DD SERIES
3-4-6 CYLINDER
DIESEL ENGINES

OPERATION AND MAINTENANCE MANUAL FOR

DD SERIES

THREE-FOUR-SIX CYLINDER

DIESEL ENGINES

JUNE 1958

HERCULES

HERCULES MOTORS CORPORATION
Canton, Ohio, U.S.A.

OPERATION AND MAINTENANCE MANUAL FOR DD SERIES ENGINES

DD Three Cylinder Serial Numbers	3600001 - 3650000
DD Four Cylinder Serial Numbers	3200001 - 3300000
DD Six Cylinder Serial Numbers	3400001 - 3500000

THREE CYLINDER MODELS

MODEL	BORE		STROKE
DD-130	3-1/2"	X	4-1/2"
DD-149	3-3/4"	X	4-1/2"
DD-169	4"	X	4-1/2"

FOUR CYLINDER MODELS

DD-173	3-1/2"	X	4-1/2"
DD-198	3-3/4"	X	4-1/2"
DD-226	4"	X	4-1/2"

SIX CYLINDER MODELS

DD-260	3-1/2"	X	4-1/2"
DD-298	3-3/4"	X	4-1/2"
DD-339	4"	X	4-1/2"

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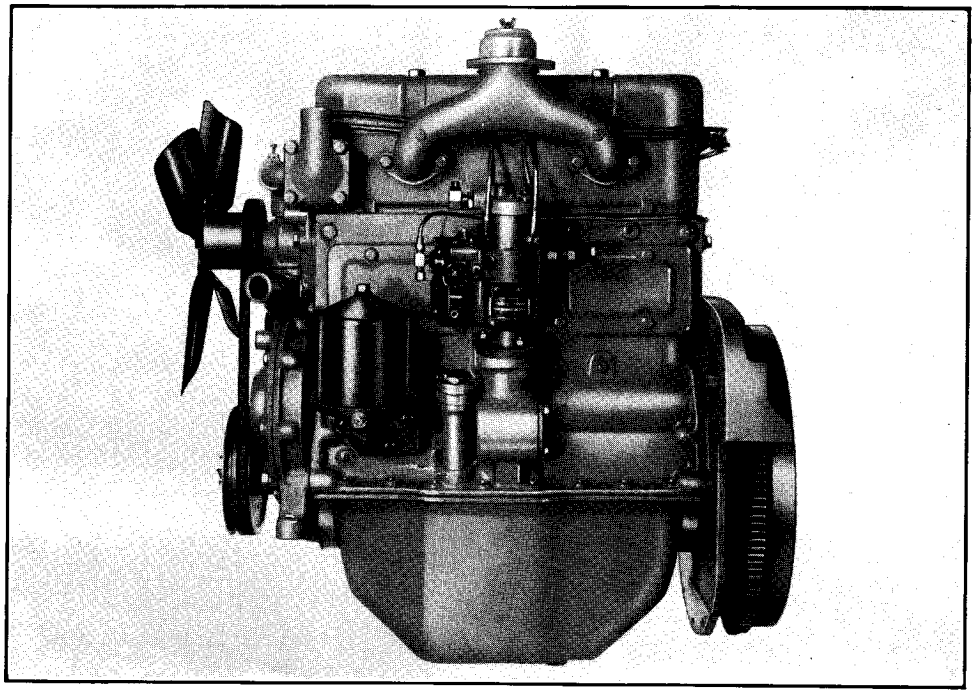
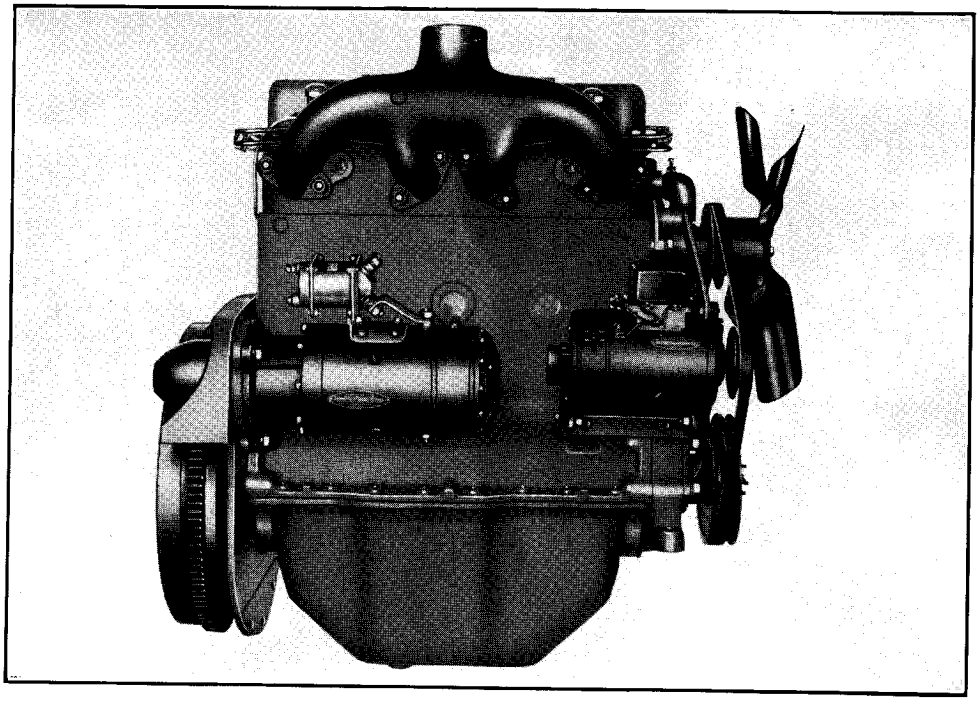
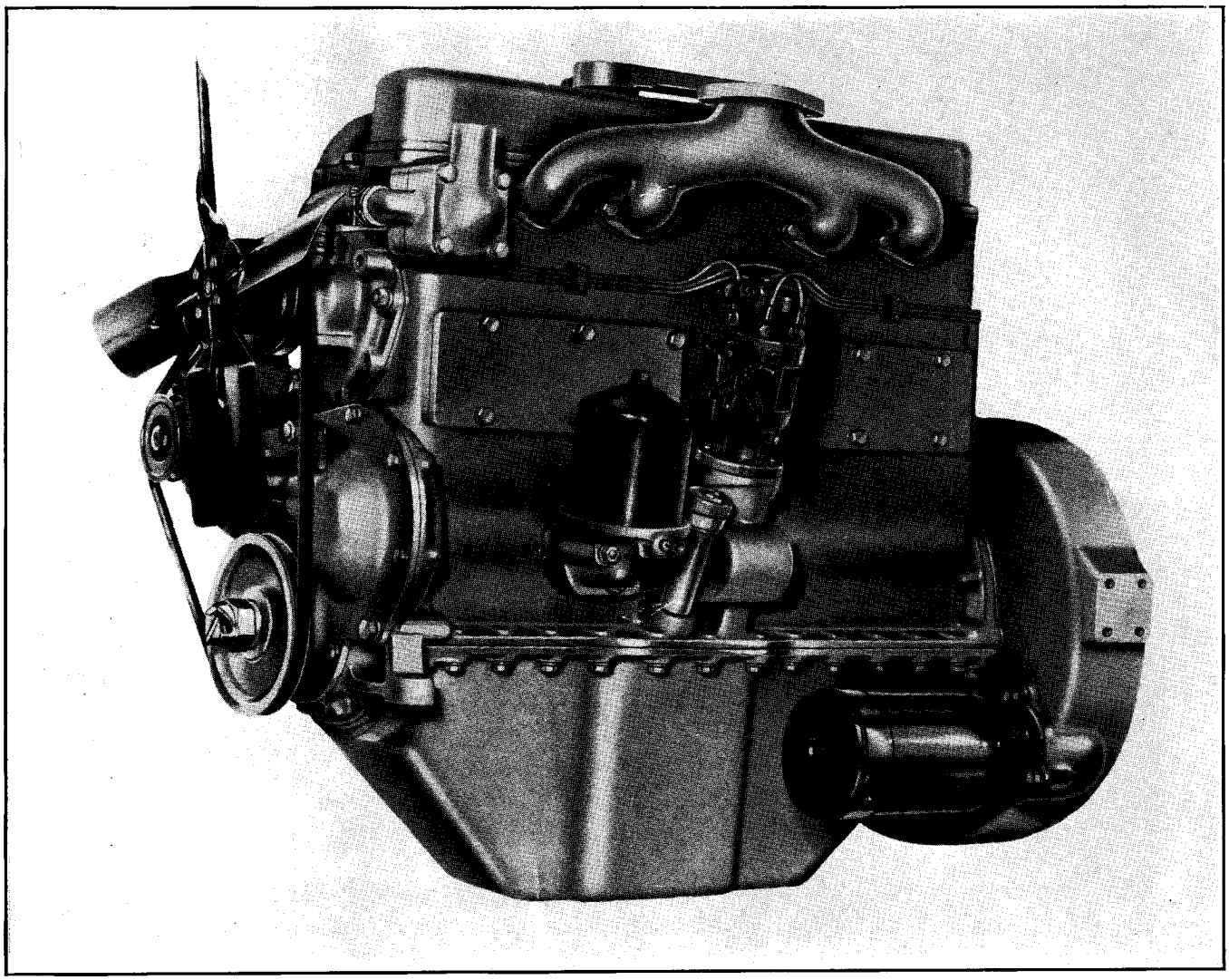


DD 4 Cylinder Series - Fuel Pump Side



DD 4 Cylinder Series - Generator Side



DD 6 Cylinder Series - Fuel Pump Side

HERCULES MOTORS CORPORATION

CANTON, OHIO

Hercules Motors Corporation is a Member of the Internal Combustion Engine Institute and is pleased to warrant all Hercules products sold by it in accordance with the following Basic Warranty adopted by the Institute May 8, 1947, which is subject to future amendment without notice. This warranty is in lieu of any warranty expressed or implied by law and supersedes any different warranty in customer's purchase orders.

BASIC WARRANTY

The Manufacturer warrants each new engine sold by the Manufacturer to be free from defects in material and workmanship for six (6) months from date of shipment, but not to exceed ninety (90) days of service, or such other period of time as may be agreed upon in respect to the application in which the engine is used. The obligation under this Warranty, statutory or otherwise, is limited to the replacement or repair at the Manufacturer's factory or at a point designated by the Manufacturer, of such part as shall appear to the Manufacturer, upon inspection at such point, to have been defective in material or workmanship.

This Warranty does not obligate the Manufacturer to bear the cost of labor or transportation charges in connection with the replacement or repair of defective parts, nor shall it apply to an engine upon which repairs or alterations have been made unless authorized by the Manufacturer.

The Manufacturer makes no Warranty in respect to trade accessories, such being subject to the Warranties of their respective Manufacturers.

The Manufacturer shall in no event be liable for consequential damages or contingent liabilities arising out of the failure of any engine or parts to operate properly.

No express, implied or statutory Warranty other than herein set forth is made or authorized by the Manufacturer.

New service parts are sold subject to the same warranty as new engines.

Introduction

The Hercules DD series of engines consists of nine models, three three-cylinder models, three four-cylinder models and three six-cylinder models, overhead valve, four cycle, heavy-duty, commercial type engines. The design is the result of years of development and field experience. Extensive tests have proven that these engines are adaptable to purposes for which such sizes and types are required.

All locations given as right-hand (R.H.) or left-hand (L.H.) have reference to the observer's position when facing the flywheel or clutch. The cylinder block is reversible; therefore, the camshaft and distributor may be on either the right-hand or left-hand side, depending upon the application. The front of the engine is the timing gear end, irregardless of the cylinder block position. The flywheel and clutch end is the rear end of the engine. Therefore, when reference is made to No. 1 cylinder or front main bearing, it is always the one nearest the timing gears. Cylinders, connecting rods, etc., are numbered from the front or timing gear end of the engine. All dimensions are given in inches and fractions of inches, except as otherwise noted. All weights and measures are in United States avoirdupois or liquid measure standards.

This book is divided into the following sections, which appear in the order named — Specifications, Operation, Lubrication, Description and Maintenance, Trouble Shooting, Clearances and Tools.

Where necessary to refer to accessories which are not furnished by the Hercules Motors Corporation, information and comments given are general and may not apply to the specific accessory used.

As an operator, you owe it to yourself to read this book carefully.

SPECIFICATIONS

THREE CYLINDER

	D. D. 130	D. D. 149	D. D. 169
Bore and Stroke	3½" x 4½"	3¾" x 4½"	4" x 4½"
..Millimeters	88.9 x 114.3	95.2 x 114.3	101.6 x 114.3
Number of Cylinders	3	3	3
N.A.C.C. Horsepower	14.7	16.9	19.2
Piston Displacement, Cu. In.	130	149	169
Liters	2.13	2.43	2.78

FOUR CYLINDER

	D. D. 173	D. D. 198	D. D. 226
Bore and Stroke	3½" x 4½"	3¾" x 4½"	4" x 4½"
..Millimeters	88.9 x 114.3	95.2 x 114.3	101.6 x 114.3
Number of Cylinders	4	4	4
N.A.C.C. Horsepower	19.6	22.5	25.6
Piston Displacement, Cu. In.	173	198	226
Liters	2.84	3.24	3.71

SIX CYLINDER

	D. D. 260	D. D. 298	D. D. 339
Bore and Stroke	3½" x 4½"	3¾" x 4½"	4" x 4½"
..Millimeters	88.9 x 114.3	95.2 x 114.3	101.6 x 114.3
Number of Cylinders	6	6	6
N.A.C.C. Horsepower	29.4	33.75	38.4
Piston Displacement, Cu. In.	260	298	339
Liters	4.26	4.89	5.56

MAIN BEARING

	Three Cylinder	Four Cylinder	Six Cylinder
Number of Bearings	4	5	7
Bearing Diameter (Main)	2½" — 63.5 MM	2½" — 63.5 MM	2½" — 63.5 MM
Bearing Length (Front)	1 5/16" — 33.3 MM	1 5/16" — 33.3 MM	1 5/16" — 33.3 MM
Bearing Length (Center)		2⅛" — 54.0 MM	2⅛" — 54.0 MM
Bearing Length (Rear)	1 7/16" — 36.5 MM	1 7/16" — 36.5 MM	1 7/16" — 36.5 MM
Bearing Length (Intermediate)		1 5/16" — 33.3 MM	1 5/16" — 33.3 MM
Bearing Length (No. 2)	1 5/16" — 33.3 MM		
Bearing Length (No. 3)	2⅛" — 54.0 MM		

CAMSHAFT

		Helical Gear	
Drive			
Number of Bearings	3	4	4
Diameter of Bearings	2 1/16" — 52.4 MM	2 1/16" — 52.4 MM	2 1/16" — 52.4 MM
Bearing Length (Front)	1 1/16" — 27.6 MM	1⅛" — 28.6 MM	1⅛" — 28.6 MM
Bearing Length (Intermediate)	13/16" — 20.6 MM	13/16" — 20.6 MM	13/16" — 20.6 MM
Bearing Length (Rear)	1 1/16" — 28.6 MM	1⅛" — 28.6 MM	1⅛" — 28.6 MM

CONNECTING ROD

Bearing Diameter	2" — 50.8 MM	2" — 50.8 MM	2" — 50.8 MM
Bearing Length	1½" — 38.1 MM	1½" — 38.1 MM	1½" — 38.1 MM
Rod Length (C to C)	8" — 203.2 MM	8" — 203.2 MM	8" — 203.2 MM

GENERAL DATA

Cooling	Centrifugal Pump
Generator Mounting	Standard Swivel Type Generators
Water Pump—Fan Assembly	Mounted in Front of Cylinder Block
Method of Suspension	3 or 4 Point
Flywheel	For Any Standard Clutch

GENERAL DESCRIPTION AND FEATURES OF DESIGN

CYLINDER BLOCK AND CRANKCASE

The cylinder block and crankcase are cast in one piece, in order to permit more efficient cooling, by water jacketing the cylinders the full length of the bore. This construction results in a very rigid unit, which provides a sturdy support for the crankshaft.

The cylinder block is so designed as to be reversible; that is, the crankshaft may be installed in the crankcase so that the camshaft may be on either the right-hand or the left-hand side of the engine. The timing gears can be assembled to either end of the cylinder block, the same as the flywheel and bellhousing. However, a different gear housing and cover is required. Therefore, it is essential that, when this engine is torn down for rebuilding, it be known and recorded which way the cylinder block is installed. That is, if the fuel pump is mounted on either the right or left-hand side of the engine.

MAIN BEARINGS

The three cylinder engine has four main bearings, the four cylinder engine has five main bearings and the six cylinder has seven main bearings. This places a main bearing on each side of each connecting rod bearing, see Illustration No. 1. This construction helps to eliminate vibration at high speeds. The center main bearing cap is held in position by four alloy steel cap screws $\frac{7}{16}$" in diameter while the remaining bearing caps are held by two alloy steel cap screws $\frac{1}{2}$" in diameter.

The crankshaft end thrust is controlled by the center main bearing. This shell has suitable flanges on both sides of the bearing, which form a thrust bearing.

Precision or insert type bearings are used. In this construction there is a removable shell in each cap, as well as for the upper part, and the upper shell is interchangeable with the lower shell for each bearing. These bearing shells are completely finished before being put in place and no line reaming or scraping is required. This allows removal of the bearings to be easily accomplished. Each bearing shell has a small ear or projection which fits into a recess in the cylinder block or cap, which allows the ear or projection to rest against the adjoining case or cap to prevent the shell from rocking or rotating. These shells are approximately $\frac{1}{16}$" thick, and the bearing metals commonly used are harder and have a higher melting point than ordinary babbitt metal. This permits the use of a hardened crankshaft.

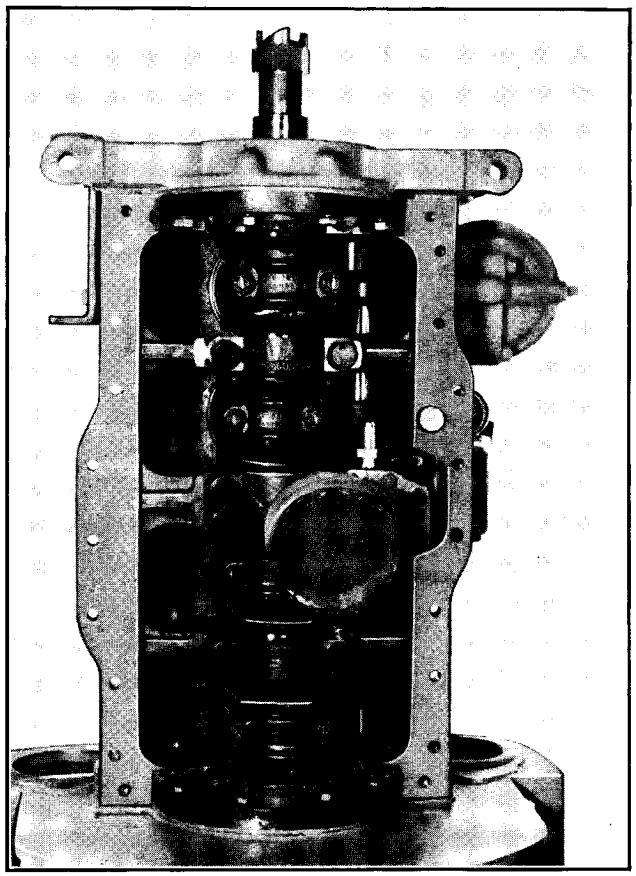


Illustration No. 1

CYLINDER HEAD

The cylinder head is a one piece casting and is detachable. The valve seats are a part of this casting while the valve guides are removable bushings. The head is held to the cylinder block by studs and screws; and, in order to insure against leaks, the head must be carefully drawn down by means of the stud nuts which should be progressively tightened, working from the center of the head toward the ends.

A torque wrench is recommended for this operation. See **"Wrench Tension"** for recommended tensions. If a torque wrench is not available, a wrench approximately 18" long should be used for this operation.

CONNECTING RODS AND PISTONS

Like the main bearings, the connecting rods have the precision or insert type of bearing construction. No shims are used; therefore, bearing adjustment is accomplished by installation of new bearing inserts.

The piston pin is of very large diameter and is of the full floating type. This means that the pin can rotate in either the piston bosses or in the bushing at the top end of the connecting rod, but the fit in the piston is intended to be much tighter than the fit in the connecting rod bushing. Consequently, the movement in the piston consists of a light, creeping action while the normal rotation of the pin occurs in the bushing in the connecting rod. The piston pin is prevented from moving endwise and making connection with the cylinder wall by means of snap rings, which are located in grooves machined in the bosses of the piston.

CAMSHAFT

The camshaft is supported on bearings in the crankcase. Some bearings may be machined directly in the block, and no separate bushings used, while others may have removable bushings. At the center of the shaft is located the spiral gear, which meshes with the gear attached to the oil pump shaft and drives the oil pump. The distributor is also driven from this gear by a tongue and groove arrangement. The camshaft end thrust is controlled by a thrust plate located between the front camshaft bearing and the camshaft gear. This plate is held to the cylinder block by two cap screws.

VALVES

The valves are installed in the cylinder head. The intake valve head is larger in diameter than the exhaust valve head in order to increase the efficiency and insure more power. Both intake and exhaust valves are forged from special alloy steel and the exhaust valves, in particular, are of high heat resisting material. The valves of some engines may be equipped with a rotocap which permits this valve to rotate slightly during the opening and closing cycles. The valve tappets are of the mushroom type and are hollow to allow the push rod to properly seat.

OILING SYSTEM

The oil pump is of the gear type and is fastened to the block so that the suction end is in the oil pan oil sump and needs no priming. The oil pump is provided with a pressure release mechanism to control the oil pressure. The oil, under pressure, is delivered through a suitable passage in the crankcase, which extends from the front to the rear of the engine on the side opposite the camshaft and is closed at either end by means of suitable threaded plugs. Radial holes are drilled from the crankshaft bearings to meet this horizontal oil passage; this permits oil to be delivered, under pressure, to the main bearings and through drilled holes in the crankshaft to the connecting rod bearings. The camshaft bearings are also lubricated from this horizontal passage through suitable drilled holes. The rear camshaft bearing meters the oil which is carried through suitable passages up through the cylinder block and cylinder head studs to the rocker arms. The cylinder bores, tappets, and so forth, are lubricated by means of a mist of oil thrown off around the connecting rod bearings.

FUNCTION OF DIFFERENT STROKES

Intake Stroke—Pure, clean air is drawn through the air intake valve, which is opened by the rocker arm actuated by a cam through tappets and rods, into the cylinder as the piston travels downward.

Compression Stroke—The intake valve has now closed and the exhaust valve remains closed so all the air taken into the cylinder on the intake stroke is now being compressed between the cylinder head and piston. This compression of the air heats it to temperatures higher than the ignition point of the fuel soon to be injected.

Fuel Injection—This is not a stroke but is approximately the end of the compression stroke and the beginning of the expansion stroke. The fuel begins to inject at approximately 32° before top center and continues for approximately 30° when the engine is carrying full load. This injection is controlled by the fuel pump timing, the nozzle pressure setting and the load on the engine operating the governor which, in turn, controls the length of time the fuel pump will continue injection.

Expansion or Power Stroke—The rapid rise in temperature of the gases, due to burning of the fuel oil, causes them to expand. As the only movable part in the cylinder is the piston, these expanding gases push it downward and this downward force is transmitted to the crankshaft, through the piston pin, connecting rod and connecting rod bearing, where this force is converted to rotary motion and useful work.

Exhaust Stroke—The exhaust valve is now opened by its rocker arm, which is actuated by its cam through a tappet and push rod, and the exhaust gases are expelled the same as in the gasoline engine.

The intake valve opens about the time the piston reaches top center and a similar cycle is begun.

DD SERIES

PRELUDE TO OPERATION

The "DD" series Hercules Diesel Engine consists of three three-cylinder models, three four-cylinder models and three six-cylinder models. See **"Specifications."**

All information relative to operation and maintenance is the result of many contacts with a variety of operations of Hercules Diesel Engines and suggestions contained in different sections of this book are based on actual experience.

The book has been compiled for your use in obtaining the maximum efficiency and trouble-free operation which have been built into your diesel engine by Hercules craftsmanship.

Should you have a particular problem not covered in this book, we invite you to write to the Service Department, Hercules Motors Corporation, Canton, Ohio, U. S. A., whose experienced personnel will be pleased to assist you.

If additional information relative to the various accessories is desired, a letter to the manufacturers of these will always get a prompt reply.

OPERATION

This section covers those items which are of particular interest to the operator and does not cover such work as might be required of a maintenance crew. This does not mean that an operator should not acquaint himself with the various subjects covered in other sections of this book.

PRECAUTIONS—READ BEFORE STARTING THE ENGINE

The following precautions, if followed, will help eliminate operating difficulties and abnormal wear:

1. **Filters**—keep them clean—they are the guardians of your engine—dirty filters cause rapid wear and low engine power output.
2. **Fuel Oil**—keep it clean—do not use dirty containers to handle it—insist on the fuel being clean and acid free when you get it. Procure it from a reputable company—See **"Fuel Oil Specifications."**
3. **Lubricating Oil**—keep it clean—drain the crankcase often. Use the best brands obtainable, regardless of cost, to obtain the minimum operating costs. Avoid oils having additives detrimental to alloy bearings.
4. Do not allow the **oil level** to fall much below the 4/4 mark on the bayonet gauge. As the lubricating oil is the medium for removing the friction heat in the bearings, the larger the volume, the more heat can be absorbed. Do not fill above the 4/4 mark on the bayonet gauge.
5. **Do not run the engine** at any time without lubricating oil or a cooling solution (water or anti-freeze mixture).
6. Do not use oil, fuel oil or kerosene in the cooling solution or as a cooling medium, as these will be detrimental to the synthetic rubber water pump seal.
7. **Never run the engine** with the water or anti-freeze solution **boiling.** This allows lubrication to break down and may seriously damage the engine.
8. Do not put cold water in an **overheated engine.** It may crack the cylinder head, block, etc.
9. Do not allow the **air cleaners** to become clogged or to be operated without all of the connections being tight. Keep clean oil in them up to the proper level. These units protect your engine from undue wear only when they are given intelligent care.
10. Never allow your **batteries** to run low or dry of water. The plates will warp and ruin the battery.
11. **Do not attempt** starting the engine until the lubricating oil, water and fuel supplies have been checked and the engine properly prepared for starting.
12. **Do not run the engine** at high speed without load, as this will cause undue wear and shorten the engine's life.

13. Do not idle the engine for long periods. It is not only detrimental to the engine but also increases operating costs, as you are using fuel without any benefit.

14. **Do not use the engine** as a brake in intermediate or low gear in automotive service. The high engine speeds possible when using low or intermediate gear descending a steep grade will turn the engine much faster than the speed for which it is designed, and damage will result. Hold the vehicle speed to that used in the same gears on the level.

15. **Never allow** the engine to **run without the oil pressure** showing on the gauge. Damage from lack of lubrication will result.

16. Do not operate the **fuel injection pump** with one or more lines shut off or blocked. The high pressure may ruin the pump.

17. Do not attempt to make repairs or adjustments to the fuel injection equipment unless you are familiar with it. It is far less expensive to take it to the nearest authorized service station.

18. **Correct fuel nozzle pressure** is essential to efficient operation. Have the nozzles checked often.

19. Do not allow the fuel in the tank to run low as it may allow the fuel transfer pump line to uncover long enough to fill the lines with air and cause the engine to stop, resulting in lost time taken for re-priming.

