Servicemen's Reference Book

Caterpillar

REG. U.S. PAT. OFF.

Diesel Engines

D17000

INDUSTRIAL

ELECTRIC SET

LOCOMOTIVE

MARINE

CATERPILLAR TRACTOR CO. • PEORIA, ILLINOIS, U.S.A.

Foreword

IT is the purpose of Caterpillar Tractor Co., to build into its products the capability of a long life of useful work. The records of tens of thousands of users testify to success in the achievement of that purpose. It is natural, however, that length of life and cost of operation and maintenance will vary — top records are the reward of the owners and operators who are diligent and conscientious in the care, operation and maintenance of their machines.

The Operator's Instruction Book, a copy of which is supplied with each machine, tells what to do, and how and when to do it, with regard to the day-to-day lubrication, operation and maintenance of the machine. It is urged that these instructions be studied carefully and reread frequently until the operator is thoroughly familiar with them. By following the instructions, the operator is best assured of obtaining maximum life and performance from his machine and of minimizing the frequency, number and cost of repairs.

Even the best of care will not eliminate the necessity, in course of time, of making minor repairs or complete reconditioning.

Your "Caterpillar" dealer has exceptionally complete facilities for such work. He carries a stock of genuine replacement parts and has in his employ competent factory trained servicemen. For work that cannot be done in the field, dealers have well equipped shops. Both the shop and the field servicemen have many special tools, designed and developed by "Caterpillar", that make easier and quicker the disassembly and assembly operations.

Though most "Caterpillar" owners prefer to make use of the excellent service and shop facilities of their dealers, some are themselves skilled mechanics or have such mechanics in their employ for reconditioning their equipment. To those owners this book, issued as a guide for "Caterpillar" dealer servicemen, will be of equal value.

The special tools pictured in various operations throughout are among the many which can be purchased from dealers. These tools are illustrated and listed in the Catalog for Service Tools, a copy of which is available on request.

T4200

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SPECIFICATIONS

DIESEL ENGINE

Bore and stroke—number of cylinders	$5\frac{3}{4}$x8—8 Cyl.
Firing order	1-8-5-4-7-2-3-6

Camshaft

Bearing journal diameter	2.619- 2.620 -in.
Bearing clearance	.003 - .006 -in.
Maximum permissible clearance	.010 -in.
End clearance	.005 - .009 -in.
Maximum permissible end clearance	.025 -in.
Camshaft gear backlash	.003 - .004 -in.
Maximum backlash	.010 -in.
Minimum backlash	.003 -in.

Crankshaft

Main journal diameter	3.999 -4.000 -in.
Main bearing clearance (Aluminum)	.0065- .009 -in.
Maximum permissible clearance	.015 -in.
Main bearing clearance (Babbitt)	.0045- .0065-in.
Maximum permissible clearance	.015 -in.
End clearance	.016 - .020 -in.
Maximum permissible end clearance	.035 -in.
Main bearing stud nuts, torque	5300 in. lb.
Connecting rod, journal diameter	3.999 -4.000 -in.
Maximum permissible out-of-roundness	.007 -in.
Maximum permissible journal wear	.009 -in.

Connecting Rod

Connecting rod bearing clearance (Aluminum)	.0065- .009 -in.
Maximum permissible clearance	.015 -in.
Connecting rod bearing clearance (Babbitt)	.005 - .007 -in.
Maximum permissible clearance	.015 -in.
Connecting rod bolt nuts, torque	1500 in. lb.
Center-to-center distance between connecting rod bearing and piston pin bushing	16.000 ± .001 -in.

Cylinder Liner

Diameter	5.750 -5.751 -in.
Maximum permissible liner wear (at top of ring travel)	.020 -in.

Piston Pins

Clearance in rod bushing	.001 - .0018-in.
Maximum permissible clearance in rod	.006 -in.
Maximum permissible clearance in piston	.006 -in.

Piston Rings

Piston ring side clearance	
Top ring	.003 - .0045-in.
2nd and 3rd ring	.0025- .004 -in.
Oil control ring	.0015- .0035-in.
Maximum permissible clearance (New ring)	.012 -in.
Ring gap, top	.012 - .017 -in.
Ring gap, all others	.020 - .030 -in.

Valves

Clearance (Hot)	.012 -in.
Exhaust valves:	
Stem clearance in bushing	.006 - .008 -in.
Maximum permissible clearance in bushing	.013 -in.
Valve seat angle	45°
Inlet valves:	
Stem clearance in bushing	.005 - .007 -in.
Maximum permissible clearance in bushing	.012 -in.
Valve seat angle	45°

Valve Timing

Exhaust opening	50° BBC
Exhaust closing	22° ATC
Inlet opening	12° BTC
Inlet closing	30° ABC

Valve Spring—Outer

Pounds pressure	71-79
When compressed to	$3\frac{1}{8}$-in.

Valve Spring—Inner

Pounds pressure	9-11
When compressed to	2 13/32-in.

Rocker Arm Bushings

Clearance between shaft and bushing	.002 - .003 -in.

Oil Pump

Clearance between gears and separator plate	.002 - .004 -in.

Fuel Injection Pump Lifter Setting

Camshafts 2A4511 and 3F1670	1.721-in.
Camshaft 2A5716	1.736-in.

Fuel Pump Plunger

Length	2.6575-2.6577-in.
Maximum wear	.005 -in.

Flywheel Housing

Bore run-out	
Electric set	.007 -in.
All others	.010 -in.
Face run-out	
Electric set	.007 -in.
All others	.010 -in.
Capscrew torque	1800 in.-lb.

Flywheel Run-Out

Outside diameter (Maximum)	.006 -in.
Face (Maximum)	.006 -in.

Cylinder Head

Tighten nuts numerically:	
First time	750 in. lb.
Second time	1200 in. lb.
Expected tightness after run-in	850 in. lb.

Accessory Shaft

End clearance	.003 - .007 -in.
Maximum	.012 -in.

Compression Release

Push rod clearance	.025 - .030 -in.

Timing Gear Housing

Capscrew torque	960 in. lb.

Hour Meter

Bearing clearance (Maximum)	.012 -in.

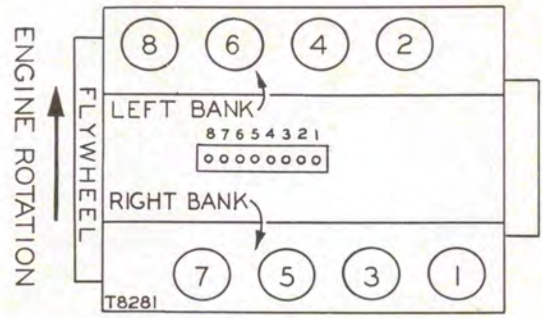
Pre-Combustion Chamber

Torque	1800 in. lb.

Fuel Injection Pump Timing

Fuel injection starts	16° BTC

The following illustration shows the numbering of the cylinders and of fuel injection pumps.



STARTING ENGINE

Bore and stroke	3¾x4
Brake horsepower	27 at 3000 RPM
Spark plug gap	.025 -in.

Camshaft

Bearing, journal diameter, front	2.2455-2.2465-in.
Bearing, journal diameter, rear	1.496 -1.497 -in.
Bearing clearance, front	.0025- .0045-in.
Bearing clearance, rear	.002 - .004 -in.
End clearance	.011 - .018 -in.

Crankshaft

Main journal, diameter, front	3.749 -3.750 -in.
Main journal, diameter, rear	2.874 -2.875 -in.
Main bearing clearance, front	.007 - .011 -in.
Main bearing clearance, rear	.006 - .010 -in.
Maximum permissible clearance	.017 -in.
End clearance, front main bearing	.010 - .018 -in.
Maximum permissible end clearance	.025 -in.
Connecting rod journal diameter	1.999 -2.000 -in.
Maximum permissible out-of-roundness (Journal)	.003 -in.

Connecting Rod

Connecting rod bearing clearance	.0025- .0045-in.
Maximum permissible clearance	.009 -in.
Center-to-center distance between connecting rod bearing and piston pin bushing	8.499 -8.501 -in.

Cylinder Bore

Diameter	3.751 -3.752 -in.
Cylinder bore wear limit (Out-of-roundness)	.003 -in.
Cylinder bore wear limit (Taper)	.005 -in.
Piston clearance (Skirt)	.006 - .008 -in.

Cylinder Head

Nut torque	960 in. lb.

Piston Pins

Clearance in connecting rod bushing	.0008- .0013-in.
Maximum permissible clearance between bushing and pin	.003 -in.
Clearance in piston	.0004- .001 -in.
Maximum permissible clearance between piston and pin	.0025-in.

Piston Rings

Compression ring gap	.012 - .022 -in.
Oil ring gap	.012 - .020 -in.
Compression ring groove clearance	.0015- .003 -in.
Oil ring groove clearance	.001 - .0025-in.
Maximum permissible groove clearance (New ring)	
Compression and oil rings	.009 -in.

Valves

Exhaust and inlet clearance (Cold)	.007 - .010 -in.
Valve seat angle	45°
Bushing clearance, exhaust valve	.003 - .005 -in.
Maximum clearance	.007 -in.
Bushing clearance, inlet valve	.0015- .003 -in.
Maximum clearance	.005 -in.

Valve Timing

Exhaust opening	40° BBC
Exhaust closing	50° ATC
Inlet opening	10° BTC
Inlet closing	35° ABC

To Check Valve Timing

(With clearance same as valve clearance above, and dial indicator mounted above valve, readings are taken with valve .075" off valve seat.)

Exhaust opening	16° 52′ BBC
Exhaust closing	18° 7′ BTC
Inlet opening	13° 7′ ATC
Inlet closing	11° 54′ ABC

Valve Spring

Pounds pressure	54-60
When compressed to	2¾-in.

Oil Pump

Gear backlash	.004 - .008 -in.

CARBURETOR, ELECTRICAL EQUIPMENT AND AIR STARTING

Generator (Delco-Remy 1102536)

Brush spring tension (main springs)	25-oz.
Brush spring tension (third spring)	17-oz.

Step-Voltage Control (Delco-Remy 5901)

Cut-out Relay	
Air gap	.015-in.
Point opening	.020-in.
Closing voltage	12.5—14.0-V.
Step-Voltage Control	
Flat spring tension	3/4-oz.
Air gap	.030-in.
Armature travel	.030-in.
Contact point opening	.010-in.
Opening voltage	14.0—15.5-V.
Closing voltage	12.5—14.0-V.
Minimum difference between opening and closing voltage	1.5-V.

Generator (Delco-Remy 1102734)

Brush spring tension	28-oz.

Regulator (Delco-Remy 1118377)

Cutout Relay	
Air gap	.020-in.
Point opening	.020-in.
Closing voltage	5.9—6.8-V.
Voltage Regulator	
Air gap	.075-in.
Voltage setting (8-10 amperes)	7.0—7.7-V.
Current Regulator	
Air gap	.075-in.
Current setting	17-21-Amp.

Generator (Leece-Neville 1960 G 15235)

Ampere output regulated by third brush.

Voltage Regulator Control Unit (Leece-Neville 3204-R12)

Voltage Regulator	
Contact point gap	.020-.025-in.
Open circuit voltage	28.4-28.6-V.
Cutout Relay	
Contact gap	.070-.075-in.
Auxiliary contact gap	.040-.045-in.
Hinge gap	.005-.010-in.
Closing voltage	22.0-22.5-V.

Generators
(Leece-Neville 24 Volt 1910G 15272)
(Leece-Neville 32 Volt 1912G 15272)

Ampere output regulated by third brush.

Voltage Regulator Control Unit (Leece-Neville 3192-R12)

Voltage Regulator	
Contact point gap	.020-.025-in.
Open circuit voltage	28.4-28.6-V.
Cutout Relay	
Contact gap	.070-.075-in.
Auxiliary gap	.040-.045-in.
Hinge gap	.005-.010-in.
Closing voltage	22.0-22.5-V.

(Leece-Neville 3194-R15)

Voltage Regulator	
Contact point gap	.027-.030-in.
Open circuit voltage	35.5-36.0-V.
Cutout Relay	
Contact gap	.070-.075-in.
Auxiliary gap	.040-.045-in.
Hinge gap	.005-.010-in.
Closing voltage	27.0-28.0-V.

Generator

(Leece-Neville 1946G-15052)

Ampere output regulated by third brush.

Voltage Regulator Control Unit

(Leece-Neville 3196-R15)

Voltage Regulator	
Open circuit voltage	35.5-36.0-V.
Contact gap	.045-.051-in.
Core gap	.027-.033-in.
Cutout Relay	
Closing voltage	27.0-28.0-V.
Hinge gap	.005-.010-in.
Main contact gap	.070-.075-in.
Auxiliary contact gap	.040-.045-in.
Core gap	.020-.025-in.

Electric Starting Motors

(Delco-Remy 1107436, 6 Volt— 1107822, 12 Volt)

Brush holder spring tension	24-28-oz.

Magneto (Bosch)

Breaker point gap	.014-.018-in.
Edge distance	.068-in.

Magneto (Eisemann)

Contact point gap	.020-in.

Carburetor

Float level	1 9/16±3/64-in.

Air Starting Motor

Clearance between plate and rotor	.004-.006-in.

General Instructions

These general instructions will be extremely helpful in following the detailed instructions in the main sections of the book. They should be read and then kept in mind while assembling or disassembling the engine.

KEEP DIRT OUT

The most important single item in preserving the long life of the engine is to keep dirt out of vital working parts. Caterpillar Tractor Co. has taken precautions to safeguard against dirt entering working parts. Enclosed compartments, seals and filters have been provided to keep the supply of air, fuel, and lubricants clean. It is highly important that the effectiveness of these safeguards be maintained. Filters should be replaced or cleaned regularly. Worn seals or broken gaskets should be replaced immediately.

Lubricant must be changed at recommended intervals. Use clean containers. Before removing a filler cap, brush away the dirt with the brush provided in the tool kit.

Wear on fuel injection pumps and other parts of the fuel system will be almost negligible if the fuel is perfectly clean. Adequate fuel filters have been provided to safeguard fuel injection equipment. However, dirty fuel caused by careless handling or improper storage facilities will cause wear on the fuel transfer pump, prematurely clog the fuel filter, and eventually result in improper operation of the Diesel engine.

MAINTAIN ADJUSTMENTS

Operating adjustments have been kept to a minimum on "Caterpillar"-built engines but they are important and should be carefully maintained.

Keep the fan belt adjusted to the proper tension to obtain maximum belt life and proper cooling.

Follow the recommendations in the Operator's Instruction Book.

INSPECT FREQUENTLY AND CORRECT MINOR TROUBLES

"A stitch in time saves nine" applies to engine maintenance.

A bearing changed in time will save a crankshaft. A water leak corrected prevents loss of coolant and an overheated engine. A nut tightened in time will prevent the loss or breakage of an associated part.

RECONDITIONING PROCEDURE

This book has been arranged for the disassembly and reconditioning of the individual assemblies of the engine. If the engine is to be disassembled for complete inspection and rebuilding let the following procedure be your guide. If possible, determine which assemblies will not be disassembled, in order to remove a group of assemblies as a unit at one time. This will save time and labor if an assembly is not to be reconditioned and if it can be removed from the engine without disturbing the assembly.

1. Drain, disconnect and remove the radiator and oil cooler assembly.
2. Remove the fan group and the crankshaft damper weight (if installed).
3. Remove the air cleaners and the air cleaner support bracket as a unit.
4. Remove the water temperature regulator housing, the water pump and the water lines.
5. Remove the exhaust manifold Y-pipe.
6. Remove all fuel injection pump lines and put on protectors to keep out dirt.
7. Disconnect and remove the Diesel starting engine if equipped with one.
8. Remove valve rocker arm assemblies, valve push rods, and dust tubes.
9. Remove each bank of heads as a group with the water, inlet, and exhaust manifolds attached (if the individual heads are not to be reconditioned). In cases where the heads are to be reconditioned, it would be more desirable to remove the heads and manifolds separately.
10. Remove the fuel transfer pump, transfer pump drive and the hand priming pump (if installed) as a unit.
11. Remove the fuel filter housing and the remaining fuel lines.
12. Remove the oil filters and oil filter base.
13. (Locomotive) Remove the externally mounted oil lines, oil pump and oil pump drive.
14. Remove the remaining crankcase inspection covers, the oil pan, and the oil pump drive.
15. Remove the valve lifters and guides.
16. Support the engine with blocks and remove the engine front support.

17. Remove the timing gear cover, the timing gears and the timing gear housing and support the governor housing.

18. Remove the camshafts.

19. Remove the fuel injection pump housing and the governor housing. (They can be removed as a unit if desired, see the topic in which the removal is described in this book).

20. Remove the connecting rods, pistons and cylinder blocks.

21. Support the engine at the rear of the crankcase and remove the flywheel and flywheel housing.

22. Remove the main bearings and the crankshaft.

23. Remove the oil manifold and the oil filter manifold from the crankcase.

Instructions for removing and disassembling of these parts are contained in this reference book, although not necessarily in the above order.

Safety and Workmanship Suggestions

There are certain practices which should be followed in the interest of safety and good workmanship when working around machinery.

Always show proper respect for weight. Do not attempt to lift heavy parts where a hoist should be used. Never leave heavy parts in an unstable position. When jacking up a machine make sure that it is blocked securely. Then block it up so that the weight will be supported by the blocks rather than the jack.

Tools

All service tools should be kept in first class condition. Use the proper tool for the job at hand. Special service tools are available for specific jobs and they should be used when recommended. The use of these tools will save time and prevent damage to parts.

In the following pages puller arrangements are illustrated for separating tightly fitted parts. However, if the machine is being reconditioned in a shop, it may in many cases be easier and faster to use a press. When pulling a bearing or gear from a shaft, always use a centering spacer between the forcing screw and the end of the shaft.

Disassembly

If a part offers unexpected resistance to removal, check carefully to see that all nuts and capscrews have been removed before using force. Possibly some other part is interfering and should be removed first. Parts which are fitted together with tapered splines are always very tight. If they are not tight when disassembled, inspect the tapered splines and discard the part if the splines are worn.

Identical parts, such as pistons and valves, should be kept in order or marked so they can be reinstalled in the same position from which they were removed.

Where shims are used, be sure to remove them all. Tie the shims together and identify them as to their location. Then keep them clean and flat until they are installed.

Whenever fuel injection lines are disconnected the ends of the lines should be capped with the fittings supplied in the tool kit. Also cap the pumps and valves. This will prevent dirt and other foreign matter from entering the fuel injection system.

CLEANING AND INSPECTION

Clean all parts thoroughly after they are removed and inspect them. Be sure all lubricant passages and oil holes are open. Badly worn or damaged parts should not be put back in the machine. Cover all parts to keep them clean until they are installed.

Anti-friction bearings should receive special handling. As soon as a bearing is removed, cover it to keep out dirt and abrasives. Wash bearings in non-inflammable cleaning solution and inspect the races and balls or rollers. Discard the bearings if they are pitted, scored, or burned. If the bearing is serviceable, coat it with light oil and wrap it in clean paper. Do not unwrap new bearings until ready to install them.

ASSEMBLY

Clean the rust preventive compound from all machined surfaces of new parts before installing them. Be sure to install parts in the proper location and position.

When one part is pressed into another, use white lead or a suitable prepared compound to lubricate the mating surfaces. Tapered parts, however, should be assembled dry. Before assembling parts with tapered splines, be sure the splines are clean, dry and free from burrs. Then press the parts together tightly.

When possible, soak new rawhide seals in warm oil for a half hour before installing. Install the seal with the wiping edge turned in the

PROTECTING SEAL DURING INSTALLATION

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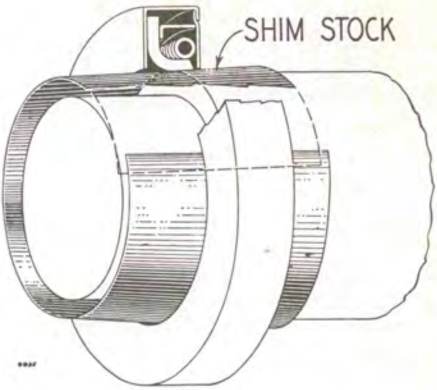
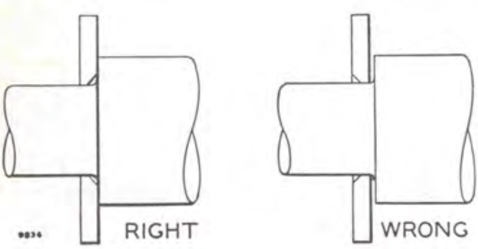


direction recommended. Be careful not to cut the leather seal as it is installed or when installing a shaft through the seal. Use shim stock if necessary to protect the seal from shoulders or sharp edges during installation. Packing-type seals should always be renewed if the contacting part is removed.

When installing a bearing, spacer, or washer against a shoulder on a shaft, be sure the chamfered side is toward the shoulder. If the washer is turned in the wrong direction the radius may interfere and prevent the washer from seating against the shoulder.

Do not install bushings by driving them in with a hammer. Use a press if possible and be sure to apply the pressure directly in line with the bore. If a bushing must be driven in, use a bushing driver or a bar with a smooth flat end. If the bushing has an oil hole, be sure it is lined up with the oil hole in the part in which it is assembled.



HOW TO INSTALL SPACER AGAINST SHOULDER ON SHAFT

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Install gaskets where required and use new ones if necessary. Never use cork or felt gaskets or seals a second time. Be sure the holes in the gaskets correspond with the lubricant passages in the mating parts. If it is necessary to make gaskets, select stock of the proper type and thickness and be sure to cut sufficient holes in the right places. Blank gaskets can cause serious damage.

Use capscrews of the correct length. A capscrew which is too long may bottom before the head is tight against the part it is to hold, and in addition the threads may be damaged when the capscrew is removed.

If a capscrew is too short, there will not be enough threads to hold the part securely.

HOW TO INSTALL CLOVER LEAF LOCKS

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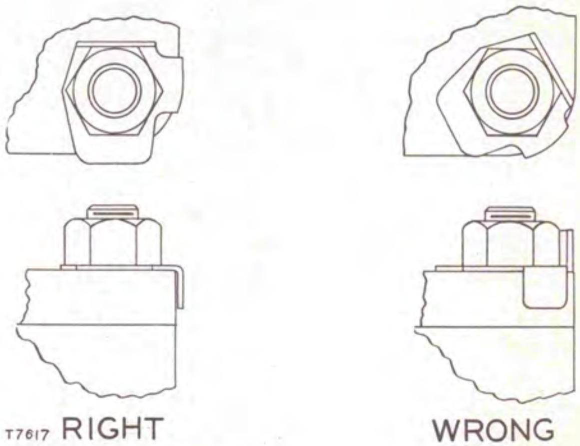
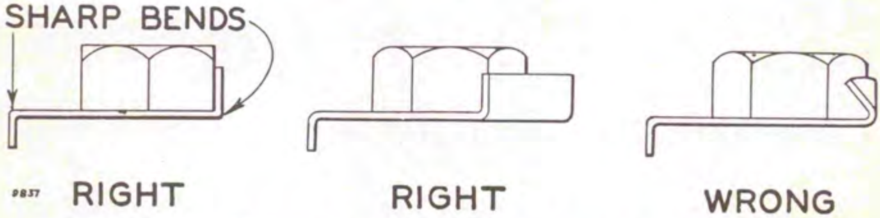


Lockwashers, cotter pins, or flat metal locks should be used to lock each nut and capscrew. Flat metal locks must be installed properly to be effective. Bend one end of the lock sharply around the edge of the part. Bend the other end sharply against one flat surface of the nut or capscrew head. Do not bend the lock against more than one side of the nut.



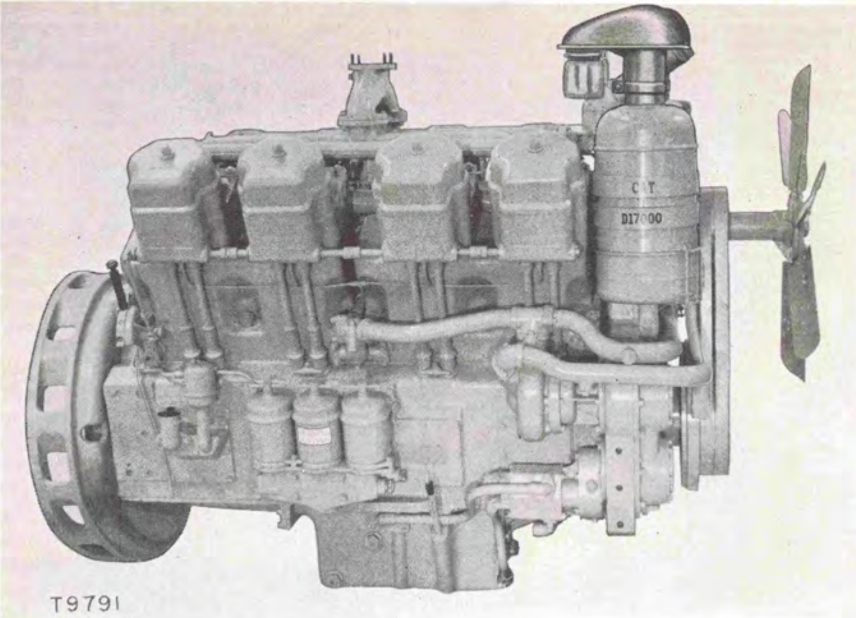
HOW TO INSTALL FLAT METAL LOCKS

When assembling a machine complete each step in turn. Do not leave one part partially assembled and start assembling some other part. Make all adjustments as recommended. Always check the job after it is completed to see that nothing has been overlooked.

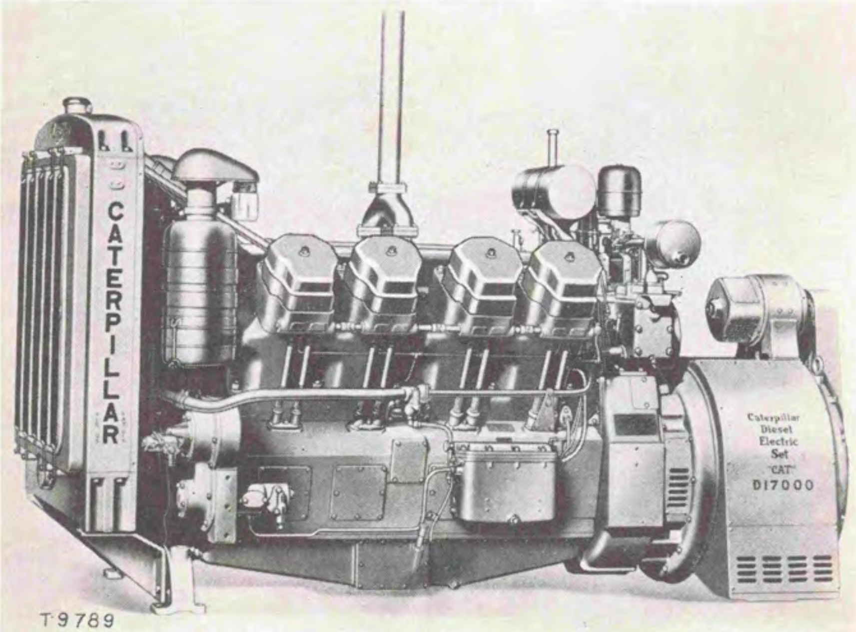
PREPARATION FOR STARTING

After assembling a machine, lubricate it thoroughly. Fill the various compartments with the type and grade of lubricant recommended in the Operator's Instruction Book. Fill the crankcases of both the Diesel engine and starting engine with the grade of oil recommended for the prevailing temperature. Fill the cooling system with water or anti-freeze solution.

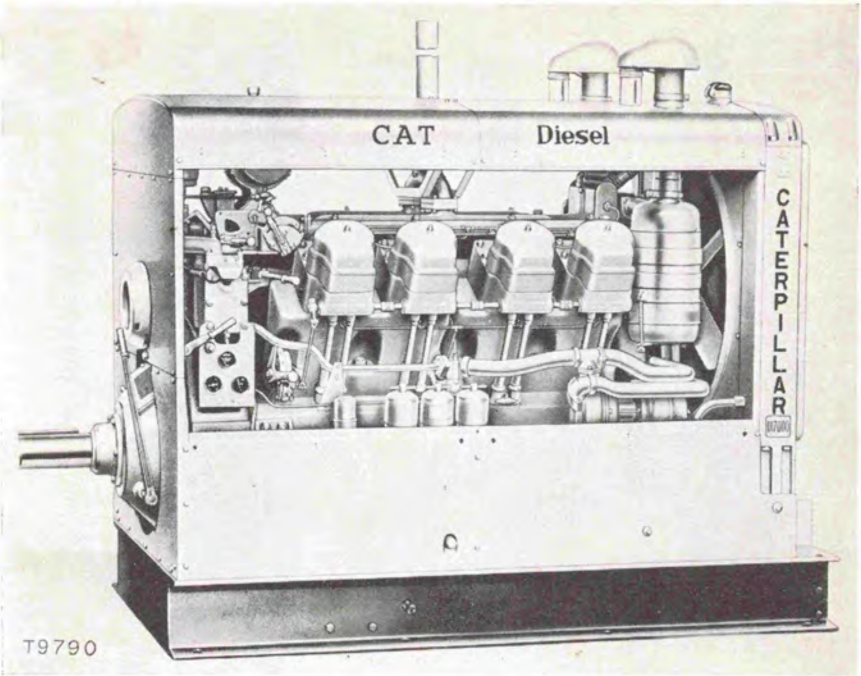
Recheck the various adjustments by operating the machine before returning it to the job. If a machine has been completely rebuilt, it should be run-in gradually before subjecting it to a full load. See the topic, RUNNING-IN SCHEDULE.



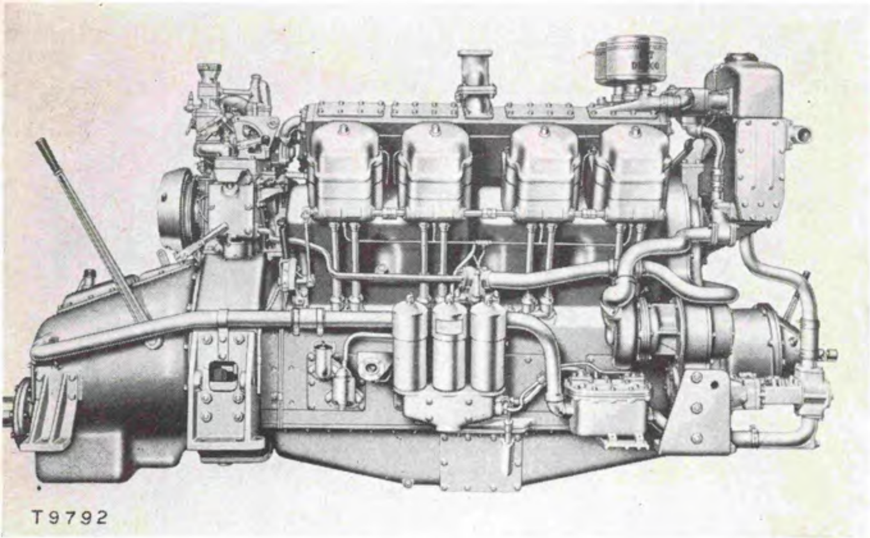
LOCOMOTIVE
(D17000L)



ELECTRIC SET
(D17000E)



INDUSTRIAL
(D17000I)



MARINE
(D17000M)

Introduction

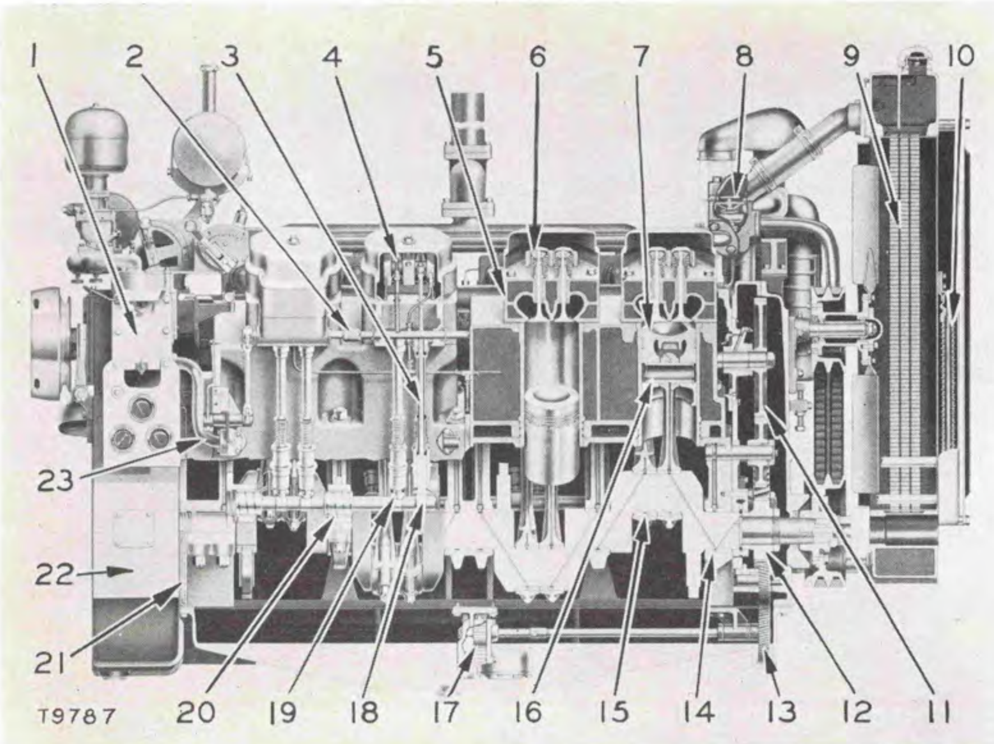
The major applications of the D17000 Diesel Engine as shown in the accompanying illustrations are covered in this book.

An abbreviation of each model is used: D17000L for the engine as used in Diesel-electric locomotives; D17000I, the industrial version; D17000E, the engine used in the electric set; D17000M, the marine engine.

The first section of the book describes the locomotive engine. The second section covers those items on the other engines which differ from similar items in the locomotive engine. The third section covers the starting engine; the fourth section, electrical equipment, carburetor and air starting.

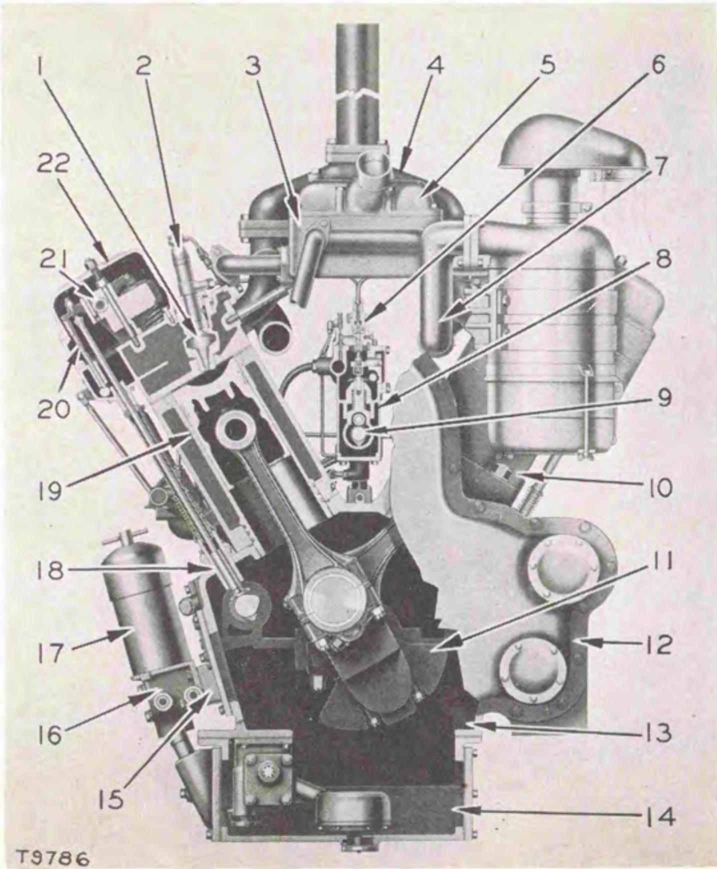
Certain items which are standard equipment on some models and are optional or attachments on others, are covered in the appropriate places along with standard parts with no differentiation noted.

Heat exchanger cooling, the use of the raw water pump, etc., are considered as the D17000M, but it is understood that these items can be used on other installations.



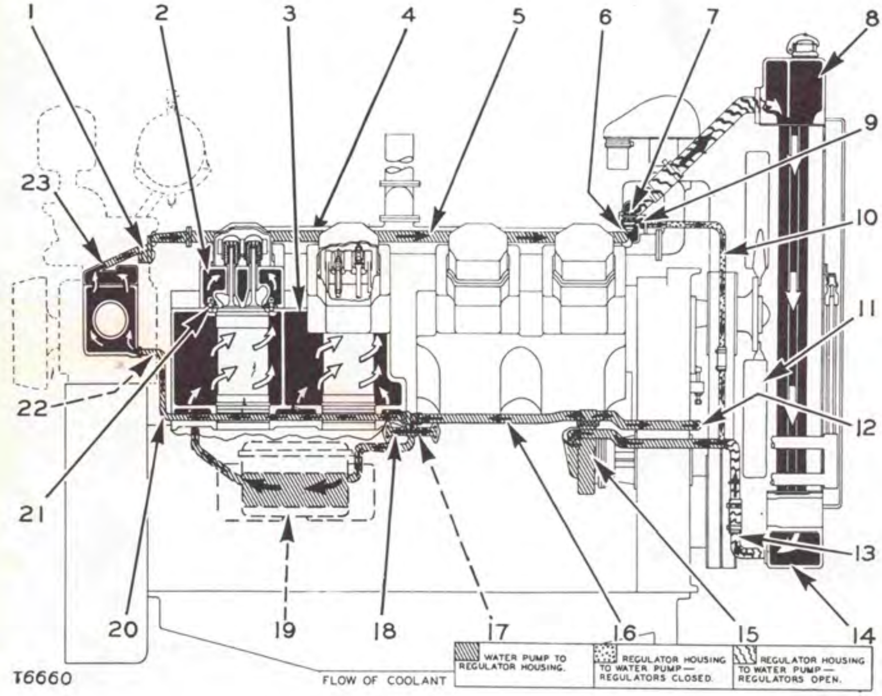
D17000 ENGINE CUTAWAY VIEW FROM RIGHT SIDE

1. Starting Engine Cylinder Head
2. Compression Release Mechanism
3. Push Rod
4. Valve Rocker Arm
5. Diesel Engine Cylinder Head
6. Valve Sleeve
7. Piston
8. Water Temperature Regulator
9. Water Radiator Core
10. Oil Cooler Core
11. Accessory Shaft Gear
12. Crankshaft Gear
13. Oil Pump Drive Gear
14. Front Main Bearing
15. Connecting Rod Bearing
16. Piston Pin
17. Lubricating Oil Pump
18. Right Camshaft
19. Valve Lifter
20. Camshaft Bearing
21. Rear Main Bearing Packing
22. Flywheel Housing
23. Water Elbow, Diesel Engine to Starting Engine



D17000 ENGINE CUTAWAY VIEW FROM FRONT END

1. Pre-combustion Chamber
2. Fuel Injection Valve
3. Water Temperature Regulator Housing
4. Exhaust Manifold Y-pipe
5. Water Temperature Regulator Housing Cover
6. Fuel Injection Pump
7. Air Inlet Pipe
8. Fuel Injection Pump Housing
9. Fuel Injection Pump Camshaft
10. Cylinder Block
11. Crankshaft Counterweight
12. Timing Gear Cover
13. Crankcase
14. Oil Pan
15. Oil Filter Manifold
16. Oil Filter Base
17. Oil Filters
18. Valve Lifter Guide
19. Cylinder Liner
20. Compression Release Rod
21. Rocker Arm Assembly
22. Rocker Arm Cover



FLOW OF COOLANT (SIDE VIEW)
(Radiator- cooled engine with starting engine)

1—Starting engine water pump. 2—Head. 3—Cylinder block. 4—Water manifold (left). 5—Water manifold (right). 6—Regulator housing. 7—Water temperature regulator. 8—Radiator top tank. 9—Outer passage (regulator housing). 10—By-pass water line. 11—Fan. 12—Discharge water pipe to left side of engine. 13—Water line (suction). 14—Radiator bottom tank. 15—Water pump. 16—Discharge water pipe to right side of engine. 17—Water inlet elbow (to left cylinder blocks). 18—Water inlet elbow (to right cylinder blocks). 19—Fuel filter housing. 20—Inlet water line (right side of starting engine). 21—Water director. 22—Inlet water line (left side of starting engine). 23—Top cover (starting engine).

DIESEL ENGINE—PART I

This section covers the topics common to all engines, as well as the additional topics pertaining to the locomotive, or to the locomotive, electric set and industrial engines. Different topics required for the electric set, industrial and marine engines are found in DIESEL ENGINE—PART II.

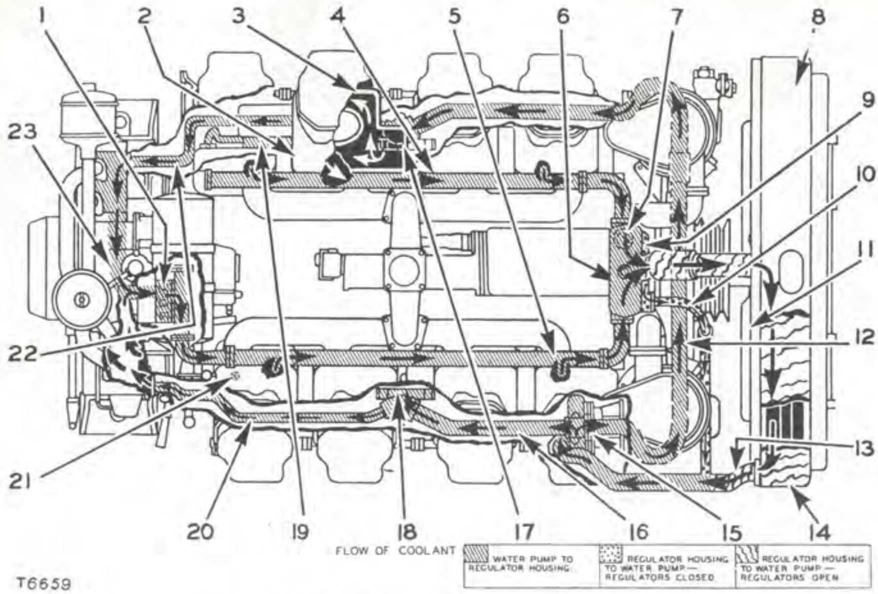
Cooling System
(D17000L-E-I)

FLOW OF COOLANT
(D17000L-E-I)

The gear driven, centrifugal-type water pump **(15)** circulates the coolant through the cooling system. The water pump is mounted into the right rear side of the timing gear housing, and is driven by the camshaft gear on that side of the engine. The water lines **(12)** and **(16)** are connected to the discharge side of the water pump and deliver the coolant to the water inlet elbows **(17)** and **(18)**, which transmit the coolant into the cylinder blocks **(3)**. The coolant passes into the heads **(2)** through the water ferrules, and is directed to areas around the exhaust valves and pre-combustion chambers by the water directors **(21)**. The water manifolds **(4)** and **(5)** are connected to the heads **(2)** and deliver the coolant into the lower compartment of the regulator housing **(6)** below the water temperature regulators **(7)**.

The flow of the coolant from the water regulator housing to the water pump is as follows: On initial starting the temperature of the coolant is not sufficient to open the water temperature regulators, which remain closed until the engine coolant is approximately 170° F. In this case none of the coolant is admitted to the radiator, thus assuring rapid warmup. The outer passage **(9)** of the regulator housing connects the water manifolds **(4)** and **(5)**, where the coolant flows into the by-pass water line **(10)**, which is connected to the inlet side of the water pump and returns the coolant to the water pump. Thus the circuit is completed for the flow of coolant with the regulators in a closed position.

The flow with the water temperature regulators in the open position is as follows: When the engine coolant is at approximately 170° F., the regulators open and the coolant passes through to the radiator top tank **(8)**. As the coolant passes through the radiator cores, it is aided in cooling by the fan **(11)** and it is admitted to the radiator bottom tank **(14)**. The water line **(13)** is attached to the suction side of the water pump, and returns the coolant to the water pump. A small portion of the coolant flows through the by-pass water line **(10)** even when the regulators are in the open position.



FLOW OF COOLANT (TOP VIEW)
(Radiator-cooled engine with starting engine)
(NOMENCLATURE SAME AS PRECEDING ILLUSTRATION)

The fuel filter housing **(19)** is mounted on the left side of the engine. The fuel compartment of the fuel filter housing is warmed by the coolant as it passes through cored water passages in the fuel filter housing.

On Diesel engines that have a starting engine installed the flow of the coolant is as follows: The starting engine cooling system is interconnected with the Diesel engine cooling system, and is filled at the same time the Diesel engine is filled. The inlet water lines **(20)** and **(22)** allow the starting engine to receive its supply of coolant. The coolant is distributed to the starting engine cylinder block, heads, and the top cover **(23)** where the starting engine water pump **(1)** is mounted. When the starting engine is running the starting engine water pump discharges the warm water into the Diesel engine water manifold to warm the Diesel engine and aid starting.

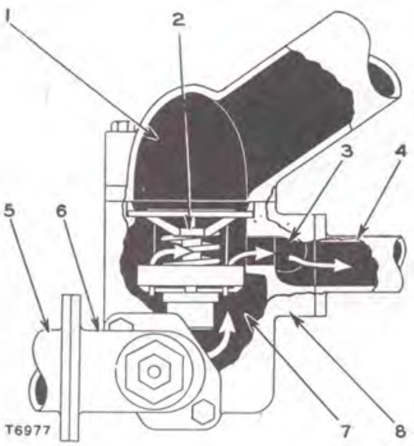
Some earlier models used two gear driven water pumps for the Diesel engine cooling system. The flow was basically the same, with a water pump for each side of the engine. See the topic, FRESH WATER PUMP (ALL EARLIER MODELS).

Use soft water or clean rain water in the cooling system whenever possible. If it is necessary to use hard water, it should first be treated with water softener. The use of "Caterpillar" Rust Inhibitor in cooling systems is recommended. This soluble oil will increase the life and efficiency of the cooling system by retarding mineral deposits when hard water is used and by preventing the formation of rust.

Flow of the Coolant through Water Temperature Regulator Housing (D17000L-E-I)

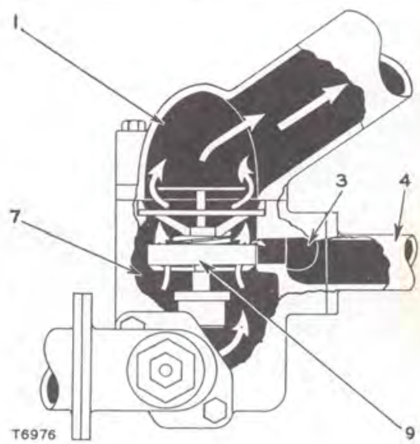
When the water temperature regulators are in the closed position on initial starting as illustrated by the regulator **(2)**, the flow of the coolant is as follows. The coolant enters the water elbows **(6)** from the water manifolds **(5)** and passes into the lower compartment **(7)** of the regulator housing **(8)**. The regulators when closed will not permit the coolant to enter into the upper compartment **(1)**. The coolant then passes into the outer passage **(3)** and the by-pass line **(4)** to return to the water pump.

When the temperature of the coolant has reached approximately 175° F., the water temperature regulators are in the open position as illustrated by the regulator **(9)**. The coolant then passes from the lower compartment **(7)** through the regulators and into the upper compartment **(1)** and to the radiator to be cooled. A small portion of the coolant passes through the outer passage **(3)** and the by-pass line **(4)** at all times.



WATER TEMPERATURE REGULATORS CLOSED

1—Upper compartment. 2—Regulator. 3—Outer passage. 4—By-pass line. 5—Water manifold. 6—Elbow. 7—Lower compartment. 8—Regulator housing.



