 167 | 23.0961 | 226.4186 | 210 | 29.0430 | 284.7180 |
| | -18 | 170 | 23.5110 | 230.4860 | | | | 240 | 33.1920 | 325.3920 |
| 3/4 | -10 | 270 | 37.3410 | 366.0660 | 280 | 38.7240 | 379.6240 | 375 | 51.8625 | 508.4250 |
| | -16 | 295 | 40.7985 | 399.9610 | | | | 420 | 58.0860 | 568.4360 |
| 7/8 | - 9 | 395 | 54.6285 | 535.5410 | 440 | 60.8520 | 596.5520 | 605 | 83.6715 | 820.2590 |
| | -14 | 435 | 60.1605 | 589.7730 | | | | 675 | 93.3525 | 915.1650 |
| 1.0 | - 8 | 590 | 81.5970 | 799.9220 | 660 | 91.2780 | 894.8280 | 910 | 125.8530 | 1233.7780 |
| | -14 | 660 | 91.2780 | 849.8280 | | | | 990 | 136.9170 | 1342.2420 |

**Table D-1. Capscrew Markings and Torque Values-CONT**

Capscrew Head Markings

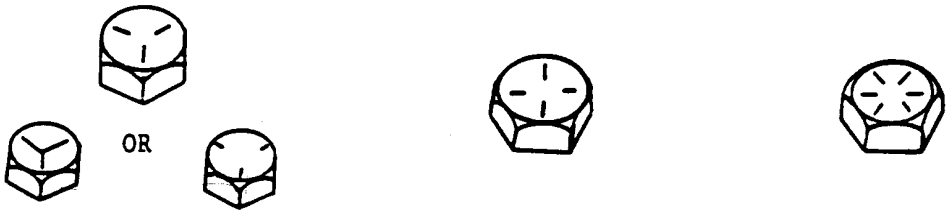


**Table D-2. Pipe Plug Torque Values**

| Size | | | In Aluminum Components | | In Cast Iron or Steel Components | |
|---|---|---|---|---|---|---|
| Thread | Actual Thread O.D. | | Torque | | Torque | |
| in | mm | (in) | N ·m | (ft-lb) | N ·m | (ft-lb) |
| 1/16 | 8.1 | (0.32) | 5 | (45 in-lb) | 15 | (10) |
| 1/8 | 10.4 | (0.41) | 15 | (10) | 20 | (15) |
| 1/4 | 13.7 | (0.54) | 20 | (15) | 25 | (20) |
| 3/8 | 17.3 | (0.68) | 25 | (20) | 35 | (25) |
| 1/2 | 21.6 | (0.85) | 35 | (25) | 55 | (40) |
| 3/4 | 26.7 | (1.05) | 45 | (35) | 75 | (55) |
| 1 | 33.5 | (1.32) | 60 | (45) | 95 | (70) |
| 1-1/4 | 42.2 | (1.66) | 75 | (55) | 115 | (85) |
| 1-1/2 | 48.3 | (1.90) | 85 | (65) | 135 | (100) |

**Table D-3. Metric Bolt Torque Values**

| Thread for general purposes | Cast Iron or Steel Head Mark 4 | | Cast Iron or Steel Head Mark 7 | |
|---|---|---|---|---|
| | Torque | | Torque | |
| (size x pitch (mm) | ft-lb | (N ·m) | ft-lb | (N ·m) |
| 6 x 1.0 | 2.2 to 2.9 | (3.0 to 3.9) | 3.6 to 5.8 | (4.9 to 7.8) |
| 8 x 1.25 | 5.8 to 8.7 | (7.9 to 12) | 9.4 to 14 | (13 to 19) |
| 10 x 1.25 | 12 to 17 | (16 to 23) | 20 to 29 | (27 to 39) |
| 12 x 1.25 | 21 to 32 | (29 to 43) | 35 to 53 | (47 to 72) |
| 14 x 1.5 | 35 to 52 | (48 to 70) | 57 to 85 | (77 to 110) |
| 16 x 1.5 | 51 to 77 | (67 to 100) | 90 to 120 | (130 to 160) |
| 18 x 1.5 | 74 to 110 | (100 to 150) | 130 to 170 | (180 to 230) |
| 20 x 1.5 | 110 to 140 | (150 to 190) | 190 to 240 | (160 to 320) |
| 22 x 1.5 | 150 to 190 | (200 to 260) | 250 to 320 | (340 to 430) |
| 24 x 1.5 | 190 to 240 | (260 to 320) | 310 to 410 | (420 to 550) |

