MAINTENANCE MANUAL

THREE, FOUR & SIX CYLINDER DIESEL ENGINES

MODELS: D1700, D2000, D2300, D3000, D3400

P/N 40-0090205

HERCULES ENGINES, INC.

Engine Specialists Since 1915

TABLE OF CONTENTS

* Indicates items to be checked as part of tuneup

TABLE OF CONTENTS (continued)

* Indicates items to be checked as part of tuneup

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

LIST OF TABLES

SECTION I
GENERAL INFORMATION

1-1. GENERAL DESCRIPTION.

1-2. This manual contains instructions for operation, maintenance, troubleshooting, and overhaul of Hercules D Series Diesel Engines (Figures 1-1 and 1-2) manufactured by Hercules Engines, Inc., Canton, Ohio.

1-3. The D Series diesel engine consists of three, four, and six cylinder models. The engines are all overhead-valve, four-cycle, heavy-duty commercial types, built either as vertical or horizontal engines. Since the instructions are the same or very similar for all models, all are covered in this manual.

1-4. These engines are used in many different applications with different accessories. This manual is designed for service personnel who overhaul the engines and components supplied as part of the engine only. The instructions cover the essential operations necessary to disassemble, inspect, repair, assemble, and test the engine. Brief instructions for the operation and maintenance of the engines are also given.

1-5. All locations given as right-hand or left-hand refer to the observer's position when facing the flywheel or clutch. On the four and six cylinder models the camshaft, oil pump, and fuel pump may be on either the right-hand or left-hand side of the engine block, depending on the application. The front of the engine is the timing gear end, regardless of the cylinder block position. The flywheel and clutch end is the rear of the engine. When reference is made to No. 1 cylinder or front main bearing, it is always the one nearest the timing gears. Cylinders, connecting rods, and main bearing caps are numbered from the front or timing gear end and are stamped on the camshaft side of the engine.

1-6. Where necessary to refer to accessories and components not furnished with the Hercules engine, information and comments given are general and may not apply to the specific acessory and application where used. If additiona information about the various accessories is desired, a letter should be directed to the specific manufacturer.

1-7. Should you have a particular problem not covered in this manual, we invite you to write to Hercules Engines, Inc. Service Department, Canton, Ohio USA., whose experienced personnel will be pleased to assist you.

1-8. SPECIFICATIONS.

Specifications for the D Series Diesel Engines are given in table 1-1.

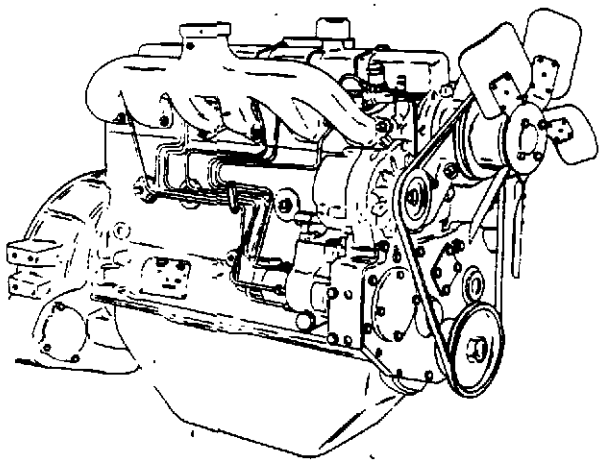


Figure 1-1. Six Cylinder Engine, Right-Hand Side

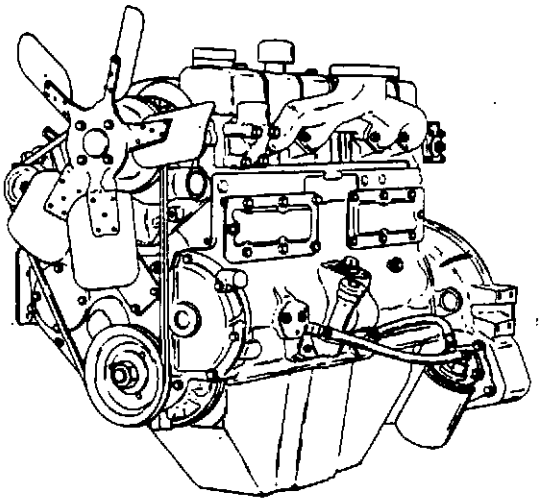


Figure 1-2. Six Cylinder Engine, Left-Hand Side

Table 1-1. Specifications

(Also see Fits and Tolerances, Section VII)

Model	No. Cyl.	Bore and Stroke
D-1500	3	3-3/4 x 4-1/2 in.
D-1700	3	4 x 4-1/2 in.
D-2000	4	3-3/4 x 4-1/2 in.
D-2300	4	4 x 4-1/2 in.
D-3000	6	3-3/4 x 4-1/2 in.
D-3400	6	4 x 4-1/2 in.

Military approved engines

#D-198-ER	4	3-3/4 x 4-1/2 in.
*D-298-ER	6	3-3/4 x 4-1/2 in.

For all other information refer to model D-2000 or 4 Cylinder engine.
* For all other information refer to model D-3000 or 6 Cylinder engine.

MAIN BEARING

	Three Cylinder	Four Cylinder	Six Cylinder
Number of bearings	4	5	7
Bearing diameter (main)	2-7/8 in. (73.0 mm)	2-7/8 in. (73.0 mm)	2-7/8 in. (73.0 mm)
Bearing length (front)	1-1/32 in. (26.2 mm)	1-1/32 in. (26.2 mm)	1-1/32 in. (26.2 mm)
Bearing length (center)		2-1/8 in. (54.0 mm)	2-1/8 in. (54.0 mm)
Bearing length (rear)	1-1/32 in. (26.2 mm)	1-1/32 in. (26.2 mm)	1-1/32 in. (26.2 mm)
Bearing length (intermediate)		1-1/32 in. (26.2 mm)	1-1/32 in. (26.2 mm)
Bearing length (No. 2)	1-1/32 in. (26.2 mm)		
Bearing length (No. 3)	2-1/8 in. (54.0 mm)		

CAMSHAFT BEARING

	Three Cylinder	Four Cylinder	Six Cylinder
Number of bearings	3	4	4
Bearing diameter	2-1/16 in. (52.4 mm)	2-1/16 in. (52.4 mm)	2-1/16 in. (52.4 mm)
Bearing length (front)	1-1/16 in. (27.0 mm)	1-1/16 in. (27.0 mm)	1-1/16 in. (27.0 mm)
Bearing length (intermediate)	13/16 in. (20.6 mm)	13/16 in. (20.6 mm)	13/16 in. (20.6 mm)
Bearing length (rear)	1-1/16 in. (27.0 mm)	1-1/16 in. (27.0 mm)	1-1/16 in. (27.0 mm)

Table 1-1. Specifications (Continued)

(Also see Fits and Tolerances, Section VII) (Continued)

CONNECTING ROD

	Three Cylinder	Four Cylinder	Six Cylinder
Bearing diameter	2-3/8 in. (60.32 mm)	2-3/8 in. (60.32 mm)	2-3/8 in. (60.32 mm)
Bearing length	1-11/64 in. (29.8 mm)	1-11/64 in. (29.8 mm)	1-11/64 in. (29.8 mm)
Rod length (C to C)	8 in. (203.2 mm)	8 in. (203.2 mm)	8 in. (203.2 mm)

GENERAL DATA

Cooling	Belt Driven Centrifugal Pump
Water pump - fan assembly	Mounted on Front of Cylinder Block
Method of suspension	3 or 4 Point
Flywheel	For Any Standard Clutch

1-9. SAFETY PRECAUTIONS.

Observe all normal safety precautions during the operation, overhaul, and testing of the engine. These precautions include the following:

a. Do not operate the engine indoors without providing adequate measures to remove the exhaust gases from the enclosure. This can be done by piping exhaust gases to the outside. Exhaust gases contain carbon monoxide — a colorless, odorless, deadly poisonous gas.

b. Provide adequate ventilation when using cleaning solvents or other chemicals. Repeated or prolonged inhalation of solvent fumes can cause illness or death.

c. Use protective goggles, gloves, and other clothing when using solvents and chemicals. Prolonged or repeated exposure of the skin to chemicals can cause illness or death. If solvents are accidentally splashed onto the skin, wash the area immediately with soap and warm water.

d. Do not use compressed air for blowing dirt from clothing or from the skin. Compressed air can enter body openings and cause severe injury or death.

e. Unless it is absolutely necessary to make adjustments while the engine is in operation, shut off the engine before performing any adjustments or other corrective actions.

f. Always disconnect the positive battery cable from the battery before removing the engine electrical components or leads.

g. Remove rings, ties, watches, identification bracelets, and other jewelry while working on the equipment.

1-10. BASIC SAFETY PRECAUTIONS (TURBOCHARGER)

Misuse, misapplication or modification of the turbocharger can result in serious injury and property damage. Basic safety precautions including the following should always be followed:

1. Install turbocharger only on an engine which has been approved for such application. The turbocharger is a precision built product which has been matched and tested for use on specific engines only.

2. Do not modify or substitute any parts of turbocharger. Do not remove metal from any part of the turbocharger.

3. Do not modify or substitute any parts of engine except in accordance with engine owner's manual. Do not modify engine fuel control system or restrict exhaust system or air inlet excessively.

4. Do not operate at excessive altitudes.

5. Do not modify oil supply system or decrease the diameter of the oil drain line.

6. Always warm up the engine to allow warm oil to reach the turbocharger before operating under load.

SECTION II
OPERATION

2-1. SERVICING EQUIPMENT PRIOR TO INITIAL STARTING.

To start the engine for the first time or after a long period of shutdown, proceed as follows:

a. Perform a visual inspection of the engine to make sure there are no loose bolts, nuts, and screws.

CAUTION

Check that no loose bars, tools, and parts are lying in or on any part of the engine when starting. They could cause serious damage to the engine or bodily injury to nearby personnel.

b. Remove all plugs, caps, covers, and tape from all openings of the engine, fuel tank, and electrical equipment. Do not overlook the exhaust pipe.

c. Check the entire electrical system to be sure there are no loose connections and all component parts are securely mounted.

d. Check the lubrication of the alternator and other accessories. Check the air cleaners to make sure they are not obstructed, that they are clean and properly installed.

e. Fill the cooling system with clean water or, if the engine will be subjected to ambient air temperatures below freezing, use an antifreeze solution.

f. Remove any paper that was inserted between the pulleys and the belts to prevent belt sticking. Adjust fan belt tension by positioning the alternator so that the fan belts can be deflected approximately 3/4 inch per foot of belt span when thumb pressure is applied at midpoint of the belt. Tighten alternator mounting screws.

g. Drain the fuel system of preservative or special fuel oil. Open the drain on the bottom of the fuel supply tank and allow all water and sediment in the tank to drain. Open water separator drain in primary fuel filter (if used) to drain accumulated water from fuel system.

NOTE

Give special attention to engines in which P-9 Preserving Oil or oil of similar viscosity has been used in the system. This preserving oil is used most frequently in the "ER" (Government) engines. Take extra care to purge all such oil from the system.

CAUTION

Under no circumstances should the engine be motored with the starter or by any other means until the fuel system is completely emptied of preserving oil and properly primed with prescribed diesel fuel as outlined below.

h. Check all fuel supply lines from the supply tank to the filter to make sure the connections are tight and the lines are open with no obstructions or kinks.

i. Fill the fuel supply tank with recommended fuel oil. Refer to Table 3-5, Fuel Oil Specifications. Bleed the air from the fuel lines and filter: refer to paragraph 2-2.

j. Drain the crankcase, replace the oil filter element, and fill to the FULL mark on the oil level bayonet gauge, using lubricating oil recommended in Table 3-4, Recommended Lubricating Oil Specifications. Add 1 quart of oil to compensate for the filter.

k. Turn the engine by hand three or four revolutions to spread the lubricating oil on the cylinder walls and bearings. This hand cranking also prevents possibilities of damage due to water accumulation in the cylinders. Because of the high compression ratio of diesel engines, the clearance between the cylinder head and piston top is so small that a small amount of water in the cylinder will cause serious damage if the engine is rotated rapidly as with an electric starting motor.

CAUTION

Because there are several different engine applications with varying stopping procedures, it is important to become familiar with the specific stopping procedure for the engine before starting.

l. Place the throttle control lever at about half throttle.

m. Make sure the stop control is not in the STOP position.

NOTE

If the ambient air temperature is less than 50°F, refer to the cold weather starting instructions in paragraph 2-5.

CAUTION

Do not crank the engine for more than 15 seconds at a time. Allow the starting motor to cool for 1 minute between periods of cranking.

n. Operate the start switch to crank the engine. It should start almost at once. If the engine does not start after two or three attempts, the fuel system may need priming. Refer to paragraph 2-2.

o. To enable the engine to warm up properly and insure proper lubrication, allow the engine to run for several minutes before load is applied.

2-2. PRIMING THE FUEL SYSTEM.

Air in the fuel injection system is the most frequent cause of failure to start or of hard starting if the proper fuel is used. Air binding or air lock is caused mainly from leaking fuel line connections or lack of fuel. To prime the fuel system, proceed as follows:

a. Place the manual stop control in STOP position so engine will not start. See figure 2-1.

b. Open bleed valve at fuel injection pump inlet.

c. On engines equipped with either a diaphragm-type pump with hand priming lever or hand priming pump, use priming device to purge

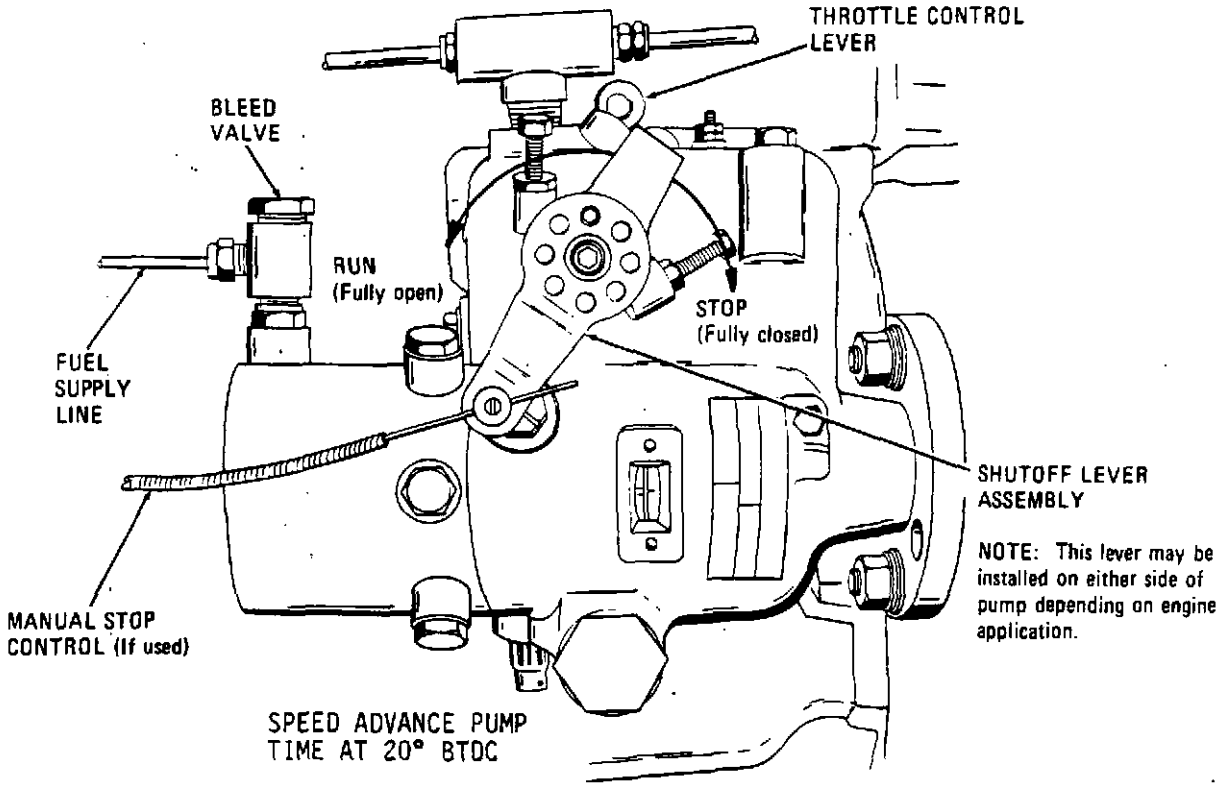


Figure 2-1. Fuel Injection Pump Installation

system of air. The fuel system is sufficiently purged when air-free fuel flows from the bleed valve.

d. On engines equipped with electric fuel supply pump, energize the pump with start switch until system is purged of air.

e. Close the bleed valve.

f. Place the manual stop control in RUN position; refer to appropriate starting instructions.

2-3. ROUTINE STARTING.

If the engine has been operating recently and components have not been removed or repaired since it last operated, proceed as follows:

a. Check that there is an adequate fuel supply.

b. Check the lubricating oil level in the engine with the oil level bayonet gauge. Be sure the oil level is at the FULL mark on the gauge.

c. Check for proper level of coolant solution in the radiator.

d. Inspect the installation to see that all is secure and in good order, and that no loose tools, bars, or parts are lying on the engine.

NOTE

If the ambient temperature is less than 50°F, refer to paragraph 2-5 for cold weather starting instructions.

e. Place the throttle control lever at half open position.

f. Be sure the stop control is not in the STOP position.

g. Operate the start switch to crank the engine and start it.

CAUTION

Do not crank the engine for more than 15 seconds at a time. Allow the starting motor to cool for 1 minute between cranking intervals.

2-4. STOPPING.

Because there are several different engine applications and stopping procedures, it is important to become familiar with the specific stopping procedure for each engine. To stop the engine, proceed as follows:

a. Close the throttle and allow the engine to cool down by running at idle for a few minutes after the engine load has been removed.

b. On most engines equipped with electric fuel shutoff, stop the engine by placing the start switch in the OFF position. On some other engines, a stop switch is used to energize the fuel shutoff and stop the engine.

CAUTION

The electric fuel shutoff solenoid is cooled by the fuel circulating through the fuel injection pump as the engine runs. The switch must not be left in position to keep the solenoid energized for extended periods of time unless the engine is running.

c. On engines with manual shutoff only, operate the stop control to the STOP position to stop the engine.

d. If the ambient temperature is below freezing, and no antifreeze solution is used, the complete coolant circulating system should be drained. This includes the engine water jackets, water pump, radiator, and all water pipes.

e. If antifreeze solution is used, the solution should be checked with a hydrometer to make sure it is the strength recommended to provide protection below the lowest expected temperature.

2-5. COLD WEATHER STARTING.

In a diesel engine, the fuel sprayed into the combustion chamber is ignited by the heat generated as air is compressed into the cylinder. However, if the metal surrounding this chamber and cylinder is extremely cold and the air entering the cylinder before compression is cold, the resultant temperature may not be sufficient to ignite the fuel mist. The following methods are available to aid starting in cold temperatures, between 50° and 0°F:

a. Various types of cold starting aids are available which make cold-weather starting

easier. If a spray-type starting aid is used, do not spray into the manifold unless engine is being cranked by starting motor.

b. In extremely cold temperatures of 0°F and below, if the engine is not equipped with a cold starting aid, it may be necessary to heat the water, oil, and air to start the engine. Low temperatures reduce battery output so the battery should be conserved in every possible way.

2-6. OPERATION.

After the engine has started, make a thorough inspection of the engine unit to ensure that all parts are functioning properly. Proceed as follows:

a. Look at the lubricating oil gauge. If insufficient pressure shows after the engine has run 10 or 12 seconds, shut down the engine and determine the trouble. With bearings in good condition and the proper grade of oil being used, the pressure should be 40 to 60 psi at full engine speed. If the oil is very cold or heavy, this pressure may be much higher. As the oil heats, the pressure will reduce.

b. Check the coolant temperature; if it exceeds 200°F, shut down the engine and determine the cause. Never operate the engine with the water at boiling temperature. This excessive heat on the cylinder walls will break down the oil film, causing rapid engine wear. Rapid coolant loss will also result due to steaming.

c. Check ammeter charging rate. The ammeter should indicate a charge immediately after starting and should drop to near zero soon after. If the ammeter does not indicate proper operation, stop the engine and thoroughly check out the engine charging system.

d. Check the engine for smooth, quiet operation and for proper exhaust condition. If the fuel is the correct grade and has the proper ignition and burning qualities, a cold engine may still run erratically because a cylinder or two is firing irregularly. As the engine begins to warm up, however, all cylinders should fire regularly. If they do not, bleed the air from each of the fuel lines as follows:

1. Loosen the nut connecting the fuel line to the nozzle holder, one cylinder at a time, and allow fuel to flow until all air has been purged.

WARNING

When bleeding the fuel system, loosen fuel line nuts only slightly. Fuel is under high pressure, and excessively loosened nuts may come off causing a fuel spray that could injure personnel.

2. As each fuel line nut is loosened, check the related cylinder for misfiring. If the engine speed remains the same and the exhaust sounds the same, the cylinder is not firing or is firing irregularly.

3. If, after bleeding the fuel lines, any cylinder is still misfiring, shut down the engine and determine the cause. Refer to Troubleshooting, Section IV.

e. If rough operation continues, check for an adequate supply of fuel in the tank, then check that fuel is being delivered to the fuel pump, as follows:

1. Shut down engine and slightly loosen the nut connecting the supply pipe to the fuel pump. Operate the hand primer or electric fuel pump, and if a good quantity of fuel appears, it is an indication that the fuel injection pump is being supplied with sufficient fuel.

2. If no fuel or very little fuel appears, shut down the engine and check the fuel lines from the tank to the transfer pump and from the transfer pump to the filters. Look for leaks from loose connections, broken nuts, and cracked or broken lines.

3. If all lines are secure and are free from cracks and leaks, check for pinched lines or lines having internal obstructions.

4. If the lines are satisfactory, check the transfer pump for adequate pumping capacity.

f. Check that there are no oil or coolant leaks.

g. Check for proper fan and belt operation. Loose fan belts allow slippage which reduces the efficiency of the fan and water pump.

2-7. HIGH ALTITUDE OPERATION.

a. Diesel engines encounter starting and operation difficulties at higher altitudes. These difficulties usually are not noticeable below 3000 feet. Engine efficiency loss at this altitude is

about 10 percent. At 6000 feet, however, the power loss is about 21 percent. Make compensations for the reduced power output at these higher altitudes.

b. Since air at higher altitudes is much lighter and contains less oxygen than at sea level, less air or oxygen is drawn into the cylinders. This lowers compression pressures, causing hard starting and poor combustion. The following suggestions may make starting easier and improve overall high-altitude performance:

1. Reduce the amount of fuel entering the cylinder. At the original fuel setting, but a reduced amount of oxygen, combustion is incomplete and smoky exhaust results.

NOTE

The fuel reduction procedure should be performed only by qualified personnel familiar with fuel injection systems.

2. Following the cold weather starting procedures (paragraph 2-5) sometimes promotes better high-altitude starting.

3. For additional information on specific cases, contact: Hercules Engines, Inc. Service Department, Canton, Ohio USA, giving as much data as available.

2-8. LONG-TERM STORAGE.

If the engine is to be idle for a month or more, take special precautions to prepare the engine so that rust will not form on the wearing surfaces or in the fuel system as follows:

a. Start and operate the engine a few minutes under load until the water and oil temperatures are normal. Then shut down and drain all the lubricating oil from the oil pan and oil filters.

b. Refill the crankcase to the FULL mark on the bayonet gauge with a preservative lubricating oil meeting requirements of MIL-L-21260 (Gulf No-Rust Engine Oil, Grade No. 1 or 2; Shell Enis MIL-L-21260, Code 66200, or Code 66202; or equivalent). Use SAE10 or SAE30, whichever viscosity is necessary to suit the climatic conditions.

NOTE

It is recommended that an oil of this type be used when the end unit is to be shipped with lubricating oil in the engine or when the unit is used for demonstration purposes.

CAUTION

It is imperative that the fuel injection system be properly protected from rust or corrosion when the engine is stored for long periods of time or in humid atmospheric conditions.

c. Disconnect the fuel supply line at the secondary fuel filter and connect a two-quart container of slushing oil to the fuel filter. (Use Shell Injector Oil, Code 66631, viscosity 36-38SSU at 100°F; Viscor No. L-1487B; Gulf Rust "C"; or equivalent.) Operate the engine until this slushing oil has been completely taken into the fuel system, then shut down the engine.

d. Remove the slushing oil container and connect the regular fuel supply line.

e. Remove the nozzle and holder assemblies from the engine. Use a pump-type oil can having a long narrow spout and a tip smaller than the 7/32-inch hole in the nozzle sleeve. Insert the spout into the hole in the nozzle sleeve. Give each cylinder three or four squirts of the preservative lubricating oil.

CAUTION

Do not use too much oil. Excess oil in the cylinders can damage the engine when restarting.

f. Remove the cylinder head cover and valve tappet side cover plates. Squirt or spray the valve stems, tappets, and rocker arms thoroughly with preservative lubricating oil. Reinstall the covers, making sure the gaskets are in good condition.

g. If the engine cooling system has not been winterized and/or rust treated, it should be flushed thoroughly with a water-soluble oil or other rust inhibitor to prevent rust formation.

h. Disconnect the battery cables. Remove the batteries and store them, preferably where they can be recharged periodically since batteries tend to lose their charge when not in use.

i. Clean the entire engine exterior, except electrical system, with fuel oil.

j. Release the fan belt(s) tension while the engine is in storage. Heavy paper strips inserted between the pulleys and belt(s) will prevent belt sticking.

k. Cover the ends of the exhaust pipe and air inlets with waterproof and vaporproof material so that moisture cannot reach the valve parts and cylinders. Store the engine where it will not be exposed to the elements, and preferably where it will be kept warm and dry. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

l. Coat unpainted exterior and interior surfaces of the air cleaner with preservative lubricating oil. If engines are stored with the clutch removed, coat the clutch contact surfaces, ring gear, and flywheel with oil. Rust-proof accessories such as air compressor, turbocharger, and external governor parts.

m. Periodically rotate the crankshaft while the engine is in storage. One-half turn every two weeks should suffice.

n. Periodically inspect the stored engine. Should there by any indication of rust or corrosion, take corrective steps at once to prevent damage to engine parts.

2-9. INTERNAL OIL FLOW

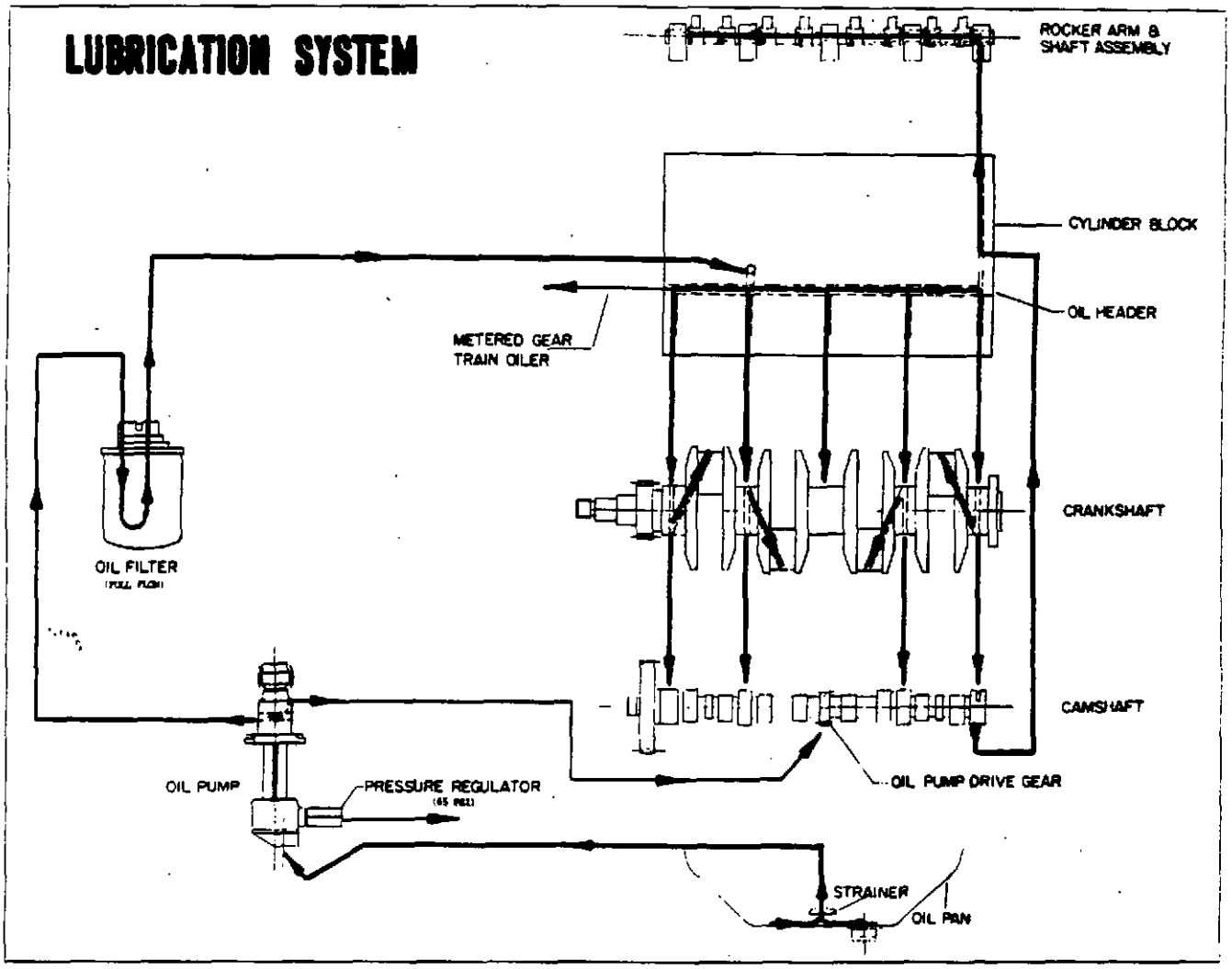


Figure 2-2. Internal Oil Flow

SECTION III
LUBRICATION AND PREVENTIVE MAINTENANCE

3-1. LUBRICATION AND PREVENTIVE MAINTENANCE SCHEDULE.

To obtain long life and maximum efficiency from a Hercules diesel engine, a definite maintenance program shall be set up and followed. Table 3-1, Lubrication and Preventive Maintenance Schedule, provides a basic maintenance schedule which may be altered for a specific application or fit into the user's own preventive maintenance program.

The daily instructions pertain to routine starting of the engine and not to a new or reconditioned engine or one that has been in storage. For a new or stored engine, follow instructions given in paragraph 2-1, Servicing Equipment Prior to Initial Starting.

The time intervals of 50, 100, and 500 hours given in table 3-1 are actual operating hours of the engine. For engines used in road vehicles, the corresponding mileages — 1500, 3000, and 12,000 miles — are also given.

Table 3-1 indicates the items which must be serviced and the required interval of service. The following paragraphs provide detailed instruction for performing maintenance procedures at intervals indicated in the schedule.

3-2. DAILY MAINTENANCE.

a. Check Overall Condition of Engine.

Inspect for evidence of fuel, oil, or coolant leaks on floor, cylinder head, or block. Tighten loose connections. Check for damaged, loose, or missing parts. Tighten, repair, or replace parts as necessary. When engine is operating, observe the oil pressure gauge to make sure oil pressure is 40 to 60 psi at full engine speed.

b. Check Oil Level Before Operation.

Add oil, if necessary, to bring level to the FULL mark on the oil level bayonet gauge, as indicated in figure 3-1. Select the proper grade of oil in accordance with the instructions in paragraph 3-6.

c. Check Radiator.

Check the coolant level and maintain it so that fluid is visible in radiator reservoir.

NOTE

Do not completely fill a cold radiator with coolant. The fluid will expand when heated and will overflow.

d. Check Fuel Tank.

Fill the fuel tank at the end of each day's operation to prevent condensation forming in the tank. Select the proper grade of fuel in accordance with the Diesel Fuel Oil Specifications. During operation, maintain a close check of fuel level to prevent the tank from running empty.

e. Check Air Cleaner.

Several varieties of air cleaners are used on Hercules diesel engines. All are dry-types. Use the following as a guide for servicing air cleaners:

1. Under normal conditions, dry-type air cleaners require servicing every 50 hours of operation. However, under extremely dusty conditions, the air cleaner must be cleaned daily. Remove the filter element from the air cleaner and clean by blowing compressed air through the element from the inside out. Do not apply air closer than 2 inches and do not use more

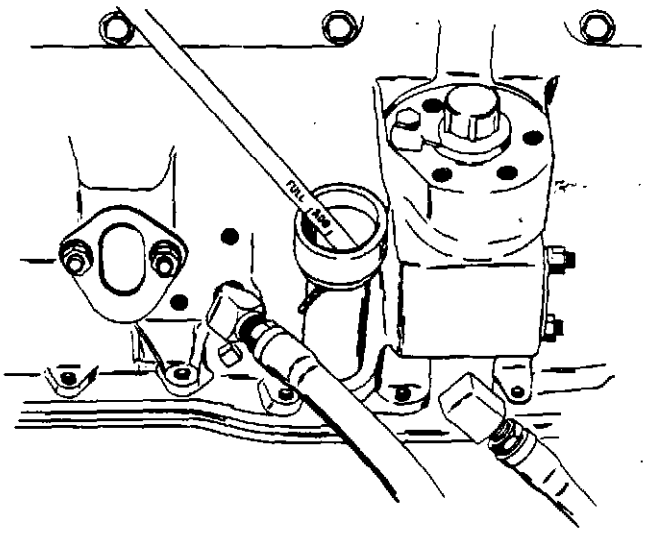


Figure 3-1. Checking Engine Oil Level

Table 3-1. Lubrication and Preventive Maintenance Schedule

Operation	Time Interval: Hours / Miles	8 Daily	50 1500	100 3000	500 12,000	Remarks
Lubrication system						
Engine oil		*		*		
Oil filter				*		Replace at every other oil change.
Cooling system						
Coolant		*				
Radiator			*			
Water pump						Inspect and lubricate at engine overhaul.
Hoses					*	
Fuel system						
Fuel filters				*		
Fuel nozzles					*	
Fuel tank		*			*	
Air system						
Air cleaner		*	*			
Crankcase breather			*			Clean breather cap at every oil change.
Electrical system						
Starting motor				*		Lubricate and service as directed in manufacturer's instructions.
Alternator				*	*	Lubricate and service as directed in manufacturer's instructions.
Battery			*		*	
Miscellaneous accessories						Lubricate and service as directed in manufacturer's instructions.
General condition		*				
Drive belts			*			Tighten new belts after 8 hours of operation.
Engine tuneup					*	As required by engine performance.

*Indicates that service or inspection is required. Refer to manual paragraph covering that time interval for detailed instructions.

than 50 psi pressure. Move the air jet up and down the filter, slowly rotating the element, until no more dust is removed. The element can be effectively cleaned only a few times, after which the element must be replaced.

2. Inspect all hoses, clamps, and connections between air cleaner and engine. Tighten loose clamps and replace damaged hoses promptly. All connections between air cleaner and intake manifold must be air-tight.

3-3. 50 HOURS OR 1500 MILES.

a. Repeat daily maintenance schedule.

b. Change Crankcase Oil.

1. Frequency of oil changes depends on the application of the engine and the type of operation. An extremely clean operation could go 150 hours while a dusty operation could require service in 50 hours or less. It is recommended that new or reconditioned engines be started with 50-hour oil change periods. Under normal operating conditions, the change interval can be gradually increased to 100 hours.

2. Drain the oil after the engine has been operating and while the oil is hot. Remove the drain plug from the oil pan and drain the oil into a suitable container. Select the proper grade of oil in accordance with the instructions in paragraph 3-6. Reinstall the oil drain plug and gasket and fill the crankcase to the FULL mark on the bayonet gauge. The engine oil capacities vary with the different sizes of oil pans available. Refer to Table 3-2, Crankcase Oil Capacities.

c. Check Radiator Air Flow.