20. Loss of power, erratic running and poor performance often result from **air in the fuel injection system.** Be sure there are no leaks in the fuel lines and filters which will allow this condition to exist. Vent cocks on top of the filters are for bleeding off any air which may accumulate from bubbles in the fuel and very minor leaks; therefore, it is essential to bleed these often until the operator is sure air is not entering the fuel system.

21. Remember, dirt, grit, water, lint or any foreign matter in both the fuel and lubricating oils are detrimental to the engine and it is your duty, as an operator, to see that they do not get into the engine.

22. Do not attempt to start the engine in cold weather until you have read **"Cold Weather Starting."**

23. Some external heat will help starting in cold weather and saves the batteries.

24. Never run the starting motor longer than 30 seconds at one time without a rest period of at least one minute before allowing it to run again. Failure to follow this procedure may result in a burned out starting motor.

25. Do not attempt to start or operate this engine without first reading the instructions in this book carefully. As an operator, you owe it to yourself.

STOPPING THE ENGINE

CAUTION:—Be sure all the equipment and engine controls are fully understood before starting the engine.

1. Stopping is generally effected by moving the stop control to the stop position until the engine stops.

2. If the atmospheric temperature is below freezing and no anti-freeze solution is used, the complete water circulating system should be drained. This includes the engine water jackets, water pump, radiator (if used) and all water pipes.

3. If an anti-freeze solution is used, the solution should be checked with a hydrometer to make sure the solution will not freeze. It is best to have a solution that will not freeze at temperatures far below those then being experienced.

4. Do not fill the batteries with water when shutting down as this makes them more liable to freezing. Fill the batteries just before starting up for the day's run.

NOTE:—If the engine is kept in warm storage or is located in a warm building where freezing is not liable, Nos. 2, 3 and 4 can be disregarded.

INSPECTION OR ADJUSTMENTS

To Be Made Daily

1. Go over the entire engine daily to make sure there are no loose bolts, nuts, screws, electrical connections or parts and, also, stop all fuel, lubricating oil and water leaks. There will probably be very little tightening needed but one loose part may cause serious damage.

2. Check the lubricating oil level in the engine and keep filled to the full mark on the gauge.

3. Remove the pipe plug in the bottom of both the fuel and lubricating oil filters and drain all water and sediment which may have accumulated.

4. Air cleaners should be inspected and cleaned before starting the day's run. If the oil bath type is used, renew the oil, filling to the proper level, if necessary. If the engine is working in extremely dusty atmosphere, it may be necessary to clean these units more often than once a day.
5. See that there is a day's supply of clean fuel in the tanks before starting.
6. Electrical equipment requires very little attention but the batteries should be checked daily for water which should be kept at a proper level.
7. The water circulating system probably receives less attention and care than any part of the engine installation and yet it is one of the most important units. Water should be added daily to make up for that lost in evaporation and leaks. Also, observe if scale or sediment is forming in the cooling system; if it is, obtain water from a supply which will not cause these troubles. If the water pump is leaking, replace the seal with a new one.
8. If the air temperature is freezing or liable to go down to freezing, check the anti-freeze solution, making sure it will not freeze at temperatures well below those being experienced.

Inspection or Adjustments To Be Made After Each 100 Hours' Operation

1. Inspect and adjust the fan belts, if loose.
2. Inspect the radiator and clean, if clogged or shows scale formation.
3. Drain the fuel supply tank and wash out thoroughly with clean fuel oil to remove all dirt and sediment. Remove the air from the fuel filters. See **"Priming the Fuel System."**

Lubrication of Electrical Equipment at Each 500 Hours' Operation

1. Lubricate the generator. Three to four drops of the same grade and quality lubricating oil as is used in the engine crankcase is all that is necessary. Too much lubrication is as bad as too little, as too much will flood the generator with oil and get on the commutator and brushes, causing the brushes to stick in the holes.
2. Lubricate the starting motor, if equipped with oilers, with the same grade of oil as is used in lubricating the generator. These motors have absorbing bushings so fill the cups with oil until the bearings are saturated. Motors not equipped with oilers have oilless bushings and need no lubrication except at the time of overhaul.

STARTING AND OPERATING SUGGESTIONS

1. Procure a good brand of fuel oil coming up to the specifications of A.S.T.M. D-1 fuel oil.
2. Use only the best lubricating oil obtainable.
3. An SAE 20 oil is a good grade to start with; from this, the proper grade can be determined by observing the pressure gauge and the condition of the oil at change periods.
4. Fill the cooling system with clean water (if in a locality where the water has a large percentage of dissolved minerals or is alkaline—use rain water). Allow sufficient time for the water to seek the lowest level, then complete the filling.
5. If a 12-volt battery is not furnished with the unit, procure only those of a good brand and with the following capacity: 210 ampere hours (similar to Exide 6XCK25-3R, 12-volt, 25 plate or Willard RHD-25-6, 12-volt, 25 plate). **NOTE**—Some applications may call for 24 or 32-volt systems. Correct batteries should then be obtained for these special applications.
6. Be sure the batteries are hooked up properly before pressing the starter button.
7. Turn the engine over three or four times by hand to be sure there is nothing sticking or water has not seeped into a cylinder, as the starting motor has sufficient power to bend or break certain parts should anything be out of place.
8. Be sure all fuel line connections are tight and the fuel system properly primed.
9. Always follow the starting directions outlined below to eliminate difficulties.

STARTING THE ENGINE

Save Your Batteries. The commonly used 25 plate, 12-volt battery will crank the engine against compression for about six periods of 30 seconds each with a recuperation or rest of one minute between each period of cranking. Hand cranking, or electric starter cranking, with the nozzle holders removed during tests for fuel oil delivery to the nozzles, will conserve the battery charge.

If the atmospheric air temperature is 50° F. or over, the following instructions should enable anyone to readily start the engine. If the air temperature is below 50° F., read **"Cold Weather Starting."**

First Time the Engine Started or starting the engine after a long period of shutdown.

1. Fill the fuel tank with suitable fuel oil. Bleed the air from the fuel lines and filter, see 6 below.
2. Fill the cooling system with clean, pure water or, if the atmosphere is below freezing and the engine is to stand or operate in these temperatures, use an anti-freeze solution.
3. Fill the crankcase with suitable lubricating oil to the 4/4 or full mark on the oil gauge rod.
4. Leave the nozzles out of the engine while hand cranking to relieve compression.
5. Turn the engine over by means of the hand crank three or four times to start oil circulation and distribute the oil already on the surfaces. This hand cranking also prevents possibilities of damage due to water having accumulated in the cylinders. The clearance between the cylinder head and piston top is so little that a small amount of water in the cylinder would cause serious damage or wreckage if the engine were rotated rapidly as with an electric starter.

Priming the Fuel System—Air Lock Trouble

1. Air or gas binding or lock in the fuel injection system is the most general cause of failure to start or hard starting if the proper fuel is used. Air binding or lock is caused mainly from leaky fuel valves, check valves or running out of fuel. Gas binding or lock is caused by heating of the fuel to a point higher than that at which the particular fuel used begins to throw off gaseous vapors. To eliminate the air or gas lock caused by either of these difficulties, the following procedure should be followed:

Loosen the secondary fuel filter vent cock (if the filter is placed between the transfer pump and the injection pump) and, by using the hand priming pump, force the fuel from the tank into the filter until solid fuel comes from the vent cock. Close the vent cock, loosen the bleeder screw on the fuel pump and continue pumping until all air bubbles have been expelled. Tighten the bleeder screw.

NOTE: It may be necessary to crank the engine over (in rare cases) to permit the priming pump to draw fuel through the transfer pump.

2. In addition to the procedure just described check the lubrication of the generator, starter, air compressor or vacuum pump (if used) and any other accessories. Check the air cleaners to make sure there are no obstructions, that they are properly installed, and are clean, and that they are properly filled with oil (if oil bath cleaners are used, as recommended).
3. Check the entire electrical system to be sure there are no loose connections and all component parts are properly connected together.
4. See that no loose bars, tools, parts, etc., are lying in, or on, any part of the engine as they could cause serious damage or wreckage of the engine or bodily injury to anyone near.
5. Start the engine by operating the starting button. If the atmospheric temperature is 50° F. or above, and if all of the foregoing instructions have been properly followed and the proper grade and type of fuel oil has been used, the engine will start at once.
6. Allow the engine to run for several minutes before load is applied to enable the engine to properly warm up and insure proper lubrication.

Usual Routine Way of Starting the Engine. If the engine has been operating recently and nothing has been removed or repaired since it last operated, the following is all that is necessary to start:

1. Check the fuel supply.
2. Check the lubricating oil in the engine base with the gauge rod. Be sure the oil is to the 4/4 or full mark on the rod. Recheck after the engine has run 3 or 4 minutes.
3. Check the cooling water or solution.
4. If the atmospheric temperature is 50° F. or above, nothing special need be done in preparation for starting. If below this temperature, see **"Cold Weather Starting."**

5. Inspect the installation to see all is in good order and tight and no loose tools, bars or parts are lying on the engine.
6. **Place the governor control lever at half throttle or load position.**
7. **Be sure the stop control is not in the shut off position.**
8. Start the engine by operating the starter button.
9. Check the engine, as under **"Operating Instructions After Starting."**

COLD WEATHER STARTING

The increased temperature of the air due to compression is the only means of igniting the fuel sprayed into the combustion chamber.

If the iron surrounding this chamber and cylinder is extremely cold and, in addition, the air entering the cylinder before compression is cold, the resultant temperature may not be sufficient to ignite the mist of fuel. The faster the starter turns the engine, the less time is available for the heat of compression to be absorbed by the iron and water.

Two methods are available to increase this temperature.

1. Heat the water or cooling solution.
2. Heat the air before it reaches the cylinder.

One or both of the methods may be necessary, depending upon the temperatures of the engine and air.

Various types of cold starting aids are available which make starting easier in extremely cold weather or climate. Any of these devices can be installed by any competent mechanic or service station.

Starting Between 50° F. and 32° F. If the engines are not equipped with a cold starting aid, much time can be saved and excessive drain on the starting battery can be avoided by following these suggestions:

1. Crank the engine over by hand several turns.
2. Remove the large pipe plug in the intake manifold or remove the air cleaning equipment, if no pipe plug is available.
3. Before attempting to start, take an ordinary blowtorch and direct the flame for a minute on the outside of each branch of the air intake manifold of the cylinder heads.
4. **Place the governor control lever at half throttle or load position.**
5. **Be sure the stop control is not in the shut off position.**
6. As the operator depresses the starter button, hold the torch so the flame will be sucked into the air intake manifold through the opening exposed by the removal of the air cleaner or pipe plug in the manifold. Do not hold the torch so the flame is directed into the manifold, as the flame may be extinguished just when it is most needed or all of the oxygen may be burned from the air.
7. After the engine has started, replace the pipe plug in the manifold or replace the air cleaner, whichever was removed.

Starting Between 32° F. and 0° F. (If the engines are not equipped with a cold starting aid.) To obtain maximum cranking speed, the oil must not be too heavy. When the temperatures approach freezing, many experienced operators drain all of the crankcase oil from the engine at the end of the day's run and heat it before returning it to the crankcase when ready to start. This is a good practice for the hot oil insures more immediate circulation to the bearings and helps warm the engine. At freezing temperatures, the water or cooling system should be drained from the engine and radiator and heated to near the boiling point if water, and as hot as possible if some solution is used. (Beware of fire if an alcohol solution is used.) When this is poured into the engine the cold iron parts are heated and the oil on the cylinders thinned down. This operation does not take nearly as long as changing batteries after they are run down and will greatly aid in starting.

Starting 0° F. and Below. If the engines are not equipped with a cold starting aid, heating of the water, oil and air may be found desirable. Battery output is reduced at these low temperatures so every means should be used to conserve your battery.

COLD STARTING AIDS

In addition to the cold starting suggestion outlined above, there are various types of auxiliary cold starting aids.

Two types of priming systems are described on the following pages.

PRESSURE PRIMER

The pressure primer consists of a discharger which is connected by copper tubing to a nozzle in the air intake system, Illustration No. 2. A steel pressurized capsule, containing the starting fluid under approximately 250 pounds pressure, is inserted in the discharger which is operated as follows:

1. Place the throttle in the wide-open position.
2. Place the stop control in the "on" position.
3. Unscrew the cap of the pressure primer discharger, Illustration No. 3, insert the pressure primer steel bulb, neck down, Illustration No. 4, and replace the cap, Illustration No. 5. The cap should be screwed down tight.
4. Discharge the pressure primer bulb by pushing, Illustration No. 6, (or pulling) up and over 180 degrees swing on the actuating lever (A), Illustration No. 2, of the discharger during cranking after the starting motor has brought the engine up to the cranking speed. The bulb requires approximately 15 seconds to discharge completely.
5. After the bulb in the discharger has had time to empty itself, plus 3 or 4 seconds, throw the lever back to the original position, Illustration No. 7, unscrew the discharger cap and insert another bulb in the discharger for subsequent use.

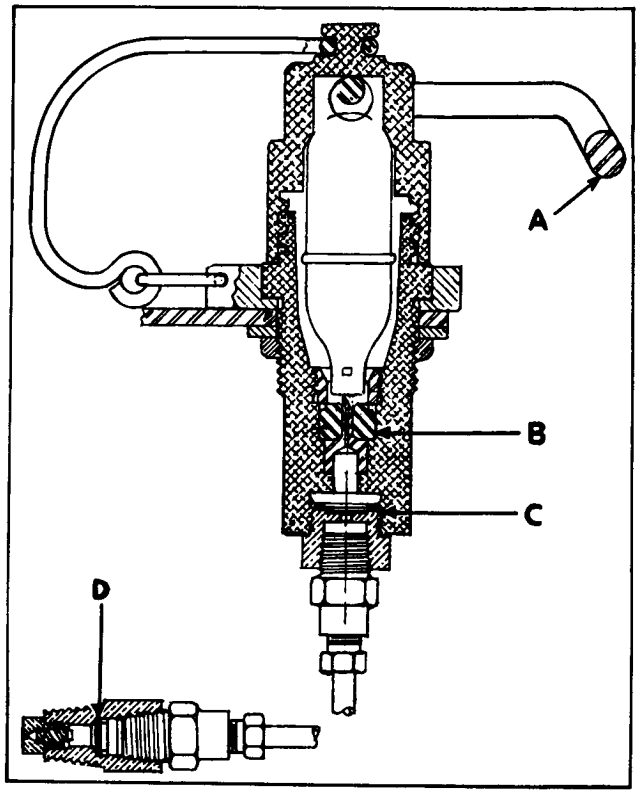


Illustration No. 2

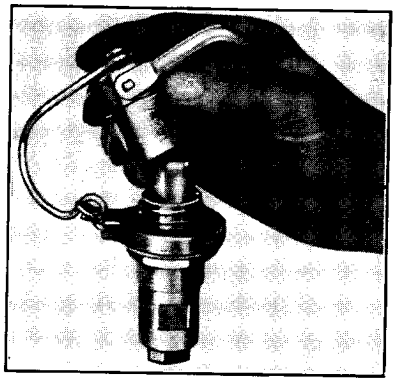


Illustration No. 3

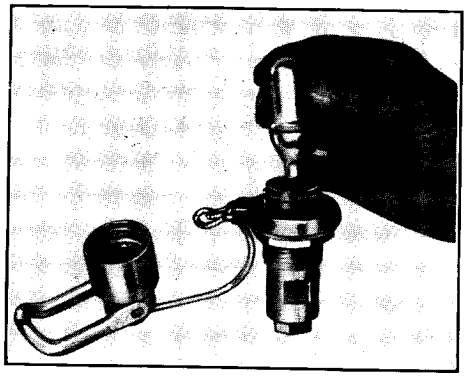


Illustration No. 4

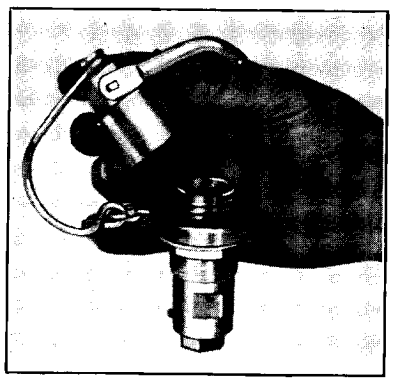


Illustration No. 5

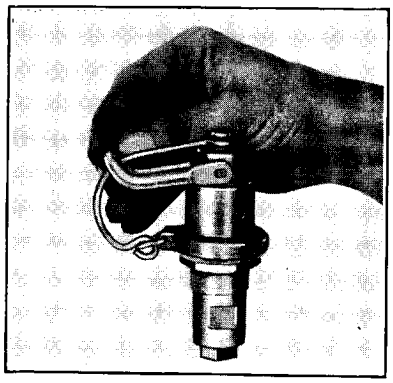


Illustration No. 6

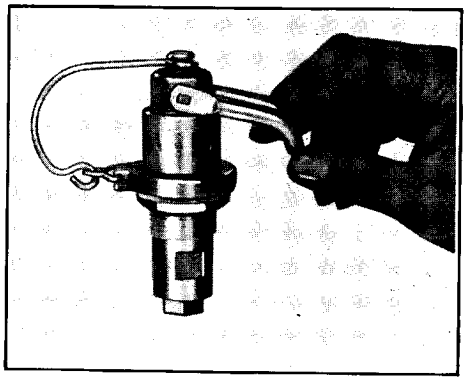


Illustration No. 7

The bulb neck washer (B), Illustration No. 2, should be replaced should there be an excessive leakage into the bulb compartment of the discharger.

PRECAUTIONS

The pressure primer steel bulbs contain priming fuel, which is highly flammable, mixed with a flammable gas at approximately 250 pounds pressure. These primer bulbs are made of steel with welded closures, and their bursting pressure is in excess of 6,000 pounds per square inch. They, therefore, provide the maximum safety in storage, handling and use. The principal precautions to be taken are:

1. Do not heat the bulbs.

2. Should the pressure primer be used for testing, inspection or other use while not installed on the engine, it is imperative that the contents of the primer bulbs not be discharged in confined areas or near an open flame.

MAINTENANCE

The priming system needs very little attention after it has been installed on the equipment. However, it should be periodically cleaned to insure continued satisfactory performance. This cleaning operation consists of removing the screen (C), Illustration No. 2, cleaning this and also removing the nozzle tip from the manifold and then removing the screen and cleaning the nozzle screen. On reinstalling these screens be sure that all connections are tight.

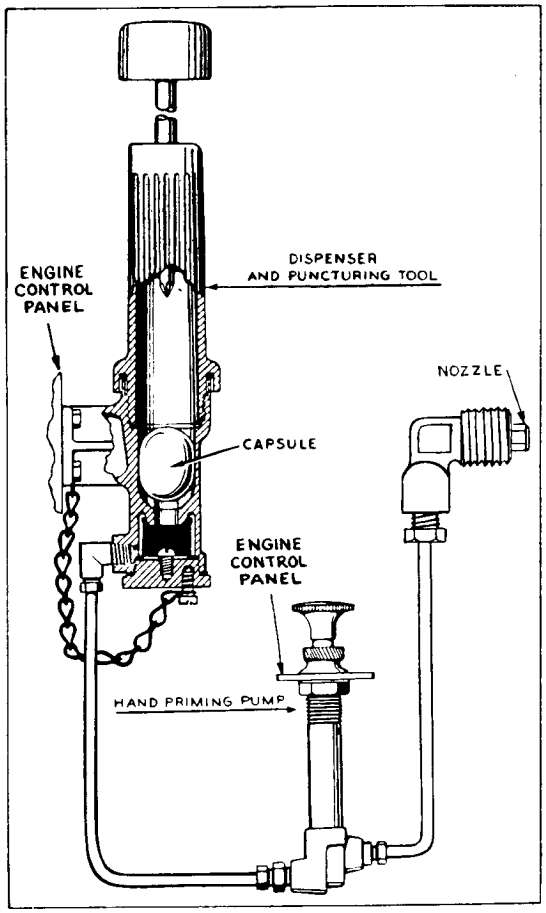


Illustration No. 8

BULB TYPE PRIMER

This unit is composed of a capsule puncturing device, hand priming pump and a spray nozzle located in the air intake system, Illustration No. 8.

A capsule containing the starting fluid, which is a material possessing high volatility, low ignition temperature and a wide inflammability range, is placed in a capsule puncturing device.

The fluid is introduced to the air intake system as outlined below:

1. Place the throttle control in the wide-open position and the stop control in the "on" position.
2. Press down the handle of the puncturing device to puncture the capsule.
3. Press the starter button to begin the cranking cycle and, at the same time, use the hand priming pump to inject the starting fluid to the air intake system.

CAUTION:

1. Do not inject the fluid unless the engine is cranking. If the fluid is introduced while the engine is not cranking, the first cylinder to make an intake stroke may receive the entire charge, which can result in serious damage to the engine in the way of broken rings, ring lands and pistons.
2. When the capsules are cold, they are somewhat brittle and, when punctured, may shatter in fine pieces which can plug up the screen at the outlet of the puncturing device and also the spray nozzle.

   To avoid this difficulty, hold the capsule in your hand until it becomes pliable.

OPERATING INSTRUCTIONS AFTER STARTING

After the engine has started, an inspection of the whole engine unit should be made to make sure all parts are functioning properly.

1. Look at the lubricating oil gauge. If no pressure shows after the engine has run 10 or 12 seconds, shut down the engine and ascertain what the trouble may be. With the bearings in good condition and the proper grade of oil, the pressure should be 30 to 45 pounds at full engine speed. If the oil is very cold or heavy, this pressure may be much higher. As the oil heats up, the pressure will reduce.
2. Check the water temperature. If the water temperature is above 200° F., shut down the engine and ascertain what the trouble may be. Never operate with the water boiling, as this heat on the cylinder walls breaks down the oil film and also causes considerable water loss due to steaming.
3. See that no loose tools or parts are lying on, or near, the unit as they might fall into a place where they would cause damage or personal injury.
4. Observe the engine operation for smoothness, quietness and exhaust condition. If the fuel is up to specifications and has the proper ignition and burning qualities, the engine may still run raggedly because a cylinder or two is firing irregularly due to being cold. As the engine begins to warm up, however, all cylinders should fire regularly. If they do not, the nut connecting the fuel line to the nozzle holder should be slightly loosened, one cylinder at a time, and fuel allowed to flow until all air has been expelled. When this nut is loosened, if the engine speed remains the same and the exhaust sounds the same, that cylinder is not firing or is firing irregularly. If, after checking this trouble and allowing fuel to flow from the loosened nut a few times, any cylinder still continues to fire irregularly or not at all, shut down the engine and trace out the trouble, some hints of which will be found in **"Trouble Shooting."**
5. See that there is an adequate supply of fuel in the tank and that fuel is being delivered to the fuel pump. The delivery can be checked by slightly loosening the nut connecting the supply pipe to the secondary fuel filter; and, if a good quantity of fuel appears, it is an indication that the fuel injection pump is being supplied with sufficient fuel. If no fuel or very little appears, shut down the engine and check the supply tank again. If the fuel supply is adequate, check the fuel lines from the tank to the transfer pump and the transfer pump to the filters for leaks from loose connections, broken nuts and cracked or broken lines. Also, check the lines for obstructions inside or having been pinched closed or nearly so. If the lines are found satisfactory, check the transfer pump.
6. Check and see that there are no oil or water leaks.
7. Observe the fan and belt operation. Loose fan belts allow slippage which reduces the efficiency of the fan and wears the belts out rapidly and, also, affects the efficiency of the water pump.
8. See that the radiator, if one is used, is free of obstructions between the fins or tubes as they will obstruct the air flow and reduce the cooling efficiency of the radiator unit.

STORING THE ENGINE FOR LONG PERIODS

If the engine is to be idle for a month or more, special preparations should be made to properly prepare the engine so that rust will not form on the wearing surfaces or in the fuel system.

A—Fuel Injection Equipment.

It is imperative that the fuel injection system be properly protected from rust or other corrosion if the engine is to be stored for a long period of time or in humid atmosphere.

1. This may be easily accomplished by disconnecting the fuel supply line at the secondary fuel filter and connecting a two quart container of slushing oil similar to Shell Oil Co.-Pella oil No. 911; operate the engine until this oil has been taken in the fuel system, then shut the engine down. Also, see Paragraph B-4.

If slushing oil is not available, clean crankcase lubricating oil heated to about 180° to 200° may be substituted. However, this does not have the protection qualities of the slushing oil and should be periodically reapplied.

2. When the engine is shut down after filling the fuel system, remove all of the fuel or spray nozzle holders. Remove the fuel nozzle body from the nozzle holder and then remove the valve from the body. Put a coating of vaseline on the valve and return the valve to the body, then cover the outside of the body with vaseline. Reassemble the body and holder.

B—Preparing the Engine.

1. Before reinstalling the nozzle holders, take a pump type oil can with a long narrow spout, with a tip that will fit into the 7/32" or larger hole of the spray nozzle sleeve, and give it six or eight squirts per cylinder, then turn the engine over slowly a few times to distribute the oil.

   BEFORE STARTING, remove the spray nozzles and turn the engine over with the starting motor to blow the excess oil out.

2. Drain the entire engine and water circulating system thoroughly.

3. Drain the lubricating oil from the engine base and filters.

4. The crankcase should be filled to the FULL mark on the bayonet gauge with an oil similar to the following:

   Gulf No-Rust Engine Oil, Grade 2

   Shell ENSIS 412, Specification 2-126, Grade 2

This oil should be placed in the engine crankcase at the beginning of the run outlined in paragraph A-1.

The above oils are graded the same as regular motor oil according to SAE weight. Therefore, the proper weight of oil for the climatic conditions should be chosen to facilitate starting.

5. Disconnect the wires leading to the batteries and remove the batteries, storing them preferably at some place where they can be charged periodically, as batteries lose their charge rapidly if not in use.

6. Cover the ends of the air inlet and exhaust pipe so moisture cannot reach the valve ports and cylinders; store the engine where it will not be exposed to the elements such as sun, rain, snow, hail, etc., and preferably where it can be kept warm and dry.

7. Every two weeks the engine should be cranked over by hand eight or ten revolutions to redistribute the oil film over the wearing surfaces. This will prevent rusting of the wearing surfaces inside the engine.

The above methods have proven successful; however, the Hercules Motors Corporation cannot assume responsibility for engine storage.

Preparing the Engine For Starting After A Long Shutdown. If the engine has been stored as outlined above, it will be necessary to pursue the following procedure to prepare it for starting again:

1. Drain the entire fuel system of lubricating or special oil. Open the drain on the bottom of the main fuel supply tank and allow all water and sediment in the tank to drain, then reconnect the tube.

2. Check all fuel supply lines from the main supply tank to the filter to make sure the connections are tight and the lines are open with no obstruction or "pinched" places.

3. Remove the nozzle holders and wipe the vaseline from the outside surface of each nozzle. Do not wipe the vaseline off the valve in the valve body. Prime the fuel system, see **"Priming the Fuel System."**

4. If the nozzles do not function properly, clean as described under **"Care of the Fuel Nozzle."**

5. Turn the engine by hand three or four revolutions to spread the lubricating oil on the walls and bearings and start oil circulation.

6. Install the fuel or spray nozzles and connect the lines tightly.

7. Drain the lubricating oil filtrator of all water and sediment.

8. Fill the cooling system with clean water or an anti-freeze solution.

9. Follow the instructions as given for **"Starting the Engine the First Time."**

10. After the engine is running follow the instructions as given for **"Operating Instructions After the Engine Is Started."**

HIGH ALTITUDE OPERATION

The starting and operation of Diesel engines encounter certain difficulties at higher altitudes. These difficulties are not commonly noticeable until 3000 feet is reached. While the engine has lost only about ten percent at 3000 feet, at 6000 feet the loss is about 21%. From these figures one can readily see that no difficulty will be encountered in the first 3000 feet but that some consideration must be made in the power requirements at these higher altitudes.