WATER TEMPERATURE REGULATORS OPEN

1—Upper compartment. 3—Outer passage. 4—By-pass line. 7—Lower compartment. 9—Regulator.

Overheating (D17000L-E-I)

If difficulty is experienced with the engine overheating, check the following possible causes:

1. Coolant Level.

   Insufficient water in cooling system. If the water level has been allowed to fall so low that the water is no longer circulating, the engine should be stopped immediately and allowed to cool before adding water. If there is still good circulation, add makeup water slowly while the engine is running. These precautions will minimize the possibility of cracking of the cylinder heads.

2. Fan.

   Loose fan belt.

3. Radiator Clogging—External.

   Accumulation of leaves, mud and debris on oil cooler core or between oil cooler and radiator core. In some cases, these accumulations can be removed by flushing with water or compressed air from the back of the radiator. It may become necessary eventually to remove the radiator guard and oil cooler to clean the cores effectively.

4. Water Temperature Regulators.

   Failure of water temperature regulator to open. Check the regulator for opening temperature as described in the topic, TESTING WATER TEMPERATURE REGULATORS (ALL MODELS). Observe the amount of scale deposited on the regulators. Too much scale will obstruct their operation. Never operate the engine with the regulators removed.

5. Water Pump.

   Badly corroded water pump impeller or impeller loose on shaft.

6. Internal Clogging.

   Excessive scale or sediment deposits in radiator, cylinder head and block. Such deposits can cause serious damage to the engine by retarding the transfer of heat from the head and cylinders to the cooling water. In such cases, the water temperature may not be above normal. However, loose scale and sediment may deposit in water passages to such an extent that circulation will be retarded, in which case the water temperature may go above normal.

   To check for lime and scale in the cooling system, remove one of the pre-combustion chambers and inspect the surface which comes in contact with the cooling water. To remove hard scale follow the directions under the topic, CLEANING THE COOLING SYSTEM (ALL MODELS).

7. Continuous Overload.

   Operating an engine at full throttle under a continuous overload which lugs the engine speed down below its rated speed may also cause overheating. As a correction, the engine should be operated under a lighter load.

8. Altitude.

   The altitude at which the engine is operating should be considered when overheating is encountered. The horsepower of the engine is decreased as the altitude increases. Also, the boiling point of water is lowered at the higher altitudes.

9. Water Temperature Indicator.

   It may be that the indicator is not registering correctly. If the indicator is suspected of giving a false reading, install a new one and check the reading.

Cleaning the Cooling System (All Models)

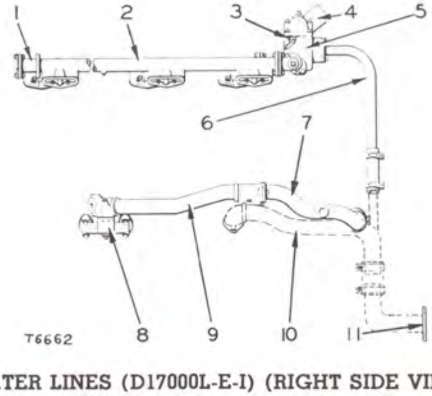
If hard water is used in the cooling system, it will eventually become necessary to remove the lime and scale deposits which gradually build up.

To remove the scale, fill the cooling system with a mixture consisting of five parts of commercial hydrochloric (muriatic) acid, one part formaldehyde, and forty-eight parts water. Mix the formaldehyde and water and then the acid.

Operate the engine for three hours and then drain the cleaning solution. Flush the system thoroughly to remove all traces of the acid and refill with clean, soft water.

WATER LINES
(D17000L-E-I)

The water lines as shown here are externally mounted and transmit the coolant as described in the topic, COOLING SYSTEM (D17000L-E-I).



WATER LINES (D17000L-E-I) (RIGHT SIDE VIEW)

1—Left water manifold. 2—Right water manifold. 3—Water temperature regulator. 4—Outlet from regulator housing to radiator. 5—Regulator housing. 6—Water by-pass line. 7—Water discharge line (to the left bank of cylinders). 8—Right water inlet elbow. 9—Water discharge line (to the right bank of cylinders). 10—Inlet to water pump. 11—Outlet from radiator (to water pump).

Water Lines Removal (All Models)

When it becomes necessary to remove any of the water lines, they can be removed in most cases without disturbing other assemblies or attachments.

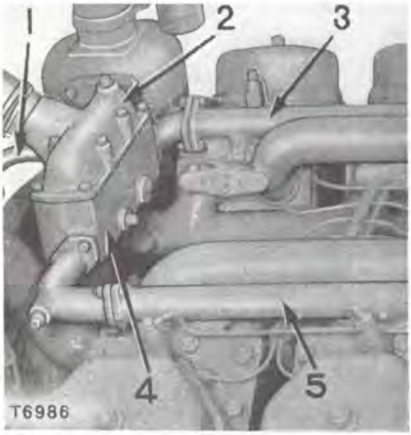
There are various drain plugs installed throughout the cooling system. Drain out only the amount of coolant necessary to facilitate the removal of the desired assembly without loss of the coolant. (When anti-freeze is drained out it can be drained into a container and used over, if desired).

Draining just enough coolant can be done by determining how far down the coolant should be drained, and removing one of the drain plugs below the assembly being removed. When enough coolant has been drained, install the drain plug. This will save time and labor when filling the cooling system.

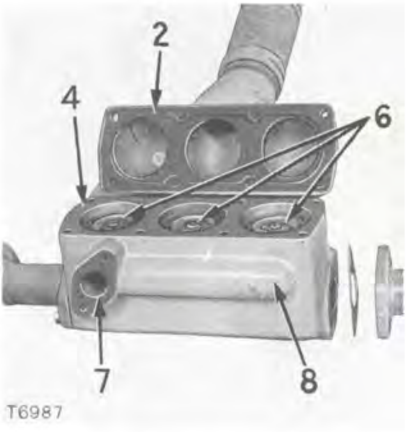
WATER REGULATOR HOUSING AND WATER TEMPERATURE REGULATORS (D17000L-E-I)

The water regulator housing consisting of the upper compartment or cover **(2)** and lower compartment or housing **(4)** is located at the forward end of the engine within the V between the two banks of cylinders. The regulator housing connects the water manifolds **(3)** and **(5)** together in the lower compartment or housing **(4)** of the regulator housing.

The water temperature regulators **(6)** (shown in a closed position)



LOCATION OF REGULATOR HOUSING
1—By-pass line. 2—Cover. 3—Water manifold. 4—Housing. 5—Water manifold.



LOCATION OF REGULATORS
2—Cover. 4—Housing. 6—Regulators. 7—Outlets to by-pass line. 8—Outer passage.

are located within the regulator housing, and direct the flow of the coolant from the regulator housing to the water pump.

When the temperature regulators are in the closed position on initial starting, or when the engine temperature is below 170° F., the coolant flows in the following direction: The outer passage **(8)** merges the coolant into the water by-pass outlet **(7)** and line **(1)** which is connected directly to the suction side of the water pump.

When the temperature regulators are in the open position (due to sufficient engine temperature), the direction of the coolant is the normal flow circuit as follows. The coolant passes through the regulators, through the cover **(2)** and into the radiator top tank, radiator cores, the radiator bottom tank and then to the water pump.

Water Temperature Regulator Removal (D17000L-E-I)

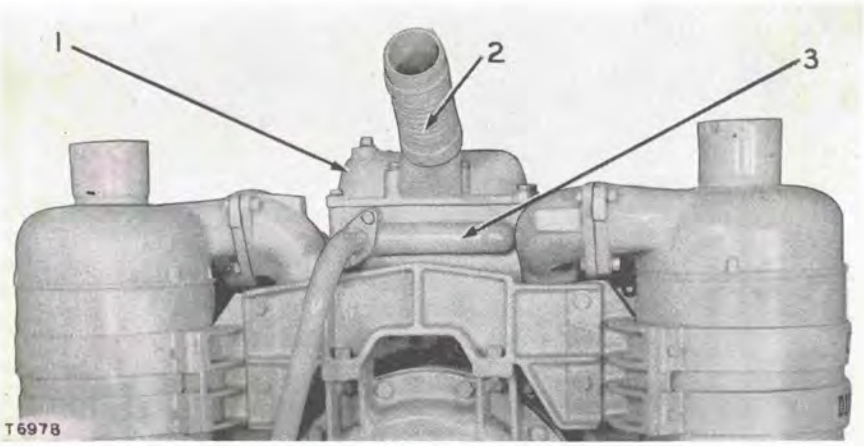
Drain the cooling system until the level is below the water regulator housing.

If desired, the water regulators can be removed from the engine without removing the regulator housing **(3)** from the engine.

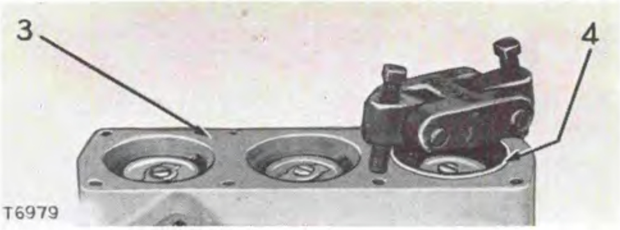
Disconnect the top radiator hose **(2)** (from the radiator).

Remove the capscrews holding the cover **(1)** to the regulator housing, and lift off the cover.

Using the 3B7184 Puller, remove the retainer ring **(4)** and lift out the water regulator. In engines where the regulators have been installed for some time, it is advisable to clean the housing bore before attempting to remove the regulators.



REMOVING REGULATOR HOUSING COVER
1—Cover. 2—Top radiator hose. 3—Regulator housing.



REMOVING RETAINER RING
3—Regulator housing. 4—Retainer ring.

Removing Water Regulator Housing (D17000L-E-I)

Drain the cooling system a sufficient amount to permit the removal of the regulator housing without loss of the coolant.

Disconnect (and place in a position so as not to interfere) the top radiator hose **(2)** and the water by-pass line **(1)**.

DISCONNECTIONS AT REGULATOR HOUSING
1—Water by-pass line. 2—Radiator hose.

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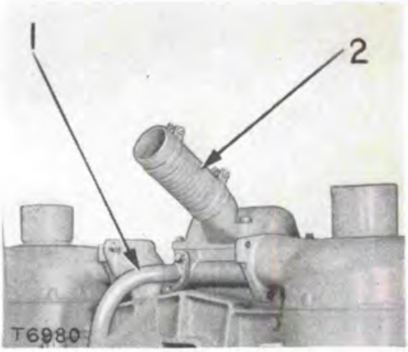
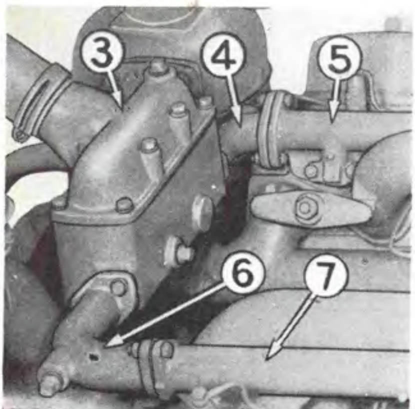


Remove the bolts, nuts and lockwashers holding the water elbows **(4)** and **(6)** to the water manifolds **(5)** and **(7)** and remove the regulator housing **(3)** with the elbows attached.



REMOVING REGULATOR HOUSING
3—Regulator housing. 4—Water elbow. 5—Water manifold. 6—Water elbow. 7—Water manifold.

◆

Testing Water Temperature Regulators (All Models)

Remove the regulator assemblies from the regulator housing and test each regulator.

Suspend the regulators, one at a time, in a pan of water as shown. Apply heat to the pan and observe the temperature. The opening temperature should be approximately 175° F., and the regulator should be fully open at 185° F. During engine operation the regulators are operated under pressures that are greater than atmospheric pressure, and the regulators open at 170° F.

Use an accurate thermometer to note the temperature. Stir the water to obtain a more accurate check.

If the regulators do not operate correctly, due to accumulated rust, scale or sludge, they can be cleaned as described in the topic, CLEANING WATER TEMPERATURE REGULATORS (ALL MODELS).

TESTING WATER TEMPERATURE REGULATORS

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Cleaning Water Temperature Regulators (All Models)

In areas where extremely corrosive water is used in the fresh water system of Diesel engines, some difficulty has been experienced with inoperative temperature regulators of the hydraulic expanding type. Accumulations of rust, scale and sludge may restrict the action of the parts inside the regulator. This regulator may be easily disassembled for cleaning the piston, which in many instances is all that is required to restore the regulator to service. The only tool necessary is a 2″ length of 1¼″ pipe having a sawed slot as shown. Slide the pipe over the power element, place the unit in a vise and compress the springs. Remove the two brass retaining straps. Remove the unit from the vise, lift off the valve plate and pull out the piston (about ¼″ diameter). On the inner end of

WATER TEMPERATURE REGULATOR DISASSEMBLY

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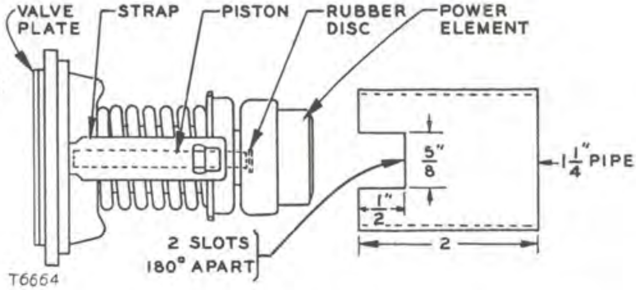


the piston there is a small rubber disc. Be careful not to lose this. Clean off the piston with crocus cloth and lubricate it with water pump grease. Replace the rubber disc and the piston and reassemble. This does not change the original temperature adjustment.

Installing Water Temperature Regulators (All Models)

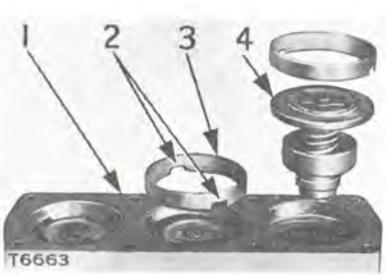
Clean the regulator housing **(1)**.

If there is reason to believe that the regulators are not operating properly, they should be checked and tested. See the topic, TESTING WATER TEMPERATURE REGULATORS (ALL MODELS).

Install the water temperature regulator **(4)** into the housing.

Place the retainer ring **(3)** into the housing bore, with the puller notches **(2)** down.

Drive the retainer ring down flush with the top of the regulator housing.



INSTALLING WATER TEMPERATURE REGULATORS

1—Regulator housing. 2—Puller notches. 3—Retainer ring. 4—Water temperature regulator.

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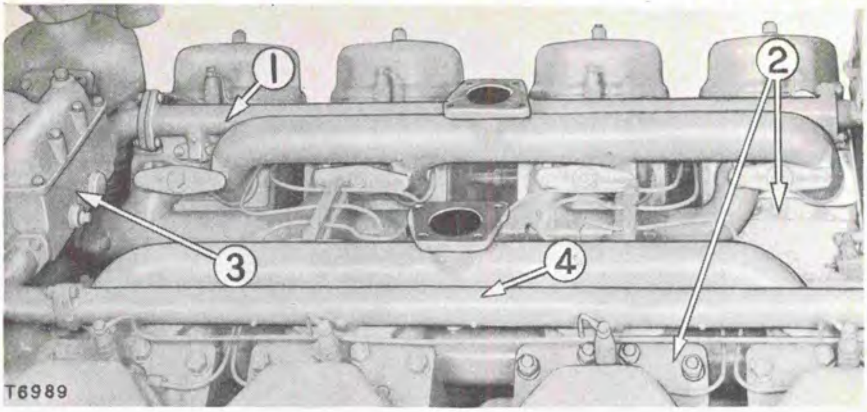
WATER MANIFOLDS (D17000L-E-I)

This engine is provided with two water manifolds **(1)** and **(4)**, which are attached to the cylinder heads **(2)** to transmit the coolant into the water regulator housing **(3)**.



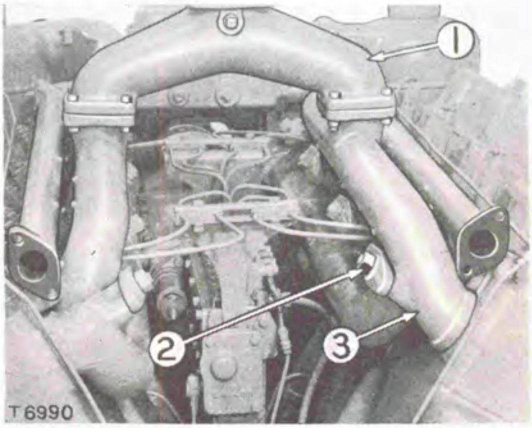
WATER MANIFOLDS
1—Water manifold. 2—Heads. 3—Regulator housing. 4—Water manifold.

The normal flow of the coolant, through the water manifold, is from the rear, toward the front of the engine to the regulator housing.

Removing Water Manifolds (D17000L-E-I)

Remove the manifold Y-pipe **(1)** and the clamps and nuts **(2)** holding the exhaust manifold pipe **(3)** to the heads.

Remove the exhaust pipe, cover the exhaust ports to prevent the possibility of anything falling into the cylinder heads.



REMOVING MANIFOLD Y-PIPE
1—Manifold Y-pipe. 2—Clamps and nuts. 3—Exhaust manifold pipe.

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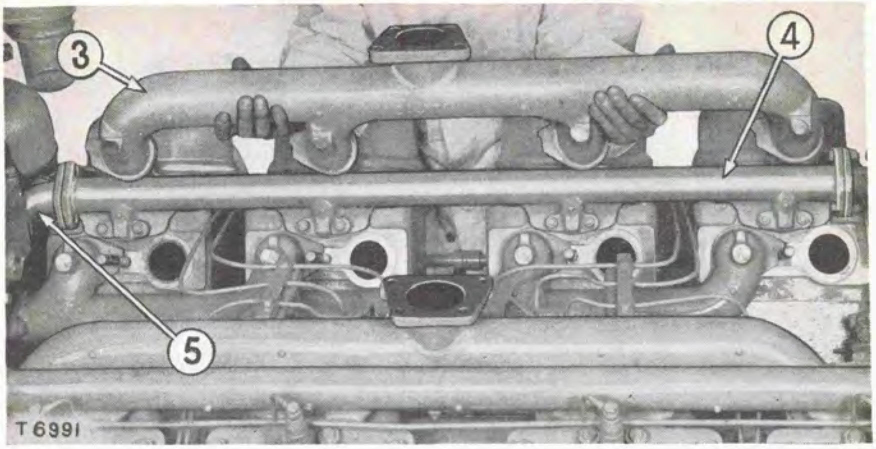
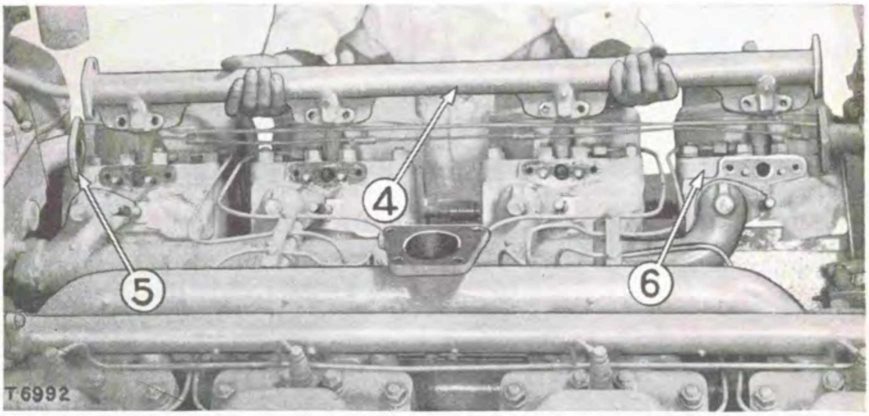
Disconnect the water manifold from the water regulator elbow **(5)**.

Remove the nuts and lockwashers holding the water manifold **(4)** to the cylinder heads **(6)** and remove the water manifold.

The left water manifold may be removed in the same manner as described above.



REMOVING EXHAUST MANIFOLD PIPE
3—Exhaust manifold pipe. 4—Water manifold. 5—Water elbow.



REMOVING WATER MANIFOLD
4—Water manifold. 5—Water elbow. 6—Cylinder head.

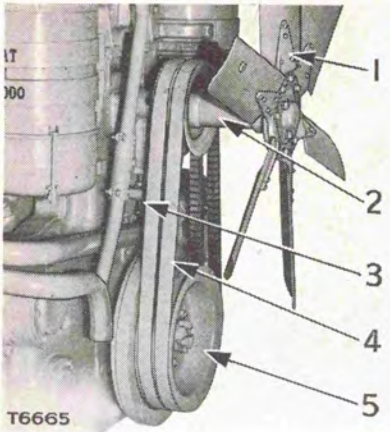
FAN GROUP
(D17000L Illustrated)

Fan Belt Replacement (D17000L-E-I)

The fan is driven by two V-belts from a pulley on the crankshaft. The belts and pulleys should be kept clean of an accumulation of dirt and grease to prevent excessive wear.

The fan group consists of the fan drive pulley **(5)**, the fan belts **(4)**, the fan hub assembly **(2)** and the fan spider assembly **(1)**.

The fan belts can be replaced as follows. Loosen the nuts holding the fan assembly to the timing gear housing and the lock nut on the adjust-



FAN GROUP

1—Fan spider assembly. 2—Fan hub assembly. 3—Adjusting screw. 4—Fan belts. 5—Fan drive pulley.

ing screw **(3)**. Turn the adjusting screw to permit the fan hub assembly to drop down and release the tension on the fan belts.

Remove the fan belts by guiding them over the spider assembly and the drive pulley.

Fan Hub Assembly Removal (D17000L-E-I)

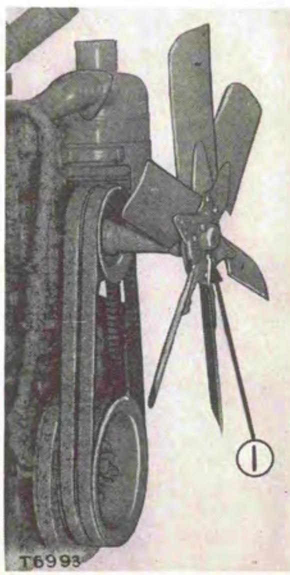
Remove the fan spider assembly **(1)**.

Loosen the nuts **(3)** holding the fan hub assembly **(6)** to the timing gear housing.

Loosen the lock nut **(2)** and back the adjusting screw **(5)** several turns to permit the tension to be relieved on the fan belts **(4)**.

FAN SPIDER REMOVAL

1—Fan spider assembly.



FAN BRACKET REMOVAL

2—Lock nut. 3—Nut. 4—Fan belt. 5—Adjusting screw. 6—Fan hub assembly.

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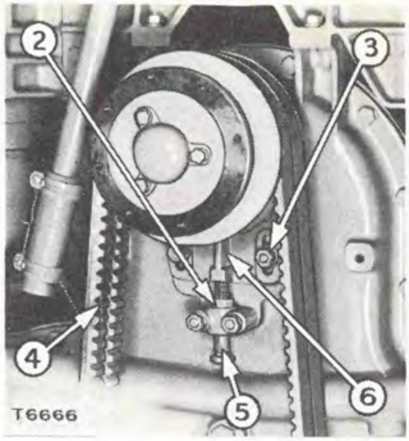


Remove the nuts, lockwashers and flat washers and remove the fan belts and fan hub assembly.

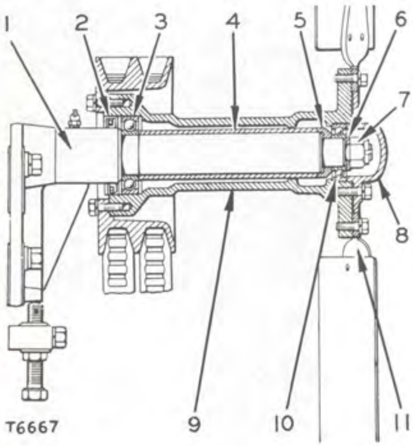
Fan Hub Disassembly and Assembly (D17000L-E-I)

Remove the fan assembly as described in the topic, FAN HUB ASSEMBLY REMOVAL (D17000L-E-I).

Remove the spider assembly **(11)**.

Remove the cover **(8)**, the cotter pin and nut **(7)**, and the washer **(6)**.

Remove the hub **(9)** with the bearing **(10)** installed in the hub, using the 8B7546 Puller. After the hub has been removed, remove the bearing **(10)** by pressing it out or by a light tap with a plastic hammer or similar tool.



FAN

1—Shaft and bracket assembly. 2—Seal. 3—Bearing. 4—Spacer. 5—Spacer. 6—Washer. 7—Cotter pin and nut. 8—Cover. 9—Hub. 10—Bearing. 11—Spider assembly.

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PULLING HUB

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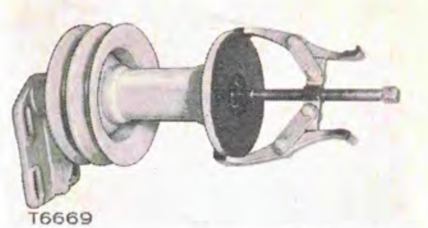
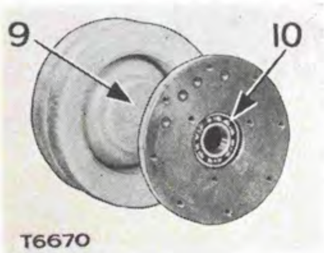


Remove the spacer **(5)**, the spacer **(4)**, the bearing **(3)** (a light press fit) and the seal **(2)** from the shaft and bracket assembly **(1)**.

Fill the hub with grease when assembling the fan. This may be done through the grease fitting located in the shaft and bracket assembly.



REMOVING BEARING FROM HUB

9—Hub assembly. 10—Bearing.

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REMOVING BEARING AND SEAL FROM SHAFT

1—Shaft and bracket assembly. 2—Seal. 3—Bearing. 4—Spacer. 5—Spacer.

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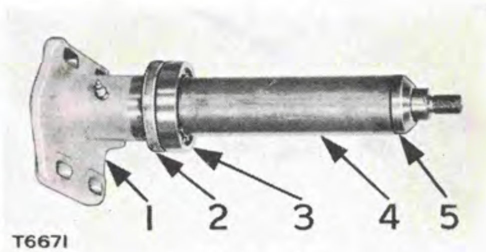

Fan Drive Pulley Removal (D17000L-E-I)

The fan drive pulley **(3)** is attached to the forward end of the crankshaft and drives the fan assembly **(1)** by the two V-belts **(2)**.

Remove the fan belts as described in the topic, FAN BELT REPLACEMENT (D17000L-E-I).

Remove the nuts and lockwashers **(4)** holding the fan drive pulley **(3)** to the crankshaft hub **(5)** and remove the fan drive pulley.

FAN DRIVE PULLEY

1—Fan assembly. 2—"V" fan belts. 3—Fan drive pulley.

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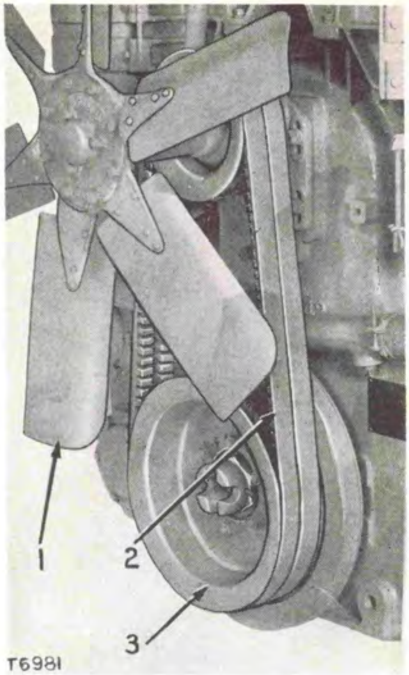

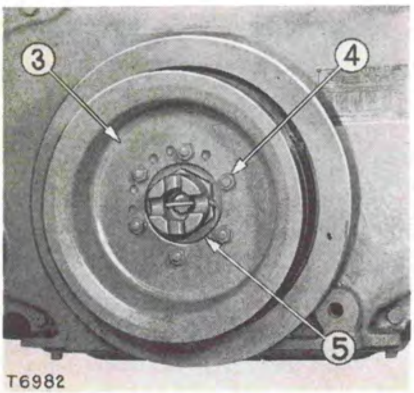

FAN DRIVE PULLEY REMOVAL

3—Fan drive pulley. 4—Nut and lock-washer. 5—Crankshaft hub.

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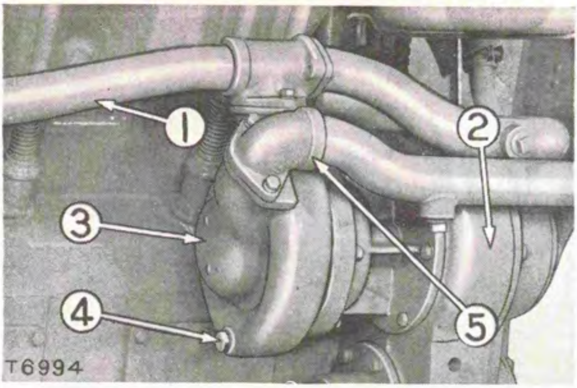
FRESH WATER PUMP (All Later Models)

Water Pump Removal (All Later Models)

The water pump **(3)** is mounted into the right rear side of the timing gear housing **(2)** and is driven by the right camshaft gear.

Later engines use one water pump while earlier models used two water pumps, having a pump for each bank of cylinders.



WATER PUMP REMOVAL
1—Discharge water pipe. 2—Timing gear housing. 3—Water pump. 4—Drain plug. 5—Inlet water pipe.

Reconditioning work can be done more readily by removing the water pump from the engine as follows:

Remove the drain plug **(4)** and drain the coolant.

Remove the inlet water pipe **(5)**.

Remove or disconnect the discharge water pipe **(1)** from the water pump.

Remove the capscrews holding the water pump to the timing gear housing and remove the water pump, as shown.

REMOVING WATER PUMP

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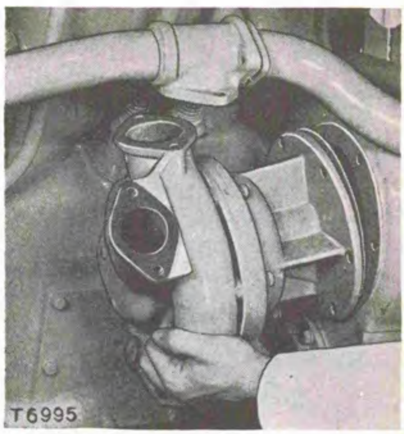
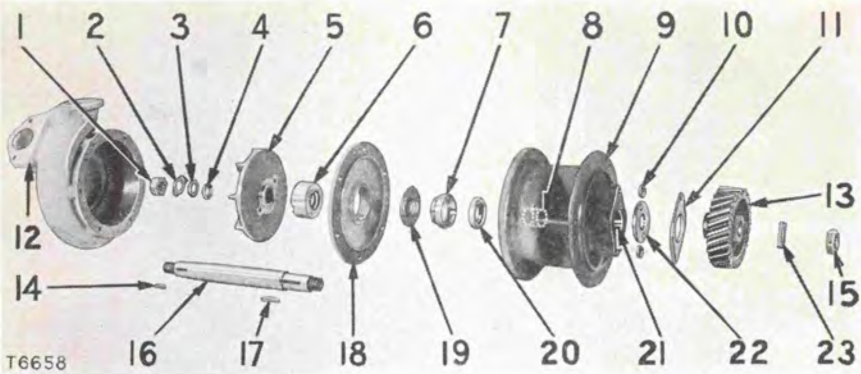


Water Pump Disassembly (All Later Models)

Before disassembling the water pump make an identification mark **(A)** on the water pump body **(12)**, the adapter plate **(18)** and the water pump



WATER PUMP (EXPLODED VIEW)

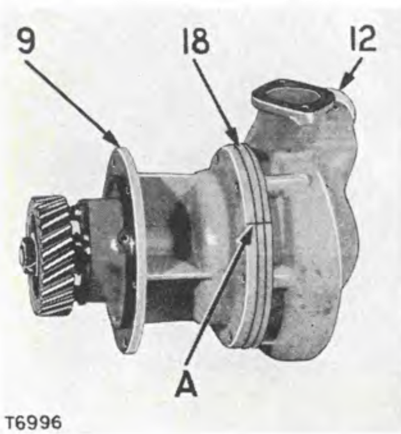
1—Nut. 2—Lock. 3—Washer. 4—Cork seal. 5—Impeller. 6—Water seal assembly. 7—Baffle. 8—Bushing. 9—Housing. 10—Spacer. 11—Thrust plate. 12—Body. 13—Gear. 14—Key. 15—Nut. 16—Shaft. 17—Key. 18—Adapter plate. 19—Thrower. 20—Oil seal. 21—Bushing. 22—Thrust washer. 23—Lock.

housing **(9)**. This will assure the correct location of these parts at the time of assembly, since it is possible to install them incorrectly.

Remove the capscrews and lockwashers holding the housing **(9)** and the adapter plate **(18)** to the body **(12)** and remove the body.

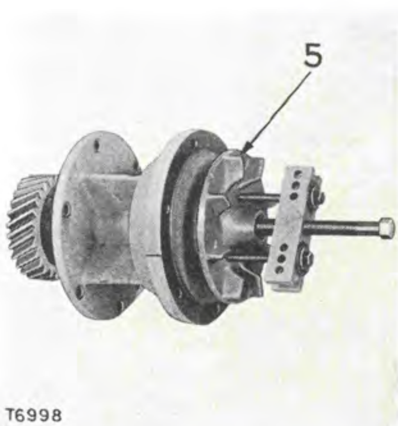
Remove the nut **(1)**, lock **(2)**, washer **(3)** and cork seal **(4)** holding the impeller **(5)** to the water pump shaft **(16)**.

Remove the impeller using two 3/8" standard capscrews and the 5F7465 Puller with a centering spacer.



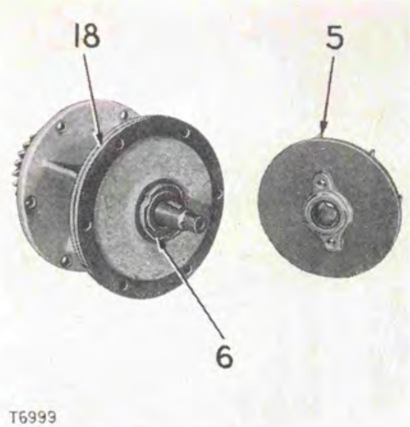
IDENTIFICATION MARKS ON WATER PUMP

A—Indentification mark. 9—Housing. 12—Body. 18—Adapter plate.

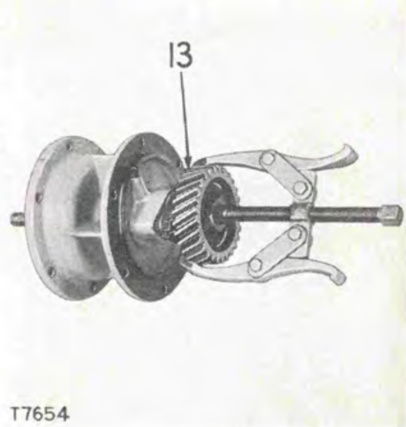


PULLING IMPELLER

5—Impeller.



LOCATION OF WATER SEAL
5—Impeller. 6—Seal assembly. 18—Adapter plate.



REMOVING DRIVE GEAR
13—Drive Gear.

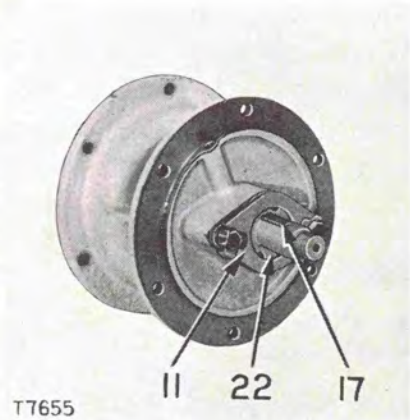
CAUTION

The water pump seal **(6)**, which is directly in back of the impeller, can be damaged if the puller capscrews are inserted too far through the impeller.

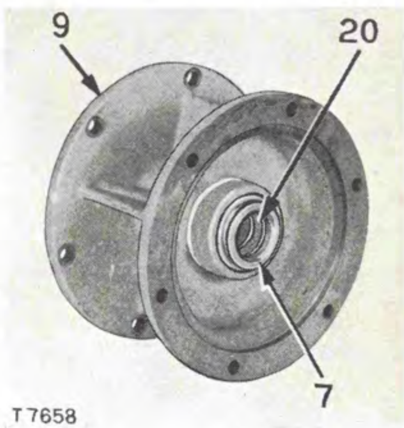
Remove the woodruff key **(14)** from the shaft **(16)** (impeller end).

Lift off the adapter plate **(18)** and water seal assembly **(6)** as a unit.

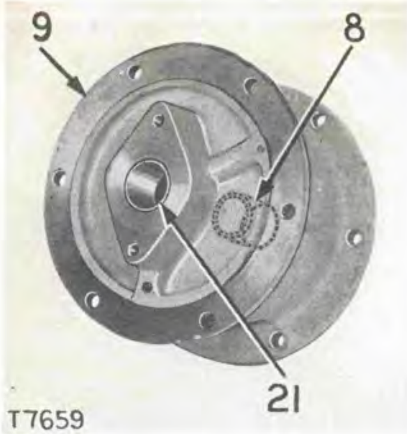
The water pump seal assembly **(6)** is pressed into the adapter plate **(18)**. Unless the seal is leaking or shows excessive wear, it need not be



REMOVING THRUST PLATE
11—Thrust plate. 17—Key. 22—Thrust washer.



REMOVING OIL SEAL
7—Baffle. 9—Housing. 20—Oil seal.



WATER PUMP BUSHINGS
8—Bushing. 9—Housing. 21—Bushings.

removed from the adapter plate. If it is desired, however, to remove the seal, it can be removed by bending the ears of the brass case and lifting out the carbon thrust washer and the neoprene bellows. If the brass case is damaged, it can be removed and a new one installed. See the topic, WATER PUMP SEAL REPLACEMENT (ALL LATER MODELS), which covers the water seal more completely.

Remove the nut **(15)** and lock **(23)** holding the drive gear to the shaft. Using the 8B7546 Puller as shown, remove the drive gear **(13)**.

Remove the woodruff key **(17)**.

Bend the locks and remove the capscrews holding the thrust plate **(11)**.

Remove the thrust plate **(11)** and spacers **(10)** and the thrust washers **(22)**.

Remove the shaft **(16)** from the water pump housing. The water thrower **(19)** can be pressed off the shaft, if desired.

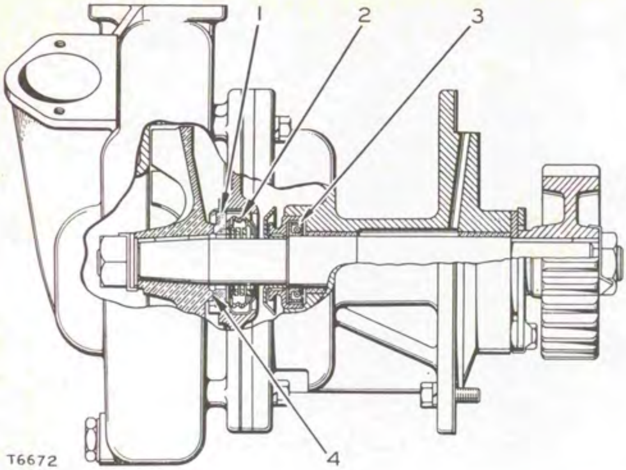
If the leather oil seal **(20)** shows wear, remove the baffle **(7)** from the water pump housing **(9)**, and remove the oil seal.

The water pump bushings **(8)** and **(21)** are pressed into the housing. If excessive wear is shown, they can be replaced by the use of an arbor press.

Assembling the Water Pump (All Later Models)

Install a new leather oil seal **(3)** with the sealing lip pointing toward the drive gear and away from the impeller.

Install a new carbon thrust washer **(1)** and neoprene bellows **(2)** if necessary. Inspect the impeller bearing face **(4)** for wear, since it is in contact with the carbon thrust washer **(1)**. The impeller bearing face must have a smooth lapped finish.



WATER PUMP

1—Carbon thrust washer. 2—Neoprene bellows (water seal). 3—Oil seal. 4—Impeller bearing face.

◆

Using the identification marks as described in the topic, WATER PUMP DISASSEMBLY (ALL LATER MODELS), assemble the remaining parts in reverse order of disassembly.

IMPELLER BEARING FACE AND CARBON THRUST WASHER

1—Carbon thrust washer. 4—Impeller bearing face.

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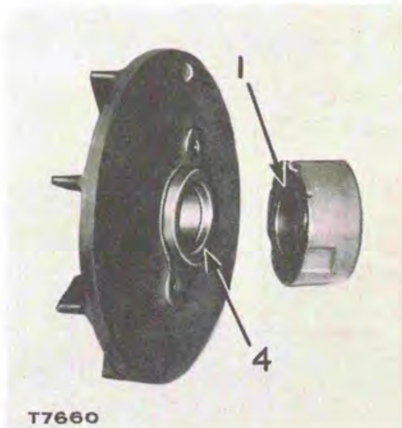
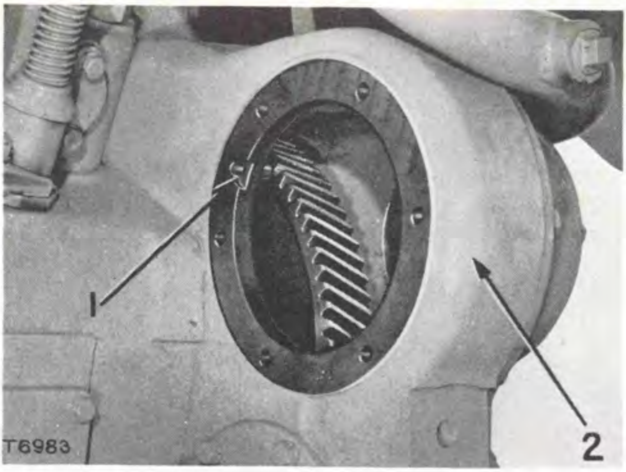


Water Pump Lubrication (All Later Models)

If for some reason the water pump has been removed from the engine, see the topic, WATER PUMP INSTALLATION (ALL LATER MODELS), before installing the water pump on the engine.

The water pump is pressure-lubricated by a supply of oil from the timing gear housing, which in turn receives its supply from the oil manifold. The oil flow is as follows: The water pump **(7)** when installed has an oil passage **(6)** which is in alignment with the supply passage **(1)** in the timing gear housing **(2)**.

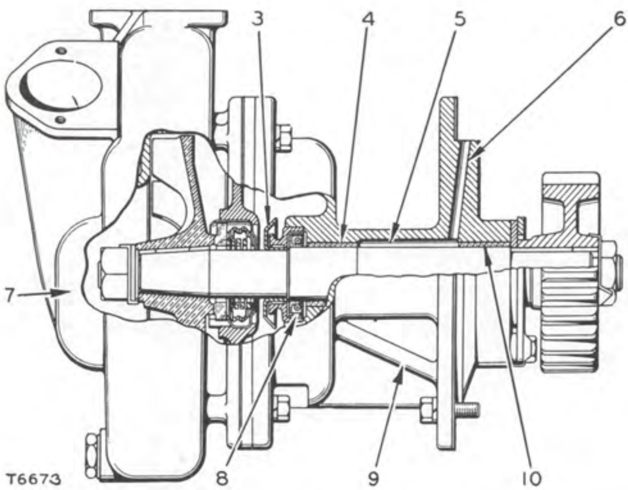


OIL SUPPLY PASSAGE
1—Oil supply passage. 2—Timing gear housing.

The oil passage **(6)** delivers the oil into the oil compartment **(5)** which supplies oil to the bushings **(4)** and **(10)**. The thrust plate and washer are splash-lubricated by the engine timing gears.

The oil seal **(8)** is installed to prevent oil from entering the water system.

The water thrower **(3)** deflects any water away from the oil compartment.



WATER PUMP LUBRICATION
3—Water thrower. 4—Bushing. 5—Oil compartment. 6—Oil passage. 7—Water pump. 8—Oil seal. 9—Oil drain passage. 10—Bushing.

The oil drain passage **(9)** returns the excess oil in the oil compartment to the timing gear housing. It is located to drain the oil away from the oil seal, thus giving the oil seal longer life.

Water Pump Seal Replacement (All Later Models)

Water leaking from the drain opening in the underside of the water pump indicates that the water seal should be replaced.

Remove and disassemble the water pump to the point where the water seal is accessible as described in the topics, WATER PUMP REMOVAL (ALL LATER MODELS) and WATER PUMP DISASSEMBLY (ALL LATER MODELS). The seal can be replaced without removing the complete water pump from the engine. The water pump can be disassembled on the engine to the point which will permit the removal of the seal.

The seal **(5)** is an assembly of a carbon thrust washer **(3)** and a spring enclosed by a neoprene bellows **(2)**. These two parts which make up the replaceable unit are contained in a brass case **(1)** which is pressed in the water pump adapter plate **(4)**. It is not necessary to remove the brass case **(1)** from the water pump adapter plate **(4)** for seal replacement. The carbon thrust washer and the bellows seal are removed from the brass case by bending back the three ears holding them in place. When replacing the carbon thrust washer be careful not to crack or scratch it. After the bellows seal and thrust washer are installed in the brass case, see that the washer moves freely under finger pressure.

If the brass case has been damaged, it is necessary to further disassemble the water pump and remove the adapter plate before the brass

WATER SEAL ASSEMBLY
1—Case. 2—Neoprene bellows. 3—Carbon thrust washer.

REMOVING WATER SEAL ASSEMBLY
4—Water pump adapter plate. 5—Seal assembly.

case can be removed. When installing a new brass case, coat the case and adapter plate bore with drawing compound or a similar lubricant to avoid shearing the brass case and also to provide a positive seal against water leakage. Make sure the brass case bottoms squarely in the bore so the carbon washer will bear evenly against the impeller contact surface.

Complete the assembly of the water pump.

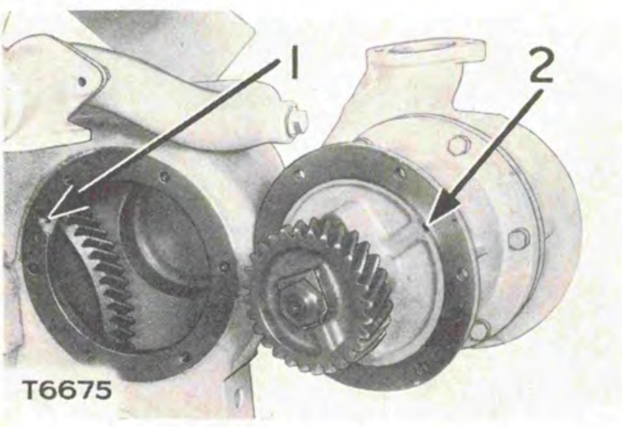
See the topic, WATER PUMP INSTALLATION (ALL LATER MODELS), before installing the water pump to the timing gear housing. The water pump is pressure-lubricated by oil and it must be installed in the correct position to assure lubrication.

Water Pump Installation (All Later Models)

Clean the mating surfaces of the timing gear housing and the water pump, and install a new gasket.

CAUTION

> When installing the water pump, the oil passage **(2)** of the water pump must be in alignment with the oil supply passage **(1)** in the timing gear housing. Unless these passages are in alignment, the water pump will be damaged through lack of lubrication.



WATER PUMP INSTALLATION
1—Oil supply passage (in timing gear housing). 2—Oil passage (in water pump).

FRESH WATER PUMP
(All Earlier Models)

Earlier engines use two centrifugal-type water pumps. Later engines use only one water pump, and it is a different design than the earlier-type. See the topic, FRESH WATER PUMP (ALL LATER MODELS).

Each earlier type pump serves a bank of cylinders. The pumps are mounted into the rear of the timing gear housing.