Check the exterior of the radiator core air passages for dirt, grease, or chaff that could restrict air flow. Clean with solvent and blow dry with compressed air from the direction opposite that of normal air flow.

d. Drain Fuel Filters.

Remove the pipe plug in the bottom of the fuel oil filter and drain accumulated water and sediment.

e. Clean Air Cleaner.

Clean the air cleaner on a normal 50-hour schedule as indicated in paragraph 3-2e.

f. Clean Crankcase Breather.

The crankcase breather is mounted on the cylinder head cover. Inspect and clean the breather every time the oil is changed. Clean with fresh fuel oil or solvent and blow dry with compressed air. Before reassembly to the engine, apply a small amount of engine lubricating oil to the breather cap screens.

g. Check Fan Belt Tension.

Inspect the fan belt(s) for wear and deterioration. Check alignment and belt tension. Adjust the tension so that the belt deflects 3/4 inch with thumb pressure at a point midway between pulleys. Too tight a belt will damage bearings; too loose a belt will slip causing engine overheating and belt wear.

h. Check the Electrolyte Level in the Battery.

Add mineral-free or distilled water if necessary so that the water level is in accordance with battery manufacturer's recommendations.

3-4. 100 HOURS OR 3000 MILES.

a. Repeat daily and 50-hour maintenance schedules.

b. Change Oil Filter.

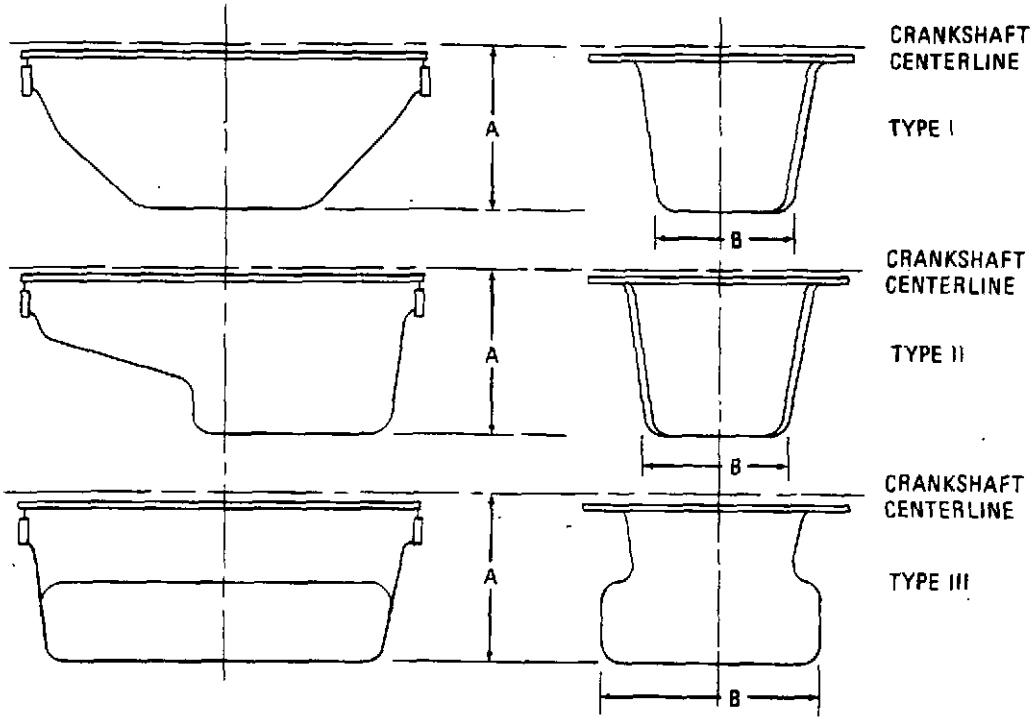
Replace the oil filter and gasket with this oil change. In normal operation, the oil filter should be replaced at every other oil change. Install filter while oil is drained from engine. Add 1 extra quart of engine oil to compensate for filter requirements. Check for oil leaks after starting the engine.

c. Clean Fuel Filters.

1. The fuel filters are equipped with replaceable elements. Remove the filter, and replace the elements. Wipe the inside of the filter shells with a clean, dry cloth and install new elements. If spin-on type fuel filter is used, discard and replace. Dirty or plugged fuel filters will result in loss of power and may prevent operation of the engine.

2. To reduce the frequency of filter replacement, use clean fuel oil and handle it in clean containers. Frequency of replacement is also affected by the amount of gum or wax in the fuel oil.

Table 3-2. Crankcase Oil Capacities



Engine Type	Oil Pan Type	Oil Pan Dimensions (Inches) A	Oil Pan Dimensions (Inches) B	Crankcase Capacity (Quarts) (Not Including Oil Filter)
3 Cylinder	I	7-9/16	8-9/16	5
	III	11-5/8	11-3/4	5
4 Cylinder	I	9	7-1/2	5-1/2
	III	10-7/8	12-1/4	8
6 Cylinder	I	10	7-3/16	7
	I	9	7-7/16	6
	I	12	8-7/16	8
	II	11	7-5/8	8
	III	12-5/8	11-7/8	7

3. Some specialized applications may have a different fuel filtering system but the preceding paragraphs will serve as a guide for maintaining a clean fuel system.

d. Lubricate the Starting Motor.

1. Some starting motors have an oil cup which should be kept filled with lubricating oil. Other starting motors have no provision for oiling; they are lubricated at the time of overhaul.

2. Clean and service the starting motor as indicated in the manufacturer's instructions.

e. Lubricate the Alternator.

Add 3 to 5 drops of medium grade engine oil to the oilers or oil wicks in the end heads.

3-5. 500 HOURS OR 12,000 MILES.

a. Repeat daily, 50-hour, and 100-hour maintenance schedules.

b. Check Cooling System Hoses.

Inspect all of the cooling system hoses for leakage, damage, or signs of deterioration. Replace hoses if necessary.

c. Check Fuel Nozzles.

NOTE

The fuel nozzle and holder assemblies must be handled with care at all times. The nozzle and holder assemblies should only be disassembled, cleaned, and adjusted by a competent fuel system technician, using proper fuel nozzle testing equipment.

1. The following conditions indicate the need for nozzle cleaning or servicing:

(a) Increased amounts of black or dark smoke in engine exhaust.

(b) Loss of power accompanied with foul exhaust or increased leakage of fuel through the bypass leakoff of the spray nozzle.

(c) Rough or erratic engine operation.

(d) Irregular fuel knocks.

(e) One or more engine cylinders miss continuously.

2. Check nozzle operating pressure using a static fuel nozzle testing fixture. The nominal opening pressure should be 2750 psi. To adjust the opening pressure, remove the cap nut and turn the screw clockwise to increase or counterclockwise to decrease spring tension. This raises or lowers opening pressure.

3. New nozzle and holder assemblies are shipped from the factory set at 2900 psi to compensate for the setting of the spring in the first few hours of operation.

d. Drain Fuel Tank.

Open the drain at the bottom of fuel tank and drain off accumulated water or sediment.

e. Check Battery.

1. Clean the battery top and cable ends with a solution of water and baking soda to neutralize the acid on the parts. Do not allow the soda solution to enter the battery. Inspect the battery for cracks, corrosion, and other damage. Coat the battery cable clamps with grease to prevent corrosion.

2. Using a hydrometer, check the specific gravity of the electrolyte in each cell of the battery. In warm weather it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

f. Inspect Alternator.

1. The intervals between inspections will vary, depending upon the type of operation. Dirt, dust, and high speed operation will contribute to increased wear of bearings and brushes. Inspect for broken wires and check that all connections are clean and tight. Make sure that ground connections at the battery and alternator are secure. Brushes must slide freely in their holders. If the brushes are oil-soaked or if they are worn to less than one-half their original length, replace them.

2. Service and repair the alternator and regulator according to manufacturer's instructions or take to an authorized service center for inspection and repairs.

g. Perform Engine Tuneup. See Table of Contents. Items indicated with an asterisk (*) should be checked as part of tuneup. These references are to Section V, Engine Repair and Overhaul.

1. No scheduled interval for performing an engine tuneup can be established. As long as the engine is operating satisfactorily, no tuneup is necessary. Valve, nozzle, and fuel injector control adjustments must be made periodically to compensate for normal wear on parts. Normally, when performing a tuneup it is necessary to check the various adjustments for a possible change in settings and to adjust as necessary.

2. While performing a tuneup, make a detailed visual inspection of the general condition of the engine.

3. Make all of the following tuneup checks and adjustments with the engine at normal operating temperature. Run the engine between adjustments if necessary to maintain normal operating temperature.

(a) Check and Adjust Valve Clearance.

(1) Start the engine and allow it to warm to operating temperature.

(2) Remove the cylinder head cover and gasket.

(3) With the engine running at slow idle, check for 0.015 inch clearance between the rocker arm and end of the valve stem, using a feeler gauge as shown in figure 3-2.

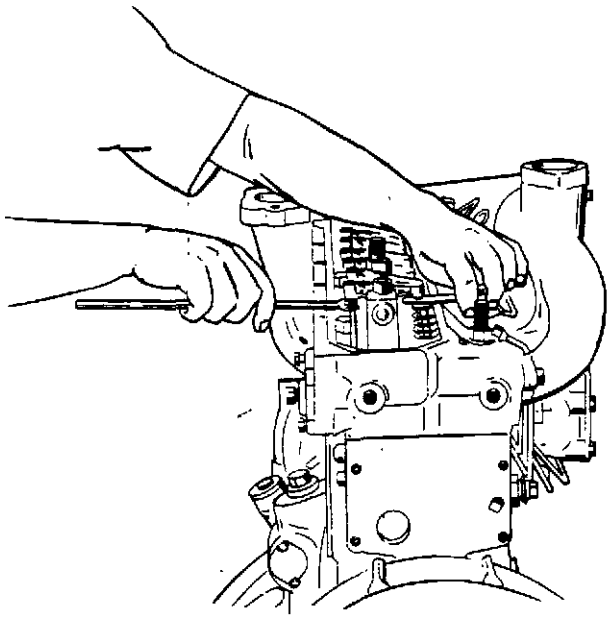


Figure 3-2. Valve Clearance Check and Adjustment

(4) If the valve clearance is incorrect, adjust the setting of the adjusting screw to provide the required clearance. Refer to figure 3-2. When properly adjusted, there will be a slight drag on the feeler gauge with the valve in the unoperated position.

NOTE

After valve grinding or rocker arm or cylinder head removal, it is necessary to do a preliminary valve clearance adjustment with the engine shut down and using cold settings. Refer to paragraph 5-26f for instructions.

(5) The adjusting screw is self-locking, therefore lock nuts are not required.

(6) Repeat the procedure to adjust the remaining intake and exhaust valves. Adjust all valves to the same clearance.

(7) Reinstall the cylinder head cover and gasket. Use a new gasket if the old one shows any signs of cracking or deterioration.

(b) Check and Adjust Fuel Injection Pump Timing.

(1) Rotate the engine until the required timing mark on the flywheel aligns with the mark on the flywheel housing as shown in

figure 3-3. Refer to Table 3-3, Fuel Injection Pump Timing.

(2) Remove the timing hole cover plate on the fuel injection pump. The timing marks on the pump should be aligned as shown in figure 3-4. If the marks are not aligned, fine adjustment may be made by loosening the fuel injection pump mounting bolts and rotating the pump slightly. When the marks on the pump are aligned, check that the timing marks on the flywheel are still aligned, then tighten the fuel injection pump mounting bolts. For a large adjustment, loosen the drive shaft and reposition. (Excessive movement of lines will cause overstress.)

(3) Install timing hole cover plate.

(c) Check and Adjust Idle Speed.

If the idle speed has altered slightly from the recommended speed, adjust it by loosening the adjusting screw lock nut and turning the adjusting screw in or out as necessary. Refer to figure 3-5. The required idle speed will vary for various engine applications.

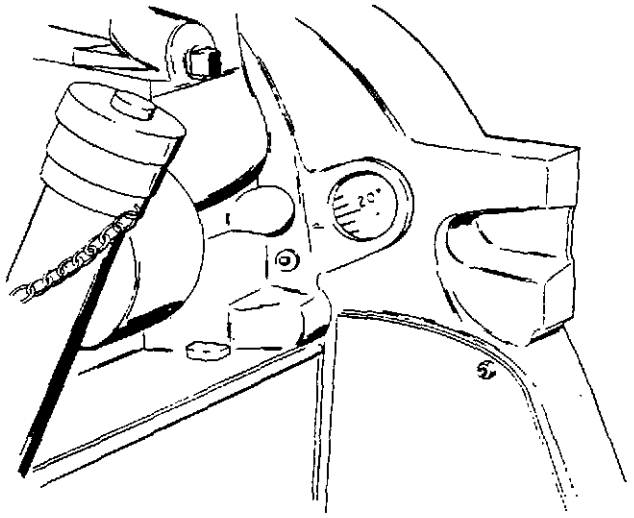


Figure 3-3. Flywheel Timing Marks

Table 3-3. Fuel Injection Pump Timing

VERTICAL FUEL PUMP		
Engine	Timing Cylinder (On Compression Stroke)	
3 Cyl.	1	All speed Advance Pumps (Figure 3-4) are timed at 20° BTDC. All non-speed Advance Pumps (Figure 3-5) are timed at 28° BTDC.
4 Cyl.	1	
6 Cyl.	1	
It is important that the oil pump be timed to proper cylinder. See oil pump installation (paragraph 5-6c).		

HORIZONTAL FUEL PUMP		
Engine	Timing Cylinder (On Compression Stroke)	
3 Cyl.	1	All speed Advance Pumps (Figure 3-4) are timed at 20° BTDC. All non-speed Advance Pumps (Figure 3-5) are timed at 28° BTDC.
4 Cyl.	1	
6 Cyl.	1	

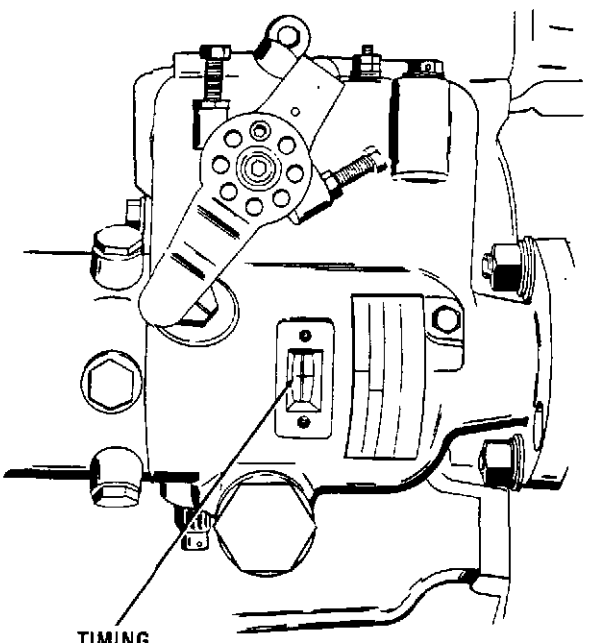


Figure 3-4. Fuel Injection Pump Timing Marks

(d) Check and Adjust Maximum Engine Speed.

With no load on the engine, operate the throttle control to full open position. Check the full throttle speed. If the maximum speed has altered slightly from the recommended speed, adjust it by loosening the adjusting screw lock nut and turning the high speed adjusting screw in or out as necessary. Refer to figure 3-5. The required maximum speed will vary for various engine applications. Do not exceed the recommended full-throttle, no-load speed.

3-6. LUBRICATING OIL SPECIFICATIONS.

a. The lubricating oil recommendations are based on engine design, type of service, and ambient air temperature. High quality oils combined with necessary oil and filter changes are required to assure maximum performance, long engine life, and minimum operating cost.

b. Use Table 3-4, Recommended Lubricating Oil Specifications, as a guide for selection of a good diesel lubricating oil.

3-7. FUEL OIL SPECIFICATIONS.

a. To insure maximum power and engine performance, use only No. 2 distillate fuels, summer and winter grades, which conform to ASTM Designation D-975.

b. Use this section and Table 3-5, Fuel Oil Specifications, as a guide for selection of a good diesel fuel.

Table 3-4. Recommended Lubricating Oil Specifications

Ambient Air Temperature	Viscosity Grade	Use single viscosity, low ash oil with API Classification as shown below. Select viscosity grade according to ambient temperature.
-10° to 30° F 30° to 60° F 40° and up	10W 20 - 20W 30	
-10° F and up	15W - 40	NOTE: Multigrade oils with CD Classification Only are acceptable for Diesel engines.
API CLASSIFICATION		
Naturally Aspirated Diesel (MIL-L-2104B or C) ----- CC (Single Viscosity) or CD		
Turbocharged Diesel Engine (MIL-L-2104C) ---------- CD		

Table 3-5. Fuel Oil Specifications

Flash point	125°F, minimum
Carbon residue	0.35 percent
Water and sediment (see note 3)	0.10 percent by volume, maximum
Ash	0.02 percent by weight, maximum
Distillation, 90 percent point (see note 4)	640 maximum 540 minimum
Viscosity at 100°F	2.0 centistokes, minimum 4.3 centistokes, maximum
Sulphur (see note 4)	1.0 percent, maximum
Cetane number (see note 4)	45 minimum

NOTES:

1. The fuel oil must be clean, completely distilled, stable, and noncorrosive.

2. In cold weather, the cloud point (temperature at which wax crystals begin to form in the fuel oil) should be 10°F below the lowest expected fuel temperature to prevent clogging of the fuel filters by wax crystals.

3. The fuel filters are sensitive to water and care should be taken to keep the water content low.

4. Distillation range, sulphur content, and cetane number are three of the most important properties in the selection of fuel for optimum combustion and minimum wear.

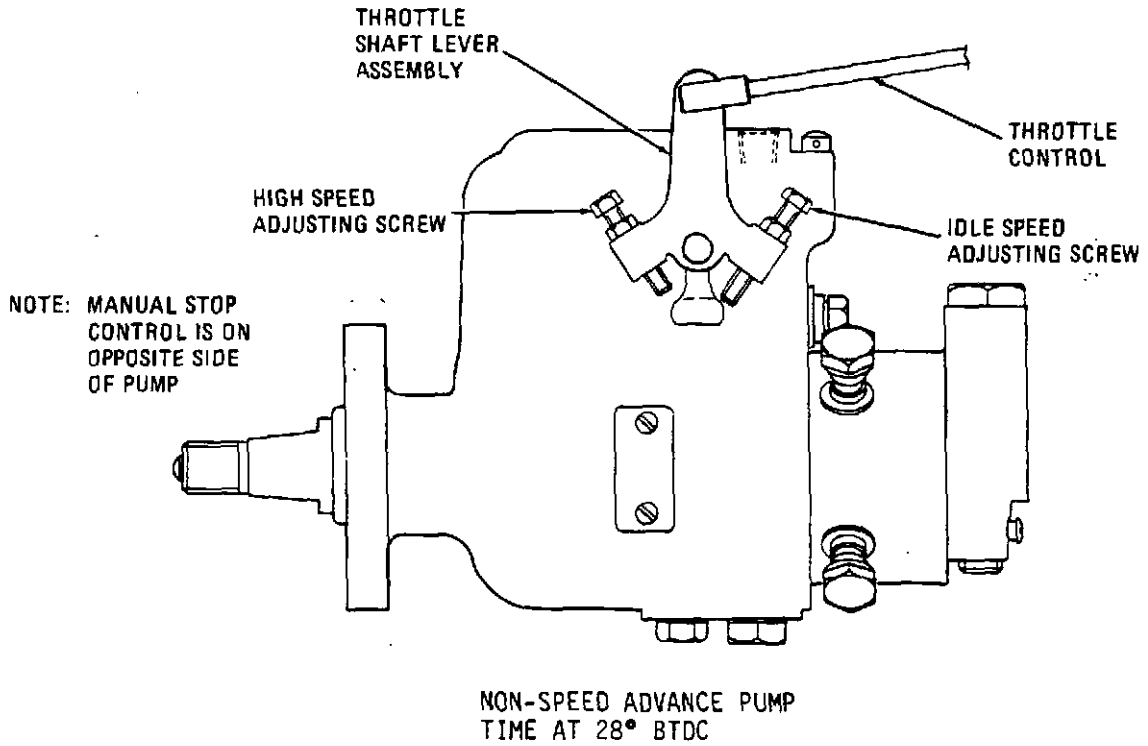


Figure 3-5. Fuel Injection Pump Speed Adjustments

SECTION IV
TROUBLESHOOTING

4-1. GENERAL INFORMATION.

This troubleshooting section includes some of the most common problems that may be encountered during operation of a diesel engine. Table 4-1, Troubleshooting Chart, lists symptoms, probable causes, and possible remedies. The chart refers to applicable paragraphs in the manual where possible remedial procedures will be found. No references are made for problems with obvious remedies, such as an empty fuel tank.

4-2. TROUBLESHOOTING PROCEDURES.

a. Note unusual operation and symptoms. Refer to table 4-1 to determine possible cause.

b. Always check the easiest and most obvious causes first to save time and trouble. Do not disassemble engine or components until all other possible causes and remedies for a specific problem have been examined.

c. After a mechanical failure has been corrected, locate and correct the cause of the trouble so that the failure will not reoccur.

Table 4-1. Troubleshooting Chart

CAUSE	ENGINE WILL NOT START	HARD STARTING	ENGINE STOPS	ERRATIC ENGINE PERFORMANCE	BLACK EXHAUST SMOKE	BLUE EXHAUST SMOKE	WHITE EXHAUST SMOKE	LOW POWER	ENGINE OVERHEATING	ENGINE OVERCOOLING	ENGINE KNOCKING	LOW OIL PRESSURE	BEARING FAILURES	POSSIBLE REMEDY
	SYMPTOM													
Air cleaner dirty		X		X	X	X		X						Para 3-2e and 5-17.
Air inlet restricted	X	X		X	X	X		X						
Exhaust system restricted			X	X	X			X	X					Para 5-20.
Battery weak or discharged	X	X	X	X										
Battery cables - loose connections	X	X	X	X										
Foreign matter on pistons				X				X			X			Para 3-5g and 5-31.
Low cylinder compression	X	X		X		X		X						
Worn pistons, rings, etc.		X				X		X			X			
Scored pistons				X		X		X	X		X		X	
Valves leaking		X		X		X		X						Para 5-26.
Valves sticking	X	X		X	X			X			X			
Valves incorrectly adjusted	X	X		X				X			X			
Luboil level too low											X	X	X	Para 3-6.
Luboil level too high		X				X		X						
Wrong type of luboil		X				X						X	X	
Oil pump inlet screen plugged											X	X	X	Para 5-6.
Pressure regulator not functioning											X	X	X	Para 5-6.
Luboil contaminated											X	X	X	Para 3-3b.
Rocker arm shaft upside down						X						X		Para 5-24.
Oil header plug missing or loose												X	X	Para 5-33.
Bearings failed - main, rod, cam				X		X		X			X	X	X	Para 5-30, 5-31, and 5-32.
Excessive angle operations						X					X	X	X	Para 5-30 and 5-32.
Excessive thrust pressure on shafts	X	X	X									X	X	
Fuel tank empty	X		X											
Fuel tank valve closed	X		X											
Fuel tank vent plugged				X	X									
Fuel transfer pump worn	X	X		X				X						Para 5-12.
Fuel contamination	X	X		X		X		X			X			Para 3-3d.
Fuel incorrect for conditions	X	X	X	X	X	X		X						Para 3-7.
Engine too cold to ignite fuel properly	X	X		X			X	X						Para 2-5.
Stop control in stop position	X		X											
Electric fuel shutoff not functioning	X		X											
Throttle linkage adjustment incorrect or sticking				X				X						
Fuel filters dirty or plugged	X	X	X	X				X						Para 5-13.
Air leaks in fuel system	X	X	X	X				X						Para 2-2.
Fuel pump incorrectly timed	X	X		X	X		X	X	X		X			Para 5-14c.
Sticking or fouled nozzle		X		X	X			X			X			Para 5-15.
Fuel return plugged or restricted		X	X	X				X			X			Para 5-15.
Incorrect fuel setting				X	X			X						Para 5-15.
Nozzle opening pressure incorrect				X	X			X			X			Para 5-15.
Nozzle incorrectly torqued				X				X			X			Para 5-15.
Fan belt loose or slipping								X	X					Para 5-9.
Radiator fins or tubes dirty or restricted								X	X					Para 3-3c.
Water system piped incorrectly									X	X				
Low Coolant level								X	X					
Coolant in cylinders	X	X		X		X		X	X		X			Para 5-25b.
Inoperative thermostat					X	X		X	X	X				Para 5-10.
Thermostat missing					X	X		X		X				Para 5-10.
Engine overloaded					X			X	X		X		X	
Engine overspeeded					X				X		X		X	

SECTION V
ENGINE REPAIR AND OVERHAUL

5-1. GENERAL INFORMATION.

This section includes brief descriptions of engine components and instruction for disassembly, repair and overhaul, and reassembly of the component parts of the Hercules D Series Engine.

Before removal or disassembly of a component or disassembly of the engine, inspect the overall condition and note all symptoms of faulty operation. This helps to determine causes of failure or faulty operation, and facilitates repair.

Provide a clean place to work, facilities for cleaning the engine and parts, and an engine overhaul stand.

Standard engine overhaul shop tools and resurfacing equipment are necessary. These tools save time and insure good workmanship.

Engine components and parts are overhauled in one of the following systems: Lubrication System, Cooling System, Fuel System, Air Supply and Exhaust Systems, Electrical System, and Engine. Instructions are given for removal, disassembly, repair or replacement, and reassembly of each component separately. Remove components and parts as required, and note any necessary precautions or special procedures.

5-2. ENGINE REMOVAL FROM UNIT.

Instructions given in this section are not for any specific engine application but serve as guides for a typical engine removal and disassembly procedure. Alter these procedures to suit a specific engine application.

a. Preparation for Removal.

1. Disconnect and remove electrical leads from the starting motor to the battery.

2. Remove the muffler and exhaust piping.

3. Remove the air cleaner and piping.

4. Drain the engine cooling system.

5. Remove side covers, top, rear covers, and associated parts of engine housing.

6. Remove the radiator, radiator supports, and cooling system hoses.

7. Disconnect the throttle and stop control linkages from the fuel injection pump.

8. Shut off fuel supply and disconnect fuel supply line from engine.

9. Disconnect and remove the engine instrument panel.

10. Remove the transmission, clutch, or power take-off.

b. Engine Removal.

1. Use a sling on the engine and support the weight of the engine with a hoist.

2. Remove the attaching hardware securing the engine to the front engine supports.

3. Remove the attaching hardware securing the engine to the rear engine supports.

4. Disconnect drive shaft or any other drive members secured to the engine.

5. Hoist the engine from the unit and rest the engine on blocks or mount it on an overhaul stand.

CAUTION

Do not rest the engine on the oil pan. Severe damage to the oil pan or engine can result.

c. Removal of Engine Accessories.

1. Remove the engine alternator.

2. Remove the engine starting motor.

3. Remove turbocharger, if used.

4. Remove clutch, torque converter, or other drive unit.

d. Installation of Engine.

Reinstall the engine by reversing the removal procedure.

5-3. LUBRICATION SYSTEM.

The engine lubrication system consists of an oil pump, oil filter, oil lines, oil cooler (if used), and pressure regulator valve. External connection diagrams of the lubrication system are shown in figure 5-1. Internal Oil Flow shown in Figure 2-2 Page 2-6.

The oil pump forces the oil under pressure through a full-flow oil filter to the main oil header in the cylinder block. This oil header is a drilled passage extending the length of the cylinder block on the side opposite the camshaft and is closed at both ends with plugs.

From the main header the oil is distributed, under controlled pressure, through drilled passages to all main and camshaft bearings. Refer to Figure 2-2, page 2-6 and note in the center of the radius on the rear camshaft journal there is a groove half the distance of the complete journal. This is known as a chopper camshaft. This groove allows a metered amount of oil to be distributed to the rocker arms and valve stems. When troubleshooting and checking the system for oil pressure, be sure the ungrooved part of the camshaft journal is not closing off the oil to the rocker arms. Oil for lubricating the connecting rod bearings is provided through drilled passages in the crankshaft from the main bearings. The cylinder walls, piston pins, and valve tappets are lubricated by oil drain-back and by the mist of oil thrown from the various pressure-lubricated bearings. The gear train is lubricated by overflow oil from the camshaft.

External openings are provided for connection of an oil pressure gauge, turbocharger lubrication, or other accessories requiring pressure lubrication.

5-4. OIL FILTER AND LINES.

The engines use a full-flow oil filter employing either spin-on or cartridge-type filter elements. Use the following as a guide, altering the instructions as necessary for the particular application.

a. Removal.

1. Drain the oil from the crankcase.

2. Disconnect and remove the oil line assemblies (1 and 2, figure 5-2) from the oil filter and cylinder block or oil cooler, if used.

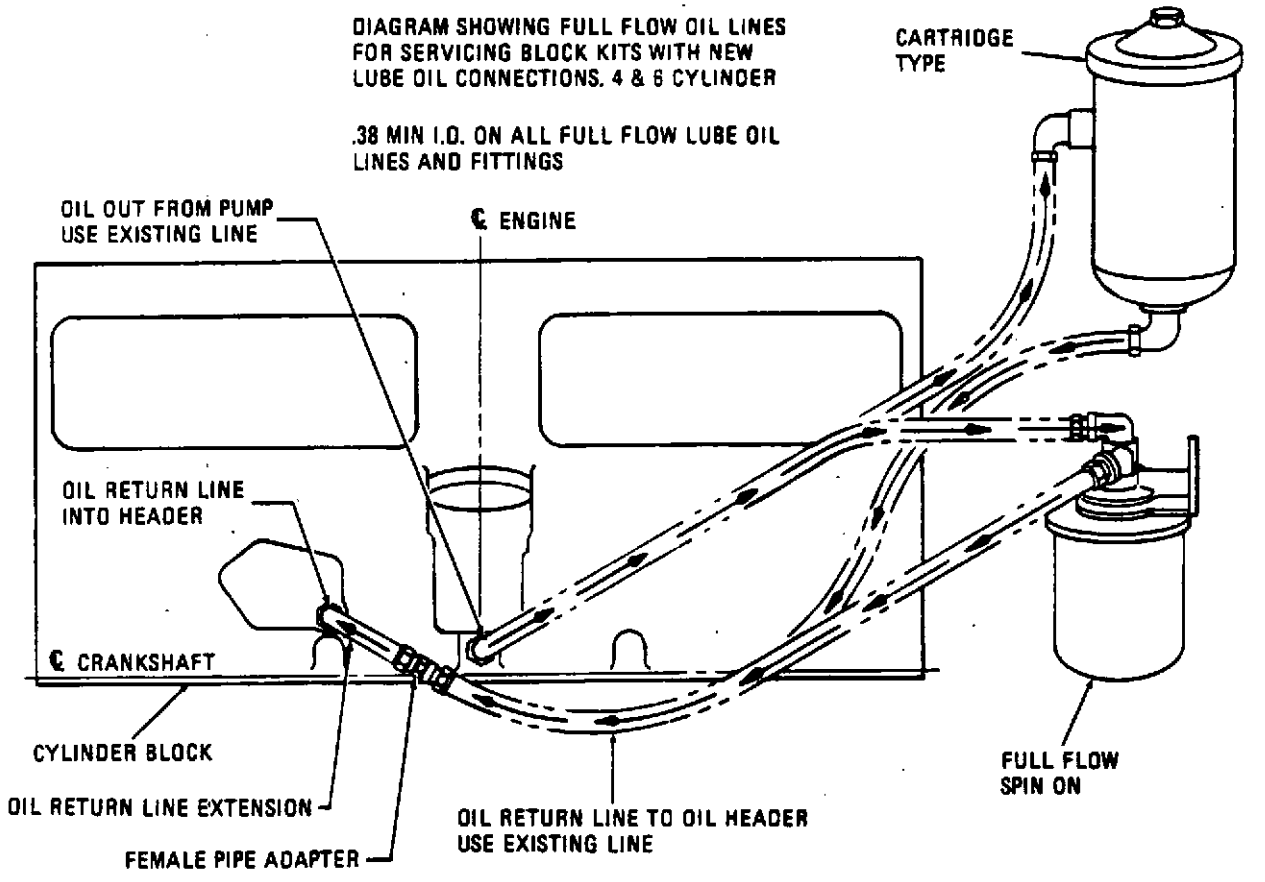
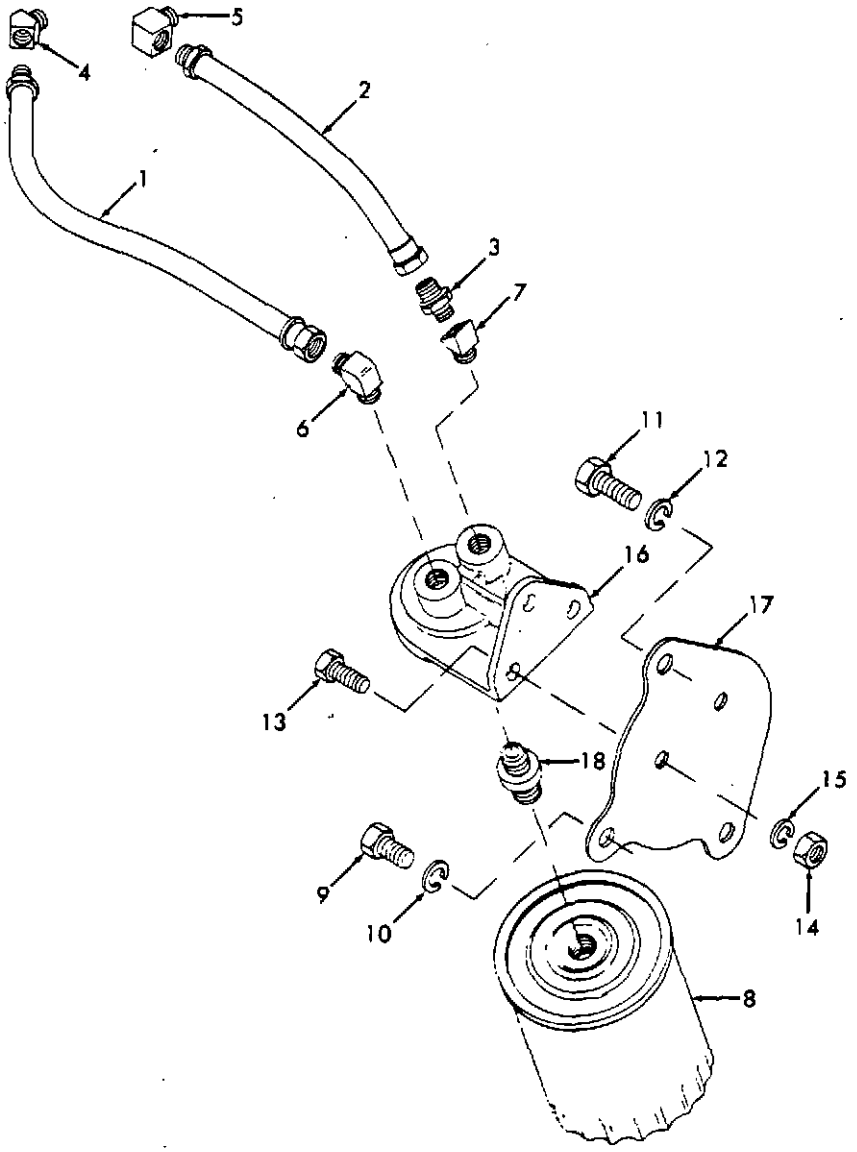


Figure 5-1. Engine Lubricating System External Connection Diagrams



1. Oil line
2. Oil line
3. Union
4. Elbow
5. Elbow
6. Elbow
7. Elbow
8. Oil filter element
9. Bolt
10. Lock washer
11. Bolt
12. Lock washer
13. Bolt
14. Nut
15. Lock washer
16. Base assembly
17. Bracket
18. Stud

Figure 5-2. Oil Filter and Lines, Exploded View

3. Remove the oil filter element (8) from the base assembly (16).

4. Remove the base assembly from the mounting bracket (17) by removing two each bolts (13), nuts (14), and lock washers (15).

b. Cleaning and Inspection.