**Table D-4. Fuel Pump Torque Specifications**

| | Minimum | Maximum |
|---|---|---|
| **Air Fuel Control** | | |
| Check valve in the AFC cover (ft-lb (N•m)) | 8 (11) | 11 (15) |
| Cover capscrews (in-lb (N•m)) | 30 (3.4) | 35 (4) |
| Needle valve jam nut (in-lb (N•m)) | 30 (3.4) | 45 (5) |
| Needle valve plug (in-lb (N•m)) | 30 (3.4) | 45 (5) |
| Plunger jam nut (in-lb (N•m)) | 25 (2.8) | 35 (4) |
| Piston jam nut (in-lb (N•m)) | 30 (3.4) | 40 (4.5) |
| **Front Cover** | | |
| Drive coupling capscrew (ft-lb (N•m)) | 5 (7) | |
| Mounting capscrew (ft-lb (N•m)) | 9 (12) | 11 (15) |
| Mounting allen screws (ft-lb (N•m)) | 4 (5) | 5 (7) |
| Tachometer Drive Housing (ft-lb (N•m)) | 35 (47) | 45 (61) |
| **Fuel Pump Housing** | | |
| Filter screen cap (ft-lb (N•m)) | 8 (11) | 12 (16) |
| Throttle stop locknuts (in-lb (N•m)) | 70 (8) | 90 (10) |
| Throttle shaft plunger pipe plug (in-lb (N•m)) | 40 (4.5) | 55 (6.2) |
| Torque modification device (ft-lb (N•m)) | 17 (23) | 20 (27) |
| VS governor barrel setscrew (in-lb (N•m)) | 70 (8) | 90 (10) |
| Pressure regulator cap (ft-lb (N•m)) | 20 (27) | 25 (34) |
| **Governor Spring Assembly** | | |
| Cover capscrews (ft-lb (N•m)) | 9 (12) | 11 (15) |
| **Gear Pump** | | |
| Cover to body capscrew (ft-lb (N•m)) | 11 (15) | 13 (18) |
| Gear pump to fuel pump housing (ft-lb (N•m)) | 11 (15) | 13 (18) |
| Fuel damper to gear pump (ft-lb (N•m)) | 11 (15) | 13 (18) |
| Fuel damper assembly capscrews (ft-lb (N•m)) | 9 (12) | 11 (15) |
| Check valve in the gear pump (ft-lb (N•m)) | 5 (7) | 14 (19) |
| **Shutoff Valve** | | |
| Coil capscrews (in-lb (N•m)) | 25 (2.8) | 30 (3.4) |
| Mounting capscrews (ft-lb (N•m)) | 9 (12) | 11 (15) |
| **Pipe Plugs** | | |
| 1/4 inch (ft-lb (N•m)) | 25 (34) | 30 (41) |
| 1/8 inch in bottom of housing (ft-lb (N•m)) | 5 (7) | 8 (11) |

# GLOSSARY

## SECTION I. ABBREVIATIONS

| | |
|---|---|
| ac | alternating current |
| AFC | automatic flow control |
| AOAP | Army Oil Analysis Program |
| ATDC | after top dead center |
| ATV | automatic trip valve |
| AVR | automatic voltage regulator |
| BDC | bottom dead center |
| BTDC | before top dead center |
| cc | cubic centimeters |
| cfm | cubic feet per minute |
| cm | centimeter |
| cm Hg | Centimeters Mercury |
| CPL | Control Parts List |
| dc | direct current |
| DCA | diesel coolant additive |
| EFC | electric fuel control |
| EIR | Equipment Improvement Recommendations |
| FFC | full flow cooling |
| ft | foot |
| ft-lb. | foot-pound |
| $H_20$ | water |
| HP | Horsepower |
| hz | Hertz |
| id | inside diameter |
| ILS | Isochronous Load Sharing |
| in | inch |
| in-lb | inch-pound |
| in $H_20$ | inch-water |
| in Hg | inch-Mercury |
| in2 | square inch |
| in3 | cubic inch |
| kg | kilogram |
| kPa | Kilos Pascal (metric equivalent to psi) |
| kw | kilowatt |
| lb | pounds |
| lm | litres per pound |
| mm | millimeter |
| mm Hg | millimeter-mercury |
| N• | Newtons-metric (equivalent to ft-lb) |
| N•m | Newtons |
| od | outside diameter |
| psi | pounds per square inch |
| psig | pounds per square inch gauge |
| PT | pressure time |
| rpm | revolutions per minute |
| TDC | top dead center |
| TIR | total indicator reading |
| VAC | volts, alternating current |
| VS | variable speed |