Since air at higher altitudes is much lighter and contains less oxygen than at sea level, the amount of air or oxygen drawn into the cylinders at higher altitudes is much less. This lowers the compression pressures, causing hard starting and poor combustion.

It is necessary to reduce the amount of fuel entering the cylinder, as with the original fuel setting and the smaller amount of oxygen, the combustion is incomplete and a smoky exhaust results.

It is sometimes desirable to follow the starting methods as outlined under **"Cold Weather Starting."**

Starting aids are available which make starting easier in extremely cold weather or climate. This device can be installed by any competent mechanic or service station.

For additional information on specific cases, please write to the Service Department, Hercules Motors Corporation, Canton, Ohio, U.S.A., giving as much data as available.

LUBRICATION

DESCRIPTION OF THE LUBRICATING SYSTEM

The lubricating system on this engine is the forced feed type to all main and connecting rod bearings by means of a gear type pressure pump. The oil pump is driven through a suitable gear arrangement at the center of the camshaft. The pump picks up the oil from the center sump of the oil pan and delivers it to a drilled passage in the block. From there, it flows through an oil manifold and through various leads to the main bearings. From the main bearings, the oil flows through suitable drilled holes in the crankshaft to the connecting rod bearings. The bypass type pressure regulator, consisting of a spring loaded piston, is incorporated in the oil pump body. The idler shaft and accessory shaft are pressure lubricated. The cam bearings, valve tappets, valve stems and cylinders are lubricated by the mist of oil thrown off by the main and connecting rod bearings.

LUBRICATION INSTRUCTIONS

Oil Level. The level of the oil in the crankcase is determined by a bayonet or dip stick type of gauge. Wipe off the gauge and reinsert to determine the oil level accurately. The oil level should be maintained at, or near, the 4/4 (or FULL) mark on the gauge. See Illustration No. 13.

OIL CHANGING

Frequency of oil changes depends upon the application of the engine and the severity of the operation. Under normal operating conditions the oil should be changed every 50 hours. A new or reconditioned engine should have the oil changed more often for the first 100 hours of operation. (Suggest first change after 20 hours.)

Frequent and regular oil changing, together with the use of good oil, is low cost insurance against expensive repairs.

USE GOOD OIL

The Hercules Motors Corporation recommends that only the best quality, heavy-duty, detergent type oil produced by recognized concerns familiar with the lubrication requirements of internal combustion engines be used. A Series No. 3 oil having an A.P.I. service designation of "DS" is recommended.

VISCOSITY GRADES

The S.A.E. numbers indicate the relative viscosity or body of the lubricating oil. Select grade of oil from the following tabulation:

Air Temperature	S.A.E. Number
60° F. and above	30
+10° F. to +60° F.	20
—10° F. to +10° F.	10
—10° F. and below	5-W

For breaking in a new engine we suggest an S.A.E. 20 oil for normal conditions and a lighter oil if cold weather or cold climate conditions prevail.

The filter element should be changed at the same time the oil is changed in the crankcase. Recheck the oil level after running the engine approximately five minutes to fill the filters. Use the bayonet gauge when replenishing the oil supply and fill to the 4/4 (or FULL) mark on this gauge.

ACCESSORIES

Accessories mounted on the engine usually carry their own lubricating instructions, which should be followed.

OIL PRESSURE

Refer to **"Oil Pressure."**

LUBRICATION RECORD

DATE	HOURS	CRANKCASE OIL CHANGE			ACCESSORIES *					FUEL FILTER CLEANED
		BRAND	GRADE (SYMBOL)	QUANTITY		GOVERNOR	STARTER	OIL FILT.	WATER PUMP	

* **Mark in date if different from crankcase oil change, otherwise check.**

DESCRIPTION AND MAINTENANCE

This section covers a brief description and function of the various parts of the engine along with complete instructions covering the repair, disassembly and reassembly of the various component parts of the DD series engine.

This section has the various subjects arranged alphabetically for convenience in locating.

AIR CLEANER

Since dirt is the greatest enemy of any internal combustion engine, it is necessary to take every precauuon to prevent it from entering the engine. This is usually accomplished by an oil bath type air cleaner or filter. There are many types of air cleaners, two different types are shown in Illustrations No. 9 and No. 10. The oil bath air filters generally used accumulate the dirt, which they separate from the incoming air, in the screen and oil reservoir. As this dirt builds up, due to lack of proper maintenance, it has an action similar to closing the choke valve. Since both cause a restriction, which increases the suction on the carburetor jets, it has a tendency to cause loss of power, excessive fuel consumption, internal engine deposits, dilution of the lubricating oil and results in short engine life. Very little restriction, due to dirty air filters, is sufficient to create a very rich mixture. Therefore, one of the most essential preventive measures is proper maintenance of the air intake filter. This unit should be checked at least once a day and, if operating in dusty conditions, may require cleaning every six to eight hours.

It is also essential that all connections between the air cleaner and manifold be absolutely air tight. It is possible, under certain conditions, for enough abrasive laden air to be drawn into the engine through a loose connection to cause rapid wear of the pistons, rings and upper cylinder surfaces.

Two popular types of oil bath cleaners are shown, disassembled for clarity, in Illustrations No. 9 and No. 10. They differ in details of construction but their functions are the same; therefore, they require the same basic procedure.

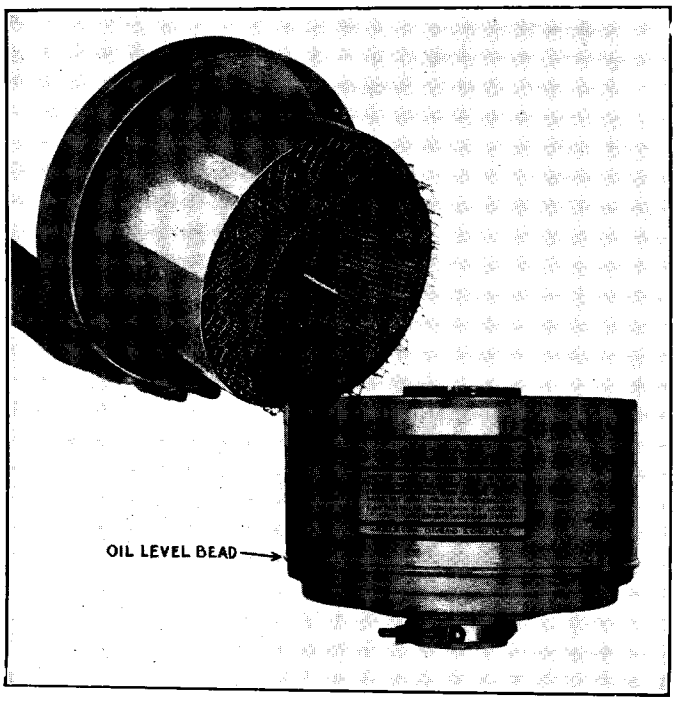


Illustration No. 9

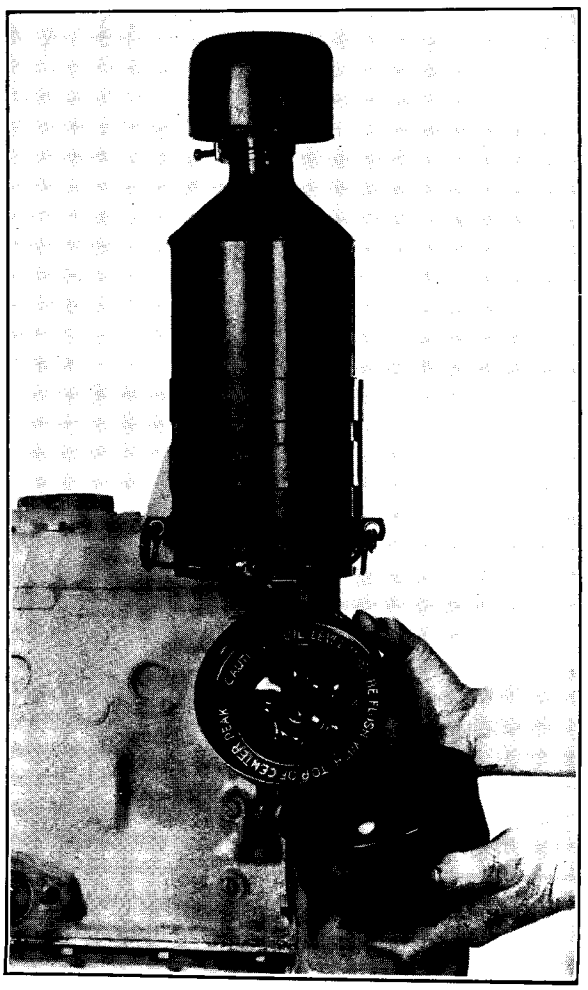


Illustration No. 10

At least once a day the oil cup should be checked and serviced, if necessary. If operating in very dusty conditions, the air cleaner may require cleaning and servicing every six to eight hours.

Each 100 to 150 hours, or until a satisfactory maintenance schedule suited to actual operating conditions can be worked out, the air cleaner should be removed from the engine, thoroughly washed and cleaned. The oil reservoir and screen should be soaked and washed with solvent or gasoline and blown dry with compressed air, if available. If compressed air is not available, wipe the air cleaner bowl dry and shake the screen as dry as possible. Before reassembling the cleaner, dip the screen in clean lubricating oil and fill the reservoir to the proper level (use the same grade as used in the engine crankcase). Inspect the bowl gasket and, if broken or torn, replace with a new gasket. Reassemble the air cleaner and install the complete unit on the engine, making sure all connections between the air cleaner and manifold are air tight.

NOTE:—If a precleaner is used, it also must be removed and serviced regularly.

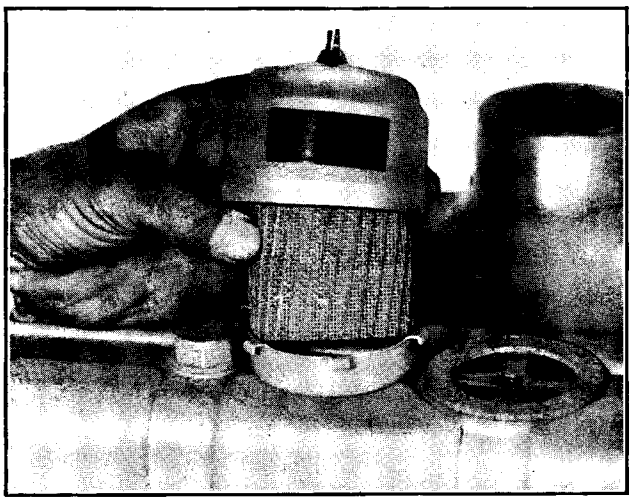


Illustration No. 11

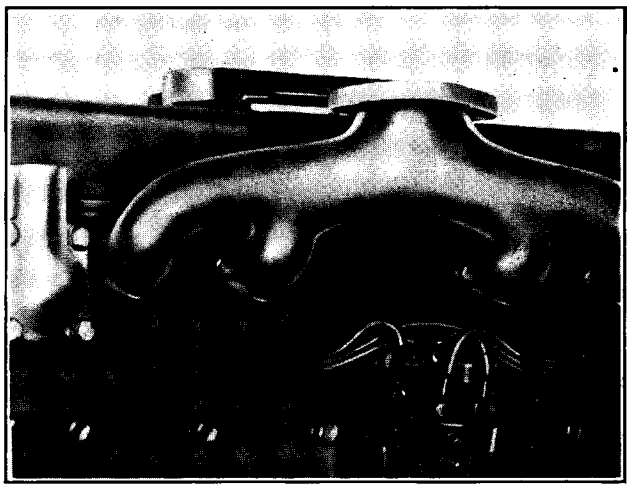


Illustration No. 12

BREATHER

The breather allows clean air to enter or accumulated gases to escape from the crankcase, the normal process of engine breathing. The two breathers illustrated, Illustrations No. 11 and No. 12, are the screen type and are easily removed for servicing.

They should be inspected at frequent and regular intervals, the period depending on the kind or conditions of operation. If required, all parts should be thoroughly cleaned with solvent and blown dry with compressed air to insure free breathing action.

Before reassembly to the engine, apply a small quantity of lubricating oil (the same as used in the engine crankcase) to the screens.

BAYONET GAUGE

The bayonet gauge is used to determine the amount of oil in the oil pan and is readily accessible. The oil level in the oil pan should always be maintained at, or near, the FULL mark, Illustration No. 13. When the oil level drops to the ADD mark on the gauge, add one U. S. quart.

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, some of which may be a plate type housing and others which 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 motor support.

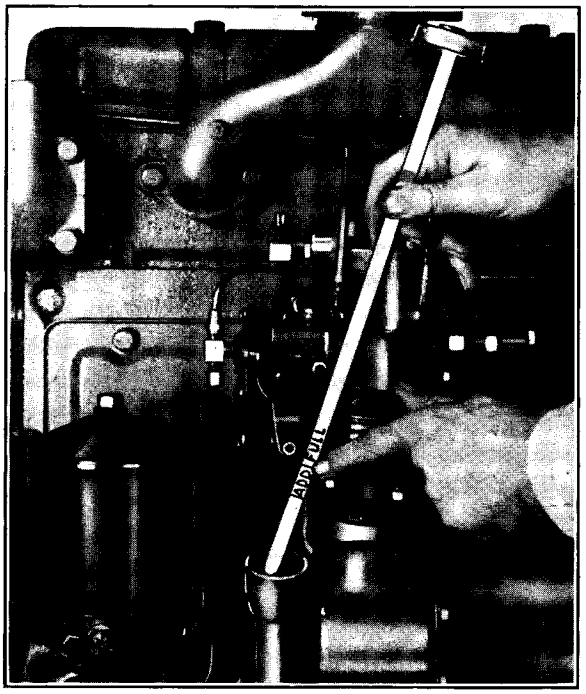


Illustration No. 13

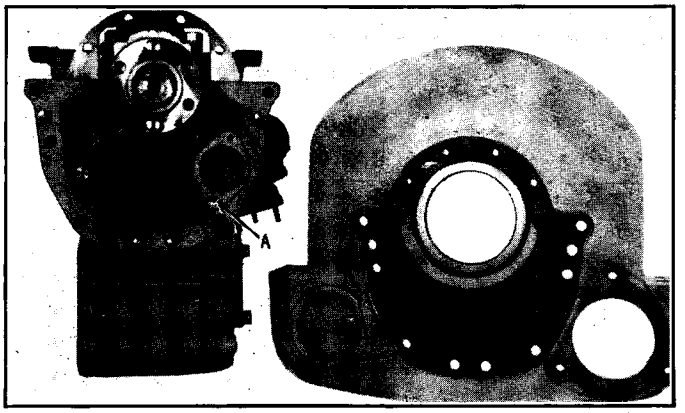


Illustration No. 14

TO REMOVE THE BELLHOUSING

1. Drain the crankcase oil.
2. Remove the clutch or power take-off mechanism and oil pan.
3. Remove the flywheel. See **"Flywheel."**
4. If the engine is in the unit, place suitable supports under the rear of the crankcase to support the engine.
5. Remove the rear motor support screws.
6. Remove the bellhousing attaching screws and stud nuts.
7. Pull the bellhousing away from the engine, Illustration No. 14. It may be necessary to tap the housing with a soft hammer to loosen from the dowels or gaskets sticking to the block.

TO INSTALL THE BELLHOUSING

1. Install a new oil seal in the bellhousing, using a small amount of sealing compound in the bore before pressing in the seal. Cement a new gasket to the bellhousing, allowing the cement to dry sufficiently to prevent the gasket from skidding.
2. Clean and polish the oil seal surface of the crankshaft, making sure there are no nicks or scratches present. Crocus cloth or very fine polishing cloth is suitable for this purpose.
3. Apply a thin coat of oil soap to the seal and the seal surface of the crankshaft. Be sure the hole marked (A), Illustration No. 14, is plugged with the socket head screw. Using care in placing the oil seal over the crankshaft and making sure that the dowels properly enter their respective holes, assemble the bellhousing to the engine and secure in place with the screws and nuts as removed. Check the bellhousing mounting dowels to be sure that they are tight and in good condition.
4. Install the rear motor support screws and remove the jack or block from under the crankcase.
5. Install the flywheel. See **"Flywheel."**
6. Install the clutch or power take-off mechanism and oil pan.
7. Fill the crankcase to the proper level with the correct grade of lubricating oil.

CAMSHAFT

The camshaft is supported on large diameter pressure lubricated bearings in the crankcase and is driven by means of a suitable gear which meshes with the crankshaft gear.

The timing of these two gears requires no check of position of the valve. It is only necessary to line up the punch marks on the two gears, the cam gear being shown as (A) and the crank gear as (B) in Illustration No. 15.

The camshaft end play is controlled by a thrust plate (A), Illustration No. 16, located between the front camshaft bearing and the camshaft gear. Correct end play of .0015″ to .0035″ is regulated by the thickness of the thrust plate.

To decrease the end play, it is permissible to remove by draw filing a small amount of metal from the camshaft gear hub on which the thrust plate rides.

To increase the end play, it will be necessary to 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.

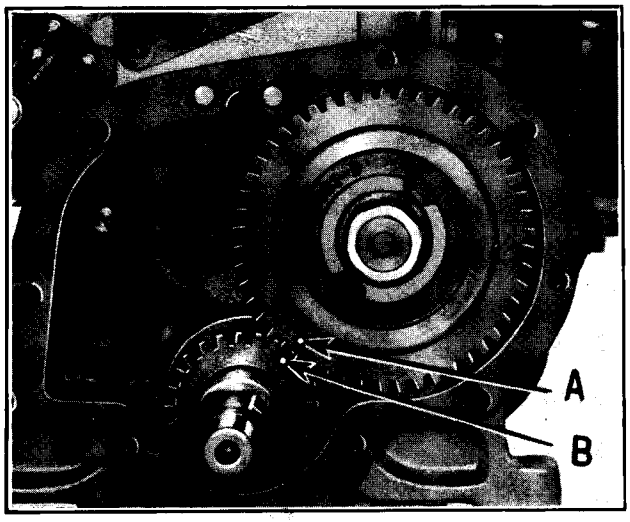


Illustration No. 15

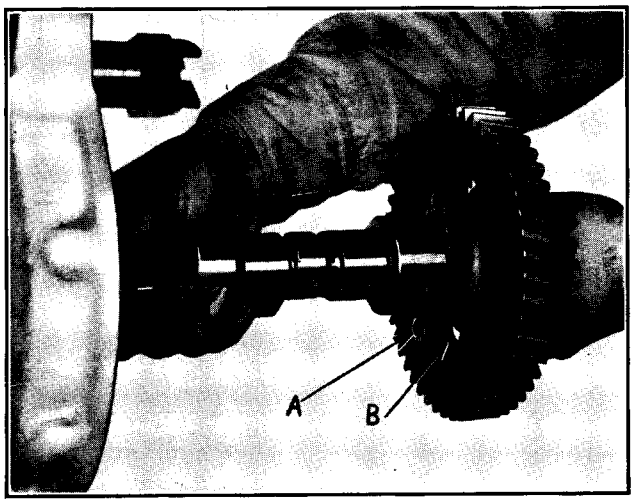


Illustration No. 16

TO REMOVE THE CAMSHAFT

Assuming that the radiator, and so forth, have been removed, the camshaft may be removed, as follows, without removing the engine from the chassis.

1. Drain the lubricating oil and remove the oil pan.
2. Turn the engine over until the No. 1 cylinder is on top dead center and remove the oil pump.
3. Disconnect and remove the fuel pump.
4. Remove the fan blade and belt for easier access to the gear cover and gears.
5. Remove the crank grab nut and fan drive pulley.
6. Remove the gear cover. See **"Gear Cover."**
7. Remove the rocker arm cover, rocker arms and push rods.
8. Valve tappets must be held in the "up" position in order to remove and insert the camshaft. One method of accomplishing this is to make a holder, Illustration No. 17, from music wire by bending a "V" on one end of the wire. This holder may be inserted into the hollow part of the tappet and the tappet lifted away from the camshaft. This holder is then bent over the push rod hole edge of the cylinder head so that the tappet will remain in this position. Use one wire for each tappet.

NOTE:—To remove and assemble the camshaft to the engine with the engine out of the chassis, the same procedure is followed, except Item No. 8 is disregarded. With the engine out of the chassis, it is only necessary 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 "up" position and remove the camshaft.

9. With the tappets in the raised position, rotate the engine until the two holes in the camshaft gear expose the thrust plate attaching screws, Illustration No. 18.

10. Remove the thrust plate attaching screws and pull the camshaft forward out of the engine block.

Inspect the camshaft lobes, oil pump gear, journals, etc., for wear or damage. Also, inspect the thrust plate for clearance. If any of the parts need replacement or adjustment, disassemble the camshaft and drive gear as follows:

Remove the nut, place the shaft in an arbor press and, with suitable supports under the gears, press the shaft out of the gear.

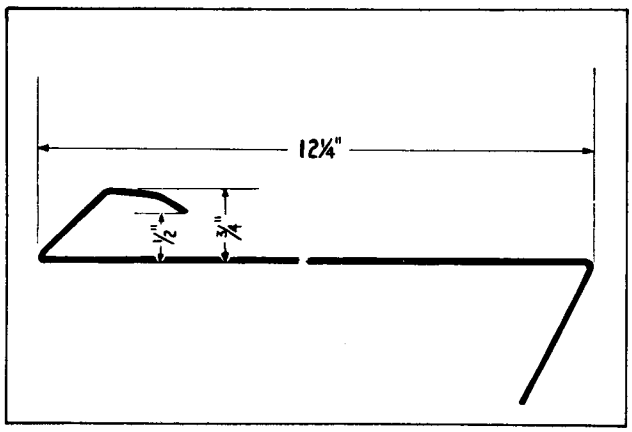


Illustration No. 17

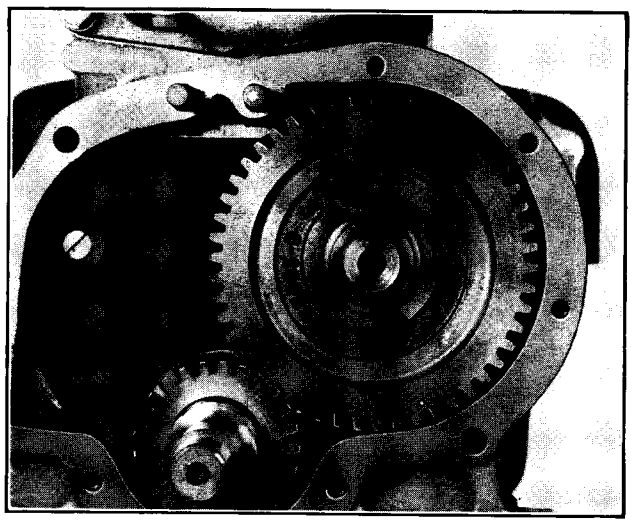


Illustration No. 18

CONNECTING ROD

The connecting rods are heavy alloy steel forgings with precision type bearings for the shaft and bronze bushings for the piston pins. With this precision or insert shell type bearing, the cap and rod is split slightly below center so that the bearing split opposite the locking lugs does not match with the split in the forging. No shims are used and, therefore, when reconditioning of the bearings is necessary, only the bearing shells need to be replaced.

CAUTION:—Do not file or grind the caps, as new bearings cannot be installed in a connecting rod that has been filed.

NOTE:—As built at the factory, the connecting rods and caps are marked on the camshaft side and to the front of the engine with the cylinder number in which they are used.

TO REMOVE THE CONNECTING RODS

CAUTION:—Connecting rods and caps are matched—keep them paired together, as otherwise they cannot be reinstalled.

1. Drain the radiator and disconnect the hoses.

2. Remove the thermostat housing and thermostat so that the water pump bypass hose can be removed from the water pump. Also, disconnect the water temperature gauge thermocouple.

3. Disconnect and remove the air cleaner from the manifold.

4. Disconnect the exhaust pipe from the manifold.

5. Disconnect the fuel lines and remove the fuel pump from the engine. See **"Fuel Pump."**
6. Remove the cylinder head cover, rocker arm assemblies and push rods.
7. Remove the cylinder head screws and nuts and lift the cylinder head assembly carefully from the engine (manifold may be removed with the head).
8. Remove the oil pan and crank the engine so that No. 1 cylinder is in firing position and remove the oil pump. If the tachometer drive is used, this must be removed before the oil pump can be removed.
9. Carefully scrape the carbon deposit from the top of each cylinder bore so that the pistons can be removed without damage to the rings.
10. Turn the engine so that No. 1 and No. 4 connecting rod caps can be removed and the piston and rod assembly pushed carefully upward with a block of wood or hammer handle, Illustration No. 19, to remove from the engine.

NOTE:—Keep the rod caps and bearings of each respective rod together—do not mix.

11. Turn the engine, as required, so that the other rods and pistons may be removed.

TO DISCONNECT THE CONNECTING RODS FROM THE PISTONS

Remove the piston pin retaining rings and push the pin out of the piston and connecting rod bushing. The pistons may be heated in boiling water to facilitate removal of the piston pins.

Inspect the piston pin and bushing for wear and replace, if necessary. If new parts are used, check the connecting rod alignment on a standard aligning fixture.

TO INSTALL THE CONNECTING RODS

1. Assemble the connecting rod and piston and insert the retaining rings.

NOTE:—To make it easier to assemble these parts, the piston may be heated in boiling water for a few minutes. Do not heat the piston pin.

2. Inspect the crankshaft for any rough or scored marks that might damage the connecting rod bearing. If any rough marks are found, use an oil stone, very fine emery cloth or Crocus cloth to polish the shaft. Clean the shaft thoroughly after polishing.
3. Install the piston rings on the pistons. See **"Piston Rings."**

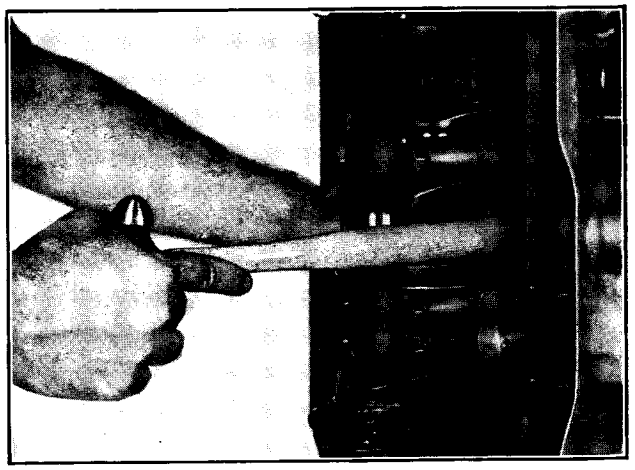


Illustration No. 19

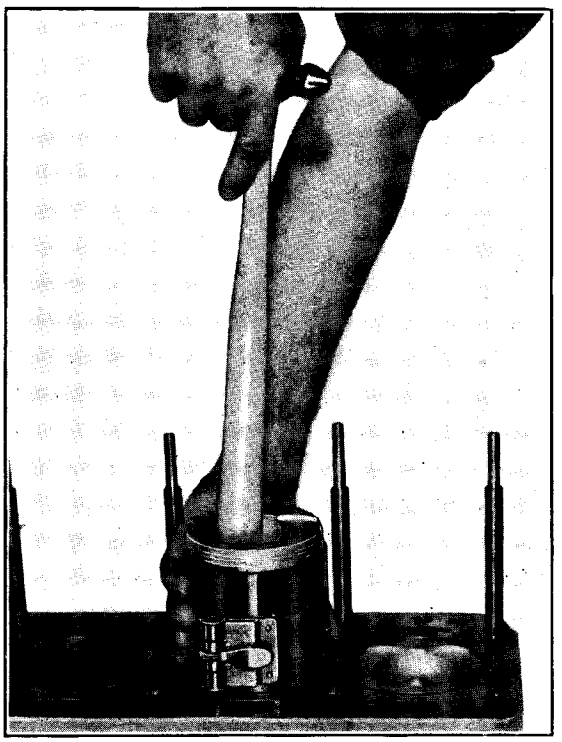


Illustration No. 20

4. Select the proper piston and connecting rod assembly and turn the crankshaft so that it is in the correct position.

5. Apply a liberal coat of lubricating oil to the cylinder bores, pistons, rings and piston pin. Space the piston rings so that no two slots are in line.