1. Discard and replace the oil filter element and gaskets.

2. Clean all remaining parts with cleaning solvent; dry thoroughly.

3. Inspect the oil line assemblies for cracked, frayed, cut, or deteriorated hoses, worn or damaged threads. Replace damaged oil line assemblies.

4. Inspect the base assembly for cracks, clogged passages, damaged filter gasket seat, stripped threads, and other damage.

5. Remove and replace the stud (18) if damaged. Use Loctite at installation of stud. Replace a damaged base assembly.

c. Installation.

1. Install the base assembly (16) on the mounting bracket (17) and secure with two each bolts (13), nuts (14), and lock washers (15).

2. Refer to figure 5-2 and connect the oil line assemblies.

3. Install new oil filter element (8).

5-5. OIL PAN.

The oil pan serves as a cover for the bottom of the crankcase and as an oil reservoir.

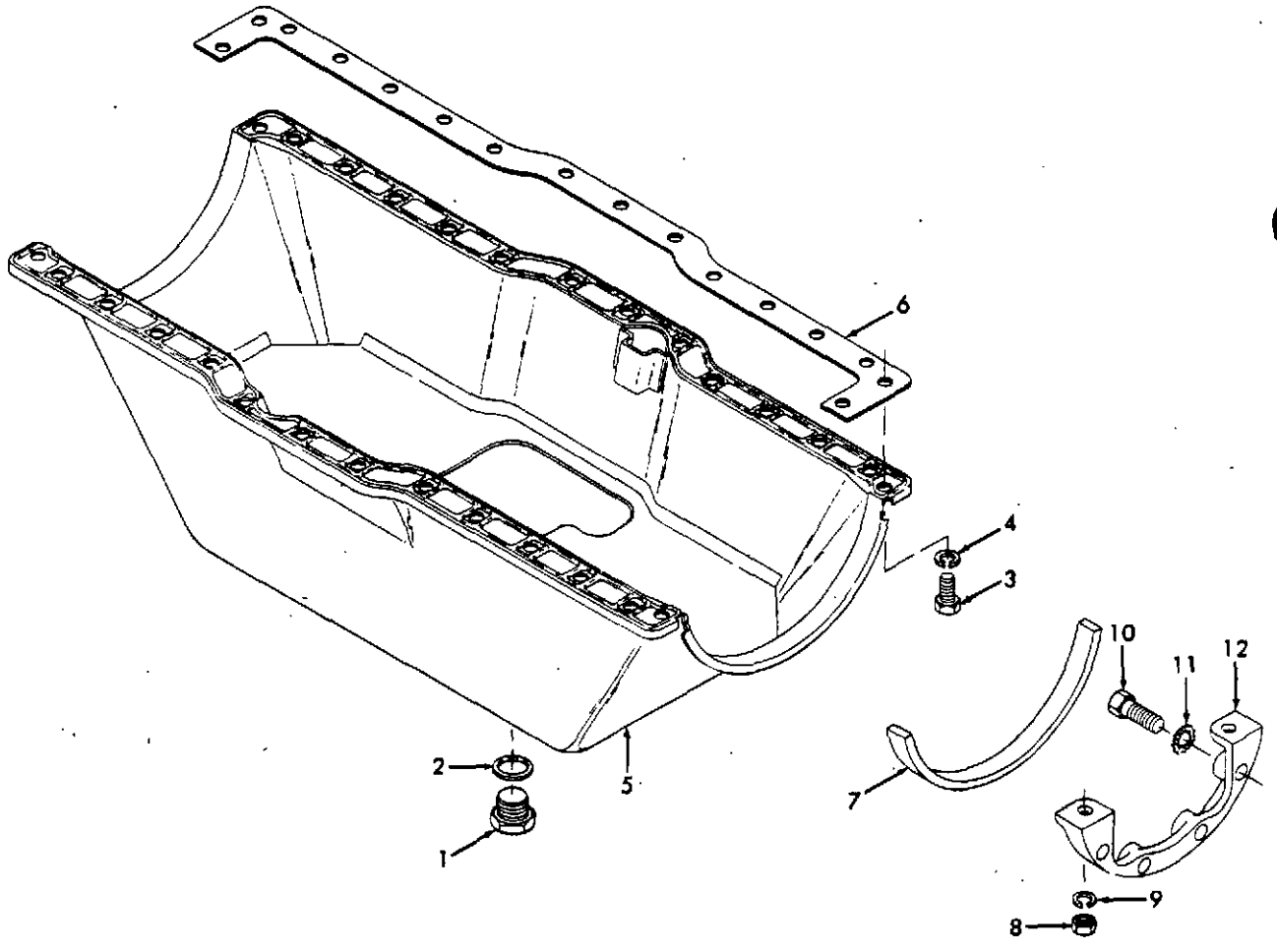
a. Removal.

1. Remove the oil drain plug (1, figure 5-3) and gasket (2); drain the crankcase oil into a suitable container. If possible, drain the oil when the engine is at operating temperature.

2. If the starting motor is mounted below the oil pan level and will interfere with oil pan removal, disconnect the electrical leads and remove the starting motor from the bell-housing. Refer to paragraph 5-22.

3. Support the oil pan and remove the bolts (3, figure 5-3) and lock washers (4). Remove the oil pan (5) and gaskets (6).

4. Remove front and rear pan seals (7).



1. Drain plug
2. Gasket
3. Bolt
4. Lock washer
5. Oil pan
6. Gasket
7. Seal
8. Nut
9. Lock washer
10. Bolt
11. Lock washer
12. Adapter

Figure 5-3. Oil Pan and Adapters, Exploded View

b. Cleaning and Inspection.

1. Discard all gaskets and seals. Make sure the gasket mounting surfaces on the oil pan, cylinder block, and oil pan adapters are clean and free from burrs.

2. Steam-clean pan and all mounting parts.

3. Inspect the oil pan for distortion, dents, and cracks. Check for signs of leakage. Repair small cracks in pan by welding. Do not weld finished surfaces.

4. Check threaded holes and bolts for damaged threads.

5. Repair a damaged oil pan plug hole by drilling it out and tapping for one size larger pipe plug.

c. Installation.

1. Before installing the oil pan, inspect the inside of the engine for loose nuts, screws, cotter pins, and lock wires; tighten or replace.

2. Remove all gasket particles from gasket mounting surface before applying new gasket. Cement the new oil pan side gaskets (6, figure 5-3) to the cylinder block using shellac, or equivalent.

3. Remove protective coverings from oil pan adapter seals (7) and apply seals to adapters (12). Make sure both ends of the seal contact the pan gaskets (6) on each side. Seal surfaces on adapters must be free of oil and dirt.

4. Put the oil pan (5) in place and carefully start all the bolts (3). Be sure the lock washers (4) are on the bolts. Tighten all bolts evenly and progressively. This will allow the oil pan to center on the adapter blocks. Do not overtighten oil pan bolts.

5. Install the drain plug (1) and gasket (2).

6. Install the starting motor, if removed, and connect the electrical leads.

7. Refill with recommended oil to the correct level. Refer to table 3-4.

5-6. OIL PUMP.

The oil pump is attached to the side of the cylinder block with the lower end extending into the oil pan. The oil is drawn into the pump through a large screen which prevents coarse dirt from entering the pump. The pump requires no priming and is driven by a gear that engages a toothed portion of the camshaft, located near the center of the camshaft.

a. Removal and Disassembly.

1. Drain the oil from the crankcase and remove the oil pan. Refer to paragraph 5-5.

2. Turn the engine crankshaft so that No. 1, 4, or 6 piston is in the firing position. In this position the piston assembly is fully extended above the crankshaft.

3. If the engine is equipped with a tachometer drive, remove the drive before attempting to remove the oil pump.

4. Remove the two attaching bolts (1, figure 5-4) and lock washers (2) from the pump flange and pull the oil pump from the engine.

NOTE

When the engine is equipped with a counterbalanced crankshaft, it is necessary to rotate the crankshaft and, at the same time, remove the oil pump with a spiral motion.

5. Bend up tangs on lock washer (4) and remove the regulator assembly (3) and shims (5). Do not disassemble the regulating valve.

6. Remove the oil pump strainer (6) from the pump impeller cover by turning counterclockwise. Do not turn on the screen portion of the strainer.

7. Use a gear puller to remove drive gear (7) from shaft (13).

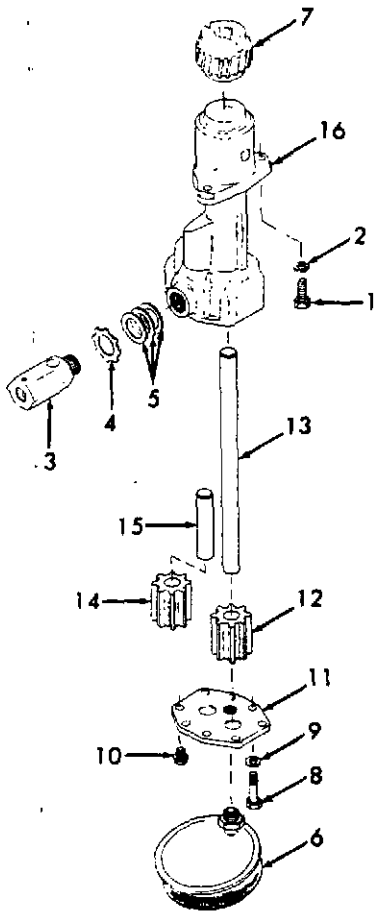
8. Remove the bolts (8), assembled washer bolts (10), and washers (9) from the pump impeller cover (11); remove the cover.

9. Remove the impeller (12) and shaft (13) as an assembly. Press the impeller from the shaft if necessary.

10. Remove impeller (14) from the idler shaft (15). On some older style oil pumps, the shaft can be removed manually from the pump body (16). On later pumps, the shaft is pressed into the pump body.

b. Cleaning and Inspection.

1. Clean all pump parts in cleaning solvent; dry with compressed air.



1. Bolt
2. Lock washer
3. Regulator
4. Lock washer
5. Shim
6. Strainer
7. Drive gear
8. Bolt
9. Washer
10. Assembled washer bolt
11. Pump impeller cover
12. Drive impeller
13. Drive shaft
14. Idler impeller
15. Idler shaft
16. Body

Figure 5-4. Oil Pump, Exploded View

2. Inspect the oil pump strainer for clogged screen, holes, damaged threads, dents, or other damage. Make sure the oil passage is clear and unobstructed. Replace a damaged or distorted strainer.

3. Inspect all gears for worn or broken teeth; replace if damaged.

4. Inspect all parts for burrs, pitting, rust, scoring, cracks, breaks, and damaged threads. Replace any damaged parts.

5. Replace idler shaft (15) if shaft has turned in pump body or is worn smaller than 0.6220-inch diameter at gear bearing area.

6. Replace drive shaft (13) if shaft has turned in gears or is worn smaller than 0.6220-inch diameter at bearing points.

7. Test piston in regulator body; replace regulator if piston binds.

c. Reassembly and Installation.

1. Press impeller (12) onto the drive shaft (13) so that the outside face of the impeller and the end of the shaft are flush. Once removed, do not press old parts back together.

2. Insert the shaft and impeller assembly into the pump body (16). Press the drive gear (7) onto the shaft. Replace gear that can be pressed onto the shaft with less than 35 pounds gauge pressure. Press the gear onto the shaft to the dimensions shown in figure 5-5.

3. Install the idler shaft (15, figure 5-4), if removed, and install the idler impeller (14).

4. Install the pump impeller cover (11) and secure with bolts (8), assembled washer bolts (10), and washers (9). Tighten the bolts progressively and evenly.

5. When inserting the oil pump into the cylinder block, make sure the arrow on the oil pump gear is aligned with the arrow on the fuel pump attaching pad. The positions of the arrows are the same when timing to cylinder number one, four, or six on either left- or right-hand camshaft applications. Secure pump with two bolts (1) and lock washers (2). Tighten bolts securely but not excessively.

6. Install the oil pump strainer (6) on the pump impeller cover by turning in clockwise. Do not apply force against the screen.

7. Install the 65 psi oil pressure regulator (3) with a new lock washer (4). The regulator, when mounted on the pump, must be turned so that the relief hole is aligned within 30° of horizontal (see figure 5-6). This position will prevent oil from spraying up into the cylinder bore, and will direct the spray toward the center of the engine and against the oil pan surface. If the oil pressure regulator is in an incorrect

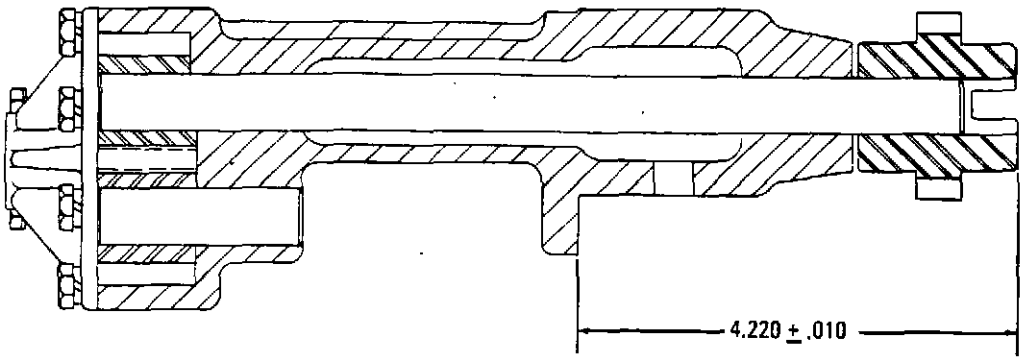


Figure 5-5. Oil Pump Drive Gear Installation Dimensions

position when tightened, add shims (5, figure 5-4) until the proper alignment is achieved.

8. Install the oil pan (paragraph 5-5).

9. Install the tachometer drive, if used.

10. Fill the crankcase to the proper level with the recommended grade of lubricating oil.

5-7. OIL COOLER.

An oil cooler is used on some engines to help maintain the required operating temperatures. The oil cooler is a heat exchanger which transfers heat from the hot engine oil to the engine coolant.

a. Removal.

1. Remove drain plug (1, figure 5-7) and drain the coolant from the oil cooler. Open radiator drain to speed draining.

2. Disconnect oil line assemblies (2 and 3) from the oil cooler.

3. Loosen hose clamps (5 and 6) and disconnect coolant hoses (7 and 8) from oil cooler (12).

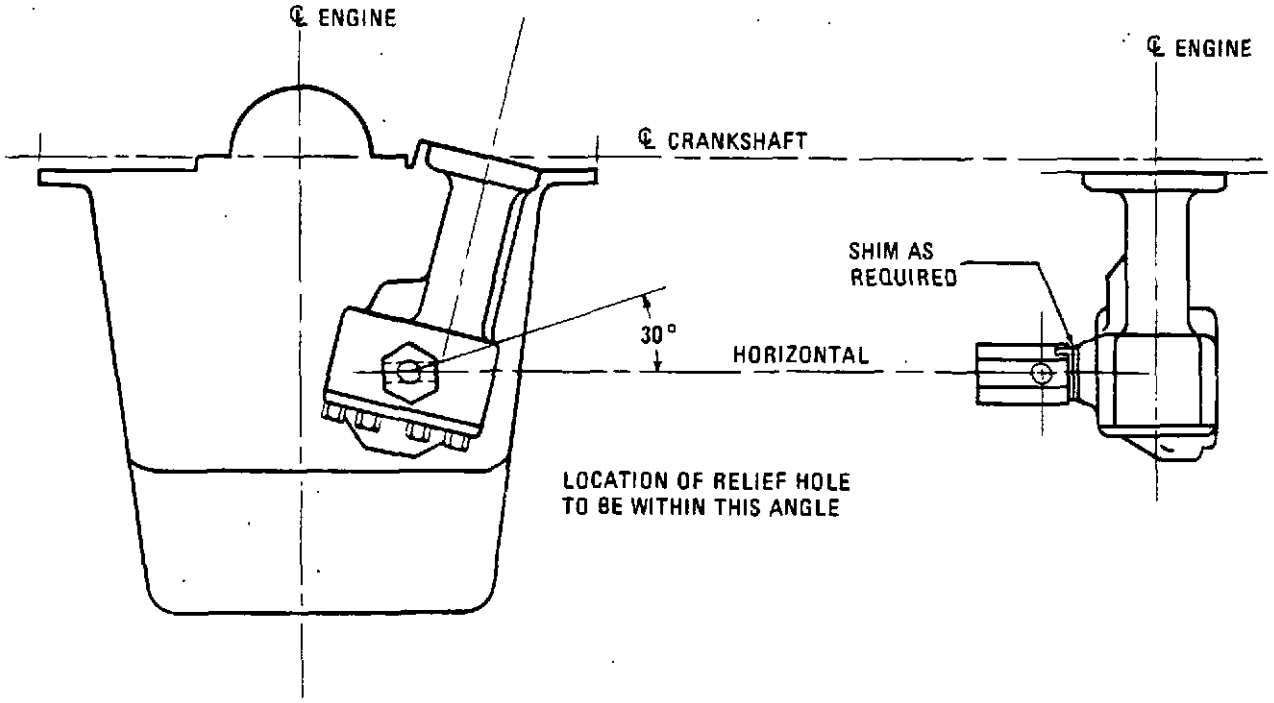


Figure 5-6. Oil Pressure Regulator Installation

4. Remove the oil cooler from mounting bracket by removing nuts (9), lock washers (10), and U-bolt (11).

b. Cleaning and Inspection.

1. Clean all parts in cleaning solvent and dry thoroughly.

2. Inspect the oil cooler for cracks, dents, damaged threads, signs of leakage, or other damage. Replace a damaged oil cooler.

3. Check that oil and water passages are clear and unobstructed by blowing through with compressed air.

4. Check all remaining parts for cracks, damaged threads, deterioration, or other damage. Replace any damaged parts.

c. Installation.

1. Mount the oil cooler (12) on the bracket (15) with U-bolt (11), nuts (9), and lock washers (10).

2. Install coolant hoses (7 and 8) and tighten clamps (5 and 6).

3. Install drain plug (1) and oil line assemblies (2 and 3).

4. Make sure radiator drain is closed and fill cooling system with clean water or antifreeze.

5. Make sure the engine oil level is to the FULL mark after installation.

6. Start the engine and check for oil and coolant leaks.

5-8. COOLING SYSTEM.

A typical engine cooling system consists of a radiator, fan, water pump, thermostat, and coolant bypass. The coolant is drawn from the bottom of the radiator and into the water pump. The water pump forces the coolant into the coolant passages in the cylinder block, around the cylinders, through to the cylinder head coolant passages, through the thermostat, and into the top of the radiator. The radiator acts as a heat exchanger between the coolant and the surrounding air, so that the coolant is cooled as it passes through to the bottom of the radiator. The fan maintains a supply of cool air around the radiator tubes and fins.

During engine warmup, the thermostat remains closed and the coolant bypasses the radiator and returns directly to the water pump through the bypass tube. This accelerates the warmup time, since the coolant in the radiator is not heated until the engine is warm.

5-9. WATER PUMP AND FAN ASSEMBLY.

The centrifugal-type water pump is driven from a crankshaft-mounted drive pulley by use of one or more V-belts. Various accessories mounted on the engine may be driven by these belts.

The cooling fan is mounted on the water pump driven pulley.

a. Removal and Disassembly.

1. Drain the radiator and remove the radiator, hoses, and radiator support brackets.

2. Remove the fan (3, figure 5-8) by removing four bolts (1) and lock washers (2) securing fan to pulley (20).

3. Remove the fan belt(s) (4) by loosening the alternator attaching bolts and moving the alterator until the belt(s) can be removed.

4. Remove the bypass hose (7) and disconnect the water inlet hose (10) from the water pump.

5. Remove the three bolts (11) and lock washers (12) securing the assembled water pump and inlet pipe to the cylinder block and remove the assembly from the engine. Remove water pump gasket (13).

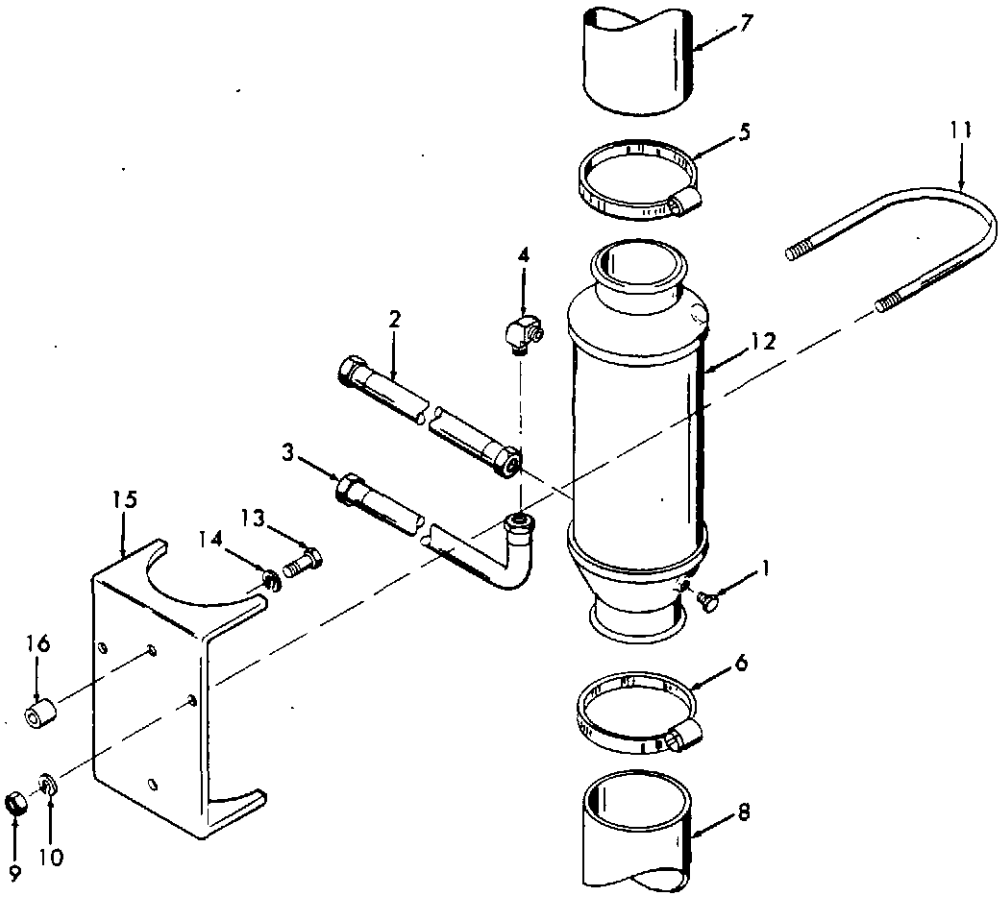
6. Remove bolts (14 and 16) and lock washers (15 and 17) that secure the water inlet pipe (18) and gasket (19) to the pump body (30).

7. Disassemble the water pump by removing the pulley (20) from the adapter (22).

8. Remove retaining ring (21) and use a puller to remove the pulley adapter (22) from the shaft. Remove retaining ring (23).

9. Remove cover plate (25) and gasket (26) by removing screws (24).

10. Place the front of the pump on a support in an arbor press and press the shaft and bearing assembly (27) out of the pump body (30) and impeller (28). The shaft and bearing assembly is one unit. Do not attempt to disassemble these parts.



1. Drain plug
2. Oil line
3. Oil line
4. Elbow
5. Hose clamp
6. Hose clamp
7. Hose
8. Hose
9. Nut
10. Lock washer
11. U-bolt
12. Oil cooler
13. Bolt
14. Lock washer
15. Bracket
16. Spacer

Figure 5-7. Oil Cooler, Exploded View

11. Press the seal (29) out of the pump body.

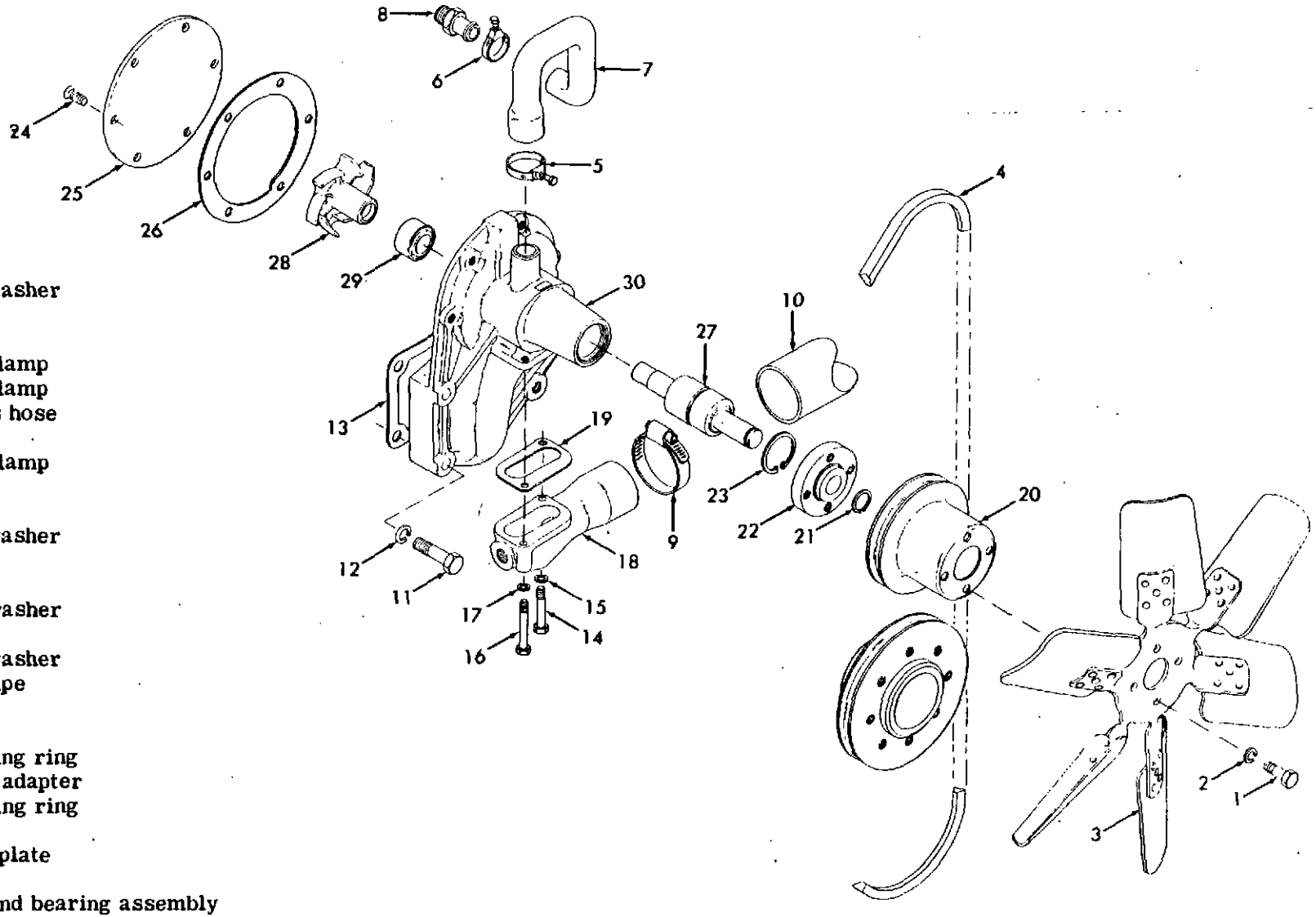
b. Cleaning and Inspection.

1. Discard gaskets and seals.

2. Wipe the fan blade with a cloth dampened with cleaning solvent. Clean all remaining parts except the shaft and bearing assembly with cleaning solvent; dry thoroughly.

CAUTION

Do not immerse the shaft and bearing assembly in cleaning solvent. This may wash dirt into the bearings and contaminate the lubricant. The solvent cannot be removed entirely from the assembly after immersion.



1. Bolt
2. Lock washer
3. Fan
4. V-belt
5. Hose clamp
6. Hose clamp
7. Bypass hose
8. Nipple
9. Hose clamp
10. Hose
11. Bolt
12. Lock washer
13. Gasket
14. Bolt
15. Lock washer
16. Bolt
17. Lock washer
18. Inlet pipe
19. Gasket
20. Pulley
21. Retaining ring
22. Pulley adapter
23. Retaining ring
24. Screw
25. Cover plate
26. Gasket
27. Shaft and bearing assembly
28. Impeller
29. Seal
30. Pump body

Figure 5-8. Water Pump and Fan Assembly, Exploded View

3. Inspect the fan for cracks and for bent blades; replace if damaged.

CAUTION

Do not attempt to straighten badly bent fan blades. Straightening blades may weaken them, resulting in failure during operation.

4. Inspect the fan pulley for cracks and distortion. Check the pulley groove(s) for rust and for rough spots. Clean up roughness or rust with fine emery cloth. Replace a worn or damaged pulley.

5. Inspect the fan belt(s) for cracks, deterioration, fraying, and wear. If more than one belt is used, replace as a matched set.

6. Inspect the bypass tube for cracks, dents, clogging, and other damage; replace a damaged bypass tube.

7. Inspect the pump shaft and bearing assembly for cracks, distortion, and signs of overheating. Check the bearings by rotating them on the shaft. If rough spots are detected, replace the shaft and bearing assembly using a service kit to assure the required press between pulley and shaft.

8. If the bearings can be reused, check the seal surface of the shaft for a rough or grooved condition. If these conditions exist, a new shaft and bearing assembly must be installed.

9. Inspect the impeller for cracks, broken vanes, and wear. Replace a damaged impeller.

10. Inspect the pump body assembly and inlet pipe for cracks and for worn or damaged threads. Replace if damaged beyond repair.

c. Reassembly and Installation.

Reassembly and installation is essentially the reverse of the removal and disassembly sequence; refer to figure 5-8. Note the following:

1. Press a new seal (29) into the pump body (30). Press only on the outer flange of the seal to avoid damaging the seal.

2. Coat the seal surface of the shaft with grease and press the shaft and bearing assembly (27) into the body. Press only on the outer bearing race and not on the end of the shaft.

3. After installing retaining ring (23), support the pump shaft on the outer shaft end and press the impeller (28) onto the shaft. There must be 0.010-inch clearance between the impeller and a straightedge placed across the rear face of the pump body. See figure 5-9.

4. Support the pump on the impeller end of the shaft and press the fan pulley adapter (22, figure 5-8) onto the shaft. Install the retaining ring (21).

5. Install a new cover gasket (26) and cover plate (25); and stake screws securely.

6. Install the pulley (20) on adapter (22).

7. Use bolts (14 and 16) and lock washers (15 and 17) to mount water inlet pipe (18) and new gasket (19) to the water pump.

8. Install the assembled water pump and inlet pipe and gasket (13) on the engine; secure with bolts (11) and lock washers (12). Tighten the attaching bolts evenly and alternately to prevent possible damage.

9. Connect the water inlet hose (10) to the water pump and connect the bypass hose (7).

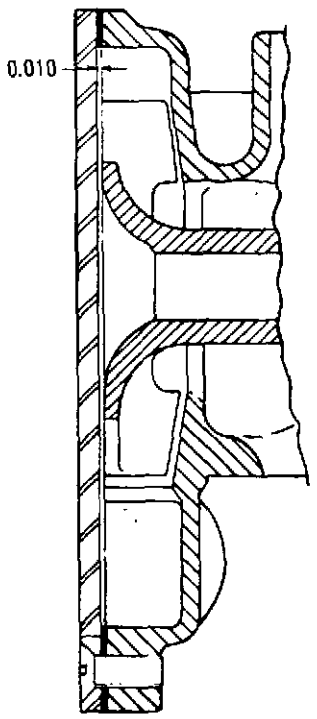


Figure 5-9. Water Pump Impeller Installation Dimension

10. Install the fan belt(s) (4) but do not adjust belt tension at this time.

11. Install the fan (3) and secure the fan and pulley (20) to the adapter (22) with four bolts (1) and lock washers (2). Rotate the fan and check for binding or excessive resistance. If excessive resistance is felt, remove water pump and check for proper rotation of shaft and bearing assembly and for proper impeller clearance.

12. Adjust the fan belt tension by positioning the alternator in or out from the engine. Tighten the adjusting bolts. When properly tensioned, the belt deflects 3/4 inch with thumb pressure at a point midway between pulleys.

13. Install the radiator, hoses, and support brackets. Fill radiator with water or antifreeze.

5-10. THERMOSTAT.

The thermostat, located in the thermostat housing on side of the cylinder head, regulates coolant flow through the engine. It will not allow coolant from the engine to circulate through the radiator until the water in the engine reaches operating temperature. Instead, it bypasses water from the cylinder head through the bypass tube to the inlet side of water pump, where it is again circulated through the engine.

a. Removal.

1. Open the radiator drain cock and drain the radiator enough so that coolant will not flow from thermostat opening.

2. Loosen the hose clamp and disconnect the water return hose from the thermostat housing.

3. Remove the thermostat housing (5, figure 5-16) and gasket (6) from the cylinder head by removing four bolts (1 and 3) and lock washers (2 and 4).

4. Remove the thermostat (7).

b. Cleaning and Inspection.

1. Discard gasket (6).

2. Clean the exterior of all parts with a cloth dampened in cleaning solvent.

3. Inspect the thermostat housing for cracks, distortion, loose plug (8), and other damage; replace a damaged housing.

4. Inspect the thermostat for cracks, excessive scale, and other damage. Immerse the thermostat and a thermometer in a pan of water so that both are raised from the bottom of the container. Heat the water. Check that the thermostat starts to open at about 180°F, and is fully open at 200°F ±5°. Replace a damaged or defective thermostat.

c. Installation.

1. Install the thermostat (7) in the cylinder head so that the cone-shaped end points out.

2. Install the thermostat housing (5) and gasket (6) on the cylinder head; secure with four bolts (1 and 3) and lock washers (2 and 4).

3. Connect the water return hose and secure with a hose clamp.

4. Fill the radiator with required coolant. Make sure the drain is closed.

5-11. FUEL SYSTEM.

The engine fuel system consists of a fuel filter, fuel transfer pump, fuel lines, fuel injector pump, and fuel nozzles, as shown on schematic diagram in figure 5-10.

The fuel transfer pump draws fuel from the fuel tank and pumps it through the filter(s) to remove particles of dirt and moisture. Fuel is then forced into the fuel injector pump where it is metered and delivered to the proper fuel nozzle at the correct time. The nozzle atomizes and distributes the fuel into the combustion chamber. Unused fuel returns to the inlet of the fuel injector pump. Some of the fuel oil passes into the housing where it lubricates and cools the pump and then is returned to the fuel supply tank, carrying with it any air that may have been in the pump.

5-12. FUEL TRANSFER PUMP.

The fuel transfer pump facilitates the flow of fuel from the fuel tank to the fuel injection pump. The mechanical-type pump is a conventional cam-driven diaphragm pump that mounts on the engine block. The electric fuel pump is operated by current from the battery while the engine is running. The electric fuel pump is normally mounted on a vibration-free frame member.