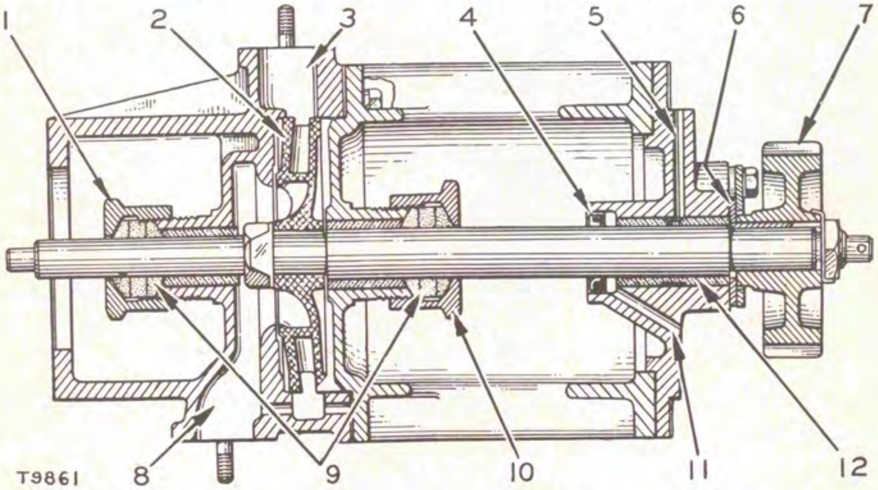
The left water pump is driven by the left camshaft gear, and the right water pump is driven by the right camshaft gear.

The water pumps are pressure-lubricated by a supply of oil from the oil manifold and the timing gear housing. Oil enters the water pump at the passage **(5)** and then flows to the bushing **(12)** and the thrust washer **(6)**. The gear **(7)** is lubricated by oil from the camshaft gear.

The oil seal **(4)** retains the oil in the oil compartment, and the oil passage **(11)** returns the oil to the timing gear housing.

The coolant enters the water pump at the passage **(8)** and is discharged at the passage **(3)** by the impeller **(2)**.

The packing **(9)** can be replaced if necessary in the following manner. Loosen the nuts **(1)** and **(10)** and slide them away from the impeller. Remove the old packing by using a hook and pulling it out.



WATER PUMP CROSS-SECTION
1—Nut. 2—Impeller. 3—Passage (outlet). 4—Oil seal. 5—Passage. 6—Thrust washer. 7—Gear. 8—Passage (inlet). 9—Packing. 10—Nut. 11—Passage. 12—Bushing.

Install new packing and tighten the nuts slightly.

When tightening the nuts to stop the coolant from leaking at the water pump, tighten them only enough to stop the leak and then loosen the nuts approximately 1/4 turn.

If the water pumps are removed, see the topic, WATER PUMP INSTALLATION (ALL EARLIER MODELS). The water pumps must be installed correctly to assure lubrication of the water pump.

Water Pump Removal (All Earlier Models)

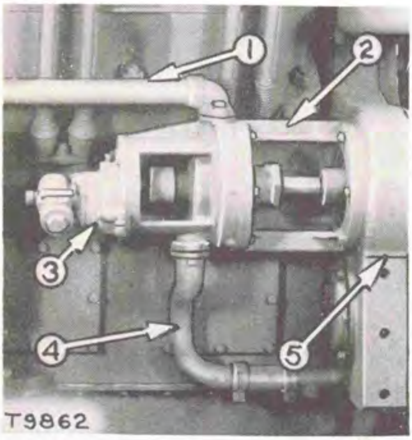
The earlier water pumps (either the left or the right) can be removed in the following manner.

Drain the fresh water cooling system.

Disconnect or remove the inlet water pipe **(4)**.

Disconnect or remove the outlet water pipe **(1)**.

Remove the capscrews holding the water pump **(2)** to the timing gear housing **(5)** and lift off the water pump with the hour meter drive **(3)** installed.



PREPARATION FOR WATER PUMP REMOVAL (RIGHT SIDE)

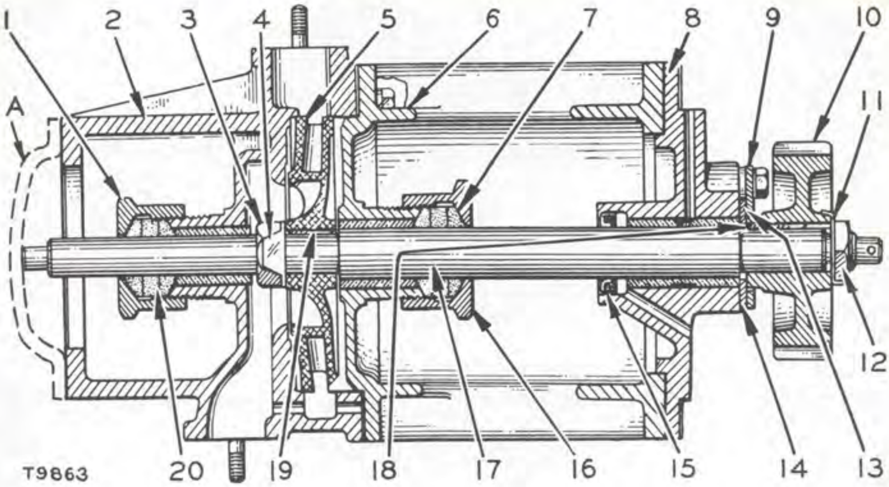
1—Outlet pipe. 2—Water pump (right). 3—Hour meter drive. 4—Inlet pipe. 5—Timing gear housing.

Water Pump Disassembly and Assembly (All Earlier Models)

Either the right or the left water pump of the early-type can be disassembled in the same manner.

Remove the cover or attachment **(A)**. Early-type water pumps either had a cover or an attachment installed to the body assembly **(2)**.

Loosen the packing nut **(1)** and remove it and the packing **(20)**.



WATER PUMP (CROSS-SECTION)
(Right Water Pump Illustrated)

A—Cover or attachment. 1—Packing nut. 2—Body assembly. 3—Nut. 4—Lock. 5—Impeller. 6—Bracket assembly. 7—Packing. 8—Bearing assembly. 9—Thrust plate. 10—Gear. 11—Lock. 12—Nut. 13—Thrust washer. 14—Spacer. 15—Oil seal. 16—Packing nut. 17—Shaft. 18—Woodruff key. 19—Woodruff key. 20—Packing.

Remove the nuts and lockwashers holding the body assembly **(2)** to the bracket assembly **(6)**.

NOTE

> The impeller **(5)** can be removed if necessary at this point, by bending the lock **(4)** and removing the nut **(3)**. (Some water pumps use a taper pin to secure the impeller, on these pumps drive out the tapered pin). The impeller can be removed by the use of a suitable puller. Remove the woodruff key **(19)**.

Bend the lock **(11)** and remove the nut **(12)**.

Using a suitable gear puller, pull the gear **(10)**.

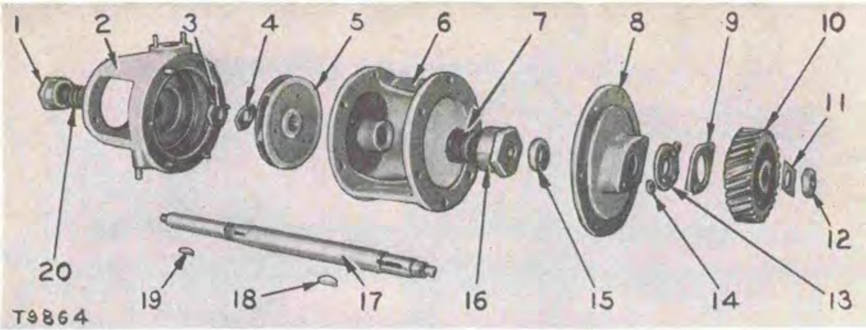
Bend the locks and remove the capscrews holding the thrust plate **(9)**, the spacers **(14)** and the thrust washer **(13)** to the bearing assembly **(8)**.

Remove the thrust plate, the spacers and the thrust washer.

Remove the woodruff key **(18)**.

Remove the bearing assembly **(8)**.

Inspect the oil seal **(15)**. Remove and replace with a new seal if necessary. The lip should point toward the gear **(10)**.



WATER PUMP (EXPLODED VIEW)

1—Packing nut. 2—Body assembly. 3—Nut. 4—Lock. 5—Impeller. 6—Bracket assembly. 7—Packing. 8—Bearing assembly. 9—Thrust plate. 10—Gear. 11—Lock. 12—Nut. 13—Thrust washer. 14—Spacer. 15—Oil seal. 16—Packing nut. 17—Shaft. 18—Woodruff key. 19—Woodruff key. 20—Packing.

Remove the packing nut **(16)** and the packing **(7)**.

Slide out the shaft **(17)** and the impeller **(5)**, (if the impeller has not already been removed).

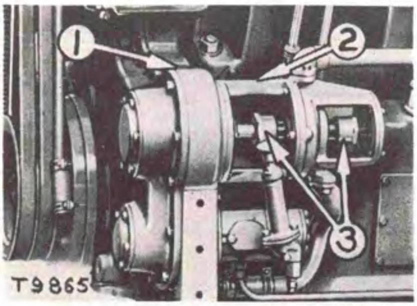
Clean all parts and check the bushings for excessive wear. The bushings can be removed and installed by the use of an arbor press.

Assemble the pump in the reverse order of disassembly.

Always install new gaskets and packing, and tighten the packing nuts only slightly. The final tightening should be made during engine operation.

Water Pump Installation (All Earlier Models)

At first appearance, the left water pump **(2)** and the right water pump **(4)** look identical, but each water pump must be installed into the timing gear housing **(1)** on its respective side of the engine.



LEFT WATER PUMP

1—Timing gear housing.
2—Left water pump. 3—Packing nuts.

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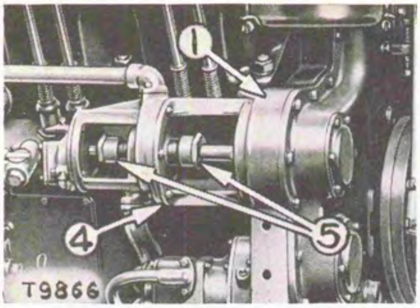


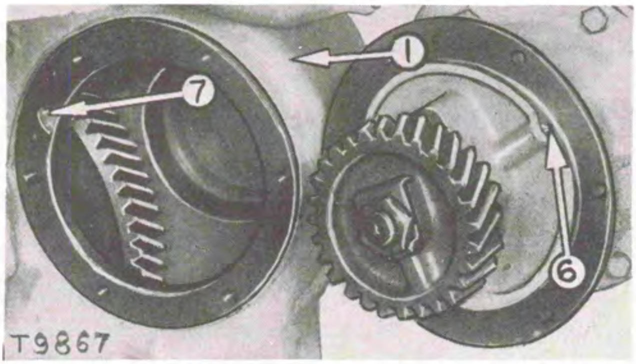
RIGHT WATER PUMP

1—Timing gear housing. 4—Right water pump. 5— Packing nuts.

♦

The water pumps must be installed to permit the packing nuts **(5)** and **(3)** and the water pump packing to be accessible as illustrated.

All water pumps receive a supply of lubricating oil from the oil manifold and they must be installed with the inlet oil hole **(6)** of the water pump in alignment with the oil supply passage **(7)** of the timing gear housing. (The right water pump is illustrated.)



ALIGNING OIL SUPPLY PASSAGE AND INLET OIL HOLE (RIGHT WATER PUMP ILLUSTRATED)

1—Timing gear housing. 6—Inlet oil hole. 7—Oil supply passage.

Lubricating System

FLOW OF LUBRICATING OIL (D17000L)

The flow of oil for the locomotive engine is as follows:

a. The oil pump assembly **(19)** is driven by the oil pump drive **(16)** which in turn is driven by the right camshaft gear **(13)**. The oil pump is externally mounted on the oil pump drive and the oil pump drive is mounted into the right rear side of the timing gear housing.

b. The oil pump assembly has two pumps within it, the scavenger pump **(21)** and the pressure pump **(20)**. See the topic, OIL PUMP (D17000L) for further detail on the oil pump.

c. The pressure pump draws the oil from the supply tank into the oil tube **(18)** and delivers oil into the oil pan.

d. The oil pressure control by-pass valve is mounted in the oil pan, and as the oil enters the oil pan the by-pass valve controls the amount of oil to be by-passed into the lower sump **(22)**. See the topic, OIL PRESSURE CONTROL BY-PASS VALVE (D17000L).

e. A vertical passage in the oil pan delivers the oil into the vertical drilled passage **(14)** in the crankcase, which delivers the oil into the oil filter manifold then into the engine mounted oil filter base **(26)**.

f. The oil tube **(24)** transmits the oil from the oil filter base to the oil cooler. The lubricating oil is cooled, then delivered back to the engine oil filter base by the oil tube **(25)**.

NOTE

g.

> The oil filter base has mounted within it, the oil cooler by-pass valve. If the oil cooler should become clogged or the passages become restricted in some manner, the pressure will unseat the by-pass valve and permit the oil to by-pass the oil cooler. See the topic, OIL COOLER BY-PASS VALVE (D17000L).

h. The oil passes into the oil filters **(27)** which are mounted on the oil filter base. The oil is then filtered and delivered into the oil filter manifold **(15)** through the passage **(4)** and then into the oil tube **(6)** (which is pressed into the crankcase). See the topics, FLOW OF OIL THROUGH OIL FILTERS (D17000L), FLOW OF OIL THROUGH OIL FILTER BASE (D17000L), and OIL FILTER MANIFOLD (D17000L).

NOTE

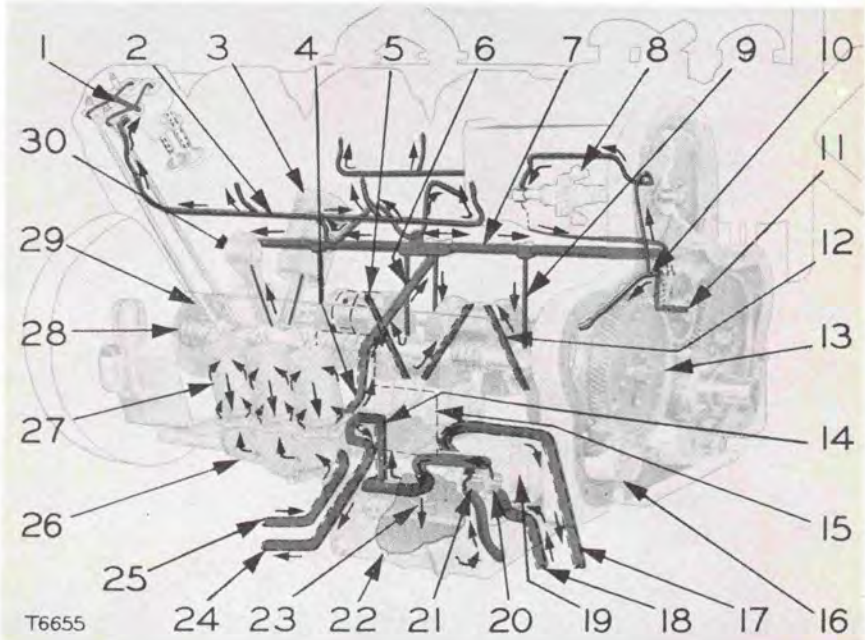
i.

The oil filters have by-pass valves installed, to permit the oil to by-pass the filters if they should become clogged. See the topic, OIL FILTERS AND BY-PASS VALVES (D17000L).

j. The oil tube **(6)** supplies oil to the oil manifold **(7)**. See the topic, OIL MANIFOLD (ALL MODELS).

k. The oil manifold supplies oil to the drilled passage **(9)** in the crankcase, which delivers the oil to the main bearings (and drilled passages in the crankshaft)

l. The crankshaft has drilled passages **(12)** to deliver oil from the main bearings to the connecting rod bearings **(5)**.



FLOW OF LUBRICATING OIL (D17000L)

1—Rocker arm assembly. 2—Oil tube (supply for rocker arms). 3—Piston and rings. 4—Passage (in oil filter manifold). 5—Connecting rod bearing. 6—Oil tube (pressed into crankcase). 7—Oil manifold. 8—Governor. 9—Drilled passage in crankcase. 10—Oil line (supply to water pump and governor). 11—Idler gear shaft. 12—Drilled passage in crankshaft. 13—Right camshaft gear. 14—Vertical drilled passage (in crankcase). 15—Oil filter manifold. 16—Oil pump drive. 17—Oil tube (to oil supply tank). 18—Oil tube (from oil supply tank). 19—Oil pump assembly. 20—Oil pressure pump. 21—Oil scavenger pump. 22—Lower sump in oil pan. 23—Overflow pipe. 24—Oil tube (to oil cooler). 25—Oil tube (from oil cooler). 26—Oil filter base. 27—Oil filters. 28—Camshaft bearing journal. 29—Valve lifter. 30—Piston pin bushing.

m. Grooves in the connecting rod bearings are in alignment with a drilled passage in the connecting rods. The oil passes through these passages to the piston pin bushing **(30)**. A portion of the oil is sprayed onto the inside top of each piston **(3)** from holes in the top of the connecting rod.

n. The oil tubes **(2)** are connected to the oil manifold and they transmit the oil to the rocker arm assemblies **(1)**, valve stem bushings and the push rods. Oil from the rocker arm assemblies drains down onto the push rods, and then to the valve lifters **(29)** to lubricate the valve lifters as they operate in the valve lifter bushings and on the camshaft.

o. The camshaft bearings are lubricated by oil splashed onto the camshaft bearing journals **(28)** and carried into the bearings by the grooves in the journals.

p. The oil line **(10)** is connected to the oil manifold **(7)** by a passage in the crankcase. This oil line supplies oil to the governor **(8)** and the water pump. See the topics, GOVERNOR LUBRICATION (ALL MODELS), WATER PUMP LUBRICATION (ALL LATER MODELS) and FRESH WATER PUMP (ALL EARLIER MODELS).

q. The idler gear shaft **(11)** receives a supply of oil from the oil manifold and this lubricates the idler gear and drains onto the timing gears. See the topic, TIMING GEAR LUBRICATION (ALL MODELS).

r. The pistons and rings **(3)** are lubricated by oil that is splashed or thrown by the crankshaft and the camshafts. See the topic, PISTON AND RING LUBRICATION (ALL MODELS).

s. After the oil has been delivered throughout the engine for lubrication, it then drains into the oil pan, and settles into the upper sump of the oil pan. See the topic, OIL PAN (D17000L).

t. The oil drains down the overflow pipe **(23)** and into the lower sump **(22)** of the oil pan.

u. The scavenger pump **(21)** picks up the oil in the lower sump and it is delivered to the supply tank by the oil tube **(17)**, thus completing the oil circuit.

OIL PRESSURE GAUGE
(All Models)

When the engine is warm and running at rated engine speed, the oil pressure gauge should register midway in the "operating range". A lower pressure reading is normal at low idling speeds.

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LUBRICATING OIL PRESSURE GAUGE

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If for any reason the oil gauge ceases to register, the engine should be stopped immediately until it can be determined whether the oil pump is operating correctly or whether the gauge itself is at fault. If the fault lies in the gauge, it should be replaced.

LOW OIL PRESSURE
(All Models)

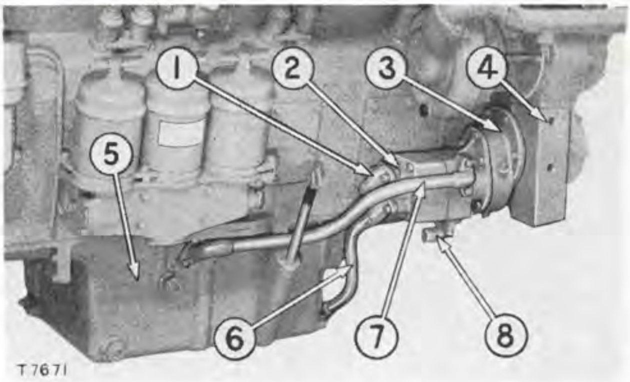
If the oil pressure gauge indicates a low oil pressure or none at all, check for the following.

1. Low oil level in the crankcase.
2. Clogged oil filters.
3. Defective oil gauge or clogged or broken line to the gauge.
4. Leaking connections.
5. Worn bearings with excessive clearance.
6. Oil pressure control by-pass valve holding open.
7. Worn oil pump gears.

OIL PUMP
(D17000L)

The locomotive engine is equipped with an externally-mounted oil pump **(2)**, consisting of the scavenger pump **(9)** and the pressure pump **(10)**. This assembly is attached to and driven by the oil pump drive **(3)**. The oil pump drive is mounted into the right rear side of the timing gear housing **(4)** and is driven by the right camshaft gear.

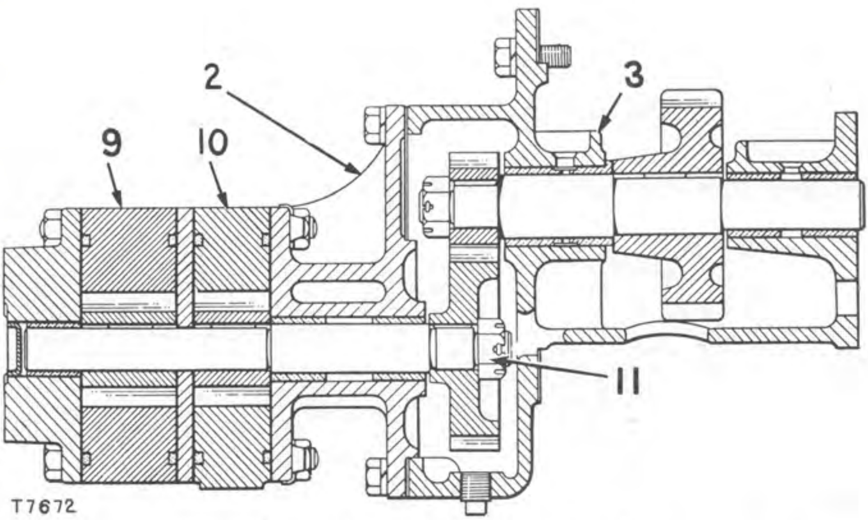
The scavenger pump oil suction line **(6)** draws the oil from the lower sump of the oil pan **(5)** and delivers the oil to the supply tank through the scavenger pump oil pressure line **(1)** (which is only partially shown). The



OIL PUMP
1—Scavenger pump oil line (pressure). 2—Oil pump. 3—Oil pump drive. 4—Timing gear housing. 5—Oil pan. 6—Scavenger pump oil line (suction). 7—Pressure pump oil line (pressure). 8—Pressure pump oil line (suction).

pressure pump oil suction line **(8)** (partially shown) draws oil from the supply tank and the oil is discharged into the engine by the pressure pump oil pressure line **(7)**.

The oil pump consists of two sections, the pressure pump **(10)** and the scavenger pump **(9)** which are driven by the same drive shaft and gear **(11)**. See the topic, OIL PAN (D17000L) for a complete story on the upper and lower sumps, and their association with the oil pump.



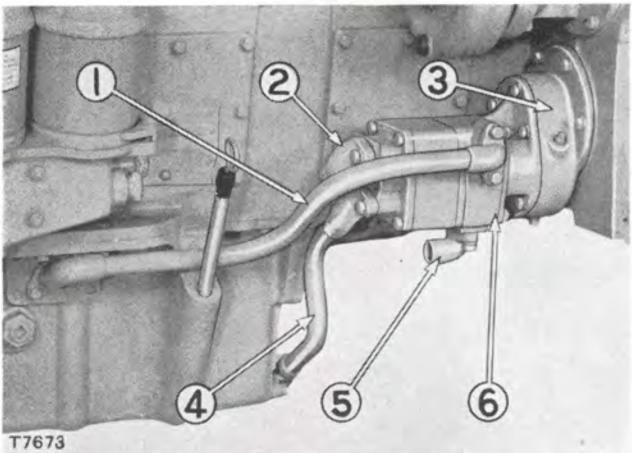
OIL PUMP AND OIL PUMP DRIVE
2—Oil pump. 3—Oil pump drive. 9—Scavenger pump. 10—Pressure pump. 11—Drive shaft and gear.

Oil Pump Removal and Installation (D17000L)

Remove the oil line **(1)** from the oil pump and the oil pan.

Remove the oil line **(4)** from the rear of the oil pump to the bottom of the oil pan.

Remove the oil line **(2)** at the top rear of the oil pump. Partly shown, this line delivers oil to the supply tank.



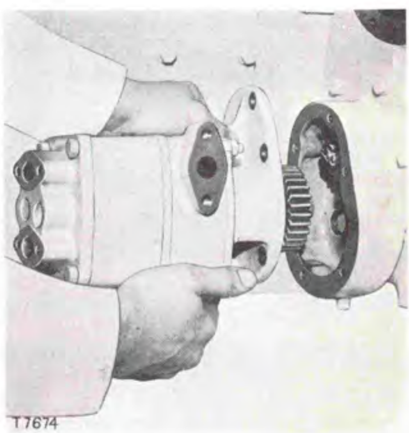
OIL PUMP REMOVAL
1—Oil line (pressure). 2—Oil line (pressure). 3—Oil pump drive. 4—Oil line (suction). 5—Oil line (suction). 6—Oil pump.

Remove the oil line **(5)** at the bottom center of the oil pump. Partly shown, this line draws the oil out of the supply tank.

Remove the capscrews holding the oil pump **(6)** to the oil pump drive **(3)** and remove the oil pump.

REMOVING OIL PUMP

◆



When installing the oil pump, use new gaskets, and clean all parts and oil lines.

Oil Pump Disassembly (D17000L)

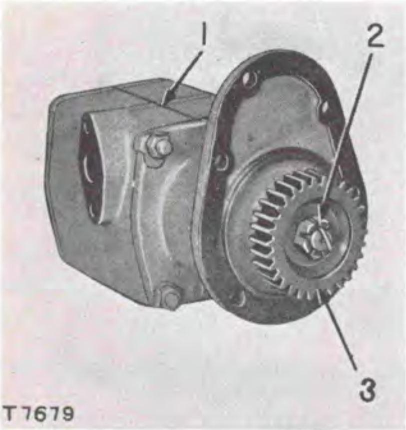
Before disassembling the oil pump, make an identification mark **(1)** as shown, to assure proper location of the parts when they are assembled.

NOTE

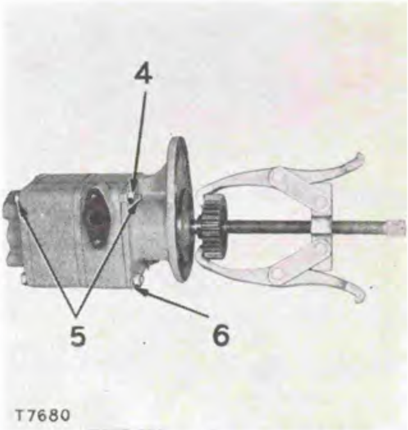
When disassembling the oil pump, note the position of the pump idler gears, so they can be installed in their original position when assembled. (The idler gears have an oil groove machined on one end).

Remove the cotter pin and nut **(2)**.

Remove the oil pump gear **(3)** using the 8B7546 Puller.



OIL PUMP GEAR REMOVAL
1—Identification mark. 2—Cotter pin and nut. 3—Oil pump gear.



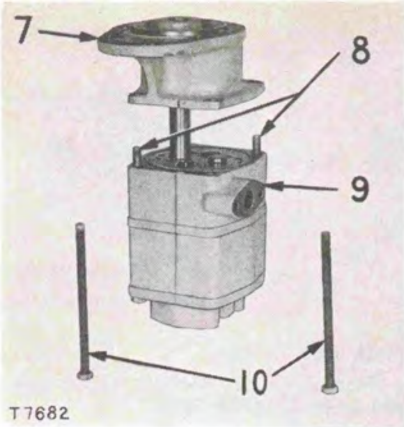
REMOVING OIL PUMP GEAR
4—Nut. 5—Bolt. 6—Lock.

Bend the locks **(6)** and remove the nuts **(4)** from the bolts **(5)**. Slide out the standard bolts **(10)** and permit the machine-ground bolts **(8)** to remain in the oil pump assembly. The machine-ground bolts serve as dowels to keep the pump in alignment.

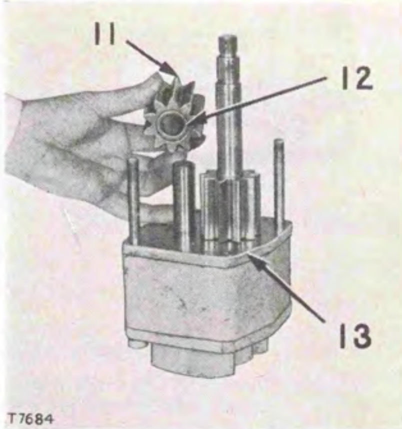
Remove the adapter assembly **(7)**.

Remove the pressure pump body **(9)**.

Remove the pressure pump idler gear **(11)**, noting that the position of the oil groove **(12)** is toward the spacer plate **(13)**.



REMOVING ADAPTER ASSEMBLY AND PRESSURE PUMP BODY
7—Adapter assembly. 8—Machine-ground bolts. 9—Pressure pump body. 10—Standard bolts.

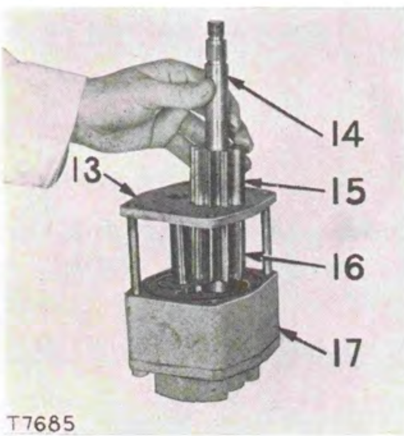


OIL GROOVE IN PRESSURE PUMP IDLER GEAR
11—Pressure pump idler gear. 12—Oil groove. 13—Spacer plate.

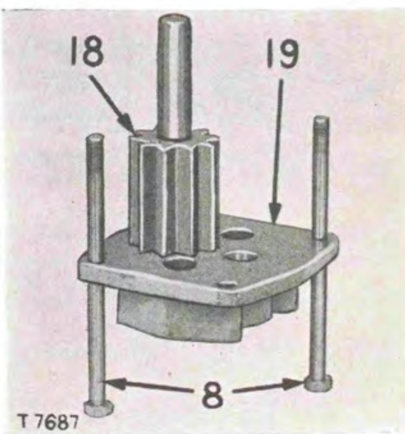
Remove the drive shaft **(14)**, the pressure pump drive gear **(15)**, the spacer plate **(13)** and the scavenger pump drive gear **(16)** as a unit.

Remove the scavenger pump body **(17)**.

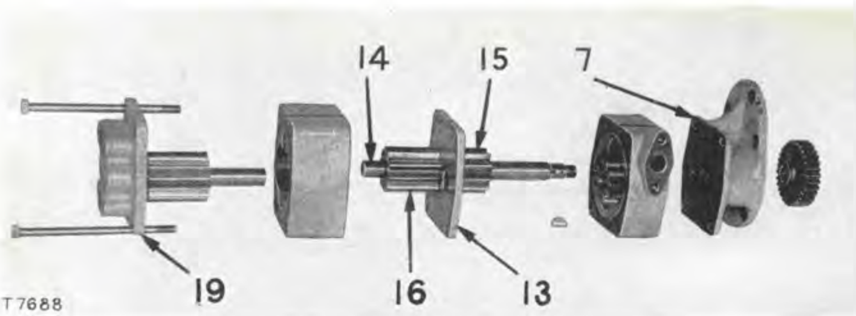
Remove the scavenger pump idler gear **(18)** and the machine-ground bolts **(8)** from the end cover **(19)**. The oil groove in the scavenger pump idler gear is toward the end cover.



REMOVING DRIVE SHAFT AND DRIVE GEARS
13—Spacer plate. 14—Drive shaft. 15—Drive gear (pressure pump). 16—Drive gear (scavenger pump). 17—Scavenger pump body.



SCAVENGER PUMP IDLER GEAR REMOVAL
8—Machine-ground bolts. 18—Scavenger pump idler gear. 19—End cover.

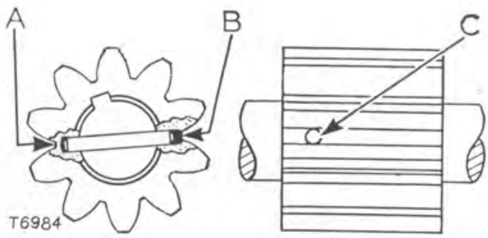


ADAPTER ASSEMBLY AND END COVER
7—Adapter assembly. 13—Spacer plate. 14—Drive shaft. 15—Pressure pump drive gear. 16—Scavenger pump drive gear. 19—End cover.

The bushings in the adapter assembly **(7)** and the end cover **(19)** may be replaced if necessary by the use of an arbor press.

Ordinarily, oil pump gears should not have to be replaced unless they have worn sufficiently to cause a considerable drop in oil pressure or unless they have been damaged. If it is necessary to replace the drive gears **(15)** and **(16)**, they can be removed from the drive shaft **(14)** in the following manner.

Using a $1/8''$ drill clean up the hole **(B)** that has been peened to retain the pin **(C)** and drill out at point **(A)**.



REMOVING PIN FROM DRIVE GEAR

◆

Using a drift pin through the hole, drive out the straight pin **(C)** from the gear and shaft and remove the pressure pump drive gear from the shaft.

Remove the key and the spacer plate **(13)** from the drive shaft **(14)**.

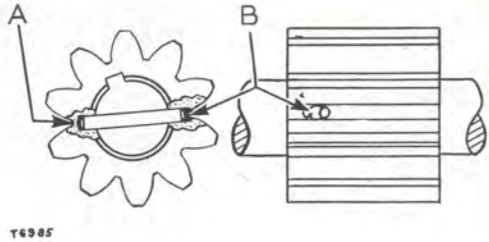
Press the scavenger pump drive gear from the shaft.

Assembling the Oil Pump (D17000L)

When it becomes necessary to replace the gears, inspect the separator plate **(3)**, the adapter assembly **(5)** and the end cover **(1)** for wear adjacent to the ends of the gears.

INSTALLING DRIVE GEAR PIN

◆



Replace any parts that show excessive wear.

When a new pressure pump drive gear and shaft are installed, place the key in the shaft and press the gear on the shaft until the holes in the gear and shaft are in alignment. Using these holes as a guide, drill a 1/8″ hole into the gear and shaft to a depth of 1 9/32 inches. Install a new pin and peen the gear **(B)** over the end of the pin.

CAUTION

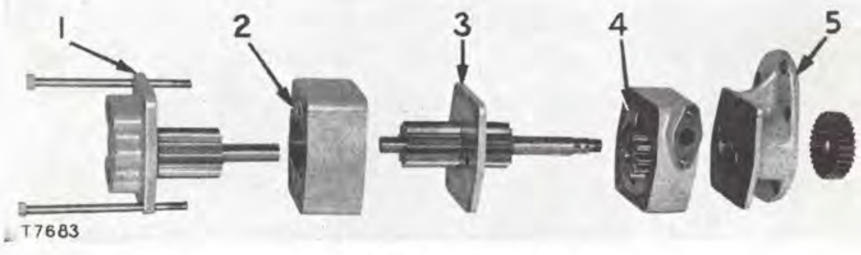
> The end of the pin should not protrude beyond the surface of the gear. Any roughness at **(A)** or **(B)** caused by drilling or peening should be removed from the gear teeth.

When reassembling the pump, use the identification mark as described in the topic, OIL PUMP DISASSEMBLY (D17000L), as a guide.

Install new ring seals **(2)** and **(4)**.

Any nicks or burrs should be dressed off with crocus cloth. Pull the nuts down evenly on the studs which pass through the pump. Check that the shaft turns freely with no binding or drag on the gears. If the gears bind, loosen the nuts slightly and relocate the pump bodies by tapping them lightly until the shaft turns freely. Retighten the nuts and bend the locks.

The clearances between the moving and stationary parts of the pump are necessarily small and for this reason, ground joints instead of gaskets are used between the pump bodies and the separator plate. The clearance between the gears and the separator plate is .002″-.004″.



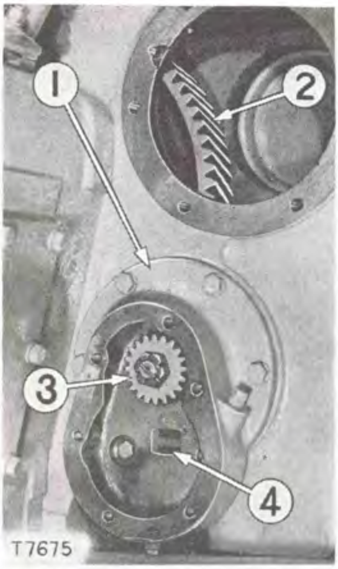
OIL PUMP DISASSEMBLED

1—End cover. 2—Ring seal. 3—Separator plate. 4—Ring seal. 5—Adapter assembly.

OIL PUMP DRIVE
(D17000L)

The oil pump drive **(1)** is driven by the right camshaft gear **(2)**. When the oil pump is mounted on the oil pump drive, it is driven by the gear **(3)**.

The hole **(4)** maintains the oil level in the oil pump drive.



OIL PUMP DRIVE

1—Oil pump drive. 2—Right camshaft gear. 3—Gear. 4—Hole.

◆

Oil Pump Drive Removal and Installation (D17000L)

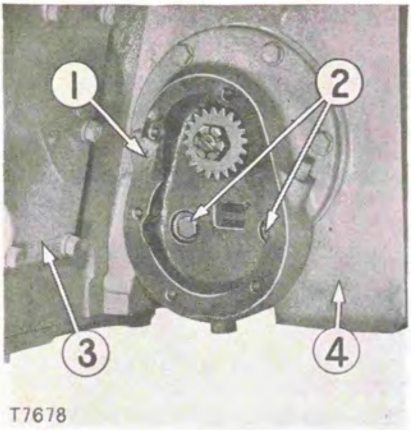
The oil pump drive **(1)** is mounted into the right rear side of the timing gear housing **(4)**. The oil pump is mounted on and driven by the oil pump drive.

The oil pump must first be removed, to permit the removal of the oil pump drive. See the topic, OIL PUMP REMOVAL AND INSTALLATION (D17000L). The oil pump drive is partly secured to the timing gear housing by the capscrews **(2)** which are inaccessible until the oil pump has been removed.

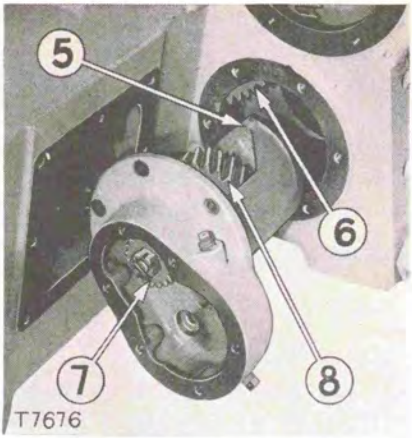
Remove the right front crankcase inspection plate **(3)**.

Remove all the capscrews holding the oil pump drive to the timing gear housing.

The oil pump drive must be positioned as shown when removing or installing, to permit the forward end **(5)** of the pump drive to clear the camshaft gear **(6)**.



OIL PUMP DRIVE
1—Oil pump drive. 2—Capscrews. 3—Inspection plate. 4—Timing gear housing.

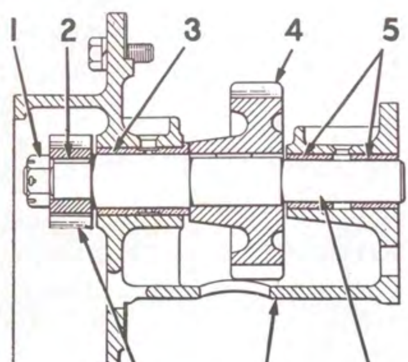


OIL PUMP REMOVAL
5—Forward end (oil pump drive). 6—Camshaft gear. 7—Gear. 8—Gear.

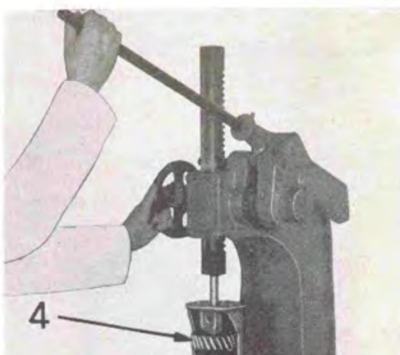
When installing the oil pump drive, the gear **(8)** is engaged into the camshaft gear **(6)**. Secure the oil pump drive to the timing gear housing. Check the backlash between the gears **(8)** and **(6)** by moving the gear **(7)**. The backlash is pre-determined, and this check is made only to see that the oil pump drive has been installed correctly into the timing gear housing.

Oil Pump Drive Disassembly (D17000L)

Remove the cotter pin and nut **(1)**.



OIL PUMP DRIVE ASSEMBLY
1—Cotter pin and nut. 2—Woodruff key. 3—Bushing. 4—Gear. 5—Bushings. 6—Gear. 7—Housing. 8—Shaft.



PRESSING SHAFT FROM GEAR AND HOUSING
4—Gear.

Remove the gear **(6)** (this gear is only a light press fit) and the woodruff key **(2)**.

Press the shaft **(8)** from the gear **(4)** and the oil pump drive housing **(7)**.

Lift out the gear.

The bushings **(3)** and **(5)** can be pressed out and replaced with new ones by the use of an arbor press.

The bushings need not be replaced unless excessive wear is evident.

OIL PAN
(D17000L)

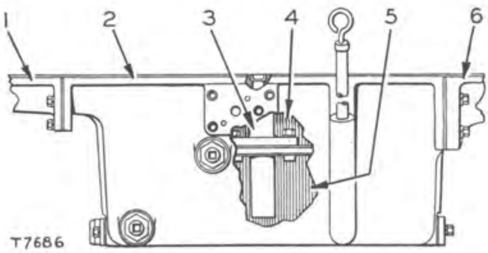
The locomotive oil pan is made in three sections (some earlier models were the two-section type). This facilitates easier removal of the oil pan since it can be removed in sections.

The front pan **(6)** and the rear pan **(1)** are shallow and permit the oil to drain into the center pan assembly **(2)**.

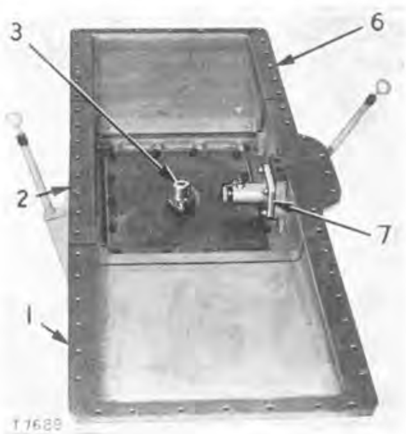
OIL PAN

1—Rear pan. 2—Center pan assembly. 3—Overflow pipe. 4—Upper sump. 5—Lower sump. 6—Front pan.

◆



The center pan assembly **(2)** consists of the following. The upper sump **(4)**, the lower sump **(5)**, the overflow pipe **(3)** and the oil pressure control by-pass valve **(7)**. After the oil has lubricated the engine, it drops or drains into the upper sump. The oil overflows into the overflow pipe **(3)** to the lower sump. The upper sump acts as a settling basin to trap condensation and other foreign materials.



UPPER SUMP OF OIL PAN (D17000L)

1—Rear pan. 2—Center pan assembly. 3—Overflow pipe. 6—Front pan. 7—Oil pressure control by-pass valve.

◆

The oil pressure control by-pass valve is mounted in the oil pan within the upper sump and controls the inlet supply of oil admitted to the engine. See the topic, OIL PRESSURE CONTROL BY-PASS VALVE (D17000L).

Oil Pan Removal and Installation (D17000L)

The oil pan can be removed in the following manner.

Place a jack **(1)** under front end of the oil pan **(3)** and another jack under the rear end of the oil pan, using a block of wood between the oil pan and the jacks as illustrated.

Place a large wooden block **(2)** directly below the oil pan.

Remove all the capscrews holding the oil pan except the two on each side.

Install two 3/8" guide pins **(4)** on each side of the crankcase. (These guide pins will keep the oil pan in alignment with the crankcase when the oil pan is being removed or installed).

Remove the remaining capscrews.

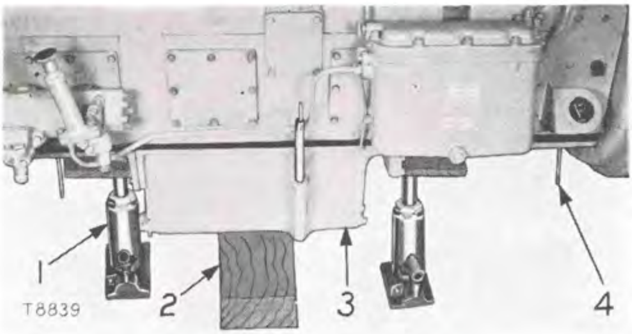
Lower the oil pan onto the wooden block **(2)**.

Remove the guide pins and slide the oil pan out on the wooden block.

The locomotive oil pan is shown in the illustration, but all oil pans can be removed in the manner described above, with the exception of the use of guide pins.

The locomotive oil pan consists of three sections and can be removed by sections if desired, without removing the complete assembly.

The oil pan also can be installed by using the jacks to lift it into place.



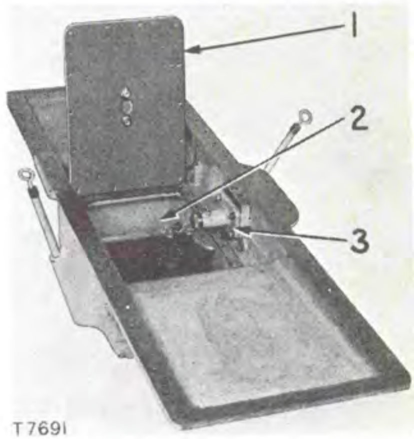
OIL PAN REMOVAL (D17000L ILLUSTRATED)
1—Jack. 2—Wooden block. 3—Oil pan. 4—3/8" guide pin.

Oil Pan Disassembly and Assembly (D17000L)

Remove the oil pan separating cover **(1)**. Clean out the lower sump **(2)**.

Using air pressure check all oil passages in the oil pan seeing that they are open, and that the pressure control by-pass valve is operating.

Remove the nuts and lockwashers holding the pressure control by-pass valve assembly **(3)** and remove the valve assembly. See the topic, OIL PRESSURE CONTROL BY-PASS VALVE (D17000L).



OIL PAN SEPARATING COVER REMOVAL

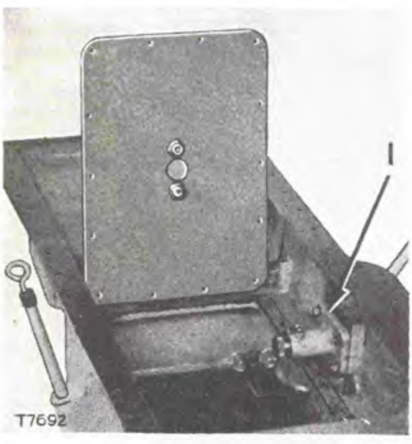
1—Separating cover. 2—Lower sump. 3—Oil pressure control by-pass valve assembly.

◆

OIL PRESSURE CONTROL BY-PASS VALVE (D17000L)

The pressure control by-pass valve assembly **(1)** is located in the upper sump **(8)** of the oil pan. See the topics, OIL PAN (D17000L) and OIL PAN DISASSEMBLY AND ASSEMBLY (D17000L).