6. With the piston rings compressed as shown in Illustration No. 20, use a hammer handle or block of wood to force the piston and rings into the cylinder bore. At the same time, use care that the connecting rod is in line with the crankshaft journal.

7. With the piston entirely in the cylinder bore, insert the upper bearing shell and pull the connecting rod down to the crankshaft.

8. Place a ¼" x ½" x .003" piece of feeler stock in the cap. Place the lower shell in the cap and assemble the cap to the connecting rod. Tighten the cap screws to the proper tension and try the connecting rod for side movement. The connecting rod should move sideways with a firm pressure of the hand. After obtaining the proper movement of the rod in the above manner, remove the piece of feeler stock and reassemble the connecting rod cap. Tighten the screws, as before, and again try the side movement of the rod. It should move easily. See **"Clearance Table"** for proper clearance and **"Wrench Tension"** for proper nut tension. If no torque wrench is available, this tension would require a tight pull on a 12" wrench.

9. Repeat the above operations for all connecting rods.

10. Install the cotter pins.

11. Install the oil pump. See **"Oil Pump."**

12. Inspect the top of the cylinder block and pistons. Be sure no foreign matter is present and install the cylinder head gasket.

13. Install the cylinder head. See **"Cylinder Head."**

14. Insert the valve push rods and install the rocker arm assemblies.

15. Adjust the tappets to the proper clearance. See **"Valves."**

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

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

18. Install the fuel pump and fuel lines. See **"Fuel Pump."**

19. Install and connect the air cleaner and connect the exhaust pipe to the manifold.

20. Connect the radiator hoses and fill the radiator with clean water or anti-freeze.

21. Install the oil pan, using new gaskets, and fill the crankcase with the proper grade of lubricating oil.

CONNECTING ROD BEARING REPLACEMENT

If excessive clearance develops between the shaft and bearing shells, new bearing shells should be installed. If the clearance is excessive with the new bearings, regrind the shaft and use undersized bearings.

The connecting rod bearings may be replaced as outlined below.

1. Remove the oil pan. See **"Oil Pan."**

2. Locate the crankshaft so the connecting rod cap can be removed.

3. Remove the cotter pins, nuts and cap screws.

4. With a soft hammer, tap the cap to loosen it and remove the cap.

5. Replace the bearing shells as outlined under Nos. 8, 9 and 10 above.

6. Reassemble the oil pan to the engine. See **"Oil Pan."**

COOLING SYSTEM

Perhaps the best method for care of the cooling system is to clean and flush the system periodically; also, use some good rust and corrosion preventive between cleaning periods. Almost all natural water contains some mineral salts which stimulate corrosion.

Exhaust gas leakage between the cylinder head and the gasket also results in corrosion if the exhaust gases discharge into the water, combining to form a variety of acids such as carbonic, nitrous and sulphurous, all supporting electrolytic corrosion. It is, therefore, important that the cylinder head stud nuts be drawn down at regular and frequent intervals to prevent exhaust gases from leaking into the water jacket.

Air leaks around the hose connections and through the water pump should be carefully guarded against, since oxygen is a major factor in promoting corrosion. Check the hose connections frequently for air leaks.

If the engine or unit is equipped with a pressure type sealed system, it is imperative that the correct type of radiator cap be used. This is determined by the type of system used.

There are two types of sealed cooling systems which are used extensively. One type has a safety relief valve arrangement built into the radiator filler cap, Illustration No. 21. The overflow pipe is also connected to the radiator filler neck above the lower seat of the pressure cap. In this manner, if excessive pressure develops in the cooling system, the lower part of the pressure cap will raise from its seat and allow the vapor to escape through the overflow pipe.

This type of cap should never be removed quickly. Always turn the cap off slowly until the pressure has escaped through the overflow pipe, then remove the cap.

The second type of pressure sealed cooling system has the pressure relief valve and overflow pipe built into the top tank as a separate unit (not connected to the filler neck).

However, if any type of sealed cooling system is used, the proper filler cap, good gaskets and a smooth gasket surface are essential if excessive loss of the coolant is to be prevented.

From the above, it can readily be understood why serious overheating of the engine results when the incorrect filler cap, bad gaskets or a rough surface are encountered.

Use a good commercial neutralizer in the cooling system—one purchased from a reputable company. To obtain the best results, follow the instructions of the manufacturer.

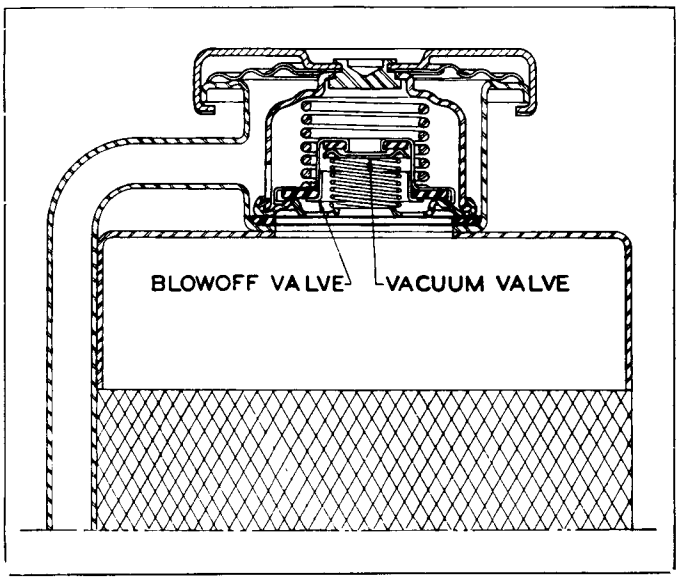


Illustration No. 21

GLANCE at the Instrument Panel gauges often. They tell how your engine is functioning.

LUBRICATION is your biggest asset to offset your greatest liability . . . .

UNNECESSARY REPAIRS . . . . . Use only the BEST OIL obtainable

CRANKSHAFT

The crankshaft is a machined forging having all bearing journals surface-hardened. The nominal diameter of the main bearings is 2½" while the nominal diameter of the connecting rod journals is 2". The shaft has passages drilled to carry oil, under pressure, to the connecting rod bearings. These passages should be cleaned with a wire brush, see Illustration No. 22, before the shaft is installed in the engine.

While the diameters given above are only nominal, the following table gives the actual sizes, both standard and undersize, to which the shaft may be reground.

WARNING! When regrinding a crankshaft, it is imperative that the original radius from journal to cheek be maintained. Crankshaft breakage may result from improper grinding of this fillet.

Size	Main	Connecting Rod
Standard	2.4975/2.4965"	1.988/1.987"
.020" U. S.	2.4775/2.4765"	1.968/1.967"
.040" U. S.	2.4575/2.4565"	1.948/1.947"
.060" U. S.	2.4375/2.4365"	1.928/1.927"

To replace the crankshaft main bearings, see **"Main Bearings."** To replace the crankshaft connecting rod bearings, see **"Connecting Rod."**

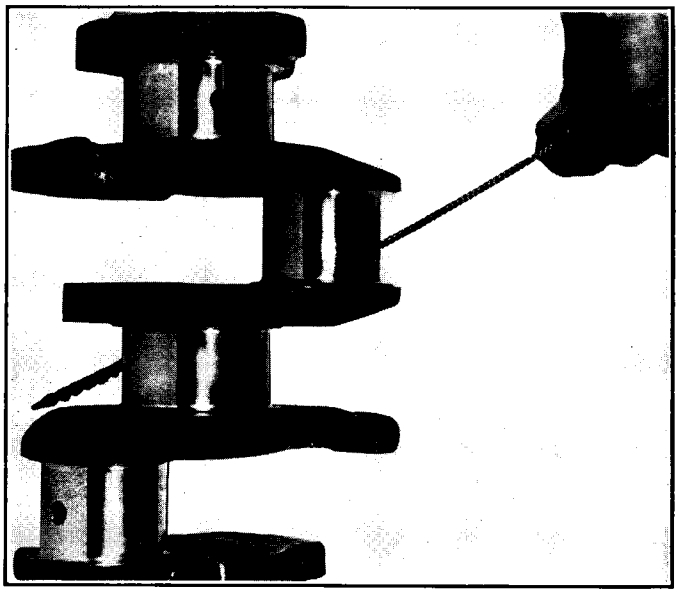


Illustration No. 22

TO REMOVE THE CRANKSHAFT GEAR

If a suitable arbor press is not available, the following method may be used:
Due to the extremely tight fit of the crankshaft gear on the crankshaft, it is almost impossible to pull this gear with any of the commercial pullers. Since replacement of this gear would only be brought about by the gear being badly worn or damaged, it may be removed in the following manner: Using a ¼" diameter drill centered midway between the edge of the keyway and the base of the gear teeth, drill through the gear parallel with the keyway, then spread the gear with a chisel and pull from the shaft. **CAUTION:** Be careful not to drill into the crankshaft.

TO INSTALL A NEW GEAR

1. Insert the Woodruff key in the shaft.
2. Lay the gear on a sheet of asbestos or other fireproof material and heat the gear with a blowtorch 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.)
3. Assemble the hot gear on the crankshaft and, with a suitable driver, quickly force the gear into the correct position. A piece of 2" diameter pipe may be used as a driver.
4. Allow the gear and shaft to cool.

CYLINDER AND CRANKCASE

The cylinders are cast integral with the crankcase and have the water jacket carried the full length of the cylinders. This results in uniform cooling of the piston and cylinder wall and has a very definite bearing upon maintenance of lower oil temperatures than is possible with any other type of construction without the use of an oil cooler.

Material is cast iron with forged bearing caps fastened to the crankcase with ½" and 7/16" cap screws. The most casual inspection of the cylinder block will disclose the very rigid construction provided to support the crankshaft and this rigidity, coupled with the large diameter of the crankshaft, results in a very rugged and smooth running engine.

Some engines are equipped with dry, removable cylinder sleeves. See **"Cylinder Sleeve."** Those not equipped with cylinder sleeves may be rebored up to .060" oversize.

The cylinder block has a drilled passageway running the length of the block, which is closed on the ends with suitable pipe plugs, known as an oil header. From this header, various passages are drilled to carry oil to the main bearings, camshaft bearings and rocker arms. The passageway for the rocker arms is open at the camshaft thrust flange screw on the rear of the block, and this screw hole (A), Illustration No. 14, must be plugged to prevent oil leakage.

All oil passages should be thoroughly cleaned with a wire brush and solvent at overhaul time.

To replace the main bearings, see **"Main Bearings."**

Core openings are closed by expansion type brass or steel plugs. If any of these should leak, remove and replace with new plugs.

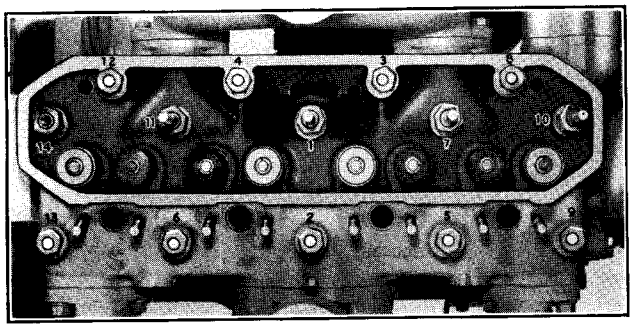


Illustration No. 23

CYLINDER HEAD

The cylinder head is a one piece casting and is detachable. The valve seats are a part of this casting while the valve guides are removable bushings. The head is held to the cylinder block by studs; and, in order to insure against leaks, the head must be carefully drawn down by means of the stud nuts which should be progressively tightened, working from the center of the head toward the ends, as shown in Illustration No. 23.

A torque wrench is recommended for this operation. See **"Wrench Tension"** for recommended tensions. If a torque wrench is not available, a wrench approximately 18" long should be used for this operation.

If cylinder head gasket failure is encountered, a thorough check should be made of contributing factors. Detonation, pre-ignition or spark knock (caused by ignition which is too far advanced) will cause a shock load in the combustion chamber which will damage cylinder head gaskets and, if allowed to continue, may destroy the pistons and piston rings. Fuel with an octane rating too low may also contribute to detonation and corrosion of the gasket to the point where it will start 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.

TO REMOVE THE CYLINDER HEAD

1. Drain the radiator and remove the water thermostat housing and hoses. Also, disconnect the water temperature gauge thermocouple from the cylinder head.
2. Disconnect the exhaust pipe from the exhaust manifold.
3. Disconnect the air cleaner or pipe from the intake manifold and remove.
4. Remove the fuel line.
5. Remove the cylinder head cover, rocker arm assemblies and push rods.
6. Remove the cylinder head nuts and lift the cylinder head from the engine. Tap the head lightly with a soft hammer, if necessary, to loosen it. Do not pry on the contact surfaces.

TO REPLACE THE CYLINDER HEAD

1. Before installing the cylinder head, clean out the carbon deposits by scraping or brushing. If the valves are to be ground or otherwise serviced, see **"Valves."**
2. Clean out the cap screw holes in the cylinder block, using a tap, if necessary.
3. Clean the cylinder block and cylinder head contact surfaces.
4. Install a clean, new cylinder head gasket on the cylinder block. The gasket must be assembled with the bead (rolled edge around the combustion chamber) down. No shellac or gasket cement is necessary.
5. Place the cylinder head and valve assembly on the block.
6. Start the head nuts and tighten evenly, using a torque wrench. Start at the center of the head and work progressively to the outer ends, Illustration No. 23. See **"Wrench Tension."**
7. Install the push rods and rocker arms.
8. Adjust the valve tappets to the proper clearance. See **"Valves."**
9. Install the cylinder head cover, using a new gasket, if required.
10. Install the fuel lines.
11. Inspect the thermostat. See **"Thermostat."**
12. Install the thermostat, housing and hoses. Connect the water temperature gauge thermocouple to the cylinder head.
13. Install the manifold and air cleaner or pipe, using new gaskets, if required.
14. Connect the exhaust pipe to the manifold.
15. Fill the cooling system with the proper solution (water or anti-freeze).

CYLINDER SLEEVES

When the engines are equipped with cylinder sleeves, these are fit to the cylinder block with a very light press fit and a sleeve puller should not be required to remove or install them. A block of wood or a suitable driver may be used to bump the sleeves out and, also, to install them.

These sleeves are precision machined to size before installation and no honing is necessary.

FAN ASSEMBLY (Cooling)

The cooling fan is mounted on the water pump driven pulley, which is driven from a drive pulley mounted on the crankshaft by the use of one or more "vee" belts. Various accessories may be mounted on the engine and driven by these belts. Therefore, it is not possible to list the fan belt specifications.

FLYWHEEL

Various flywheels used on the DD series engines are usually made of cast iron and may be machined to accommodate different types and sizes of clutches, as well as generators and other types of couplings. The flywheel is fastened to the crankshaft with four bolts and two dowels. One of these dowels is off center so that the flywheel can only be installed in one position. This properly locates the flywheel on the crankshaft for timing purposes. The timing mark, which indicates that No. 1 piston is on top center, may be seen (depending on the type of the bellhousing) through either a drilled hole provided in the bellhousing, Illustration No. 24, or as shown in Illustration No. 25. All flywheels have a line marked DC (dead center) and from this line are graduations designating degrees of crankshaft travel. From DC these lines are marked 5°, 10°, 20°, 30° and 40°, see Illustration No. 26. Intermediate lines between 10° and 40° are spaced at 2° intervals and are not marked.

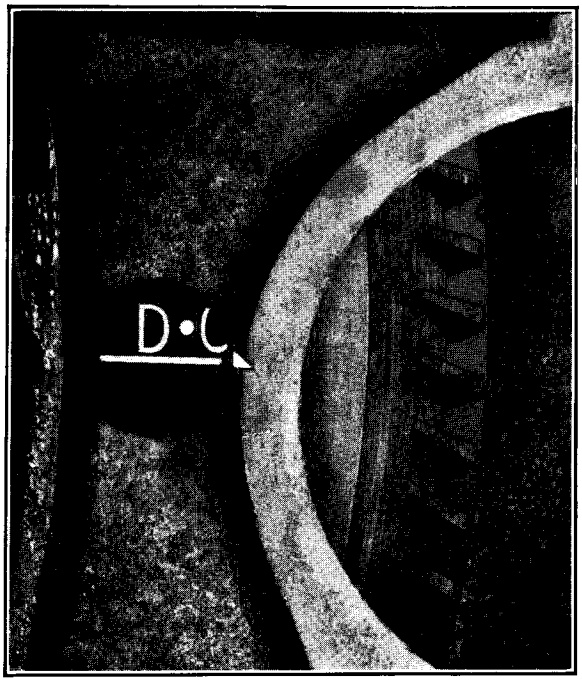


Illustration No. 24

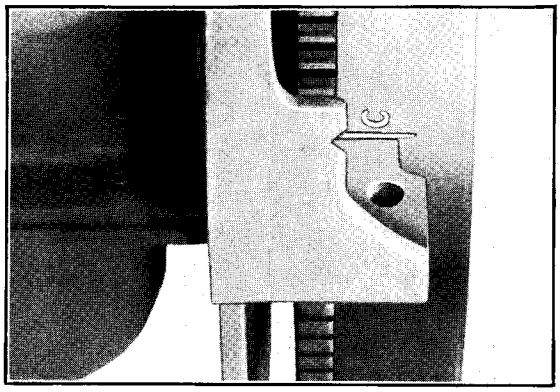


Illustration No. 25

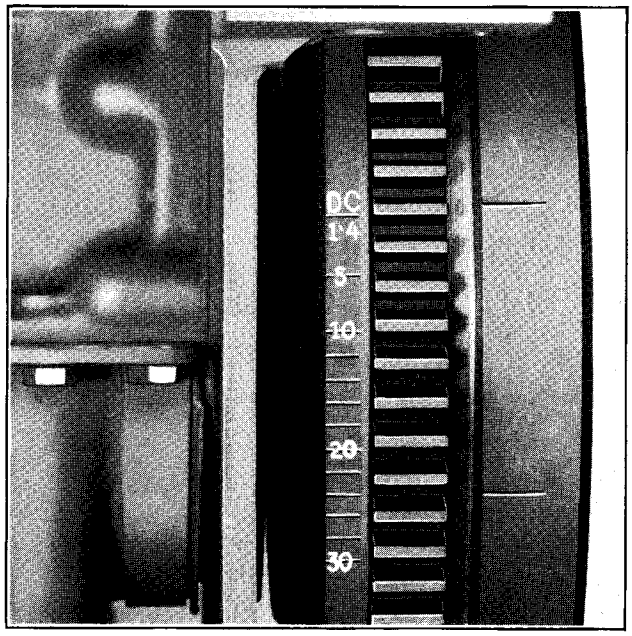


Illustration No. 26

TO REMOVE THE FLYWHEEL

1. Disconnect and remove the power take-off or transmission and clutch, whichever is used.
2. Remove the flywheel cotter pins or lock wires and remove the flywheel screws or nuts.
3. Using a Lady-Foot pry bar, pull the flywheel from the crankshaft.

TO INSTALL THE FLYWHEEL

1. Insert the flywheel dowels in the crankshaft and turn the crankshaft so that the No. 1 cylinder is in the top dead center position.
2. Turn the flywheel so that the timing mark is in line with the timing hole in the bellhousing. Then, install the flywheel on the crankshaft and draw in place with the flywheel attaching nuts or screws. Do not draw any one nut or screw tight until all are progressively tightened.

NOTE:—Some flywheels have the dowel holes machined so that they are blind holes while others have the holes drilled through; expansion plugs are used to cover the dowels.

3. Attach the indicator, as shown in Illustration No. 27, to check the concentricity of the pilot bore. This should not exceed .005″ total reading.
4. Attach the indicator, as shown in Illustration No. 28, to check the face of the flywheel. This should not exceed .005″ total reading.
5. Install the cotter pins or lock wires, as required, and insert the expansion plugs, if used.
6. Install the starting motor.
7. Install the clutch and transmission or power take-off, as removed.

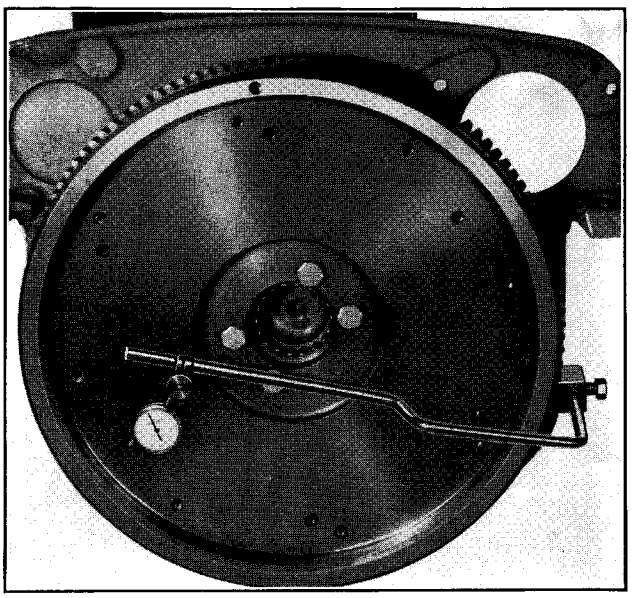


Illustration No. 27

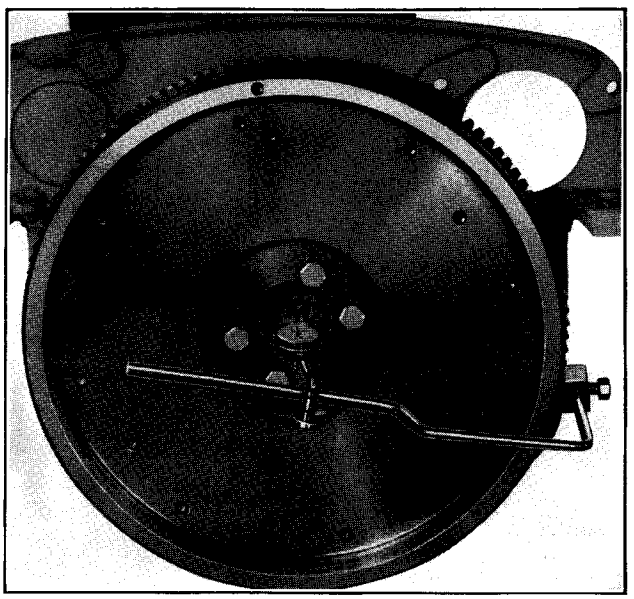


Illustration No. 28

PROPER FUEL AND CLEANLINESS WITH CORRECT NOZZLE PRESSURE INSURE TROUBLE FREE OPERATION

FUEL OIL FILTERS

Because of the extremely accurate construction of the various parts of the fuel injection system and since repairs to these units are quite expensive, the Hercules Motors Corporation has worked out a filtering system which, with intelligent care, will reduce the wear on the accurately fitted parts of the injection system. This filtering system contains the following filters:

A large fuel filter is used between the fuel tank and the fuel transfer pump. This unit is to remove the larger particles of dirt and water.

A smaller final filter is installed between the fuel transfer pump and the fuel injection pump.

Both of these filters are usually equipped with throwaway type elements.

On some installations the final filter may be of the sealed type instead of the metal and cloth combination. Units having this type of filter should have the filter changed at regular intervals, depending on the service demanded of the engine and the cleanliness of the fuel oil.

TO CLEAN THE FUEL FILTERS

The fuel filters are equipped with replaceable elements; these elements should be inspected frequently until a definite schedule is established for replacement.

CAUTION: A dirty or plugged fuel filter will result in loss of power and may prevent operation of the engine.

To reduce the amount of cleaning the filters should receive, insist on the fuel oil being clean and then handle it with clean containers. Frequency of cleaning is determined by the amount of dirt and gum or wax in the fuel oil.

Some specialized installations may have a different fuel filtering system but the above will also serve as a guide in maintaining a clean fuel system. Since dirty fuel filters affect the efficiency of the engine, it is necessary to keep them clean for low cost operation.

FUEL OIL SPECIFICATIONS

American Society for Testing Materials Specifications

Fuel Oil Specifications. To be a chemically neutral distillate petroleum fuel oil of the following characteristics:

1.	Viscosity at 100° F.	Minimum	33 sec.
	Saybolt Universal (Preferably 40 to 70)	Maximum	100 sec.
2.	Sulphur (By Weight)	Maximum	1.5%
3.	Conradson Carbon Residue (% by weight)	Maximum	.2%
4.	Ash Content	Maximum	.02%
5.	Moisture and Sediment (B.S. & W.) (% by volume)	Maximum	.05%
6.	Flash (For insurance purposes only)	Minimum	150° F.
7.	Pour point at least 10° less than lowest temperature where engine operates.		
8.	Cetane number, min.		45

The following paragraphs are not part of the A.S.T.M. specifications but are inserted here to allow interested parties to check the gum content of the fuel being used.

The "gum" content in the fuel oil is not to exceed 75 milligrams per 1000 cc's of fuel as determined by the "burn-out" test as follows:

Put 1000 cc's (approximately one quart) of the fuel in an enameled steel pan such as an ordinary wash basin. Set the pan at an angle of about three or four degrees. Ignite the fuel by the aid of three or four teaspoons of gasoline and allow to burn out completely. Keep the pan in a place free from draft.

At the completion of burning, the gum content is the tarry residue remaining in the bottom of the pan unburned. This amount should not exceed 75 milligrams as determined by brushing away all loose dry carbon soot, then dissolve the tarry gum residue with benzene and filter. Distill off the benzene and weigh the remaining residue.

If convenient methods of weighing this "gum" are not available, the maximum permissible quantity of "gum" without causing excessive ring sticking can be observed in the bottom of the pan as not exceeding an area of approximately 1" in diameter and $\frac{1}{64}$" thick.

NOTE:—Recracked or recycled fuel oils are usually not satisfactory.

Fuel oil that has been "recracked" or "recycled" at the refineries is usually a hard oil to ignite. The ignitability of fuel oil cannot be determined by the usual characteristics of the physical state of the oil, such as gravity, viscosity or color, all of which have no influence whatever on the ignitability of the oil. Refineries and oil distributors' agencies should assume the responsibility of supplying a fuel oil of good ignition and burning qualities. They can determine the ignitability of their oil by methods recommended by A.S.T.M.

FUEL PUMP TIMING—ROOSA

(For Bosch Pump Timing—See page 36)

Model		Roosa Pump
DD	3 Cylinder	34° B.T.D.C.
DD	4 Cylinder	34° B.T.D.C.
DD	6 Cylinder	36° B.T.D.C.

CAUTION: When timing the Roosa fuel injection pumps on the DD series engines:

A. If the fuel pump is mounted on the left-hand side of the engine, time the pump on No. 1 cylinder.

B. If the fuel pump is mounted on the right-hand side of the engine, time the DD-6 on No. 6 cylinder and the DD-4 on No. 4 cylinder.

The above timing chart is considered as standard. However, there may be installations where modifications may be necessary.