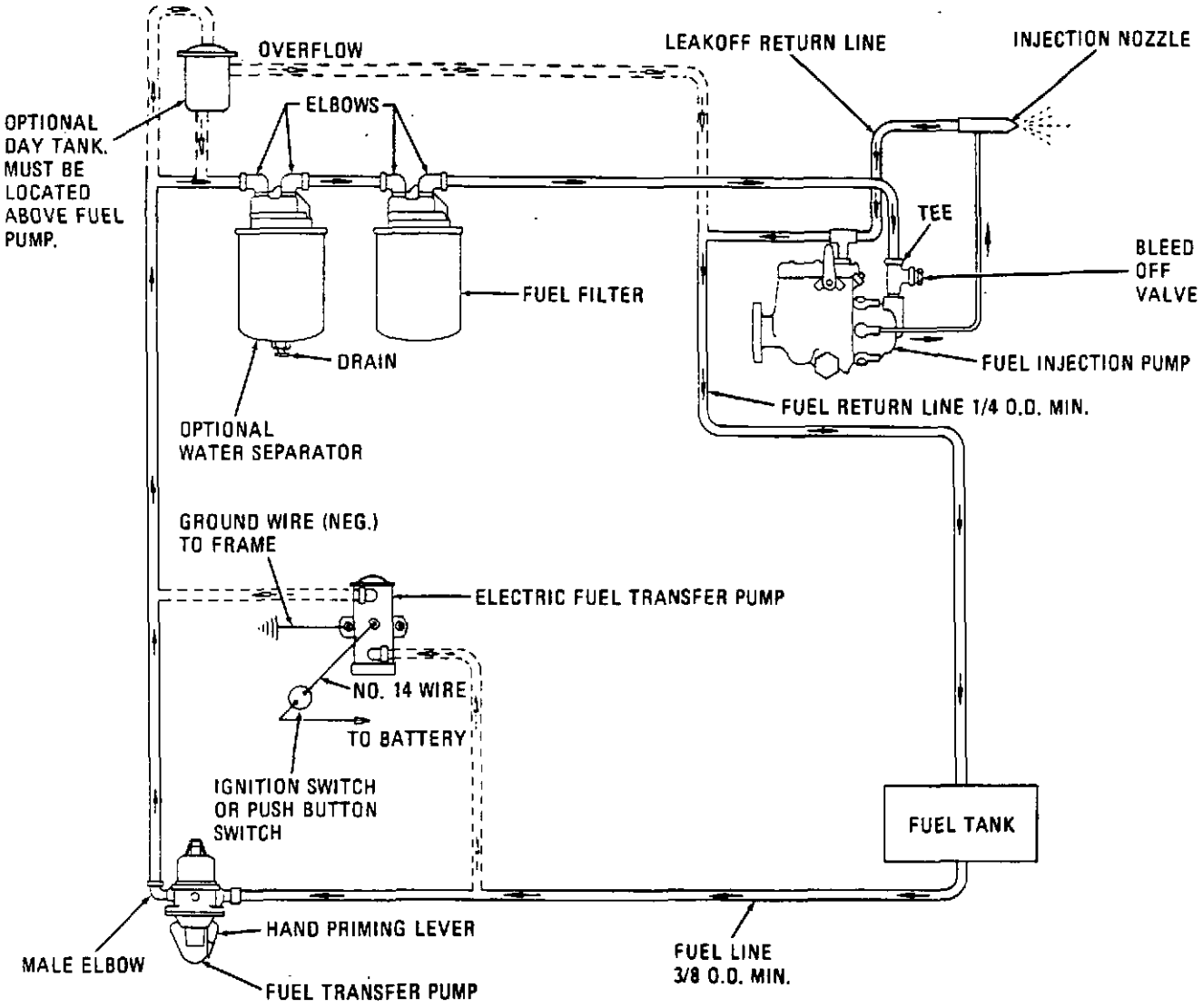


Figure 5-10. Fuel System Schematic Diagram

a. Mechanical Fuel Pump.

1. Removal.

(a) Shut off fuel to the engine.

(b) Disconnect and remove the fuel lines from the fuel tank at the pump. Be careful not to lose eyelets (5 and 6, figure 5-11) from fuel lines.

(c) Remove the fuel transfer pump (9) and gasket (10) from cylinder block by removing two bolts (7) and lock washers (8).

2. Cleaning and Inspection.

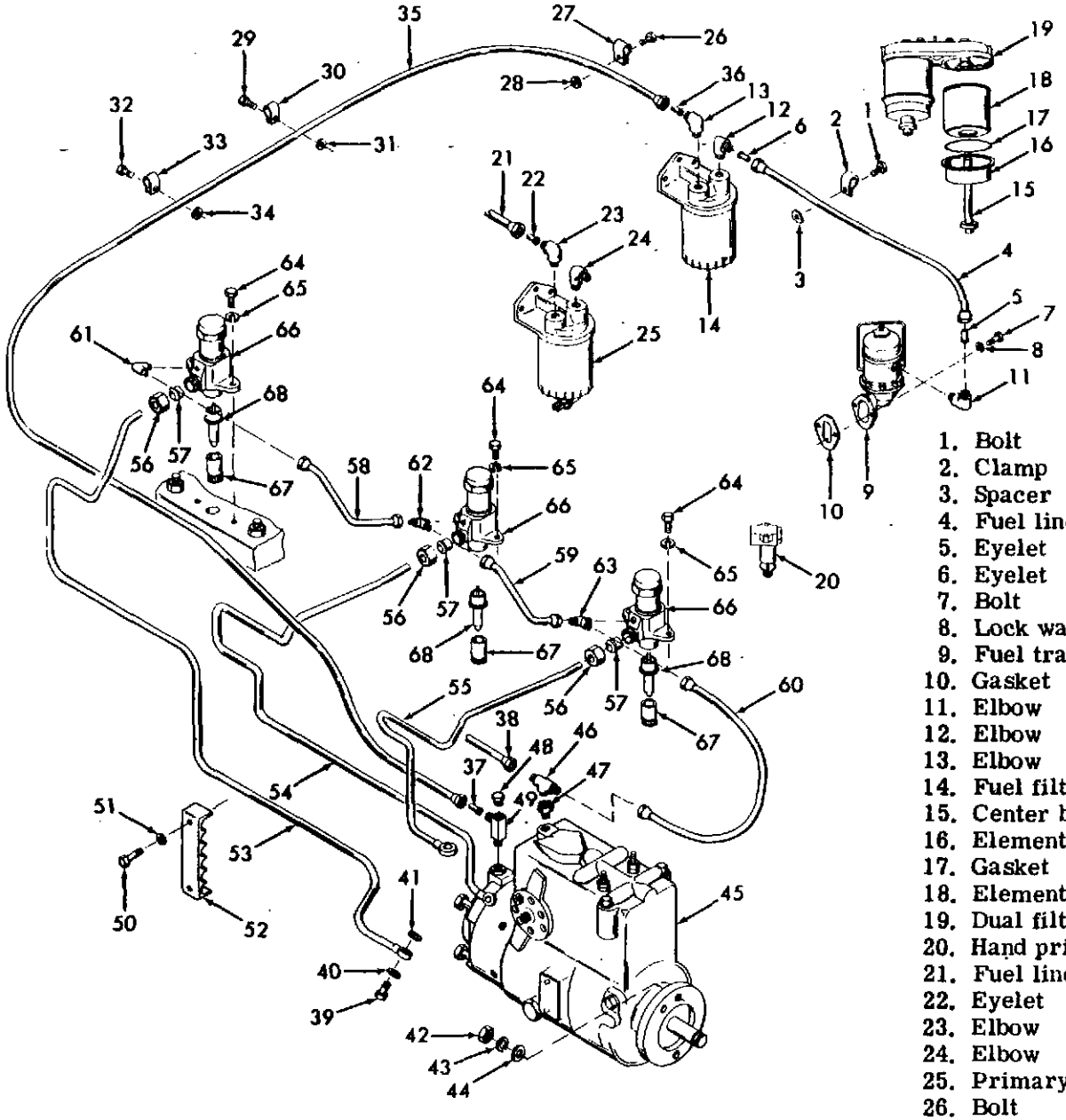
(a) Discard all gaskets.

(b) Wipe the exterior of the fuel transfer pump with a cloth dampened in cleaning solvent.

(c) Clean all remaining parts in cleaning solvent; dry thoroughly. Blow air through the fuel lines and fittings to make sure they are clear and unobstructed.

(d) Check the fuel pump rocker arm for free operation and excessive wear. Check that the priming lever operates freely without binding. Check for damaged threads.

(e) Inspect the fuel line for cracks, missing eyelets, kinks, and other signs of damage. Replace a damaged fuel line.



1. Bolt
2. Clamp
3. Spacer
4. Fuel line
5. Eyelet
6. Eyelet
7. Bolt
8. Lock washer
9. Fuel transfer pump
10. Gasket
11. Elbow
12. Elbow
13. Elbow
14. Fuel filter
15. Center bolt
16. Element retainer
17. Gasket
18. Element
19. Dual filter base assembly
20. Hand primer
21. Fuel line
22. Eyelet
23. Elbow
24. Elbow
25. Primary fuel filter
26. Bolt
27. Clamp
28. Spacer
29. Bolt
30. Clamp
31. Spacer
32. Bolt
33. Clamp
34. Spacer
35. Fuel line
36. Eyelet
37. Eyelet
38. Fuel line
39. Fuel passage bolt
40. Gasket
41. Gasket
42. Nut
43. Lock washer
44. Washer
45. Fuel injection pump
46. Pipe tee
47. Bushing
48. Pipe plug
49. Pipe tee
50. Bolt
51. Lock washer
52. Clamp
53. Fuel injection line
54. Fuel injection line
55. Fuel injection line
56. Nut
57. Ferrule
58. Fuel leakoff line
59. Fuel leakoff line
60. Fuel leakoff line
61. Elbow
62. Pipe tee
63. Pipe tee
64. Bolt
65. Lock washer
66. Nozzle holder
67. Retaining nut
68. Nozzle

Figure 5-11. Fuel Syste[illegible] Exploded View

(f) Inspect the fittings to make sure they are clear and check for damaged threads.

3. Installation.

(a) Using new gasket (10), install the fuel transfer pump (9) to the engine and secure with two bolts (7) and lock washers (8).

(b) Connect the fuel lines to the fuel transfer pump. Make sure the eyelet (5) is in the fuel line end. Perform an on-engine test of the fuel transfer pump; refer to following subparagraph 4.

4. Testing.

The operation of the fuel transfer pump can be tested on the engine by one of the following methods:

(a) Disconnect the fuel line from the fuel filter and install a 3/8-18 NPTF tee in the fuel filter base. Connect the fuel line and a pressure gauge to the pipe tee. Start the engine and run it at approximately 1800 rpm. The gauge should register a pressure of 3 to 4-1/2 psi. Replace the fuel pump if pressure is less than 3 psi.

(b) If no pressure gauge is available, test the fuel transfer pump by disconnecting the fuel line at the fuel filter. Crank the engine and check to see if fuel is being forcefully pumped from the fuel line. Replace pump if it is not operating properly.

b. Electric Fuel Pump.

1. Removal.

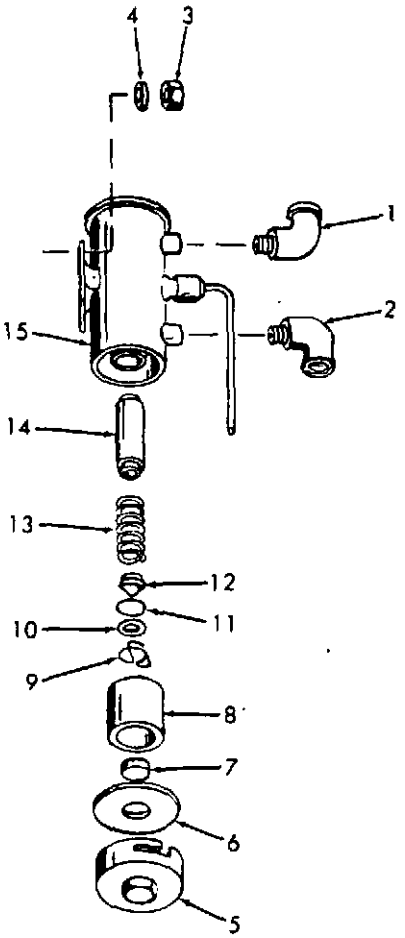
(a) Shut off fuel to the engine.

(b) Tag and disconnect the ground lead and electrical lead to either the start switch or fuel injection pump solenoid terminal from the electric fuel pump.

(c) Disconnect and remove fuel line from the fuel pump. Take care not to lose eyelets (5 and 6, figure 5-11) from fuel line.

(d) Remove elbow fittings (1 and 2, figure 5-12) from fuel pump.

(e) Remove the fuel pump by removing nuts (3) and insulating washers (4).



1. Elbow
2. Elbow
3. Nut
4. Insulating washer
5. Cover
6. Gasket
7. Magnet
8. Filter
9. Retainer spring
10. Washer
11. O-ring seal
12. Cup valve
13. Plunger spring
14. Plunger
15. Body

Figure 5-12. Electric Fuel Pump, Exploded View

2. Disassembly.

(a) Loosen the bottom cover (5) from bayonet fittings with a 5/8-inch wrench. Twist and remove cover from pump body (15) by hand.

(b) Remove cover gasket (6), magnet (7), and filter (8) from pump body.

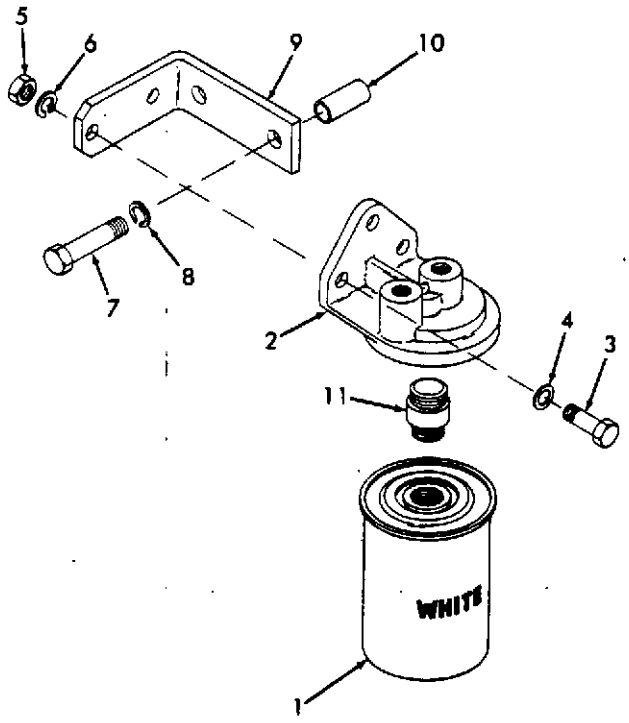
(c) Remove retainer spring (9) from pump plunger tube using thin nose pliers to spread and disengage ends of retainer from tube. Remove washer (10), O-ring seal (11), cup valve (12), plunger spring (13), and plunger (14) from tube.

3. Cleaning and Inspection.

(a) Discard gaskets and seals.

(b) Wash the filter in cleaning solvent and blow out dirt and cleaning solvent with dry, filtered compressed air.

(c) Clean all other parts with cleaning solvent and dry thoroughly with compressed air. Clean the inside of the tube with a cotton swab or with a clean cloth wrapped around a stick or metal rod.



1. Filter element
2. Base assembly
3. Bolt
4. Washer
5. Nut
6. Lock washer
7. Bolt
8. Lock washer
9. Bracket
10. Spacer
11. Adapter

Figure 5-13. Fuel Filter, Exploded View

(d) If plunger does not wash clean if there are any rough spots, clean gently w crocus cloth.

CAUTION

Do not tamper with seal at center of pump body mounting bracket. It retains the dry gas which surrounds the electrical components in the upper portion of the pump.

4. Reassembly and Installation.

To reassemble and install the electric fuel pump, refer to figure 5-12 and reverse the order of removal and disassembly. Note the following:

(a) Use new gaskets and seals.

(b) Make certain eyelets are in place in fuel lines before installing lines.

(c) Connect the electrical leads from the fuel pump to the proper terminals.

(d) Open fuel supply.

5-13. FUEL FILTER.

Fuel filters remove solid particles from the fuel, preventing the particles from damaging the injection pump and clogging fuel nozzle. Filter installation varies for different types of engine applications. Some systems use both a primary and secondary filter. A double-element filter which provides both primary and secondary filtering functions is used in some applications. Some engines are equipped with a water separator which should be drained periodically. Refer to the Maintenance section for routine filter maintenance instructions.

a. Removal.

1. Shut off fuel supply to the engine.

2. Disconnect the fuel lines from the fuel filter assemblies.

3. Remove the spin-on type fuel filter (1, figure 5-13) from the base assembly by turning off counterclockwise. Remove the fuel filter element (18, figure 5-11) (if used) by removing the center bolt (15) and element retainer (16).

2. Remove the timing hole cover plate from the injection pump. Turn the rotor in the direction of engine rotation so that the timing lines of the pump coincide as shown in figure 3-4. This times the pump so that it can be positioned on the engine which has the crankshaft aligned to the proper timing position.

NOTE

If the fuel pump drive shaft has been removed, note that the shaft has a tang with an off-center drilled hole that aligns with a matching drilled hole in the distributor rotor. Check the alignment of these holes to assure correct installation.

3. Install the vertically mounted fuel pump as follows:

(a) Be sure that the thrust spring and button is in the end of the drive shaft.

(b) Insert pump into opening in fuel pump pad and onto pump mounting studs. Install nuts (42, figure 5-11), lock washers (43) and flat washers (44), but tighten only finger tight.

(c) Rotate the pump until the timing marks are in register as shown in fugure 3-4. Tighten the nuts securely. See Timing Chart Page 3-7.

4. Install the horizontally mounted fuel pump as follows:

(a) Insert the drive shaft into the taper of the drive gear (43, figure 5-26) and onto mounting studs.

(b) Install nuts (42, figure 5-11), lock washers (43), and flat washers (44); tighten only finger tight.

(c) Install lock washer (42, figure 5-26) and nut (41) on fuel pump drive shaft. Rotate tapered shaft until timing marks are aligned as shown in figure 3-4, and tighten nut to 65 foot-pounds. See Timing Chart Page 3-7.

(d) Insert spring (50, figure 5-26) and thrust plug (51) in hole in end of fuel pump drive shaft.

(e) Install thrust plate gasket (23), thrust plate (22), washer (21), and bolts (20). Tighten bolts securely.

5. Install pump timing cover plate on the fuel pump.

6. Remove the fuel passage bolts (39, figure 5-11) from the ports of the fuel injection pump and connect the fuel lines to their respective ports. Refer to Table 5-1, Fuel Line Installation on Pump, for proper installation positions. Use new gaskets (40 and 41) when installing fuel lines. Tighten fuel passage bolts to 35 foot-pounds.

7. Connect the throttle and stop control linkages to the pump. Make sure the linkages are adjusted so that they provide full movement of the associated levers when controls are operated.

8. Connect the fuel return line (38) and fittings on top of the pump.

9. Connect the leakoff manifold line (60) to the pump.

10. Connect the fuel line (35) to the pipe tee (49) and the fuel filter. Make sure the eyelets (36 and 37) are in place in the line before installation.

11. Open fuel supply to engine from tank. Start the engine and check for fuel leaks.

5-15. FUEL INJECTION NOZZLES AND LINES.

Fuel injection nozzles receive fuel under high pressure from the fuel injection pump. The fuel charge is properly timed to engine operation so that the nozzle introduces a finely atomized spray into the cylinder at the exact instant necessary for the engine power stroke. If fuel nozzles are defective, they must be cleaned, tested, disassembled, and adjusted only by competent fuel system technicians. Handle nozzles with care at all times to prevent damage.

a. Removal and Disassembly.

1. Loosen fuel injection line nuts (56, figure 5-11) and disconnect the fuel lines from the injection nozzles. Do not remove nuts or ferrules (57) from the fuel lines.

2. Disconnect the fuel leakoff lines (58, 59, and 60) from each of the nozzles. Tag leakoff lines to assure that they'll be assembled to their original nozzles.

3. Remove each fuel injection nozzle and holder assembly from the cylinder head by removing two bolts (64) and lock washers (65). Tag each nozzle and holder assembly to identify its position in the cylinder head.

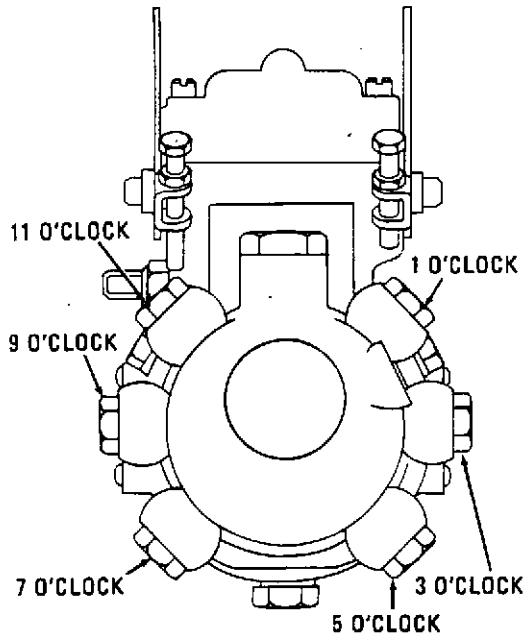


Table 5-1. Fuel Line Installation on Pump

Engine	No. 1 Port Position	Firing Order
All three-cylinder	11 o'clock	1-3-2
All four-cylinder	1 o'clock	1-2-4-3
Six cylinder:		
Vertical, with RH camshaft	7 o'clock	1-5-3-6-2-4
Vertical, with LH camshaft	1 o'clock	1-5-3-6-2-4
Horizontal, with RH camshaft	9 o'clock	1-5-3-6-2-4
Horizontal, with LH camshaft	1 o'clock	1-5-3-6-2-4

NOTE

The fuel nozzle and holder assemblies must be handled with care at all times. The nozzle and holder assemblies should only be disassembled, cleaned, and adjusted by a competent fuel system technician, using proper fuel nozzle testing equipment.

4. The fuel nozzle and holder assembly can be disassembled by using a twelve point, 3/4-inch box wrench to remove the fuel nozzle retaining nut (67). Carefully remove the fuel nozzle (68) and washer (if used) from the nozzle holder (66).

b. Cleaning and Inspection.

1. Discard all gaskets and seals.

2. Clean the fuel injection nozzles in clean diesel fuel or solvent; dry thoroughly with filtered, dry compressed air. Blow air through the fuel lines to assure that they are clear and unobstructed.

3. Inspect the fuel lines for cracks, dents, kinks, loose or damaged ferrules, and nuts with damaged threads. Replace damaged lines.

4. Visually inspect the fuel nozzle and holder assemblies for damaged threads, cracks, or other visible signs of damage. Replace a damaged fuel nozzle and holder assembly. Fuel nozzle and holder assemblies are to be repaired or serviced only by authorized service centers.

c. Installation.

1. Insert the assembled fuel nozzle and holder into the cylinder head bore from which it was removed.

2. Install two securing bolts (64) and lock washers (65) for each nozzle and holder assembly. Tighten the bolts evenly to assure proper alignment of the fuel nozzle and holder assembly. Uneven tightening of the securing bolts may distort the nozzle holder or nozzle tip. This will cause engine misfiring or possible destruction of the complete assembly. Use a torque wrench to progressively tighten the bolts to 25 to 30 foot-pounds to insure equal tension on both sides of the flange of the nozzle and holder assembly.

3. Install and connect the fuel lines (53, 54, and 55); tighten the nuts (56) securely but not excessively. If new fuel lines are installed, install new ferrules (57) and nuts (56) on lines during installation.

4. Install and connect the leakoff manifold lines (58, 59, and 60) between proper nozzles.

5. If removed, connect the fuel lines and leakoff lines to proper fittings on the fuel injection pump. When installing fuel lines, use new gaskets (40 and 41).

6. Open fuel supply to engine; start engine and check for leaks in the fuel system. Correct leaking by tightening fittings. If necessary remove, inspect, and reclean the leaking components.

4. Remove the base assembly (2, figure 5-13) from the mounting bracket (9) by removing two securing bolts (3), washers (4), lock washers (6), and nuts (5).

b. Cleaning and Inspection.

1. Discard fuel filter elements and gaskets.

2. Clean all parts in cleaning solvent; dry thoroughly.

3. Inspect the base assembly for cracks, stripped threads, and distortion. Remove and replace adapter (11) if damaged.

4. Inspect the fittings to make sure they are clear. Check for damaged threads.

c. Installation.

1. Install the base assembly (2, figure 5-13) on the mounting bracket. Use bolts (3), washers (4), nuts (5), and lock washers (6).

2. Install the elbows (12 and 13, figure 5-11) in the base assembly.

3. Make sure the gasket of the spin-on filter rotates freely by hand in the filter, then coat it lightly with engine oil. Install filter until it makes contact with the base, then tighten one turn by hand. Install new elements (18) and gaskets (17) in the dual filter retainer; secure to base with center bolt (15) and retainer (16).

4. Connect fuel lines to fittings in base. Make sure the eyelets are in place in the fuel lines.

5-14. FUEL INJECTION PUMP.

The fuel pump draws in fuel, distributes, and delivers an accurately metered amount to each injection nozzle in properly timed relationship. A flyball-type governor provides automatic control of the fuel charge in accordance with the engine load at any given speed range within the minimum and maximum speed settings.

The pump has no ball bearings, poppet valves, or internal gears. It is driven by an idler gear at one half the speed of the crankshaft. It requires no special lubrication system since it is lubricated with the filtered fuel it pumps. The pump mechanism, governor, and pressure regulating piston are enclosed in an oil-tight compartment in which pressure is maintained, thus preventing entrance of dust, water, or any foreign matter.

CAUTION

Fuel pump or fuel nozzle repairs should be made only by authorized service centers or competent fuel system technicians. It is recommended that faulty fuel pumps be returned to the pump manufacturer for servicing.

NOTE

If severe pump failure occurs, both pump and nozzles should be sent to the manufacturer for servicing, since one or more of the nozzles may have caused pump failure. Number the nozzles so that they can be reinstalled in their original positions in the engine.

a. Removal.

Use the following procedure to remove the fuel pump from the engine. If this sequence is followed in detail, the reinstallation of the pump will be easier.

1. Shut off the fuel supply to the engine.

2. Clean and wash down the engine adjacent to the fuel injection equipment to prevent dirt from entering the system when the lines are disconnected.

3. Remove the cover plate from the side of the fuel pump and turn over the engine crankshaft in the direction of its normal rotation until the timing lines on the pump can be seen through the timing hole as shown in figure 3-4. Align the timing lines.

4. Check that the piston of the cylinder to which the injection pump is timed is at the proper position before top center. This can be determined as follows:

(a) Remove the injection nozzle from the cylinder to which the pump is timed (refer to table 3-3). Place thumb over the nozzle opening and feel for air being forced out during the compression stroke as the engine is cranked.

(b) Check the timing mark on the flywheel in relation to the timing mark on the fuel pump. With the fuel injection pump timing

marks exactly aligned as shown in figure 3-4, the exact pump timing is indicated by the flywheel degree mark which is aligned with the timing pointer. Record this information for reference when reinstalling the fuel injection pump. (This information is also shown on the engine nameplate.)

5. Disconnect and remove fuel line (35, figure 5-11). Disconnect the leakoff manifold line (60). Disconnect the fuel return line (38) from the pump to the supply tank.

6. Disconnect the throttle and stop controls.

7. Disconnect the fuel injection lines (53, 54, and 55) from the fuel injection pump by removing fuel passage bolts (39) and gaskets (40 and 41). After removing each fuel line, reinstall the bolts (39) to keep dirt from entering the pump.

8. Remove vertically mounted fuel pumps as follows:

(a) Remove the nuts (42), lock washers (43), and flat washers (44) that secure the fuel injection pump (45) to the pump attaching pad.

(b) Pull straight up on fuel pump to disengage the drive shaft from its coupling slot in the oil pump. The drive shaft will remain in the fuel pump.

9. Remove horizontally mounted fuel pumps as follows:

(a) Remove bolts (20, figure 5-26) and lock washers (21) that secure the thrust plate (22) to the gear housing cover; remove thrust plate (22) and gasket (23).

(b) Remove thrust plug (51) and spring (50) from fuel pump drive shaft.

(c) Remove nut (41) and washer (42) that secure fuel pump drive gear (43) to pump drive shaft.

(d) Remove the nuts (42, figure 5-11), lock washers (43) and flat washers (44) that secure fuel pump to gear housing.

(e) Disengage pump from gear housing approximately 1/4 inch. Using a soft hammer, tap fuel pump drive shaft to remove pump from drive gear.

CAUTION

When a pump is removed from an engine for repair, secure the throttle in the wide open position after removal. This will prevent the governor weights from dislodging inside the pump housing while the pump is in transit or storage.

10. Remove the fittings (46, 47, and 49, figure 5-11) from the fuel injection pump and install plugs or tape to keep dirt from entering the pump.

b. Cleaning and Inspection.

1. Discard and replace all gaskets and seals.

2. Clean the exterior of the fuel injection pump with a cloth dampened with cleaning solvent; dry thoroughly.

3. Blow clean, dry compressed air through the fuel lines to make sure they are clear and unobstructed.

4. Inspect fuel lines for cracks, dents, kinks, and other damage; replace damaged fuel lines. Check for missing eyelets (36 and 37, figure 5-11) in the ends of the plastic fuel lines.

5. Check the fittings for damaged threads and to make sure fuel passages are clear.

6. Always remove the pump to a clean place for repair.

c. Installation and Timing.

1. Rotate the crankshaft to align the engine flywheel at the proper (before top dead center) degree mark of the timed cylinder on its compression stroke. If the disassembly procedure was followed, and the engine crankshaft position has not been changed since pump removal, the flywheel timing mark should be aligned.

CAUTION

Do not rotate the pump shaft backwards to align the internal timing marks. Always rotate it in the same direction as the engine crankshaft, when viewed from the front or timing gear end of the engine.

5-16. AIR SUPPLY AND EXHAUST SYSTEMS.

After combustion occurs in the engine cylinder, the burned gases must be removed from the cylinder and replaced by fresh, clean air. On naturally aspirated engines, the exhaust stroke of the piston forces out the burned gases and the intake stroke draws in air required for combustion. This scavenging process can be aided by a turbocharger. The turbocharger, driven by the engine exhaust gases, supplies the engine with a greater amount of fresh air, permitting combustion of a greater amount of fuel. This results in increased power output.

The intake air first passes through an air cleaning system, which removes all foreign matter, dust, and grit which would otherwise cause excessive engine wear. This is accomplished by a dry-type air cleaner which filters the air through a porous paper element.

From the air cleaner, the air passes into the intake manifold where it is distributed into the cylinders for combustion. After combustion occurs in the cylinders, the hot exhaust gases are forced out of the cylinder and pass into the exhaust manifold. From the manifold they pass to the atmosphere through the muffler or the turbocharger.

CAUTION

The turbocharger acts as an efficient muffler. Do not attempt to install an additional muffler on a turbocharged unit. This will decrease efficiency of the turbocharger.

The breather cap mounted on the cylinder head cover allows clean, fresh air to enter the crankcase and accumulated gases to escape, maintaining crankcase at atmospheric temperatures.

5-17. AIR CLEANERS.

It is important to perform extensive inspections of the air cleaner system from time to time. Figure 5-14 illustrates a typical air intake system. Check particularly for the following:

a. Check carefully for leaks which could allow unfiltered air to enter the engine. Make sure all gaskets are in good condition and that all tubes, hoses, and pipes are free from cracks, holes, and faulty connections.

b. Check the element of dry-type air cleaners for cracks, holes, clogging, and defective sealing surfaces. If the element is damaged, or if it has been cleaned more than six times, the element must be replaced.

c. Check the air cleaner-to-manifold hoses. Accumulations of dust and dirt in the interior of the hoses indicate inefficient air cleaner operation. Determine and correct the reason for the faulty operation.

d. Check the air cleaner mounting to make sure it is secure. A loosely mounted air cleaner may shake loose the interconnecting lines to the engine.

NOTE

Maximum allowable restriction of a dirty air filter is 25 inches of water.

5-18. INTAKE MANIFOLD.

The intake manifold maintains a supply of fresh air to each cylinder so that air can be drawn into the cylinder on the intake stroke. In some applications, the air cleaner is mounted directly onto the intake manifold. On turbocharged engines, the air supply to the cylinder is kept under pressure by the turbocharger to provide additional power from the engine. Ether-type cold weather starting aids supply an ether charge directly into the manifold to facilitate starting.

a. Removal.

1. Remove the air cleaner or air cleaner connections from the manifold. Refer to figure 5-14.

2. Remove the manifold attaching nuts (16) and lock washers (17) from studs (21) in cylinder head; remove the intake manifold (18) and gaskets (19).

b. Cleaning and Inspection.

1. Discard all gaskets.

2. Clean the manifold with cleaning solvent. Make sure all gasket mounting surfaces are clean. Dust and dirt in the interior of the manifold indicate poor air cleaner operation. Correct the cause at reassembly.

3. Inspect the intake manifold for cracks, distortion, damaged threads, and other damage. Replace a damaged manifold.

4. Replace damaged manifold mounting studs or intake pipe mounting studs.

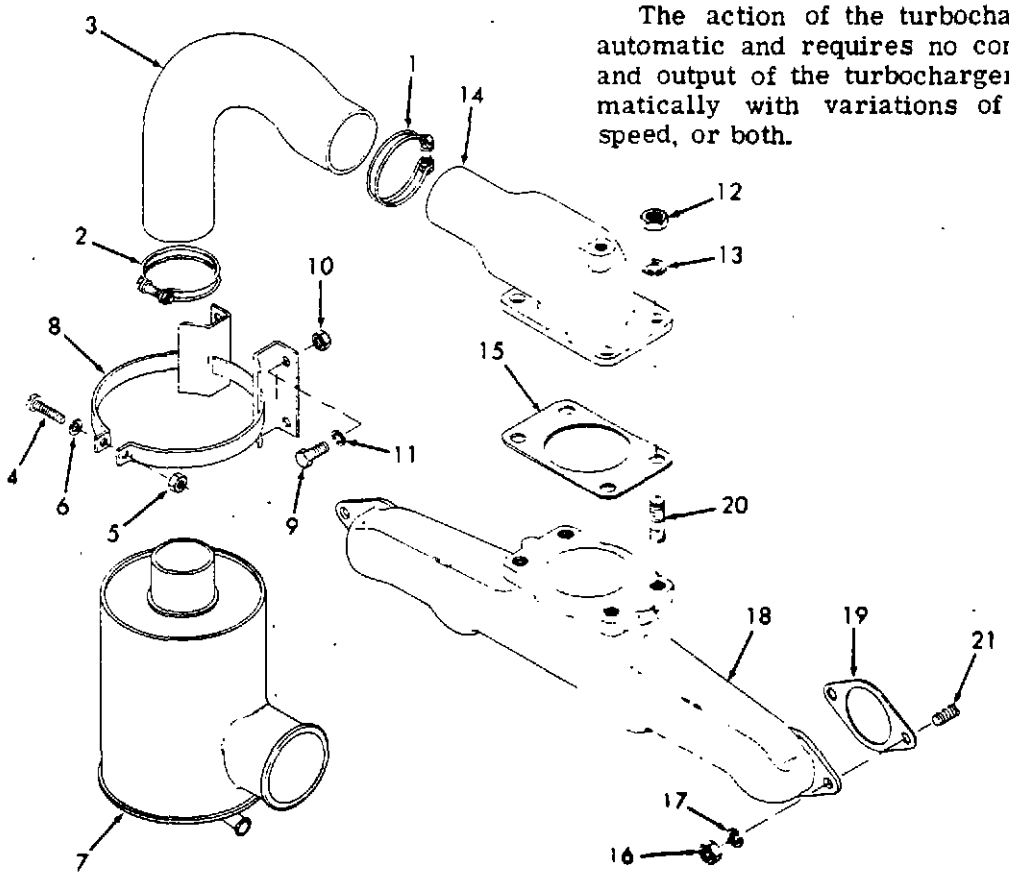
c. Installation.