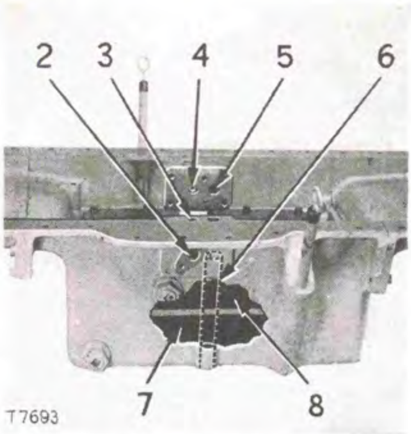
The oil enters the oil pan at the horizontal passage **(2)** (from the pressure pump section of the oil pump). This passage is connected to the



LOCATION OF PRESSURE CONTROL BY-PASS VALVE (VIEW FROM FRONT)

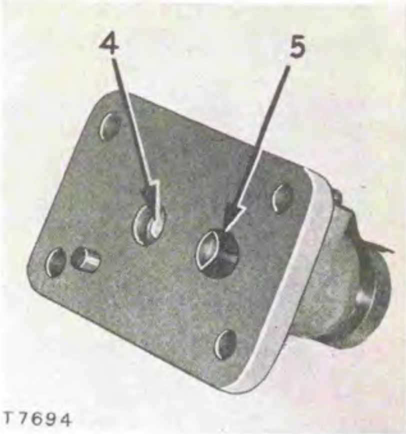
1—Pressure control by-pass valve assembly. (With separating cover removed to show lower sump).

◆



FLOW OF OIL TO PRESSURE CONTROL VALVE (CONTROL VALVE RAISED UP OUT OF POSITION—VIEW FROM LEFT SIDE)

2—Horizontal passage. 3—Vertical passage. 4—Plunger. 5—Passage (in control valve housing). 6—Passage (in oil pan to lower sump). 7—Lower sump. 8—Upper sump.



PRESSURE CONTROL VALVE

4—Plunger. 5—Passage (showing the pressure control by-pass valve as it seats in housing).

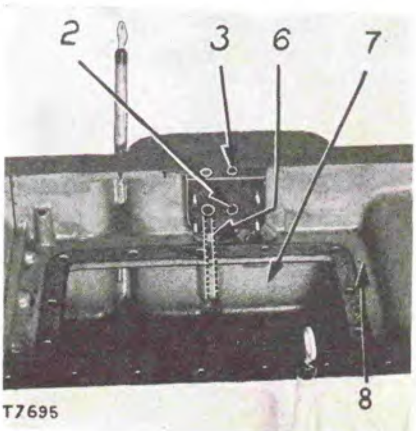
vertical passage **(3)** which delivers the oil into another passage in the cylinder block.

The oil pump supplies more oil than required for engine lubrication, thus requiring a by-pass valve. The plunger **(4)** is part of the by-pass valve assembly **(1)** and seats in the horizontal passage **(2)** When the oil pressure exceeds the normal amount required for engine lubrication, the pressure unseats the plunger **(4)**. The surplus oil is then by-passed through the passages **(5)** and **(6)** to the lower sump **(7)** where it is picked up by the scavenger pump and delivered to the supply tank.

PASSAGES IN OIL PAN

2—Horizontal passage. 3—Vertical passage. 6—Passage (to lower sump). 7—Lower sump. 8—Upper sump.

◆



See the topics, OIL PUMP (D17000L) and LUBRICATING SYSTEM, for complete description of the lubricating system.

Disassembling the Oil Pressure Control By-Pass Valve (D17000L)

If the oil pressure control by-pass valve assembly is disassembled for any reason, notice in particular the number of threads on the adjusting screw **(1)** that are out of the housing **(2)**. Use this as a guide when installing the screw.

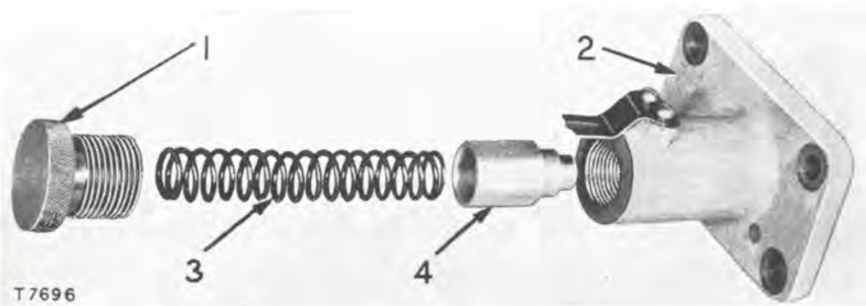
Remove the adjusting screw **(1)**, the spring **(3)** and the plunger **(4)**.

Check the seats of the plunger and the housing for any roughness.

When assembling, adjust the screw to its original position. The spring pressure on the plunger **(4)** can be adjusted by turning the screw in or out.

Turning the screw in creates a greater spring pressure on the plunger, which raises the engine oil pressure through by-passing a smaller quantity of oil to the lower sump.

Turning the screw out permits the oil pressure to unseat the control plunger more easily and allows a greater quantity of oil to by-pass to the lower sump.

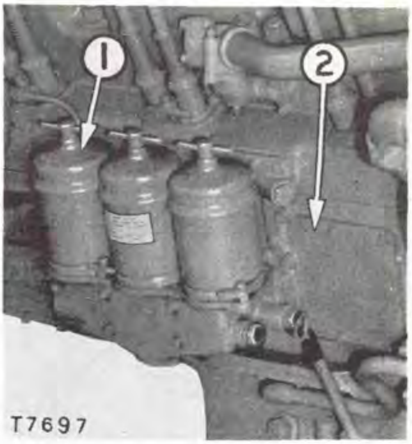


OIL PRESSURE CONTROL BY-PASS VALVE DISASSEMBLED
1—Adjusting screw. 2—Housing. 3—Spring. 4—Plunger.

OIL FILTERS AND BY-PASS VALVES (D17000L)

The oil filters **(1)** and oil filter base are located on the right side of the engine and are mounted on the oil filter manifold **(2)** which in turn is mounted on the crankcase.

Each filter has an inner metallic strainer element **(6)** and an outer metallic strainer element **(3)** which are removable and can be washed. See the topic, CHECKING THE OIL FILTERS AND OIL FILTER BASE (D17000L).

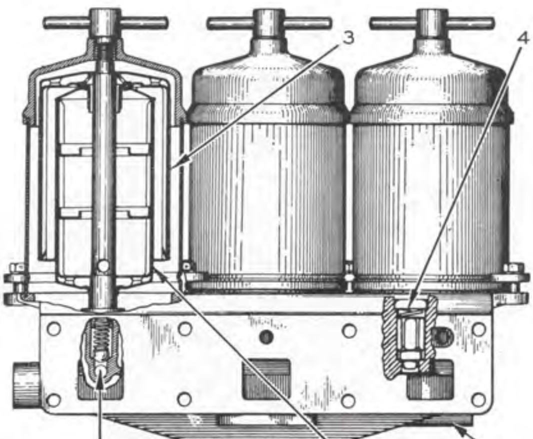


LOCATION OF OIL FILTERS
1—Oil filter. 2—Oil filter manifold.

◆

If the metallic strainer elements should become clogged, the oil filter by-pass valves **(5)** are located in a position to permit the oil to by-pass the metallic elements and to go directly to the bearings. Each filter has an oil filter by-pass valve to serve it.

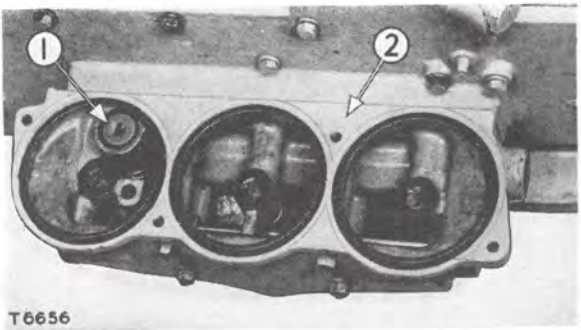
The oil cooler by-pass valve **(4)** is located in the oil filter base **(7)**. If the oil cooler should become clogged, and the flow of oil is restricted or the oil is cold or heavy enough to cause a high pressure, the oil cooler by-pass valve will become unseated and permit the oil to by-pass the oil cooler. Thus, the engine is assured lubrication, even if a restriction or a high pressure occurs in the filters or the oil cooler. See the topics, OIL COOLER BY-PASS VALVE (D17000L) and FLOW OF OIL THROUGH OIL FILTER BASE (D17000L).



METALLIC FILTER ELEMENTS AND BY-PASS VALVES
3—Outer metallic strainer element. 4—Oil cooler by-pass valve. 5—Oil filter by-pass valve. 6—Inner metallic strainer element. 7—Oil filter base.

Oil Cooler By-pass Valve (D17000L)

The oil cooler by-pass valve **(1)** is located in the oil filter base **(2)** and is a safety feature to permit the oil to by-pass the oil cooler. The valve opens when there is a restriction in the oil cooler due either to being clogged or if the oil is cold and heavy and does not need to be cooled. See the topic, OIL FILTER AND OIL FILTER BASE DISASSEMBLY (D17000L) for the removal of the oil filters.

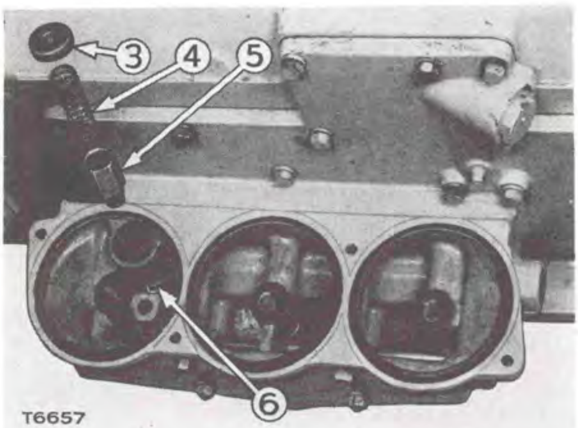


LOCATION OF THE OIL COOLER BY-PASS VALVE
1—Oil cooler by-pass valve. 2—Oil filter base.

When excessive oil pressure unseats the plunger, the oil is then permitted to go through the passage **(6)**, thus by-passing the oil cooler.

The oil cooler by-pass valve is removed as follows. Remove the plug **(3)**, the spring **(4)** and lift out the plunger **(5)**.

Check the seats of the plunger and the oil filter base, wash and flush out the oil filter base and assemble in reverse order of disassembly.



OIL COOLER BY-PASS VALVE REMOVED
3—Plug. 4—Spring. 5—Plunger. 6—Passage.

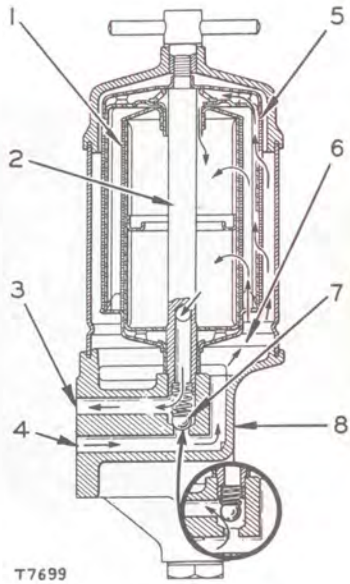
Flow of Oil through Oil Filters (D17000L)

The oil enters the oil filter base **(8)** at the inlet passage **(4)** and travels into the oil filter compartment **(6)**.

The oil passes through either the outer metallic strainer element **(5)** or the inner metallic strainer element **(1)**. The metallic elements are made in such a way as to permit the oil to pass through only one of the elements, then it is delivered on for lubrication.

The filtered oil passes down the center of the hollow filter stud **(2)** to the outlet passage **(3)** in the oil filter base.

The oil filter by-pass valve **(7)** is located so as to permit the oil to by-pass the filter elements, if they become clogged. The oil filter by-pass valve is shown in the open position in the inset. When the by-pass valve is in the open position, the oil takes the path of least resistance and passes from passage **(4)** directly into passage **(3)**.



FLOW OF OIL THROUGH OIL FILTERS (END VIEW FROM REAR)

1—Inner metallic strainer element. 2—Filter stud. 3—Outlet passage. 4—Inlet passage. 5—Outer metallic strainer element. 6—Oil filter compartment. 7—Oil filter by-pass (spring and ball). 8—Filter base.

◆

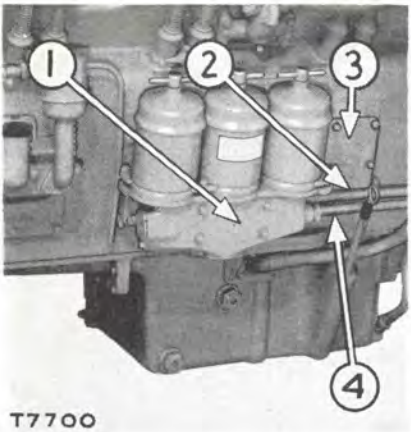
Disconnecting Oil Filters and Oil Filter Base (All Models, D17000L Illustrated)

Prepare the oil filter and oil filter base for removal from the oil filter manifold **(3)** by performing the following steps.

Drain the oil from the oil filters and from the oil filter base **(1)**.

Remove the oil tube **(2)** (outlet from filter base to oil cooler).

Remove the oil tube **(4)** (inlet to filter base from the oil cooler).



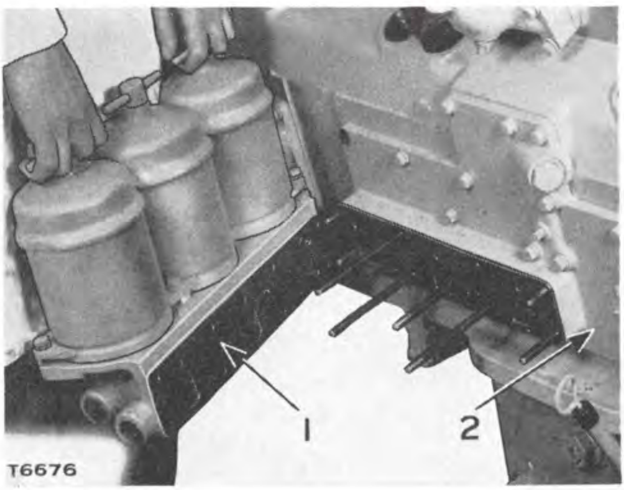
DISCONNECTING
OIL FILTERS AND OIL FILTER BASE

1—Oil filters and oil filter base. 2—Oil tube (outlet from filter base to oil cooler). 3—Oil filter manifold. 4—Oil tube (inlet to filter base from the oil cooler).

◆

Oil Filter and Oil Filter Base Removal (All Models, D17000L Illustrated)

Remove all the nuts and lockwashers holding the oil filter base to the oil filter manifold **(2)** and remove the oil filters and the oil filter base **(1)** as a unit.



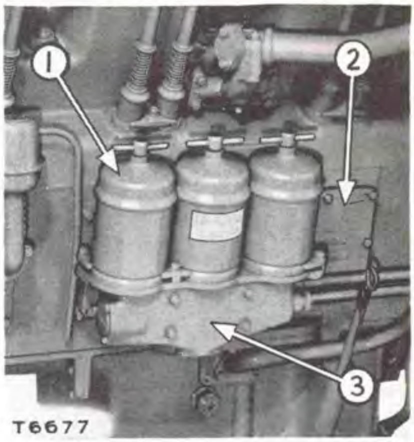
REMOVING OIL FILTERS AND OIL FILTER BASE
1—Oil filters and oil filter base. 2—Oil filter manifold.

Flow of Oil through Oil Filter Base (D17000L)

The oil filters **(1)** are mounted to the oil filter base **(3)**, and the oil filter base is attached to the oil filter manifold **(2)**.

The oil passes through the oil filter base in the following manner.

Uncooled, unfiltered oil enters the passages **(8)** from the elongated passage **(6)** in the oil filter manifold **(2)**.



LOCATION OF OIL FILTER BASE

1—Oil filter. 2—Oil filter manifold. 3—Oil filter base.

◆

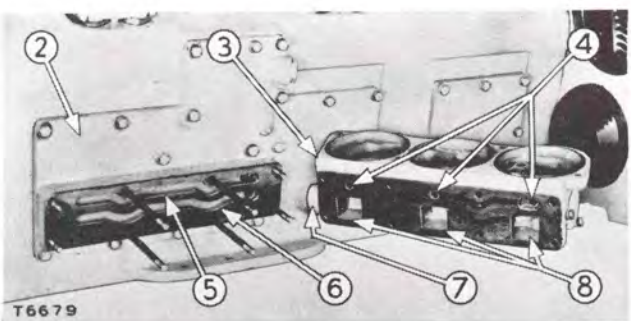
The passage **(9)** takes the uncooled, unfiltered oil from the passages **(8)** to the outlet **(7)**.

The outlet **(7)** delivers the oil (through an oil tube) to the oil cooler.

The oil that has been cooled enters the oil filter base at the inlet **(13)** and flows into the passage **(12)** where it is then admitted to the oil filters and is filtered.

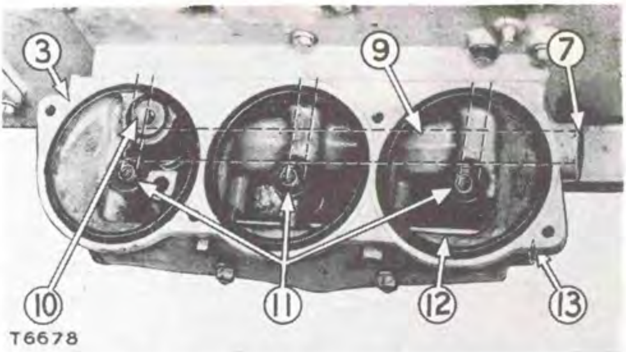
The filtered oil enters the passages **(11)** and passes through the oil filter base where the passages **(4)** discharge the filtered oil into the elongated passage **(5)** of the oil filter manifold where it is then delivered into the engine for lubrication.

The oil cooler by-pass valve **(10)** is located in a position to permit the oil to go directly from the oil filter manifold to the oil filters when the by-pass valve is unseated. See the topic, OIL COOLER BY-PASS VALVE (D17000L) for further information.



FLOW OF OIL THROUGH OIL FILTER BASE

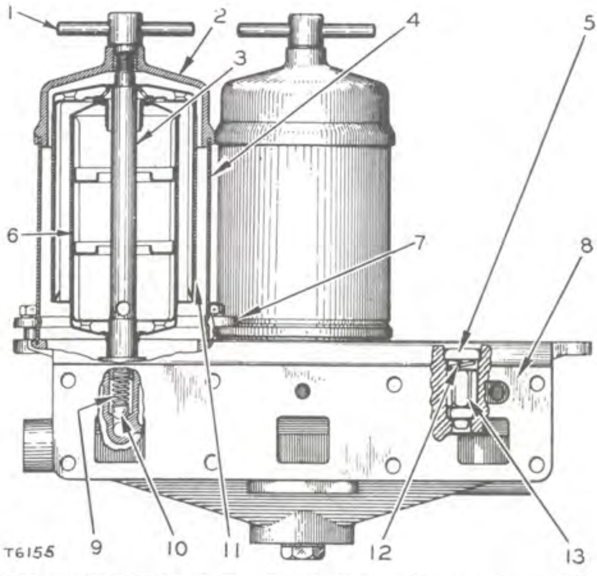
2—Oil filter manifold. 3—Oil filter base. 4—Passages (filtered oil). 5—Elongated passage (filtered oil). 6—Elongated passage (unfiltered oil). 7—Outlet. 8—Passages (unfiltered oil).



FLOW OF OIL THROUGH OIL FILTER BASE
3—Oil filter base. 7—Outlet. 9—Passage (unfiltered, uncooled oil). 10—Oil cooler by-pass valve. 11—Passages (filtered oil). 12—Passage (unfiltered, cooled oil). 13—Inlet.

Oil Filter and Oil Filter Base Disassembly (D17000L)

Turn the handle **(1)** in a counterclockwise direction to loosen, and remove the handle and the cover **(2)**.

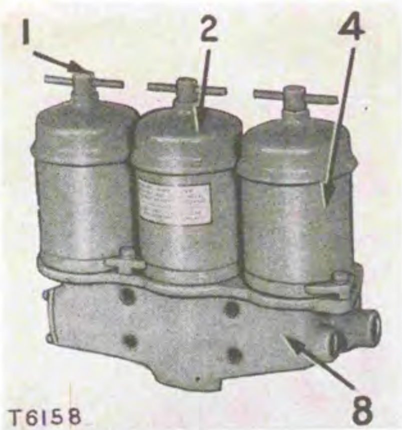


DISASSEMBLING THE OIL FILTERS AND FILTER BASE
1—Handle. 2—Cover. 3—Filter stud. 4—Case. 5—Plug. 6—Inner metallic strainer element. 7—Capscrew and clamp. 8—Oil filter base. 9—Spring. 10—Ball. 11—Outer metallic strainer element. 12—Spring. 13—Plunger.

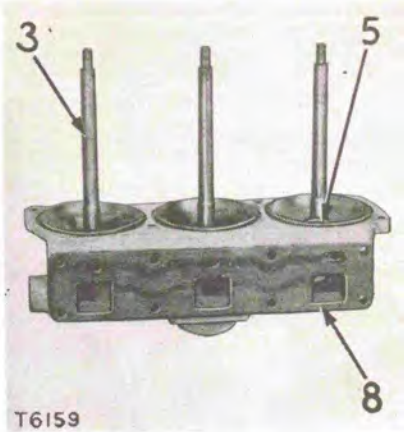
Lift out the outer metallic strainer element **(11)**.

Lift out the inner metallic strainer element **(6)**.

Remove the capscrews and clamps **(7)** holding down the case **(4)** and remove the case from the filter base **(8)**.



OIL FILTERS AND OIL FILTER BASE
1—Handle. 2—Cover. 4—Case. 8—Oil filter base.

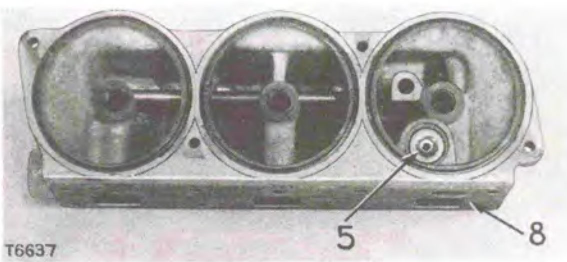


REMOVING FILTER STUDS
3—Filter stud. 5—Plug. 8—Oil filter base.

Remove the filter stud **(3)** using a rod or round bar stock inserted through the hole in the filter stud, so as not to damage the stud. The metallic elements fit snugly over the stud.

Remove the spring **(9)** and the ball **(10)**, which form the oil filter by-pass valve, as described in the topic, OIL FILTERS AND BY-PASS VALVES (D17000L).

Remove the oil cooler by-pass valve assembly which consists of the plug **(5)**, the spring **(12)** and the plunger **(13)**. See the topic, OIL COOLER BY-PASS VALVE (D17000L).



REMOVING OIL COOLER BY-PASS
5—Plug. 8—Oil filter base.

Checking the Oil Filters and Oil Filter Base (D17000L)

Eventually, gums and lacquers may clog the metallic elements even though they appear clean on the outside. The internal condition of the elements can be checked by comparing them with a new element. Plug the holes in the bottom of both elements and immerse them to the top rim in kerosene. Compare the rate at which the kerosene rises inside the elements. Discard the used element if it is not at least three-fourths full when the new element is completely filled.

Make sure that all passages are open, and that the by-pass valves are seating properly.

Assembling the Oil Filters and Oil Filter Base (D17000L)

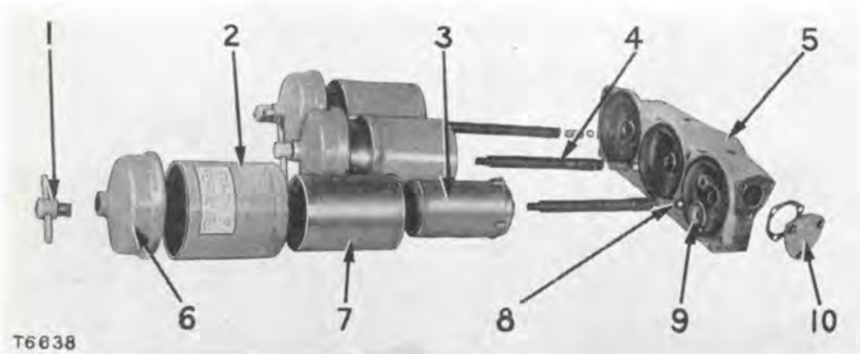
Install the oil cooler by-pass valve assembly **(9)**. See the topic, OIL COOLER BY-PASS VALVE (D17000L).

Install the oil filter by-pass assembly **(8)** (consisting of a spring and ball), the filter studs **(4)** and the gasket and cover **(10)**.

Install the case **(2)** using new gaskets where the case seats in the filter base **(5)**.

Install the inner metallic strainer element **(3)** and the outer metallic strainer element **(7)**.

Install the cover **(6)** and the handle **(1)** using new gaskets. Position the covers so they will have the flat machined sides together. This will permit the covers to be tightened down without interference from the cover next to it.

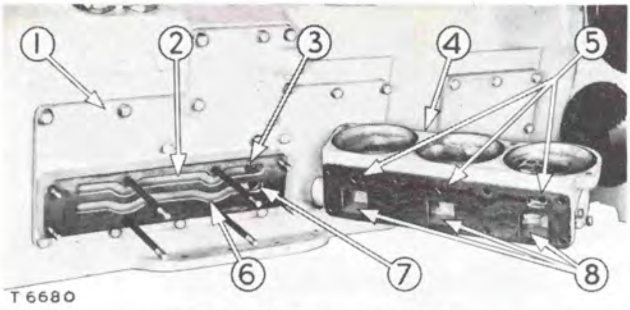


ASSEMBLING THE OIL FILTER AND FILTER BASE
1—Handle. 2—Case. 3—Inner metallic strainer element. 4—Filter stud. 5—Filter base. 6—Cover. 7—Outer metallic strainer element. 8—Oil filter by-pass valve (spring and ball). 9—Oil cooler by-pass valve. 10—Gasket and cover.

OIL FILTER MANIFOLD (D17000L)

The unfiltered oil from the engine oil pump is discharged into the oil filter manifold **(1)** and through the passage **(7)**. The elongated passage **(6)** delivers the unfiltered oil into the passages **(8)** of the oil filter base **(4)**.

The oil is delivered to the oil cooler, is cooled and returns through the oil filter base to the filters where it is filtered. For a further description of the oil flow, see the topic, OIL FILTERS AND BY-PASS VALVES (D17000L).



OIL FLOW THROUGH THE OIL FILTER MANIFOLD
1—Oil filter manifold. 2—Elongated passage (filtered oil). 3—Passage (filtered oil outlet). 4—Oil filter base. 5—Passages (outlet, filtered oil). 6—Elongated passage (unfiltered oil). 7—Passage (inlet to oil filter manifold). 8—Passages (unfiltered oil).

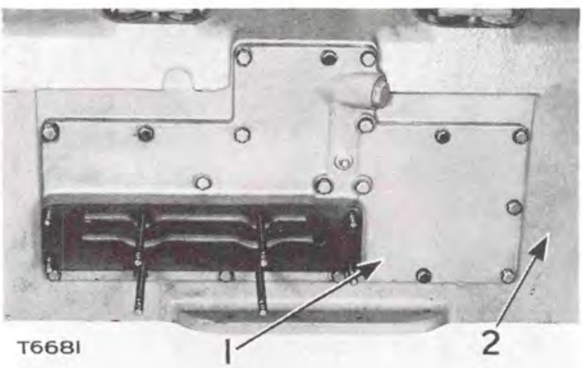
Filtered oil from the passages **(5)** enters the elongated passage **(2)** and returns to the engine crankcase for lubrication at the passage **(3)**. See the topic, OIL FILTER MANIFOLD REMOVAL (ALL MODELS) for illustration showing the passages on the rear side of the oil filter manifold.

Oil Filter Manifold Removal (All Models)

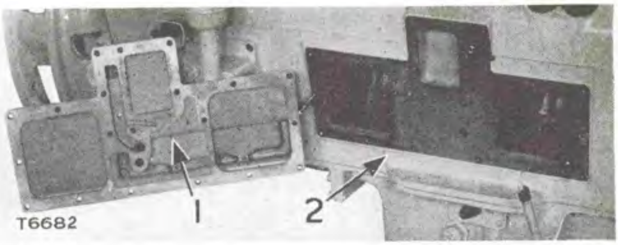
Remove the capscrews holding the oil filter manifold **(1)** to the crankcase **(2)** and remove the oil filter manifold.

Remove the gasket.

If desired, the oil filter manifold can be removed with the oil filter base and the oil filters attached, by removing the combined assemblies in the same manner as described previously.



OIL FILTER MANIFOLD REMOVAL
1—Oil filter manifold. 2—Crankcase.



OIL FILTER MANIFOLD REMOVED
1—Oil filter manifold. 2—Crankcase.

After the manifold has been removed, the center connecting rods can be reached through the openings in the crankcase.

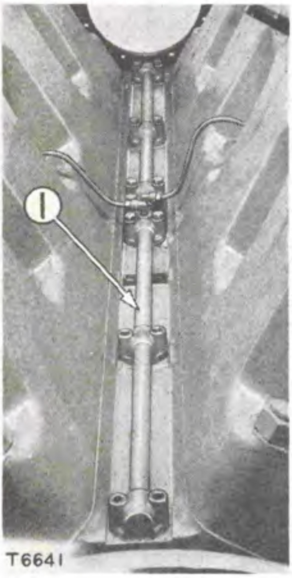
OIL MANIFOLD
(All Models)

The oil manifold **(1)** is mounted on the crankcase, and is located in the V between the two banks of cylinders.

The oil manifold supplies filtered oil to the main bearings, which admit oil to the crankshaft. The crankshaft has passages that supply oil to the connecting rods which in turn supply oil to the piston pins.

Some earlier models did not have the connecting rods drilled to supply oil to the piston pins.

The oil manifold also supplies oil to the timing gear housing, the water pump bushings, the governor bushings and the rocker arm assemblies.



LOCATION OF OIL MANIFOLD
1—Oil manifold.

◆

Oil Manifold Removal and Installation (All Models)

To permit the removal of the oil manifold, remove the fuel pump housing and the governor housing. See the topics in which their removal is described.

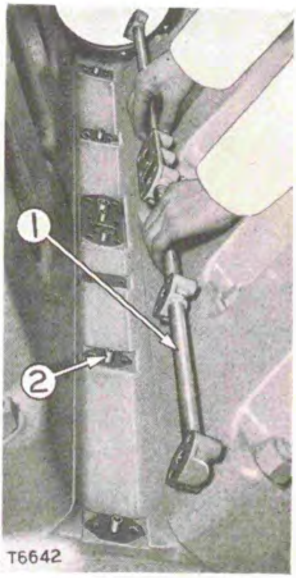
Remove the capscrews and lockwashers holding the oil manifold to the crankcase, and lift the oil manifold **(1)** from the dowels **(2)**.

Before installing the oil manifold, clean out all oil passages. Clean the mating surfaces and install new gaskets. Tighten the capscrews evenly and securely.

REMOVING OIL MANIFOLD

1—Oil manifold. 2—Dowel.

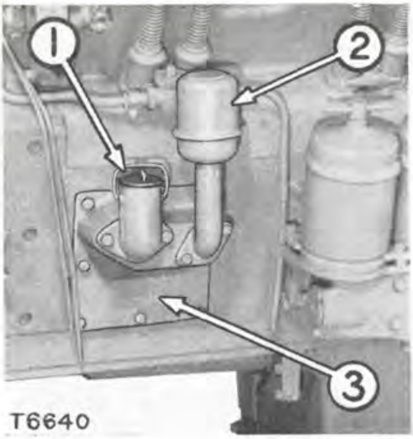
◆



OIL FILLER AND CRANKCASE BREATHER REMOVAL (All Models)

The oil filler **(1)** and the crankcase breather **(2)** are attached to the right rear crankcase inspection plate **(3)**.

Remove the capscrews holding the inspection plate and remove the assembly from the crankcase.



OIL FILLER AND CRANKCASE BREATHER
1—Oil filler. 2—Crankcase breather. 3—Inspection plate.

OIL FILLER AND CRANKCASE BREATHER REMOVED
3—Inspection plate.

FLOW OF THE OIL FROM THE OIL PUMP TO THE OIL MANIFOLD (All Models, D17000L Illustrated)

The accompanying illustration shows the flow of oil from the oil pump through the crankcase **(11)**, the oil filter manifold **(7)**, the oil filter base **(1)**, the oil filters **(5)**, the oil supply tube **(14)** and then to the oil manifold. The oil manifold is not shown in this illustration. See the topic, OIL MANIFOLD (ALL MODELS).

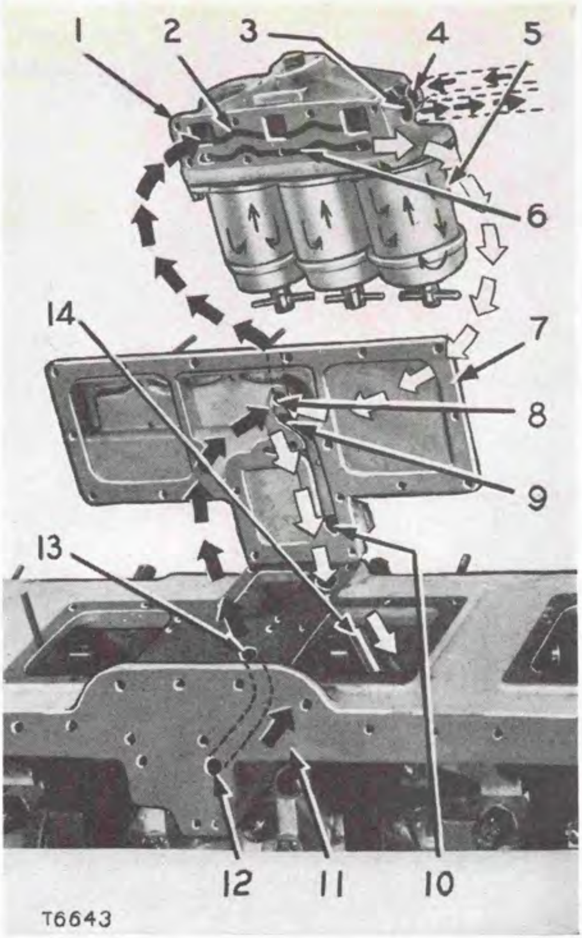
The engine has been placed on its left side, showing the right side bottom view, for better illustration.

The oil flow is as follows. The oil pump supplies oil to the passage **(12)** in the crankcase **(11)**. The passage **(13)** delivers the oil into the oil filter manifold **(7)** at the passage **(8)**. The passages **(13)** and **(8)** are mating passages.

The oil passes through the lower elongated passage of the oil filter manifold (as observed when the engine is in an upright position).

NOTE

The elongated passages are located on the reverse side of the oil filter manifold as it is shown in this illustration. See the topics, OIL FILTER MANIFOLD (D17000L) and OIL FILTER MANIFOLD REMOVAL (ALL MODELS), for a better illustration. When assembled, the elongated passages are in alignment with the outline of these passages **(2)** and **(6)** as shown on the oil filter base **(1)**.



FLOW OF OIL FROM THE OIL PUMP TO THE OIL MANIFOLD (RIGHT SIDE, BOTTOM VIEW)

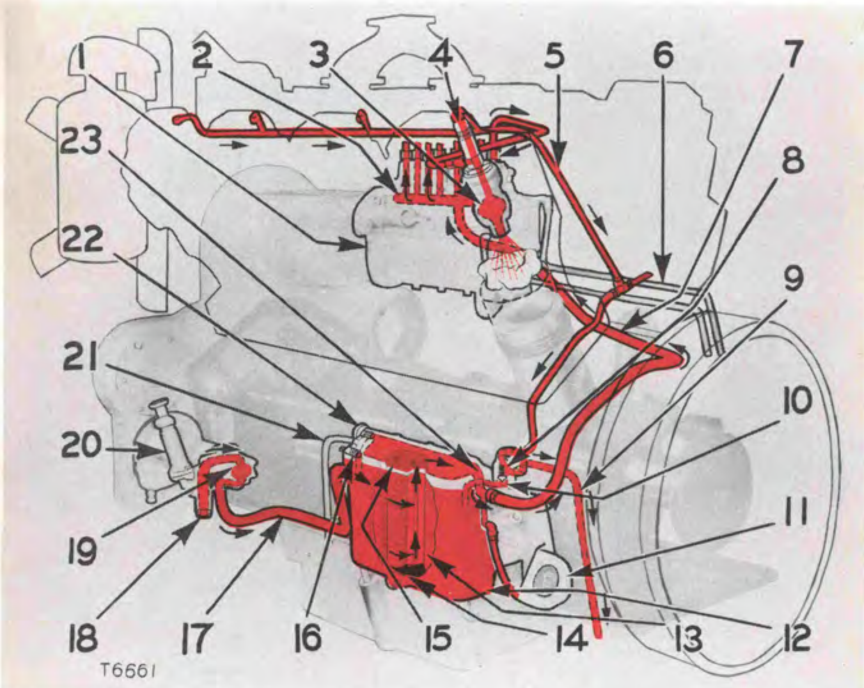
1—Oil filter base. 2—Elongated passage (unfiltered oil). 3—Outlet to oil cooler. 4—Inlet from oil cooler. 5—Oil filters. 6—Elongated passage (filtered oil). 7—Oil filter manifold. 8—Passage (unfiltered oil). 9—Passage (filtered oil). 10—Passage (filtered oil). 11—Crankcase. 12—Passage (inlet to crankcase). 13—Passage (outlet to oil filter manifold). 14—Oil supply tube.

The elongated passage (of the oil filter manifold), which is in alignment with the outline **(2)**, delivers the oil into the oil filter base. The outlet **(3)** (of the oil filter base) delivers the oil to the oil cooler. See the topic, FLOW OF OIL THROUGH THE OIL FILTER BASE (D17000L).

The inlet **(4)** returns the oil from the oil cooler and the oil then goes to the oil filters **(5)**. The oil is filtered, then admitted to the elongated passage of the oil filter manifold which is in alignment with the outline **(6)**. The oil flows through the passages **(9)** and **(10)** to the oil supply tube **(14)** which is pressed into the crankcase. The oil supply tube **(14)** supplies oil to the oil manifold.

The oil manifold (located between the two banks of cylinders on top of the crankcase) supplies oil to the following: the main bearings, the connecting rods bearings, the piston pin bushings, the governor bushings, the water pump bushings and the rocker arm assemblies. See the topic, OIL MANIFOLD (ALL MODELS).

Fuel System
(All Models)



FUEL SYSTEM
1—Fuel injection pump housing. 2—Fuel supply manifold. 3—Pre-combustion chamber. 4—Fuel injection valve. 5—Overflow tube. 6—Fuel pump bleed tube. 7—Fuel line. 8—By-pass valve. 9—Fuel return tube. 10—Passage (from lower chamber to by-pass valve seat). 11—Fuel pressure gauge. 12—Filter housing. 13—Filter element. 14—Lower chamber. 15—Upper chamber. 16—Bleed vent (lower chamber). 17—Fuel line. 18—Inlet to transfer pump. 19—Fuel transfer pump. 20—Hand priming pump. 21—Bleed tube. 22—Bleed vent (upper chamber). 23—Drilled passage.

Fuel System

(All Models)

The fuel is supplied to the Diesel engine in the following manner.

Fuel from the fuel tank is admitted to the fuel transfer pump **(19)** at the inlet **(18)** and is delivered under pressure into the lower chamber **(14)** of the fuel filter housing **(12)**, by the fuel line **(17)**. The fuel is filtered as it passes through the fuel filter elements **(13)** into the upper chamber **(15)** of the fuel filter housing. The by-pass valve **(8)** seats in the passage **(10)** which is connected to the lower chamber **(14).**

The transfer pump supplies an amount of fuel in excess of the fuel required for engine operation. The by-pass valve becomes unseated if the pressure becomes too great in the lower chamber, thus permitting the excess fuel to pass through the fuel return tube **(9)** and return preferably to the supply tank or to the suction side of the fuel transfer pump if the supply tank is above the engine.

The drilled passage **(23)** in the fuel filter housing delivers the filtered fuel to the fuel line **(7).** The fuel pressure gauge **(11)** is also connected to the drilled passage **(23)** to register the pressure of filtered fuel in the upper chamber.

The fuel line **(7)** transmits filtered fuel to the fuel supply manifold **(2)** in the fuel injection pump housing **(1).** From this manifold, the fuel is supplied by separate passages to the individual fuel injection pumps.

The fuel injection pumps deliver the fuel to the individual fuel injection valves **(4)** at the proper time. The fuel is discharged into the pre-combustion chambers **(3)** and is admitted into each individual cylinder as its piston is approximately 16° before top center on its compression stroke. The fuel is ignited by the heat of air compression, thus creating a pressure on the piston to deliver the power stroke. Overflow from the fuel injection valves is carried to the supply tank or the suction side of the fuel transfer pump by the overflow tube **(5)** and the fuel return tube **(9)**.

Air can be eliminated from the fuel filter housing by opening the bleed valves **(16)** and **(22)**. The bleed valve **(16)** is connected to the lower chamber, and the bleed valve **(22)** is connected to the upper chamber. When a solid stream of fuel is discharged at the bleed tube **(21)**, it indicates the air has been eliminated. Close the bleed valves after a solid stream of fuel has been obtained.

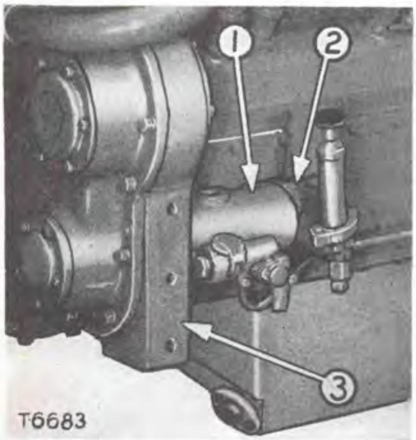
Air trapped in the fuel injection pump housing can be eliminated by opening the individual bleed vents on each fuel pump. A solid stream of fuel from the fuel pump bleed tube **(6)** indicates the system is free of air.

Some installations have a hand priming pump **(20)** installed. See the topic, HAND PRIMING PUMP (ALL MODELS), for the method of priming and bleeding the fuel system using the hand priming pump. The hand priming pump is used to supply the engine with fuel for initial starting, and bleeding the air from the fuel system (primarily for engines that do not have a starting engine).

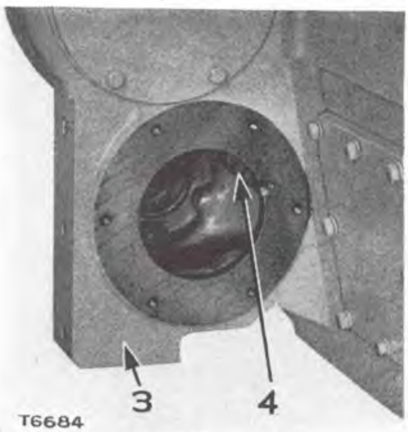
FUEL TRANSFER PUMP AND TRANSFER PUMP DRIVE (All Models)

The fuel transfer pump **(2)** is mounted on the rear of the fuel transfer pump drive **(1).** The transfer pump drive is mounted on the timing gear housing **(3)** and is driven by the left camshaft gear **(4).** The fuel flows by gravity from the Diesel fuel tank toward the transfer pump, which delivers the fuel under pressure to the fuel filter housing.

The pump delivers an excess amount of fuel required for engine operation. This excess is returned to the fuel tank or the suction side of the fuel transfer pump by the by-pass valve. See the topic, FUEL BY-PASS (ALL MODELS).



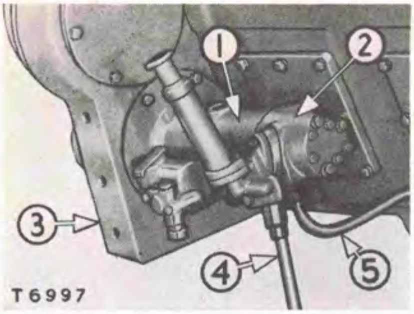
FUEL TRANSFER PUMP AND TRANSFER PUMP DRIVE
1—Transfer pump drive. 2—Fuel transfer pump. 3—Timing gear housing.



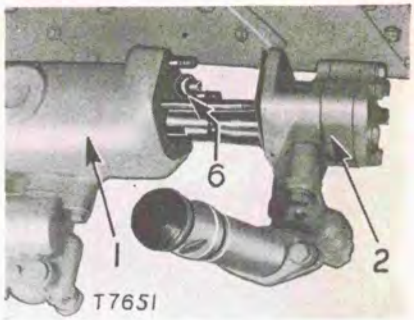
TIMING GEAR HOUSING
3—Timing gear housing.
4—Left camshaft gear.

Fuel Transfer Pump Removal (All Models)

If it is desired, the fuel transfer pump **(2)** may be removed from the fuel transfer pump drive **(1)**, without removing the drive from the timing gear housing **(3).**



PREPARING FOR TRANSFER PUMP REMOVAL
1—Fuel transfer pump drive. 2—Fuel transfer pump. 3—Timing gear housing. 4—Fuel supply line. 5—Pressure fuel line (to fuel filter housing).



REMOVING FUEL TRANSFER PUMP
1—Fuel transfer pump drive. 2—Fuel transfer pump. 6—Seal and ferrule.

Disconnect the pressure fuel line **(5).** If the fuel supply line **(4)** from the Diesel fuel tank has not already been disconnected, it should be. Remove the nuts and lockwashers holding the transfer pump to the transfer pump drive, and remove the pump. Remove the seal and ferrule **(6)** from the pump drive.

The transfer pump and the transfer pump drive can be removed as a unit, if desired. See the topic, FUEL TRANSFER PUMP DRIVE REMOVAL (ALL MODELS).

Fuel Transfer Pump Disassembly and Assembly (All Models)

Remove the adapter **(A)** and the hand priming pump attached.

NOTE

Some engines do not have the hand priming pump. In that case remove the adapter **(A).**

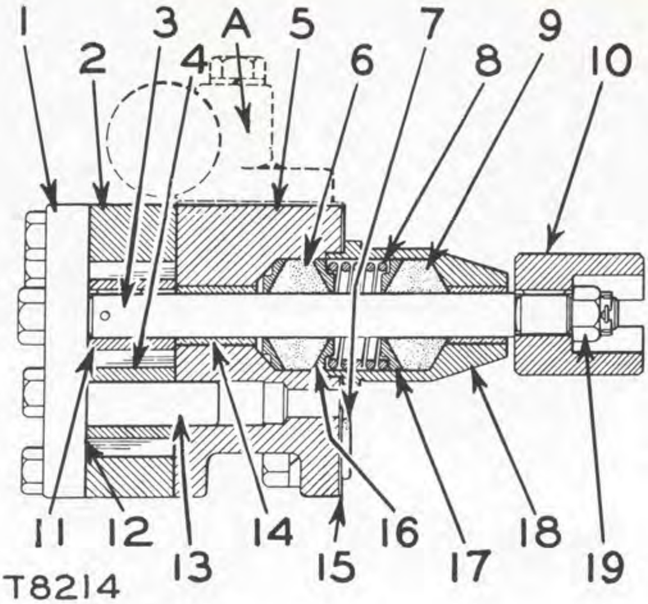
Remove the seal **(7).**

Remove the cotter pin and the nut **(19).**

Remove the coupling drive **(10)** and the woodruff key from the shaft **(3).**

Remove the seat assembly **(18)**, (a bushing is part of the assembly), the gasket **(15)**, the seal **(9)**, the retainer **(17)**, the spring **(8)**, and the retainer **(16)**.

Remove the capscrews holding the end cover **(1)** and the body **(2)** to the housing **(5)** and remove the cover and the body.



TRANSFER PUMP

A—Adapter. 1—End cover. 2—Body. 3—Drive gear shaft. 4—Idler gear. 5—Housing. 6—Seal and retainer. 7—Seal. 8—Spring. 9—Seal. 10—Coupling. 11—Drive gear. 12—Oil groove (in idler gear). 13—Idler gear shaft. 14—Bushing. 15—Gasket. 16—Retainer. 17—Retainer. 18—Seat assembly. 19—Nut.

Lift off the idler gear **(4)** from the idler gear shaft **(13)**, noting that the oil groove **(12)** is toward the end cover.

Slide out the drive gear **(11)** and the drive shaft **(3).** The drive gear is pinned to the drive shaft.