## GLOSSARY - CONT

### SECTION II. Definitions

| | | |
|---|---|---|
| AIR GAP | - | The radial space between the rotating and the stationary elements of a generator. The magnetic field passes through this space. |
| ALTERNATING CURRENT | - | Electrical current which repeatedly varies from zero to a positive maximum value to zero to a negative maximum value and back to zero at a periodic rate. Since the applied voltage continually reverses polarity, the resultant current flow alternates in direction within the circuit. |
| AMBIENT TEMPERATURE | - | The atmospheric temperature of the immediate surrounding area. |
| AMMETER | - | An instrument designed to measure electric current. |
| AMP | - | An abbreviation for the term Ampere. |
| AMPERE | - | The unit of measure of electrical current flow. One ampere of current will flow when one volt of electrical potential is applied across one ohm of resistance. |
| ANODS | - | Active metals such as zinc and magnesium which, when attached to steel or other metal in a water environment, prevent the corrosion of the metal. The anodes corrode and are sacrificed instead of the steel. |
| ANTIFREEZE | - | A solution which, when mixed with water, lowers the freezing point. |
| CAPACITOR | - | A device possessing the property of capacitance. A typical capacitor consists of two conducting surfaces separated by an insulating material. A capacitor stores electrical energy, blocks the flow of dc, and permits the flow of ac to a degree largely dependent on the capacitance and the frequency of the applied ac. |
| CIRCUIT | - | An electrical path through which an electric current may flow from a voltage or complete circuit is one where current is flowing. An open circuit is one where the path has been disrupted, such as an open switch or circuit breaker, thus stopping current flow. |
| CIRCUIT BREAKER | - | A protective device for opening a circuit when current when current flow exceeds a predetermined value. |

## GLOSSARY - CONT

| | | |
|---|---|---|
| CONDUCTOR | - | A wire, cable, bus, or other device intended to distribute current from the supply to the load. Technically, a conductor is any device which will permit the flow of current. |
| COOLANT | - | The circulating element, generally fresh water, which carries away the head generated by the friction of moving parts of an engine. |
| CURRENT | - | The flow of electrons in a circuit forced by an applied voltage potential (See Alternating Current and direct Current). |
| CYCLE | - | A complete set of events before repetition occurs. In alternating current or voltage, a cycle starts at zero, continues to a maximum positive value, returns to zero, continues to a maximum negative value, and is completed at zero. |
| EXCITATION | - | The direct current input to the field coils of a generator which produces the magnetic flux required for inducing voltage into the generator stator coils. |
| EXCITER | - | An electrical device used for supplying the excitation to the generator field (see Exciter Rotor and Exciter Stator). |
| EXCITER CURRENT | - | The direct current supplied to the exciter field coils which is controlled by the voltage regulator. |
| EXCITER ROTOR | - | The rotating member of the exciter into which a three-phase alternating voltage is induced. The resulting ac is then rectified into direct current and applied to the rotating generator field windings. |
| EXCITER STATOR | - | The stationary member of the exciter which serves as the exciter field producing the magnetic field from the direct current supplied by the automatic voltage regulator. |
| FIELD | - | That part of the generator and exciter which, when supplied with direct current, will produce a magnetic field. The exciter stator serves as the exciter field while the main generator rotor serves as the generator field. |
| FREQUENCY | - | The number of complete cycles of alternating current per unit of time. Typically, frequency is expressed in cycles per second or Hertz (Hz). |

## GLOSSARY - CONT

| | | |
|---|---|---|
| GENERATOR ROTOR | - | The rotating member of the generator. |
| GENERATOR STATOR | - | The stationary member of the main generator which supplies the three-phase output power to the load. |
| GLYCOLS | - | A group of chemicals used to lower the freezing point of water. |
| GOVERNOR | - | A device which controls engine speed and thus the generator output frequency. |
| GROUND | - | A connection, either accidental or intentional, between an electrical potential and the earth or some conducting body serving in place of the earth. |
| HEAT SINK | - | A device which absorbs heat from electrical devices such as diodes and SCRs and dissipates the heat to the surrounding air. |
| HERTZ | - | A term equivalent to cycles per second (see frequency). |
| HUNTING | - | Oscillation in frequency or in voltage where steady-state conditions are not reached, particularly after a load transient change. |
| INSULATION | - | A non-conductive material such as rubber or plastic intended to prevent current from flowing. Technically, insulation is any material which resists the flow of current. |
| INSULATION RESISTANCE | - | A measure of the ability of insulation to prevent current from flowing. A megohmmeter is used to measure the resistance in millions of ohms between the windings and metal frame of a generator to determine the insulation resistance of the windings. |
| ISOCHRONOUS | - | As it applies to engine governors, maintaining constant steady-state speed regardless of the load within the rating of the engine. Thus, a generator set is said to be isochronous if the frequency remains the same regardless of load. |
| LINE-TO-LINE-VOLTAGE | - | The voltage between any two phases of a multi-phase system. |
| MEGOHMMETER | - | A high range high voltage ohmmeter. By measuring the current flow caused by the applied voltage, insulation resistance can be determined. |
| OHM | - | The unit of measure of electrical resistance. One ohm of resistance will allow a current of one ampere to flow with an applied potential of one volt. |