This section contains all the information necessary to remove and install the fuel injection pump. If more complete information is necessary, fill in and mail the attached postcard.

The vertically mounted fuel injection pump, Illustration No. 30, is considered a single cylinder, opposed plunger, inlet metering, distributor type pump. Its broad objective is to meter and spray liquid fuel oil through nozzles into the engine cylinders.

Specifically, it draws fuel from the fuel tank, through an arrangement of filters, distributes and delivers an accurately metered amount to the various injection nozzles in properly timed relationship. A fly-ball type governor is provided to automatically control the fuel charge in accordance with the engine load at any given speed range within the minimum and maximum speed settings.

This pump has no ball bearings, no poppet valves and no gears. It is driven from the oil pump drive gear through a tongue and groove arrangement. It requires no special lubrication system since it is lubricated with the filtered fuel it pumps. The pump mechanism, governor, transfer pump 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.

Fuel is drawn through the primary fuel filters into the transfer pump; from the transfer pump, it is forced through the secondary filters and back into the fuel pump proper where it is forced through a drilled passageway in the hydraulic head, metered, compressed and delivered to the proper fuel nozzle at the correct time. A portion of the fuel oil is passed into the housing of the pump 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. This prevents the fuel pump from becoming air locked.

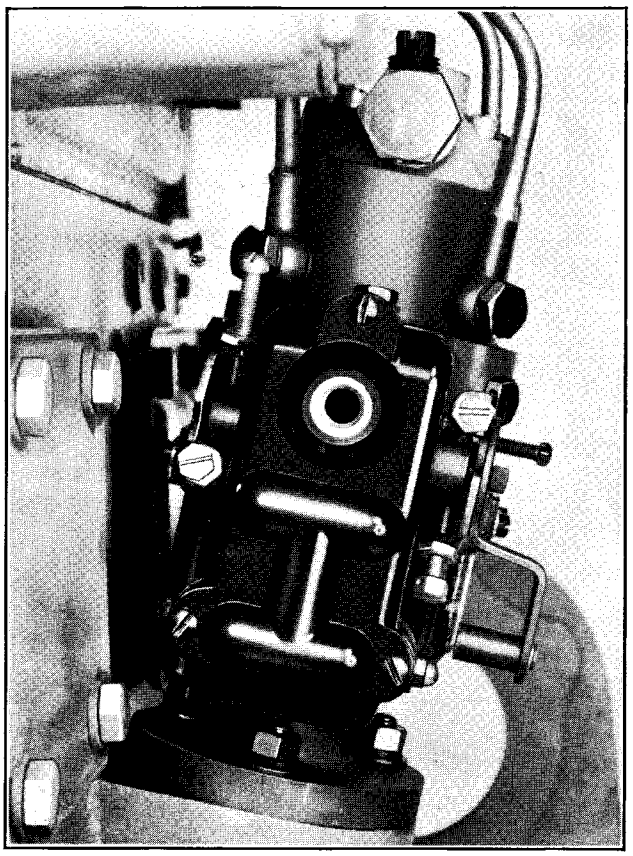


Illustration No. 30

TO REMOVE THE FUEL PUMP

The following procedure should be followed to remove the fuel pump from the engine. If it is followed in detail, the reinstallation of the pump will be more easily accomplished.

1. Clean and wash down the engine adjacent to the fuel injection equipment to eliminate any chance of dirt entering the fuel injection system when the lines are disconnected.

Illustration No. 31

2. Remove the cover plate from the side of the fuel pump, Illustration No. 31, and turn the engine over in the direction of its normal rotation until the timing lines on the pump can be seen through this opening. Check to see that the piston of No. 1 cylinder is the proper degree before top center, see **"Timing Chart."** This can be determined as follows:

   a. Remove the cylinder head cover and observe that No. 4 (or No. 6) cylinder exhaust valve is nearly closed.

b. The timing line on the flywheel, indicating that No. 1 piston is before top center, is in line with the pointer in the flywheel housing, see Illustrations No. 24 and No. 25.

3. Remove the pump from the engine as follows:
   a. Disconnect the fuel supply line, transfer pump to filter line and filter to pump line; also, disconnect the leak-off manifold.
   b. Disconnect the fuel return line from the pump; also, disconnect the throttle and stop control linkage.
   c. Disconnect the high pressure lines from the fuel pump.
   d. Remove the fuel pump attaching screws and lift the fuel pump out of the drive coupling.
   e. Inspect the drive parts for wear.

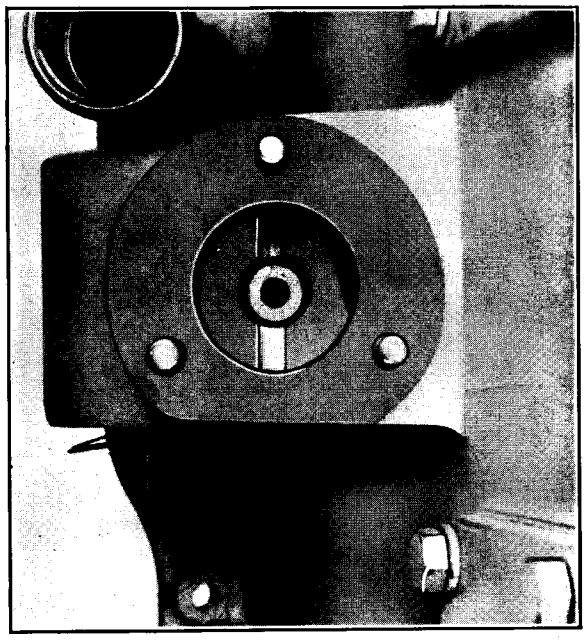


Illustration No. 32

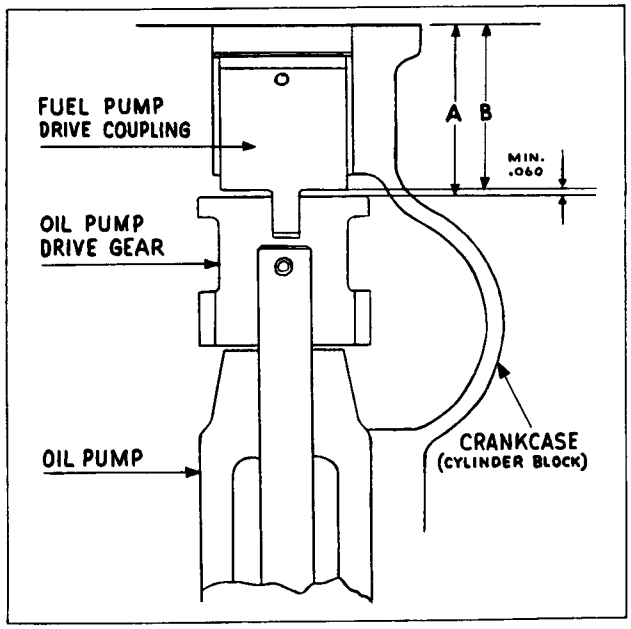


Illustration No. 33

FUEL PUMP REPAIRS

Fuel pump repairs should not be attempted by anyone other than qualified personnel who are fully conversant with fuel injection pumps.

TO INSTALL THE FUEL PUMP (Timing)

The fuel pump is driven from the oil pump drive gear through a tongue and groove type coupling. The tongue and groove of the coupling parts are slightly off center to prevent incorrect installation of the fuel pump, as can be seen in Illustration No. 32. The tongue and groove are offset away from the camshaft when the engine is properly spotted with No. 1 cylinder at top dead center in firing position. As can be noted in Illustration No. 32, the groove in the top of the oil pump gear is parallel with the engine camshaft when the flywheel mark is on dead center.

CAUTION:—It is important that a minimum clearance of .060" (1/16) be maintained between the oil pump drive gear and the fuel pump drive coupling, Illustration No. 33.

Always use a new gasket to install the fuel pump.

This clearance may be determined by measuring the distance (B), Illustration No. 33 (distance from the fuel pump coupling to the attaching flange of the fuel pump. The new gasket should be placed on the fuel pump before measuring or add 1/32" to the measurement), and subtract this dimension from dimension (A) (distance from the fuel pump attaching face of the cylinder block to the top of the oil pump drive gear).

Additional gaskets may be added, if necessary, to obtain the correct clearance.

The first step in installing the fuel pump is to locate the DC mark on the flywheel and line it up with the mark on the bellhousing, see **"Flywheel."** To determine whether the engine is in firing position for No. 1 cylinder, the engine can be cranked with the No. 1 fuel nozzle removed to determine the compression stroke of the No. 1 cylinder by "feel" or the cylinder head cover can be removed and the position of the valves noted. If both rocker arms of No. 1 cylinder are clear, indicating that the valves are closed, and the

exhaust valve of No. 4 cylinder (or No. 6 cylinder on a 6 cylinder engine) is not completely closed, this will indicate the approximate firing position for No. 1 cylinder.

Turn the fuel pump coupling so that the marks shown in Illustration No. 31 are in view and assemble the fuel pump to the cylinder block and coupling. Tighten the attaching nuts sufficiently to hold the pump in place and still allow it to be turned.

Rotate the engine backward past the correct degree marks on the flywheel; then, bring it back so that the proper degree mark is in line with the mark on the bellhousing. Rotate the fuel pump body so that the marks, Illustration No. 31, are exactly in line. Tighten the pump attaching nuts securely and install the fuel pump cover plate.

Reinstall the No. 1 nozzle, if it has been removed, and assemble the high pressure lines from the fuel pump to the nozzles.

Connect the throttle and stop control linkage, making sure that full movement of the levers is permitted.

Connect the fuel supply and return lines, transfer pump line and leakoff manifold.

Prime the fuel system, see **"Priming the Fuel System."**

FUEL PUMP TIMING--BOSH

(For Roosa Pump Timing—See page 33)

DD-3	Below 1700 R.P.M.	24° B.T.D.C.	Above 1700 R.P.M.	26° B.T.D.C.
DD-4	Below 1700 R.P.M.	24° B.T.D.C.	Above 1700 R.P.M.	26° B.T.D.C.
DD-6	Below 1700 R.P.M.	26° B.T.D.C.	Above 1700 R.P.M.	28° B.T.D.C.

The American Bosch type PSB fuel injection pump is of the constant-stroke, distributing-plunger, sleeve-control type, the plunger being actuated by a cam and tappet arrangement which also carries gearing for the distribution function. The purpose of the pump is to deliver accurately metered quantities of fuel oil under high pressure to the spray nozzles through which the fuel is injected into the engine cylinders, at a definite timing in relation to the engine firing cycle and within the required injection period.

An integral governor, of the mechanical-centrifugal type, is used with this pump to control fuel delivery as a function of speed. It is driven directly off the rear of the pump camshaft without gearing.

A gear-type fuel supply pump is provided for direct attachment to the pump at the front, driven from the distributor drive gear on the camshaft.

This fuel injection pump is mounted on the timing gear case and driven by the camshaft gear. The pump is pressure lubricated from the engine lubricating system through an auxiliary oil line.

The priming procedure is similar to that outlined for the Roosa injection pump.

The Bosch PSB type injection pump is installed and timed as outlined below.

INSTALLATION AND TIMING

1. Spot the engine flywheel at the proper degree mark before top center on compression stroke on No. 1 cylinder.
2. Position the fuel injection pump for firing on No. 1 cylinder as follows:
   a. Remove the timing cover from the side of the injection pump.
   b. Rotate the injection pump shaft until the mark on the plunger drive gear is visible through the timing window. This mark must be visible during the timing procedure.
3. The drive gear is marked on the front inner diameter, and this mark must be aligned with a similar mark on the gear hub when assembling these parts. The drive gear also has one tooth marked with two punch marks. These marks must be aligned with the two punch marks on the engine camshaft gear when assembling the injection pump to the engine.
4. Rotate the drive gear and hub slightly to align the mark on the drive gear hub with the timing pointer in the injection pump housing.
5. Remove the drive gear cover plate from the gear housing cover plate.

6. Assemble the injection pump to the engine. Recheck the timing as outlined in paragraph 4. If necessary, loosen the gear to hub attaching screws and rotate the hub to obtain correct alignment of the timing marks, see paragraph 4 above. Tighten and lock the screws with the lock plates.

   NOTE: There is also a plug located in the gear housing over the injection pump drive gear, which, when removed reveals a passage for sighting the alignment of the timing marks.

7. Install the drive gear cover plate and replace the sight plug.

8. Connect the fuel lines, lubricating oil line and control rods as removed.

   CAUTION: Be sure to start and tighten the line nuts finger tight before using a wrench for final tightening to prevent possible damage to these parts.

9. Prime the fuel system.

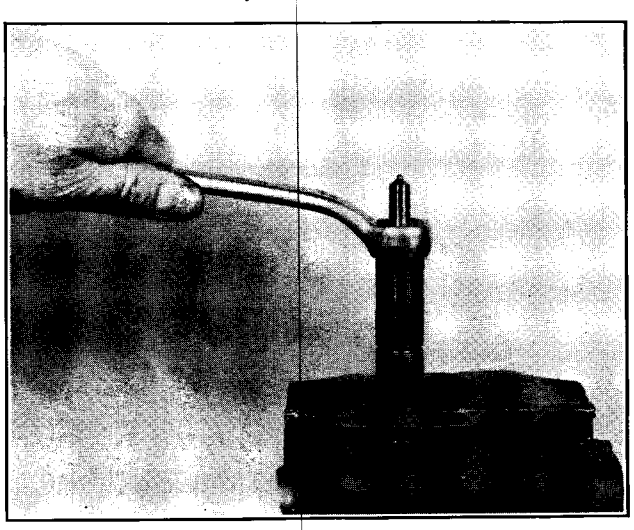


Illustration No. 34

FUEL NOZZLE AND HOLDER ASSEMBLY

The fuel nozzle and holder assembly is shown in Illustration No. 34 clamped in a vise preparatory to disassembling, while Illustration No. 35 shows the complete details of the nozzle and holder assembly, the component parts of which are as follows:

No. 1 Nozzle Body Retaining Nut
No. 2 Fuel Nozzle Body
No. 3 Fuel Nozzle Pintle
No. 4 Holder Assembly
No. 5 Pressure Adjustment Cap Gasket
No. 6 Pressure Adjustment Cap Gasket

Parts No. 2 and No. 3 are not interchangeable with similar parts of other assemblies and should be used as pairs as originally furnished.

DO NOT MIX THESE PARTS — KEEP THEM IN SETS.

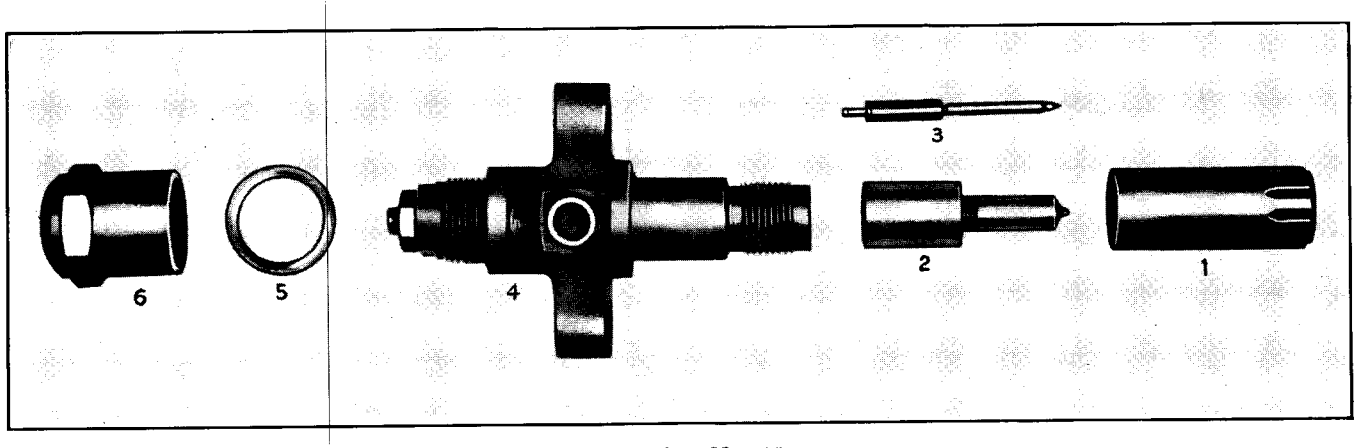


Illustration No. 35

CARE OF THE FUEL NOZZLES

Cleaning the spray nozzles is necessitated by:

1. Dirt or foreign matter in the fuel oil which is not removed by the fuel strainers, acid and gum in particular.
2. By an overheated engine and the spray nozzles causing the fuel oil in the nozzles to decompose or coke around the pintle stem of the valve, spray hole and face of the nozzle.
3. Acid in the fuel oil etching or corroding the nozzle valve and body. This type of fuel should never be used under any circumstances. It will ruin the pumps and nozzles. Fuel oil which is contaminated with acid may be detected by dipping one end of blue litmus paper in the oil for a few seconds. If acid is present in the oil, the litmus paper will turn pink.

When to clean the spray nozzles:

1. When the engine exhaust has increased the amount of black or dark smoke.
2. Loss of power accompanied with foul exhaust or increased leakage of fuel through the by-pass leakoff of the spray nozzle.
3. When the engine runs rough or "ragged."
4. Irregular fuel knocks.
5. Engine missing on one or more cylinders continuously.

Cleaning and Testing the Spray Nozzles. The most important part of spray nozzle cleaning, testing and examination is CLEANLINESS. Spread some clean paper on the workbench and have available a clean dish or open container of clean fuel or kerosene, approximately one pint is sufficient. Also, have a supply of soft (not fluffy), dry, clean, wiping cloths, a clean squirt can of lubricating oil or a jar of vaseline available.

Spray nozzles should be cleaned by first soaking them in kerosene or clean fuel oil to soften the dirt. The interior of the body can be cleaned with a small strip of wood dipped in the cleaning oil and the spray hole with a pointed piece of wood. The nozzle valve should be rubbed with a clean, oil soaked, soft rag (but not fluffy).

Hard or sharp tools, emery paper, Crocus cloth, grinding powder or any abrasive of any kind should never be used.

The fuel nozzle body must be positioned correctly on the holder assembly when it is reassembled.

Two types of indexing are used; one type has two marks (A,B), Illustration No. 35-A, which must be aligned when reassembled and the other has a locating dowel (C), Illustration No. 35-A, which correctly locates the nozzle on the holder.

Before assembling, wash and rinse all parts carefully and have them perfectly clean, coat with good clean lubricating oil or vaseline so that the valve revolves freely. Tighten the nozzle retaining nut up hard.

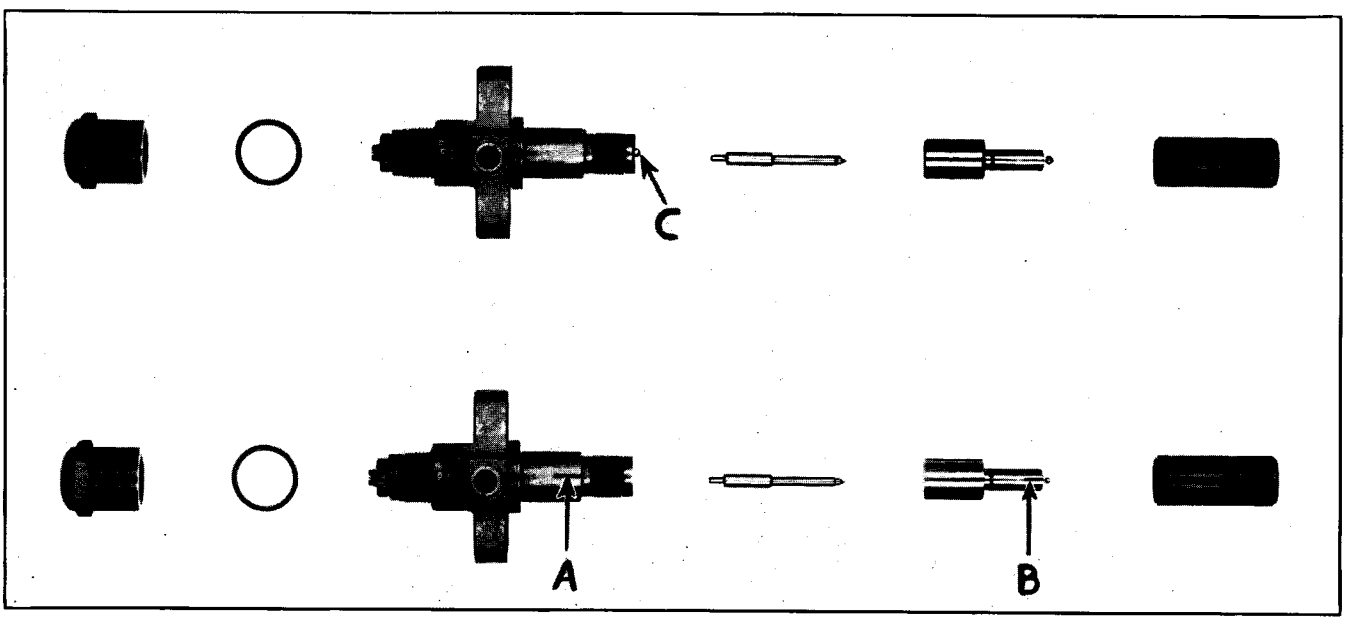


Illustration No. 35-A

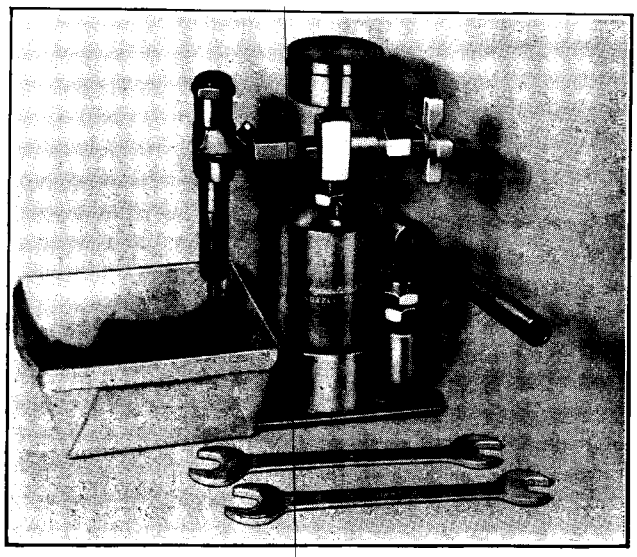


Illustration No. 36

If spray nozzle testing is necessary, it can be done on a hand operated testing unit, see Illustration No. 36, or it may be done by running the engine with the spray nozzle attached to the fuel delivery pipe, but not installed in the engine. Occasionally set the throttle in full load position momentarily, while observing the spray and possible leakage.

The spray should be smooth and even, that is, free from uneven branches or streams and the same thickness of oil spray all around the oil spray core as observed 2 to 5 inches from the nozzle. Unevenness or roughness of the stream indicates a dirty nozzle hole and pintle of the valve which must be polished with a pointed stick and soft cloth.

An "after dribble" or "drool" of oil out of the nozzle after the spray is completed indicates that the nozzle hole and pintle are not clean and should be polished as above. Be sure both the valve and barrel are perfectly clean, with no lint, dirt or foreign substance on the surface of either when assembling.

FUEL NOZZLE PRESSURE

Fuel nozzles should be set for 2250 pounds per square inch pressure on a static fuel nozzle testing fixture (this fixture may be purchased from the Hercules Motors Corporation, Canton, Ohio, U.S.A.). However, no adjustment is required if this pressure has only dropped to 2200 pounds.

Adjustment is effected by removing the cap nut and turning the screw clockwise to increase or anticlockwise to decrease the spring tension, thus raising or lowering the pressure.

New nozzle and holder assemblies are shipped from the factory set at 2300 pounds to compensate for the setting of the spring in the first few hours' running.

Never attempt to adjust the pressure without the proper testing fixture.

GEAR COVER

The gear cover consists of the cover and a gear housing. The gear housing also forms the front support for the engine and is doweled to the cylinder block. The cover plate covers the gear housing and gears. The front oil seal for the crankshaft is also installed in the cover plate. This cover plate can be removed for inspection of the gears, and so forth, without removing the gear housing, Illustration No. 37.

If necessary to remove the gear housing, remove the camshaft as outlined under **"Camshaft,"** remove the two housing attaching screws and pull the housing forward away from the cylinder block. It may be necessary to tap the adapter with a soft hammer to loosen it from the dowels or gasket cement.

TO REMOVE THE GEAR COVER

Assuming that the radiator has been removed, the gear cover may be removed as follows:

1. Remove the fan blade and belt for easier access to the gear cover and gears.
2. Remove the crank grab nut and fan drive pulley.
3. Remove the screws from the gear cover and pull the gear cover forward away from the engine.

INSPECTION

The gear cover and housing should be carefully inspected for possible cracks, binding, etc. Be sure that the camshaft gear retaining nut is tight. Replace any worn or damaged parts.

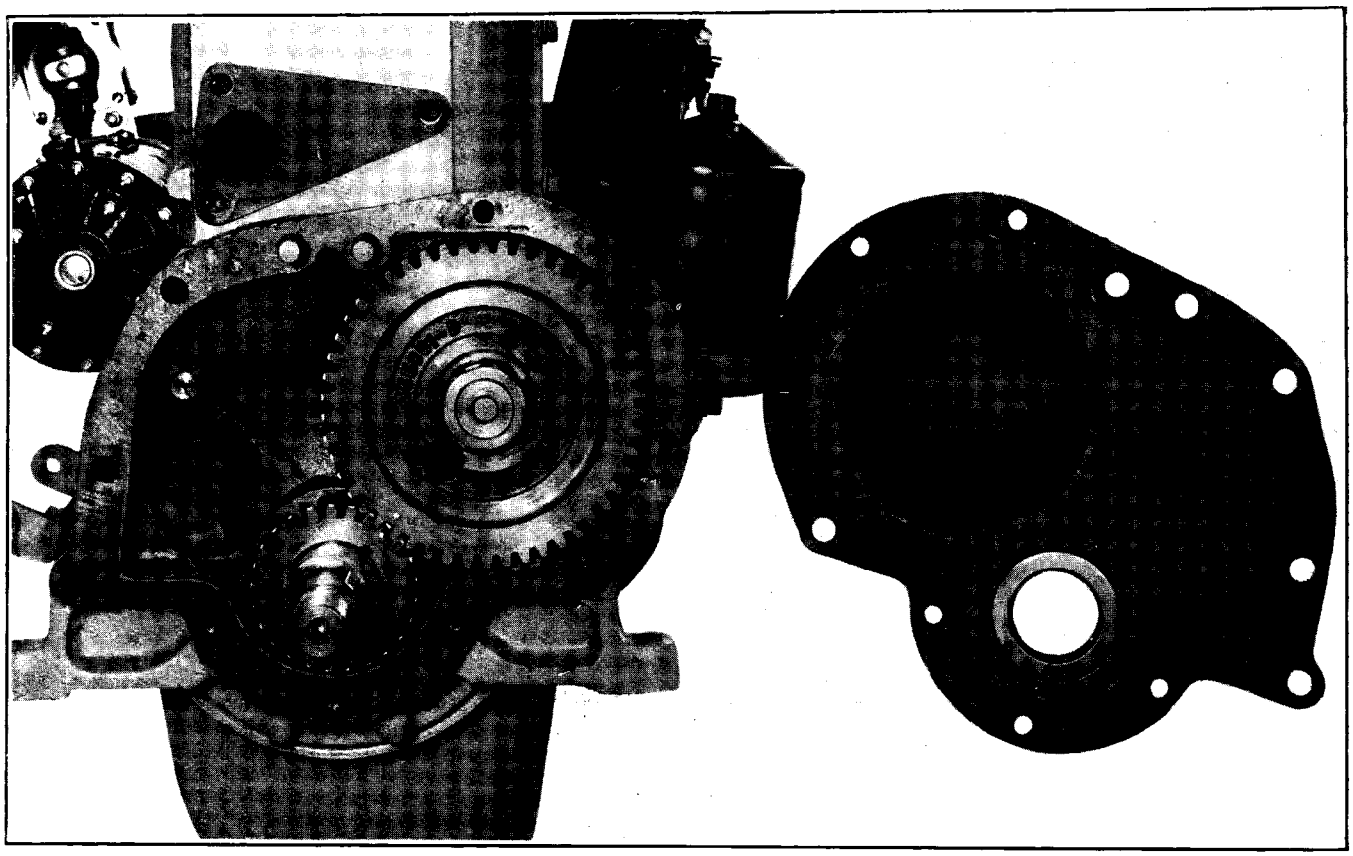


Illustration No. 37

GENERATOR

A periodic inspection should be made of the charging circuit. The intervals between these checks will vary, depending upon the type of service. Dirt, dust and high speed operation are factors which will contribute to increased wear of the bearings, brushes, etc. Under normal conditions, an inspection of the generator should be made every 100 hours.