Always use new gaskets (19, figure 5-14) when assembling the manifold (18) to the engine. Secure with nuts (16) and lock washers (17). Tighten all nuts lightly at first: then, starting at the center of the manifold, work outward, tightening the nuts in progressive steps to 30 to 40 foot-pounds torque.

5-19. TURBOCHARGER.

The turbocharger is a self-contained unit composed of a gas turbine and a centrifugal blower mounted on a common shaft with the necessary surrounding castings. The exhaust gas from the engine is forced into the turbine side of the turbocharger, where the energy of the gas is used to drive the turbine. The blower mounted on the opposite end of the shaft forces air under pressure into the intake system. By providing a greater amount of fresh air, a greater amount of fuel can be burned. This increases power output from the turbocharged engine.

The action of the turbocharger is entirely automatic and requires no control. The speed and output of the turbocharger will vary automatically with variations of engine load or speed, or both.



1. Hose clamp
2. Hose clamp
3. Hose
4. Bolt
5. Nut
6. Lock washer
7. Air cleaner
8. Clamping band
9. Bolt
10. Nut
11. Lock washer
12. Nut
13. Lock washer
14. Intake pipe
15. Gasket
16. Nut
17. Lock washer
18. Intake manifold
19. Gasket
20. Stud
21. Stud

Figure 5-14. Typical Air Intake System, Exploded View

Turbochargers are ruggedly constructed and have a rotor assembly which is fitted and finely balanced to operate at speeds which may exceed 75,000 rpm. Rotating force is obtained from hot exhaust gases which rotate the turbine rotor. This rotating force is transmitted through a sleeve-bearing supported shaft to a second rotor which draws in fresh, cool air and compresses it in the intake manifold system from which the cylinders are charged as the intake valves open. The shaft and sleeve bearing are lubricated and cooled by engine lubricating oil filtered by the turbocharger oil filter.

The exhaust system of a turbocharged engine installation must be very carefully designed to eliminate restriction of the free flow of exhaust gases from the turbocharger. The turbocharger exhaust outlet pipe flange is normally shipped with engine equipped with turbochargers. The flange is threaded to accept the recommended size outlet pipe. No reduction in this pipe size is permissible. Bends or turns in the outlet pipe must be limited to a minimum radius of 12 inches. For installations requiring a radius less than 12 inches, write to White Engines, Inc., Engineering Department, Canton, Ohio, U.S.A., for specific recommendations.

NOTE

Back pressure in the exhaust system, measured near the turbocharger, should not exceed 2.5" Hg or 35" H_2O. An increase in exhaust back pressure will result in a corresponding decrease in engine power output.

See Basic Safety Precautions Page 1-4.

Mufflers are not recommended for turbocharger-equipped engines. The turbocharger is an efficient muffler due to the speed and design of the turbocharger rotor.

Turbocharger repairs should be made only by authorized service centers or competent turbocharger technicians.

a. Removal.

1. Loosen hose clamp and disconnect air cleaner hose from inlet side of the turbocharger.

2. Remove outlet pipe from adapter flange on turbocharger.

3. Loosen clamps and disconnect hose between turbocharger and air intake tube assembly. Remove air intake tube assembly by removing bolts and washers that secure it to air intake manifold.

4. Disconnect and remove the oil inlet hose, oil drain hose, and fittings from the turbocharger.

5. Remove the turbocharger by removing nuts and lock washers that secure it to the exhaust manifold.

b. Cleaning and Inspection.

1. Wipe the exterior of the turbocharger with a cloth dampened in cleaning solvent. Clean all remaining parts with cleaning solvent and dry thoroughly. Blow compressed air through the hoses and fittings to make certain they are clear and unobstructed.

2. Inspect all hoses for cracks, splits, signs of deterioration, damaged threads, or other damage. Replace damaged hoses.

3. Inspect all remaining parts for cracks, distortion, damaged threads, or other damage. Repair or replace as necessary.

c. Installation.

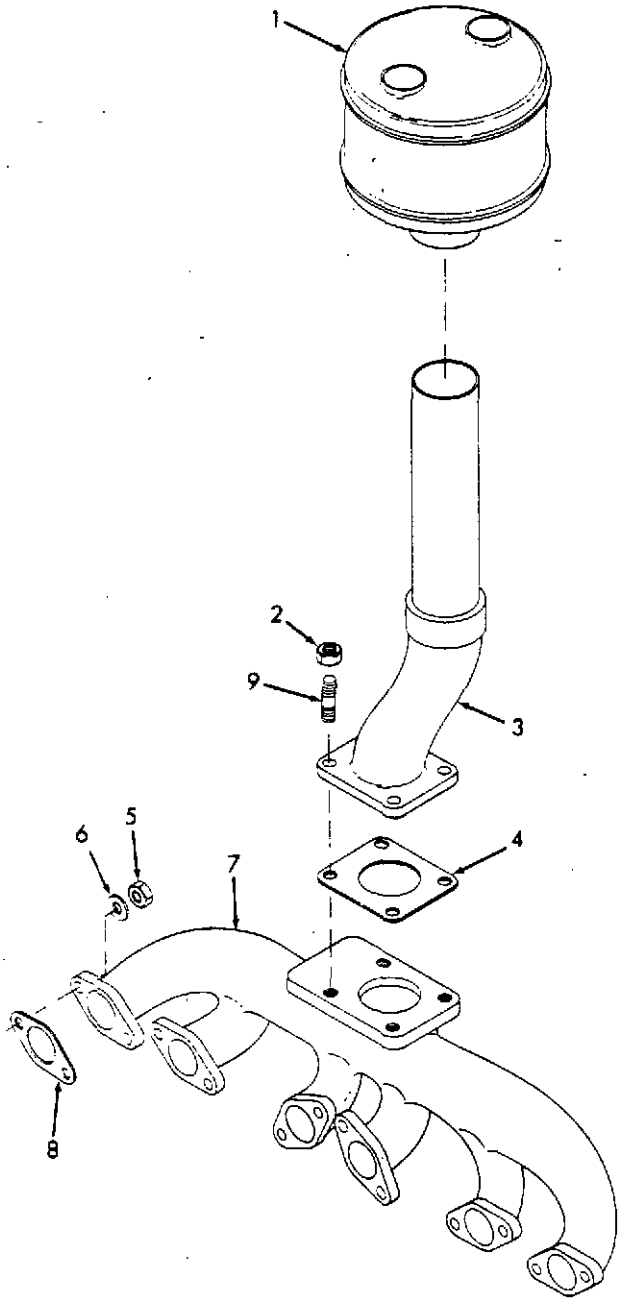
Always use new gaskets when installing the turbocharger. Tighten the turbocharger mounting nuts alternately and progressively to prevent distortion of the mounting flange. After installation, start the engine and check for air, exhaust, and lubricant leaks.

5-20. EXHAUST MANIFOLD.

The exhaust manifold conducts the hot exhaust gases from the cylinders and out of the engine. In some applications, an exhaust pipe and muffler are mounted on the manifold. On turbocharged engines, the turbocharger is flange-mounted on the manifold outlet so that the hot gases are forced directly into the turbine side of the turbocharger.

a. Removal.

1. Remove the muffler (1, figure 5-15) or turbocharger from the exhaust manifold. Remove any muffler adapters (3) and gaskets (4) used by removing attaching nuts (2) from manifold studs (9).



1. Muffler
2. Nut
3. Adapter
4. Gasket
5. Nut
6. Washer
7. Exhaust manifold
8. Gasket
9. Stud

Figure 5-15. Muffler and Exhaust Manifold, Exploded View

2. Remove the exhaust manifold (7) and gaskets (8) from the engine by removing nuts (5) and washers (6).

b. Cleaning and Inspection.

1. Discard all gaskets.

2. Clean the exhaust manifold and related parts with a wire brush.

3. Inspect the exhaust manifold for cracks, distortion, severe rust, and damaged threads. If the studs are damaged, replace them.

4. Inspect the remaining parts for cracks, distortion, corrosion, damaged threads and other damage: replace damaged parts.

c. Installation.

Always use new exhaust gaskets (8) at installation. Tighten the nuts to 30 to 40 foot-pounds torque. Start the tightening sequence at the center of the manifold and work outward, tightening the nuts in progressive steps.

5-21. ELECTRICAL SYSTEM.

The engine electrical system consists primarily of a starting motor, alternator, and voltage regulator. Some engines may require extra circuitry for a solenoid-operated fuel injection pump, and an electric fuel primer.

The starting motor cranks the engine when the start switch closes the circuit between the battery and the motor. The Bendix drive engages the starting motor with the engine flywheel when the motor cranks the engine, and disengages when the engine starts.

The alternator provides charging current for the battery. The voltage regulator controls the battery charging rate to maintain an adequate charge on the batteries and to prevent overcharging. Battery charge and discharge rates are usually monitored by an ammeter located on the engine control panel.

Some engines are equipped with a fuel injection pump containing a solenoid-type stop control mounted inside the pump cover. There are two distinct types of solenoids. One is energized to run and requires a switch which is turned on to start and run the engine, and turned off to stop the engine. The second type is energized only to stop the fuel injection pump operation. A switch is closed to energize the solenoid and held closed until the engine is fully stopped. The switch is then opened, deenergizing the solenoid, and the fuel injection pump returns to the run position.

Some engines are equipped with an electric fuel transfer pump that is wired either to the start switch or fuel injection pump solenoid contacts, when solenoid is used.

5-22. STARTING MOTOR

The starting motor cranks the engine when the switch closes the circuit between the storage battery and the starter. Refer to manufacturer's service manual for repair and testing of the starting motor.

Some starting motor models have oil cups and require periodic lubrication as indicated in Section III. If no oil cups are provided, the starting motor requires lubrication only at overhaul.

If the starting motor fails to crank the engine, or cranks erratically, or if it fails to crank with sufficient speed to start the engine, check for poor cable connections, damaged leads, or worn brushes. Replace brushes if worn to less than half their original length. Clean and tighten cable and wire connections. If the starting motor still fails to operate properly, take it to an authorized service center.

a. Removal.

1. Disconnect and tag the electrical leads to the starting motor solenoid. Tape electrical lead ends to prevent shorting.

2. Remove the three nuts and lock washers securing the starting motor to the bellhousing.

b. Cleaning.

To clean the starting motor, wipe the exterior with a cloth dampened in cleaning solvent; dry thoroughly.

c. Installation.

1. Align the three holes on the starting motor mounting flange with the studs on the bellhousing.

2. Secure the starting motor with nuts and lock washers.

3. Connect the electrical leads to the starting motor solenoid.

4. Check starter operation. The starter drive must engage the ring gear smoothly and quietly, and the starting motor must crank the engine smoothly, without excessive noise, and with enough speed to start the engine.

5-23. ALTERNATOR AND REGULATOR.

The alternator and regulator operate together to maintain the required charge on the battery. The ammeter provides a good check of alternator output and regulator control. If the alternator charges at a higher rate immediately after starting and then slowly tapers off to a near-zero charging rate, the alternator is probably functioning properly.

Faulty operation may be due to high resistance wiring connections, broken wires, faulty ground connection, or worn brushes. Replace brushes if they are worn to less than half their original length.

Some alternator models require periodic lubrication as indicated in Section III. This is essential to the proper operation of the alternator. A noisy alternator is usually a sign of bearing failure.

If the alternator fails to retain the battery charge, and replacement of the voltage regulator fails to correct the problem, take the alternator to an authorized service center for repairs.

a. Removal.

1. Disconnect and tag electrical leads from the alternator.

2. Loosen the hinge bolt in the mounting bracket and loosen the bolt in the alternator adjusting arm. Remove the belts from the alternator pulley.

3. Support the alternator and remove the hinge bolt. Remove the alternator mounting bolt from adjusting arm; remove the alternator from the engine.

4. Remove the pulley and alternator fan by removing nut and lock washer from alternator shaft.

b. Cleaning and Inspection.

1. Wipe the exterior of the alternator with a cloth dampened in cleaning solvent. Be careful not to allow solvent to enter the alternator.

2. Clean all remaining parts with cleaning solvent; dry thoroughly.

3. Inspect all parts for cracks, distortion, damaged threads, or other damage. Replace any damaged parts.

c. Installation.

1. Mount the fan and pulley on the alternator shaft and secure with a nut and lock washer.

2. Install alternator and secure with hinge bolt and adjusting arm bolt, but do not tighten. Place belt(s) on alternator pulley and adjust belt tension. The belt(s) tension is correct when thumb pressure midway between pulleys deflects the belt(s) 3/4 inch. Tighten bolts.

3. Connect electrical leads to alternator.

5-24. ROCKER ARM ASSEMBLY.

The rocker arm assembly is mounted on top of the cylinder head to operate the intake and exhaust valves. The rocker arms are pivoted on the rocker arm shaft by the camshaft-operated push rods which engage one end of the rocker arms. As the rocker arms raise at one end, the opposite end pushes down on the ends of the valve stems to open the valves. In this manner, the valves control the intake and exhaust cycles of the engine. The rocker arms are pressure lubricated through an axial passage in the rocker arm shaft. When disassembling earlier model rocker arm assemblies, take care to identify the positions of the shaft supports to facilitate reassembly. On later model rocker arm assemblies, shaft supports are identifical and require no differentiation. Spacer washers are used on the shaft to space the rocker arms.

a. Removal and Disassembly.

1. Remove the cylinder head cover (12, figure 5-16) and gasket (13) by removing the nuts (9) and washers (10 and 11) securing it to the cylinder head (33).

2. Remove the nuts (15) and washers (16) that secure the rocker arm assembly to the cylinder head. On six-cylinder engines, the rocker arm shaft is in two sections. When removing rocker arms from six-cylinder engines, it is suggested that a wire be used between the No. 1 and No. 12 rear rocker arms to hold the two shaft assemblies together and prevent accidental disassembly of the rocker arms. Carefully lift the complete assembly from the cylinder head.

3. Disassemble the rocker arm assembly by removing the retaining rings (17) from the shaft ends. Slide the shaft supports (18), rocker arms (19), spacing springs (20), and spacers (21 and 22) from the rocker arm shaft (23). Earlier engines used several sizes of shaft supports. Facilitate reassembly by marking the order and position of the shaft supports as removed.

b. Cleaning and Inspection.

1. Clean all parts with cleaning solvent and dry thoroughly with compressed air. Make sure all gasket material is removed from sealing edge of cylinder head cover.

2. Blow out the rocker arm lubricating passages with compressed air.

3. Check the rocker arms for cracks and surface imperfections by magnetic inspection.

4. Check the spacer springs for damaged ends and misaligned coils. A 10-pound load on the spring should compress it to 1 inch. Replace a damaged or weak spring.

5. Check the ball end of the rocker arm adjusting screw (25) and the rocker arm. Replace the screw if flat on bottom or if there is evidence of scratching or wearing. If rocker arm contact surfaces are worn or damaged, replace with new rocker arm.

6. Check for damaged threads on all adjusting screws and rocker arms. The adjusting screws are self-locking and must take a minimum of 3 foot-pounds torque to turn into the rocker arms. Replace any loose-fitting adjusting screws.

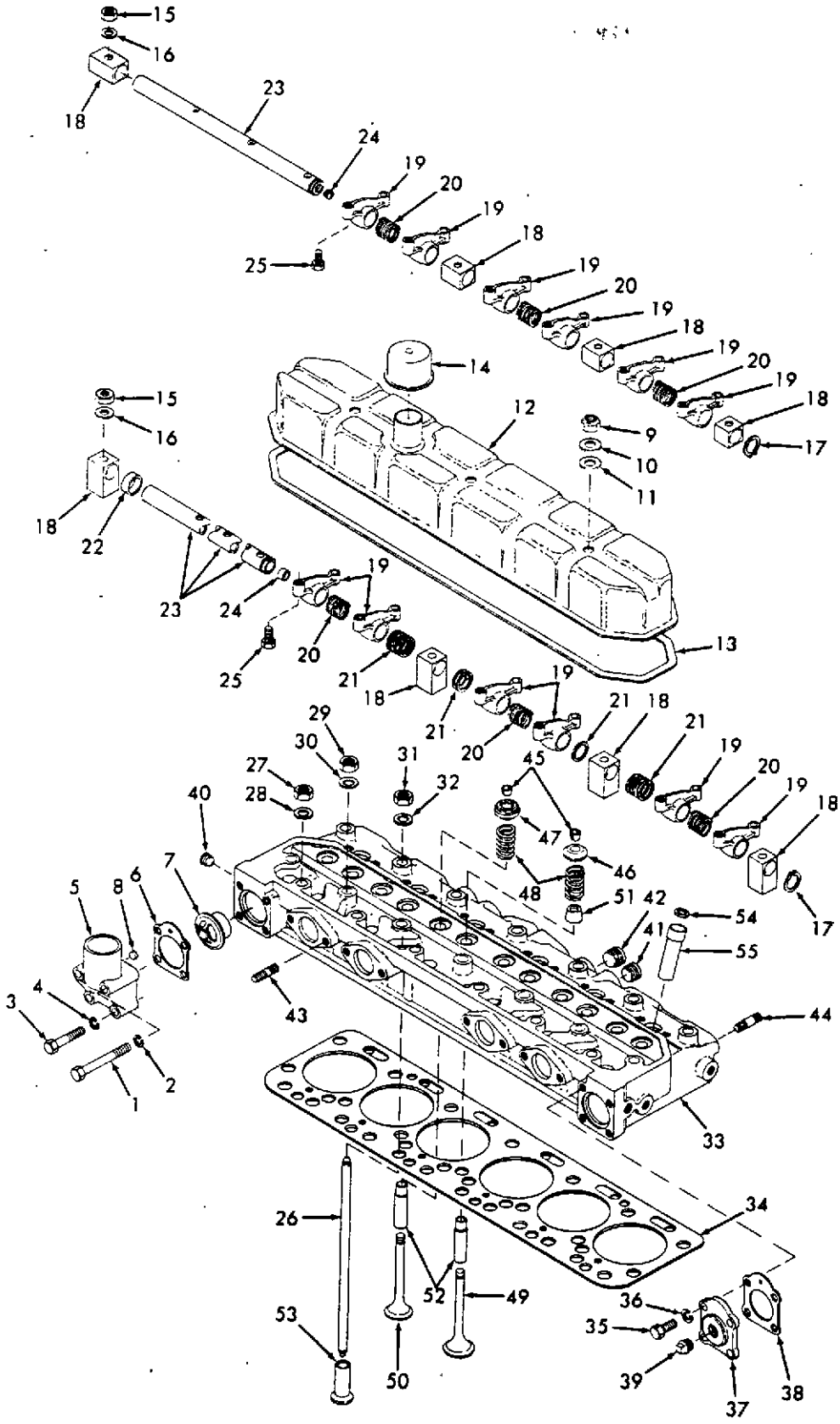
7. Check the rocker arms for worn shaft bore diameter. The maximum allowable diameter is 0.8665 inch. Discard worn rocker arms if damaged or worn beyond this limit.

8. Check rocker arm shaft for wear or scoring. If shaft has shoulders or ridges due to rocker arm action on shaft, replace with new shaft. The rocker arm shaft diameter should not be worn to less than 0.8560 inch.

9. Inspect the cylinder head cover for cracks, dents, and distorted sealing area. Discard and replace if damaged. Make sure the breather screen is clean and in good condition and that the breather cap fits securely on the cylinder head cover.

c. Reassembly and Installation.

The rocker arms are lubricated by means of oil forced through a hollow cylinder head stud into the rocker arm shaft. Oil is forced



1. Bolt
2. Lock washer
3. Bolt
4. Lock washer
5. Thermostat housing
6. Gasket
7. Thermostat
8. Plug
9. Nut
10. Washer
11. Washer
12. Cylinder head cover
13. Gasket
14. Breather cap
15. Nut
16. Washer
17. Retaining ring
18. Shaft support
19. Rocker arm
20. Spring
21. Spacer
22. Spacer
23. Rocker arm shaft
24. Shaft plug
25. Adjusting screw
26. Pushrod
27. Nut
28. Washer
29. Nut
30. Washer
31. Nut
32. Washer
33. Cylinder head
34. Gasket
35. Bolt
36. Lock washer
37. Water outlet cover
38. Gasket
39. Pipe plug
40. Pipe plug
41. Pipe plug
42. Pipe plug
43. Stud
44. Stud
45. Seat lock
46. Valve spring seat
47. Valve rotator
48. Spring
49. Intake valve
50. Exhaust valve
51. Intake valve stem seal
52. Valve guide
53. Tappet
54. Washer
55. Fuel nozzle holder sleeve

Figure 5-16. Rocker Arm, Cylinder Head, and Valve Assemblies, Exploded View

out through small holes in the rocker arms, over the valve stems and push rods. For proper lubrication it is imperative that the rocker arm and shaft be correctly assembled and installed on the engine. To reassemble and install the rocker arm assembly, proceed as follows:

1. Coat the rocker arm shaft (23) lightly with clean lubricating oil. Slide the shaft supports (18), rocker arms (19), spacing springs (20), and spacers (21 and 22) onto the rocker arm shaft. Install the spacers on the shaft of engine models that use them, as indicated in figure 5-17. On the three- and four-cylinder engines, make certain that the oil holes in the shaft face downward and toward the camshaft side of the engine, as shown in figure 5-18. On older type D Series engines, there are two oil holes for each rocker arm and they must face downward as shown in figure 5-18. Newer type rocker arms shown on figure 5-17 have only one mounting hole which must be assembled downward. On older D Series engines, the shaft supports (18, figure 5-16) vary in size and mounting hole location and must be assembled exactly as shown in figure 5-19. Install the retaining rings (17, figure 5-16) on each end of the rocker arm shaft.

2. Before installing the rocker arm assembly on the cylinder head, check that rocker arms are properly installed and that they move freely on the shaft. It will aid installation of the six-cylinder engine rocker arm assembly if a wire is used to hold the shaft together as in removal.

3. Install the rocker arm assembly over the cylinder head stud extensions and seat it firmly on the cylinder head. Make certain the rocker arm adjusting screws (25, figure 5-16) are positioned over the pushrods (26). Secure the rocker arm assembly to the cylinder head with nuts (15) and washers (16).

4. Adjust the valve clearance; refer to paragraph 5-26f.

5. Start the engine and warm up to operating temperatures. With the engine idling slowly, readjust the valve clearance; refer to paragraph 5-26f.

6. Install the cylinder head cover (12) and new gasket (13) and secure to cylinder head with nuts (9) and washers (10 and 11).

7. Install breather cap on the cylinder head cover.

5-25. CYLINDER HEAD.

The cylinder head is a one-piece casting which mounts the valves and rocker arms and provides inlet and outlet passage to and from the valves. The valve seats are formed as part of the casting. The valve guides are removable. The cylinder head contains cored passages for water flow to promote cooling of the head.

a. Removal.

1. Drain the radiator and remove the thermostat housing, hoses, and the bypass hose (paragraphs 5-9 and 5-10). Disconnect the coolant temperature gauge thermocouple from the cylinder head.

2. Remove the exhaust manifold (paragraph 5-20).

3. Remove the intake manifold (paragraph 5-18).

4. Remove the fuel nozzle and holder assemblies (paragraph 5-15).

5. Remove the cylinder head cover and rocker arm assembly (paragraph 5-24).

6. Lift out the pushrods (26, figure 5-16).

7. Remove the cylinder head nuts (27, 29, and 31) and washers (28, 30, and 32); lift the cylinder head (33) and gasket (34) from the engine. It may be necessary to tap the head lightly with a soft hammer to loosen it. Do not pry on the contact surfaces.

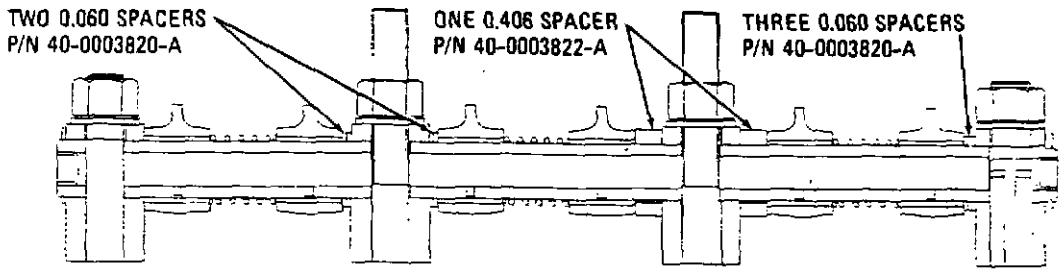
8. Remove the water outlet cover (37) and gasket (38) by removing four bolts (35) and lock washers (36).

9. Disassemble the cylinder head by removing the valve assemblies (paragraph 5-26).

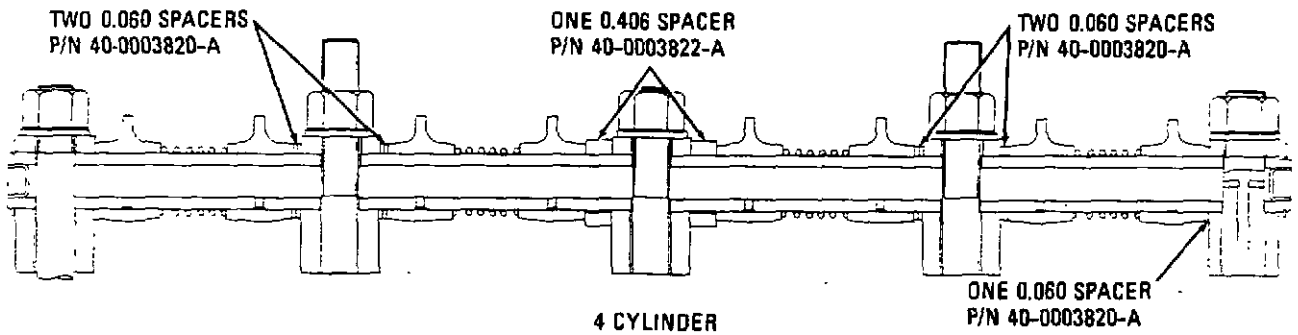
10. Do not remove plugs (40, 41, and 42), studs (43 and 44), or fuel nozzle holder sleeves (55) unless they are damaged and require replacement.

b. Cleaning and Inspection.

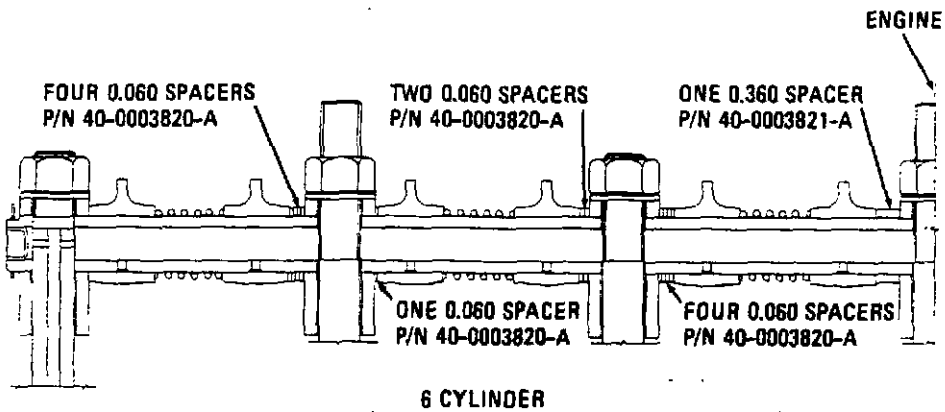
1. Before cleaning the cylinder head, inspect the cylinder head gasket and cylinder head for indications of gasket failure and leaking. If cylinder head gasket failure is apparent, make a thorough check of contributing factors. Detonation (caused by fuel pump being improperly



3 CYLINDER
AS VIEWED FROM VALVE SIDE



4 CYLINDER
AS VIEWED FROM VALVE SIDE



6 CYLINDER
AS VIEWED FROM VALVE SIDE

Figure 5-17. Rocker Arm Shaft Showing Spacer Position for Engines Having Identically Sized Shaft Supports

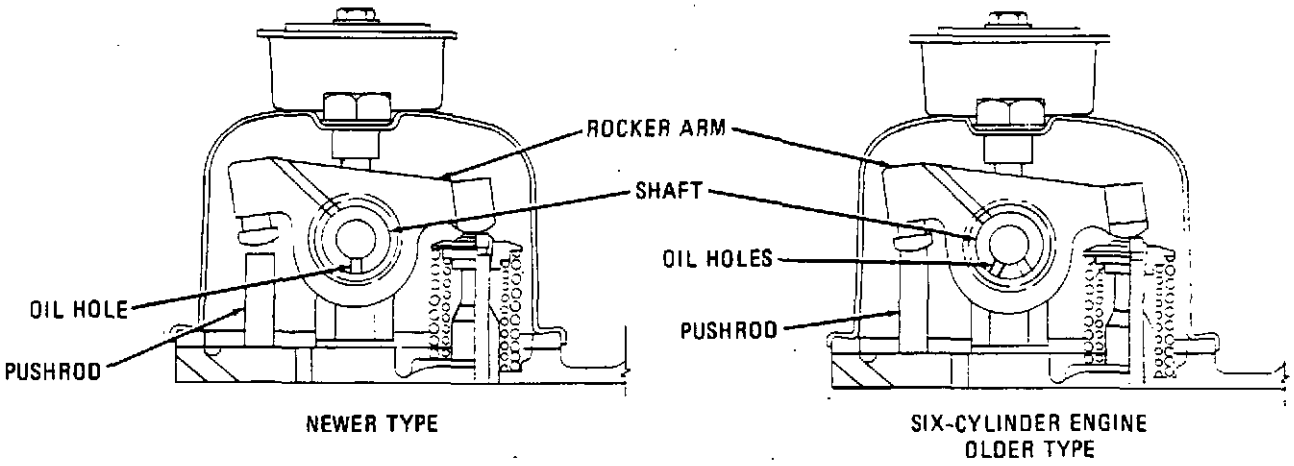


Figure 5-18. Rocker Arm Shaft Showing Oil Hole Positions

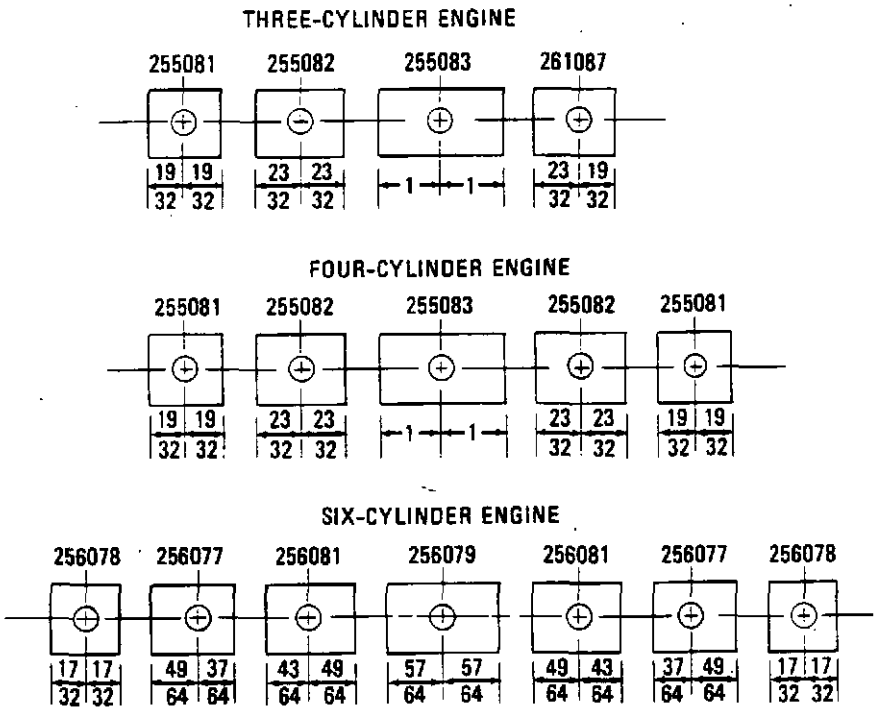


Figure 5-19. Rocker Arm Shaft Support Installation for Engines Having Variable Sized Supports

timed or excessive use of ether for cold starting) will cause a shock load in the combustion chamber which will damage cylinder head gaskets and, if allowed to continue, may destroy the piston pins and piston rings. Fuel with a cetane rating too low may also contribute to detonation and corrosion of the gasket and may eventually cause leaking. Cooling solutions which are contaminated by corrosive combustion gases leaking into the cooling system are very detrimental to the internal parts of the entire cooling system.

2. Remove all carbon from combustion areas using a scraper and wire brush.

3. Clean the cylinder head thoroughly with a solvent or degreasing solution and dry thoroughly with dry, compressed air.

4. Make sure that gasket contact surfaces on the head and block are clean, smooth, and flat. Rework contact surfaces to assure that they are free of erosion, pits, burrs, scratches, or blemishes.

5. Check out-of-flatness with straight edge and feeler gauge; maximum allowable is 0.005 inch on width or length. Out-of-flatness should vary gradually and uniformly from end to end and side to side. Resurface the cylinder head as necessary by light sanding with an orbital sander.

6. Check for free water flow through the cylinder head. If restriction is evident, remove plugs and injector sleeves; clean water jackets of salt, lime, or sludge by submerging cylinder head into a tank of heated cleaning solution. Circulate the cleaning solution. When clean, remove cylinder head from tank and dry with compressed air.

7. Inspect for loose or damaged fuel nozzle holder sleeves. If necessary, pull out the sleeves and press in new ones. To pull the sleeves, it may be necessary to thread the inner diameter to provide a pulling surface.

8. Water-test the cylinder head for cracks and leaks. Check for cracks in the valve and injector port areas using magnetic detection.

9. Check for loose valve seat inserts, if used, by lightly tapping head near inserts. If valve seat insert is loose enough to bounce, remove and replace insert.

10. Inspect all other parts for cracks, distortion, damaged threads, and other damage. Replace any damaged parts.

c. Reassembly and Installation.

1. Before reassembling the cylinder head, regrind or service the valves as necessary. Refer to paragraph 5-26 for valve servicing and installation.

2. Make sure the cylinder block contact surface is clean of carbon deposits. Install a new cylinder head gasket on the cylinder block. The gasket must be assembled with the bead (rolled edge around the combustion chamber) down. For sealing, use any good cylinder head gasket cement.

3. Install water outlet cover (37, figure 5-16) and gasket (38) on cylinder head and secure with bolts (35) and lock washers (36).

4. Install the valve assemblies into the cylinder head; refer to paragraph 5-26e.

5. Place the cylinder head assembly on the block. Be careful not to damage contact surfaces or the cylinder head studs.

6. Install the cylinder head nuts (27, 29, and 31) and washers (28, 30, and 32). Tighten evenly, working from the center of the head outward. Refer to figure 5-20 for tightening sequence, torque, and procedure for tightening cylinder head to cylinder block. Tighten all nuts first to 75 foot-pounds torque in the sequence indicated, then 125 foot-pounds torque and so forth.