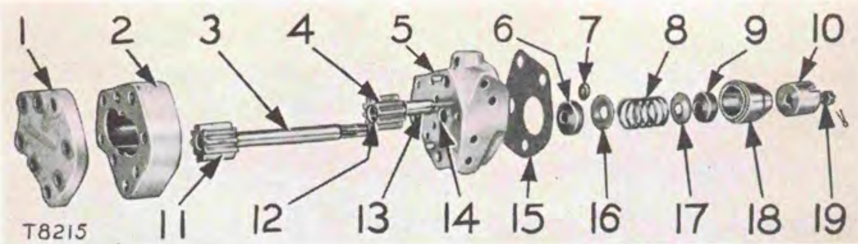
Remove the seal and retainer **(6).**

The gears need not be replaced unless excess wear is shown or they have been damaged.

If the drive gear is to be replaced, drill a 1/8" hole, or smaller, through the gear 180° directly opposite the peened hole in the gear, so a punch can be inserted to drive out the pin. The gear can then be pressed from the shaft and the key removed.

Inspect the end cover and the body for wear. Also check the bushing **(14)** in the housing and the bushing in the seat assembly **(18).** They should be replaced if excessive wear is shown.

When a new drive shaft and gear are installed, replace the key and press the gear on the shaft until the end of the shaft is flush with the lower face of the gear. Using the drilled hole in the gear as a guide, drill a 1/8" hole though the shaft and into the gear to a depth of 3/4 inch. Install a new pin and peen the gear over the end of the pin.



TRANSFER PUMP DISASSEMBLY
1—End cover. 2—Body. 3—Drive gear shaft. 4—Idler gear. 5—Housing. 6—Seal and retainer. 7—Seal. 8—Spring. 9—Seal. 10—Coupling. 11—Drive gear. 12—Oil groove (in idler gear). 13—Idler gear shaft. 14—Bushing. 15—Gasket. 16—Retainer. 17—Retainer. 18—Seat assembly. 19—Nut.

CAUTION

The end of the pin should not protrude beyond the surface of the gear. Any roughness caused by drilling or peening should be removed from the gear teeth.

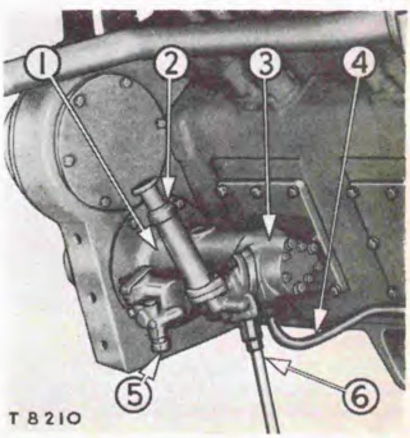
Place the gasket **(15)** against the face of the pump housing **(5)** before installing the seat assembly **(18).** The gasket will not pass over the seat assembly.

Fuel Transfer Pump Drive Removal (All Models)

The fuel transfer pump drive **(1)** with the fuel transfer pump **(3)**, the hand priming pump **(2)** and the tachometer drive **(5)** installed, (some models may not have the assemblies **(2)** and **(5)** installed) (earlier models had the hour meter assembly mounted elsewhere) can be removed from the engine in the following manner.

FUEL TRANSFER PUMP DRIVE REMOVAL

1—Fuel transfer pump drive. 2—Hand priming pump. 3—Fuel transfer pump. 4—Pressure fuel line. 5—Tachometer drive. 6—Fuel supply line.



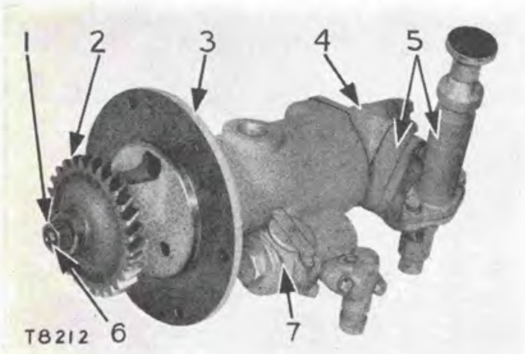
Disconnect the fuel supply line **(6)** from the transfer pump, and the pressure fuel line **(4)** from the transfer pump to the fuel filter housing. Remove the capscrews holding the pump drive to the timing gear housing and remove the transfer pump drive assembly.

Disassembling the Fuel Transfer Pump Drive (All Models)

Remove the hand priming pump **(5)** and spacer.

Remove the hour meter assembly **(7)**.

Remove the fuel transfer pump **(4)** and the ferrule and seal between the fuel transfer pump and the transfer pump drive.



DISASSEMBLING THE FUEL TRANSFER PUMP DRIVE

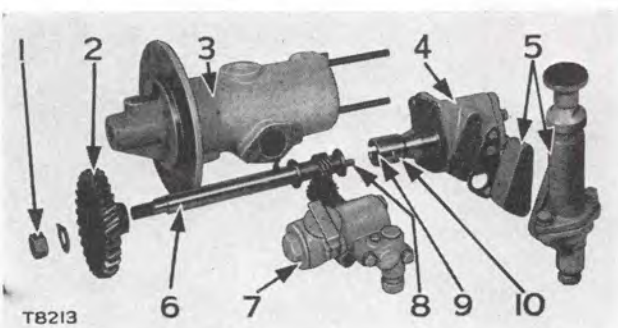
1—Nut. 2—Gear. 3—Housing. 4—Fuel transfer pump. 5—Hand priming pump and spacer. 6—Shaft. 7—Hour meter.

◆

Bend the lock and remove the nut **(1)** and the gear **(2)**. The gear is a light press fit.

Slide the shaft **(6)** out of the transfer pump drive housing **(3)**.

The bushings can be pressed out of the housing **(3)** if they need to be replaced.



FUEL TRANSFER PUMP DRIVE DISASSEMBLED
1—Nut. 2—Gear. 3—Housing. 4—Fuel transfer pump. 5—Hand priming pump and spacer. 6—Shaft. 7—Hour meter. 8—Tang on shaft (6). 9—Slot in coupling (10). 10—Coupling.

When assembling the fuel transfer pump to the drive housing assembly, place the ferrule and seal in the seal bore of the pump drive housing. Check the alignment of the slot **(9)** in the fuel transfer pump coupling **(10)** so that it slides over the tang **(8)** on the shaft **(6).**

Fuel Transfer Pump Drive Lubrication (All Models)

The fuel transfer pump drive is lubricated by oil that is splashed or thrown by the engine timing gears.

The oil collects in the oil pocket **(1)**, and then is distributed to the front bushing **(3)** and into the housing **(2).**

Oil in the housing lubricates the hour meter gear **(6).** The hour meter shaft and bushing are lubricated by oil that enters the hole **(4).** The oil hole **(5)** maintains the proper oil level in the housing. Excessive oil in the housing drains out this hole and returns to the oil pan.

FUEL TRANSFER PUMP DRIVE LUBRICATION

1—Oil pocket. 2—Housing. 3—Bushing. 4—Oil hole. 5—Oil hole. 6—Hour meter gear.

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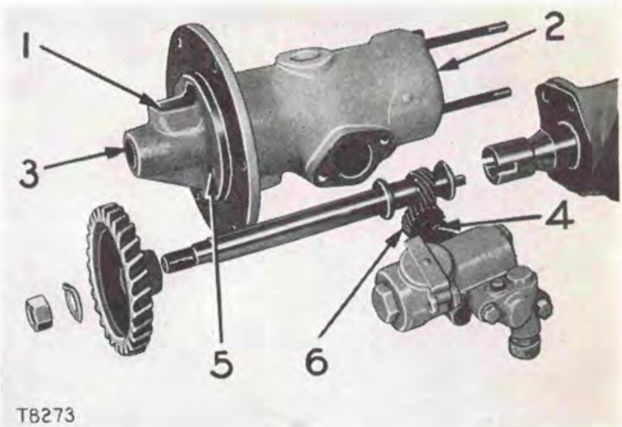


HAND PRIMING PUMP (All Models)

The hand priming pump mounted on the fuel transfer pump is used to supply fuel to the fuel filters and fuel pumps for initial starting.

NOTE

Engines that are equipped with a gasoline starting engine do not require a hand priming pump.

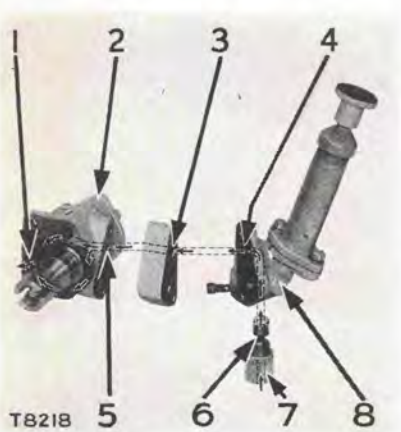
When priming the fuel system, make sure the emergency fuel shut-off valve is open. Check the fuel tank supply, open the fuel filter vent valves. Unscrew the hand priming fuel pump plunger and operate with full and steady strokes. When the flow of fuel through the vents becomes continuous and contains no air bubbles, close the vents. Then open each fuel injection pump vent in turn, continuing to operate the hand priming pump until each vent discharges solid fuel. Open and close the vents several times in succession to be sure that all of the air is bled from the system. When engines are equipped with an electric fuel pump and day tanks, see the locomotive or other manufacturer's instructions.

After the system is primed, the hand priming pump plunger should be pushed to the bottom of the cylinder and screwed into place. This closes the valve seat located in the bottom of the cylinder and prevents air from leaking by the piston, into the fuel system.

Flow of Fuel through the Hand Priming Pump Adapter and Fuel Transfer Pump (All Models)

The normal flow of the fuel when the hand priming pump is not being used and when the engine is running is as follows. The fuel enters the passage **(7)** unseats the check valve **(6)** and goes into the adapter **(8)**, passes through the passages **(4)** and **(3)** to the passage **(5)** in the fuel transfer pump **(2)**. The pump discharges the fuel under pressure at the ferrule **(1)** where it is then delivered to the fuel filter housing.

The flow of fuel when the hand priming pump is operated, is as follows. When the handle **(10)** is pulled out the fuel enters the passage **(7)**, unseats the check valve **(6)** and goes into the passage **(9)** in the adapter **(8)**. When the handle is pushed in, the check valve **(6)** seats and will not permit the fuel to return to the supply tank. The transfer pump gears (since they are not turning) will not permit the fuel to pass through the pump. The pressure unseats the ball **(15)** and compresses the spring **(13)** and the fuel passes through the hollow retainer **(14)** and the passage **(12)** to the passage **(11)** where it by-passes the pump gears and is discharged under hand pressure at the ferrule **(1)**. The fuel is then delivered to the fuel filter housing and the fuel pumps.



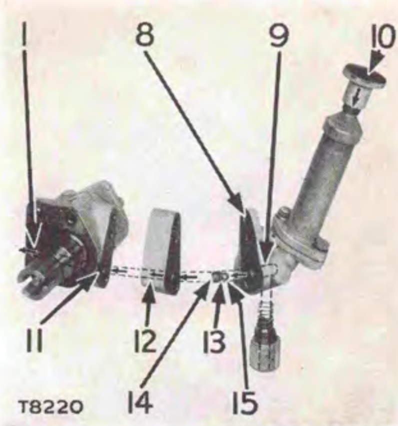
NORMAL FLOW OF FUEL (HAND PRIMING PUMP NOT OPERATING)

1—Ferrule. 2—Fuel transfer pump. 3—Passage. 4—Passage. 5—Passage (inlet to transfer pump). 6—Check valve. 7—Passage (fuel from supply tank). 8—Adapter.

◆

FLOW OF FUEL WHEN HANDLE IS PULLED OUT (HAND PRIMING PUMP)

6—Check valve. 7—Passage (fuel from supply tank). 8—Adapter. 9—Passage. 10—Handle.



FLOW OF FUEL WHEN HANDLE IS PUSHED IN (HAND PRIMING PUMP)

1—Ferrule. 8—Adapter. 9—Passage. 10—Handle. 11—Passage. 12—Passage. 13—Spring. 14—Retainer. 15—Ball.

FUEL FILTER HOUSING
(All Models)

The fuel filter housing **(2)** is mounted to the left rear side of the crankcase **(1)** and has a passage to receive the engine coolant. The coolant passes through the housing and warms the fuel compartment of the filter housing, which is adjacent to the coolant passage. The fuel compartment contains twelve fuel filter elements **(5)** located in the lower compartment **(3)**, which is the unfiltered section.

The filter elements are mounted to the filter element plate **(4)**, which will not permit unfiltered fuel to pass into the upper chamber **(6).** The fuel that enters the upper chamber has been filtered by passing through the filter elements.

LOCATION OF FUEL FILTER HOUSING

1—Crankcase. 2—Fuel filter housing.

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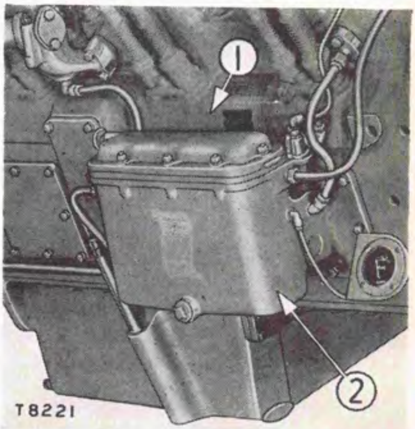
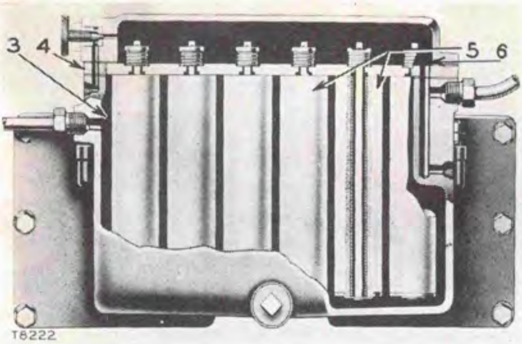




FUEL FILTER HOUSING
3—Lower compartment. 4—Filter element plate. 5—Fuel filter elements. 6—Upper chamber.

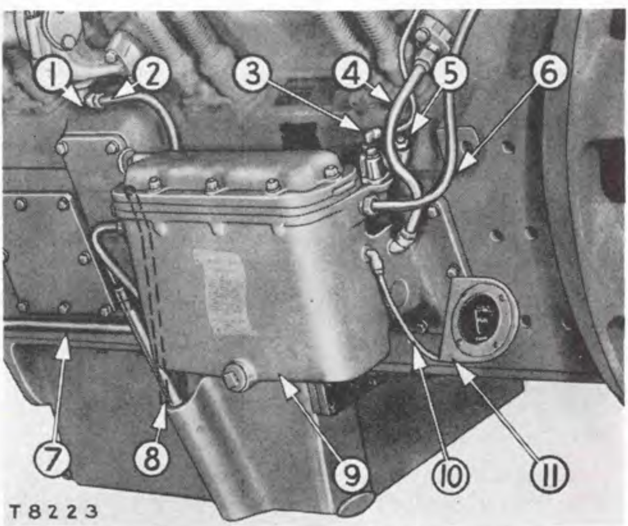
Fuel Filter Housing Removal and Installation (All Models)

Drain the fuel from the fuel filter housing **(9).**

Remove the water line **(2)** from the housing to the water elbow fitting **(1)** and also the water line **(4)** from the housing to the rear of the cylinder block. The filter housing has a cored passage through which the engine coolant passes.

Remove the fuel gauge bracket **(11)** (with the fuel gauge installed) and the fuel gauge tube **(10).**

Remove the fuel bleeder drain tube **(8)** (hidden, in this view).



FUEL FILTER HOUSING REMOVAL AND INSTALLATION
1—Water elbow fitting. 2—Water line. 3—Elbow fitting. 4—Water Line. 5—Fuel by-pass return line (partially hidden). 6—Filter fuel pressure line. 7—Pressure supply line (unfiltered). 8—Bleeder drain tube (hidden in this view). 9—Fuel filter housing. 10—Fuel gauge tube. 11—Fuel gauge bracket.

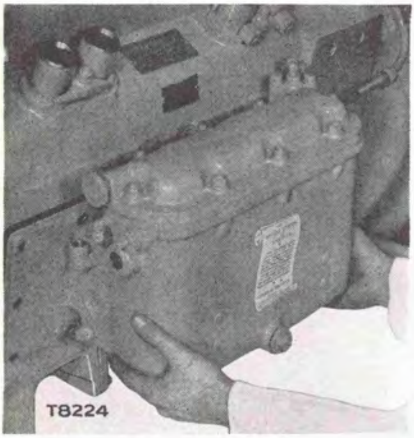
Disconnect the fuel line **(6)** which carries filtered fuel to the injection pumps.

Disconnect the unfiltered fuel pressure supply line **(7).**

Disconnect the fuel return line from the elbow fitting **(3).** This line returns the excess fuel to the fuel by-pass valve.

Disconnect the fuel by-pass return line **(5)** which is only partially shown but which connects the fuel by-pass valve to the supply tank. See the topic, FUEL BY-PASS (ALL MODELS).

Remove all the capscrews holding the filter housing to the crankcase and remove the filter housing.



REMOVING FUEL FILTER HOUSING

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Fuel Filter Housing Disassembly (All Models)

The fuel filter housing can be disassembled while installed on the engine in the following manner.

DISASSEMBLING FUEL FILTER HOUSING

1—Cover.

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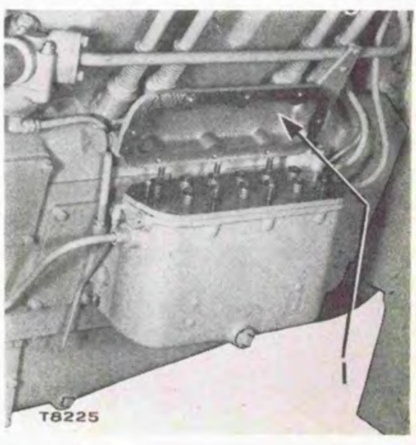
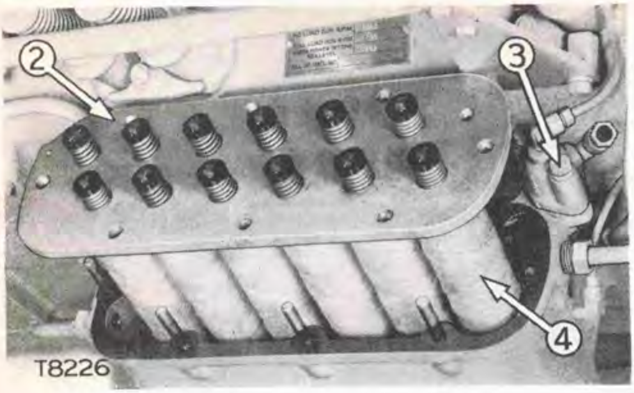




REMOVING FILTER ELEMENT PLATE

2—Filter element plate. 3—Fuel filter by-pass valve. 4—Fuel filter elements.

♦

Thoroughly clean the top of the filter cover and around the edges of the gasket joint between the filter body and cover, to guard against loose dirt dropping into the filter housing when the cover is removed. Close the Diesel fuel tank valve, remove the filter housing drain plug, open the lower and then the upper filter housing vents.

Remove the cover **(1)** and the gasket.

Lift out the filter element plate **(2)** with the fuel filter elements **(4)** attached.

For the disassembly of the fuel filter by-pass valve **(3)** see the topic, FUEL BY-PASS (ALL MODELS).

FUEL BY-PASS
(All Models)

The fuel by-pass adapter housing **(1)** is mounted on the fuel filter housing **(2)** and it can be removed without disturbing the filter housing.

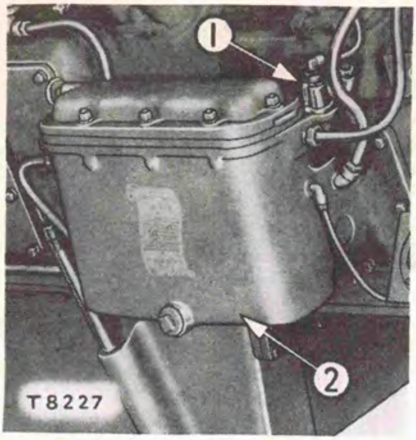
The fuel by-pass valve is located in a passage which is connected to the lower compartment of the fuel filter housing. This is the unfiltered side of the fuel system. If the fuel filter elements become clogged, the plunger is unseated and the fuel is returned to the supply tank or the suction side of the fuel transfer pump. This is a safety feature, thus preventing excessive pressure that might cause damage to the fuel filter housing or the fuel pressure gauge.

When the fuel injection pumps do not use all the fuel supplied by the transfer pump, the excess fuel is returned to the fuel supply through the fuel by-pass adapter housing.

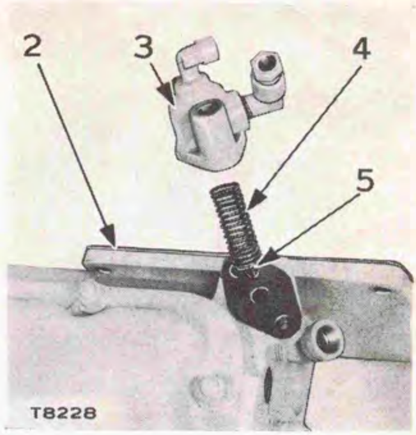
The fuel by-pass adapter housing **(3)** is removed as follows.

Disconnect the fuel tubes attached to the by-pass adapter housing.

Remove the adapter from the fuel filter housing **(2)**.



LOCATION OF FUEL BY-PASS ASSEMBLY
1—Fuel by-pass assembly. 2—Fuel filter housing.



FUEL BY-PASS ASSEMBLY DISASSEMBLED
2—Fuel filter housing. 3—Adapter. 4—Spring. 5—Plunger.

The by-pass valve consists of the spring **(4)** and the plunger **(5)**.

Lift out the plunger and the spring.

Check the seat in the fuel filter housing and the plunger for any roughness.

NOTE

When assembling, the plunger must have the small end positioned to seat in the filter housing, and the large end of the plunger inserted in the spring.

FUEL INJECTION EQUIPMENT
(All Models)

The most likely causes for faulty fuel injection are:

1. Insufficient fuel transfer pump pressure.
2. Low fuel supply.
3. Clogged fuel filters.
4. Water in the fuel.
5. Air in the fuel system.

If these conditions are checked and corrected and the engine still does not operate as it should, it is well to check the fuel injection equipment.

Checking Fuel Injection Equipment (All Models)

Before removing a fuel injection pump or valve for testing on an engine that is missing or puffing black smoke at the exhaust, a simple check can be made to determine which cylinder is causing the difficulty. With the engine running at a speed which makes the defect most pronounced, momentarily loosen the fuel line nut on the injection pump sufficiently to "cut out" the cylinder. Check each cylinder in the same manner. If one is found where loosening makes no difference in the irregular operation of the engine or causes puffing of black smoke at exhaust to cease, probably the pump and valve for only that cylinder need be tested.

It is important to clean the Diesel fuel tank and fuel lines when new fuel injection equipment is installed. This will prevent former dirt and sediment accumulations from damaging the newly installed equipment.

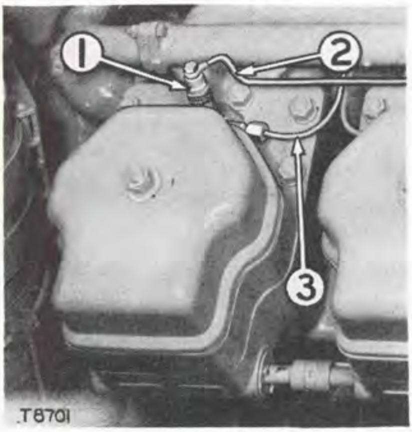
FUEL INJECTION VALVE
(All Models)

Fuel Injection Valve Removal and Installation (All Models)

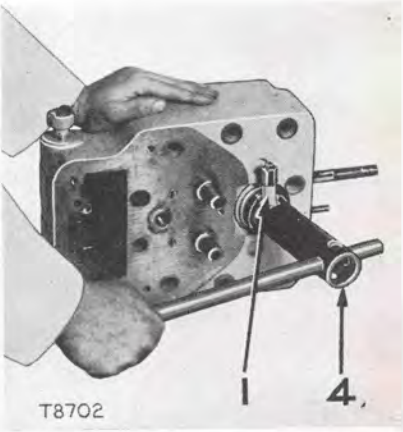
The fuel injection valve **(1)** can be removed from the cylinder head by disconnecting the supply line **(3)** and the overflow line **(2)**.

CAUTION

Immediately cap and plug the fuel injection valves and the fuel lines with the seals, caps and plugs provided in the tool equipment to protect them from dirt.



PREPARING TO REMOVE FUEL INJECTION VALVE
1—Fuel injection valve. 2—Overflow line. 3—Supply line.



REMOVING FUEL INJECTION VALVE (HEAD REMOVED FOR ILLUSTRATION ONLY)
1—Fuel injection valve. 4—7B4973 wrench.

Using the 7B4973 Wrench **(4)** remove the injection valve by turning it in a counterclockwise direction. Cover the pre-combustion chamber to prevent dirt from falling in.

When installing the injection valve into the pre-combustion chamber, inspect both the injection valve and the pre-combustion chamber to be sure they are clean.

Position the injection valve, to permit the supply line to be connected to the injection valve.

Tighten the injection valve securely.

Install the supply line and connect the overflow line.

Cleaning a Fuel Injection Valve (All Models)

If the spray characteristics of a fuel injection valve are not satisfactory, remove any carbon from the nozzle end with a blunt piece of wood and clean the fuel discharge hole with a 5B1401 Cleaning Tool as illustrated.

CLEANING FUEL DISCHARGE HOLE

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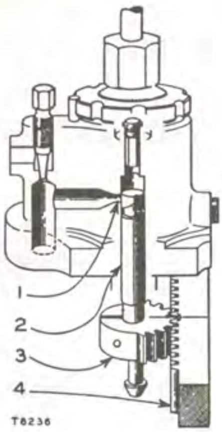
FUEL INJECTION PUMPS (All Models)

Each pump measures the amount of fuel to be injected into its particular cylinder and produces the pressure for injection. The injection pump plunger **(2)** is lifted by a cam and always makes a full stroke. The amount of fuel pumped during any one stroke is varied by turning the plunger in the barrel. The plunger is turned by the governor action through the rack **(4)** which meshes with the gear segment **(3)** on the bottom of the pump plunger.

Figures A, B and C illustrate the functioning of an injection pump as the plunger makes a stroke.

In Fig. A the plunger is down and the inlet port **(1)** is uncovered. Fuel flows into the space above the plunger through the slot and into the recess around the plunger.



FUEL INJECTION PUMP

1—Inlet port. 2—Pump plunger. 3—Gear segment. 4—Rack.

◆

In Fig. B the plunger has started up and the port is covered. The fuel is trapped and will be forced through the check valve, fuel line and injection valve as the plunger moves upward.

In Fig. C the plunger has risen until the port is uncovered by the recess in the plunger. The fuel can now escape back through the port into the fuel manifold and injection will cease.

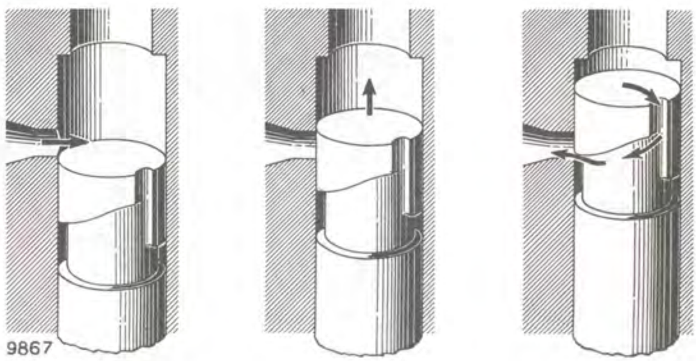


FIG. A
PORT UNCOVERED
FUEL ENTERS BARREL

FIG. B
PORT COVERED
INJECTION BEGINS

FIG. C
PORT UNCOVERED
INJECTION ENDS

It will be noted that the recess in the pump plunger forms a helix around the upper end of the plunger. Figures D, E and F illustrate how rotating the pump plunger affects the quantity of fuel injected.

In Fig. D the plunger has been rotated into the shut off position. The slot connecting the top of the plunger with the recess is in line with the port, therefore, no fuel can be trapped and injected.

In Fig. E the plunger has been rotated into the idling position. The narrow part of the plunger formed by the helix will cover the port for

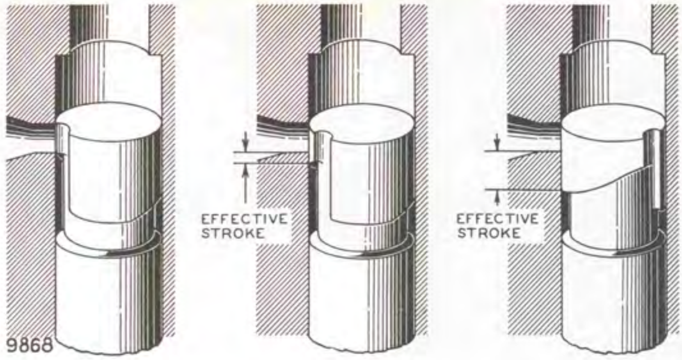


FIG. D
SHUT OFF

FIG. E
IDLING POSITION

FIG. F
FULL LOAD POSITION

only a short part of the stroke. This permits only a small amount of fuel to be injected per stroke.

In Fig. F the plunger has been rotated into the full load speed position. The wide part of the plunger formed by the helix covers the port for a longer part of the stroke. This permits a larger amount of fuel to be injected per stroke.

Worn fuel injection pumps will result in loss of power and hard starting. These same conditions may be present if the piston rings and cylinder liners are badly worn. However, in the case of worn piston rings and liners, the hard starting and loss of power will be accompanied by poor compression, a smoky exhaust and excessive blow-by gases from the crankcase breather.

Ordinarily, if one fuel injection pump on an engine is not supplying sufficient fuel, it will be found that all of the injection pumps are worn and need replacing.

Failure to replace all of the worn injection pumps may result in erratic and irregular engine operation.

Fuel Injection Pump Shut-Off (All Models)

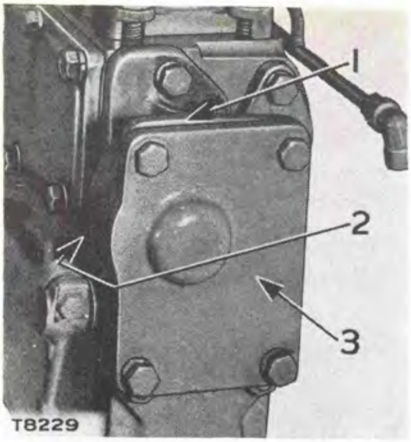
The fuel pump shut-off is located in the housing **(1)** which is attached to the rear end of the fuel injection pump housing **(2)**.

The housing assembly can be removed and disassembled in the following manner.

Remove the cover **(3)**, and remove the housing assembly **(1)** from the fuel injection pump housing.

Drive out the taper pin **(8)** and remove the lever **(7)** from the shaft.

Slide the shaft and the control arm **(4)** from the housing.

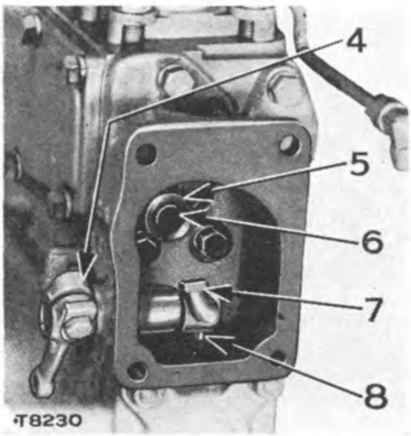


LOCATION OF FUEL SHUT-OFF
1—Fuel shut-off housing assembly. 2—Fuel injection pump housing. 3—Cover.

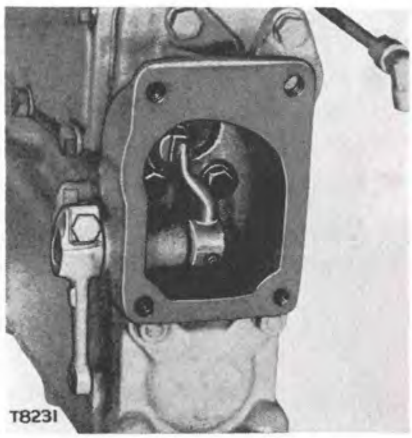
When installing the taper pin, hit the larger end with a sharp blow to assure proper seating of the taper pin.

The slide bar **(6)** is connected to the fuel pump rack. When the control arm **(4)** is pulled back the lever **(7)** pushes the bar into the fuel injection pump housing until the stop **(5)** touches the pump housing. In this position the fuel is shut off, and no fuel is admitted to the fuel injection valves.

The fuel rack is in the open position when the lever **(4)** is moved forward which in turn moves the lever **(7)** so it is not in contact with the slide bar **(6)**.



REMOVING FUEL SHUT-OFF HOUSING
4—Control arm. 5—Stop. 6—Slide bar. 7—Lever. 8—Taper pin.



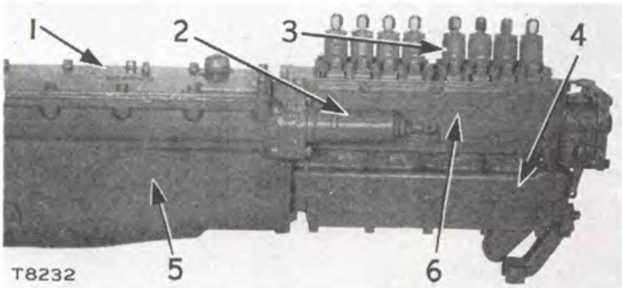
FUEL RACK IN THE SHUT-OFF POSITION

Fuel Injection Pump Rack Setting (All Models)

The fuel pump rack can be set on the engine in the following manner.

Remove the governor housing inspection cover **(1)**.

Remove the capscrews holding the governor and fuel pump control mechanism **(2)** to the governor housing **(5)**. Move the control mechanism to the side to permit the fuel pump housing inspection cover **(6)** to be removed from the fuel injection pump housing **(4)**.



PREPARING TO ADJUST THE FUEL RACK SETTING
1—Governor housing inspection cover. 2—Governor and fuel pump control mechanism. 3—No. 5 fuel pump and plunger. 4—Fuel injection pump housing. 5—Governor housing. 6—Fuel injection pump housing cover.

Remove the inspection cover, and install the capscrews in the control mechanism and governor housing to locate the control mechanism in its proper position.

Remove the No. 5 fuel pump and plunger **(3)**.

Install the 1F7945 Rack Setting Fixture in place of the No. 5 fuel pump and plunger.

FUEL RACK SETTING FIXTURE

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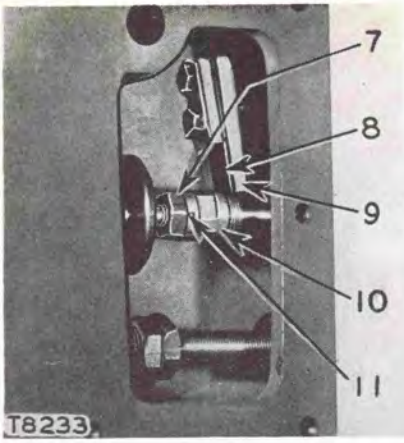

REMOVING L-SHAPED KEY

7—Lock nut. 8—Torque spring. 9—Steel block. 10—Rack nut. 11—L-shaped key.

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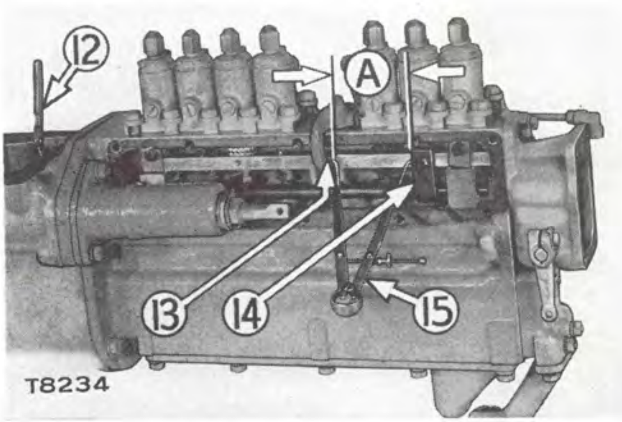
Loosen the locknut **(7)** and remove the L-shaped lock **(11)**, to permit the rack nut **(10)** to be adjusted.

Insert a spacer **(12)** (.075" thick) between the torque spring **(8)** and the steel block **(9)** to provide a solid stop for the rack nut. This will permit the rack to be adjusted at the correct measurement when the rack nut is touching the torque spring, without bending the torque spring.

Move the fuel pump rack toward the open position (which is away from the governor housing).

Measure the distance **(A)** from the ground surface **(13)** on the rack setting fixture to the connector block **(14)**. Rack settings for maximum rated and continuous horsepower are furnished Caterpillar dealers.



MEASURING RACK SETTING
12—Spacer. 13—Surface. 14—Connector block. 15—Calipers.
A—Distance from the rack setting fixture to the connector block.

Inside calipers **(15)** may be used for this measurement after setting them to the desired opening with an outside micrometer.

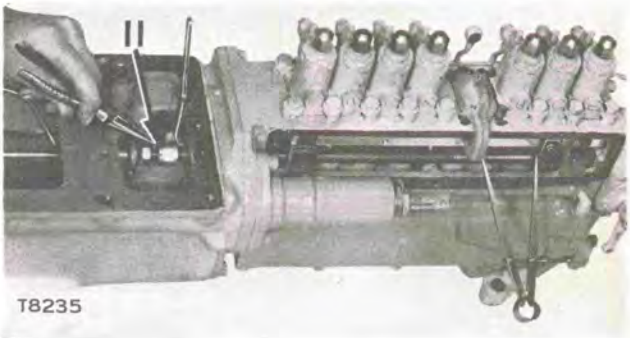
With the inside calipers set to the desired rack setting, adjust the rack nut to the point where the face of the rack nut just touches the torque spring with the .075" spacer **(12)** installed.

Install the L-shaped key **(11)** in the elongated slot of the rack and the nearest groove of the rack nut.

Tighten the lock nut and remove the rack setting fixture.

INSTALLING L-SHAPED KEY

11—L-shaped key.



When setting the fuel rack on engines that have a safety shut-off, the measurement must be taken from the connector block as described above and not from the adapter which is installed to the connector block.

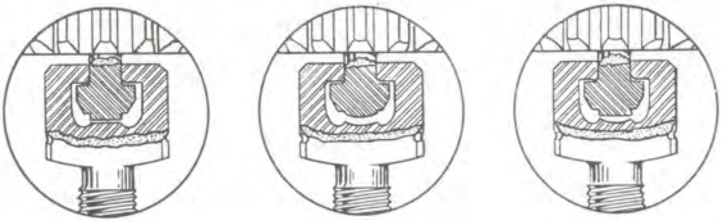
Install the fuel pump and plunger and the inspection covers.

Fuel Pump Lifter Yoke and Pump Plunger Inspection (All Models)

Adjusting the fuel pump lifters is necessary whenever they have been removed from the housing. The adjustment should also be checked periodically to compensate for wear in the timing gears, lifters or the ends of the pump plungers to assure that the point of fuel injection is correct. If the lifter is too high, injection will begin early, and, if too low, injection will be late.

When pump plunger wear becomes excessive, the lifter yoke may also be worn in such a manner that it will not make full contact with the end of a new plunger. To avoid rapid wear on the end of the new plunger, lifter yokes showing visible wear should always be replaced.

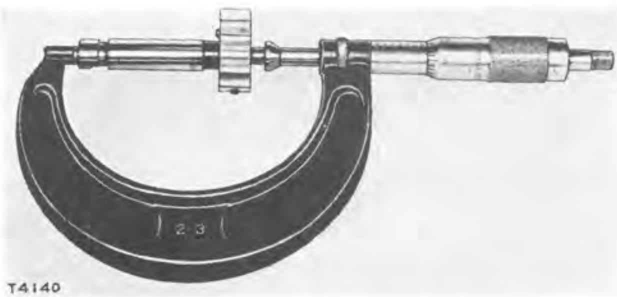
Fig. A illustrates the contact surfaces of a new pump plunger and a new lifter yoke. In Fig. B, the pump plunger and lifter yoke have worn considerably. Fig. C shows how the flat end of a new plunger makes poor contact with a worn lifter yoke, resulting in rapid wear to both parts.



T4896 FIG. A FIG. B FIG. C

WEAR BETWEEN PLUNGER AND YOKE

A pump can maintain a satisfactory discharge rate and yet be unserviceable because of delayed timing resulting from wear on the lower end of the plunger. When testing a pump which has been in use for a long time, the length of the plunger should be checked and the pump discarded if the plunger wear exceeds .005″. The length of new plungers is 2.6575″ — 2.6577″. The length should be checked with a micrometer as shown.



T4140

CHECKING LENGTH OF PLUNGER

Fuel Pump Lifter Settings (All Models)

If the injection pump lifters have been removed, or disturbed from their original settings, it is necessary to reset them.

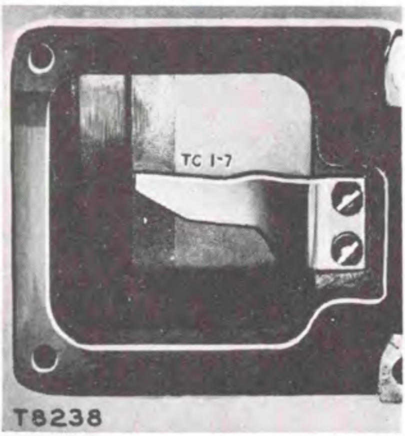
Periodically the lifter settings should be checked and reset if necessary, to account for worn timing gears, worn pump lifters or wear on the bottom of the pump plungers. See the topic, FUEL INJECTION PUMP LIFTER YOKE AND PUMP PLUNGER INSPECTION (ALL MODELS).

The fuel pump lifter settings can be made with the fuel pump housing installed on the engine, if the part number of the fuel pump camshaft is known.

The fuel pump camshaft number can be determined by draining and removing the fuel injection pump housing. After removing the bottom cover the part number can be seen stamped on the fuel pump camshaft between the cam lobes. After the part number has been determined replace the inspection cover, and install the fuel injection pump housing to the engine. See the topics covering the removal and installation of the fuel injection pump housing.

The lifter settings can be set in the following manner.

Turn the crankshaft in the direction of the engine rotation to "Top Center" (TC) on the compression stroke of the cylinder for which lifter is to be set. Using the flywheel pointer and the "Top Center" marks on the flywheel, locate the top center of the cylinder to be set. See the topic, CHECKING THE FLYWHEEL TOP CENTER MARKS (ALL MODELS), if there is reason to believe that the top center marks on the flywheel are not correct.



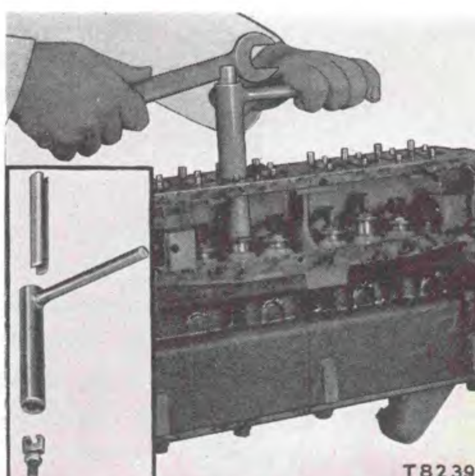
LOCATING TOP CENTER FLYWHEEL MARK

◆

If the crankshaft is accidently turned too far (for example 1/4" too far), do not just turn the crankshaft back the 1/4", as this would cause the

ADJUSTING LIFTER SETTING

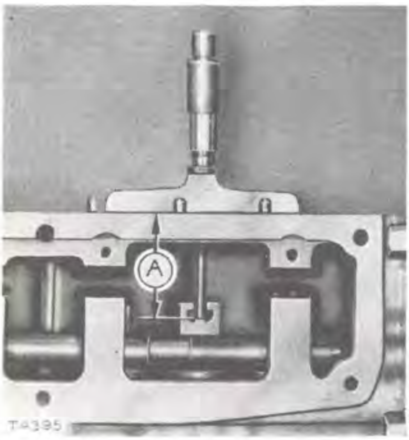
◆



backlash of the timing gears to be in the wrong direction. When the crankshaft is turned too far, turn it backwards approximately 60°, then turn the crankshaft in engine rotation to locate top center.

Check the pump lifter at this crankshaft position (top center of the cylinder for which the lifter is being set). Using the 6F6922 Micrometer Depth Gauge check the distance **(A)** and reset if necessary, using the 7F4581 Wrench and the 7F4582 Wrench.

The correct setting for the fuel pump camshafts 2A4511 and 3F1670 is 1.721". The setting for camshafts with the part number 2A5716 is 1.736".



MEASURING LIFTER SETTING

A—1.721" for fuel pump camshaft 2A4511 and 3F1670; 1.736" for fuel pump camshaft 2A5716.

◆

If all the lifters are to be checked or reset, continue the procedure in the normal firing order of the engine, which is 1-8-5-4-7-2-3-6. The fuel pumps are numbered 1 through 8 consecutively, with the No. 1 pump located nearest the front of the engine.

It is important when checking and setting the lifters that the engine be turned in the direction of engine rotation. The fuel pump camshaft can be positioned in two points when the distance from the fuel pump camshaft lobe to the top of the fuel pump housing is exactly the same. After a lifter has been checked or set according to the specifications, turn the crankshaft a few degrees in the direction of engine rotation. Again measure the distance **(A)**. This distance should be less than the measurement when checked with the crankshaft at top center thus indicating the lifter is rising and was checked at the correct position.

FUEL INJECTION PUMP HOUSING
(All Models)

Fuel Injection Pump Housing Removal (All Models)

The fuel pump housing **(6)** can be removed without removing the exhaust manifolds and the inlet manifolds. However, if the manifolds are removed the job can be completed quicker and easier.

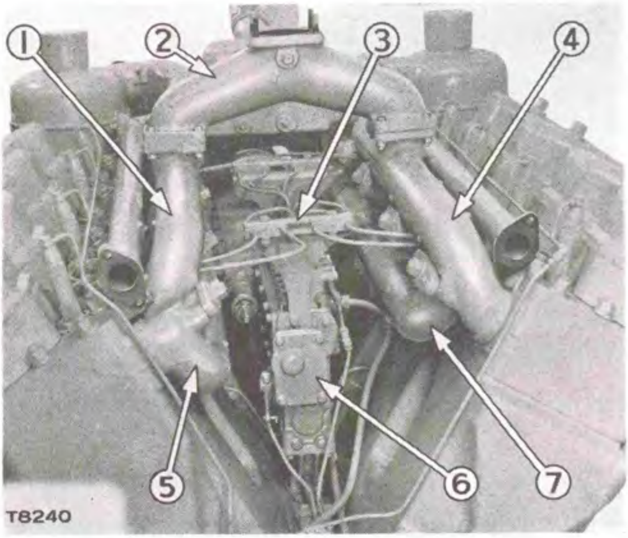
The fuel pump housing is removed as follows.

Drain the lubricating oil from the pump housing.

Remove the exhaust manifold Y-pipe **(2)** and the exhaust manifold pipes **(1)** and **(4)**.

Remove the fuel injection lines **(3)** and the fuel line supports. Install the dust caps provided to keep the dirt out of the fuel injection pumps, the injection valves and the fuel lines.

Remove the inlet manifold pipes **(5)** and **(7)**.



PREPARING FOR FUEL INJECTION PUMP HOUSING REMOVAL
1—Exhaust manifold pipe. 2—Exhaust manifold Y-pipe. 3—Fuel injection lines. 4—Exhaust manifold pipe. 5—Inlet manifold pipe. 6—Fuel injection pump housing. 7—Inlet manifold pipe.