1. **Wiring**—A visual inspection should be made of all wiring to insure that there are no broken wires and that all connections are clean and tight. Special attention should be paid to the ground connections at the battery and generator.
2. **Commutator**—If the commutator is dirty or discolored, it can be cleaned by holding a piece of 00 sandpaper against it while turning the armature slowly. Blow the sand out of the generator after cleaning the commutator. If the commutator is rough or worn, the generator should be removed from the engine, the armature removed and the commutator turned down.
3. **Brushes**—The brushes should slide freely in their holders. If the brushes are oil soaked or if they are worn to less than one-half their original length, they should be replaced.
4. **Lubrication**—Add 3 to 5 drops of medium engine oil to the oilers in the end heads every 100 hours of operation.

If the generator does not function properly after the above checks, the generator and the regulator or circuit breaker should be taken to an authorized service station for inspection and repairs.

GOVERNOR

The governor is integral with the fuel pump. It is equipped with minimum and maximum speed regulating adjusting screws. The maximum speed should never be increased above that specified in the equipment manual.

To do so may seriously damage the equipment or engine and may cause bodily injury.

An instruction book on the fuel pump and governor may be obtained by writing to the Hercules Motors Corporation, Canton, Ohio, giving the engine model and serial number.

MAIN BEARINGS

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 Illustration No. 1. This construction helps to eliminate vibration at high speeds. The center main bearing cap is held in position by four alloy steel cap screws 7/16" in diameter while the remaining ones are held in position by two alloy steel cap screws 1/2" in diameter.

The main bearings are removable, precision, shell type and the upper shell is interchangeable with the lower shell for each bearing. No shims are used. Reconditioning of this type bearing is accomplished by replacing the shells. These precision type shells are completely finished before being put in place and no line reaming or scraping is required. This allows renewal of bearings to be easily accomplished. The shells each have a small ear or projection which fits into a recess, which allows the ear to rest against the adjoining case or cap to prevent the shell from rocking or rotating. The bearing metals commonly used in precision, shell type bearings are harder and have a higher melting point than ordinary babbitt metal, and this requires the use of a hardened crankshaft.

FITTING OF THE BEARINGS

The bearings in these engines are readily accessible after the oil pan and oil pump are removed. The bearings should never be fitted so tight that they bind or drag, see **"Clearance Table."** A certain minimum clearance is required at all times to provide an adequate oil film between the shaft and bearing and insure a free running engine. The bearings in these engines are of ample proportion and the full pressure lubrication system employed will give long lasting bearings, provided they are properly installed.

Tightening of the main bearing cap screws requires some care to prevent too much strain on the parts. Special wrenches are on the market which enable the mechanic to measure the force of his pull when tightening such parts. The wrench tension values given under **"Wrench Tension"** show the correct amount of pull to use on various screws. No attempt should be made to refit these bearings by filing or grinding the caps, as this will ruin the caps so new shells cannot be installed.

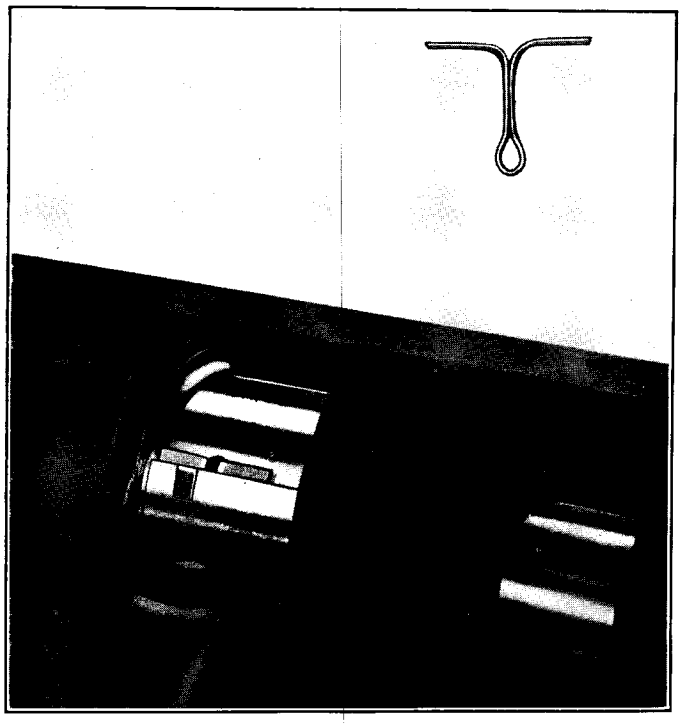


Illustration No. 38

REPLACEMENT OF THE MAIN BEARINGS

It is not necessary to remove the engine from the unit to replace the main bearings unless, of course, the crankshaft is damaged or worn to the extent that it must be replaced.

The following outline may be used as a guide for replacing the bearings when the engine has not been removed from the unit.

1. Disconnect the battery cable at the battery as a safety measure.
2. If the starter is mounted below the oil pan level and causes interference, disconnect the starter cable and wiring; then remove the starter.
3. Drain the crankcase oil.
4. Remove the oil pan. Remove the tachometer drive, if used.
5. Remove the oil pump.
6. Loosen all main bearing cap screws.
7. Remove one bearing cap at a time and make bearing replacement. To remove the upper shell, a small pin may be inserted in the crankshaft oil hole and the shaft rotated so that the pin will push the bearing out. The new bearing may be inserted in the same manner, see Illustration No. 38.

CAUTION:—Be sure to remove the pin before assembling the bearing cap.

8. Assemble the bearing cap and lower shell and tighten the screws. See **"Wrench Tension."** If no torque wrench, Illustration No. 39, is available, use a wrench with a 12" handle.
9. After installing new thrust bearings on the center main bearing, check the end thrust, Illustration No. 40. See **"Clearance Table."** It is permissible to draw file the thrust bearings to obtain the proper clearance, if necessary.
10. Thoroughly recheck the inside of the engine for loose screws, nuts, etc.
11. Install the oil pan.
12. Install the starter.
13. Connect the starter cables.
14. Connect the battery cable.

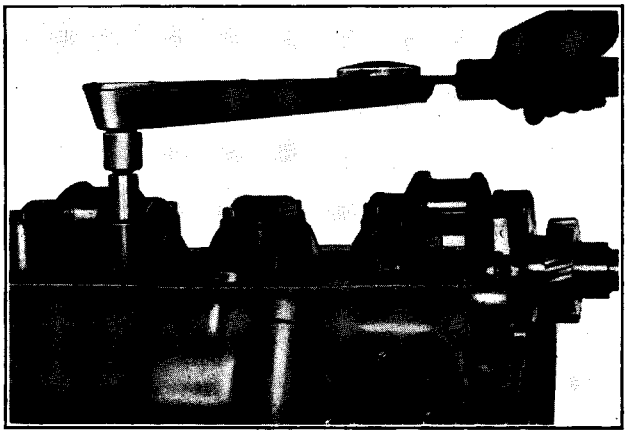


Illustration No. 39

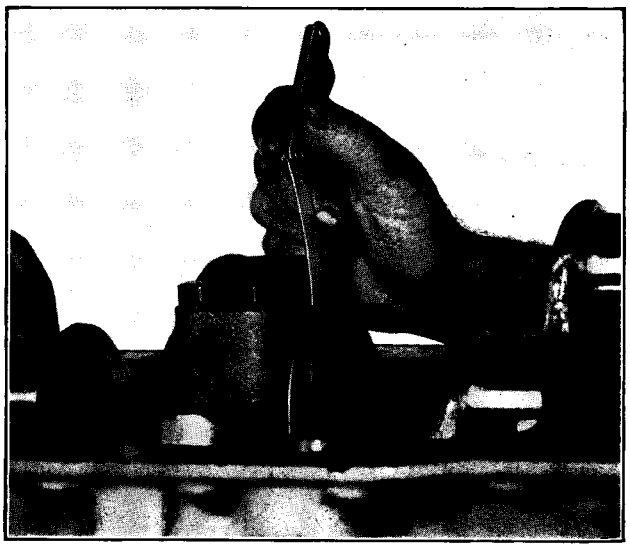


Illustration No. 40

15. Fill the crankcase to the FULL mark on the bayonet gauge, see Illustration No. 13, with the proper grade of oil.
16. Start the engine and immediately check the oil pressure. See **"Oil Pressure."** If sufficient, allow the engine to run for a few minutes while checking for oil leaks, etc.; then, stop the engine and recheck the oil level. Add oil, if necessary.

MANIFOLD (Intake and Exhaust)

There are various types of manifolds used on the DD series engines; therefore, it is not practical to discuss them at length in this book. Manifolds differ as to the air cleaner attaching flanges and shape. Different exhaust outlet flanges are used on different installations. From this list of differences, one can readily see the importance of replacing the manifold on the engine with the same type manifold unless the engine is to be applied to a different type of operation.

In installing the manifolds, it is essential to use new gaskets and to be sure that the manifold ports line up with those in the cylinder head. When tightening the manifold stud nuts, a washer should be used under the nut and the manifolds tightened progressively from the center to the end, repeating the operation at least three or four times to make sure that the manifold is tight.

In many instances, a companion flange and gasket are used for the installation of the exhaust pipe. Be sure these are drawn up tight and square with the manifold flange to avoid leaks.

TO REMOVE THE MANIFOLDS

1. Remove the air cleaner or air cleaner connections from the intake manifold.
2. Disconnect the exhaust pipe from the exhaust manifold.
3. Remove the manifold attaching nuts and washers and remove the manifold.

TO INSTALL THE MANIFOLDS

1. Make sure all gasket surfaces are clean, place the manifold gaskets on the attaching studs and assemble the manifolds to the engine with the nuts and washers as removed.
2. Tighten the manifold into place. Tighten all nuts lightly; then, starting from the center, work progressively toward the ends of the manifold, repeating until all nuts are tight.
3. Attach the exhaust pipe and tighten the screws.
4. Install the air cleaner or connect the air inlet tube to the intake manifold.
5. After the engine has been operated a day or more, tighten all manifold attaching nuts.

OIL FILTER

The engines are usually equipped with an oil filter having a throwaway type element, Illustration No. 41. This filter should receive regular and careful attention. A definite schedule for replacement of the element can be determined from observation of the lubricating oil on the application in which the engine is used. In some applications, the period between changing the filter element may be very short while in others the change period may be extended considerably. Cold engine operation and long idling periods contribute to short filter element life.

When a new filter element is installed, add sufficient oil to the crankcase so the oil level will be correct after the engine has run long enough to refill the filter.

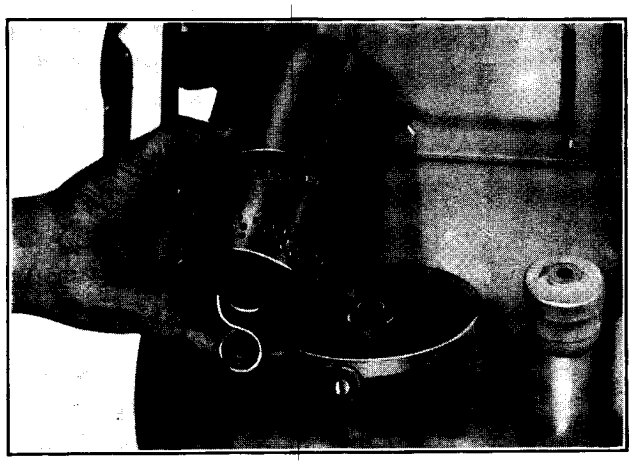


Illustration No. 41

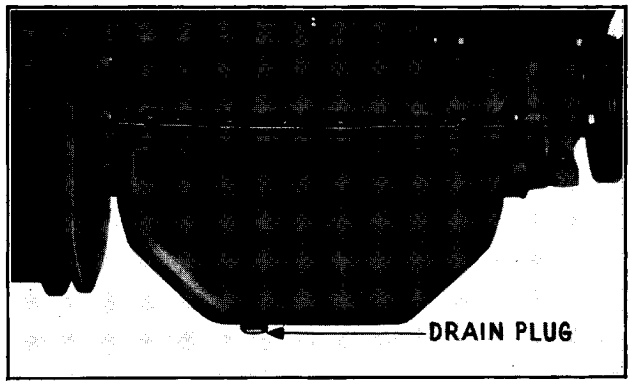


Illustration No. 42

OIL PAN

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

Suitable drain plugs are located in the bottom of the oil pan. See Illustration No. 42. The bayonet type oil gauge, used to measure the oil level in the pan, is covered under **"Bayonet Gauge."**

TO REMOVE THE OIL PAN

1. Drain the crankcase oil.
2. Disconnect the starter cable and remove the starter, if mounted below the center line. Tape any "hot" cable terminals.
3. Remove the bayonet gauge assembly.
4. Remove the cap screws from the oil pan and lift the oil pan away from the engine.

TO INSTALL THE OIL PAN

1. Clean the oil pan thoroughly; also, remove the old gaskets from the oil pan and cylinder block.
2. Inspect the inside of the engine for loose nuts, screws, cotter pins, lock wires, etc.; tighten or replace.
3. Remove the front and rear oil pan adapters and clean the gasket surfaces.

4. Cement the new oil pan side gaskets to the cylinder block.
5. Install the front and rear oil pan adapters.

NOTE:—If new bellhousing or gear housing gaskets have been used, it is necessary to cement the oil pan gaskets in place and install the adapters before tightening the bellhousing and timing gear housing attaching screws.

6. Cement the oil pan front and rear seals in the oil pan with Armstrong No. D-200 adhesive, if available, (Hercules part No. 255215-A) so that each end of the seal extends the same distance above the oil pan attaching flange. **(NOTE:** This adhesive sets quickly and the seals should be inserted at once.) **Do not** cut off the ends of the seals.
7. Apply some lubricating oil to the oil pan adapter gasket surfaces, put the oil pan in place and carefully start all screws. Be sure the lock washers are on the screws.
8. Draw up all screws evenly and progressively. This will allow the oil pan to center on the adapter blocks.
9. Install the drain plug.
10. Install the starter motor and connect the cables.
11. Refill with oil to the correct level.
12. Reinstall the bayonet gauge assembly.

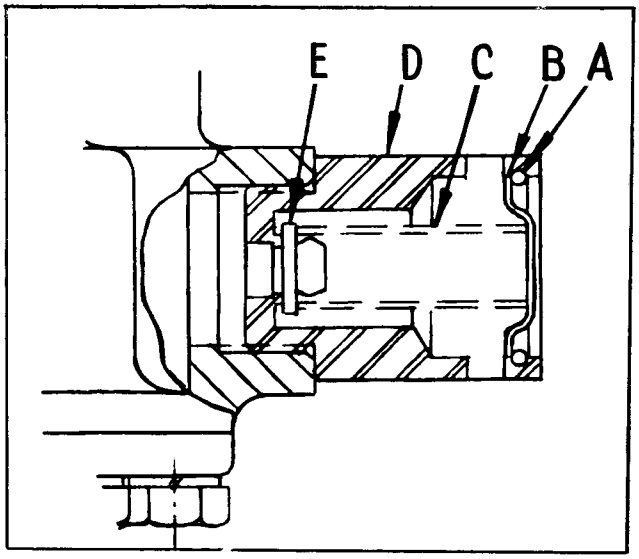


Illustration No. 43

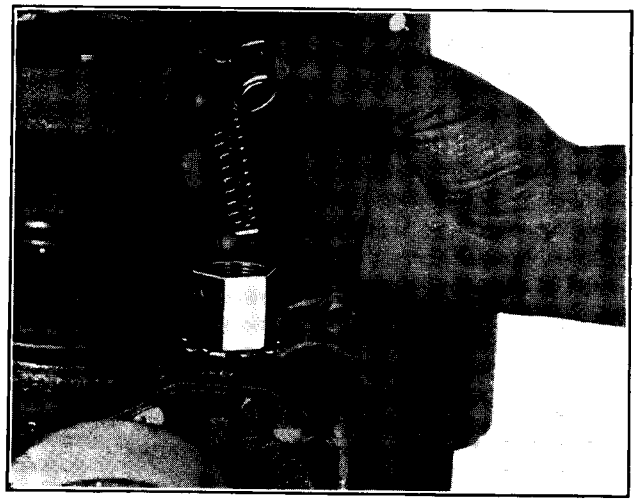


Illustration No. 44

OIL PRESSURE ADJUSTMENT

The oil pressure is automatically controlled or regulated by a compression type spring which controls a relief or bypass valve. This device is assembled to the oil pump. It controls the oil pressure through a predetermined spring pressure and, therefore, no adjustment of the oil pressure is required. However, if the pressure regulator becomes sluggish in operation, due to dirt or sludge in the oil, it should be cleaned. This may be accomplished by removing the snap ring (A), Illustration No. 43, and then removing the spring retainer (B), spring (C) and valve (E) from the pressure regulator body (D), as shown in Illustration No. 44. These parts should be thoroughly washed and cleaned and reinstalled in the reverse order as removed.

The oil pressure regulator is calibrated to maintain a pressure of 30 to 45 pounds in the system. This will vary somewhat with the temperature of the oil and the SAE weight of the oil; also, with the engine speeds.

OIL PUMP

The oil pump is attached to the cylinder block with suitable screws and is driven by a gear solid with the camshaft and located near the center of the camshaft. The lower end of the oil pump extends down into the oil pan, and the oil is drawn into the pump through a large screen, which prevents coarse dirt from being drawn into the lubricating pump. The oil pump extends into the oil; therefore, the pump needs no priming. After the oil pan is removed, the oil pump is readily removed for inspection or repairs. The various parts of the oil pump are shown in Illustration No. 45.

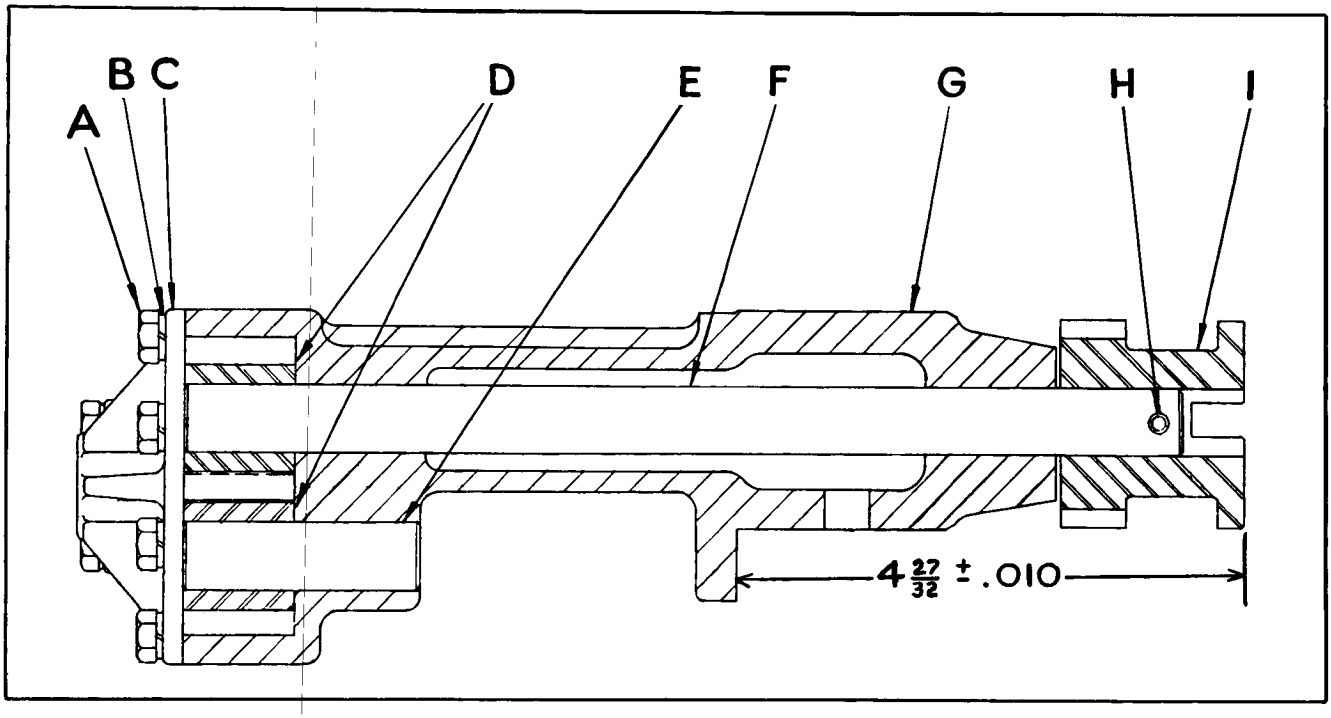


Illustration No. 45

TO REMOVE THE OIL PUMP

1. Remove the oil pan. See **"Oil Pan."**
2. Turn the engine so that the No. 1 piston is in the firing position. This may be noted from the position of the valves or from the position of the cams on the camshaft.

NOTE:—If the engine is equipped with a tachometer drive, this must be removed before attempting to remove the oil pump.

3. Remove the screws from the oil pump attaching 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.

TO DISASSEMBLE THE OIL PUMP

(Letters refer to Illustration No. 45, unless otherwise noted.)

1. Remove the drive gear pin (H) and pull the gear (I) from the shaft.

NOTE:—Puller must be under the gear and not under the fuel pump drive coupling flange.

2. Remove the screws (A) and washers (B) from the pump gear cover (C) and remove the cover.
3. Remove the gears (D) and shafts (E and F). The gears (D) may be pressed from their respective shafts, if necessary.

TO REASSEMBLE THE OIL PUMP

1. Press the gears (D) on to their respective shafts (E and F).
2. Assemble the shaft (F) in the pump body; and, lining up the hole in the gear (I) with the shaft (F), press the gear on to the shaft. This gear should be pressed on to the shaft to the dimensions shown in Illustration No. 45.
3. Insert the drive gear pin.
4. Insert the idler gear with the shaft (E) and gear (D).

5. Install the cover (C) with the screws (A) and lock washers (B) as removed.
6. Turn the pump shaft to insure freeness of rotation. If the shaft binds or is otherwise tight, disassemble and ascertain the reason. Correct and reassemble the pump.

TO INSTALL THE OIL PUMP

1. If the engine has been moved or rotated since removal of the oil pump, it is necessary to spot the engine with No. 1 cylinder in firing position. This may be noted from the position of the valves. See **"Fuel Pump."**
2. Turn the oil pump drive gear so that the flat on the flange, Illustration No. 46, is to the outside of the pump (the side opposite the pressure regulator).
3. With the flat towards the camshaft, insert the oil pump into the cylinder block and rotate the oil pump to the correct position for attaching screws.

NOTE:—When the engine is equipped with a counterbalanced crankshaft, proceed as outlined above except that, after the oil pump driven gear teeth have just been engaged in the camshaft gear, it is necessary to rotate the crankshaft and, at the same time, complete the insertion of the oil pump with a spiral motion.

NOTE:—The oil pump should not be rotated until after the drive gear is meshed with the gear of the camshaft.

4. Install the oil pump attaching screws.

   If the fuel pump was not removed, care must be exercised that when the oil pump is installed the tongue of the fuel pump drive coupling properly engages in the groove in the oil pump drive gear, with the fuel pump in firing position for No. 1 cylinder. If the fuel pump was removed, a visual inspection of the oil pump drive gear groove will show that it is parallel with the engine when the gear is properly timed, with the crankshaft spotted in No. 1 cylinder firing position.

5. Install the oil pan. See **"Oil Pan."**
6. Fill the crankcase to the proper level with the correct grade of lubricating oil.
7. Install the tachometer drive, if used.

SAVE YOUR BATTERIES

Do not turn engine with starter unnecessarily.

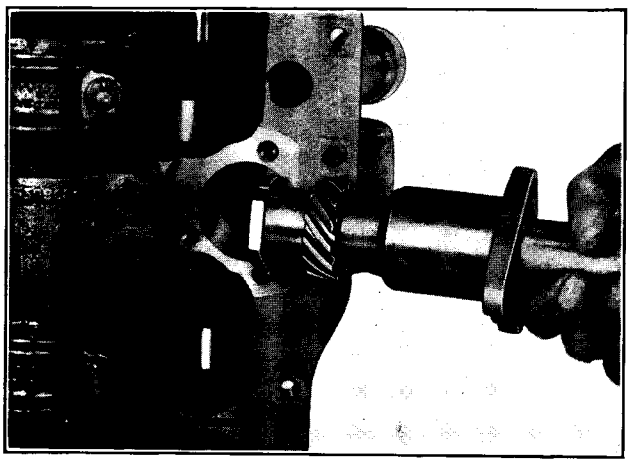


Illustration No. 46

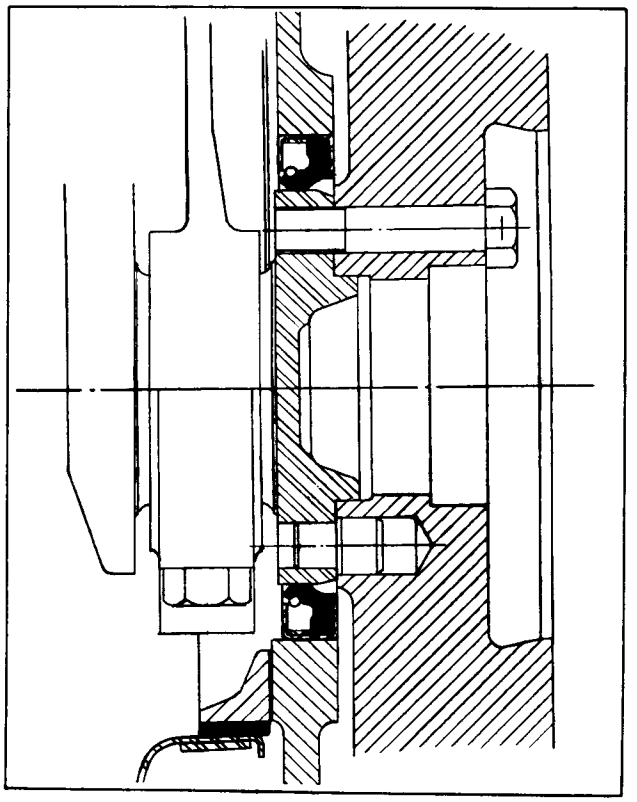


Illustration No. 47

OIL SEAL

The construction of these engines prevents oil leakage when the gaskets are in proper condition and all bolts and screws are properly tightened. Whenever a shaft extends through the engine case and there is a possibility of oil leakage, an oil seal is used which also acts as a dust seal, preventing dust from entering the engine.