## GLOSSARY - CONT

| | | |
|---|---|---|
| OHMMETER | - | An instrument for measuring electrical resistance. |
| PARALLEL OPERATION | - | The method by which two or more generators having the same voltage and frequency characteristics are connected to a common load. |
| PHASE | - | The windings or an ac generator into which a voltage is induced. In a three-phase system, there are three sets of windings, each set having a voltage alternating within it exactly one-third of a cycle after the one ahead of it because of the physical arrangement of the coils. |
| PITTING | - | Corrosion attack in localized areas, resulting in the formation of tiny cavities. |
| POLARITY | - | An electrical term which indicates the direction in which current flows in a conductor. In a direct current system, current constantly flows in the same direction. In an alternating current system, current changes direction as the polarity of the ac voltage source changes. |
| RECTIFIER | - | A device used to convert alternating current to direct current. A diode is one of several devices which act as rectifiers. |
| - | | |
| RELAY | - | An electromechanical device having a magnetic coil which, when energized, opens or closes several sets of contacts. |
| RESISTANCE | - | Opposition to the flow of current. |
| RESISTOR | - | A component which possesses resistance. |
| RHEOSTAL | - | A variable resistor. |
| RHEOSTAT | - | A variable resistor. |
| ROTOR | - | The rotating part of a generator. |
| SCALE | - | Insoluble materials that settle out of cooling water and adhere to the metallic surfaces; buildup of hard materials which interfere with the transfer of heat. |
| SOLENOID | - | An electromechanical device which, when energized, acts on a movable core or plunger in the center of the energizing coil to perform mechanical work. |

## GLOSSARY - CONT

| | | |
|---|---|---|
| STABILITY | - | A condition which describes engines governor and generator voltage regulator. These systems provide frequency and voltage stability if they can maintain or quickly re-establish steady-state regulation after a load change. |
| STATOR | - | The stationary part of a generator or exciter. |
| SURGE SUPPRESSOR | - | A device capable of conducting current in either direction in the presence of high transient voltages, thus protecting devices that could otherwise be damaged. |
| VARISTOR | - | A surge suppressor. |
| VOLTAGE REGULATOR | - | A device which controls the voltage output of a generator at a preset value regardless of the amount of load applied (see Firing Circuit). |
| VOLTMETER | - | An instrument designed to measure electrical potential or voltage. |

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# The Metric System and Equivalents

***Linear Measure***

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

***Weights***

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 dekagram = 10 grams = .35 ounce
1 hectogram = 10 dekagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

***Liquid Measure***

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

***Square Measure***

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

***Cubic Measure***

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

# Approximate Conversion Factors

| *To change* | *To* | *Multiply by* | *To change* | *To* | *Multiply by* |
|---|---|---|---|---|---|
| inches | centimeters | 2.540 | ounce-inches | newton-meters | .007062 |
| feet | meters | .305 | centimeters | inches | .394 |
| yards | meters | .914 | meters | feet | 3.280 |
| miles | kilometers | 1.609 | meters | yards | 1.094 |
| square inches | square centimeters | 6.451 | kilometers | miles | .621 |
| square feet | square meters | .093 | square centimeters | square inches | .155 |
| square yards | square meters | .836 | square meters | square feet | 10.764 |
| square miles | square kilometers | 2.590 | square meters | square yards | 1.196 |
| acres | square hectometers | .405 | square kilometers | square miles | .386 |
| cubic feet | cubic meters | .028 | square hectometers | acres | 2.471 |
| cubic yards | cubic meters | .765 | cubic meters | cubic feet | 35.315 |
| fluid ounces | milliliters | 29,573 | cubic meters | cubic yards | 1.308 |
| pints | liters | .473 | milliliters | fluid ounces | .034 |
| quarts | liters | .946 | liters | pints | 2.113 |
| gallons | liters | 3.785 | liters | quarts | 1.057 |
| ounces | grams | 28.349 | liters | gallons | .264 |
| pounds | kilograms | .454 | grams | ounces | .035 |
| short tons | metric tons | .907 | kilograms | pounds | 2.205 |
| pound-feet | newton-meters | 1.356 | metric tons | short tons | 1.102 |
| pound-inches | newton-meters | .11296 | | | |

# Temperature (Exact)

| | | | | |
|---|---|---|---|---|
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

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