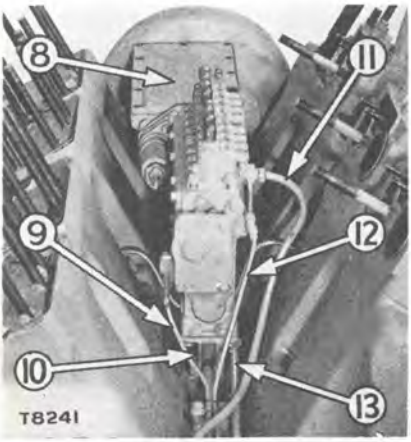
Disconnect and remove the fuel supply tube **(11)**, the overflow fuel line **(12)**, the drain line **(9)** and the oil drain tube **(13)**. The oil drain tube **(13)** may be removed after the fuel pump housing has been removed.

Remove the capscrews holding the fuel injection pump housing to the fuel pump support bracket **(10)**.

NOTE

Some installations may have shims installed between the fuel injection pump housing and the support bracket. These shims should be kept intact and installed at the time of assembly. See the topic, FUEL INJECTION PUMP HOUSING INSTALLATION (ALL MODELS).

Remove the governor inspection plate **(8)**.



DISCONNECTIONS AT FUEL PUMP HOUSING

8—Governor inspection plate. 9—Drain line. 10—Fuel pump support bracket. 11—Fuel supply tube. 12—Overflow fuel line. 13—Oil drain tube.

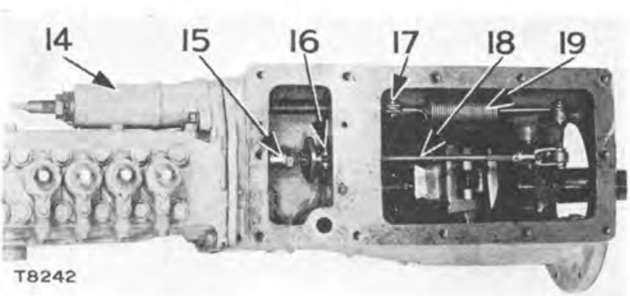
◆

Remove the pin **(16)** and disconnect the slide bar **(15)** from the rod **(18)**.

Replace the pin **(16)** to hold the retainer and spring on the fuel slide bar **(15)**, which is connected to the fuel rack.

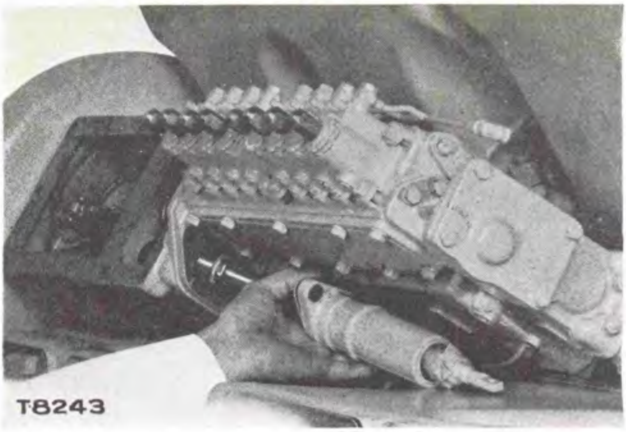
Remove the pin **(17)** and disconnect the governor spring **(19)** from the governor and fuel pump control assembly **(14)**.

Remove the governor and fuel pump control assembly **(14)**.



DISCONNECTING THE FUEL PUMP HOUSING FROM THE GOVERNOR

14—Governor and fuel pump control assembly. 15—Slide bar. 16—Pin. 17—Pin. 18—Rod. 19—Governor spring.



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REMOVING GOVERNOR AND FUEL PUMP CONTROL ASSEMBLY

◆

Place a rope sling around the fuel pump housing.

Remove the capscrews holding the fuel pump housing to the governor.

Remove the fuel pump housing by sliding it out and away from the governor until it is free, then lift the pump housing out, using a suitable hoist, and place it on a clean bench.

REMOVING FUEL PUMP HOUSING

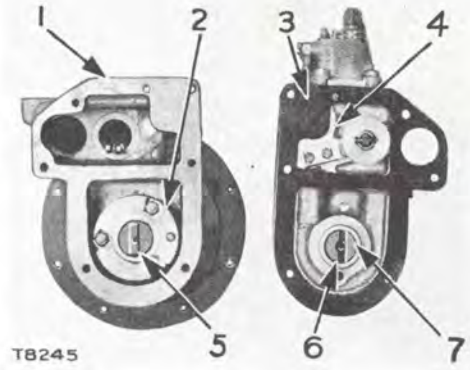
◆

T8244

Fuel Injection Pump Housing Installation (All Models)

If the fuel pump housing **(4)** has been removed from the governor housing **(1)**, and the fuel pump drive coupling **(2)** has not been disturbed or removed, the fuel pump housing can be installed as follows.

Rotate the fuel pump camshaft **(7)** to position the off-center slot **(6)** in alignment with the off-center tang **(5)** on the fuel pump drive coupling **(2)**.



PREPARING TO INSTALL FUEL PUMP HOUSING

1—Governor housing. 2—Fuel pump drive coupling. 3—Gasket. 4—Fuel pump housing. 5—Off-center tang. 6—Off-center slot. 7—Fuel pump camshaft.

◆

Install a new gasket **(3)**.

Place a rope sling around the fuel pump housing. It is important to balance the housing evenly, as this will facilitate installation.

Lower the fuel pump housing into place, and slide the fuel pump housing onto the governor housing.

If the fuel pump housing does not slide onto the governor housing easily, do not force it. Remove the fuel pump housing and check the alignment of the off-center tang and the off-center slot.

After the fuel pump housing is installed to the governor housing, tighten the capscrews evenly, and continue assembly in reverse order of removal.

On installations that had shims installed between the fuel injection pump housing and the fuel pump support bracket, use the same shims at the time of assembly if the original fuel injection pump and governor housings are used.

INSTALLING FUEL PUMP HOUSING

◆

If either a new governor housing, support bracket or fuel injection pump housing is installed, it may be necessary to add shims between the fuel injection pump housing and the support bracket. After the fuel pump housing is mounted on the governor housing as described above, the amount of shims required can be determined in the following manner. Using a feeler gauge check the space between the fuel injection pump housing and the support bracket. Fill the gap with 2A4709 Shims. The correct amount of shims required is the thickness of the gap as checked with a feeler gauge plus one 2A4709 Shim.

For further description of the fuel pump and the governor couplings see the topic, FUEL PUMP DRIVE COUPLING AND ACCESSORY SHAFT COUPLING (ALL MODELS).

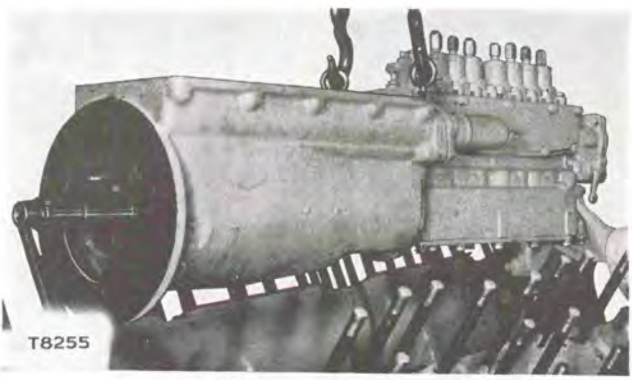
Fuel Injection Pump Housing and Governor Housing Removal as a Unit (All Models)

Many times when the engine is being reconditioned, or when major work is being done, it is desirable to have the fuel pump housing and the governor housing removed.

The fuel pump housing and the governor housing may be removed as a unit in the following manner. See the topic, FUEL INJECTION PUMP HOUSING REMOVAL (ALL MODELS), and disconnect whatever is necessary to facilitate removing the fuel pump housing from the engine (with the exception of disconnecting it from the governor housing).

See the topic, GOVERNOR HOUSING REMOVAL (ALL MODELS), and disconnect the governor and prepare it for removal as described in that topic.

Using two standard 3/8" eyebolts and a suitable hoist, lift the fuel pump housing and the governor housing off the engine as a unit, as shown.



REMOVING FUEL INJECTION PUMP HOUSING AND GOVERNOR HOUSING AS A UNIT (SHOWS HEADS REMOVED FOR BETTER ILLUSTRATION)

FUEL PUMP DRIVE COUPLING AND ACCESSORY SHAFT COUPLING
(All Models)

The accessory shaft coupling **(3)** and the fuel pump drive coupling **(4)** are covered in this topic together, because, they form the method of driving the fuel pumps and timing the fuel pumps with the engine.

The fuel pump housing **(6)** is attached to the governor housing **(2)**. The accessory shaft gear **(1)** is timed to and driven by the engine timing gears. The accessory shaft gear drives the accessory shaft **(8)**, the accessory shaft coupling **(3)** and the governor **(7)** which is mounted on the accessory shaft.

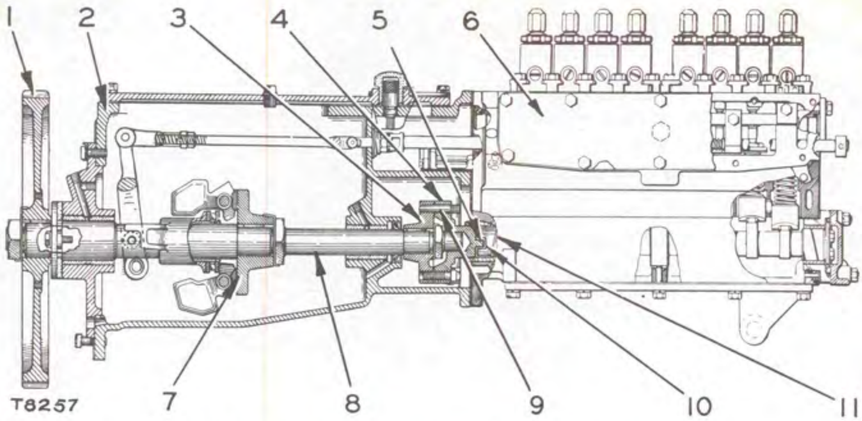
The fuel pump drive coupling **(4)** is attached to the accessory shaft coupling by capscrews and is timed to it by the tapered dowel pin **(9)**. The off-center tang **(5)** on the fuel pump drive coupling is a slip-fit into the off-center slot **(10)** in the fuel pump camshaft **(11)**. This drives the fuel injection pumps and times the fuel pumps to the engine.

LOCATION OF ACCESSORY SHAFT GEAR

1—Accessory shaft gear.

NOTE

While very little wear is likely to occur between the fuel pump drive coupling and the accessory shaft coupling it may be necessary sometime to replace them with new couplings. For this reason, instructions are given in some of the following topics for the installation of the original parts and other topics describe the installation of new couplings which must be timed, drilled and reamed.

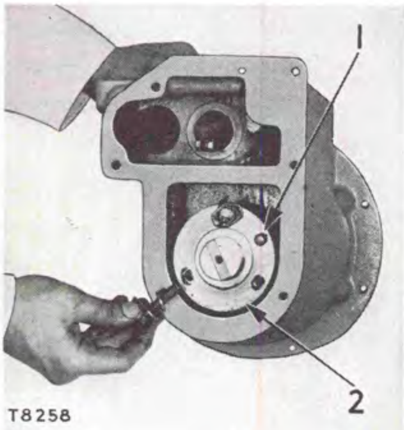


FUEL PUMP AND GOVERNOR COUPLING

1—Accessory shaft gear. 2—Governor housing. 3—Accessory shaft coupling. 4—Fuel pump drive coupling. 5—Tang. 6—Fuel pump housing. 7—Governor. 8—Accessory shaft. 9—Tapered dowel pin. 10—Slot. 11—Fuel pump camshaft.

Removing the Fuel Pump Drive Coupling and the Accessory Shaft Coupling (All Models)

Bend the locks and remove the capscrews and spacers holding the fuel pump drive coupling **(2)** to the accessory shaft coupling.



PREPARING TO REMOVE THE FUEL PUMP DRIVE COUPLING

1—Tapered dowel pin. 2—Fuel pump drive coupling.

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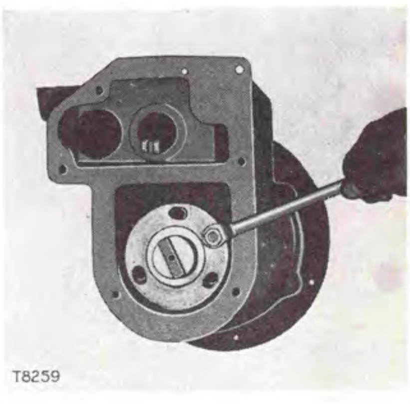

REMOVING TAPERED DOWEL PIN

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PREPARING TO REMOVE ACCESSORY SHAFT COUPLING (USING THE FUEL PUMP DRIVE COUPLING AS A PULLER)

2—Fuel pump drive coupling. 3—Nut. 4—Bar stock. 5—Accessory shaft coupling.

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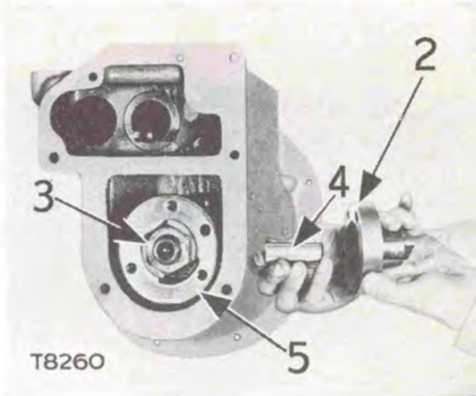
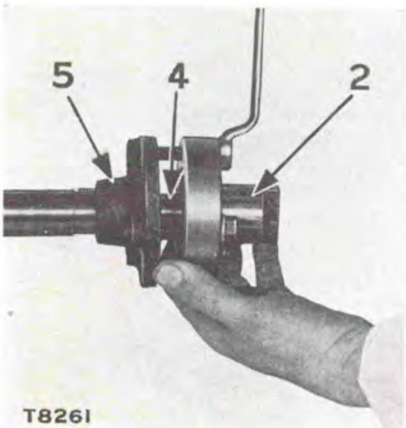


Install a 3/8" - 24 (NF) nut on the exposed threaded end of the tapered dowel pin **(1)**, and turn the nut in a clockwise rotation until the tapered dowel pin is free and remove the tapered dowel pin.

Remove the fuel pump coupling **(2)**, by sliding it off the accessory shaft.

Remove the nut **(3)** and lock, from the accessory shaft.

Insert a piece of round bar stock **(4)** approximately 2½" long and ¾" diameter between the end of the accessory shaft and the inside of the fuel pump coupling. Using three 3/8" - 24 (NF) capscrews approximately 4" long as puller screws (with spacers to protect the slotted holes) and the fuel pump coupling **(2)** as a puller, pull the accessory shaft coupling **(5)** from the accessory shaft. Tighten the capscrews evenly, to obtain an even pull when removing the accessory shaft coupling.



PULLING ACCESSORY SHAFT COUPLING

2—Fuel pump coupling. 4—Bar stock. 5—Accessory shaft coupling.

◆

Installing the Original Accessory Shaft Coupling and the Original Fuel Pump Drive Coupling (All Models)

NOTE

The method of installing the accessory shaft coupling **(3)** and the fuel pump coupling **(1)** as described in this topic is **only** for the installation of the original couplings installed at the factory. The accessory shaft coupling has been timed to the fuel pump drive coupling and located with the taper dowel pin **(2)** to retain the timing of the two couplings. As long as these couplings are used together as a unit, the timing is correct.

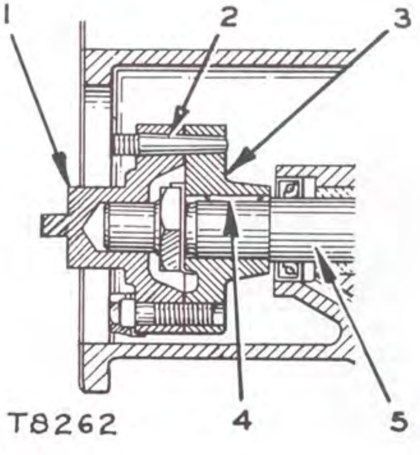
The accessory shaft coupling is installed as follows. See that the woodruff key **(4)** is seated correctly in the accessory shaft **(5)**. Check the key, the shaft and the coupling for any burrs or roughness.

Heat the accessory shaft coupling, preferably in hot oil to ease installation. Install the coupling on the accessory shaft by using a suitable driver, and install the lock and nut.

Place the fuel pump drive coupling **(1)**, on the end of the accessory shaft. Rotate the fuel pump coupling to align the elongated holes **(6)** with the threaded capscrew holes in the accessory shaft coupling.

Place the tapered dowel pin in the tapered holes of the fuel pump drive coupling and the accessory shaft coupling. This assures the correct timing, as it cannot be installed incorrectly, since the tapered dowel pin fits only into the matched tapered holes.

Install the spacers, the locks and the capscrews, and tighten slightly. Using a small drift on the end of tapered dowel pin **(2)** so as not to damage the threads, hit the drift pin a sharp blow with a light-weight hammer to seat the tapered dowel pin properly.



ACCESSORY SHAFT COUPLING AND FUEL PUMP DRIVE COUPLING

1—Fuel pump drive coupling. 2—Tapered dowel pin. 3—Accessory shaft coupling. 4—Woodruff key. 5—Accessory shaft.

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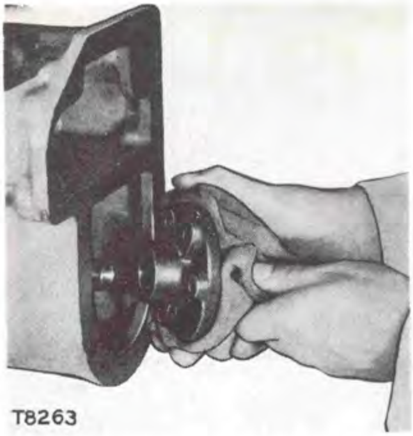
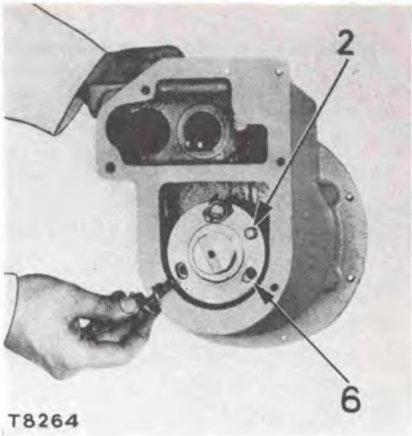


INSTALLING ACCESSORY SHAFT COUPLING



INSTALLING TAPERED DOWEL PIN
2—Tapered dowel pin. 6—Elongated hole.

Tighten securely the capscrews holding the couplings together and bend the locks.

NOTE

As there is no adjustment for these couplings after the tapered dowel pin is installed, the timing is fixed and cannot be adjusted.

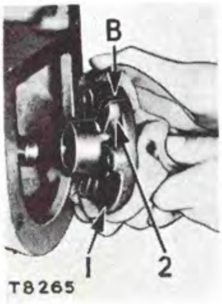
Installing a New Accessory Shaft Coupling (All Models)

NOTE

This topic describes the replacement of the accessory shaft coupling with a new coupling only.

Very little wear is likely to occur between the accessory shaft coupling and the fuel pump drive coupling. If the couplings should become damaged or lost and need to be replaced, it can be done as follows.

A new accessory shaft coupling must be timed to the fuel pump coupling.



INSTALLING THE ACCESSORY SHAFT COUPLING

B—Identification mark. 1—Accessory shaft coupling. 2—Boss.

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Make an identification mark **(B)** as illustrated on the outer edge of the accessory shaft coupling **(1)**, to show where the boss **(2)** is located. This will be helpful when the accessory shaft coupling is installed, and the boss cannot be seen.

Heat the new accessory shaft coupling **(1)**, preferably in hot oil, and install the coupling to the accessory shaft as described in the topic, INSTALLING THE ORIGINAL ACCESSORY SHAFT COUPLING AND THE ORIGINAL FUEL PUMP DRIVE COUPLING (ALL MODELS).

With a piece of chalk continue the mark **(B)**, around the face of the accessory shaft coupling.

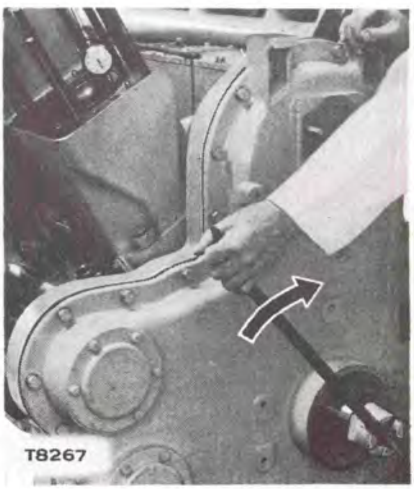
Procedure for Timing the Accessory Shaft Coupling (All Models)

Remove the cylinder head from No. 1 cylinder. See the topic, INDIVIDUAL CYLINDER HEAD REMOVAL (ALL MODELS).

Place a dial indicator as illustrated, on the No. 1 piston.

STEP 1

Turn the crankshaft in engine rotation, to locate the No. 1 piston at TDC on the compression stroke. See the topic. CHECKING FLYWHEEL TOP CENTER MARKS (ALL MODELS). Position the dial indicator to have approximately .240″ total travel, as the piston moves downward in the liner from TDC. Adjust the dial indicator to read .000″.



STEP 1

Locating the No. 1 piston at top dead center on the compression stroke and adjusting the dial indicator to read .000″.

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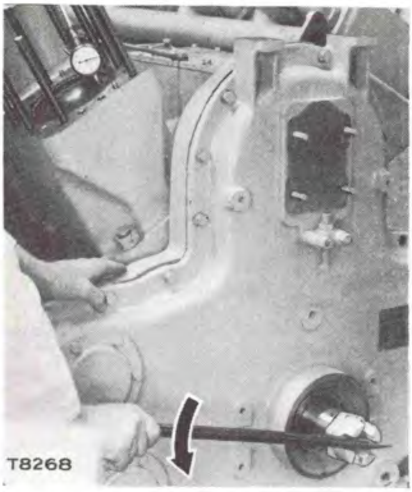
STEP 2

Turn the crankshaft opposite to engine rotation, until the piston has traveled downward in the liner approximately .235" on the dial indicator.

This locates the piston Before Top Center (BTC), but the backlash of the timing gears is in the wrong direction.



STEP 2

Locating the No. 1 piston approximately .235" BTC compression stroke, with the timing gear backlash in the wrong direction.

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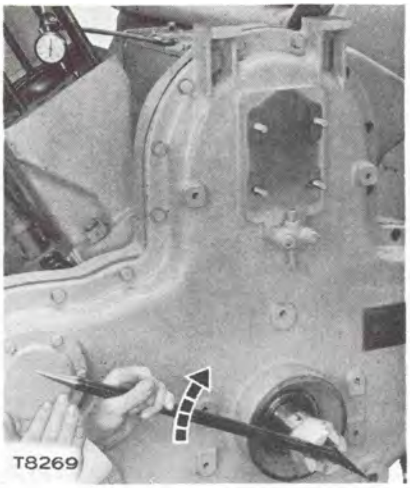
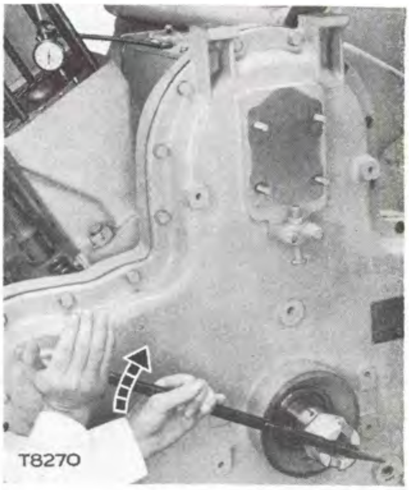
STEP 3

Turn the crankshaft in engine rotation slowly, bumping the bar by hand to assure moving the piston only a short distance at a time. Move



STEP 3

Locating the No. 1 piston in the correct timing position at .193" BTC compression stroke with the backlash in the right direction.



STEP 3 CONTINUED

Moving the piston only a short distance at a time to assure not going by the .193" BTC.

the piston upward in the liner from the dial indicator reading of .235" BTC to .193" BTC.

This locates the piston in the correct location BTC with the backlash in the right direction. The piston must be located in this position when the coupling is drilled and reamed.

CAUTION

When turning the crankshaft and moving the piston upward in the liner, do not move the piston past the reading of .193" BTC. If the piston is moved past the correct reading, repeat the Steps 2 and 3 to position the piston correctly.

Another method by which the piston can be located in the correct timing position is by using a different dial indicator reading, without removing the No. 1 cylinder head. Remove the No. 1 fuel injection valve

POSITIONING PISTON FOR DRILLING AND REAMING BY CHECKING THROUGH THE PRE-COMBUSTION CHAMBER

Method of mounting the dial indicator if the cylinder head has not been removed.

◆

and take the reading through the pre-combustion chamber. Using the same procedure as described in the Steps 1, 2 and 3 locate the piston at .199" BTC and time, drill and ream the couplings as described.

PROCEDURE FOR TIMING ACCESSORY SHAFT AND FUEL PUMP DRIVE COUPLING

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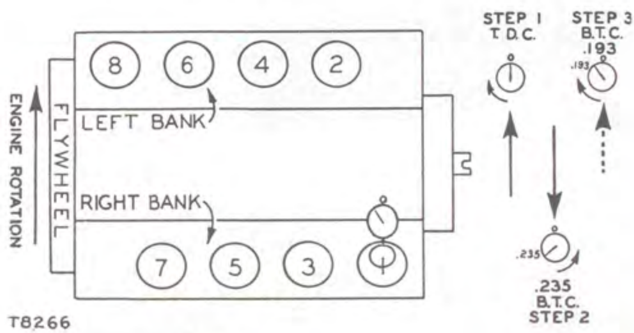


The difference in the indicator readings used in these two methods is due to the fact that the indicator is in contact with the concave area of the piston when the second method is used.

The piston must be located in the position described in Step 3 when the accessory shaft coupling is drilled and reamed.

Drilling the Accessory Shaft Coupling and the Fuel Pump Coupling (Using Drilling Fixture) (All Models)

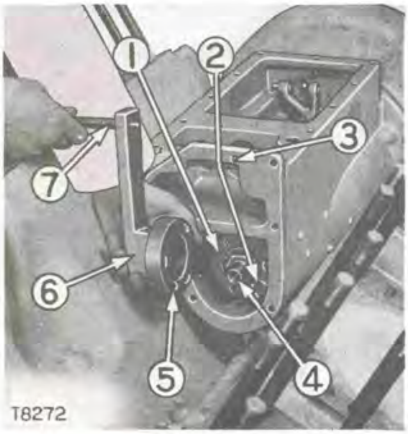
The procedure of timing the accessory shaft coupling is described in the topic, PROCEDURE FOR TIMING THE ACCESSORY SHAFT COUPLING (ALL MODELS).

NOTE

> The accessory shaft coupling must be timed to the engine, first. After the accessory shaft coupling has been timed and installed to the engine, the fuel pump drive coupling can be installed in the following manner.

Place the fuel pump drive coupling **(5)** in the accessory shaft drilling fixture **(6)**. See the topic, ACCESSORY SHAFT COUPLING DRILLING FIXTURE SPECIFICATIONS (ALL MODELS) for the fixture specifications.

The off-center tang on the fuel pump drive coupling can only fit into the drilling fixture in one position, because of the off-center slot.



ACCESSORY SHAFT COUPLING DRILLING FIXTURE INSTALLATION

1—Accessory shaft coupling. 2—Boss (indicated by dotted line). 3—Dowel. 4—Accessory shaft. 5—Fuel pump drive coupling. 6—Drilling fixture. 7—Locating pin.

♦

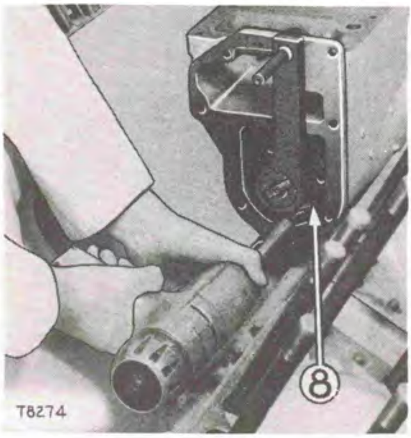
Slide the fuel pump coupling **(5)**, (with the drilling fixture **(6)** installed) on the accessory shaft **(4)** and push the drilling fixture all the way in, so that the coupling **(5)** is touching the coupling **(1)**.

Place the locating pin **(7)** through the drilling fixture and into the dowel hole **(3)** in the governor housing.

A new fuel pump drive coupling will have the guide hole **(8)** already drilled. This is the only hole in the fuel pump coupling that is not slotted. There are three slotted holes.

Using a center-punch through the guide hole **(8)**, center-punch a mark on the accessory shaft coupling.

Through the guide hole **(8)** as illustrated, drill through the accessory shaft coupling, at the boss **(2)**, using a 23/64″ drill.



DRILLING WITH FIXTURE IN PLACE

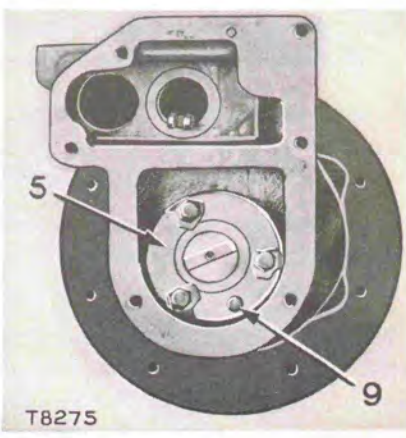
8—Guide hole.

♦

Taper ream the holes for a No. 7 taper pin.

Remove the drilling fixture and the locating pin, and clean out the metal chips caused by drilling and reaming.

Install the fuel pump drive coupling **(5)** to the accessory shaft coupling **(1)**. Install the spacers, locks, capscrews and the tapered dowel pin **(9)** as described in the topic, INSTALLING THE ORIGINAL ACCESSORY SHAFT AND THE ORIGINAL FUEL PUMP DRIVE COUPLING (ALL MODELS).



INSTALLING TAPERED DOWEL PIN

5—Fuel pump drive coupling. 9—Tapered dowel pin.

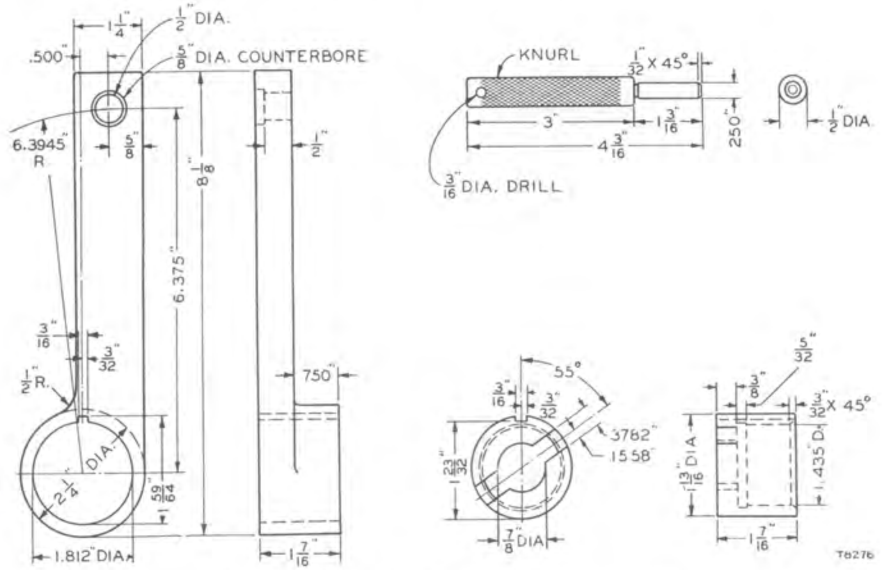
♦

Install the fuel pump housing as described in the topic, FUEL INJECTION PUMP HOUSING INSTALLATION (ALL MODELS).

Adjust the fuel pump lifters to the correct setting. This is the distance **(A)** as described in the topic, FUEL PUMP LIFTER SETTINGS (ALL MODELS).

Accessory Shaft Coupling Drilling Fixture Specifications (All Models)

When a new accessory shaft coupling is installed, the drilling fixture is used to hold the fuel pump drive coupling in the correct position while the drilling and reaming is being done.



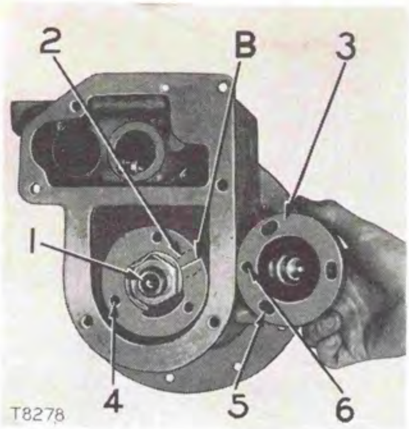
ACCESSORY SHAFT COUPLING DRILLING FIXTURE SPECIFICATIONS

Drilling the Accessory Shaft Coupling and Fuel Pump Drive Coupling (Without Using Drilling Fixture) (All Models)

The accessory shaft and fuel pump couplings can be replaced with new couplings without using a drilling fixture. The procedure of timing, drilling and reaming without using the drilling fixture is as follows.

First, with the fuel pump housing in place on the engine, adjust the fuel pump lifters to the correct lifter setting. This is the measurement **(A)** as described in the topic, FUEL PUMP LIFTER SETTINGS (ALL MODELS).

With the fuel pump housing removed from the engine make an identification mark **(B)** on the outer edge of the accessory shaft coupling, to locate the boss **(2)** when the coupling is installed and the boss cannot be seen.



INSTALLING AND POSITIONING THE FUEL PUMP DRIVE COUPLING

B—Identification mark. 1—Accessory shaft. 2—Boss. 3—Fuel pump drive coupling. 4—Threaded hole. 5—Slotted hole. 6—Guide hole.

◆

Install the accessory shaft coupling to the accessory shaft **(1)**, as described in the topic, INSTALLING THE ORIGINAL ACCESSORY SHAFT COUPLING AND THE ORIGINAL FUEL PUMP DRIVE COUPLING (ALL MODELS).

With a piece of chalk, continue the identification mark **(B)** on the outer edge around on the face of the accessory shaft coupling.

Place the fuel pump coupling **(3)** on the accessory shaft.

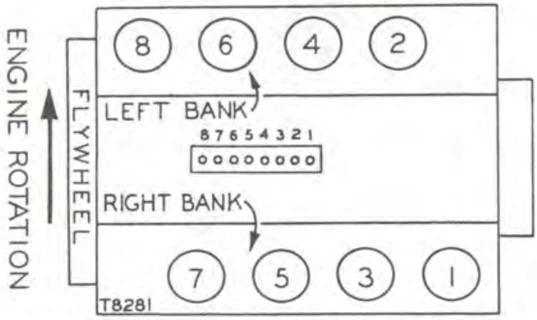
Position the three slotted holes **(5)** in alignment with the three threaded holes **(4)**, and the guide hole **(6)** in alignment with the identification mark **(B)**, which locates the boss **(2)**.

Install the capscrews, spacers and locks **(7)**, and tighten the capscrews only enough to hold the couplings, and still permit the fuel pump coupling to be turned when some pressure is applied.

INSTALLING CAPSCREWS

7—Capscrew, spacer and lock.

◆



LOCATING TOP CENTER ON NO. 1 PISTON

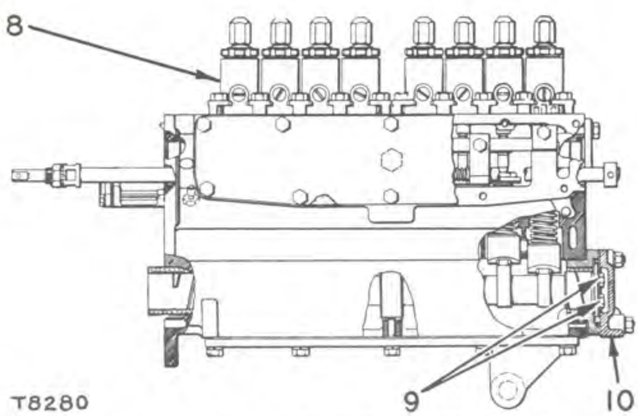
(Engine rotation counterclockwise facing the flywheel).

♦

Turn the crankshaft in engine rotation (counterclockwise facing the flywheel) to locate No. 1 piston at TDC on the compression stroke. See the topic, CHECKING THE FLYWHEEL TOP CENTER MARKS (ALL MODELS).

Remove the No. 1 fuel pump **(8)** and the fuel pump plunger.

Remove the cover **(10)** at the rear of the fuel pump housing.

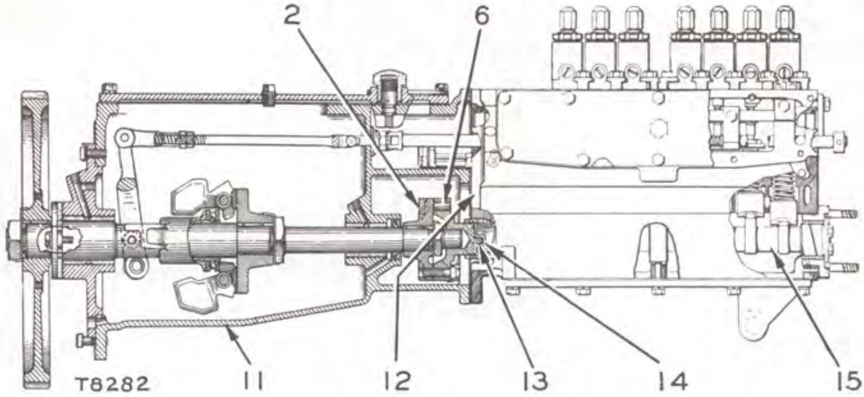


POSITIONING THE FUEL PUMP CAMSHAFT
8—No. 1 Fuel pump lifter and plunger. 9—Capscrews. 10—Cover.

Using a screwdriver placed between the capscrews **(9)**, turn the fuel pump camshaft in its normal rotation, which is clockwise at the rear of the fuel pump housing facing the capscrews **(9)**, until the lifter setting, as previously set has been located. The measurement is described in the topic, FUEL PUMP LIFTER SETTINGS (ALL MODELS). This procedure positions the fuel pump camshaft at the correct timing location in its normal rotation.

Slide the fuel injection pump housing **(12)** onto the governor housing **(11)**, mating the off-center slot **(14)** of the fuel pump camshaft **(15)** with the off-center tang **(13)** on the fuel pump drive coupling.

Install several capscrews to secure the fuel pump housing to the governor housing.



ALIGNING THE COUPLINGS
2—Boss. 6—Guide hole. 11—Governor housing. 12—Fuel injection pump housing. 13—Off-center tang. 14—Off-center slot. 15—Fuel pump camshaft.

Recheck the distance from the top of the fuel pump housing to the No. 1 fuel pump lifter. If it has been changed during the assembly of the housings turn the fuel pump camshaft so as to obtain the correct measurement. This will locate the fuel pump camshaft in the correct timing position.

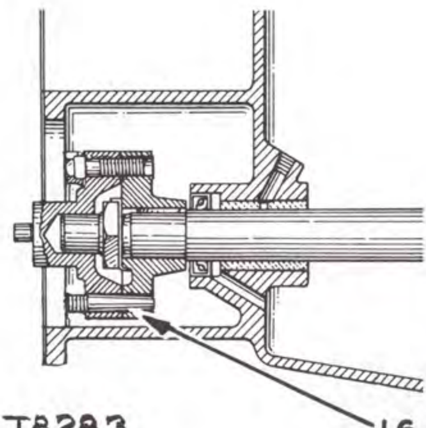
Remove the fuel pump housing and do not move the fuel pump drive coupling or the accessory shaft coupling. Tighten the capscrews and bend the locks holding the fuel pump drive coupling to the accessory shaft coupling.

Using the hole **(6)** as a guide, drill a 23/64" hole through the accessory shaft coupling and the boss **(2)**.

Taper ream the holes for a No. 7 taper pin, and install the tapered dowel pin **(16)**.

INSTALLING TAPERED DOWEL PIN
16—Tapered dowel pin.

♦



Using a small drift pin on the dowel pin and a light-weight hammer, hit the drift pin a sharp blow to secure the dowel pin to the couplings.

Clean out any metal chips caused by drilling and reaming.

Install the fuel pump housing and complete the installation.

Governor
(All Models)

The governor is connected to the fuel rack through levers and linkage. The governor regulates the amount of fuel supplied to the engine during engine operation in the following manner.

The governor spring constantly strives to move the fuel rack in a direction to increase the amount of fuel injected, while the force generated by the rotating governor weights is transmitted to the rack in a direction to decrease the amount of fuel injected. Since the governor weights are rotated by a gear on the end of the accessory shaft which is attached to the fuel injection pump camshaft, any change in engine speed correspondingly results in a change in governor weight force. The opposing force of the governor spring varies according to the fuel injection pump control lever setting.

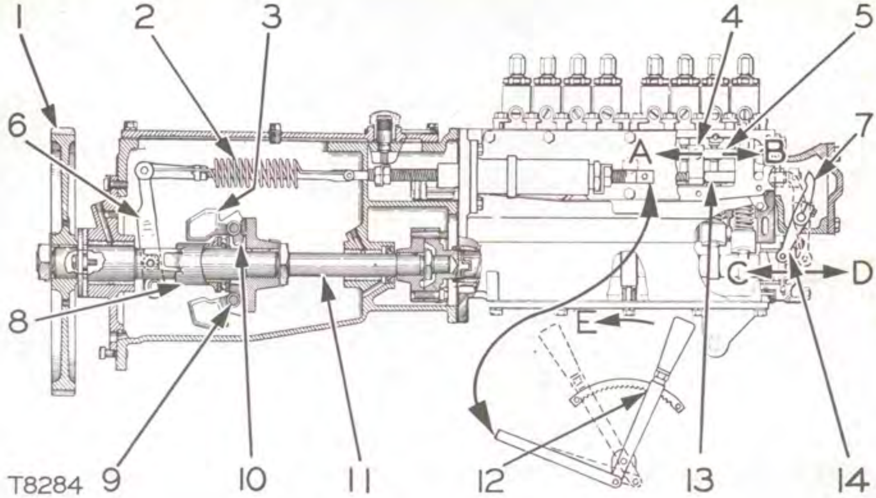
When the engine load is lightened, the engine speeds up, due to the amount of fuel it is receiving at the moment, then the governor moves the fuel rack in the direction to decrease the amount of fuel supplied. As a result the engine speed tends to remain constant even when the load is lightened.

If the engine speed slows down, due to an increase of load applied to the engine, the governor moves the fuel rack in the direction to increase the amount of fuel supplied to the engine.

GOVERNOR OPERATION
(All Models)

When the fuel supply control arm **(14)** is moved toward the direction of the arrow **(C)**, the lever **(7)** is actuated to permit the fuel rack to move to the fuel "ON" position. When the fuel injection pump control lever **(12)** is moved in the open position, toward the direction of arrow **(E)**, the operating principle of the governor is as follows.

The fuel injection pump control lever in the open position applies tension on the governor spring **(2)** which is attached to the terminal lever **(6)**. As the governor spring is stretched, the terminal lever transmits this force through the slide bar **(13)** and the connector block **(4)** to the fuel rack **(5)**. The force applied to the fuel rack from the fuel injection pump



GOVERNOR OPERATION

1—Accessory shaft gear. 2—Governor spring. 3—Governor weight. 4—Connector block. 5—Fuel rack. 6—Terminal lever. 7—Lever. 8—Bearing and sliding sleeve. 9—Anchor pin. 10—Shoulder. 11—Accessory shaft. 12—Fuel injection pump control lever. 13—Slide bar. 14—Fuel supply control arm.

A—Direction to decrease amount of fuel injected.
B—Direction to increase amount of fuel injected.
C—"ON" fuel position. D—"OFF" fuel position.
E—Direction of open position.

control lever is in the direction of the arrow **(B)** to increase the amount of fuel injected.

The accessory shaft gear **(1)** drives the accessory shaft **(11)** which in turn rotates the governor weights **(3)**. As the weights are rotated, they tend to move outward, due to centrifugal force.

As the heavy portion of the weights move outward, the weights pivot on the anchor pins **(9)**. The shoulder **(10)** on the governor weights applies pressure on the bearing and sliding sleeve **(8)**.

Any change in engine speed accordingly results in a corresponding change in speed of rotation of the weights.

The force applied to the bearing and sliding sleeve **(8)** is transmitted to the terminal lever **(6)**. This tends to move the fuel rack in the direction of the arrow **(A)** to decrease the amount of fuel injected.

Thus, the opposing forces on the terminal lever, balance the fuel rack to control and supply the proper amount of fuel for engine operation.

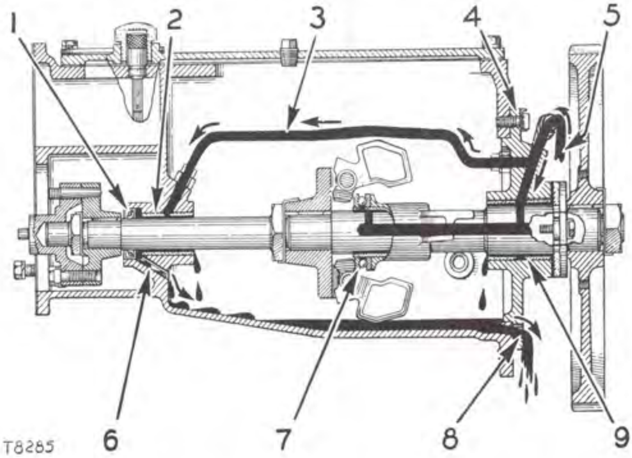
Moving the fuel supply control arm in the direction of the arrow **(D)** is the fuel "OFF" position. This is accomplished as the lever **(7)** comes in contact with the slide bar **(13)** and moves it against the housing. See the topic, FUEL INJECTION PUMP SHUT-OFF (ALL MODELS).

GOVERNOR LUBRICATION
(All Models)

The governor and governor housing is pressure-lubricated by a supply of oil from the oil manifold which is mounted on the top of the crankcase between the two banks of cylinders. See the topic, OIL MANIFOLD (ALL MODELS).

The oil tube **(5)** receives oil from the oil manifold and delivers the oil to the front bearing assembly **(4)**, in which a drilled passage supplies the front bushing **(9)**. The oil tube **(3)** is mounted within the governor housing and transmits the oil to the rear bushing **(2)**.

The drilled passage **(6)** allows the oil to drain away from the oil seal **(1)**. The governor assembly **(7)** is lubricated by a drilled passage in the accessory shaft which receives the oil from the bearing assembly **(4)**. The oil drains out the drain hole **(8)** and onto the engine timing gears.

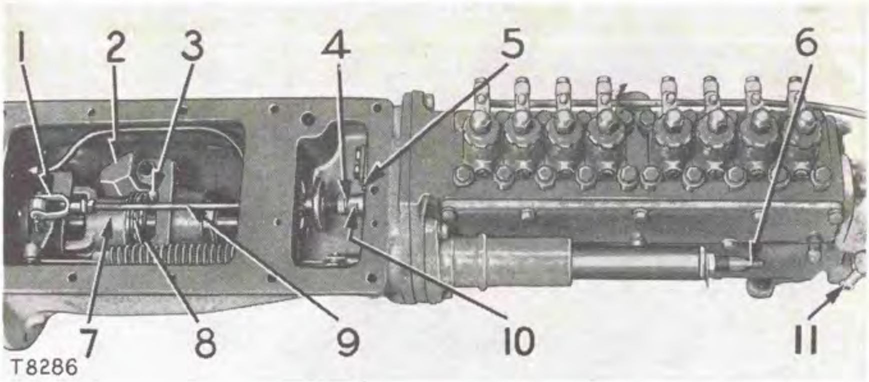


GOVERNOR LUBRICATION
1—Oil seal. 2—Rear bushing. 3—Oil tube. 4—Front bearing assembly. 5—Oil tube. 6—Drilled passage. 7—Governor assembly. 8—Drain hole. 9—Front bushing.