At the flywheel end of the crankshaft a patented type oil seal is used, Illustration No. 47. As can be seen in this illustration, the oil seal is mounted in the bellhousing so that it seals against the flange of the crankshaft.

The crankshaft is prevented from leaking, at the timing gear end, by the use of the same type of seal. This seal is pressed into the gear cover; also, in the gear cover is the seal which prevents oil leaking at the governor control shaft.

This type of seal requires very little attention; however, at assembly the shaft seal surfaces on which the seal rides must be thoroughly and carefully checked for nicks or scratches which may have a tendency to damage the seal. If any nicks or scratches are found, they should be removed with an oil stone or very fine emery cloth and polished with Crocus cloth. If the shafts have a keyway which might damage the seal during installation, this keyway should be covered with a thin feeler gauge to protect the seal.

No special tools are required to install the seals on the shafts, since the shafts are tapered to allow the seals to easily slip into place. However, a certain amount of care is required in order not to damage the seals. A coating of oil soap on the seal surfaces of the shafts and, also, on the seals themselves will be found beneficial during the run-in period.

R E M E M B E R

Good Oil changed frequently . . . Oil Filter Elements replaced often . . .

Breather and Air Cleaner kept clean and functioning properly . . . and

Engine in good adjustment . . . . . .

Mean Longer Life to the Engine and Trouble-Free Operation.

PISTON

The piston is made of an aluminum alloy and is of the solid type, having no saw slots or split in the skirt. Five piston rings are used—the upper three rings being of the compression type while the fourth ring from the top, which is above the piston pin, and, likewise, the ring located near the bottom of the skirt are of the oil regulating type. The top of the piston is made thick in order to uniformly transfer the heat from the top of the piston to the various rings and to the skirt of the piston, where it can be dissipated into the water jacket without any of the piston rings becoming extremely hot, which condition tends to rapidly destroy lubrication of such parts.

The pistons should be fitted to the cylinder bores with the proper clearance. See **"Clearance Table."** If a feeler ribbon is used, this should be a ribbon ½" wide and of the thickness indicated in the Clearance Table. A scale should be used to obtain the pull indicated in the Clearance Table.

To remove or install pistons, see **"Connecting Rod."**

Illustration No. 48

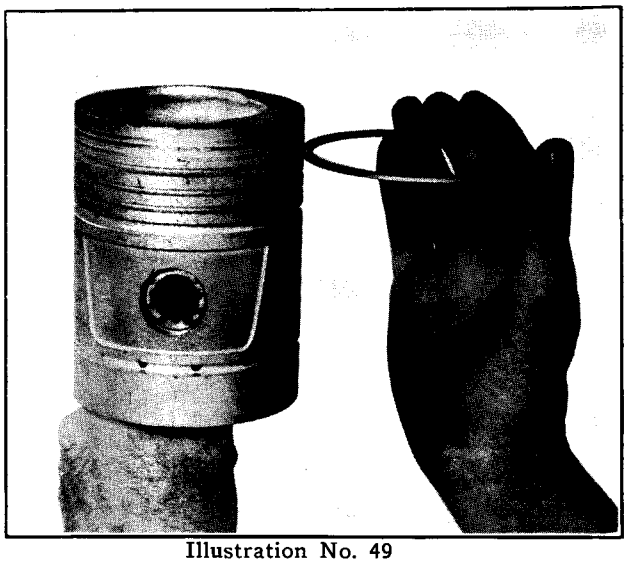


Illustration No. 49

PISTON PIN

The piston pin is a large diameter pin of the full floating type. This means that the pin can rotate in either the piston bosses or in the bushing at the top end of the connecting rod. But, the fit in the piston is intended to be much tighter than the fit in the connecting rod; consequently, the movement in the piston consists of a light, creeping action while the normal rotation of the pin occurs in the bushing at the top end of the connecting rod. The piston pin is prevented from moving endwise and making contact with the cylinder wall by means of snap rings, which locate in grooves machined in the bosses of the piston. Piston pins should be fit in the piston bosses with the proper clearance, as indicated in the Clearance Table.

PISTON RINGS

The piston rings, when fitted in the cylinder bore of the engine, should have a gap clearance between 015″ and .020″. The piston ring land clearance is indicated in the Clearance Table.

When installing new piston rings, each ring should be tried in the cylinder bore to see if it has the correct gap of .015″ to .020″. If necessary to increase the gap, the ring should be held and filed as shown in Illustration No. 48. If the ring is held in a vise, the vise jaws must be covered with some soft metal. The ends of the rings are squeezed together and the file cuts on both sides. This will insure the ends being parallel. When inserting the ring in the cylinder bore to test the gap clearance, push the ring part way through the bore, using the bottom of a piston to square the ring in the bore.

Each new ring should be tried for clearance in the piston groove by rolling the ring all the way around the groove, as shown in Illustration No. 49. If the piston grooves have been carefully cleaned, the rings will be found to fit correctly; but, if they are tight, they can be lapped slightly on a sheet of emery cloth (No. 000) laid on a flat surface. Use a light uniform pressure when lapping.

When assembling the piston rings to the piston, if a ring spreader tool, Illustration No. 50, is not available, the rings can be slipped over thin strips of metal. Whatever method is used, the rings must be handled carefully in order not to distort or break them.

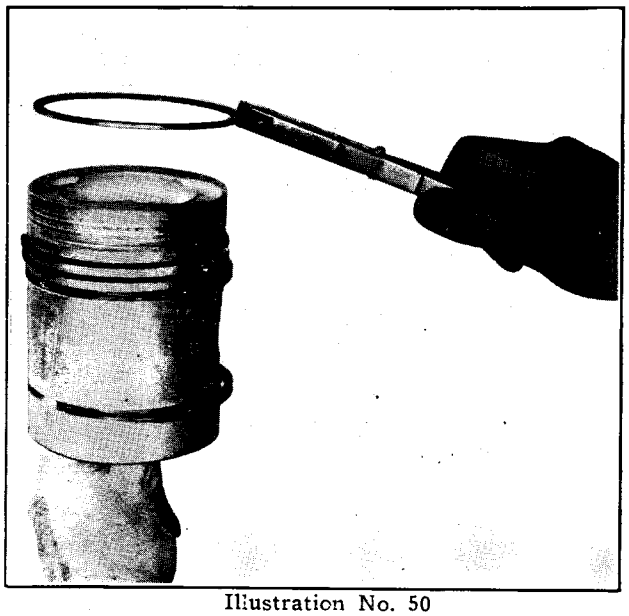


Illustration No. 50

STARTING MOTOR

The starting motor is designed to crank the engine when the switch closes the circuit between the storage battery and the motor. It consists of five main sub-assemblies: the frame and field, the armature, the commutator end head, the pinion housing and the Bendix drive. The frame and field consist of the frame which supports the components of the starting motor, the pole pieces and the field coils. The coils supply the path for the magnetic field. Illustration No. 51 is an assembly drawing of a typical starting motor.

The armature consists of a soft iron core, a commutator and the windings which are wound in slots in the core and are connected to the commutator. The commutator consists of a number of copper segments insulated from each other and from the armature shaft.

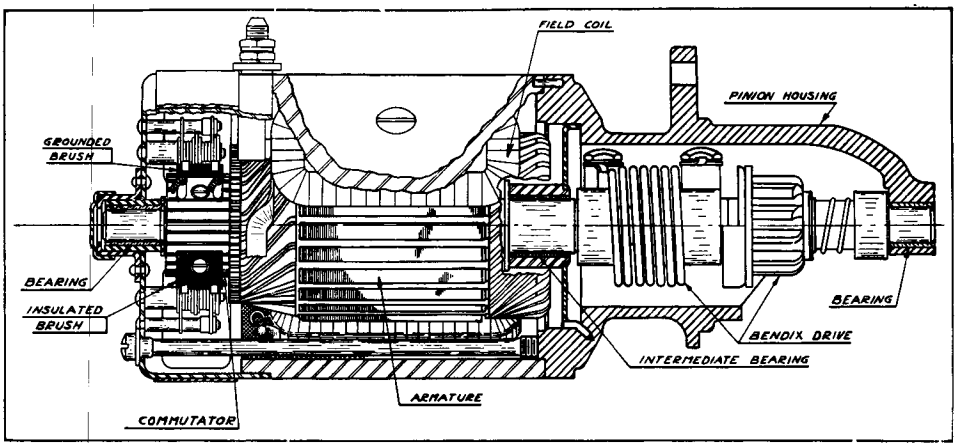


Illustration No. 51

The commutator end head supports a bearing, brush holders and brushes. The pinion housing is a cast iron housing for the Bendix drive and also provides the motor mounting lugs. The Bendix drive is an automatic clutch that engages the starting motor with the engine flywheel when the motor cranks the engine and disengages when the engine starts. It consists of a threaded sleeve fastened to the armature shaft thru a drive spring and a pinion mounted on the threads of the sleeve. When the starting circuit is closed the armature revolves, turning the sleeve within the pinion and forcing the gear forward, meshing it with the flywheel gear. The sudden shock of meshing is absorbed by the spring. When the engine starts the pinion is driven faster than the sleeve and is forced back along the threads, automatically de-meshing it from the flywheel.

LUBRICATION

Some starters are provided with an oil cup which should be filled with lubricating oil when the unit is lubricated.

Other starters have no provision for oiling; these are lubricated at the time of overhaul.

After the starting motor has been in service for an extended period it should be removed, dismantled and cleaned. Clean the Bendix drive thoroughly and lubricate sparingly with light oil. Inspect the wiring for loose or corroded connections and for broken leads. Make sure the insulation on the wiring has not become frayed.

MINOR ADJUSTMENTS

help to maintain the engine in good condition which alleviates major repairs and prolongs its usefulness.

THERMOSTAT AND BYPASS

The engines are equipped with a thermostat, Illustration No. 52, so designed that it will not allow water from the radiator to circulate through the engine until the water in the engine is at operating temperature but does bypass a certain amount of water from the cylinder block, which is carried through the bypass tube to the inlet side of the water pump, where it is again circulated through the engine. This is repeated until the water in the engine is heated to operating temperature, when the thermostat begins to open and permits the water from the engine to enter the radiator. This water is, at the same time, replaced in the engine by the water pump drawing from the bottom of the radiator. Thus, the water temperature is constantly maintained in the proper heat range.

A defective thermostat of this type must be replaced as it cannot be repaired. The thermostat should be completely open at temperature marked on thethermostat in the still water test.

The still water test is as follows:

Place approximately 4" of water in a pan or pail. Insert a thermometer of this heat range in the water and set the thermostat in the water with the bellows submerged. Heat the water slowly and carefully observe when the thermostat valve is fully open and note the water temperature. Then compare this temperature with that stamped on the thermostat.

Five degrees above or under this temperature are permissible.

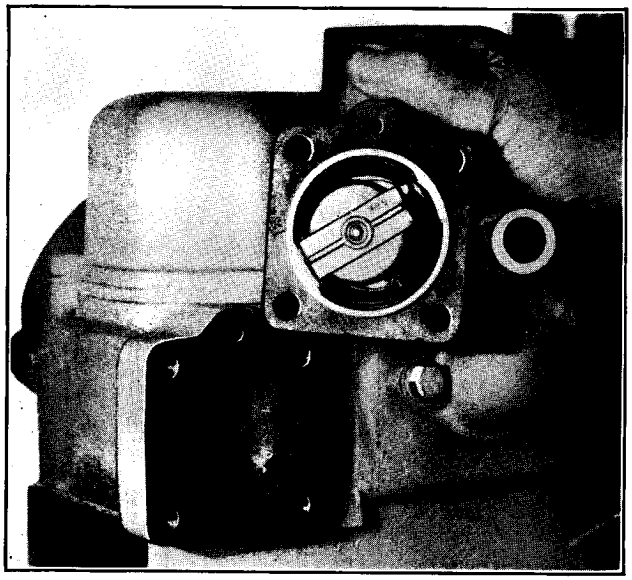


Illustration No. 52

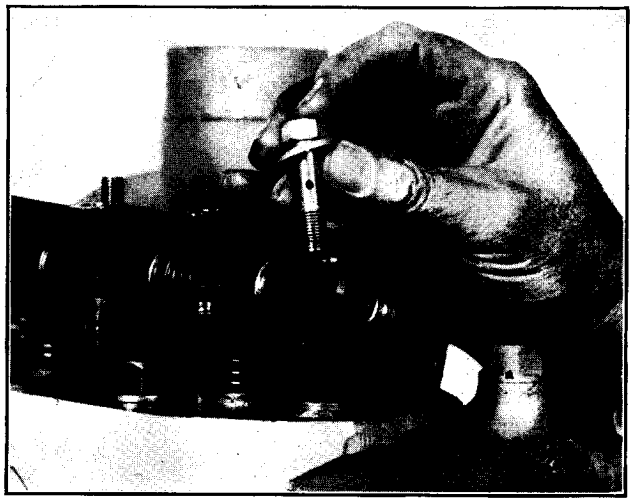


Illustration No. 53

VALVES

The intake and exhaust valves are made of special steel and operate in valve guides pressed into the cylinder head. They are held on to their seats by strong steel springs, which are fastened to the valves by suitable spring seats and valve lock arrangement. The valves, being located in the cylinder head, are operated by conventional type tappets with hollow push rods running from the tappets to the rocker arms. The rocker arms are lubricated by means of oil forced through a hollow cylinder head screw, Illustration No. 53, into the shaft on which they rotate. Oil is forced out, through small holes in the rocker arms, over the valve stems and push rods. The replacement of valves and valve guides will be found under the subject of **"Valve Grinding."** The replacement of valve tappets will be found under the subject of **"Valve Tappets."**

Some engines are equipped with a valve rotocap, which controls the motion of the valve during the lift cycle, but the valve is not located in any way which would prevent turning. The natural vibrations of the valve train and the flow of gases around the valve head cause the valve to rotate slowly, a small fraction of a revolution each lift cycle.

The rotocap requires no special attention other than to see that it is thoroughly cleaned when removed for valve overhaul jobs.

In order to continue to get good performance from an engine, it may be necessary to grind or reseat the valves at varying intervals. The frequency for doing this depends on the care in the operation of the engine. If the air cleaners have been properly cared for; if all connections between the air cleaner and carburetor have been kept air tight; if the lubricating oil has been properly maintained; and if the clearance between the valve stem and rocker arm has been properly adjusted, valve grinding will be necessary very infrequently. Their seating should be tested periodically by rocking the engine against compression. When the engine will not rock, compression is leaking through either the valves, cylinder head gasket or past the piston rings. Check the leak by listening for a "hissing" sound, when the engine is cranked by hand, either at the cylinder head gasket or in the crankcase breather. If at the cylinder head gasket, remove the head and replace the gasket. If in the breather, dismantle the engine and install new parts for those found worn or scored. If no "hissing" is heard at either of these two places, remove the cylinder head and valves. Clean both thoroughly, removing all carbon and oil. Inspect the valve seats and valves. See **"Valve Grinding."**

TO REMOVE THE VALVES

1. Remove the cylinder head. See **"Cylinder Head."**
2. With a clamp type valve spring compressor, compress the valve springs and remove the valve seat locks.
3. Remove the valve springs and seats and lift out the valves. Place the valves in a cardboard or wood block, drilled and numbered so that the valves may be reinstalled in their respective places when grinding or reassembling (do not mark the valves with a file or punch).
4. Clean all carbon from the cylinder head, piston heads, valve seats, valve guides and valves with suitable scraping or buffing tools.

VALVE GRINDING

Inspect the valve guides for excessive wear. If the valve guides are to be renewed, this should be done before any work is done on the valve seats. This will insure the seat being finished square with respect to the new guide. The exhaust valve guides will usually show the most wear. To drive out the guides, use a drift $\frac{5}{8}$" in diameter with a $\frac{3}{8}$" diameter pilot. Drive in the new guides to the same depth location as the old guides. After the new guides are driven in, they must be reamed to size on the inside diameter to correct any squeezing in or possible distortion due to being driven into place. This is important in order to get a proper fit and the proper clearance. See **"Clearance Table."**

Inspect the valve seats; and, if they are pitted or if new guides have been installed, the seats should be refinished. Valve seat tools with $\frac{3}{8}$" diameter pilots are required. The exhaust valve seats are finished on a 45° angle and should have an even width all the way around. The intake valve seats are usually finished on a 45° angle, although some engines may have 30° seats. Reseat the seats with a vibrating angle grinder type reseating tool. Because of the large diameter and surface of the valve seats, it is very difficult to obtain a good reseating job with a reamer type tool. Remove all shoulders and pits from the seat but do not grind any deeper than necessary. Then finish the new or refaced valve to the reseated seat by hand in the usual manner.

Inspect the valves carefully; and, if the stems are badly worn or are not straight or if the valves are deeply pitted, the valves should be replaced by new ones. However, valves that are only slightly pitted can be used by refacing them on a valve grinder. Valves must have an accurately finished face of the correct angle. See **"Clearance Table"** for the seat face width.

If the valves and seats are not deeply pitted or shouldered or have been refaced, grind or lap each valve to its seat. Obtain a light coil spring with enough tension to just hold the valve off the seat. Lubricate the valve stem and apply a thin coating of good quality, medium coarse grinding compound on the valve face. Insert the valve in the valve guide and rotate the valve back and forth, about a quarter of a turn, a few times, pressing firmly on the grinding tool. (Avoid continuous round and round motion that would cut grooves in the valves or seat.) Release the pressure on the tool and the spring should lift the valve from its seat. Rotate the valve 15° or 20° and repeat the grinding process. It will probably be necessary to wipe off and inspect the valve and seat during this process to see what progress is being made; also, the compound may wear off the surface being ground. In either case, reapply another thin coating of compound and continue grinding until inspection shows the surfaces are in contact. Then wipe off all heavy compound and apply a thin coating of "fine" compound and continue the grinding. When the surfaces are "finished"

and show a bright, silver-like band of uniform width on both the valve and seat, clean off all traces of the compound. Test each valve for a tight fit by making ten or twelve pencil marks, equally spaced, across the valve seat and firmly rotate the valve in the seat for a part of a turn and again lift out the valve and 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.

TO ASSEMBLE THE VALVES

1. Thoroughly clean all traces of the grinding compound off the valves, stems and guides; put a few drops of oil on the valve stems and insert the valves.
2. Using a valve spring compressor, compress the valve springs and insert the valve locks.
3. Turn the head on the exhaust manifold side and pour gasoline in the intake openings. If gasoline seeps out around any valve, remove that valve and regrind. Repeat the test, pouring gasoline in the exhaust openings. If any exhaust valves leak, regrind.
4. Install the cylinder head and valves on the engine. See **"Cylinder Head."**

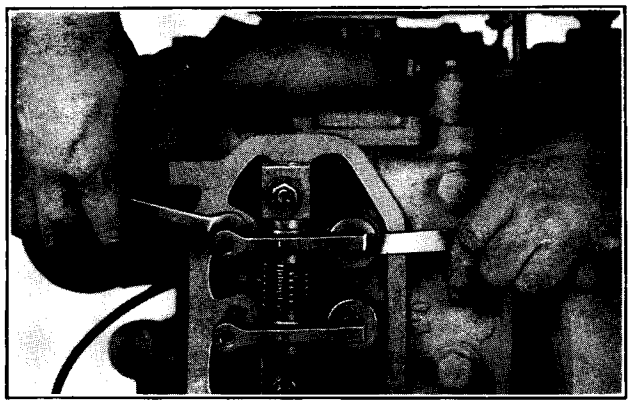


Illustration No. 54

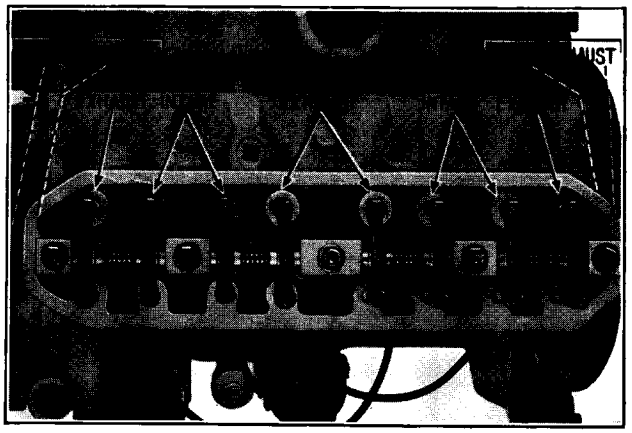


Illustration No. 55

5. Adjust the valve tappets, Illustration No.54, to the approximate setting. See **"Clearance Table."** This may be readily and systematically accomplished in the following manner. Perusal of the following paragraphs and Illustration No. 55 will point out that the spotting of the crankshaft and rocker arms follows the firing order (1-2-4-3 for the four cylinder engine and 1-5-3-6-2-4 for the six cylinder engine) of the engine (starting from the timing gear end). The valve tappet screws are self-locking and, therefore, no lock nut is used.

NOTE:—Illustration No. 55 is not of a DD series engine, however, the valve location is the same.

a. Crank the engine over until the intake valve of No. 1 cylinder just starts to open. Then adjust the tappets on No. 4 cylinder (No. 6 cylinder in a six cylinder engine).

b. Crank the engine over until the exhaust valve of No. 2 cylinder just closes and the intake valve of No. 2 cylinder just starts to open. Adjust the tappets on No. 3 cylinder.

c. Crank the engine over until the valves of No. 4 cylinder are in the position noted above and adjust the tappets on No. 1 cylinder.

d. Crank the engine over until the valves on No. 3 cylinder are in the position noted above and adjust the tappets on No. 2 cylinder.

The same outline is applicable to the six cylinder engine except that the six cylinder firing order must be followed; i.e., from a. above, crank the engine over until the exhaust valve of No. 5 cylinder just closes and the intake valve of No. 5 cylinder just starts to open. Adjust the tappets on No. 2 cylinder. Complete the adjustment, following the six cylinder engine firing order, as follows: Spot the valves for No. 3 cylinder and adjust No. 4. Spot the valves for No. 6 cylinder and adjust No. 1. Spot the valves for No. 2 cylinder and adjust No. 5. Spot the valves for No. 4 cylinder and adjust No. 3.

The above completes the valve tappet adjustment until after the engine is started and warmed up to operating temperatures, at which time the valve tappets should be readjusted to the correct hot operating clearance.

6. Install the cylinder head cover and any other parts that may have been removed.
7. Fill the cooling system with water or a cooling solution. Start the engine and warm up to operating temperatures.
8. With the engine idling slowly, readjust the tappets to the correct operating clearance.

VALVE TAPPETS

The valve tappet is of the mushroom type and is hollow to receive the push rods.

TO REMOVE THE VALVE TAPPETS

1. Remove the camshaft. See **"Camshaft."**
2. Remove the tappets from the cylinder block.
3. Check the tappets for wear and replace any that have excessive clearance.

TO INSTALL THE VALVE TAPPETS

1. Check each tappet in the cylinder block position to see that it has the correct clearance, see **"Clearance Table,"** and install the tappets.
2. Reassemble the camshaft. See **"Camshaft."**
3. Adjust the valves. See **"Valve Grinding."**

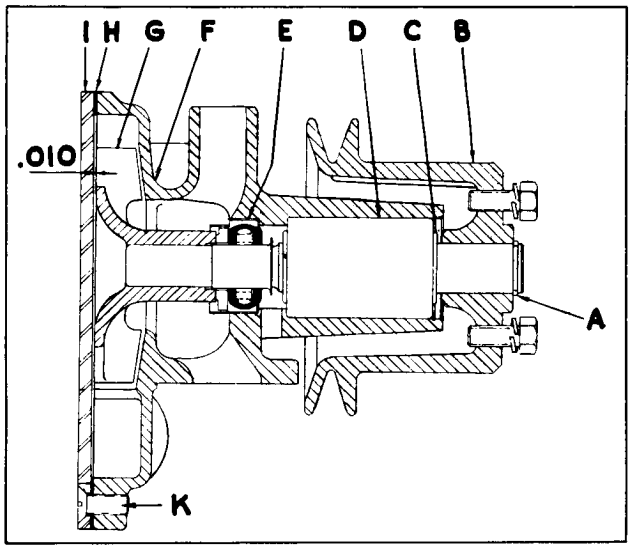


Illustration No. 56

REMEMBER

GOOD OIL CHANGED FREQUENTLY . . . OIL FILTER ELEMENTS REPLACED OFTEN . . . BREATHER AND AIR CLEANER KEPT CLEAN AND FUNCTIONING PROPERLY . . . AND ENGINE IN GOOD ADJUSTMENT . . . MEAN LONGER LIFE TO THE ENGINE AND TROUBLE-FREE OPERATION

LUBRICATION is your biggest asset to offset your greatest liability . . . Unnecessary Repairs

WATER PUMP AND FAN ASSEMBLY

Illustration No. 56 shows a sectional view of the water pump and fan (blade is not shown) as used on these engines. This pump may be readily removed from the engine after the removal of the water inlet hose, bypass hose and fan blade. Then, remove the water pump to cylinder block attaching screws and lift the pump away from the engine, Illustration No. 57.

TO DISASSEMBLE THE PUMP

(Letters refer to Illustration No. 56)

1. Remove the snap ring (A) and pull the fan pulley hub (B) from the pump shaft and remove the snap ring (C).
2. Remove the screws (K) from the water pump to cover plate and remove the plate (I) and gasket (H).
3. Place the front of the pump on a suitable support in an arbor press and press the shaft and bearing assembly out of the pump body (F) and impeller (G).
4. Press the seal (E) out of the pump body.

   The shaft and bearing assembly (D) is one unit and no attempt should be made to disassemble these parts.

   Wash and clean all parts thoroughly; inspect for wear and damage. It is advisable to reface the seal surface of the impeller if it is grooved or otherwise marked. Put a coating of grease on the seal surface before starting reassembly of the pump.

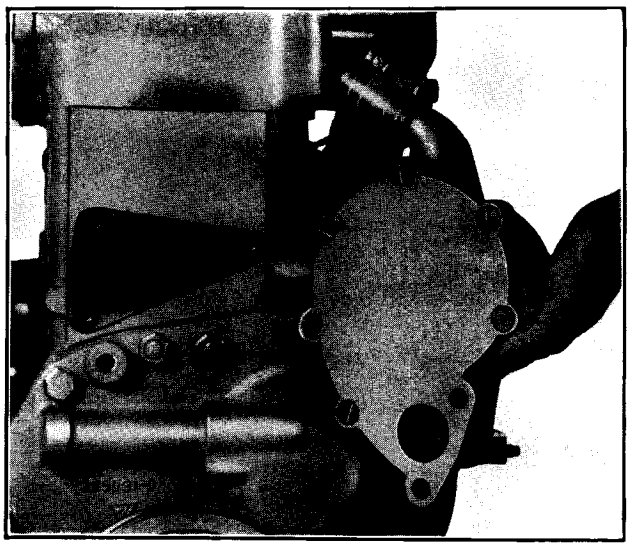


Illustration No. 57

TO ASSEMBLE THE PUMP

1. Press the new seal (E) into the pump body (F).

CAUTION:—Press on the outer flange of the seal to avoid damaging the seal.

2. Press the shaft and bearing assembly (D) into the body (F).

CAUTION:—Press only on the outer bearing face of the bearing and not on the end of the shaft.

3. Install the snap ring (C). Supporting the pump shaft on the outer shaft end, press the impeller (C) on to the shaft.

NOTE:—The impeller should be pressed on to a position which permits .010" clearance between a straight edge and the impeller when the straight edge is placed across the rear face of the pump body.