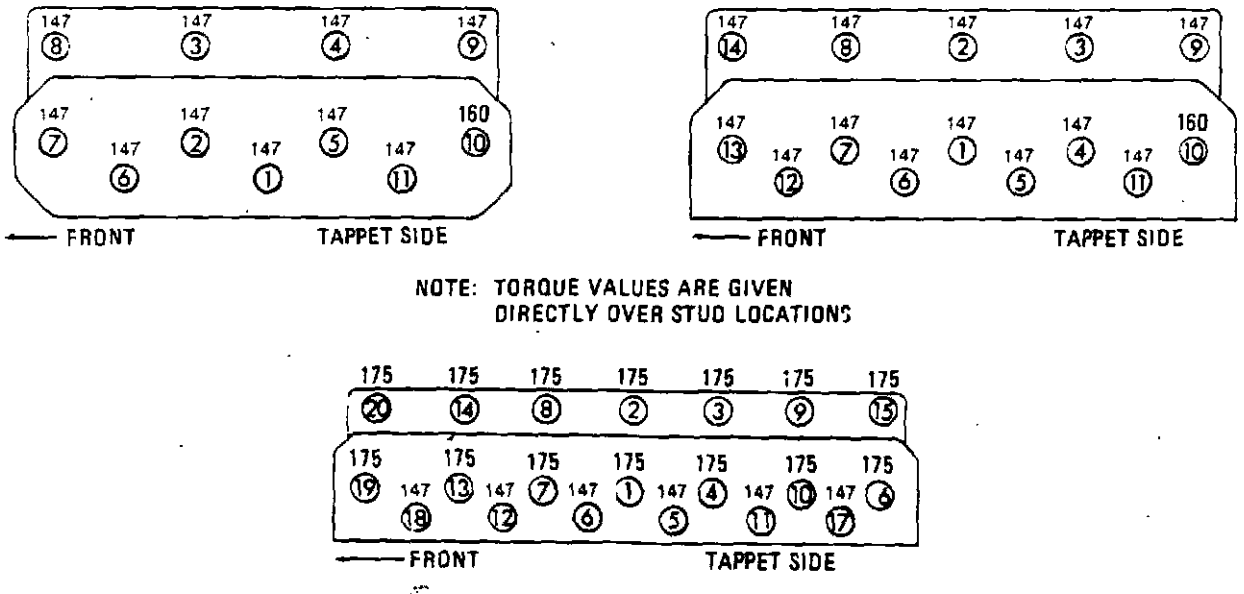


Figure 5-20. Cylinder Head Nut Tightening Sequence, and Torque Values

CAUTION

The cylinder head nuts must be retightened and the valve clearance reset after 1 hour of service.

7. Install the valve pushrods (26).

8. Install the rocker arm assembly (paragraph 5-24).

9. Install the fuel nozzle and holder assemblies (paragraph 5-15).

10. Install the air cleaner and intake manifold (paragraphs 5-17 and 5-18).

11. Install the exhaust manifold and exhaust pipe (paragraph 5-20).

12. Install coolant temperature gauge thermocouple in the cylinder head.

13. Install the thermostat and housing and the radiator hoses (paragraph 5-10). Fill the cooling system with clean water or antifreeze.

5-26. VALVES.

The intake and exhaust valves operate in valve guides pressed into the cylinder head. They are held to their seats by springs which are secured to the valves by spring seats and valve locks. The valves are operated by conventional-type tappets with hollow pushrods running from the tappets to the rocker arms.

Some engines are equipped with valve rotators, which control the motion of the exhaust valves during the lift cycle. The natural vibrations of the valve train and the flow of gases around the valve heads cause the valves to rotate slowly, a small fraction of a revolution each lift cycle. This equalizes wear and provides a wiping action to keep sealing surfaces clean.

a. Removal.

1. Remove the cylinder head (paragraph 5-25).

2. With a clamp-type valve spring compressor, compress the valve springs (48, figure 5-16) and remove the valve spring seat locks (45).

3. Remove the valve springs (48), seats (46), and valve rotators (47); lift out the valves (49 and 50). Place valves in order in a rack, with holes numbered for both intake and exhaust valves so that the valves can be installed in their respective places at reassembly.

4. Remove the intake valve stem seals (51) from the valve guides.

b. Cleaning and Inspection.

1. Discard all seals and gaskets.

2. Clean all carbon from the cylinder head, piston heads, valve seats, and valves, using suitable scraping or buffing tools.

3. Clean the valve guides. Remove lacquer or other deposits by running a valve cleaner or wire brush through the guides. Inspect the valve guides for excessive wear. The exhaust valve guides will usually show the most wear. The maximum allowable bore diameter of the intake valve guides is 0.3780 inch. The maximum allowable bore diameter of the exhaust valve guide is 0.3790 inch. Refer to Section VII, Fits and Tolerances, for tolerances.

4. Inspect the valve seats. If they are pitted or if new valve guides will be installed, the seats must be refinished.

5. Inspect the valves carefully. If the stems are bent or badly worn or if the valves are deeply pitted, the valves must be replaced by new ones. Valves that are only slightly pitted can be used by refacing them on a valve grinder. Exhaust valves must have an accurately finished 45-degree face angle and intake valves a 30-degree face angle.

c. Repair and Replacement.

1. If the valve guides are excessively worn and require replacing, it must be done before any refinishing is done on the valve seats. This will insure that the seat being finished is square with respect to the new guide. To drive out the guides, use a drift with a 5 8-inch diameter and a 3/8-inch diameter pilot. Drive in the new guides so that the dimension from the lower edge of the valve guide to the gasket face of the cylinder head is 1.3800 inches. See figure 5-21. After the new guides are driven in, ream the inside diameter to correct any squeezing in or any distortion. Ream the exhaust valve guides to 0.3750 to 0.3760 inch. Ream the intake valve guide to 0.3740 to 0.3750 inch.

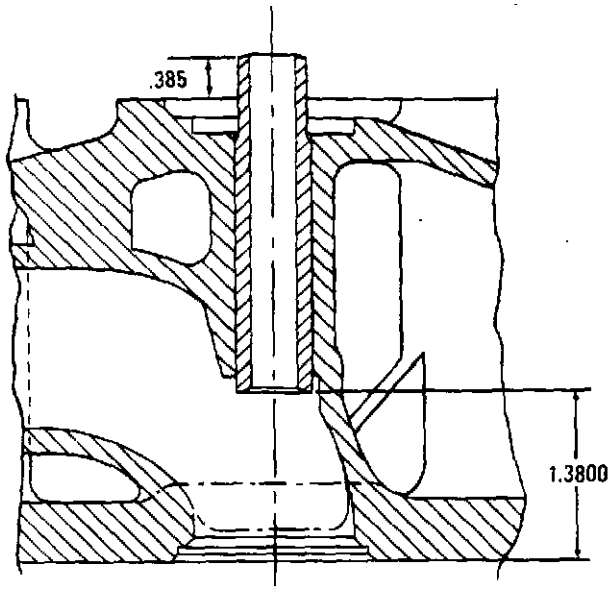


Figure 5-21. Valve Guide Installation

2. If the valve seats are pitted or if new valve guides have been installed, the seats must be refinished. The intake valve seats are finished on a 30-degree angle and the exhaust valve seats are finished on a 45-degree angle. Use a vibrating angle grinder-type reseating tool with a 3/8-inch diameter pilot. Lightly lubricate and install the pilot into the valve guide bore. Lower the grinder head over the pilot shank until the stone just clears the valve seat. Turn on the power and gently allow the stone to contact the valve seat. Very little pressure other than the weight of the stone should be used. Grind the seat sufficiently to remove shoulders and pits, and to provide an even, smooth surface. Do not grind any deeper than necessary. The finished valve seat should contact the approximate center of the valve face. Refer to figure 5-22.

d. Seating Valves.

If the valves and seats are not deeply pitted or shouldered or have been refaced, grind or lap each valve to its seat as follows:

1. Lubricate the valve stem and apply a thin coating of good quality, medium coarse grinding compound on the valve face.

2. Take a light coil spring with enough tension to just hold the valve off the seat and insert it over the valve stem. Insert the valve in the valve guide.

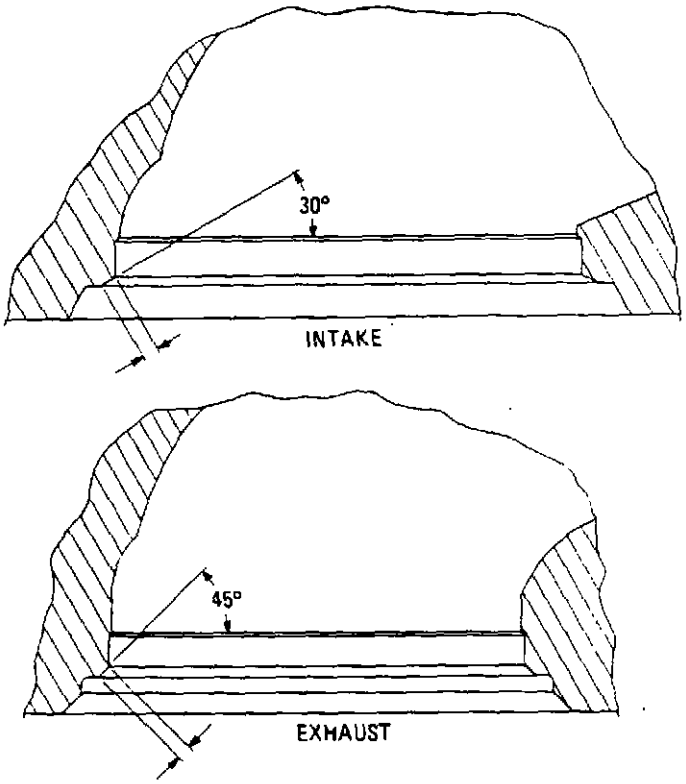


Figure 5-22. Valve Reseating Dimensions

3. Use a reciprocating grinding tool and rotate the valve a few times, pressing firmly on the grinding tool. (Avoid using a grinding tool with a continuous circular motion that will cut grooves in the valves or seat.) Release the pressure on the tool and allow the spring to lift the valve from its seat. Rotate the valve 15 or 20 degrees and repeat the grinding process. Periodically wipe off valve and seat and inspect the seating progress. Reapply another thin coating of compound and continue grinding until inspection shows the surfaces are in contact.

4. Wipe off all heavy compound, apply a thin coating of fine compound, and continue the grinding.

5. When the surfaces show a bright, silver-like band of uniform width on both the valve and seat, clean off all traces of the compound.

6. Test each valve for a tight fit as follows: Make 10 or 12 pencil marks, equally spaced, across the valve seat. Firmly rotate the valve in the seat for a part of a turn and again lift out the valve to observe if all the pencil marks are rubbed out on the contact surface. If not, regrind until this test shows a gas-tight mating of the valve and seat.

NOTE

It is imperative that the valves be assembled in the same seats to which they were ground.

e. Reassembly and Installation.

NOTE

Make certain that the valves are reinstalled in the same position from which they were removed.

1. Thoroughly clean all traces of grinding compound from the valves, stems, and guides. Lubricate the valve stems with a few drops of engine oil and insert the valves in the same holes from which they were removed.

2. Insert the intake valve stem seals (51, figure 5-16) over the ends on the intake valves (49) and secure firmly on the exposed ends of the valve guides (52).

3. Install the valve springs (48), spring seats (46), and exhaust valve rotators (47) on the valve stems. Using a valve spring compressor, compress the valve springs and install the valve locks (45).

4. Turn the head on the exhaust manifold side and pour solvent in the intake openings. If solvent seeps out around any valve, remove that valve and regrind it. Repeat the test, pouring solvent in the exhaust opening. If any exhaust valve leaks, regrind it.

5. When assured of gas-tight valve seating, install the assembled cylinder head on the engine. Refer to paragraph 5-25.

6. Install the rocker arm assembly (paragraph 5-24).

7. Adjust the valve clearance: refer to following subparagraph f.

8. Fill the cooling system with recommended coolant. Start the engine and warm to operating temperatures.

9. With the engine idling slowly, readjust the valve clearance to the correct operating clearance. Refer to following subparagraph f.

10. Install the cylinder head cover (12, figure 5-16) and new gasket (13). Secure to cylinder head cover with nuts (9) and washers (10 and 11).

f. Adjusting Valve Clearance.

Adjust valve stem-to-rocker arm clearance whenever the cylinder head has been removed from the cylinder block. Proceed as follows to adjust valve clearance:

1. Rotate the crankshaft by hand or with the starting motor until both intake and exhaust valves of No. 1 cylinder are fully closed. The valves will be fully closed when the No. 1 cylinder is at top dead center; refer to paragraph 3-5h. For a cold engine, use a 0.016- or 0.017-inch feeler gauge inserted between the rocker arm and the valve stem and adjust the adjusting screw until it just touches the pushrod. See figure 3-2. There should be a slight pull when removing the feeler gauge.

2. Adjust the remaining valve clearances in similar manner. Rotate the crankshaft in the direction of normal rotation and adjust the valves in the cylinder firing order. The firing orders for the three-, four-, and six-cylinder engines are 1-3-2, 1-2-4-3, and 1-5-3-6-2-4, respectively.

3. After all the valves have been adjusted, install the cylinder head cover and gasket. Start the engine and allow it to warm up to operating temperature. When warm, readjust the valve clearance to 0.015 inch with the engine running at low idle. Refer to paragraph 3-5h.

5-27. FLYWHEEL.

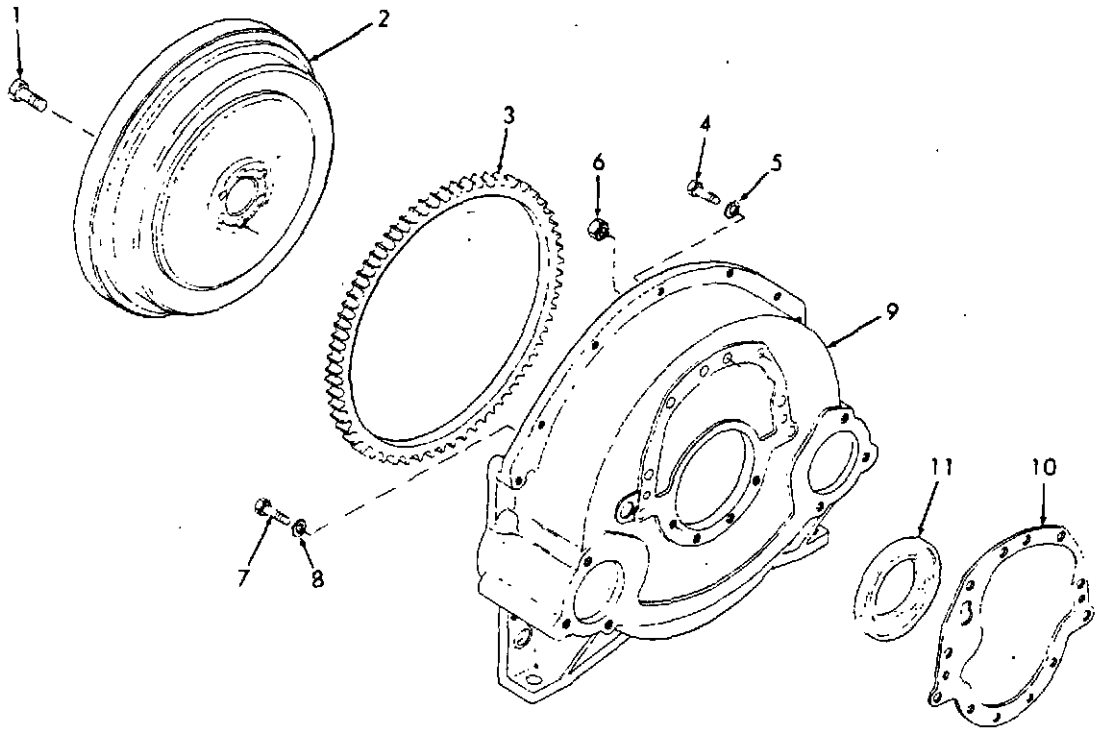
Flywheels used on this series of engines are usually made of cast iron and may be machined to accommodate different types and sizes of clutches, generators, and a variety of types of couplings. The flywheel also provides indications for timing the engine. All flywheels have a line marked DC (dead center) that can be viewed through a hole in the bellhousing; see figure 3-3. From this line are graduations designating degrees of crankshaft travel.

a. Removal.

1. Disconnect and remove the power takeoff, torque converter, transmission, or clutch, whichever is used.

2. Remove the starting motor (paragraph 5-22).

3. Remove the six flywheel bolts (1, figure 5-23).



1. Bolt
2. Flywheel
3. Ring gear
4. Bolt
5. Lock washer
6. Nut
7. Bolt
8. Lock washer
9. Bellhousing
10. Gasket
11. Oil seal

Figure 5-23. Flywheel and Bellhousing Assembly, Exploded View

4. Using a pry bar, pull the flywheel (2) from the crankshaft.

5. Do not attempt to remove the ring gear (3) from the flywheel unless it is damaged and must be replaced.

b. Cleaning, Inspection, and Replacement.

1. Clean the flywheel and attaching parts with cleaning solvent; dry thoroughly with compressed air.

2. Inspect the flywheel ring gear for broken or cracked teeth. If damage is evident and replacement is necessary, drive gear from flywheel with a blunt chisel.

3. Inspect the flywheel for distortion, cracks, or other damage or wear. Replace a damaged flywheel.

4. To install a new ring gear, heat it in an oven or with a heating torch to approximately 600°F (315.6°C). Do not overheat. Place heated ring gear on flywheel and quickly drive onto flywheel until gear is firmly seated.

c. Installation.

1. Turn the crankshaft so that the timing cylinder is in the top dead center position. Refer to table 3-3 to determine timing cylinder.

2. Turn the flywheel so that the DC timing mark is in line with the timing hole in the bellhousing. Install the flywheel on the crankshaft. Note that one of the six bolts is off center so that the flywheel can only be installed in one position. This insures proper location of the flywheel on the crankshaft for timing purposes. Draw the flywheel onto the crankshaft by tightening the six bolts alternately and evenly. Torque the bolts to 60 foot-pounds.

3. Attach the indicator, as shown in figure 5-24, to check the concentricity of the pilot bore. This should not exceed 0.005 inch total indicator reading.

4. Attach the indicator as shown in figure 5-25, to check the face of the flywheel. Runout should not exceed 0.008 inch total indicator reading. If runout is excessive, remove the flywheel and check for dirt or foreign

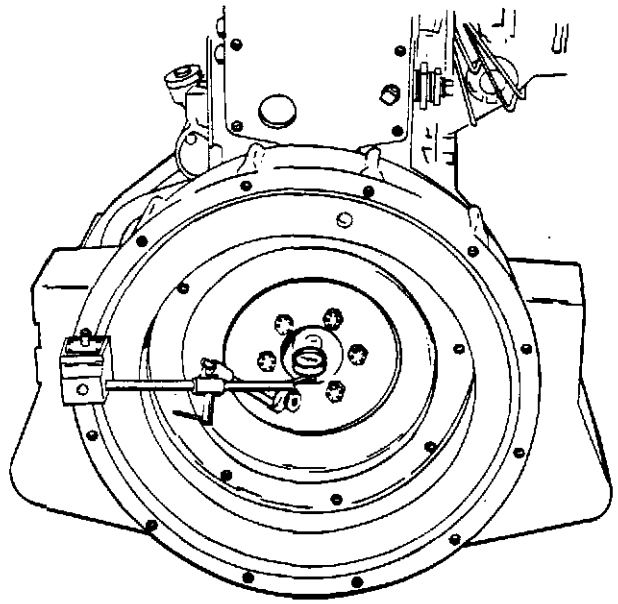


Figure 5-24. Indicating Flywheel Pilot Bore

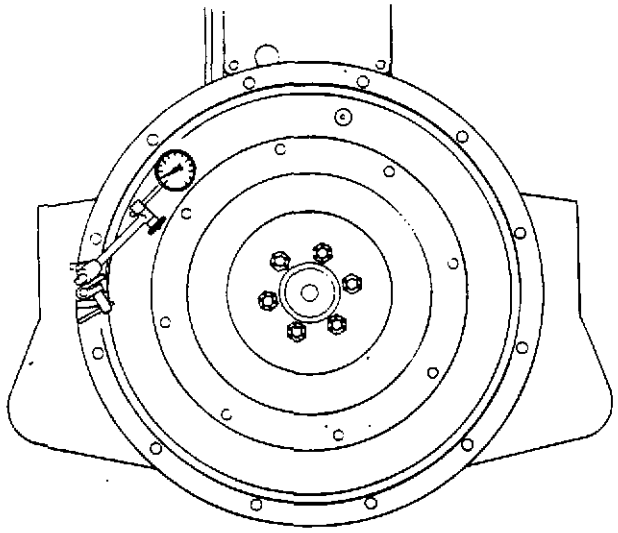


Figure 5-25. Indicating Flywheel Face

matter between the flywheel and mounting seat on the crankshaft. Reinstall and recheck.

5. Install the lock wires (if used).

6. Install the clutch and transmission or power take-off, as removed.

5-28. BELLHOUSING.

The bellhousing is a casting which covers the rear end of the cylinder block and oil pan. There are many types of housings used. One may be a plate-type housing; another type may form a complete housing for the flywheel and clutch, to which the transmission, torque converter, or other drive mechanism is attached. The bellhousing usually forms the rear engine support.

a. Removal.

1. Drain the crankcase oil.

2. Remove the clutch or power take-off mechanism.

3. Remove the flywheel (paragraph 5-27).

4. Remove the oil pan (paragraph 5-5).

4A. Starting with engine serial number 3431047, it is not necessary to remove the oil pan for bellhousing removal. All attaching bolts, including the four oil pan adapter bolts, are accessible from bellhousing.

5. Disconnect the oil lines and remove oil filter (paragraph 5-4).

6. Remove starting motor (paragraph 5-22).

7. If the engine is being serviced in the unit, place suitable supports under the rear of the crankcase to support the engine.

8. Remove the rear engine support bolts.

9. Remove the rear oil pan adapter (12, figure 5-3) by first removing the two nuts (8) and lock washers (9) securing the adapter to the cylinder block and then removing the four bolts (10) and lock washers (11) securing the adapter to the bellhousing.

10. Remove the bellhousing attaching bolts (4 and 7, figure 5-23), stud nuts (6), and lock washers (5 and 8).

11. Pull the bellhousing away from the engine. It may be necessary to tap the housing with a soft hammer to loosen it from the dowels or from gasket (10) sticking to the block.

12. Remove rear oil seal (11) from bellhousing.

b. Cleaning, Inspection, and Repair.

1. Discard the gasket (10, figure 5-23) and seal (11).

2. Clean the parts with cleaning solvent; dry thoroughly. Make sure all old gasket material is removed from the parts.

3. Inspect the bellhousing for cracks, distortion, and other damage: replace a damaged bellhousing.

4. Check that bellhousing dowel pins in the block are tight and in good condition.

c. Installation.

1. Install a new oil seal (11, figure 5-23) in the bellhousing, using a small amount of sealing compound in the bore before pressing in the seal. If new seal is pre-coated, sealing compound is not required. Cement a new gasket (10) to the bellhousing, allowing the cement to dry sufficiently to prevent the gasket from slipping at installation.

2. Clean and polish the oil seal surface of the crankshaft to remove nicks or scratches. Use crocus cloth or very fine polishing cloth.

3. Apply a thin coat of oil soap to the seal and the seal surface of the crankshaft. If seal is already oil treated, additional lubricant is not required; however, take care to keep the seal surface clean during reassembly. Make sure that the top rear cam thrust plate attaching screw hole is plugged with a setscrew. This hole runs into an oil hole in the block. Carefully place the bellhousing on the cylinder block so that the seal is not damaged as it engages the crankshaft. Align so that the dowels properly enter their respective holes. Seat the bellhousing (9) to the engine and install the bolts (4 and 7), nuts (6), and lock washers (5 and 8), but do not tighten.

4. Install the rear oil pan adapter (12, figure 5-3), securing it to the cylinder block with two nuts (8) and lock washers (9). Secure the adapter to the bellhousing with four bolts (10) and lock washers (11). Tighten down the bellhousing bolts and nuts evenly and securely.

5. Install the starting motor and connect the electrical leads (paragraph 5-22).

6. Install the oil filter and connect the oil lines (paragraph 5-4).

7. Install the rear engine support screws and remove the jack or block from under the crankcase.

8. Install the oil pan (paragraph 5-5).

9. Install the flywheel (paragraph 5-27).

10. Check concentricity of bellhousing in relation to flywheel (figures 5-24 and 5-25).

11. Install the clutch or power take-off mechanism.

12. Fill the crankcase to the proper level with the correct grade of lubricating oil. Refer to Table 3-4, Recommended Lubricating Oil Specifications.

5-29. GEAR HOUSING AND COVER.

The gear housing and cover mounted to the front of the engine covers the engine drive gears. The gear housing also forms the front support for the engine. The front oil seal for the crankshaft is also installed in the cover plate. The cover plate can be removed for inspection of the gears without removing the gear housing.

a. Removal.

1. Remove the radiator, hoses, and radiator supports from the engine.

2. Remove the fan and belt(s) for easier access to the gear cover and gears (paragraph 5-9).

3. Remove the vibration dampener (3, figure 5-26) from the drive pulley by removing lock wire (1) and bolts (2).

4. To remove an interference fit bore pulley, remove the nut (4) and lockwasher (5) and use a puller in holes provided in pulley.

4A. When a hub and pulley is used, remove nut (4), lockwasher (5), and hub washer and pulley. Place a puller on hub and remove.

4B. If a pulley (9) and cone (7) is used, position a driver on hub area of pulley and using a heavy hammer drive the pulley toward the engine until cone is loose. Insert a screwdriver or drift in slot in cone to expand for easy removal. Remove cone key (8), pulley key and flat washer (6), which is used only with a pulley and cone assembly.

5. Remove the bolts (10, 12, and 14), lock washers (11, 13, 15, and 17), and nuts (16) that secure the cover (18) to the gear housing. Remove the cover by pulling it away from the engine.

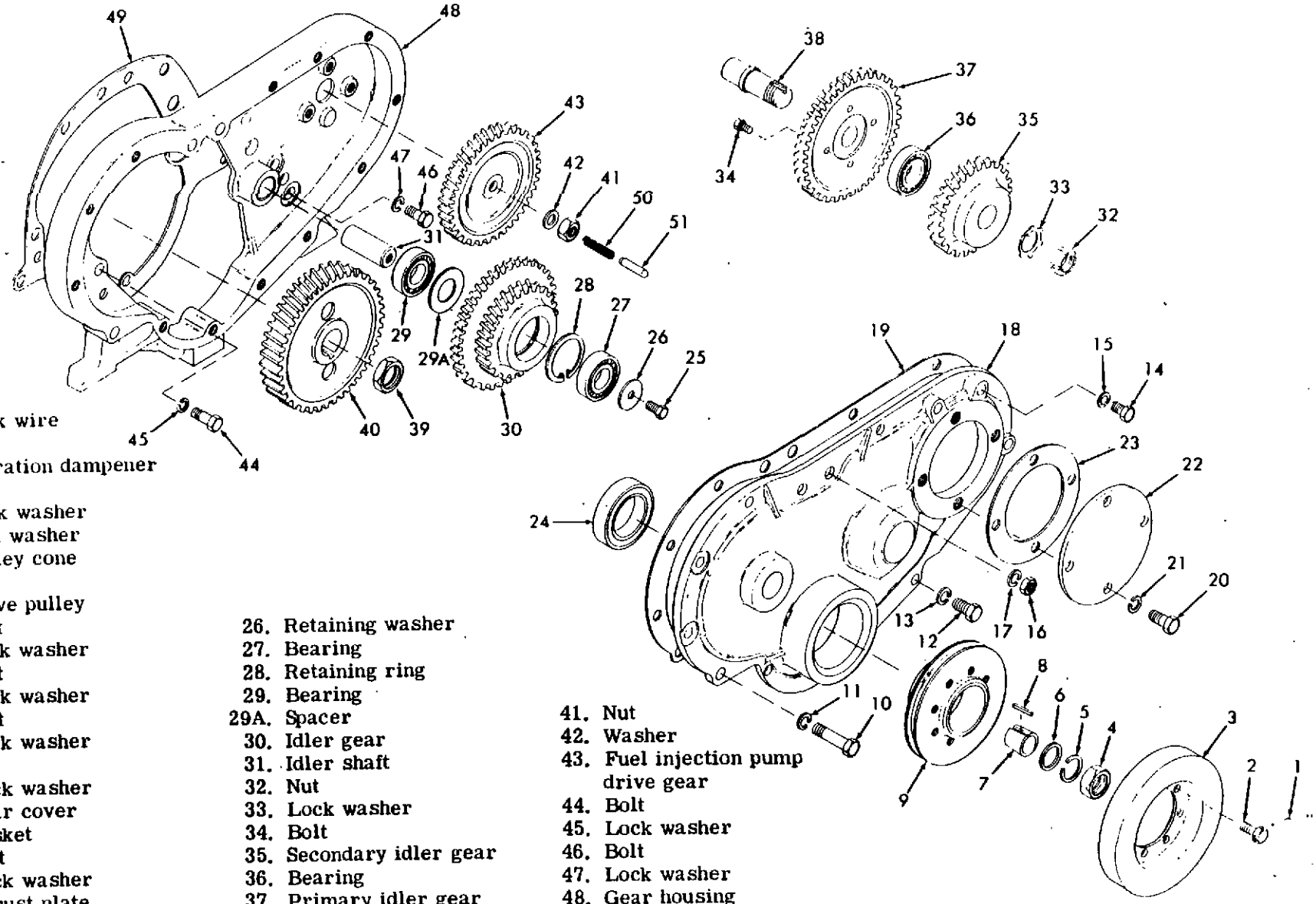
6. Remove the thrust plate (22) and gasket (23) from the gear cover by removing four bolts (20) and lock washers (21). Press the oil seal (24) from the gear cover.

7. Remove the fuel pump as directed in paragraph 5-14a(8) or (9).

8. If necessary, remove the idler gear and bearing from the idler shaft. The idler gear is retained by either a bearing nut (32) and lock washer (33) or a bolt (25) and washer (26). Refer to figure 5-26 and disassemble the assembled idler gears and bearings according to sequence of index numbers. Do not remove idler shaft (31 or 38) unless it is damaged.

9. If it is necessary to remove the gear housing from the crankcase, proceed as follows:

(a) Drain the crankcase and remove the oil pan (paragraph 5-5).



1. Lock wire
2. Bolt
3. Vibration dampener
4. Nut
5. Lock washer
6. Flat washer
7. Pulley cone
8. Key
9. Drive pulley
10. Bolt
11. Lock washer
12. Bolt
13. Lock washer
14. Bolt
15. Lock washer
16. Nut
17. Lock washer
18. Gear cover
19. Gasket
20. Bolt
21. Lock washer
22. Thrust plate
23. Gasket
24. Oil seal
25. Bolt
26. Retaining washer
27. Bearing
28. Retaining ring
29. Bearing
29A. Spacer
30. Idler gear
31. Idler shaft
32. Nut
33. Lock washer
34. Bolt
35. Secondary idler gear
36. Bearing
37. Primary idler gear
38. Idler shaft
39. Nut
40. Camshaft gear
41. Nut
42. Washer
43. Fuel injection pump drive gear
44. Bolt
45. Lock washer
46. Bolt
47. Lock washer
48. Gear housing
49. Gasket
50. Spring
51. Thrust plug

Figure 5-26. Gear Housing and Gears, Exploded View

(b) Remove the front oil pan adapter (12, figure 5-3) by first removing the two nuts (8) and lock washers (9) securing the adapter to the cylinder block and then removing the four bolts (10) and lock washers (11) securing the adapter to the gear housing.

(c) Remove the camshaft nut (39, figure 5-26). To keep the shaft from turning, insert a brass bar between crankshaft gear and camshaft gear. Using a standard foot-type puller inserted in holes in gear, pull the camshaft gear (40) from the camshaft.

(d) Remove bolts (44 and 46) and lock washers (45 and 47). Pull the gear housing away from the cylinder block. It may be necessary to tap the housing with a soft hammer to loosen it from the dowels or from gasket (49) sticking to the block.

b. Cleaning, Inspection, and Repair.

1. Discard all gaskets and seals.

2. Clean the gear cover, housing, and attaching parts with cleaning solvent. Dry thoroughly. Make sure all old gasket material is removed from the gasket surfaces.

3. Inspect the gear cover and gear housing for cracks, distortion, and other damage. Replace either if damaged.

4. Check that gear housing dowel pins and studs in the cylinder block are tight and that the stud threads are in good condition. Replace any damaged parts.

5. Inspect the fuel pump drive gear, camshaft gear, and idler gear for chipped, cracked, or broken teeth. Replace damaged gears.

6. Check the idler gear bearing for wear or rough operation. There should be just perceptible play in the bearing. Replace a worn bearing.

7. Check that the idler gear shaft is tightly fitted in the gear housing. It must withstand a direct pull of 32 pounds. Replace a loose-fitting idler gear shaft. (Use Loctite).

c. Installation.

1. If the gear housing was removed, install as follows:

(a) Cement a new gasket (49, figure 5-26) to the gear housing, allowing the cement to dry sufficiently to prevent the gasket from slipping at installation.

(b) Place the gear housing (48) on the cylinder block; install the attaching bolts (44 and 46) and lock washers (45 and 47) but do not tighten completely.

(c) Install the front oil pan adapter (12, figure 5-3), securing it to the cylinder block with two nuts (8) and lock washers (9). Secure the adapter to the gear housing with four bolts (10) and lock washers (11). Tighten the gear housing bolts and nuts evenly and securely.

(d) Install the oil pan (paragraph 5-5).

(e) Install the alternator bracket screws and lock washers (paragraph 5-23).

(f) Install the fuel injection pump and connect the fuel lines (paragraph 5-14).

(g) Install the camshaft gear (40, figure 5-26) on the camshaft, aligning the timing mark with timing mark on the crankshaft gear (see figure 5-27). Insert a brass bar between the camshaft and crankshaft gears. Pull down and secure the gear with the camshaft nut (39, figure 5-26). Tighten the nut to 125 to 135 foot-pounds torque.

2. Refer to figure 5-26 and assemble the idler gears and bearing in the reverse order of disassembly. Secure the assembled idler gear and bearing on the idler shaft with applicable bearing nut (32) and lock washer (33) or bolt (25) and washer (26). Torque bolt or nut to 25 Ft. Lbs. Use Loctite on bolt.

3. Turn the crankshaft so that the flywheel timing marks indicate the required fuel pump timing position for the timing cylinder. Refer to paragraph 3-5.

4. Install a new oil seal (24, figure 5-26) in the gear housing cover, using a small amount of sealing compound in the bore before pressing in the seal. If new seal is pre-coated, sealing compound is not required. Cement a new gasket to the gear housing cover.

5. Clean and polish the oil seal surfaces of the crankshaft to remove any nicks or scratches which could damage the seal. Use an oil stone or very fine emery cloth and polish with crocus cloth. If the shafts have a keyway which might damage the seal during installation, cover this keyway with a thin feeler gauge to protect the seal.

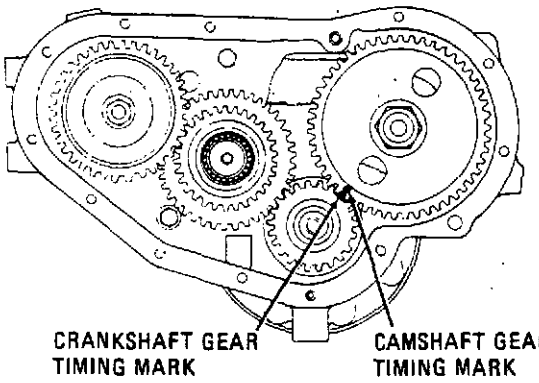


Figure 5-27. Aligning Drive Gear Timing Marks

6. Apply a thin coat of oil soap to the seal and the seal surface of the crankshaft. If seal is already oil treated, additional lubricant is not required; however, take care to keep the seal surface clean during reassembly. Carefully place the oil seal over the crankshaft to install the cover (18) on the gear housing. Secure with bolts (10, 12, and 14), nuts (16), and lock washers (11, 13, 15, and 17).

7. To install an interference fit bore pulley, insert pulley key in crankshaft. Align pulley keyway with key and tamp pulley onto crankshaft sufficiently to install lockwasher and nut. Torque to 125 foot-pounds.

7A. To install hub and pulley assembly, drive hub onto crankshaft. (Do not damage dowels). Install pulley and flat washer onto hub. Install lockwasher and nut and torque to 125 foot-pounds.