Governor Weight Adjustment (All Models)

When the fuel rack is wide open with the rack adjusting nut **(10)** touching the torque spring **(5)**, the governor weights **(2)** must have free play.

The free play can be checked and adjusted in the following manner. Move the fuel supply control arm **(11)** in the fuel "ON" position. Open the fuel rack until the rack adjusting nut touches the torque spring by extending the governor and fuel pump control rod **(6)** to the open position.



GOVERNOR WEIGHT ADJUSTMENT

1—Yoke end. 2—Governor weight. 3—Shoulder. 4—L-shaped key. 5—Torque spring. 6—Governor and fuel pump control rod. 7—Sliding sleeve. 8—Bearing. 9—Rod. 10—Rack adjusting nut. 11—Fuel supply control arm.

Adjust the yoke end **(1)** and the rod **(9)** to permit the governor weights **(2)** to move freely. When checking the free play, one governor weight may have less clearance than the other weight. In that case, make the adjustment of the clearance for the lesser of the two, disregarding the one with the greater clearance.

The primary adjustment should be set to allow approximately .045" clearance between the shoulder **(3)** of the governor weight and the bearing **(8)** on the sliding sleeve **(7)**.

If the engine surges when running, change the adjustment of the yoke end and rod to permit the engine to operate smoothly. When adjusting the yoke end to stop the engine from surging, make only a slight adjustment at a time.

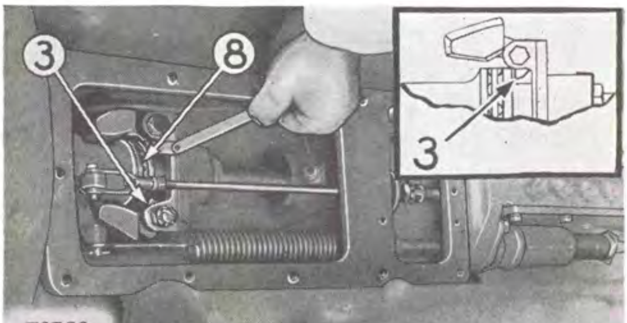
Different rack settings may also require adjusting the yoke end and rod.

The L-shaped key **(4)** should always be up after adjustments are made. This will facilitate adjusting the rack setting without disturbing the yoke

CHECKING GOVERNOR WEIGHT FREE PLAY

3—Shoulder.
8—Bearing.

◆

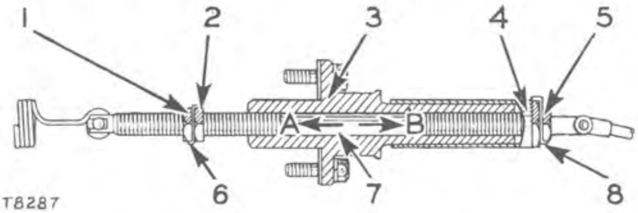


end of the rod, since the L-shaped key must be removed to change the fuel rack setting.

High and Low Idle Speed Adjustments (All Models)

The high idle engine speed is governed by the adjusting nut **(2)** which acts as a stop against the bearing **(3)**. Its position on the control rod **(7)** determines the distance the control rod can be moved in the direction of the arrow **(B)**.

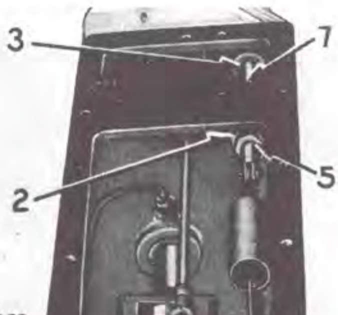
To decrease the high idle engine speed bend the lock **(6)**, and loosen the lock nut **(1)**. Move the adjusting nut **(2)** toward the bearing **(3)**. Tighten the lock nut and bend the lock.



HIGH AND LOW IDLE SPEED ADJUSTMENTS
1—Lock nut. 2—Adjusting nut. 3—Bearing. 4—Nut assembly. 5—Lock nut. 6—Lock. 7—Governor and fuel pump control rod. 8—Lock.

To increase the high idle engine speed turn the lock nut **(1)** and the adjusting nut **(2)** away from the bearing **(3)**. Tighten the lock nut and bend the lock.

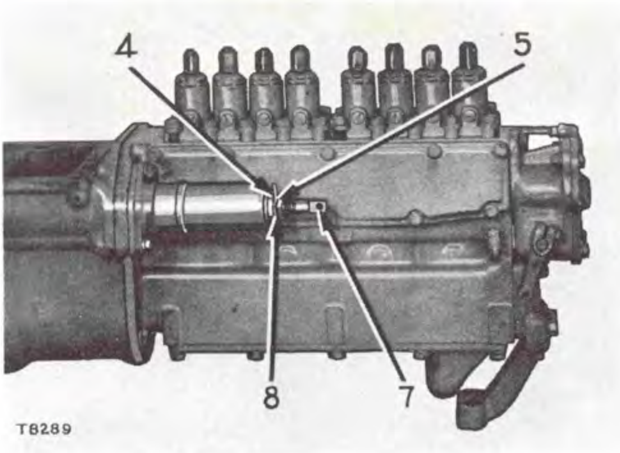
The low idle engine speed is governed by the nut assembly **(4)** which acts as a stop against the bearing **(3)**. Its position on the control rod **(7)** determines the distance the control rod can be moved in the direction of the arrow **(A)**.



LOCATION OF HIGH IDLE ADJUSTMENT

2—Adjusting nut. 3—Bearing. 5—Lock nut. 7—Governor and fuel pump control rod.

◆



LOCATION OF LOW IDLE ADJUSTMENT
4—Nut assembly. 5—Lock nut. 7—Governor and fuel pump control rod. 8—Lock.

The low idle engine speed should be 400-420 RPM.

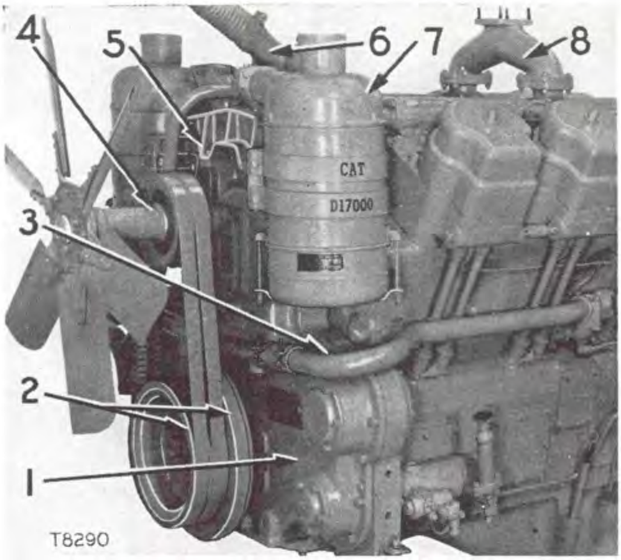
To decrease the low idle engine speed bend the lock **(8)** and loosen the lock nut **(5)**. Move the nut assembly **(4)** away from the bearing **(3)**. Tighten the lock nut and bend the lock.

To increase the low idle engine speed bend the lock **(8)** and loosen the lock nut **(5)**. Move the nut assembly **(4)** toward the bearing **(3)**. Tighten the lock nut and bend the lock.

GOVERNOR HOUSING REMOVAL
(All Models)

The governor housing **(21)** must be removed from the engine before the governor can be completely disassembled. The governor housing can be removed in the following manner.

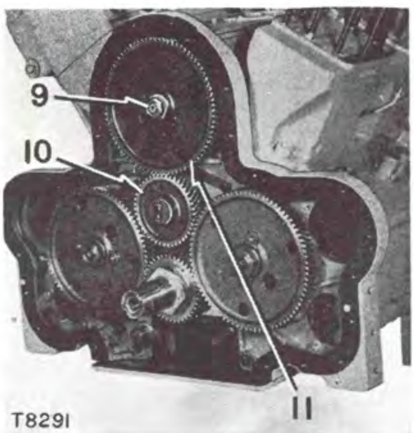
See the removal topics in which the following assemblies are described and remove them from the engine. The fan group **(4)**, the air cleaner support bracket **(5)**, the water temperature regulator housing **(6)**, the air cleaners **(7)**, the manifold exhaust Y-pipe **(8)**, the fan drive pulley and damper weight **(2)**, the timing gear cover **(1)** and the water lines **(3)**.



PREPARING FOR GOVERNOR HOUSING REMOVAL
1—Timing gear housing cover. 2—Fan drive pulley and damper weight. 3—Water lines. 4—Fan group. 5—Air cleaner support bracket. 6—Water temperature regulator housing. 7—Air cleaner. 8—Manifold exhaust Y-pipe.

The cylinder heads need not be removed. They are shown removed in some illustrations to better show the procedure of removing the governor housing.

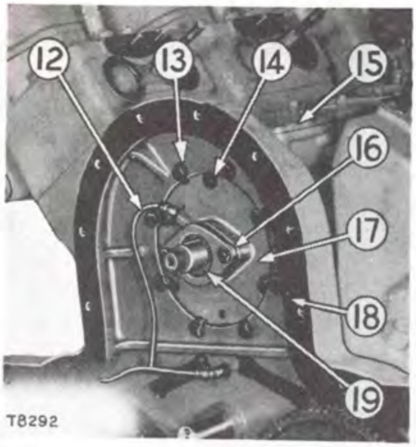
Remove the idler gear **(10)**. See the topic, REMOVING TIMING GEARS (ALL MODELS).



REMOVING ACCESSORY SHAFT IDLER GEAR AND ACCESSORY SHAFT DRIVE GEAR

9—Nut and lock. 10—Accessory shaft idler gear. 11—Accessory shaft drive gear.

♦



PREPARING TO REMOVE GOVERNOR FRONT BEARING ASSEMBLY

12—Oil Tube. 13—Capscrew and lock. 14—Capscrew and lock. 15—Governor housing inspection cover. 16—Thrust plate (and spacers). 17—Governor front bearing assembly. 18—Timing gear housing. 19—Thrust washer.

◆

Remove the nut and lock **(9)**, and the accessory shaft drive gear **(11)**. See the topic, REMOVING TIMING GEARS (ALL MODELS).

Disconnect the oil tube **(12)** from the governor front bearing assembly **(17)**.

Remove the capscrews and locks holding the thrust plate **(16)** (and spacers) and the thrust washer **(19)** to the bearing assembly. Remove the plate, spacers, washer and the woodruff key.

Remove the capscrews **(14)** and locks holding the bearing assembly **(17)** to the governor housing.

Remove the capscrews **(13)** holding the governor housing **(21)** to the timing gear housing **(18)**.

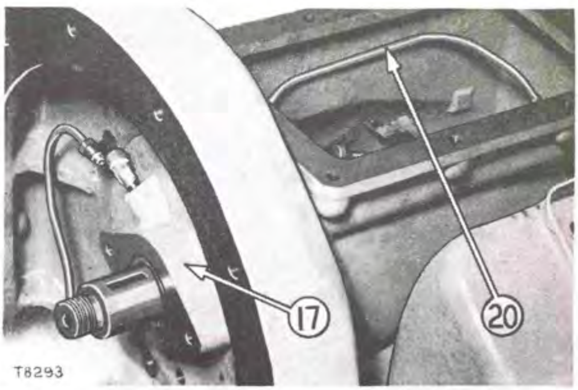
Remove the governor housing inspection cover **(15)**.

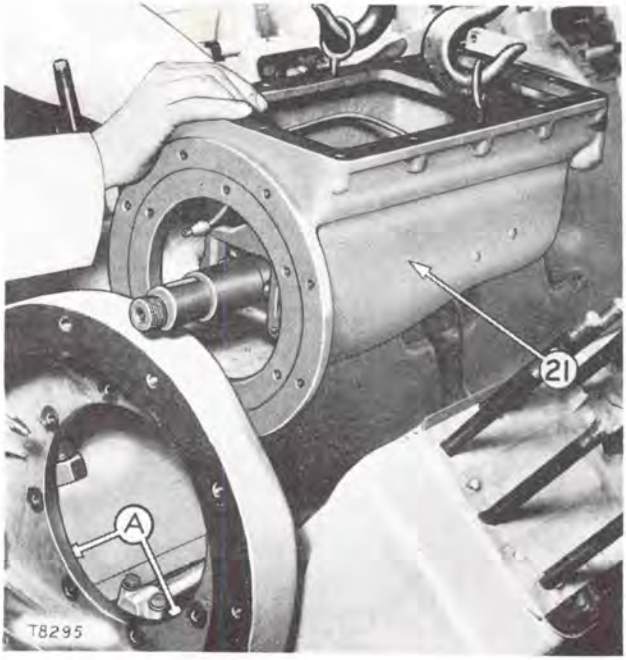
Disconnect the oil tube **(20)** from the inside of the front bearing assembly **(17)** and slide the bearing assembly out through the bore in the timing gear housing.

REMOVING GOVERNOR FRONT BEARING ASSEMBLY

17—Governor front bearing assembly. 20—Oil tube.

◆





REMOVING GOVERNOR HOUSING
A—Clearance between timing gear housing and cylinder blocks.
21—Governor housing.

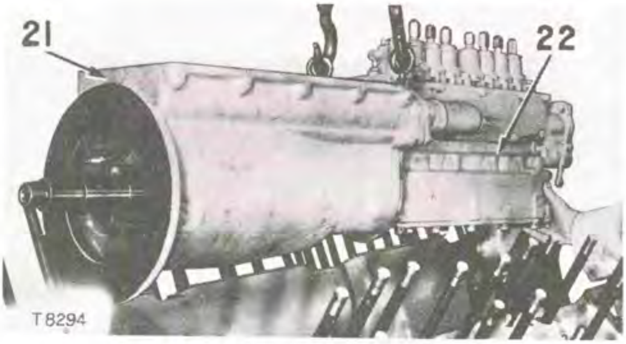
The bearing assembly **(17)** must be removed first, to permit the governor housing to be removed from the engine, because of the close clearance between the cylinder blocks and the timing gear housing, as illustrated at **(A)**. When the governor housing is being removed, it must be lifted straight up to clear the nuts holding the cylinder blocks to the crankcase.

Disconnect and remove whatever is necessary within the V (between the two banks of cylinders) to facilitate removing the governor housing.

NOTE

Occasionally the governor housing must be removed only to facilitate the removal of other assemblies of the engine. In that case it would be desirable to remove the governor housing **(21)** and the fuel injection pump housing **(22)** together as a unit. See the topic, FUEL INJECTION PUMP HOUSING AND GOVERNOR HOUSING REMOVAL AS A UNIT (ALL MODELS).

For all practical purposes, if no work is to be done on the fuel injection pump housing, or the governor housing it is advisable to remove and install the assemblies as a unit.



REMOVING GOVERNOR HOUSING AND FUEL INJECTION PUMP HOUSING AS A UNIT
21—Governor housing. 22—Fuel injection pump housing.

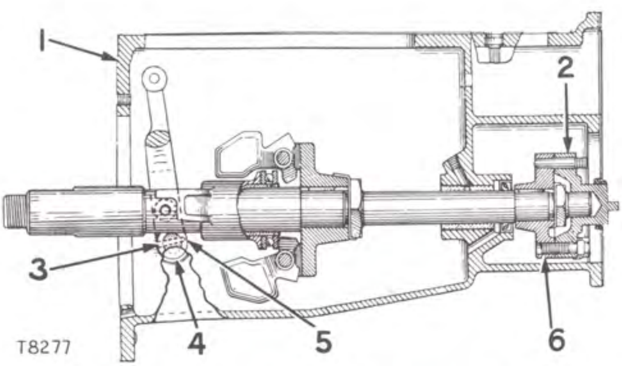
Remove the fuel injection pump housing (if it is not being removed with the governor housing as a unit.) See the topic, FUEL INJECTION PUMP HOUSING REMOVAL (ALL MODELS).

Using 3/8" standard eyebolts and a suitable hoist, lift out the governor housing as illustrated.

Governor Disassembly and Assembly (All Models)

The governor housing must be removed from the engine before the governor can be completely disassembled. See the topic, GOVERNOR HOUSING REMOVAL (ALL MODELS). Remove the governor housing.

Remove the fuel pump drive coupling **(2)** and the accessory shaft coupling **(6)** as described in the topic, REMOVING THE FUEL PUMP DRIVE COUPLING AND ACCESSORY SHAFT COUPLING (ALL MODELS).



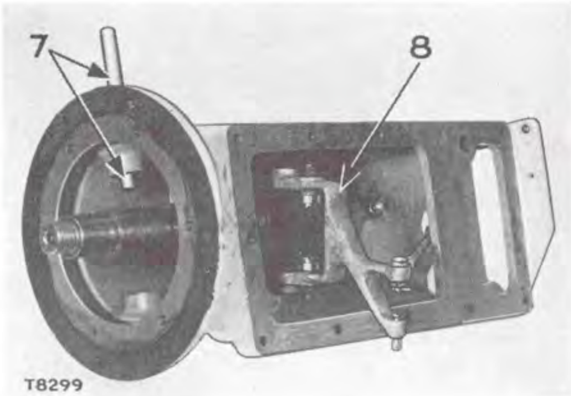
GOVERNOR HOUSING AND GOVERNOR
1—Governor housing. 2—Fuel pump drive coupling. 3—Taper pin. 4—Plug. 5—Small end of taper pin (3). 6—Accessory shaft coupling.

Remove the plug **(4)** from either side of the governor housing **(1)**.

Drive out the taper pin **(3)**, by driving on the small end **(5)** of the pin.

Using a small soft brass rod on the end of the shaft **(7)**, drive the shaft toward the remaining plug **(4)** in the side of the governor housing and remove the plug from the governor housing.

Remove the shaft **(7)** and lift out the terminal lever **(8)**.

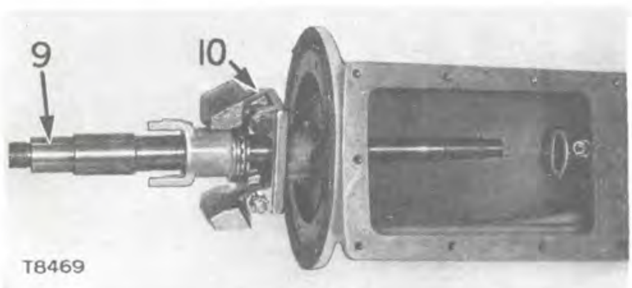


REMOVING TERMINAL LEVER

7—Shaft. 8—Terminal lever.

♦

Remove the accessory shaft **(9)** and the governor **(10)** as a unit from the governor housing.



REMOVING ACCESSORY SHAFT AND GOVERNOR

9—Accessory shaft. 10—Governor.

♦

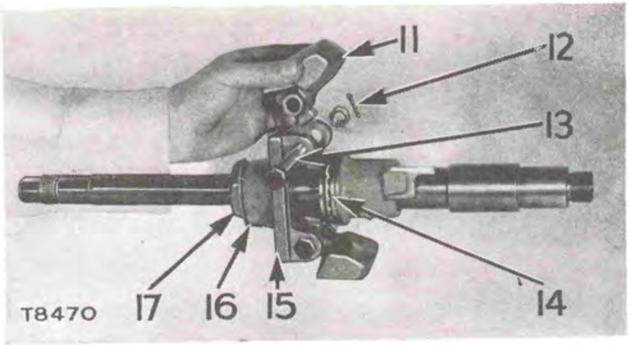
Remove the cotter pins and nuts **(12)**, slide out the anchor pins **(13)** and remove the governor weights **(11)**.

Bend the lock **(16)** and remove the nut **(17)** and the lock.

Remove the flange **(15)** by using an arbor press.

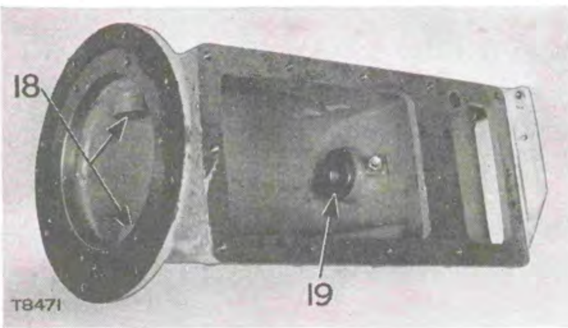
Remove the woodruff key from the accessory shaft.

Slide the bearing and sliding sleeve assembly **(14)** from the accessory shaft and inspect for wear.



REMOVING GOVERNOR WEIGHTS
11—Governor weight. 12—Cotter pin and nut. 13—Anchor pin. 14—Bearing and sliding sleeve assembly. 15—Flange. 16—Lock. 17—Nut.

The bearings **(18)** and the accessory shaft rear bushing **(19)** can be replaced by the use of an arbor press if excessive wear is shown.



LOCATION OF REAR ACCESSORY SHAFT BUSHING

18—Bearings. 19—Rear accessory shaft bushing.

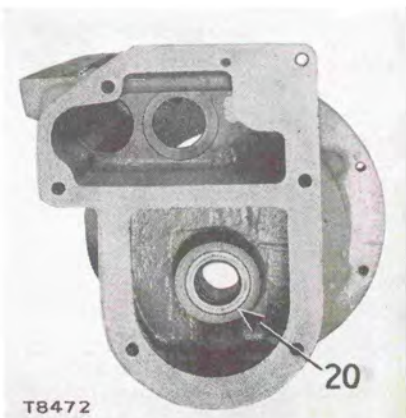
◆

Remove the oil seal **(20)** at the rear end of the governor housing.

OIL SEAL

20—Oil seal.

◆



Inspect and check the bearings **(21)** on the terminal lever **(8)**. If the bearings show wear or do not rotate freely, they can be removed and replaced by removing the cotter pins and nuts **(23)** and removing the pins **(22)**. Remove the bearings and install new ones. Install the pins, the nuts and the cotter pins.

Clean and inspect all parts and replace any part that shows excessive wear.

Install a new oil seal **(20)**, at the rear of the governor housing.

Install the bearing and sliding sleeve assembly **(14)**, the flange **(15)**, and the governor weights **(11)** to the accessory shaft and install the accessory shaft into the governor housing.

Place the terminal lever **(8)** into the governor housing positioning the bearings **(21)** under the protruding portion of the sliding sleeve as illustrated.

CAUTION

> The protruding portion of the sliding sleeve **(14)** must be positioned **above** the bearings **(21)** on the terminal lever. If this is not done the governor may be rendered inoperative and damage to the engine might result.

Install the shaft **(7)** aligning the tapered pin hole **(24)** with tapered pin hole **(25)** in the terminal lever. Install the tapered pin.

TERMINAL LEVER
8—Terminal lever. 21—Bearing.
22—Pin. 23—Cotter pin and nut.

INSTALLING TERMINAL LEVER
7—Shaft. 8—Terminal lever.
14—Sliding sleeve. 21—Bearing.
24—Taper pin hole in shaft (7).
25—Taper pin hole in terminal lever.

If a new shaft **(7)** or terminal lever **(8)** or both have been installed, they must be drilled and reamed. Using a No. 19 (.166") drill, drill through the shaft and terminal lever. Ream the hole for a $1\frac{1}{4}$" No. 2 standard taper pin. Install the taper pin.

Install new plugs on both sides of the governor housing, using a coating of sealing compound to help prevent oil leakage.

Install the governor housing as described in the topic, GOVERNOR HOUSING INSTALLATION (ALL MODELS).

Install the fuel pump housing as described in the topic, FUEL INJECTION PUMP HOUSING INSTALLATION (ALL MODELS).

GOVERNOR HOUSING INSTALLATION
(All Models)

If the governor housing and fuel injection pump housing were removed as a unit, install them in reverse order of removal.

If the fuel injection pump housing and the governor housing were removed separately, install the governor housing on the engine in the reverse order of removal. See the topic, FUEL INJECTION PUMP HOUSING INSTALLATION (ALL MODELS), for the procedure of installing the pump housing to the governor housing, and install the pump housing.

Slide the bearing assembly **(4)** into the bore of the timing gear housing **(2)** and install the capscrews and locks holding the bearing assembly to the governor housing.

Connect the oil supply tube **(3)** to the bearing assembly, and connect the oil tube inside the governor housing to the front bearing assembly. This tube delivers the oil from the front bearing assembly to the rear bushing and is not shown in this illustration. See the topic, GOVERNOR LUBRICATION (ALL MODELS).

INSTALLING THRUST WASHER AND THRUST PLATE

1—Thrust plate. 2—Timing gear housing. 3—Oil supply tube. 4—Accessory shaft front bearing assembly. 5—Spacer. 6—Woodruff key. 7—Thrust washer.

♦

CHECKING END CLEARANCE

8—Feeler gauge.

Install the woodruff key **(6)** in the accessory shaft.

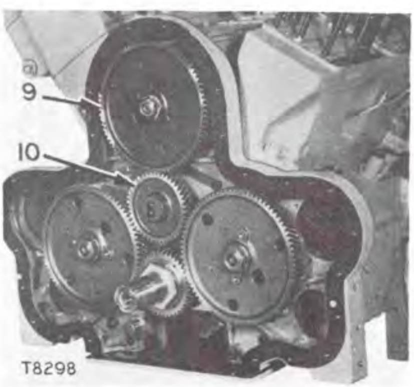
Inspect the spacers **(5)** and thrust washer **(7)** for burrs or roughness as this washer and spacers control the end clearance for the accessory shaft and accessory shaft drive gear.

Install the thrust washer, the spacers, the thrust plate **(1)**, the capscrews and locks.

Rotate the accessory shaft and thrust washer, using the regular nut provided on the accessory shaft and turning the shaft in a clockwise rotation. Pry the accessory shaft either forward or back. Place a feeler gauge **(8)** between the thrust washer and the bearing assembly or the thrust plate depending upon which way the accessory shaft has been pried. The correct clearance is from .003″ to .007″ and a maximum permissable clearance of .012″.

Remove the accessory shaft nut.

Install the accessory shaft drive gear **(9)** to the accessory shaft, mating the keyway of the gear with the key in the accessory shaft. See the topic,



INSTALLING ACCESSORY SHAFT DRIVE GEAR

9—Accessory shaft drive gear.
10—Accessory shaft idler gear.

TIMING GEARS AND TIMING MARKS (ALL MODELS), for the procedure of timing the accessory shaft idler gear **(10)**.

Install the accessory shaft idler gear.

Install the remaining assemblies in the reverse order of removal.

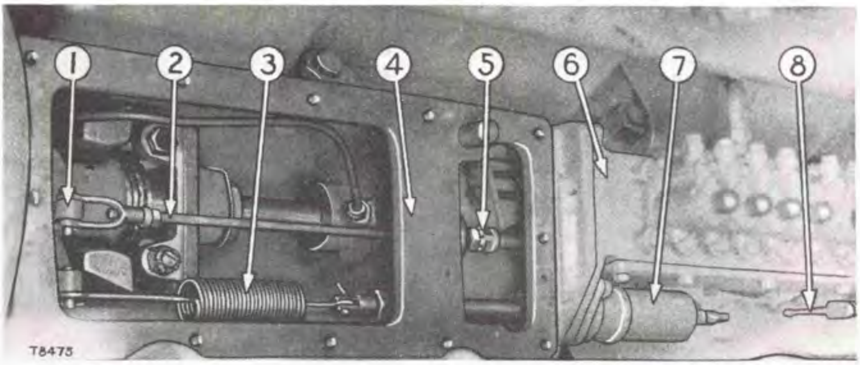
GOVERNOR AND FUEL PUMP CONTROL MECHANISM
(All Models)

The governor and fuel pump control mechanism **(7)** is mounted on the fuel injection pump housing **(6)** and into the governor housing **(4)**.

The control mechanism is connected to the governor spring **(3)** which is attached to the terminal lever **(1)**. An adjustable rod **(2)** connects the terminal lever and the control mechanism to the fuel rack slide bar **(5)** which is connected to the fuel pump rack.

The fuel shut-off control lever **(8)** is located near the rear of the fuel injection pump housing. See the topic, FUEL INJECTION PUMP SHUT-OFF (ALL MODELS).

For the adjustments of the control mechanism see the topic, HIGH AND LOW IDLE SPEED ADJUSTMENTS (ALL MODELS). Also see the topic, GOVERNOR WEIGHT ADJUSTMENT (ALL MODELS).



GOVERNOR AND FUEL PUMP CONTROL MECHANISM
1—Terminal lever. 2—Adjustable rod. 3—Governor spring. 4—Governor housing. 5—Slide bar. 6—Fuel injection pump housing. 7—Governor and fuel pump control mechanism. 8—Fuel shut-off control lever.

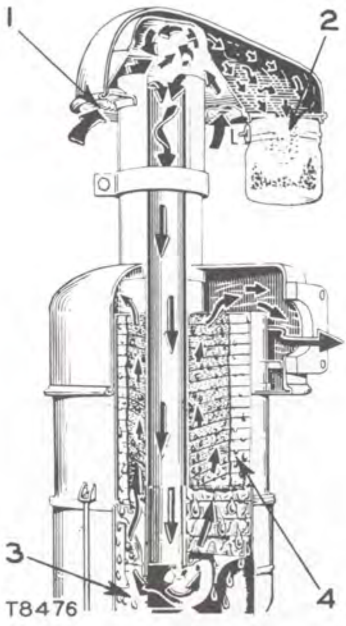
Air Cleaners
(D17000L-E-I)

Oil-bath type air cleaners are used.

Air enters the engine through the vanes of the pre-cleaner **(1)** (if one is installed) which gives it a swirling motion throwing out the heavier particles into the jar **(2)**. After passing down the pipe to the center oil cup **(3)**, the air is deflected upward through a series of screens, carrying drops of oil up onto the screens **(4)**. The oil absorbs dirt from the air as it passes through these screens. The screens are shaped so that the air sweeps the dirt-laden oil toward the outside of the cleaner where it falls down into the outside or settling cup. The oil re-enters the center cup through a small hole.

The air inlet pipe can be cleaned without removing the air cleaner.

The lower screens are removable and can be serviced and cleaned, without removing the air cleaners from the engine. To service the upper or fixed screens, the air cleaners should be removed from the engine.



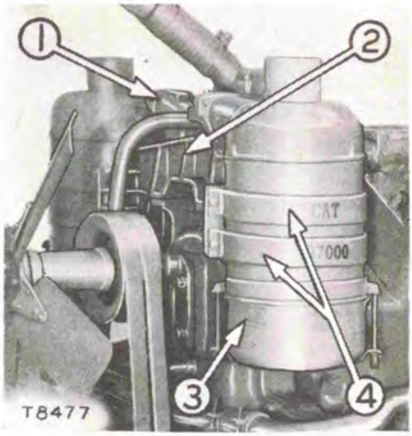
AIR CLEANERS

1—Pre-cleaner vanes. 2—Jar. 3—Center oil cup. 4—Screens.

AIR CLEANER REMOVAL (D17000L-E-I)

Remove the capscrews holding the air cleaner to the air inlet elbow **(1)**.

Remove the capscrews holding the air cleaner support bands **(4)** to the air cleaner support bracket **(2)** and remove the air cleaner **(3)**.



AIR CLEANER REMOVAL

1—Air inlet elbow. 2—Support bracket.
3—Air cleaner. 4—Support bands.

♦

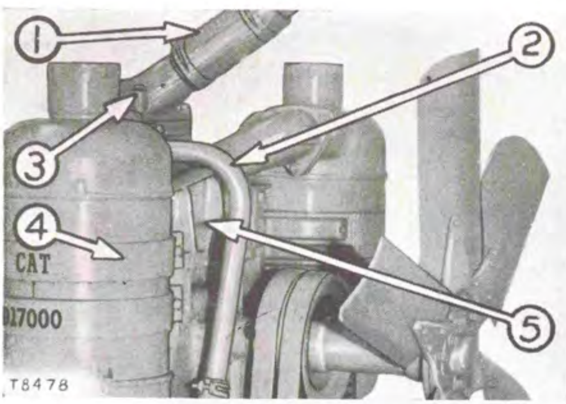
Both air cleaners are removed in the same manner.

Air Cleaners and Air Cleaner Support Brackets Removal as a Unit (D17000L-E-I)

Occasionally it will be desired to have the air cleaners **(4)** and the support brackets **(5)** removed from the engine to facilitate other work to be done. In that case it is practical to remove the air cleaners and the support brackets as a unit.

Remove the by-pass water line **(2)**.

Remove the water hose **(1)** which connects the regulator housing to the radiator. The regulator housing **(3)** need not be removed, but it can be if desired.

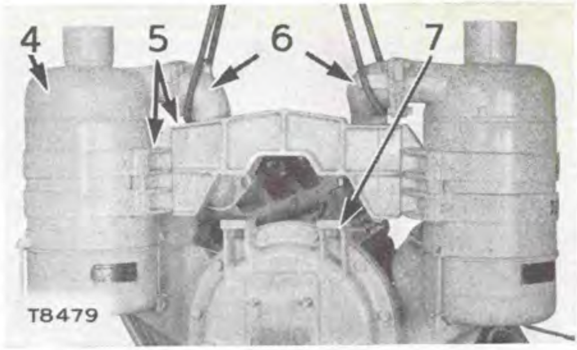


PREPARING TO REMOVE THE AIR CLEANERS AND SUPPORT BRACKETS AS A UNIT

1—Water hose. 2—Water by-pass line. 3—Regulator housing. 4—Air cleaner. 5—Support brackets.

REMOVING AIR CLEANERS AND SUPPORT BRACKETS

4—Air cleaner.
5—Support brackets.
6—Inlet elbows.
7—Timing gear housing cover.



Disconnect the air inlet elbows **(6)** from the engine inlet manifolds.

Remove the capscrews holding the air cleaner support brackets **(5)** to the timing gear housing cover **(7)**.

Place a sling around the inlet elbows **(6)** as illustrated and remove the combined assemblies.

The fan group need not be removed. In this case it has been removed for better illustration only.

Inlet and Exhaust Manifold Removal and Installation

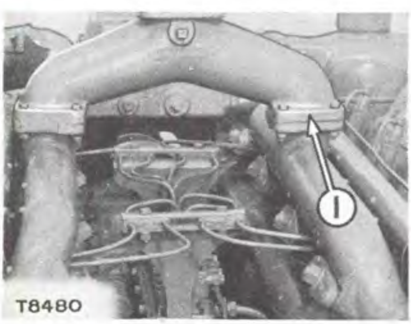
(D17000L-E-I)

The inlet and exhaust manifolds of both the right and the left banks can be removed in the following manner.

Remove the exhaust manifold Y-pipe **(1)**.

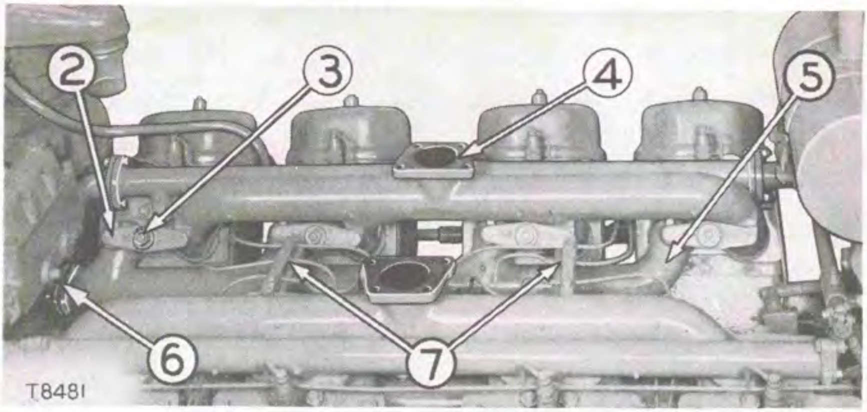
Remove the nuts **(3)** and the hold-down clamps **(2)**.

Lift off the exhaust manifold **(4)**.



REMOVING EXHAUST MANIFOLD Y-PIPE

1—Exhaust manifold Y-pipe.



REMOVING INLET AND EXHAUST MANIFOLDS
2—Clamps. 3—Nut. 4—Exhaust manifold. 5—Inlet manifold. 6—Inlet elbow. 7—Fuel injection lines (from fuel pumps to fuel injection valves).

Remove the fuel injection lines **(7)** from the fuel pumps to the fuel injection valves.

Disconnect the inlet manifolds **(5)** from the inlet elbows **(6)** that connect the inlet manifolds to the air cleaners.

Remove the inlet manifold.

Protect the inlet and exhaust ports in the heads by covering them to prevent anything falling into the heads.

When installing the manifolds, remove the protection from the inlet and exhaust ports, install new manifold gaskets and centrally locate the gaskets evenly over the inlet and exhaust ports of the heads.

Install the manifolds, the clamps, and the nuts and tighten evenly and securely. Install the Y-pipe.

Cylinder Heads and Valve Mechanism
(All Models)

An individual cylinder head is used for each cylinder. Copper water directors direct the flow of coolant around the valve ports and pre-combustion chambers. Rubber seals and ferrules seal the water passages between the cylinder heads and cylinder blocks. The inlet and exhaust valves and the valve rocker arm mechanisms are a part of the cylinder head and valve mechanism.

Properly adjusted valves will operate for many hours before they need to be reconditioned. Eventually, however, the valve faces and seats may become pitted which ultimately allows compression losses. Valve leakage can often be heard distinctly in the manifolds.

Worn piston rings, improperly adjusted valves or a damaged cylinder head gasket will result in loss of compression; therefore, these items should be checked before concluding that the valves are at fault. Worn piston rings can usually be detected, without dismantling the engine, as considerable oil vapor will come out of the breather while the engine is running. In addition, this condition will probably be accompanied by high oil consumption.

The cylinder heads can be removed individually from the engine, or each bank can be removed as a unit with the water, inlet manifold, exhaust manifold and the compression release mechanism installed. See the topics, INDIVIDUAL CYLINDER HEAD REMOVAL (ALL MODELS), and CYLINDER HEAD REMOVAL AND INSTALLATION WITH MANIFOLDS INSTALLED (ALL MODELS).

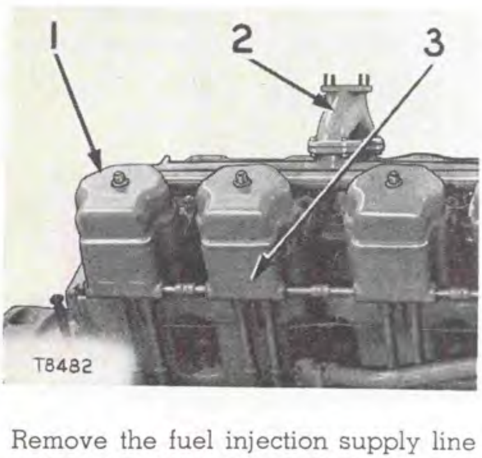
INDIVIDUAL CYLINDER HEAD REMOVAL
(All Models)

An individual cylinder head **(3)** can be removed from the engine in the following manner.

Drain the cooling system.

Remove the exhaust manifold Y-pipe **(2)**.

Remove the valve cover **(1)**.

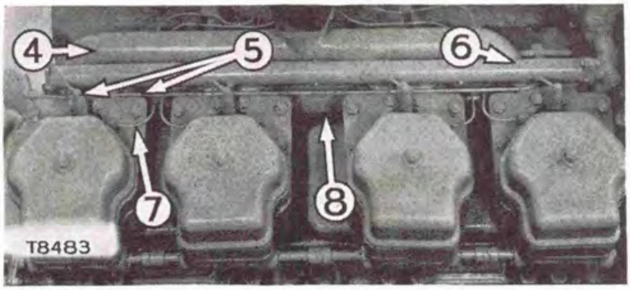


CYLINDER HEADS

1—Valve cover. 2—Exhaust manifold Y-pipe. 3—Cylinder head.

◆

Remove the fuel injection supply line **(7)** and the fuel injection valve overflow line **(5)** for the cylinder head that is to be removed. Install dust protector caps and plugs furnished in the tool equipment with the engine to keep out dirt.

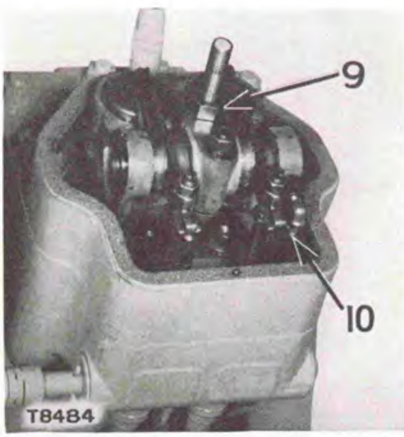


REMOVING MANIFOLDS
4—Exhaust manifold. 5—Fuel injection valve overflow line. 6—Water manifold. 7—Fuel injection supply line. 8—Inlet manifold.

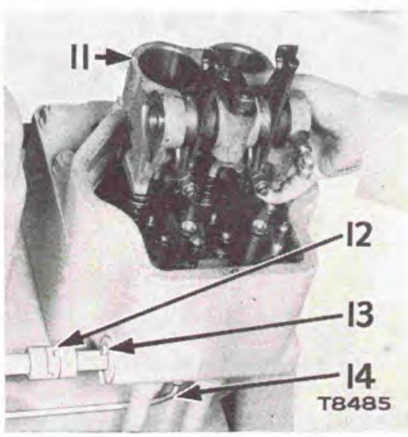
Remove the exhaust manifold **(4)**, the water manifold **(6)** and the inlet manifold **(8)**. See the topics, INLET AND EXHAUST MANIFOLD REMOVAL AND INSTALLATION (D17000L-E-I) and REMOVING WATER MANIFOLDS (D17000L-E-I).

NOTE

If desired the inlet and water manifold need not necessarily be removed. Loosen the nuts and clamps holding the inlet and exhaust manifolds to the heads. Remove the exhaust manifold. Remove the studs holding the inlet and water manifolds to the head that is to be removed. Loosen the nuts on the remaining studs of that particular bank of heads, pry the inlet and water manifolds away from the head and



PREPARING TO REMOVE THE ROCKER ARM ASSEMBLY
9—Hold-down nut. 10—Oil supply tube.



REMOVING ROCKER ARM ASSEMBLY
11—Rocker arm assembly. 12—Connecting link. 13—Cotter pin. 14—Oil line.

block them in this position. Follow the procedure as outlined in this topic for the head removal. In most cases, however, it would be more practical to remove the manifolds completely.

Remove the rocker arm bracket hold-down nut **(9)**, and disconnect the oil supply tube **(10)** to the rocker arm bracket assembly.

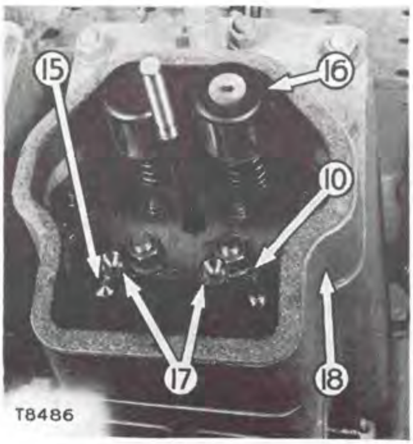
Remove the rocker arm bracket assembly **(11)**.

Remove the cotter pin **(13)** and the connecting link **(12)** from the compression release mechanism. If a center cylinder head is removed, the cotter pin and link on each side of the head should be removed.

Disconnect the oil line **(14)** at the bottom of the head.

Remove the sleeves **(16)**, the push rods **(17)** and the compression release adjustable rod **(15)**.

Remove the valve cover base **(18)** and the oil tube **(10)**.



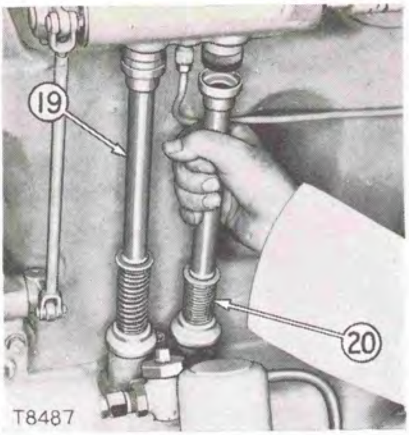
REMOVING VALVE COVER BASE

10—Oil supply tube. 15—Adjustable compression release rod. 16—Sleeve. 17—Push rods. 18—Valve cover base.

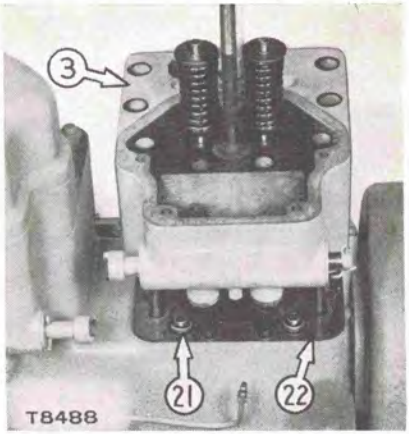
Remove the push rod dust tubes **(19)** by pushing down on the tubes and compressing the springs **(20)**.

Remove the nuts and washers holding the cylinder head.

Remove the cylinder head **(3)**, the ferrules and seals **(21)** and the cylinder head gasket **(22)**.



REMOVING PUSH ROD DUST TUBES
19—Push rod dust tube. 20—Spring.



REMOVING CYLINDER HEAD
3—Cylinder head. 21—Ferrule and seal. 22—Gasket.

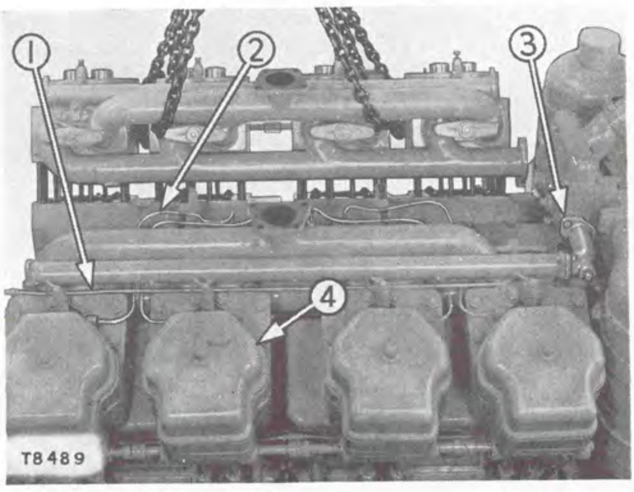
CYLINDER HEAD REMOVAL AND INSTALLATION WITH MANIFOLDS INSTALLED

(All Models)

Either the left or right bank of cylinder heads can be removed from the engine, with the manifolds installed, in the following manner.

Drain the cooling system.

Remove the fuel injection valve overflow lines **(1)**. Install dust seals on the hollow plugs, and install the plugs on the fuel injection valves.



REMOVING CYLINDER HEADS WITH MANIFOLDS INSTALLED
1—Fuel injection valve overflow line. 2—Fuel line. 3—Water elbow. 4—Valve cover.

Remove the valve covers **(4)**.

Remove the fuel lines **(2)**, from the fuel pumps to the fuel injection valves.

Remove the water elbow **(3)**, connecting the water manifold to the regulator housing. Also remove the elbow connecting the water manifold to the starting engine, if one is installed.

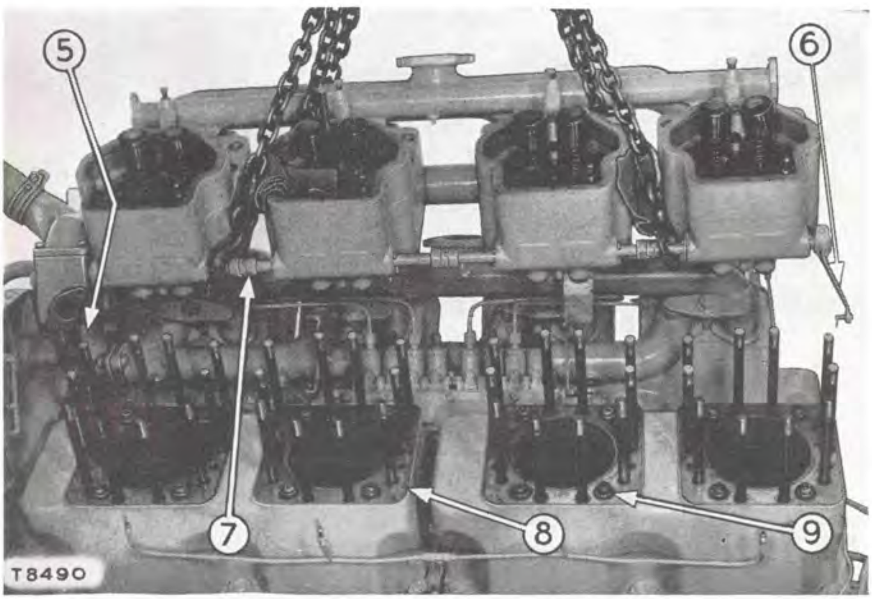
Disconnect the compression release mechanism lever **(6)** at the rear of the engine.