4. Support the pump on the impeller end of the shaft and press the fan drive pulley (B) on to the shaft and install the snap ring (A).

5. Install the new cover gasket (H) and pump cover (I), with the screws (K) as removed.

6. Test the rotation of the fan to see that it does not bind or have any excessive resistance.

When installing a water pump always use a new gasket and tighten the attaching screws evenly and alternately to prevent possible damage.

WIRING DIAGRAM

Due to many types of electrical equipment and the variety of requirements encountered in different installations, it is impossible to illustrate a typical wiring diagram.

However, the installation of wiring circuits may be more readily understood if the complete system is divided as follows:

1. THE STARTER SYSTEM:

This circuit consists of the battery (electrical energy storage unit), the starting motor and the necessary wiring to connect the battery to the starter switch and from the starter switch to the starter.

In most cases, the ground or return flow of current is carried through the framework of the unit to a point near the battery from where a short cable is connected to the battery to complete the circuit.

When a magnetic type starter switch is used, it is necessary to connect it to a control switch, which may be either a key switch or a simple push button switch. The key switch has one side connected to the battery side of the ammeter and the other side to the magnetic switch with suitable wires. The magnetic switch may have an external ground post which must be grounded to the unit framework. The push button switch has one side connected to the battery side of the ammeter and the opposite cide connected to the magnetic starter switch as outlined above.

2. BATTERY CHARGING SYSTEM:

The battery charging system consists of a generator which creates the electrical current, a regulator to control the current and an ammeter to indicate the amount of current being created or used.

The generator may be either a three-brush or a two-brush type, depending on the electrical requirements.

The three-brush generator utilizes movement of the third brush to control the amount of current being created; this type of generator may have either a simple cutout relay (which prevents reverse flow of current and a discharged battery when the generator is not charging) or a two-stage regulator which, in addition to the cutout relay, has an additional unit which controls the voltage of the current being created.

With the two-brush generator, a three-stage regulator is used. This type of regulator has the cutout relay, voltage control unit and an ampere control unit.

The single or two-stage control units are usually mounted on the generator and connected to wires incorporated in the generator.

To connect this system to the starting system and battery, one wire is connected from the battery terminal of the control unit to one side of the ammeter and from the other side of the starter switch.

With the two-brush generator and three-stage control unit, it is necessary to supply two or more additional wires. One wire is connected from the field terminal post of the generator to the field terminal of the control unit (regulator) and one wire from the armature terminal post of the generator to the armature terminal of the control unit.

When two-brush generators, which are not internally grounded, are used, it is necessary to have an additional wire from the base of the control unit (regulator) to the frame of the generator.

3. ACCESSORY SYSTEM:

The accessory system consists of lights, horns, heaters, etc.

The current to operate these accessories is usually taken from the ammeter to a suitable switch, which allows the accessories to be operated or turned off as necessary.

There are many variations of wiring systems; however, if they are broken down as outlined above, no trouble should be encountered in tracing troubles.

TROUBLE SHOOTING

This section is devoted to giving the operator and maintenance crew some hints in tracing trouble, these suggestions being based on actual experience of servicing a great number of engines in various types of operation over a long period of time.

In order to locate trouble under different headings, refer to the **"Index."**

A. ENGINE WON'T START OR HARD STARTING

Cause: No fuel in the tank.
Correction: Fill the tank.

Cause: No fuel in the pump.
Correction: See **"Starting The Engine."**

Cause: Not properly prepared for starting at the atmospheric temperature being encountered.
Correction: See **"Starting The Engine."**

Cause: Weak batteries will not turn the engine over rapidly enough.
Correction: Recharge the batteries.

Cause: Fuel too heavy to flow through the pipes properly.
Correction: Lighter fuel. See **"Fuel Oil Specifications."**

Cause: Water in the fuel.
Correction: Drain the fuel system and tanks. Change the fuel supply.

Cause: Rings or cylinder walls worn badly.
Correction: Replace with new.

Cause: Exhaust or intake valve seats pitted or worn.
Correction: Regrind the valves.

Cause: Leaking head gasket.
Correction: Replace the gasket.

Cause: Air cleaner plugged, not allowing sufficient air to pass through.
Correction: Clean the air cleaner.

Cause: Governor stop lever stuck in the shut-off or stop position.
Correction: Locate and correct the cause of the sticking.

B. ENGINE STOPS SUDDENLY

Cause: No fuel.
Correction: Fill the tank and prime the fuel system. See **"Starting The Engine."**

Cause: Fuel pumps or lines air or gas bound.
Correction: Vent the fuel system. See **"Starting The Engine."**

Cause: Fuel filters plugged.
Correction: Clean the filters; then, prime the system.

Cause: Obstruction in, or broken, fuel line.
Correction: Check, starting with the fuel tank to the strainer.

Cause: Water in the fuel.
Correction: Drain the entire system, including the tank, and clean. Fill with clean fuel; then, proceed as under **"Starting The Engine."**

Cause: Piston seizure due to lack of lubrication.
Correction: Remove the piston and replace with new, if badly scored. Change the lubricating oil after thoroughly cleaning the oil pan, lines and filter.

Cause: Bearing seizure due to lack of lubrication.
Correction: If not too badly wiped, scrape enough to clean up and reinstall. If badly wiped, replace with new.

C. ENGINE MISSING

1. ERRATICALLY OR INTERMITTENTLY—On All Cylinders

Cause: Improper fuel, fuel with poor burning qualities.
Correction: Drain the system, including the tank, and refill with suitable fuel.

Cause: Water in the fuel.
Correction: Drain the fuel system, including the tank, of all water and sediment. Refill with clean fuel.

Cause: Sticking nozzle valve stems.
Correction: Remove the stuck parts and clean. Caused usually from dirty fuel. Clean the entire system, after draining, and fill with clean fuel.

Cause: Worn piston rings or cylinders, or both.
Correction: Replace with new.

Cause: Leaky intake or exhaust valves, or both.
Correction: Regrind the valves.

Cause: Plugged air cleaner, reducing air admitted into the cylinders.
Correction: Clean the air cleaner.

Cause: Valve tappets adjusted too close.
Correction: Readjust the valve tappets to the correct clearance. See **"Valve Grinding."**

Cause: Badly worn valve guides.
Correction: Replace the valve guides.

Cause: Leaking head gasket.
Correction: Tighten the cylinder head nuts to the proper tension or replace the gasket, if necessary.

Cause: Warped or cracked cylinder head, usually due to overheating or pouring cold water in an overheated engine.
Correction: Replace the cylinder head.

Cause: Cracked water jacket, usually indicated by overheating and loss of cooling solution.
Correction: Replace the cylinder block.

2. On 1 or 2 Cylinders

To determine which cylinder or cylinders are missing, loosen the nuts connecting the fuel lines to the fuel nozzles one at a time. If the engine speed remains the same and the exhaust sounds the same, the cylinder is missing. If the engine speed slows down and the exhaust loses its same rhythm, then the cylinder is functioning.

Cause: Nozzle valve stuck in the body.
Correction: Remove and clean.

Cause: Air or gas binding in the fuel pumps or lines.
Correction: Usually, when testing to see what cylinder is missing, this condition will be cleared up as opening the nut allows the air or gas to escape.

Cause: Exhaust or intake valve stuck.
Correction: Remove the valve cover and check which valve is stuck. Free with kerosene, gasoline or alcohol poured down the stem. Alcohol is the quickest solvent. If it still sticks, remove the head and determine the cause.

Cause: Leaky exhaust or intake valve.
Correction: Regrind the valve.

Cause: Exhaust or intake valve spring or spring retainer lock broken.
Correction: Replace with new.

Cause: Improper exhaust or intake valve clearance between the valve and rocker arm.
Correction: Check the clearance and reset to the proper clearance.

Cause: Piston rings or cylinder walls badly worn.
Correction: Replace with new.

D. LOSS OF POWER

Cause: Motor missing intermittently.
Correction: See C-1 and C-2, above, for the cause and correct.

Cause: Valves or valve seats worn and leaking.
Correction: Regrind the valves. See **"Valve Grinding."**

Cause: Piston rings broken, stuck in the grooves or worn.
Correction: Replace the rings and clean the ring grooves in the piston.

Cause: Tappets sticking or set too close.
Correction: Readjust the tappets or, if sticking, remove and clean.

Cause: Worn pistons, rings, etc.
Correction: Replace the worn parts or rebuild the engine.

Cause: Worn cylinders.
Correction: Rebore the cylinders and install new oversize pistons and rings.

Cause: Worn valve stems or guides.
Correction: Replace the valves or guides.

Cause: Valve springs weak or broken.
Correction: Replace the springs.

Cause: Water or sediment in the fuel tank or filter.
Correction: Clean the fuel system.

Cause: Air cleaner clogged.
Correction: Wash the element in a suitable cleaning solution, such as gasoline, fuel oil, etc.

Cause: Exhaust pipes or muffler restricted.
Correction: Clean or replace the exhaust pipe, muffler or tail pipe.

E. SMOKE IN THE EXHAUST

The brown or black color in the exhaust is pure carbon — one of the elements of the fuel, the other being hydrogen. When combined, they form liquid oil or gas which may be perfectly transparent or clear in the case of oil and absolutely invisible in the form of gas. These minute particles of carbon are solid substances and black. Their presence in the exhaust gas makes it appear as dark or black smoke. The more carbon particles, the darker color the exhaust, ranging from a very light gray haze to brown and even black smoke. The cause is incomplete combustion. Since combustion is never perfectly complete, it is not presumed that exhaust gases will be absolutely invisible. Smoke from the exhaust, either brown or black, is not itself mechanically harmful to the engine but may indicate corrections that should be made, particularly, if an increase of smoke appears with no change in conditions such as load, speeds, temperatures, change of fuel oil or engine taken to higher altitude.

1. Increase of Brown or Black Smoke In the Exhaust Gases

Cause: Leaky cylinder head gasket.
Correction: Remove and clean or replace from spares.

Cause: Leaky valves.
Correction: Regrind.

Cause: Improper fuel oil.
Correction: Change the fuel to a brand with good ignition and burning qualities.

Cause: Dirty spray nozzles.
Correction: Clean or replace.

Cause: Fuel injection timing too early, usually accompanied with "fuel knocks" or "noisy engine."
Correction: Adjust the timing of the injection.

Cause: Fuel injection timing too late, accompanied with loss of power but smooth and quiet running engine.
Correction: Adjust the timing of the injection.

Cause: Leaky piston rings.
Correction: Replace with new rings from spares.

F. ENGINE KNOCKING

Cause: Loose or worn main bearings.
Correction: Replace the main bearings.

Cause: Loose or worn connecting rod bearings.
Correction: Adjust or replace the bearings.

Cause: Loose piston pins.
Correction: Replace the pins with oversize pins or a piston and pin assembly.

Cause: Worn cylinder bores and pistons.
Correction: Rebore the cylinders and install new oversize pistons.

Cause: Tight piston pins.
Correction: Fit the pins to the proper clearance. See **"Clearance Table."**

Cause: Tight pistons.
Correction: Fit the pistons to the proper clearance. See **"Clearance Table."**

Cause: Overheated engine.
Correction: Allow the engine to cool; then, determine the cause of the overheating. See **"Cooling System,"** paragraph H-1.

Cause: Lack of lubricating oil.
Correction: Fill the crankcase with the proper grade and quantity of oil. If the engine still knocks, check and replace the bearings.

Cause: Loose flywheel.
Correction: Tighten in place; if worn excessively by running loose, replace.

Cause: Excessive end play in the camshaft.
Correction: Adjust the end thrust. See **"Camshaft."**

Cause: Bent connecting rod.
Correction: Check and straighten or replace, if necessary.

Cause: Piston hitting the inlet and exhaust valves due to an improper gasket.
Correction: Use only those supplied by Hercules Motors Corporation.

Cause: Pistons hitting the exhaust and inlet valves due to badly worn bearings.
Correction: Replace with new bearing shells.

Cause: Valve tappet clearance too great.
Correction: Adjust the clearances.

1. Knocking In the Engine or "Fuel Knocks"

Cause: Spray nozzle valve sticking from dirt or corrosion.
Correction: Clean the valve with a cloth (not abrasives) and clean the body with a piece of wood. Turn the valve stem in the body until free; then, smear with a good, clean, engine lubricating oil or vaseline and replace.

Cause: Spray nozzle spring broken.
Correction: Replace the complete holder from spares. Never attempt to change the nozzle springs in the field, as they must be accurately calibrated with instruments at the factory.

Cause: Inlet or exhaust valve not seating properly from sticking or in need of grinding.
Correction: Free the valve with alcohol or other solvent such as clean kerosene, fuel oil or gasoline. Grind the valve, if necessary.

Cause: Leaky cylinder head gasket.
Correction: Clean or replace from spares.

2. **If "Fuel Knocking" Is In More Than One Cylinder and Erratic and Intermittent**

Cause: Improper fuel. Has poor ignition qualities.
Correction: Add equal parts, or more if needed, of fuel oil with good ignition qualities or change the fuel to a brand having good ignition and burning qualities. See **"Fuel Oil Specifications."**

Cause: Sticking nozzle valve. This comes from dirt in the fuel oil or corrosion of these parts from acid in the fuel oil.
Correction: Dismantle and clean the parts; also, the fuel strainers. If the parts are corroded, change the fuel to an acid-free brand and install a new nozzle and pintle, if necessary.

Cause: Water in the fuel oil.
Correction: Drain the fuel oil strainer sump and fuel tank of all water and sediment.

3. **If "Fuel Knocking" Is In All Cylinders Continuous and Steady and Is Usually Accompanied With Dark Smoky Exhaust**

Cause: Improper fuel oil, has poor ignition qualities.
Correction: Change the fuel to a brand of suitable ignition qualities or add equal quantities, or more if needed, of fuel oil with good ignition qualities.

G. FUEL SYSTEM

Excessive fuel consumption. This is usually accompanied by increased lubricating oil consumption due to dilution of the oil.

Cause: Sticking controls.
Correction: Oil the controls and eliminate the binding.

Cause: Excessive idling of the engine.
Correction: Shut off the engine when not in operation.

Cause: Dirty air cleaner accompanied by loss of power.
Correction: Clean the air cleaner.

Cause: Engine overheating.
Correction: See **"Cooling System,"** paragraph H-1.

Cause: Engine in poor condition and adjustment.
Correction: Overhaul the engine.

Cause: Engine overcooling.
Correction: See **"Cooling System,"** paragraph H-2.

H. COOLING SYSTEM

1. **Overheating**

Cause: Lack of cooling solution, water, anti-freeze, etc.
Correction: Refill the system with the proper solution.

Cause: Fan belt not properly adjusted.
Correction: Adjust the fan belt for approximately 1" deflection.

Cause: Thermostat sticking in the closed position.
Correction: Clean and test or replace.

Cause: Coating of calcium salts on the cylinders and the inside of the cooling system.
Correction: Clean and flush the cooling system. The use of a good commercial type inhibitor may be recommended by the manufacturer of the radiator.

Cause: Dirt or insects in the radiator air passages.
Correction: Clean or blow out with compressed air.

Cause: Hoses deteriorated. Cannot always be determined by the condition of the outside covering.
Correction: Replace the hoses.

Cause: Inlet or outlet hoses collapsing.
Correction: Replace the hoses, using a hose with an inner support, if necessary.

Cause: Water pump not functioning.
Correction: Check and replace the drive shaft, impeller, supply lines, etc.

Cause: Exhaust pipes restricted, usually noted by a hissing sound in the exhaust.
Correction: Clean the pipes and remove the restriction.

2. Overcooling

Cause: Thermostat sticking open.
Correction: Clean and test or replace the thermostat.

Cause: Weather or climatic conditions too cold to allow the thermostat to hold the temperature.
Correction: Cover the radiator sufficiently to bring the water temperature into the proper range or use winter front.

3. Loss of cooling water

Cause: Leaks in the radiator core.
Correction: Repair or replace.

Cause: Defective hose connections.
Correction: Tighten the clamps or replace the hose or clamps.

Cause: Radiator tubes clogged.
Correction: Clean or replace.

Cause: Water pump seals defective.
Correction: Replace the seals. See **"Oil Seal."**

Cause: Loose freeze plugs (core plugs)in the cylinder block.
Correction: Tighten or replace the plugs.

Cause: Cracked cylinder head or block. Blown cylinder head gasket.
Correction: Replace.

I. CLUTCH ASSEMBLY

1. Slipping

Cause: Improper adjustment.
Correction: Adjust.

Cause: Weak pressure spring.
Correction: Replace the spring.

Cause: Sticking release sleeve.
Correction: Check the sleeve and pressure spring.

Cause: Worn facings on the driven disc assembly.
Correction: Replace the facings or the disc assembly.

Cause: Facings saturated with oil.
Correction: Clean the facings and correct the cause. Check the oil seal in the bellhousing; also, the pilot on the flywheel. Do not over-lubricate the clutch shafts, bearings, etc.

2. Chattering

Cause: Oil on the facings.
Correction: Clean or replace the facings.

Cause: Sticking release sleeve.
Correction: Check the pull back spring. If broken, replace.

3. **Rattling**

Cause: Loose release fork.
Correction: Tighten the fork.

Cause: Weak or broken pull back spring.
Correction: Replace the spring.

Cause: Improper pedal adjustment.
Correction: Adjust the pedal.

J. ELECTRICAL SYSTEM

1. Starting motor

(a) Slow cranking speed may be caused by:

Cause: Crankcase lubricating oil too heavy or cold.
Correction: Change to the correct grade of oil or heat the oil before attempting to start the engine, see **"Lubrication."**

Cause: Loose or dirty cable connections.
Correction: Clean and tighten.

Cause: Worn brushes.
Correction: Replace the brushes.

Cause: Dirty or worn armature.
Correction: Clean; repair or replace the armature.

Cause: Armature rubbing the field coils.
Correction: Replace the starter shaft bushings.

Cause: Low battery voltage.
Correction: Check the generator and regulator; then, recharge the battery.

(b) Starter failing to operate may be caused by:

Cause: Battery discharged.
Correction: Recharge the battery.

Cause: Burned circuit breaker.
Correction: Replace the circuit breaker.

Cause: Broken battery cables.
Correction: Replace the cables.

Cause: Poor connections.
Correction: Clean and tighten.

Cause: Burned commutator bars.
Correction: Recut the commutator.

Cause: Open or short circuits in the armature or fields.
Correction: Check and repair.

Cause: Defective starter switch (push button or solenoid).
Correction: Check and repair the contacts or replace the switch.

2. Generator

(a) Low or no output

Cause: Fully charged battery.
Correction: None. Check the output when the battery is slightly discharged.

Cause: Dry battery.
Correction: Refill the cells with distilled water.

Cause: Burned contacts on the regulator units.
Correction: Clean or replace the contacts.

Cause: Grounded armature wires or terminal posts.
Correction: Replace the wires and insulate the terminals.

Cause: Burned commutator bars.
Correction: Recut the commutator.

Cause: Worn or sticking brushes.
Correction: Clean or replace the brushes.

Cause: Open circuits in the field or armature.
Correction: Repair or replace the defective parts.

Cause: Brush springs weak or improperly adjusted.
Correction: Adjust or replace the springs.

Cause: Rough, dirty or greasy commutator bars.
Correction: Clean the commutator bars.

Cause: High mica on the commutator.
Correction: Undercut the mica.

Cause: Commutator out of round.
Correction: Recut the commutator.

(b) Noisy generator

Cause: Loose mountings.
Correction: Tighten the mounting bolts.

Cause: Worn or loose drive pulley.
Correction: Tighten or replace the pulley.

Cause: Worn bearings.
Correction: Replace the bearings.

(c) Excessive output

Cause: Generator field grounded.
Correction: Check the wires, etc., for external ground.

Cause: Regulator circuit breaker closed.
Correction: Adjust or repair the circuit breaker. Check the generator for damage.

Cause: Defective regulator.
Correction: Replace the regulator.

K. EXCESSIVE SMOKE FROM THE EXHAUST

Cause: Too much oil in the crankcase.
Correction: Fill only to the FULL mark on the bayonet gauge.

Cause: Worn pistons, rings or cylinders.
Correction: Replace the worn parts or overhaul the engine.

L. EXCESSIVE OIL CONSUMPTION

Cause: Oil leaks at the gaskets, screws, oil seals, etc.
Correction: Tighten or replace the gaskets, etc.

Cause: Inferior grade of oil.
Correction: Use a good quality oil. See the specifications.

Cause: Overheating.
Correction: See **"Cooling System,"** paragraph H-1.

Cause: Ring gaps too great or lined up.
Correction: Install new rings. If the ring gaps are lined up, the condition will correct itself.

Cause: Worn or broken rings.
Correction: Replace the rings.

Cause: Cylinder bores out of round or excessive taper.
Correction: Rebore the cylinders; install new pistons, rings, etc.

Cause: Main or connecting rod bearings loose.
Correction: Adjust or replace the bearings.

Cause: Oil ring slots clogged with carbon.
Correction: Clean the rings. Replace, if necessary.

Cause: Piston improperly fitted or installed.
Correction: Correct or replace the piston. See **"Piston."**

Cause: Piston rings improperly fitted in the piston grooves or cylinder bores.
Correction: Fit the rings properly in the grooves and cylinders. See **"Piston Rings."**

Cause: Air cleaner not clean, allowing dirt to enter the combustion chamber with resultant wear.
Correction: Keep the air cleaner clean.

M. BEARING FAILURES

Cause: Continuous overspeeding of the engine.
Correction: Continuous operation at maximum speed, or close to it, is to be avoided. Exercise caution when going downgrade. Do not allow the vehicular speed to exceed the same speed obtainable in the same gear on level terrain.

Cause: Lack of oil.
Correction: Keep the oil level at the FULL mark on the bayonet gauge.

Cause: Inferior grade of oil or oil of improper viscosity.
Correction: Use a good quality oil of the proper viscosity.

Cause: Bent connecting rod.
Correction: Replace the connecting rod.

Cause: Crankshaft rough or out of round.
Correction: Regrind or replace the shaft.

Cause: Restricted oil passages.
Correction: Clean the oil lines and passages.

Cause: Bearings loose or improperly fitted.
Correction: Adjust or replace the main or connecting rod bearings.

Cause: Dirt or other matter in the lubricating oil.
Correction: Use clean oil and service the breather air filter regularly. Replace the oil filter cartridges or elements.

N. LOW OIL PRESSURE

Cause: Oil pump strainer screen in the oil pan clogged.
Correction: Clean the screen.

Cause: Oil too hot, resulting in low viscosity.
Correction: Correct the cause of the overheating.

Cause: Pressure regulator piston worn or clogged with carbon.
Correction: Clean.

Cause: Excessive main and connecting rod bearing clearance.
Correction: Adjust or replace the bearings.

Cause: Oil pressure gauge defective.
Correction: Replace the gauge.

Cause: Oil pressure gauge line bent or clogged.
Correction: Clean; straighten or replace the line.

O. RAPID CYLINDER OR PISTON WEAR

Cause: Breather and air cleaner not properly serviced, allowing dirt and abrasives to enter the combustion chambers.
Correction: Clean frequently and at regular intervals.

Cause: Inferior grade of lubricating oil.
Correction: Use a good quality oil. See the specifications.

Cause: Lack of oil.
Correction: Keep the oil level at the FULL mark on the bayonet gauge.

Cause: Dirty oil.
Correction: Replace or change the oil and replace the oil filter elements.

Cause: Piston rings not properly fitted to the cylinders.
Correction: Replace the piston rings. See **"Piston Rings."**

Cause: Cold operation of the engine.
Correction: Check the thermostat. Warm the engine before applying the load.

P. VALVES STICKING

Cause: Incorrect valve tappet clearance.
Correction: Adjust the clearance correctly. See **"Valve Grinding."**

Cause: Valve springs weak or broken.
Correction: Replace the springs.

Cause: Valve stems or guides scored, dirty or gummy.
Correction: Clean; polish or replace.

Cause: Incorrect clearance between the valve stem and guide.
Correction: Fit the valve stems to the correct clearance in the guides.

Q. BURNED VALVES OR VALVE SEATS

Cause: Valve tappet clearance adjusted too close.
Correction: Adjust the valves to the proper clearance.

Cause: Weak valve springs.
Correction: Replace the springs.

Cause: Excessive carbon.
Correction: Remove the carbon deposits.

Cause: Camshaft not timed correctly.
Correction: Retime the camshaft. See **"Camshaft."**

Cause: Valve seats too narrow.
Correction: Cut the seats to the correct width.

Cause: Low grade fuel.
Correction: Use a good quality fuel.

Cause: Valve heads cut too thin when refacing.
Correction: Replace the valve.

CLEARANCE TABLE

(All Dimensions in Inches)

	DD SERIES 3, 4 and 6 Cylinder Min.		Max.
Valve seat diameter—exhaust	1-15/32		
Valve seat diameter—intake	1-21/32		
Face of valve seat—exhaust	1/8		
Face of valve seat—intake	1/8		
Valve stem clearance in guide, Std. Engine—exhaust and intake	.0015		.0025
Valve tappet clearance—exhaust	.010		
Valve tappet clearance—intake	.010		
Push rod clearance	.0005		.0015
Camshaft bearing clearance	.0015		.0035
Crankshaft thrust clearance	.005		.010
Connecting rod clearance—F-77	.001		.003
Connecting rod side clearance	.005		.012
Main bearing clearance—D-49	.0009		.0034
Crankshaft gear backlash to camshaft	.000		.002
Oil pump gear backlash to camshaft	.006		.012
Piston ring gap	.010		.020
Piston ring side clearance—compression	.004		.006
Piston ring side clearance—oil	.0015		.0035
Piston pin clearance—in piston	.0000	Hand Push Fit	.0005
Piston pin clearance—in connecting rod	.0005		.0012

PISTON CLEARANCE

3-½ BORE	.006 to .007	8 lb. pull with .006 Ribbon
3-¾ BORE	.006 to .007	8 lb. pull with .006 Ribbon
4 BORE	.006 to .007	8 lb. pull with .006 Ribbon

TORQUE WRENCH TENSION

	Foot Pounds
Cylinder Head Screw	140
Cylinder Head Nut	140
Connecting Rod	56
Main Bearings—Center	70
Main Bearings—Front, Rear and Intermediate	80
Camshaft Gear Nut	130
Flywheel	80

TOOLS

PART NO.	PART NAME
11462-A	Socket—½"
3170-A	Socket—9/16"
3171-A	Socket—⅝"
3109-A	Socket—¾"
3261-A	Socket—13/16"
3172-A	Socket—⅞"
203440-A	Deep Socket—⅞"
3168-A	Socket Extension—½" x 6"
13587-B	Square Speeder Handle—½"
3189-A	Surface Ratchet—½"
2252-A	Socket Universal
13077-A	Open End Wrench—½" x 9/16"
13078-A	Open End Wrench—9/16" x ⅝"
13099-A	Open End Wrench—¾" x ⅞"
6359-A	Manifold Wrench—⅝" x ⅝"
11927-A	Flex Handle
13171-A	Piston Ring Compressor
13096-A	Valve Spring Lifter
13098-A	Piston Ring Expander
11925-A	Screwdriver - 3/16" x 5" Blade
13175-A	Screwdriver - ¼" x 6" Blade
13095-A	Pliers - 9" Heavy Duty
13278-A	Adjustable Wrench
11919-A	Feeler Gauge Set - 9" Blades
11920-A	Lady Foot Pry Bar
11921-A	Ball Pein Hammer—12 oz.
3444-A	Torque Wrench
6335-A	Tool Box

MINOR ADJUSTMENTS

help to maintain the engine in good condition which alleviates major repairs and prolongs its usefulness.

GENERAL INDEX

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