7B. To install a pulley and cone, install flat washer (6) on crankshaft, mating bevel in washer to radius on crankshaft. Install key (8) in cone (7). Insert a screwdriver or drift in slot in cone to expand for easy installation. Align cone key with keyway in pulley and insert cone in pulley. Install pulley key in crankshaft and install pulley and cone. Secure pulley with nut (4) and lockwasher (5). Torque nut to 125 foot-pounds.

8. Install the vibration dampener (3), with bolts (2); use lock wire (1) as necessary.

9. Install the thrust plate (22) and gasket (23) on the gear cover and secure with bolts (20) and lock washers (21).

10. Install the fan and belt (paragraph 5-9).

11. Install the radiator, hoses, and radiator supports.

12. Fill the crankcase to the proper level with the correct grade of lubricating oil.

13. Start the engine and check for oil, water, and fuel leaks.

5-30. CAMSHAFT.

The camshaft is supported on large diameter, pressure-lubricated, removable bearings in the crankcase and is driven by the camshaft gear which meshes with the crankshaft gear. The camshaft sometimes can be removed without removing the engine from the unit.

a. Removal.

1. Drain the radiator and remove the radiator, hoses, and radiator support bracket.

2. Drain the lubricating oil from the crankcase and remove the oil pan (paragraph 5-5).

3. Remove the oil pump (paragraph 5-6).

4. Remove the fan and belt(s) for easier access to the gear cover and gears (paragraph 5-9).

5. Remove the gear cover (paragraph 5-29).

6. Remove the cylinder head cover and rocker arm assembly (paragraph 5-24).

7. After removing the rocker arm assembly, remove the pushrods (26, figure 5-16) from the cylinder block.

8. If the engine is being serviced while in the unit, the valve tappets (53) must be held in the raised position in order to remove the camshaft. One method of accomplishing this is to make a holder, as illustrated in figure 5-28, by bending a wire to form a spring-acting hook on one end. This holder may then be inserted into the hollow part of the tappet and the tappet lifted away from the camshaft. Bend the holder over the edge of the pushrod hole in the cylinder head so that the tappet will remain in this position. Repeat this procedure for each of the remaining tappets. With the engine out of the unit, it is necessary only to set the engine on the bellhousing or upside down (support the engine with suitable blocks so that the cylinder head studs will clear), push the tappets to the raised position, and remove the camshaft.

9. With the tappets in the raised position, rotate the engine crankshaft until the two holes in the camshaft gear expose the thrust plate mounting bolts; see figure 5-29.

10. Remove the thrust plate mounting bolt and washer assembly (2, figure 5-31) and pull the camshaft assembly forward out of the cylinder block as shown in figure 5-30.

11. Remove the camshaft bearings (6, 7, and 8, figure 5-31). If the bearings cannot be withdrawn by hand, drive out the camshaft bearings with a brass drift. If difficulties are encountered removing the rear camshaft bearing, it may be necessary to remove the bellhousing.

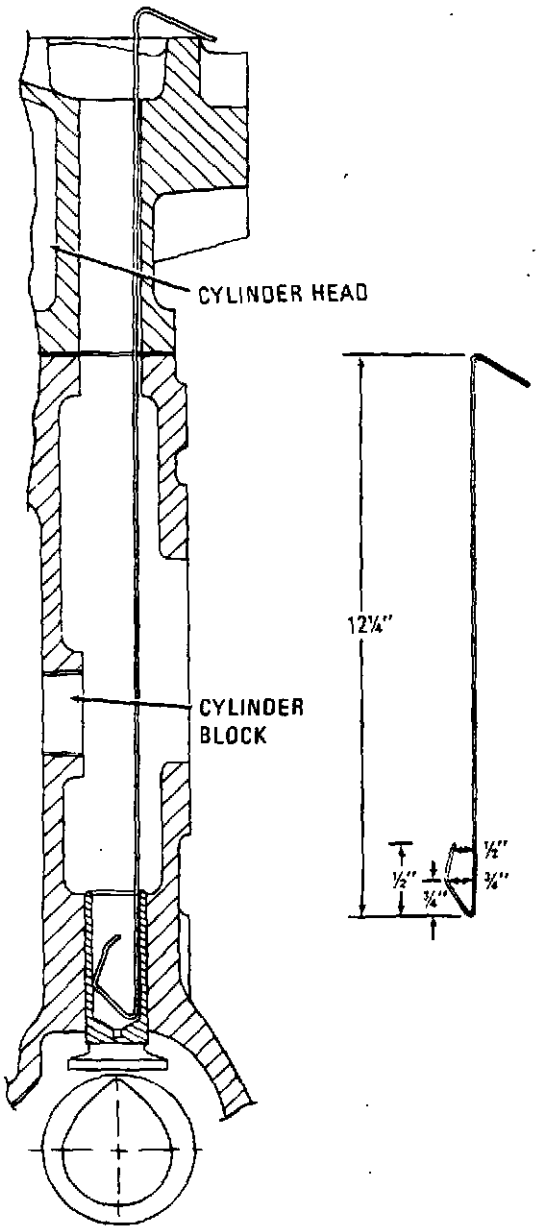


Figure 5-28. Valve Tappet Positioned for Camshaft Removal

12. If it is necessary to remove the camshaft gear (40, figure 5-26) from the camshaft, remove the nut (39), place the shaft in an arbor press and, with suitable supports under the gear, press the shaft out of the gear. Remove woodruff key (4, figure 5-31) from camshaft and remove the camshaft thrust plate (3).

13. After the camshaft has been removed from the engine, the valve tappets (53, figure 5-16) can be removed from the underside of the block.

b. Cleaning and Inspection.

1. Clean the parts with cleaning solvent.

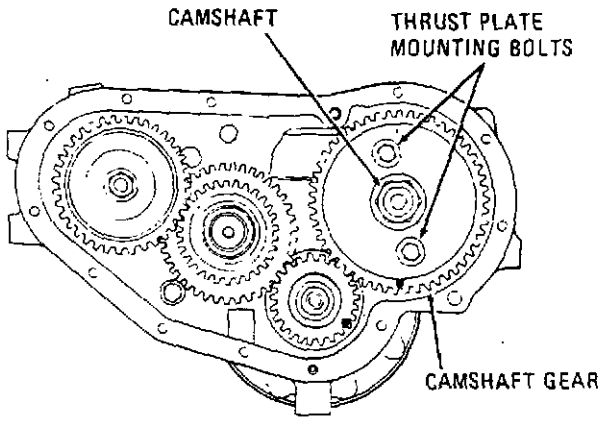


Figure 5-29. Thrust Plate Mounting Bolt Removal

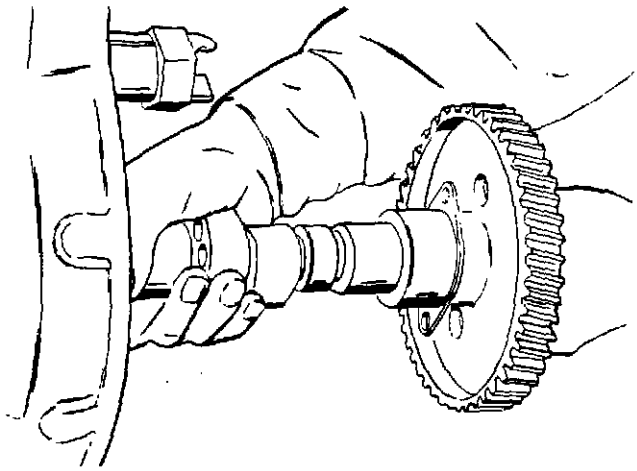


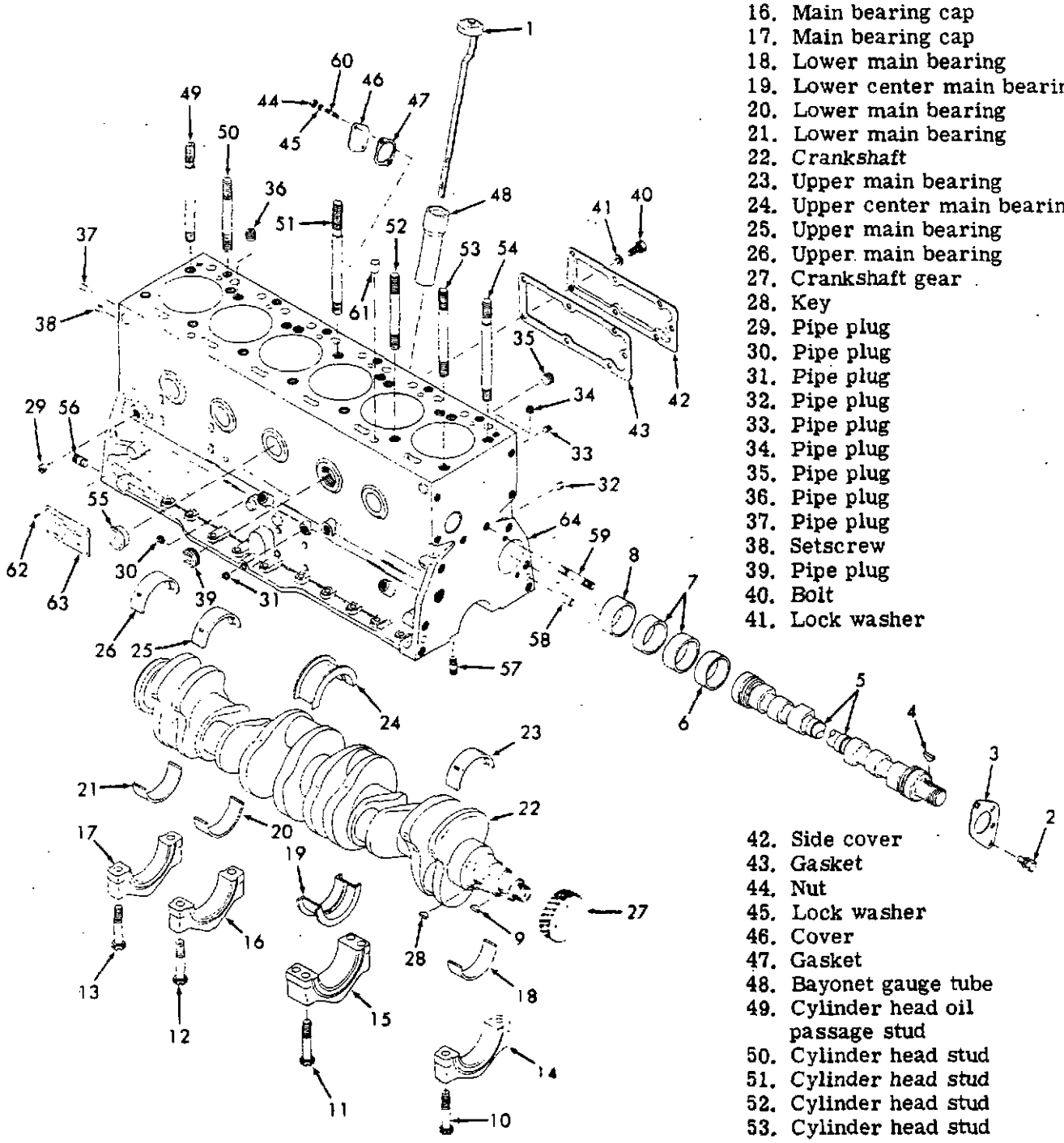
Figure 5-30. Camshaft and Thrust Plate Removal

2. Inspect the camshaft for scored or worn cams and bearing surfaces, damaged oil pump gear, threads or keyway, or worn thrust surfaces. Replace camshaft if it has scuffed, scored, or cracked valve cams. Replace camshaft if any bearing journal diameter is worn to less than 2.051 inches.

3. Inspect the bearings for scored or worn bores, cracks, or scored faces. Replace worn or damaged bearings. The maximum allowable clearance between camshaft journal and bearing bore is 0.006 inch.

4. Inspect the thrust plate for worn or scored thrust surfaces and distortion.

5. Inspect the camshaft gear for worn, cracked, or broken teeth, and worn keyway. Replace a damaged gear.



1. Oil level bayonet gauge
2. Bolt and washer assembly
3. Camshaft thrust plate
4. Key
5. Camshaft
6. Front camshaft bearing
7. Intermediate camshaft bearing
8. Rear camshaft bearing
9. Key
10. Bolt
11. Bolt
12. Bolt
13. Bolt
14. Main bearing cap
15. Center main bearing cap
16. Main bearing cap
17. Main bearing cap
18. Lower main bearing
19. Lower center main bearing
20. Lower main bearing
21. Lower main bearing
22. Crankshaft
23. Upper main bearing
24. Upper center main bearing
25. Upper main bearing
26. Upper main bearing
27. Crankshaft gear
28. Key
29. Pipe plug
30. Pipe plug
31. Pipe plug
32. Pipe plug
33. Pipe plug
34. Pipe plug
35. Pipe plug
36. Pipe plug
37. Pipe plug
38. Setscrew
39. Pipe plug
40. Bolt
41. Lock washer
42. Side cover
43. Gasket
44. Nut
45. Lock washer
46. Cover
47. Gasket
48. Bayonet gauge tube
49. Cylinder head oil passage stud
50. Cylinder head stud
51. Cylinder head stud
52. Cylinder head stud
53. Cylinder head stud
54. Cylinder head stud
55. Cup plug
56. Stud
57. Stud
58. Pin
59. Stud
60. Stud
61. Pin
62. Drive screw
63. Instruction plate
64. Cylinder block

Figure 5-31. Cylinder Block, Exploded View

6. Check the valve tappets for wear and replace any that exceed 0.005-inch clearance in the cylinder block bore.

c. Installation.

1. Insert the valve tappets (53, figure 5-16) into their respective holes in the cylinder block. Use the holding wires to keep the tappets in the raised position during camshaft installation, as shown in figure 5-28.

2. Install the front, rear, and intermediate camshaft bearings (6, 7, and 8, figure 5-31) in the cylinder block. Replacement camshaft bearings are precision cut and no line reaming is required. When installing, make sure the oil holes in the bearings are aligned with the oil holes in the drilled passageways in the cylinder block. Tap bearings into place with a bearing driver.

3. If the camshaft gear was removed from the camshaft, place the thrust plate (3) on the camshaft (5) and press the gear onto the camshaft with woodruff key (4) in place. Secure with nut (39, figure 5-26). Make certain all tappets are in the raised position. Carefully insert the assembled camshaft into the cylinder block, aligning the timing marks on the camshaft gear with the timing marks on the crankshaft gear. This insures correct timing of the valves.

4. Secure the thrust plate to the cylinder block with two bolt and washer assemblies (2, figure 5-31). Check the camshaft end play. Normal end play is 0.005 to 0.008 inch and shall not exceed 0.012 inch. To decrease end play, use a draw file to remove a small amount of metal from the camshaft gear hub on which the thrust plate rides. See figure 5-32. To increase end play, add a shim between the camshaft gear hub and the camshaft bearing, or, using a piece of very fine emery cloth on a surface plate, polish the thrust plate to the desired thickness. Check the backlash of the camshaft gear to the crankshaft gear. The backlash must be 0.0015 to 0.0025 inch.

5. Remove the wire holders, allowing the valve tappets to fall into position on the camshaft.

6. Place the pushrods (26, figure 5-16) into their proper places in the cylinder head.

7. Install the rocker arm assembly and cylinder head cover (paragraph 5-24).

8. Install the gear cover (paragraph 5-29).

9. Install the fan and belt(s) (paragraph 5-9).

10. Install the oil pump (paragraph 5-6).

11. Install the radiator, hoses, and radiator support brackets.

12. Install oil pan (paragraph 5-5c) and fill the crankcase to the proper level with the recommended grade of lubricating oil. Refer to table 3-4.

13. Adjust the valve clearance (paragraph 5-26f).

5-31. PISTON AND CONNECTING ROD ASSEMBLIES.

The pistons are the solid type, having no saw slots or splits in the skirt. Piston ring sets consist of compression rings and oil regulating rings. The piston pin is the full floating type, able to rotate in the piston as well as in the connecting rod bushing. The connecting rods are heavy alloy steel forgings with precision-type bearings for the crankshaft and bronze bushings for the piston pins.

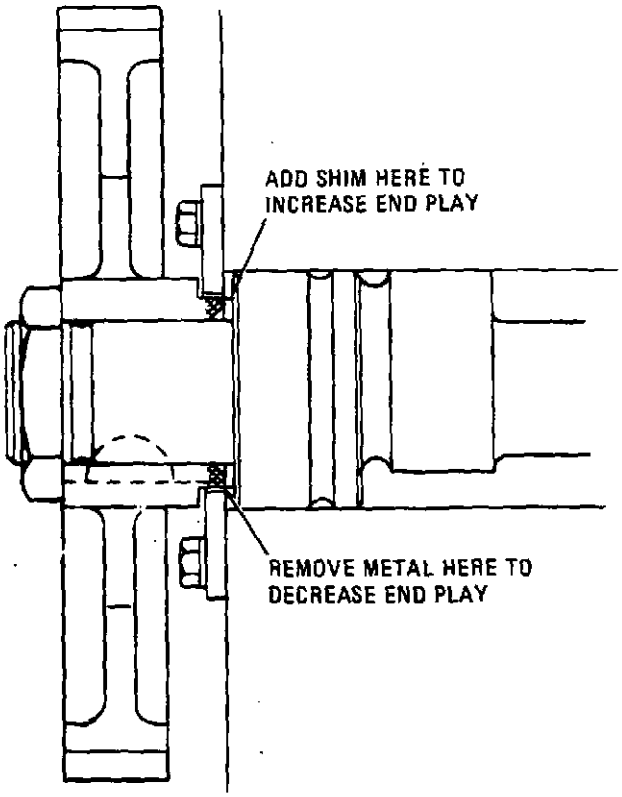


Figure 5-32. Adjusting Camshaft End Play

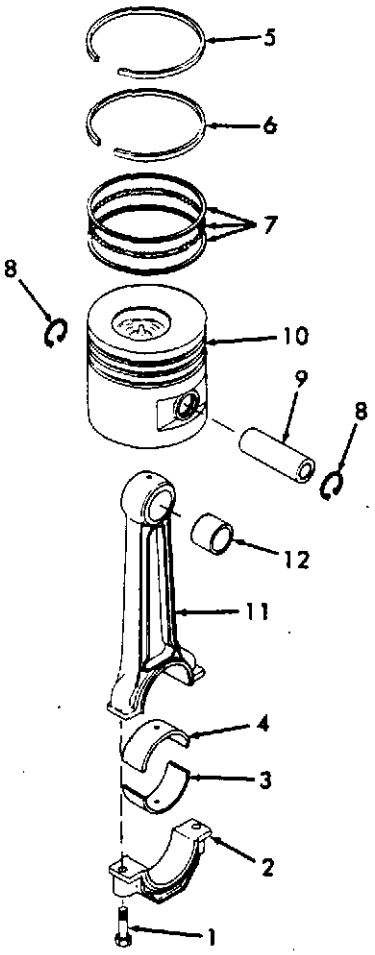
a. Removal and Disassembly.

1. Drain the radiator and disconnect the hoses.

2. Remove the thermostat housing and thermostat and remove the water pump bypass hose from the water pump. Also disconnect the water temperature gauge thermocouple.

3. Disconnect and remove the air cleaner from the manifold. Refer to figure 5-14.

4. Disconnect the exhaust pipe from the manifold.



1. Cap bolt
2. Connecting rod cap
3. Lower bearing
4. Upper bearing
5. Piston ring
6. Piston ring
7. Piston ring
8. Retaining ring
9. Piston pin
10. Piston
11. Connecting rod
12. Piston pin bushing

Figure 5-33. Piston and Connecting Rod Assembly, Exploded View

5. Disconnect the fuel lines to the fuel nozzle and holder assemblies (paragraph 5-15).

6. Remove the cylinder head cover, rocker arm assembly, and pushrods (paragraph 5-24).

7. Remove the cylinder head assembly (manifolds may be removed with the head). (Refer to paragraph 5-25.)

8. Remove the oil pan (paragraph 5-5) and oil pump (paragraph 5-6).

9. Carefully scrape the carbon deposits from the top of each cylinder bore so that the pistons can be removed without damage to the rings. On cylinder bores with excessive wear, it may be necessary to use a ridge reamer.

10. Crank the engine so that the No. 1 piston connecting rod caps can be removed. Remove the cap bolts (1, figure 5-33), connecting rod cap (2), and lower bearing (3). Be sure to keep the connecting rod, cap, and bearings for each piston together. Do not mix parts. With a block of wood or hammer handle, carefully push the piston and rod assembly out through top of the cylinder block. See figure 5-34. After the connecting rod (11, figure 5-33) and piston 10) are removed from the cylinder block, reassemble the connecting rod cap (2) and lower bearing (3) to the connecting rod.

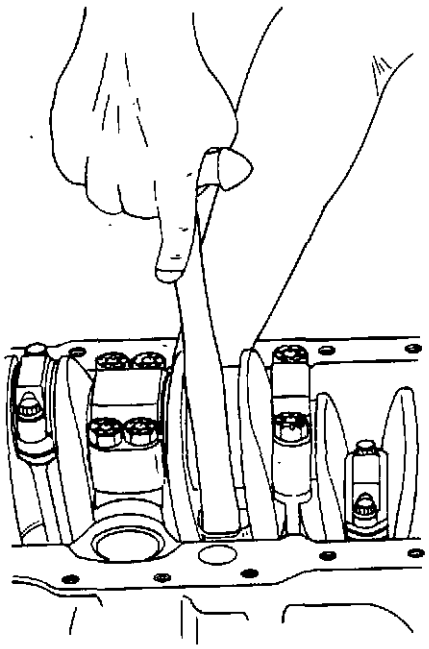


Figure 5-34. Piston and Connecting Rod Removal

11. Remove the remaining pistons and connecting rod assemblies in a similar manner. Rotate the crankshaft as necessary to provide easy access to each connecting rod cap.

12. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings (5, 6, and 7) with a piston ring expander tool.

13. To disconnect the connecting rods from the pistons, remove the piston pin retaining rings (8) and push the pin (9) out of the piston and piston pin bushing (12).

b. Cleaning and Inspection.

1. Clean the parts with cleaning solvent. If this does not remove the carbon deposits, use a chemical carbon solvent that will not attack the aluminum pistons or the bronze piston pin bushings.

2. Clean the compression ring grooves of the piston. This can be done with a broken compression ring that has been ground to a bevel edge.

3. Using a standard aligning fixture, check the connecting rod for distortion and misalignment. Check the connecting rods, caps, and bolts for cracks with magnetic particle test. Discard and replace parts if cracks are detected.

4. Inspect the connecting rod bearings for scoring, chipping, flaking, pits, cracks, and signs of overheating. Bright spots on back of bearings indicate shifting and are cause for replacement.

5. Check the piston pin bushing for scoring or wear. Replace bushing if bore is scored or if worn to more than 1.2523 inches. Press worn bushing from connecting rod and press in new one.

6. Inspect the piston pin for wear or scoring. Replace pin if worn to less than 1.2478-inch diameter. Maximum allowable pin clearance in piston is 0.0005 inch and in connecting rod is 0.0012 inch.

7. Inspect the pistons for damaged ring grooves, scoring, or cracks. Remove light scoring with fine emery cloth. Replace piston if damaged beyond repair.

c. Reassembly and Installation.

NOTE

All parts should be at room temperature to insure proper dimensional tolerances during piston and ring fitting.

1. Using a micrometer or cylinder bore indicator, measure the size of the cylinder bores. The piston size will be identified by the letter stamped on top of piston. Check the fit of the piston without rings in the cylinder bore. If any binding occurs, remove the piston and examine the piston and cylinder wall for burrs. Remove burrs with a fine hone (a flat one is preferable) before proceeding with the installation. If a new standard piston is to be installed, specify size by the letter A, B, C, D, or E stamped on top of the piston. (See Chart on Page 7-1.)

2. All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston is installed.

3. Insert one ring at a time inside of the cylinder bore, far enough down to be within the normal area of the ring travel. Use a piston to push down the ring to be sure it is parallel with the top of the cylinder bore. Measure the ring gap with a feeler gauge. All ring gaps shall be 0.010 to 0.020 inch.

4. Check the ring clearance in the piston ring grooves. See Fits and Tolerances in Section VII.

5. Assemble each piston and connecting rod assembly by placing the upper end of the connecting rod between the piston pin bosses and in line with the piston pin holes. Then, slide the piston pin (9, figure 5-33) in place. To facilitate assembly, heat the piston in boiling water for a few minutes, but do not heat the piston pin. Install the pin retaining rings (8).

6. Install the piston rings (5, 6, and 7) on the piston as follows:

(a) Install the rings on the piston with an expander tool. To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston.

(b) When installing the piston rings, stagger the positions of the ring gaps around

the piston to minimize compression loss. No two ring gaps may be in line.

(c) When installing piston rings with undercut grooves, note the following instructions:

(1) On all piston rings that have the groove on the outside diameter of the ring, place the undercut or groove towards the bottom of the piston. See figure 5-35.

(2) On all piston rings that have the groove cut on the inside diameter of the ring, place the undercut or groove towards the top of the piston. See figure 5-35.

7. Inspect the crankshaft for any rough or scored marks that might damage the connecting rod bearing. If any rough marks are found, polish the shaft with an oil stone, very fine emery cloth, or crocus cloth. Clean the shaft thoroughly after polishing.

NOTE

The cylinder number is stamped on the connecting rods and caps on the camshaft side and to the front of the engine.

8. Select the proper piston and connecting rod assembly for the first cylinder bore and turn the crankshaft so that the connecting rod journal for that cylinder is in the lowered position. Apply a coat of lubricating oil to the cylinder bores, pistons, rings, piston pin, and crankshaft journal.

9. Use a ring compressor to compress the piston rings to facilitate installation of the piston and rod assemblies. With the connecting rod bearing cap and bearings removed from the connecting rod, insert the piston from the top of the cylinder block. Use a hammer handle or block of wood against the top of the piston to push the piston into the cylinder bore. See figure 5-36. Take care that the connecting rod is in line with the crankshaft journal and will not score it.

10. Install the bearings and connect the connecting rod to the crankshaft as follows:

(a) With the piston entirely in the cylinder bore, insert the upper bearing (4, figure 5-33) in the connecting rod. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.

(b) To check crankshaft journal-to-bearing shell clearance, place a piece of plastic gauge material the full width of the lower bearing (3) about 1/4 inch off center (see figure 5-37). Rotate the crankshaft about 30° from

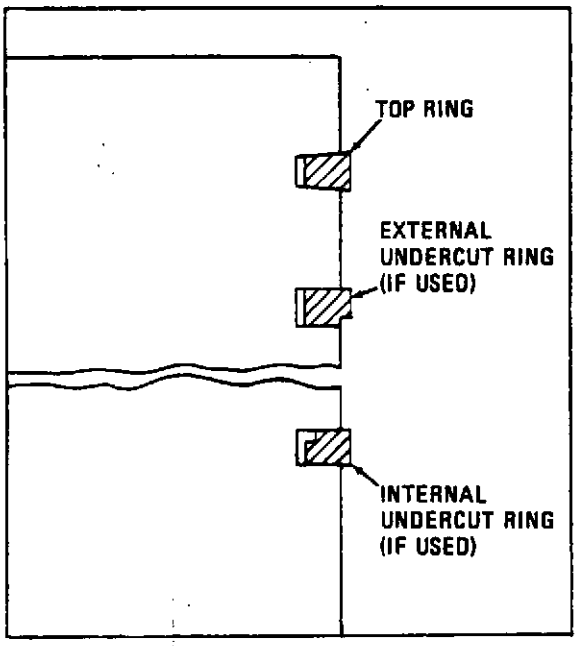


Figure 5-35. Piston Ring Installation

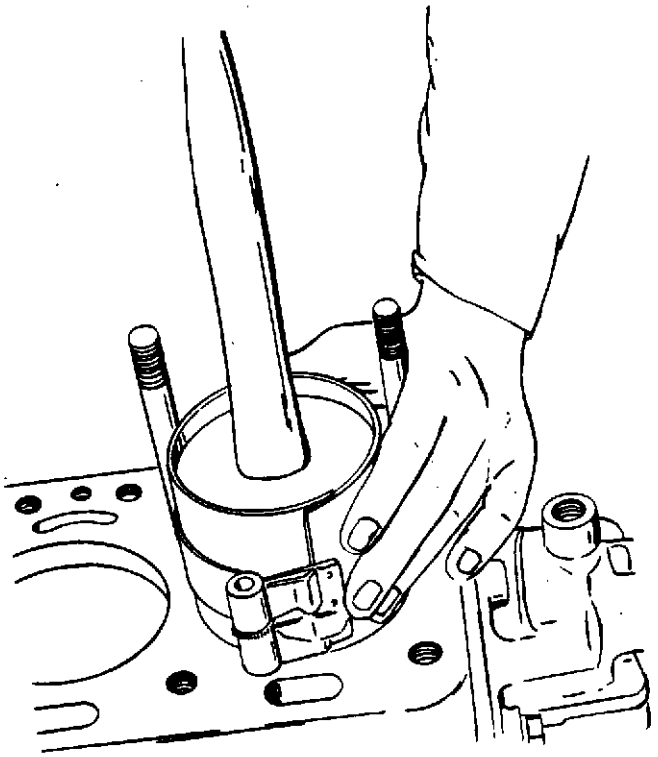


Figure 5-36. Piston Installation

bottom dead center and install the connecting rod cap. Tighten the connecting rod cap bolts to 70 foot-pounds torque.

(c) Remove the connecting rod cap. The flattened plastic gauge material will be found adhering to either the lower bearing or the crankshaft. Compare the width of the flattened plastic gauge material at its widest point with the graduations on the package, as shown in figure 5-37. The required clearance for new parts is 0.001 to 0.003 inch. With used parts, the maximum allowable clearance is 0.005 inch.

(d) If the clearance is within required limits, remove the gauge material and reinstall the connecting rod bearings and cap (2). Tighten the bolts (1) to 68 to 72 foot-pounds torque. Check the connecting rod side clearance; it should be 0.005 to 0.012 inch with a maximum clearance of 0.020 inch.

11. Install the remaining piston and connecting rod assemblies in a similar manner.

12. Install the oil pump (paragraph 5-6).

13. Inspect the top of the cylinder block and pistons. Make sure no foreign matter is present; install the cylinder head gasket.

14. Install the cylinder head (paragraph 5-25).

15. Insert the valve push rods and install the rocker arm assembly (paragraph 5-24).

16. Install the cylinder head cover, using a new gasket. Install the nuts and washers.

17. Install the thermostat, thermostat housing, and water pump bypass hose; connect the water temperature gauge thermocouple.

18. Connect fuel lines (paragraph 5-15).

19. Install and connect the air cleaner; connect the exhaust pipe to the manifold.

20. Connect the radiator hoses and fill the radiator with clean water or antifreeze.

21. Install the oil pan, using new gaskets, and fill the crankcase with the proper grade of lubricating oil (paragraph 5-5).

22. Adjust the valve clearance (paragraph 5-26f).

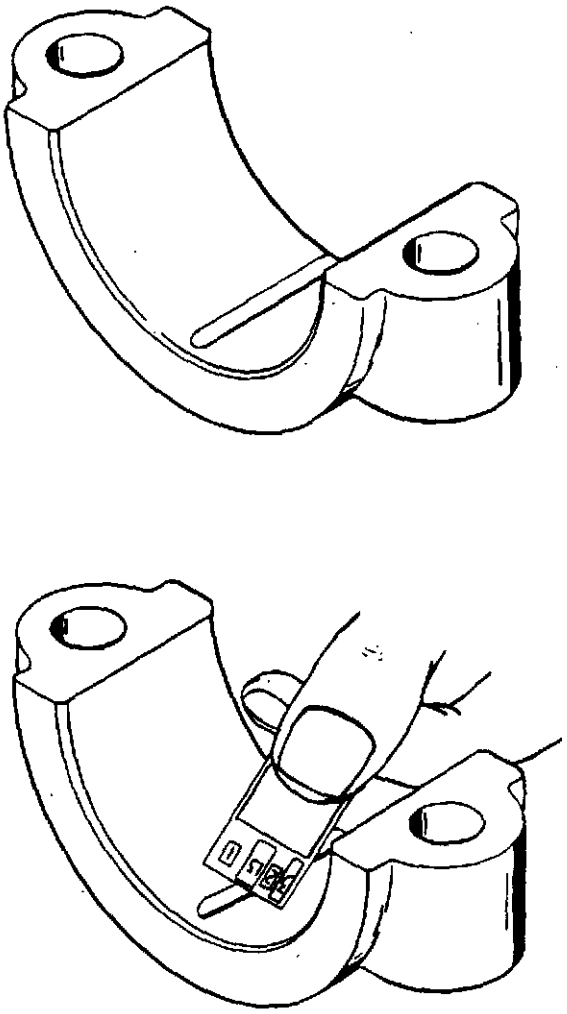


Figure 5-37. Checking Bearing Clearance

5-32. CRANKSHAFT AND MAIN BEARINGS.

The crankshaft is a machined forging with surface-hardened bearing journals. The shaft has passages drilled to carry oil, under pressure, to the connecting rod bearings. Normally, it is not necessary to remove the crankshaft gear from the crankshaft.

The use of seven main bearings in the six-cylinder engine, five in the four-cylinder, and four in the three-cylinder engine permits a main bearing to be placed on each side of each connecting rod bearing (see figure 5-38). This construction helps to eliminate vibration at high speeds. The main bearings are removable, precision, shell-type bearings. The upper shell of each bearing is not interchangeable with the lower shell. No shims are used. These precision-type shells are completely finished before being put in place and no line reaming or scraping is required.

a. Removal.

Removal of the crankshaft is greatly facilitated if the engine is mounted on an engine overhaul stand with the head and piston and connecting rod assemblies removed. However, it is not necessary to remove the engine from the unit to replace only the main bearings. To remove the main bearings only, proceed as indicated in steps 4 through 8 below. To remove the crankshaft and main bearings, the following minimum disassembly is required.

1. Drain the radiator and remove the radiator, hoses, and radiator support bracket.

2. Disconnect and remove the air cleaner from the intake manifold (figure 5-14) and disconnect the muffler and exhaust pipe from the exhaust manifold.

3. Remove the fan and belt(s) for easier access to the gear cover and gears (paragraph 5-9) and remove the fan drive pulley and gear housing cover (paragraphs 5-9 and 5-29).

4. Drain the crankcase and remove the oil pan (paragraph 5-5).

5. Remove the oil pump (paragraph 5-6). If a tachometer drive is used, it must be removed before the oil pump can be removed.

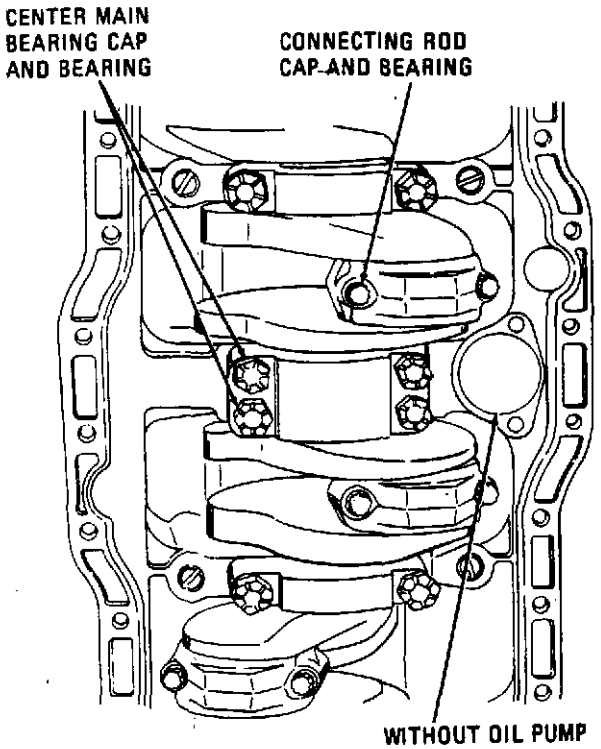


Figure 5-38. Crankshaft and Main Bearings

6. Remove the front and rear oil pan adapters (paragraphs 5-28 and 5-29).

7. Remove the main bearing caps (14, 15, 16, and 17, figure 5-31) by removing the bolts (10, 11, 12, and 13). Remove the main bearing caps and lower main bearings (18, 19, 20, and 21), one cylinder at a time. Keep each bearing matched with its bearing cap. It may be necessary to use a small pry bar to remove the main bearing caps from the cylinder block. Be careful not to score or mar the crankshaft journals.

8. To remove the upper main bearings (23, 24, 25, and 26, figure 5-31) without removing the crankshaft, insert a small tee-shaped pin in the crankshaft oil hole. Rotate the crankshaft (22) so that the pin will push the upper main bearing out, as shown in figure 5-39. If the crankshaft is to be removed, remove the upper bearings after removing the crankshaft.

9. Remove the connecting rod bearing caps and bearings (paragraph 5-31).

10. With the engine inverted on an overhaul stand, use a rope sling and a hoist to remove the crankshaft (22, figure 5-31) from the cylinder block (64). Take care to prevent scoring of the crankshaft journals.

11. Remove the upper main bearings (23, 24, 25, and 26) from the cylinder block.

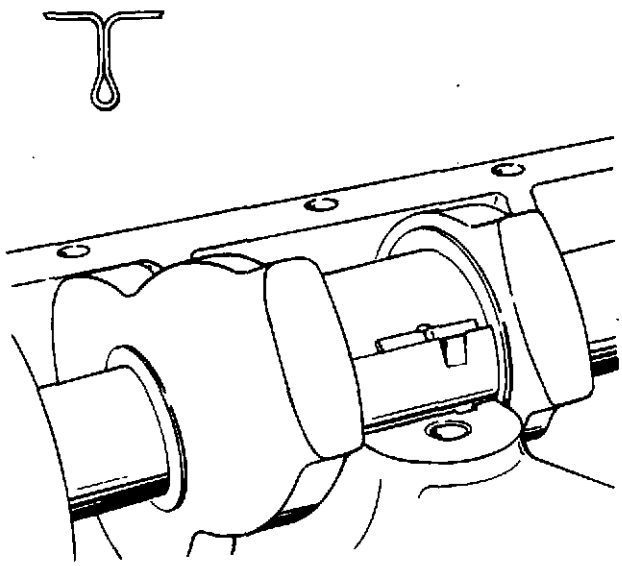


Figure 5-39. Upper Main Bearing Removal and Installation

b. Cleaning and Inspection.

1. Discard used gaskets and seals.

2. Clean all parts with cleaning solvent; dry with filtered compressed air.

3. Clean the oil passages in the crankshaft with a small tube brush.

4. Inspect the crankshaft gear for cracked or worn gear teeth. If gear removal is necessary, properly support the crankshaft and gear in an arbor press and remove the gear (27, figure 5-31) from the crankshaft. Remove the woodruff key (28). If the gear must be replaced and an arbor press is not available, use a 1/4-inch drill centered midway between the edge of the keyway and the base of the gear teeth and drill through the gear parallel with the keyway. Spread the gear with a chisel and pull from the shaft. Be careful not to drill into the crankshaft.

5. Inspect the bearing caps for cracks and distortion. Replace if damaged.

6. Inspect the main bearings for scoring, chipping, flaking, pits, and signs of overheating. Bright spots on back of bearings indicate shifting and are cause for replacement. Replace all main bearings if one or more is damaged and requires replacement.

7. Inspect the crankshaft for cracks, scored journals, and misalignment. Replace if damaged beyond repair. Perform detailed inspection of the crankshaft as follows:

(a) Check the surfaces of the crankshaft for cracks. There are several methods of determining the presence of minute cracks not visible to the eye. These inspection methods include magnetic particle, fluorescent magnetic particle, and fluorescent penetrant. Check for circumferential fillet cracks at the critical areas, and 45° cracks (45° with axis of the shaft) starting from either the critical fillet locations or the crankshaft holes. Cracks of this nature require replacement of the shaft.

(b) Inspect the keyways for cracks or wear; replace the shaft if necessary.

(c) If the crankshaft is worn so that the maximum journal-to-bearing clearance (with new bearings) exceeds 0.007 inch, or the maximum taper is 0.0015 inch, or the out-of-round is 0.002 inch, the crankshaft must be reground to 0.010, 0.020, 0.030, 0.040, or 0.060 inch undersize. Proceed as follows:

(1) Prior to grinding a crankshaft, check carefully for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshafts with such cracks must be rejected, as these cracks indicate torsional fatigue. Grinding of the shaft will increase the stress at the cracks causing eventual failure.

(2) Measure the crankshaft journals, and compare these measurements to the diameters required for various undersize bearings shown in table 5-2. These measurements will determine the size to which the crankshaft journals must be reground.

(3) If one or more main or connecting rod journals require grinding, then all main or all connecting rod journals must be ground to the same required size.

(4) When regrinding crankshafts, all journal fillets must have a 0.140- to 0.170-inch radius between the crank cheek and the crank journal, and must not have any sharp grind marks. The fillet must blend smoothly into the journal and cheek, and must be free of scratches.

(5) After all of the regrinding operations have been completed, perform another magnetic particle inspection of the crankshaft to determine whether grinding cracks have originated due either to insufficient cooling or crowding of the grinding wheel. Finally, demagnetize the crankshaft.

(6) Wash and clean the crankshaft with diesel fuel and blow dry with air. Blow out the oil passages to make sure they are clear.

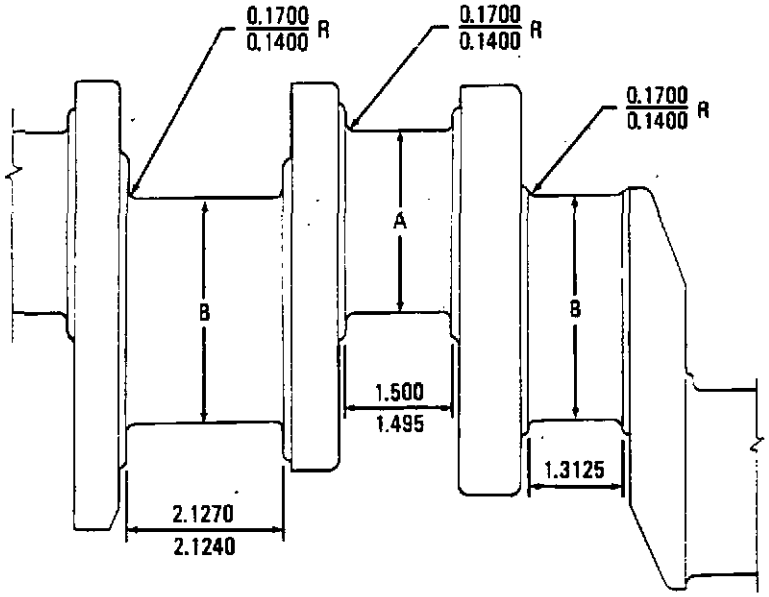
c. Reassembly and Installation.

1. Install the crankshaft gear (27, figure 5-31) onto the crankshaft (22). Use an arbor press, if available, to press the gear on the shaft. Make sure the woodruff key (28) is in place. If an arbor press is not available, the following method may be used:

(a) Insert the woodruff key (28) in the crankshaft.

(b) Lay the gear on a sheet of asbestos or other fireproof material and, with a torch, heat the gear evenly on both sides until the gear turns a pale straw yellow. (If the gear is clean and untarnished, this color will indicate it is heated to approximately 450°F.)

Table 5-2. Crankshaft Journal and Crankpin Dimensions



Bearing Sizes (Inches)	Connecting Rod Journal Dia "A" (Inches)	Main Bearing Journal Dia "B" (Inches)
Standard	2.3730/2.3740	2.8734/2.8744
0.010 Undersize	2.3630/2.3640	2.8634/2.8644
0.020 Undersize	2.3530/2.3540	2.8534/2.8544
0.030 Undersize	2.3430/2.3440	2.8434/2.8444
0.040 Undersize	2.3330/2.3340	2.8334/2.8344
0.060 Undersize	2.3130/2.3140	2.8134/2.8144

(c) Assemble the hot gear on the crankshaft and quickly drive the gear into the correct position. A piece of 2-inch diameter pipe may be used as a driver.

(d) Allow the gear and shaft to cool.

2. Install the upper main bearings (23, 24, 25, and 26) in the cylinder block. The upper bearings are the bearings with two holes and an oil groove. The bearings must be installed in the same positions from which they were removed.

NOTE

The upper main bearings can be installed with the crankshaft in place. Install a small tee-shaped pin into the crankshaft oil hole. After starting the bearing into place, rotate the crankshaft to seat it on the cylinder block, as shown in figure 5-39.

3. Apply clean engine oil to all of the crankshaft journals and bearings and, using a sling and hoist, carefully set the crankshaft in place so that the timing marks on the crankshaft gear and the camshaft gear align as shown in figure 5-27.

NOTE

On three-cylinder engines with four main bearing caps, the No. 3 cylinder bearing cap is the "center" bearing cap.

4. With the lower main bearings (18, 19, 20, and 21, figure 5-31) installed in the bearing cap (14, 15, 16, and 17) from which they were removed, install the caps in their original positions on the cylinder block. The caps are marked with the cylinder number in which they are used. The center main bearing cap is secured with four 1/2-inch diameter bolts. The remaining bearing caps are secured with two 9/16-inch diameter bolts each. Draw the bolts up snug, then rap the caps sharply with a soft

Table 5-3. Main Bearing Cap Bolt Torques

	T-Stamped Caps (Foot-Pounds)	Plain Caps (Foot-Pounds)
9/16-inch bolts for front, rear, and intermediate caps	130	80
1/2-inch bolts for center main bearing cap	100	80

hammer to seat them properly. Check the original center main bearing cap for a T stamped on the side opposite the cylinder number to determine the required torque value. Tighten the bearing cap bolts to the torque specified in table 5-3. Refer to figure 5-40. Start with the center cap and work alternately toward both ends of the block. If the bearings have been installed properly, the crankshaft will turn freely with all main bearing caps drawn down to the specified torque.

5. After installing crankshaft with new bearings and center thrust bearing, check the crankshaft end thrust. Insert different dimension feeler gauges until one just fits between the center thrust bearing and the crankshaft as shown in figure 5-41. This dimension must be between 0.005 and 0.010 inch for new bearings, and the maximum allowable clearance of 0.015 inch. Insufficient clearance can be the result of a misaligned main bearing, or a burr or dirt on the inner face of the thrust bearing flange. Disassemble, clean, and reassemble as necessary. If clearance is still insufficient, polish the thrust bearing flanges on a flat surface with crocus cloth to obtain the proper clearance.

6. Position the connecting rods so that they engage the journals of the crankshaft. Apply a coat of engine oil to the bearing shells to assure proper lubrication. Install the connecting rod bearings and bearing caps (paragraph 5-31).

7. Install the internal oil jumper line, if used.

8. Install the front and rear oil pan adapters (paragraphs 5-28 and 5-29).

9. Install the oil pump (paragraph 5-6); install the tachometer drive, if used.

10. Place a new seal in gear housing cover and install cover. Install the fan drive pulley (paragraphs 5-9 and 5-29).

11. Install the fan and belt(s) (paragraph 5-9).

12. Install muffler and exhaust pipe on the exhaust manifold and install the air cleaner on the intake manifold (figure 5-14).

13. Install the oil pan, using new gaskets. Fill the crankcase with the proper grade of lubricating oil (paragraph 5-5).

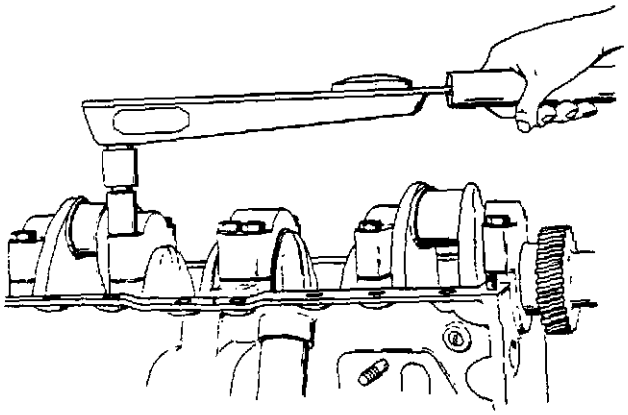


Figure 5-40. Tightening Main Bearing Cap Bolts

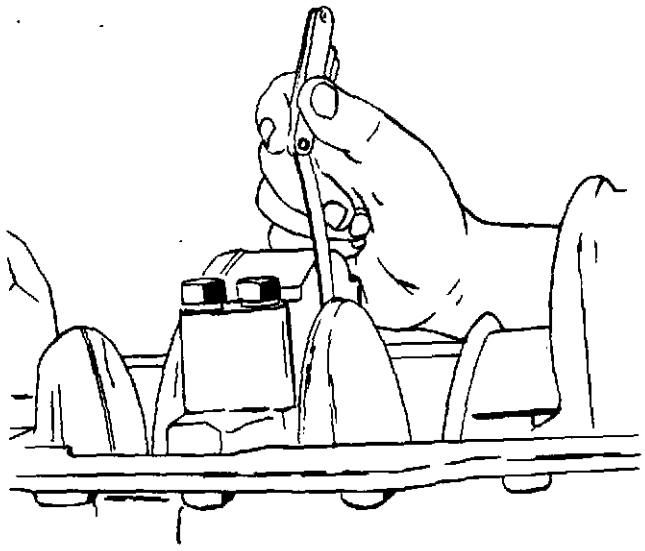


Figure 5-41. Checking Crankshaft End Thrust

14. Install the radiator, hoses, and support brackets. Fill with water or antifreeze.

5-33. CYLINDER BLOCK.

On most engines the cylinders are cast integral with the cylinder block. For uniform cooling, water jackets are carried the full length of the cylinders. Some engines are equipped with dry, removable cylinder sleeves.

The cylinder block has an oil header running the length of the block. From this header, various passages carry oil to the main bearings, camshaft bearings, and rocker arms.

a. Removal and Disassembly.

1. Remove the engine and mount it on an overhaul stand as directed in paragraph 5-2.

2. Remove the intake and exhaust manifolds (paragraphs 5-18 and 5-20).

3. Remove the fuel primer and fuel filters (paragraph 5-13).

4. Remove the fuel transfer pump (paragraph 5-12).

5. Remove the fuel injection pump (paragraph 5-14).

6. Remove the fuel nozzles and lines (paragraph 5-15).

7. Remove the water pump and fan assembly (paragraph 5-9).

8. Remove the cylinder head (paragraph 5-25).

9. Remove the flywheel (paragraph 5-27).

10. Remove the oil filters and lines (paragraph 5-4).

11. Remove the oil pan (paragraph 5-5).

12. Remove the bellhousing (paragraph 5-28).

13. Remove the gear housing (paragraph 5-29).

14. Remove the oil pump (paragraph 5-6).

15. Remove the camshaft (paragraph 5-30).

16. Remove the pistons and connecting rods (paragraph 5-31).

17. Remove the crankshaft and main bearings (paragraph 5-32).

18. Remove the bolts (40, figure 5-31) and lock washers (41) attaching the side cover (42) and gasket (43) to the engine; remove the side cover and gasket.

19. Remove the oil level bayonet gauge tube (48) from the cylinder block (64).

20. Refer to figure 5-31 and remove oil passage pipe plugs (30 thru 34, and 37) from the block. Do not remove the expansion plugs (55) in the core openings, unless they show signs of leaking.

21. Do not remove the various studs and dowel pins from the block unless they are damaged and require replacement.

b. Cleaning and Inspection.

1. Clean block by submerging in tank of heated cleaning solvent. Circulate the solvent to increase cleaning effectiveness.

NOTE

If additional machining is to be performed, clean oil passage and reinstall plugs after all machining is completed.

2. Clean oil passages by running a wire brush through them.

3. Check the cylinder block for cracks by using dye penetrants according to manufacturer's instructions. Replace a damaged block.

4. Check for excessive cylinder bore wear by determining the diameter of the wear area and comparing this with the original cylinder bore diameter. Gauge at intervals of approximately 45 degrees. Refer to table 5-4 for standard bore dimensions. Maximum allowable wear is 0.005 inch.

NOTE

If wear appears to be unusually excessive, check for original cylinder bore diameter by gauging the diameter of the cylinder below the piston ring wear area. The cylinder may already have been rebored for over-sized pistons.

Table 5-4. Cylinder Bore Dimensions

Cylinder Bore Diameter	Manufacturing Diameter	
	Minimum	Maximum
3-3/4 inch bore	3.7492	3.7516
.020 over-size	3.7692	3.7716
.040 over-size	3.7892	3.7916
4 inch bore	3.9987	4.0011
.020 over-size	4.0187	4.0211
.040 over-size	4.0387	4.0411
* SEE CYLINDER BORE AND PISTON CHART - PAGE 7-1.		

5. The out-of-round must not exceed 0.003 inch or the taper must not be more than 0.002 inch in each bore. Irregularities in the cylinder bore (out-of-round and taper) may result in galling and seizing of new pistons.

6. If the cylinder bores are worn excessively, they can be rebored for 0.020 and 0.040 oversize pistons and piston rings. Use a good commercial boring unit and follow the manufacturer's instructions. After boring, check the bore finish to be sure it is smooth.

7. Hone the cylinders and ridge ream, if necessary. After honing the cylinders, visually check the honed surface of each cylinder bore. There must not be any low spot with an area larger than a half dollar. Recheck the cylinder tolerance as described above.

8. Check the top of the block for flatness with an accurate straightedge and a feeler gauge. The top surface must not vary more than 0.005 inch on width or length. Out-of-flatness should vary gradually and uniformly from end to end and side to side. If it is necessary to machine the top surface of the block to correct for the above conditions, do not remove more than 0.005 inch of metal. The dimension from the centerline of the crankshaft to the top of the block must not be less than 13.12 inches.

9. Remove and replace any damaged or broken cylinder head studs (49 thru 54). With studs removed, inspect the tapped stud holes in the block and, if the threads are damaged, use a tap (same size as hole) to clean up the threads or retap larger and install a helical thread insert. Add locktite in hole and install new studs in the cylinder block to the dimensions indicated in table 5-5. Install the end oil passage studs so that the oil holes are within a 40-degree angle with the center line of the rocker arm shaft, as shown in figure 5-18.

10. Check the main bearing bores as follows:

(a) Install the main bearing caps in their original positions. Draw the bolts up snugly, and rap the bearing cap sharply with a soft hammer to assure proper seating. Tighten the bolts to the torques given in table 5-3.

NOTE

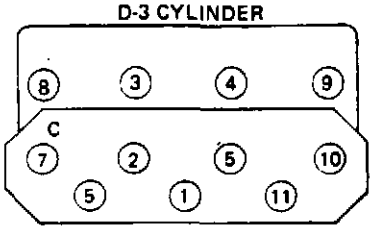
It is imperative that the main bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The caps are marked with the number of the cylinder in which they are used.

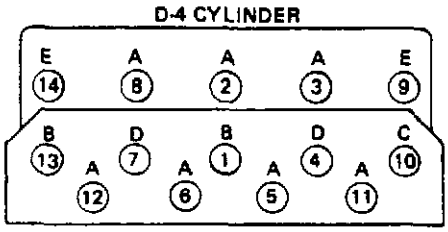
(b) Measure the main bearing bores. The bearing bores must be 3.0665 to 3.0670 inches. If the bores do not fall within these limits, discard the cylinder block.

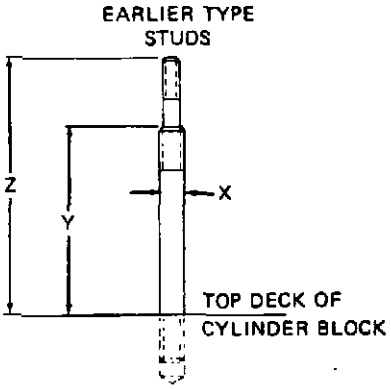
(c) Check the main bearing bores for alignment. Misalignment may be caused by a broken crankshaft, excessive heat, or other severe damage. Check bearing bore alignment. If a crankshaft having standard size journals, new standard size main bearing shells installed and lubricated, and the bearing caps properly tightened, can be rotated freely by hand, the bores are properly aligned. If a main bearing bore is out of alignment, the block must be line-bored or scraped. After boring, all bores must be within the 3.0665- to 3.0670-inch limits.

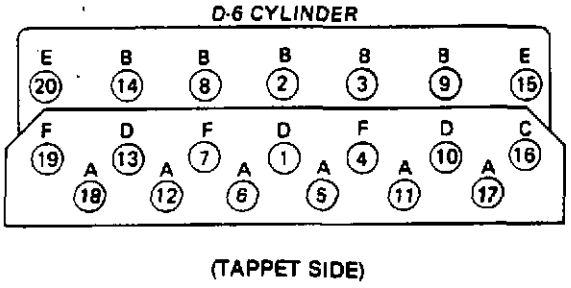
11. Check the camshaft bearing bores. The internal diameter of bearing bores must be 2.1870 to 2.1889 inches. If the bores do not fall within these limits, replace the cylinder block.

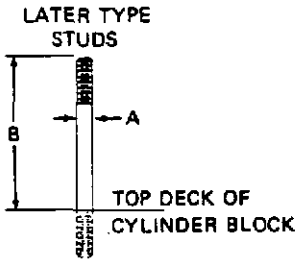
Table 5-5. Cylinder Stud Installation











EARLIER TYPE STUDS

Stud Identification	3 Cylinder			4 Cylinder			6 Cylinder		
	X-Diameter	Height		X-Diameter	Height		X-Diameter	Height	
A	.562	Y	4.625	.562	Y	4.625	.562	Y	4.625
B	.562	Y Z	4.625 6.250	.562	Y Z	4.625 6.250	.625	Y	4.688
C - Oil supply	.625	Y Z	4.625 6.250	.625	Y Z	4.625 6.250	.625	Y	4.625
D - Cover	.562	Y Z	4.625 6.562	.562	Y Z	4.625 6.250	.625	Y	4.625
E - Lift	.562	Y	5.500	.562	Y	5.500	.625	Y	5.375
F							.625	Y	4.625

LATER TYPE STUDS

Studs	3 Cylinder		4 Cylinder		6 Cylinder	
	A-Diameter	B-Height	A-Diameter	B-Height	A-Diameter	B-Height
A			.562	4.620	.562	4.620
B			.562	6.650	.625	4.680
C-Oil Supply			.625	6.620	.625	6.620
D-Cover			.562	7.430	.625	7.430
E-Lift			.562	5.750	.625	5.810
F					.625	6.620

12. Check the plugs in the vertical oil passages in the corners of the block to be sure they are flush with or below the top surface of the block.

13. Check all of the machined accessory mounting pads for flatness, nicks, and burrs. Remove nicks and burrs with a fine file.

14. Check the remaining studs and dowel pins in the block for damaged threads, distortion, cracks, or other damage. Replace any damaged parts.

15. Check all the threaded holes in the cylinder block. Make sure they are clean and the threads are in good condition. Clean up damaged threads in the tapped holes with a same-size tap or retap larger and install helical thread inserts, if necessary.

16. Inspect the covers (42 and 46, figure 5-31) and bayonet gauge tube for cracks, dents, distortion, and other damage. Replace any damaged parts.

c. Reassembly and Installation.

1. Reinstall any studs, dowel pins, or expansion plugs (55, figure 5-31) that have been removed.

2. Reinstall pipe plugs (30 thru 34, and 37) in open oil passages. Make sure the lower camshaft thrust flange mounting hole is plugged with setscrew (38). This is the rear end opening of the oil passage for the rocker arms and must be plugged to prevent oil leakage.

3. Install the oil level bayonet gauge tube (48) in the cylinder block (64).

4. Install the cover (46) and gasket (47); secure with nuts (44) and lock washers (45).

5. Install the side cover plate (42) and gasket (43); secure with bolts (40) and lock washers (41).

6. Install cylinder sleeves, if used. Cylinger sleeves require a light press to install them.

7. Install the crankshaft and main bearings (paragraph 5-32).

8. Install the pistons and connecting rods (paragraph 5-31).

9. Install the camshaft (paragraph 5-30).

10. Install the oil pump (paragraph 5-6).

11. Install the gear housing (paragraph 5-29).

12. Install the bellhousing (paragraph 5-28).

13. Install the oil pan (paragraph 5-5).

14. Install the oil filters and lines (paragraph 5-4).

15. Install the flywheel (paragraph 5-27).

16. Install the cylinder head (paragraph 5-25).

17. Install the rocker arm assembly (paragraph 5-24).

18. Install the thermostat and housing (paragraph 5-10).

19. Install the water pump and fan assembly (paragraph 5-9).

20. Install the fuel nozzles and lines (paragraph 5-15).

21. Install the fuel injection pump (paragraph 5-14).

22. Install the fuel transfer pump (paragraph 5-12).

23. Install the fuel primer and fuel filters (paragraph 5-13).

24. Install the intake and exhaust manifolds (paragraphs 5-18 and 5-20).

25. Reassemble the engine accessories and install the engine in the power unit by reversing the procedure given in paragraph 5-2.

26. After overhaul, make the following adjustments:

(a) Adjust valve clearance (paragraph 3-5h).

(b) Time fuel injection pump (paragraph 3-5h).

(c) Adjust idle speed (paragraph 3-5h).

(d) Adjust maximum governed speed (paragraph 3-5h).

SECTION VI
TORQUE SPECIFICATIONS

Table 6-1 lists the torque specifications which must be used during engine reassembly. Follow these values to insure proper fits, tolerances, and alignment of the reassembled engine.

Table 6-1. Torque Specifications

	Torque (Foot-Pounds) 3 and 4 Cylinder	6 Cylinder		Torque (Foot-Pounds) 3 and 4 Cylinder	6 Cylinder
Main bearing cap screw			Injector nozzle flange bolt	20	20
Front	130	130			
Intermediate	130	130	Fuel line (Roosa pump)	20	20
Center	100	100			
Rear	130	130	Fuel line (Bosch pump)	25	25
Older block without "T" on cap	80	80			
			Idler gear capscrew (Use Loctite)	25	25
All connecting rod bolts	70	70			
			Drive gear nut (Roosa)	65	65
Camshaft gear nut	130	130			
			Water pump attaching bolt	24	24
Crankshaft pulley	125	125			
Flywheel-to-crankshaft bolt	80	80	Oil pan attaching bolt	20	20
			Gear housing attaching bolt	40	40
Flywheel housing nuts and cap screws	60	60			
			Gear cover attaching bolt	15	15
Oil pump attaching bolt	25	25			
Cylinder head			Thermostat housing bolt	15	15
9/16" stud nut	147	147			
5/8" stud nut	160	175	Cam thrust plate bolt	9	9
Exhaust manifold nut	20	20	Oil pan adapter-to-housing bolt	15	15
Intake manifold nut	20	20			
			PTO adapter ring bolt	35	35
Fuel pump attaching nut	15	15			
Vibration damper-to-pulley nut	25	25			

SECTION VII
FITS AND TOLERANCES

CYLINDER BORE SIZE TO PISTON SIZE AND CLEARANCE

PISTON CLEARANCE: 3¾" BORE

CYLINDER BLOCK BORE SIZE 3¾" BORE		ZOLLNAR PISTON SIZE 3¾" BORE		CLEARANCE
#A.	3.7492 3.7496	*A.	3.7438 3.7442	.0050 .0058
#B.	3.7497 3.7501	*B.	3.7443 3.7447	.0050 .0058
#C.	3.7502 3.7506	*C.	3.7448 3.7452	.0050 .0058
#D.	3.7507 3.7511	*D.	3.7453 3.7457	.0050 .0058
#E.	3.7512 3.7516	*E.	3.7458 3.7462	.0050 .0058

PISTON CLEARANCE: 4" BORE

CYLINDER BLOCK BORE SIZE 4" BORE		BOHN PISTON SIZE 4" BORE		CLEARANCE
#A.	3.9987 3.9991	*A.	3.9967 3.9971	.0016 .0024
#B.	3.9992 3.9996	*B.	3.9972 3.9976	.0016 .0024
#C.	3.9997 4.0001	*C.	3.9977 3.9981	.0016 .0024
#D.	4.0002 4.0006	*D.	3.9982 3.9986	.0016 .0024
#E.	4.0007 4.0011	*E.	3.9987 3.9991	.0016 .0024

IDENTIFIES BORE SIZE — STAMPED ON BLOCK
* IDENTIFIES PISTON SIZE — STAMPED ON PISTON

SECTION VII
FITS AND TOLERANCES

Model D Series: 3, 4 and 6 Cylinder	Mfg. Tolerances		Clearance		Maximum Allowable Wear
	Minimum	Maximum	Minimum	Maximum	
CYLINDER BLOCK					
Cylinder bore diameter					
3-3/4" bore	3.7492	3.7516			0.0050
4" bore	3.9987	4.0011			0.0050
Cylinder bore out of round		0.0005			0.0030
Cylinder bore taper		0.0005			0.0020
Main bearing bore-less bearing	3.0665	3.0670			
Camshaft bearing bore-less bearing	2.1860	2.1865			
Oil pump bore	2.0000	2.0005			
Valve tappet bore	0.7496	0.7505			
CRANKSHAFT					
Main bearing journal diameter	2.8734	2.8744			0.0030
Main bearing journal out of round		0.0005			0.0020
Main bearing journal taper		0.0003			0.0015
Main bearing run-out at center		0.0020			0.0030
Connecting rod journal diameter	2.3730	2.3740			0.0020
Connecting rod journal out of round		0.0003			0.0020
Connecting rod journal taper		0.0005			0.0015
Fillet radii	0.1400	0.1700			
Crankshaft main bearing clearance			0.0009	0.0034	
Crankshaft thrust clearance			0.0050	0.0100	
Seal surface diameter - rear	4.3100	4.3150			0.0150
Seal surface diameter - front	1.8740	1.8750			0.0150
CONNECTING ROD					
Length - c/l to c/l	7.9980	8.0020			
Bearing bore - less bearing	2.5260	2.5270			
Bearing to crankshaft clearance			0.0008	0.0038	
Connecting rod side clearance			0.0050	0.0120	
Piston pin bushing bore-less bushing	1.3745	1.3755			
Piston pin bushing bore	1.2503	1.2506			0.0015
CAMSHAFT					
Bearing journal diameter - all	2.0530	2.0540			0.0020
Lobe diameter - base to tip	1.7200	1.7250			0.0100
Journal run-out in vee blocks		0.0100			0.0040
Bearing clearance			0.001	0.003	
End thrust			0.005	0.008	
Back lash camshaft to crank gear			0.0015	0.0025	
PISTON					
Clearance in cylinder bore-3-3/4" Zollner	0.0050	0.0058			
Clearance in cylinder bore-4" Bohn	0.0016	0.0024			
Piston pin bore	1.2500	1.2502			0.0010
Width of ring groove-top-Keystone	1/8 Nom.				
Width of ring groove - 2nd	0.126	0.127			0.0050
Width of ring groove - oil control	0.1880	0.189			0.0050
PISTON PIN					
Length	3.025	3.035			
Diameter	1.2498	1.2500			0.0020
Clearance in piston			0.0000	0.0005	
Clearance in connecting rod			0.0005	0.0012	

Model D Series: 3, 4 and 6 Cylinder	Mfg. Tolerances		Clearance		Maximum Allowable Wear
	Minimum	Maximum	Minimum	Maximum	
PISTON RING					
Clearance in groove - top	Keystone taper				
Clearance in groove - 2nd	0.0040	0.0060			
Clearance in groove - oil control	0.0015	0.0030			
Gap	0.0100	0.0200			
INTAKE VALVE					
Head diameter	1.6825	1.6925			
Stem diameter	0.3725	0.3732			0.0025
Stem to guide clearance			0.0005	0.0025	
Stem to rocker arm clearance - hot			0.0150		
Seat diameter in head	1.6470	1.6530			
Seat width in head		7/64			1/8
Top of valve recessed below cylinder head deck	0.020	0.030			
Valve seat angle	30°				
EXHAUST VALVE					
Head diameter	1.4950	1.5050			
Stem diameter	0.3725	0.3732			0.0025
Stem to guide clearance			0.0015	0.0035	
Stem to rocker arm clearance - hot			0.0150		
Seat diameter in head	1.618	1.630			
Seat width in head		7/64			1/8
Top of valve recessed below cylinder head deck	0.035	0.045			
Valve seat angle	45°				
VALVE GUIDE					
Length	2.0325	2.9524			
Outside diameter	0.6265	0.6270			
Bore diameter					
intake - ream	0.3745	0.3750			0.0030
exhaust - ream	0.3745	0.3750			0.0030
Depth below cylinder head deck - all	1.3700	1.3800			
TAPPET, VALVE LIFTER (PUSH ROD)					
Body diameter	0.7485	0.7490			0.0030
Overall length	2.2450	2.2550			
Clearance in bore (block)			0.0005	0.0015	
VALVE SPRINGS - INTAKE AND EXHAUST					
Free length	1.702	1.722			
Total coils	6				
Diameter wire	0.172				
Outside diameter	0.286	1.3020			
Test load at 1.4920 inches lbs.	45	51			
Test load at 1.0820 inches lbs.	130	144			
VALVE SPRING - INTAKE AND EXHAUST					
NOTE: This spring is used in some engines and is not interchangeable					
Free length	1.8630	1.9030			
Total coils	7-1/2				
Diameter wire	0.1420				
Test load at 1.5225 inches lbs.	38	45			
Test load at 1.1725 inches lbs.	80	86			

FITS AND TOLERANCES

Model D Series: 3, 4 and 6 Cylinder	Mfg. Tolerances		Clearance		Maximum Allowable Wear
	Minimum	Maximum	Minimum	Maximum	
OIL PUMP BODY					
Shaft bore diameter					
main	0.6255	0.6265			0.0030
idler	0.6255	0.6265			0.0030
Pump gear bore diameter	1.5005	1.5015			0.0050
Pump gear bore depth	1.5640	1.5650			0.0040
SHAFTS - OIL PUMP					
Length					
main	9.2400	9.2500			
idler	2.615	2.635			
Diameter					
main	0.6240	0.6245			0.0020
idler	0.6270	0.6275			0.0020
Shaft clearance in body - drive shaft			0.0010	0.0025	
Shaft clearance in body - idler shaft			.00005	0.002	PP/FIT
GEARS - OIL PUMP					
Outside diameter - both	1.4975	1.4985			0.0020
Length - both	1.5610	1.5620			
Clearance in body bore			0.0020	0.0040	
End clearance to body			0.0020	0.0040	
Backlash drive gear to camshaft			0.0060	0.0120	
FLYWHEEL					
Clutch face run out at 6 in. radius		0.0080			
Pilot bore eccentricity		0.0050			
FLYWHEEL HOUSING					
Clutch attaching face deviation		0.0080			
Clutch housing bore eccentricity		0.0050			
ROCKER ARM MECHANISM					
Rocker Shaft Length					
3 cylinder	15.1775	15.1975			
4 cylinder	19.4900	19.5100			
6 cylinder	13.699	13.739			
Rocker shaft diameter	0.8590	0.8600			0.0030
Rocker arm bore diameter	0.8625	0.8635			0.0030
Rocker arm clearance on shaft			0.0025	0.0045	
HORIZONTAL FUEL PUMP					
Gear Train Backlash					
Crank to large idler			0.0015	0.0025	
Small idler to fuel pump			0.0015	0.0025	
Total fuel pump to crank			0.003	0.005	

HERCULES ENGINES, INC.

101 Eleventh St., S.E., Canton, Ohio 44707-3802

Parts (216) 438-1025

FAX: (216) 438-1030

Service (216) 438-1035

HERCULES ENGINES, INC.

101 Eleventh St., S.E., Canton, Ohio 44707-3802

Parts (216) 438-1025
FAX: (216) 438-1030
Service (216) 438-1035

40-0090061•0389