Remove the air inlet elbow **(5)** that delivers the air from the air cleaner to the inlet manifold.

See the topic, INDIVIDUAL CYLINDER HEAD REMOVAL (ALL MODELS), and remove or disconnect the following parts as they are described in that topic: the rocker arm assembly, the push rods, the compression release adjustable rod, the oil supply line and the push rod dust tubes.

Remove all the nuts and washers holding the cylinder heads to the cylinder blocks.

Place short chains or cables, around the water manifold and the exhaust manifold.



CYLINDER HEADS AND MANIFOLDS REMOVED
5—Inlet elbow (connecting air cleaner to inlet manifold). 6—Compression release lever. 7—Compression release mechanism. 8—Head gasket. 9—Water seal.

Place a longer chain or cable around the compression release mechanism **(7)** to permit the combined assembly to be lifted off the head studs without binding.

With a pry bar positioned so not to damage the heads, pry the combined assemblies up and away from the cylinder blocks, as a final check to see that everything has been disconnected.

Using a suitable hoist remove the heads and manifolds and place them on a clean wooden work bench, so as not to damage the machined face of the heads.

When installing the heads, clean the machined face of the heads.

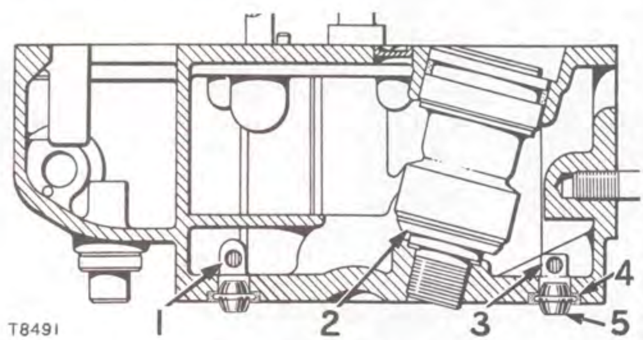
Install new head gaskets **(8)**, and new water seals **(9)** on the ferrules.

Balance the assemblies as they are lifted, to permit the assemblies to be lowered onto the head studs without binding. As the cylinder heads are set down on the dowels in the cylinder block, rock the heads gently back and forth to position them completely down on the cylinder blocks and head gaskets.

Install the washers and nuts and tighten them according to the torque specifications as outlined in the topic, CYLINDER HEAD INSTALLATION (ALL MODELS).

WATER DIRECTORS, SEALS AND FERRULES
(All Models)

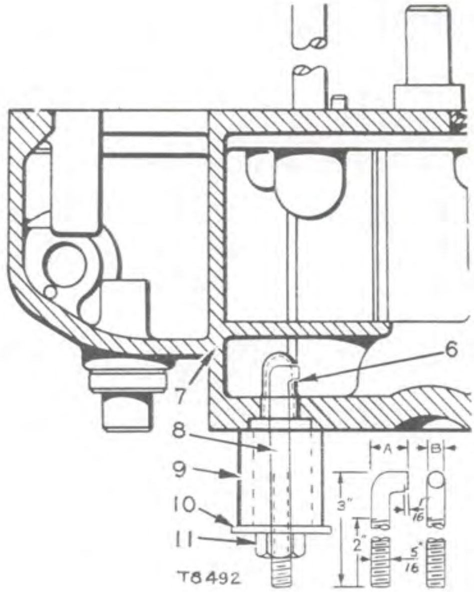
The short water directors **(3)** are located on the manifold side of the heads and the long water directors **(1)** are located on the push rod side of the heads. The coolant is directed toward the pre-combustion chamber **(2)** and the exhaust valves, after it passes from the cylinder block through the ferrules **(5)**. The seals **(4)** prevent leakage as the coolant passes from the cylinder block to the head.



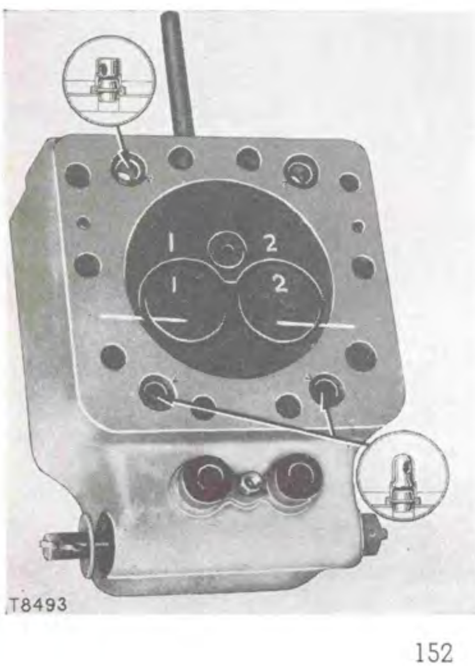
WATER DIRECTORS
1—Long water director. 2—Pre-combustion chamber. 3—Short water director. 4—Seal. 5—Ferrule.

REMOVING WATER DIRECTORS

6—Discharge hole. 7—Cylinder head. 8—Rod. 9—Spacer. 10—Washer. 11—Nut. A—Inside diameter of the director plus 1/16". B—Director hole size minus approximately 1/32".



The directors can be removed from the head **(7)** using a tool similar to the tool illustrated, by placing the hook end of the rod **(8)** into the water director discharge hole **(6)** as illustrated and using a piece of $\frac{3}{4}$" pipe approximately $1\frac{1}{2}$" long as a spacer **(9)** between the head **(7)** and the flat washer **(10)**. Install and tighten the nut **(11)** to remove the water director from the head.



INSTALLING WATER DIRECTORS

This illustration shows the valves and the cylinder head chalk-marked for identification as described in the topic, VALVE REMOVAL.

When installing the directors, align the notches on the directors with the V-marks on the head.

Drive the directors into the head with a suitable driver.

Always install new seals on the ferrules. Coat the seals with liquid soap when installing them on the ferrules for ease of installation.

PRE-COMBUSTION CHAMBERS
(All Models)

The pre-combustion chambers are threaded and are screwed into the cylinder head. They can be removed by inserting the 1F479 Tool into the pre-combustion chamber and turning in a counterclockwise direction.

If the pre-combustion chamber has been removed while the cylinder head is removed from the engine, clean out the water jacket of the head thoroughly.

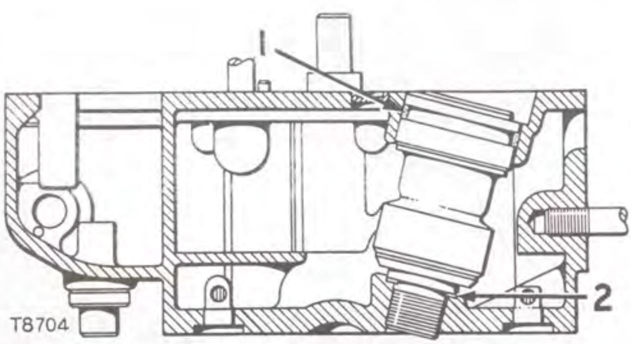
If the pre-combustion chamber is removed while the cylinder head is still on the engine, carefully clean the water jacket of the head so as not to drop anything into the cylinder. This can be done by using a long screw driver with a coating of heavy grease. The dirt will adhere to the grease and can be removed out through the pre-combustion chamber bore at the top of the head.

If a cylinder head has collected an excessive amount of scale or rust within the water jacket, remove the cylinder head and clean it thoroughly.

Use a new gasket **(2)**, coat it with a thin layer of grease on the bottom side of the gasket and place the gasket into the gasket seat bore of the cylinder head. The grease will help retain the gasket in place while installing the pre-combustion chamber.

Install a new rubber seal **(1)** on the pre-combustion chamber. Coat the seal with liquid soap for ease of installation.

Install the pre-combustion chamber and tighten to 150 foot pounds torque.

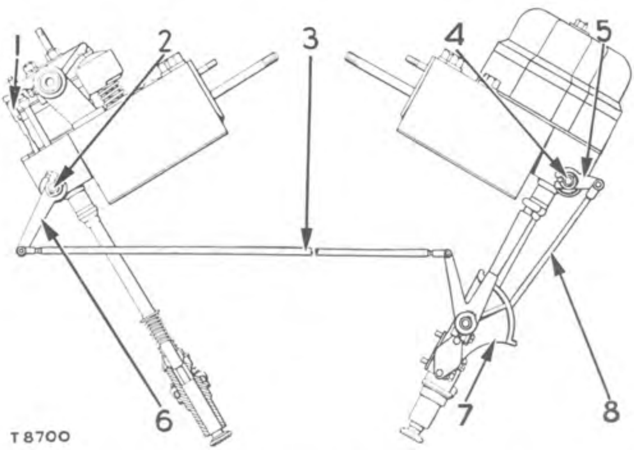


PRE-COMBUSTION CHAMBER

1—Rubber seal.
2—Gasket.

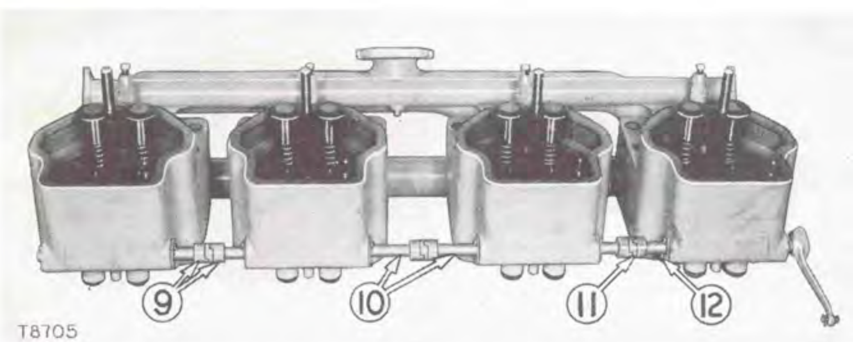
COMPRESSION RELEASE MECHANISM
(All Models)

The compression release mechanism consists of the control bracket assembly **(7)**, the rods **(3)** and **(8)**, the levers **(5)** and **(6)**, the left compression release shaft assembly **(2)**, the right compression release shaft assembly **(4)** and the compression release push rod **(1)**, which is adjustable.



COMPRESSION RELEASE MECHANISM
1—Compression release push rod. 2—Shaft assembly (left side). 3—Rod. 4—Shaft assembly (right side). 5—Lever. 6—Lever. 7—Bracket assembly. 8—Rod.

Before disassembling the compression release mechanism take notice of the different length shafts **(10)** and of the way the hubs **(9)** and the connecting discs **(11)** are installed. Unless both the right and the left



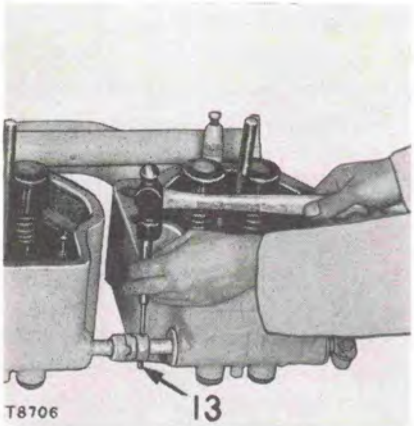
DISASSEMBLING COMPRESSION RELEASE MECHANISM
9—Hubs. 10—Shafts. 11—Connecting disc. 12—Cotter pin.

shaft assemblies need to be disassembled at the same time, it would be a good idea to leave one side together as a guide.

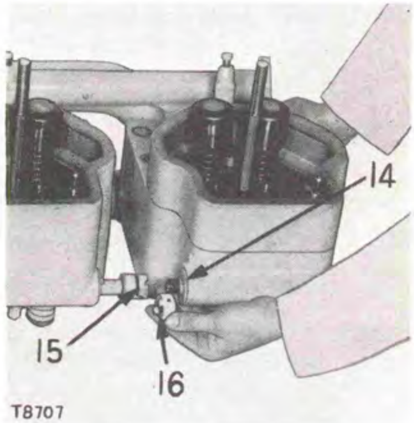
The compression release mechanism can be disassembled in the following manner.

Remove the cotter pin **(12)**.

Rotate the shaft approximately 180° and drive out the taper pin **(13)**.



DRIVE OUT TAPER PIN
13—Taper pin.

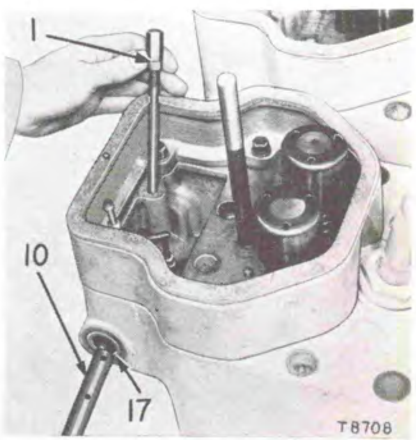


DISCONNECTING COMPRESSION RELEASE SHAFTS
14—Washer. 15—Connecting disc. 16—Hub.

Remove the hub **(16)**, the connecting disc **(15)** and the washer **(14)**.

Remove the compression release push rod **(1)**.

Carefully slide out the shaft **(10)** from the cylinder head, so as not to damage the oil seal. If a new oil seal **(17)** is installed, the lip should be pointing into the head.



REMOVING COMPRESSION RELEASE PUSH ROD

1—Compression release push rod. 10—Shaft. 17—Oil seal.

♦

After the compression release mechanism is installed, and the engine is assembled, check the clearance between the compression release rod and the underside of the exhaust rocker arm. The correct clearance should be .025" to .030" on the compression stroke.

Valves and Valve Mechanism
(All Models)

The valves, and the valve mechanism, time, admit, and release the air and gases involved in engine operation.

This engine is of the four-stroke cycle, having four separate strokes required for each cylinder to complete one cycle.

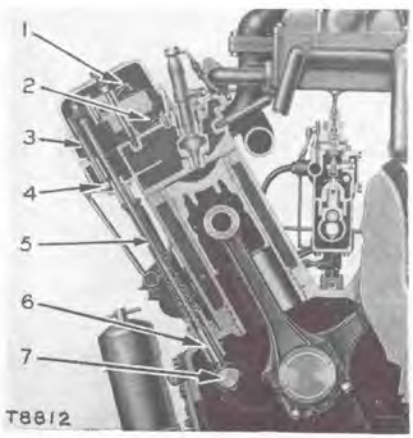
The camshafts are timed to the crankshaft by the engine timing gears and they turn one-half crankshaft speed. See the topic, TIMING GEARS AND TIMING MARKS (ALL MODELS).

The operation of the valves and the valve mechanism is as follows.

When starting or cranking the engine, the compression release mechanism is moved to the "start" position, the shaft assembly **(4)** lifts the adjustable push rods **(3)**, which in turn hold the exhaust valves slightly off their seats. The air is then permitted to escape through the exhaust valves, the exhaust ports and out the exhaust manifold.

When the compression release mechanism is positioned half-way between "start" and "run", only half of the exhaust valves will be lifted off their seats, thus permitting the compression to be released on these cylinders.

When the compression release mechanism is positioned to "run", the exhaust valves are permitted to seat in the heads, thus giving the engine compression.



VALVES AND VALVE MECHANISM

1—Rocker arm. 2—Valve spring. 3—Compression release push rod. 4—Compression release shaft assembly. 5—Push rods. 6—Valve lifter. 7—Camshaft.

♦

As the camshaft turns in time with the crankshaft, the camshaft **(7)** operates the valve lifters **(6)**, which in turn move the push rods **(5)** at the correct time.

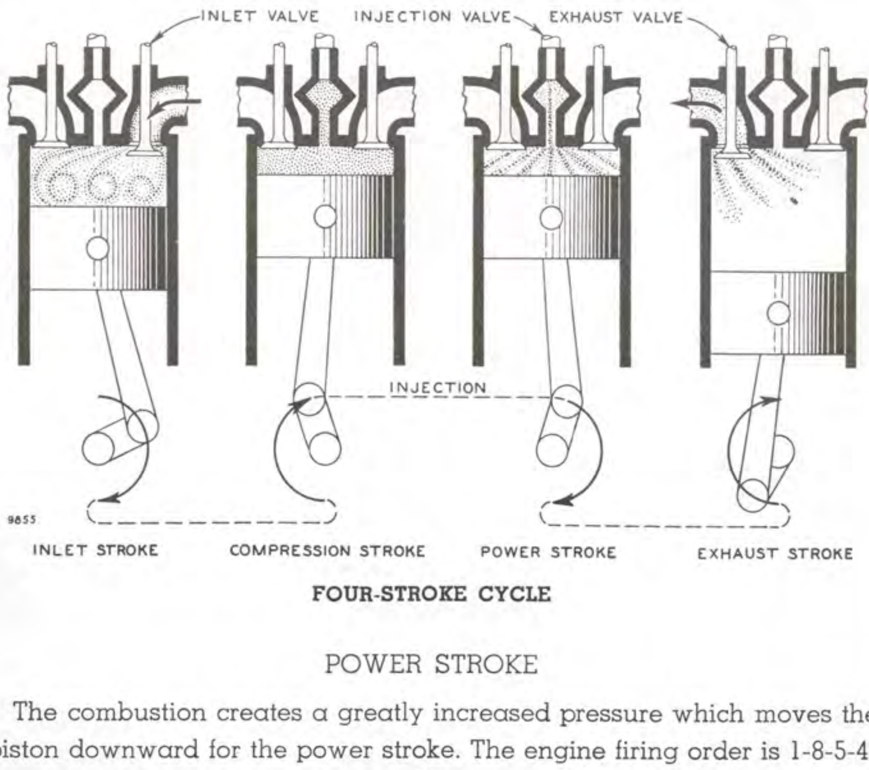
The push rods and the rocker arms **(1)** open the inlet and exhaust valves and the valve springs **(2)** close the valves.

INLET STROKE

The inlet valve opens when the crankshaft is ahead of its top center position. The valve remains open until the crankshaft is past its bottom center position. As the piston moves downward air is drawn into the cylinder.

COMPRESSION STROKE

As the piston moves upward, the trapped air becomes greatly heated. At a specified point before the crankshaft is again at its top center position, fuel is injected into the cylinder. The air temperature becomes higher as the piston moves toward the top of its stroke. The fuel becomes ignited by the heat of air compression.



FOUR-STROKE CYCLE

POWER STROKE

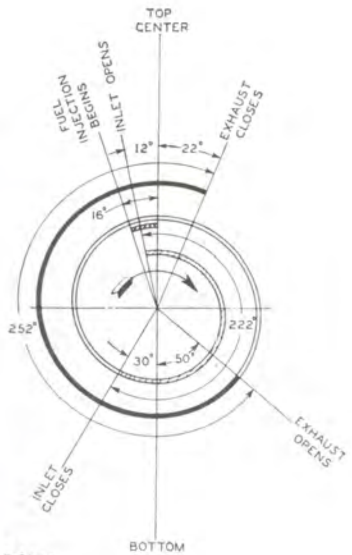
The combustion creates a greatly increased pressure which moves the piston downward for the power stroke. The engine firing order is 1-8-5-4-

7-2-3-6 and the crankshaft turns in a counterclockwise rotation when facing the flywheel.

EXHAUST STROKE

The exhaust valve opens before the crankshaft reaches its bottom center position, allowing exhaust gases to pass out of the engine on the following stroke. The exhaust valve closes after the crankshaft reaches its top center position. The cycle is now complete.

For the proper method of checking valve timing, see the topic, CHECKING VALVE TIMING (ALL MODELS).



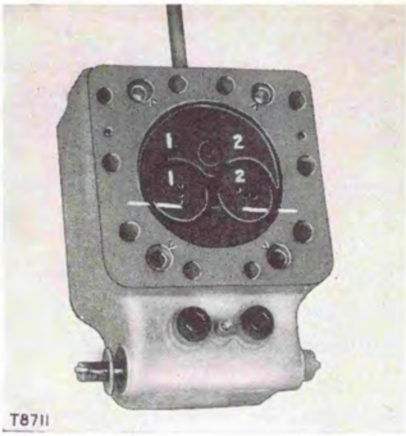
VALVE TIMING EVENTS

◆

Valve Removal (All Models)

Before removing the valves from the cylinder head, make identification marks on the face of the head and the valves as illustrated. This will be helpful if the valves are inspected only and not reconditioned. Then the valves can be installed in their original positions.

The valves can be removed by using the 7F4292 Valve Spring Compressor Group.

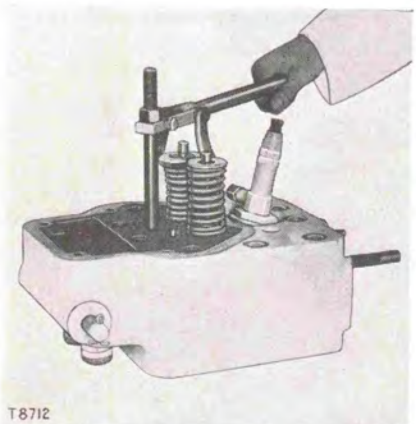


IDENTIFICATION MARKS

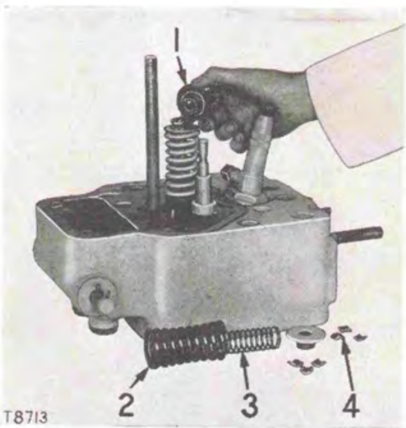
Chalk marks used for identification and location of valves.

Remove the keepers **(4)**, the retainer **(1)**, the outer valve spring **(2)** and the inner valve spring **(3)**.

Remove the valves and clean the valve stems and the valve guide bushings. Recondition or install new parts, if necessary.



COMPRESSING VALVE SPRINGS



REMOVING RETAINER

1—Retainer. 2—Outer valve spring. 3—Inner valve spring. 4—Keepers.

Valve Inspection and Reconditioning (All Models)

The valves should always be carefully inspected. If the valve faces are pitted or making poor contact with the valve seat, they can be renewed in a valve refacing machine. If the valves are deeply pitted, badly warped or worn; they should be replaced.

The 45° valve seats can be ground with a valve seat grinding tool.

Care should be exercised in its use as too much material may be removed quickly and unknowingly.

After the valve seats have been ground until they are smooth and concentric with the valve guides, all parts should be cleaned thoroughly.

Checking Valve Seats (All Models)

Coat the valve face **(1)** with Prussian blue pigment and rotate the valve in the valve seat. Remove the valve and examine the contact pattern on both valve and seat. The entire circumference of the valve seat **(2)** should indicate contact with the valve.

Minor imperfections in the valve face and valve seat can be corrected by "lapping in" the valve.

CAUTION

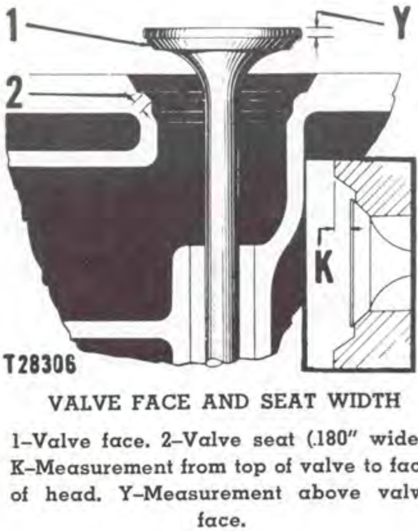
Never turn valves one complete revolution while lapping as the compound is likely to create grooves in the valve seat.

A valve seat **(2)** width of .180" should be maintained. To narrow the seat use a 30° stone or fly cutter.

When grinding or cleaning up the valve seats in the cylinder head, do not remove more than 5/64" material from the measurement J.

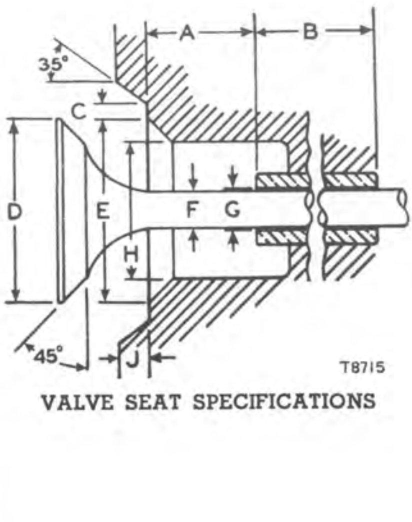
A new head has a J dimension of 17/64". The maximum permissible depth that the seat should be cut into the head is 11/32". This shall be measured after E has been restored by a 30° cutter or stone.

When grinding the valve face **(1)**, do not remove any more material than necessary. The measurement **(Y)** above the valve face **(1)**, should



VALVE FACE AND SEAT WIDTH

1–Valve face. 2–Valve seat (.180" wide). K–Measurement from top of valve to face of head. Y–Measurement above valve face.



VALVE SEAT SPECIFICATIONS

never be less than 3/32" on the exhaust valves or 9/64" on the inlet valves, to prevent "dishing out" of the top of the valve.

Valves can be checked for "dishing out" by placing a straight-edge on the top of the valve. Valves that are dished out should be replaced with new ones.

	INLET	EXHAUST		INLET	EXHAUST
A	2¼	2¼	G	.499 - .500	.499 - .500
B	4⅝	4⅝	H	2.0595 - 2.0625	2.0595 - 2.0625
C	3/32	3/32	J*	17/64	17/64
D	2⅜	2⅜	J**	11/32	11/32
E	2.3095 - 2.3125	2.3095 - 2.3125	K	.111	.111
F	.493 - .494	.492 - .493	Y	9/64	3/32

*** New head dimension.**

**** Maximum depth seat may be cut into head. This shall be measured after E has been restored by a 30° cutter or stone.**

Valve Installation (All Models)

Exhaust valves marked "EX" on the valve head should be installed in the exhaust ports. Inlet valves marked "IN" on the valve head should be installed in the inlet ports.

Inlet valves have a small groove around the top of the stem for identification after the head has been installed.

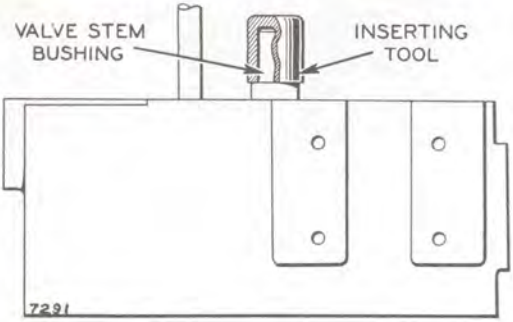
Lubricate the stems and bushings for initial starting.

Insert the valve through the valve stem bushing and install the springs and the spring retainer. Compress the springs with a compressor such as shown in the topic, VALVE REMOVAL (ALL MODELS). Insert the locks, large end down, and tap the retainer lightly as the spring compressor is removed to make sure the locks are seated properly in the retainer.

VALVE STEM BUSHINGS
(All Models)

The inlet and exhaust valves operate in replaceable valve stem bushings. After the valves have been removed, clean the valve stems and the valve stem bushings.

The valve stem bushing wear should be checked with a plug gauge or by using the pilots furnished with some makes of valve seat regrinding equipment. Generally the pilots are supplied in graduated sizes. Use a micrometer to measure the diameter of the largest pilot that will pass through the bushing. This dimension will indicate the wear in the bushing.



INSTALLING VALVE STEM BUSHING

♦

Normal valve stem clearance in the valve stem bushings is from .005" to .007" for inlet valves and .006" to .008" for exhaust valves. Maximum permissible clearance is .012" for inlet and .013" for exhaust valves.

The wear of the valve stems can be checked by the use of a 0" to 1" micrometer. The valve stem should be measured in three places. Use the measurement near the top of the valve stem where the valve stem does not touch the bushing as the original valve stem diameter.

The valve stem bushing can be pressed out from the inside of the head as illustrated, or by the use of a suitable driver.

The bushings should be pressed into place carefully with the type of driver or inserting tool shown in the accompanying illustration to prevent damage to the bushing. A .499" - .500" reamer run through the bushings after they are installed will insure correct valve stem clearance.

CYLINDER HEAD INSTALLATION
(All Models)

Cylinder head gaskets may be used more than once if they are not damaged. If the gasket shows cracks or blow-by marks, a new gasket should be installed.

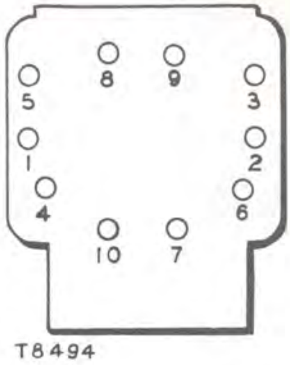
Install the head gasket, the ferrules and new rubber seals.

When installing the head on the cylinder block, see that ferrules and rubber seal start properly in the head. Rock the head gently until it seats flat on the head gasket.

Install the washers and nuts which hold down the cylinder head and tighten the nuts in the following manner.

1. Tighten the head nuts in numerical sequence to 750 lb. in. torque (62.5 lb. ft.).
2. Tighten in numerical sequence to 1200 lb. in. torque (100 lb. ft.).

SEQUENCE OF TIGHTENING HEAD NUTS



3. Expected tightness after run-in to be 850 lb. in. torque (70 lb. ft.).

Install the remaining parts in the reverse order of removal.

VALVE ROCKER ARMS
(All Models)

The push rods actuate the rocker arms as they move upward, and the rocker arms in turn open the valves. The rocker arms and the valves are returned to their original positions by the valve springs, as the push rods move downward to the bottom of their stroke.

The removal of the valve rocker arms is described in the topic, INDIVIDUAL CYLINDER HEAD REMOVAL (ALL MODELS).

Any time a rocker arm assembly has been removed from the engine, the valve clearance must be checked, and adjusted if necessary, when the rocker arm assembly has been installed. The correct valve clearance is .012" hot, and the compression release push rod clearance should be .025" - .030".

Valve Rocker Arm Disassembly and Assembly (All Models)

Remove the elbow fitting **(5)** and the straight fitting **(6)**. The straigh fitting is screwed into the rocker arm bracket **(4)** and delivers oil into the rocker arm shaft **(7)**, which supplies oil to the rocker arms.

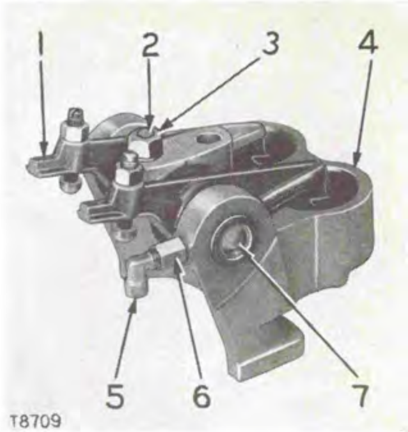
Remove the nut and lockwasher **(3)**, which holds the rocker arm locking stud **(2)** in place. Tap the stud down until the threaded end protrudes slightly from the rocker arm bracket. This will permit the rocker arm shaft to be removed.

Remove the rocker arm shaft **(7)** by pushing it out. The locking stud **(2)** may have to be positioned slightly for clearance.

Lift out the rocker arms **(1)** as the shaft is removed from the bracket.

ROCKER ARM DISASSEMBLY

1—Rocker arm. 2—Locking stud. 3—Nut and lockwasher. 4—Rocker arm bracket. 5—Elbow fitting. 6—Straight fitting. 7—Rocker arm shaft.



Wash all parts and make sure all oil passages are open.

Place the locking stud into the rocker arm bracket and position it so it will be in the correct alignment to permit the rocker arm shaft to be installed.

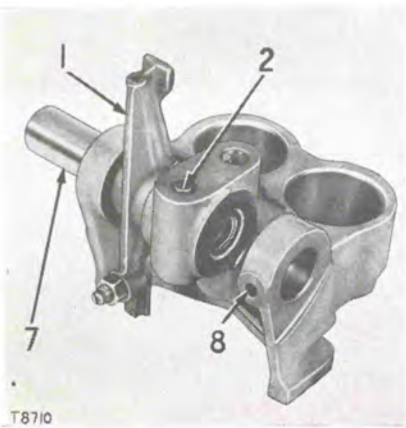
Slide the shaft into the bracket and the rocker arms.

Position the shaft so the oil inlet hole will be in alignment with the oil fitting hole **(8)**.

Install the straight fitting **(6)** into the bracket and the shaft.

Install the elbow fitting.

Install the lockwasher and nut **(3)**. Tighten to lock the locking stud against the shaft.



REMOVING THE ROCKER ARM

1—Rocker arm. 2—Locking stud (positioned so that shaft can be removed). 7—Shaft. 8—Oil fitting hole.

VALVE TIMING
(All Models)

The inlet and exhaust valves are lifted off their seats by the rocker arms which are operated by the push rods and the valve lifters.

The valve lifters in turn are moved upwards in the valve lifter guides as the camshaft lobes come in contact with the valve lifters.

After the valves have been fully opened and the valves begin to return to their seats, the valve springs supply the force to seat the valves in the cylinder heads and the valve lifters are then returned to the base circle of the camshaft and the cam lobes no longer touch the valve lifters.

This engine has two camshafts, each having a camshaft gear timed to it by a key and keyway.

The camshaft gears are timed to the crankshaft gear as described in the topic, TIMING GEARS AND TIMING MARKS (ALL MODELS).

The camshaft gears each have eighty teeth and the crankshaft gear has forty teeth, thus requiring the crankshaft gear to travel 720° in order to permit the camshafts and the camshaft gears to move 360°.

See the topic, VALVES AND VALVE MECHANISM (ALL MODELS), for the firing order and the description of the four-stroke cycle of the engine.

Seldom if ever will it be necessary to check the valve timing as there is little chance that the timing gears or the flywheel are marked incorrectly or installed incorrectly. However, if for any reason it is desired to do so, it can be done as described in the topic, CHECKING VALVE TIMING (ALL MODELS).

CHECKING VALVE TIMING
(All Models)

Adjust the valve clearance to .012″ cold. It is important that the valves be set in the correct firing order. Reset to .012″ hot after checking valve timing.

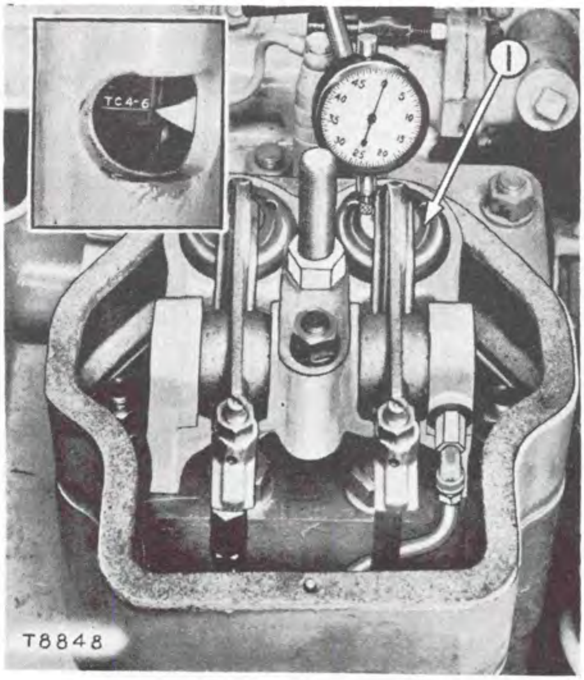
STEP 1

Rotate the crankshaft in the direction of engine rotation until No. 4 and 6 which are stamped on the flywheel, appear in alignment with the flywheel pointer with No. 4 cylinder on its firing stroke. At this point the No. 1 piston should be traveling upward on its exhaust stroke and the exhaust valve should be open, with the inlet valve closed.

Install a dial indicator as illustrated on the inlet valve sleeve **(1)** of No. 1 cylinder.

Refer to the topic, SPECIFICATIONS, for the firing order and illustration of cylinder numbering.

Adjust the dial indicator to read .000" at this point.



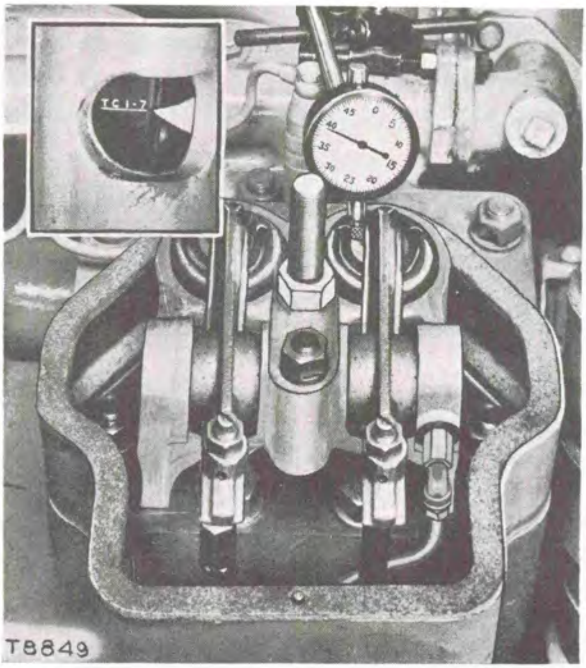
STEP 1

1—No. 1 cylinder inlet valve sleeve. (Dial indicator to read .000" with T.C. 4 and 6 in alignment with the flywheel pointer, with No. 4 cylinder on its firing stroke).

STEP 2

Rotate the crankshaft in the direction of engine rotation to align the flywheel markings 1 and 7 with the flywheel pointer, with the No. 1 piston having just finished its exhaust stroke and No. 7 ready to fire.

The dial indicator reading should then be .040" with an approximate variation of plus or minus .005", which is the amount the inlet valve of No. 1 cylinder is off its seat when the No. 1 piston is at top center ready to move downward on its inlet stroke. See the topic, VALVES AND VALVE MECHANISM (ALL MODELS).



STEP 2

(Dial indicator to read .040" plus or minus .005" with T.C. 1 and 7 in alignment with the flywheel pointer, with No. 7 cylinder on its firing stroke).

Through this check it can be determined if the inlet valve is actually opening at the proper time. If the inlet valve on No. 1 cylinder opens at the proper time in relationship to the No. 1 piston, it can be assumed the remaining valves which are operated by the right hand camshaft are also in time.

An engine that has the camshaft gear timed early to the crankshaft gear, will show a greater reading than .035"-.045", and will increase accordingly in relationship to the number of teeth it is early. A camshaft gear, which is out of time even one tooth will show a reading of .020" or more from the correct reading. When it is out of time two or more teeth, the reading shows a greater difference due to the fast rise of the camshaft lobes.

An engine that has the camshaft gear timed late to the crankshaft gear, will show a smaller reading than .035"-.045" and will decrease accordingly in relationship to the number of teeth it is late.

Since this engine has two camshafts and each camshaft is timed to the crankshaft, it is necessary to make this same check of the left hand bank of cylinders.

The left hand bank of cylinders can be checked as follows. Rotate the crankshaft 360° in the direction of engine rotation to position the No. 1 piston on its firing stroke. The flywheel pointer should align with No. 1 and 7 on the flywheel.

Install a dial indicator on the No. 2 cylinder inlet valve sleeve as described for No. 1 cylinder in STEP 1 and turn the crankshaft to locate top center marks No. 2 and 8 in alignment with the flywheel pointer. The reading should be .040" with a variation of no more than plus .005" or minus .005".

If an engine gives readings that are greatly different than the correct reading, it can be considered out of time. If the reading varies only slightly from the correct readings, check the flywheel top center marks, as described in the topic, CHECKING FLYWHEEL TOP CENTER MARKS (ALL MODELS). If the flywheel pointer is bent or distorted in any way, it would give an incorrect top center reading. The flywheel pointer can also be properly located, as described in that topic.

When an engine is out of time remove the timing gear cover as described in the topic, TIMING GEAR COVER REMOVAL AND INSTALLATION (ALL MODELS).

Remove the accessory shaft idler gear as described in the topic, REMOVING TIMING GEARS (ALL MODELS).

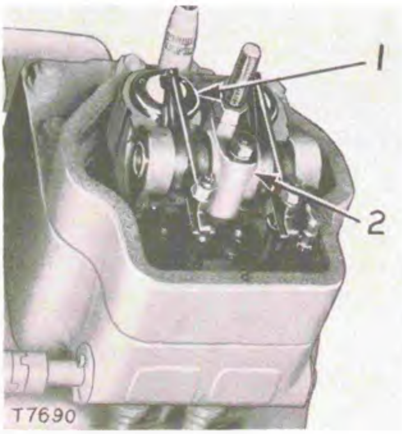
Locate all the timing gears that are marked with timing marks as described in the topic, TIMING GEARS AND TIMING MARKS (ALL MODELS) and install the accessory shaft idler gear.

After checking valve timing, check the fuel pump lifter settings as described in the topic, FUEL PUMP LIFTER SETTING (ALL MODELS).

Checking Flywheel Top Center Marks (All Models)

To check the top center mark for the No. 1 cylinder, be sure the piston is at the top on the compression stroke. This can be determined by removing the valve cover from the No. 1 cylinder and rotating the crankshaft in the direction of engine rotation until the inlet valve starts to close. The piston will then be going up on the compression stroke. Remove the front crankcase inspection cover from the right side of the engine and continue turning the crankshaft until the No. 1 connecting rod is at its uppermost point. The piston will then be at approximately top center.

Remove the rocker arm bracket assembly **(2)** from the No. 1 cylinder head as described in the topic, INDIVIDUAL CYLINDER HEAD REMOVAL (ALL MODELS).

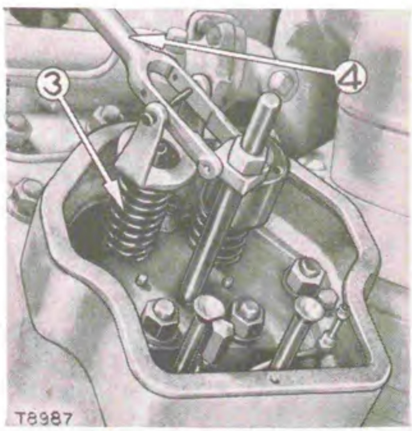


REMOVING ROCKER ARM BRACKET ASSEMBLY

1—Sleeve. 2—Rocker arm bracket assembly.

Remove the exhaust valve sleeve **(1)**.

Remove the valve keepers, the valve stem retainer and the valve



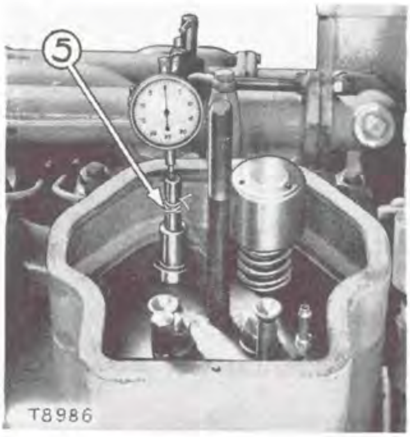
REMOVING VALVE SPRING

3—Valve spring. 4—Valve spring compressor.

springs **(3)** from the exhaust valve, using the 7F4292 Valve Spring Compressor **(4)** as illustrated. (The check can also be made on the inlet valve if desired). This permits the valve to rest on top of the No. 1 piston.

CAUTION

> Wrap a piece of wire **(5)** several times around the valve stem at the point where the keepers were installed, to prevent the valve from falling out of the cylinder head in event the crankshaft is turned too far.



INSTALLING DIAL INDICATOR
5—Wire (wrapped around valve stem).

◆

STEP 1

Place a dial indicator above the valve stem so that the anvil of the in-indicator rests on the end of the valve stem. Rotate the crankshaft clockwise and counterclockwise to locate the highest point of piston travel and set the indicator at zero at that point. Then turn the crankshaft in the direction opposite to engine rotation until the piston moves down to about .050" below the highest point of piston travel. Now turn the crankshaft in the direction of engine rotation very carefully until the piston returns to .015" below the highest point of piston travel. The figures .050" and .015" are arbitrary distances from which top center may be calculated.

If the crankshaft is accidentally turned too far, turn the crankshaft back to .050" below the highest point of piston travel and continue as before.

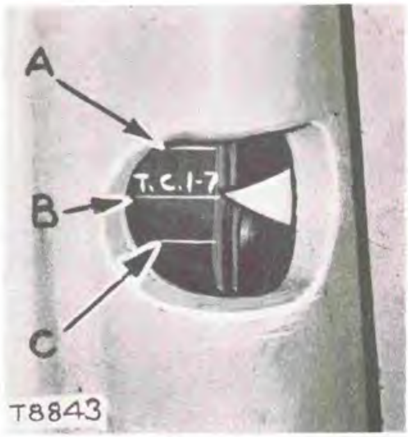
Remove the cover over the flywheel pointer, and make a mark **(A)** on the flywheel even with the pointer.

STEP 2

Turn the crankshaft in the direction of engine rotation until the piston moves down about .050" past the highest point of piston travel. Then very carefully turn the crankshaft in the direction opposite engine rotation until the piston returns to .015" below the highest point of piston travel. If the crankshaft is turned too far, repeat the operation as before. Now make another mark **(C)** on the flywheel opposite the pointer (.015" after top center). Take one-half of the distance between **(A)** and **(C)** and establish the mark **(B)**, which will be the top center mark for the No. 1 cylinder.

FLYWHEEL POINTER

A—.015" before top center.
B—Top center.
C—.015" after top center.



This method of checking top center can be used for a temporary method of marking if the marks on the flywheel are illegible or the flywheel is installed incorrectly on the crankshaft.

If it is found that the mark **(B)**, which indicates top center, is not in alignment with the flywheel pointer, it signifies the flywheel pointer is not located correctly.

Loosen the capscrews holding the flywheel pointer to the flywheel housing and shift the pointer to align with the mark **(B)** which is the top center mark.

Tighten the capscrews, being sure not to move the pointer.

When the flywheel pointer is aligned with the top center mark of No. 1 cylinder, and the inlet and exhaust valves of No. 1 cylinder are both closed, with the piston having just completed its compression stroke the fuel pump lifter timing should be checked as described in the topic, FUEL PUMP LIFTER SETTING (ALL MODELS).

The inlet and exhaust valve timing can be checked as described in the topic, CHECKING VALVE TIMING (ALL MODELS).

VALVE LIFTER REMOVAL AND INSTALLATION
(All Models)

The valve lifters move up and down in replaceable valve lifter guides, as they are operated by the camshaft lobes.

To facilitate the removal of the valve lifters, first remove the rocker arm assembly **(1)**, the push rods **(2)** and the dust tubes **(3)** as described in the topic, INDIVIDUAL CYLINDER HEAD REMOVAL (ALL MODELS).

PREPARING FOR VALVE LIFTER REMOVAL

1—Rocker arm assembly. 2—Push rods. 3—Dust tubes. 4—Hold-down clamp.

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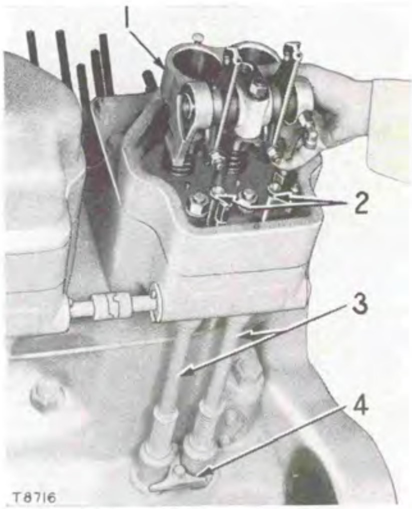
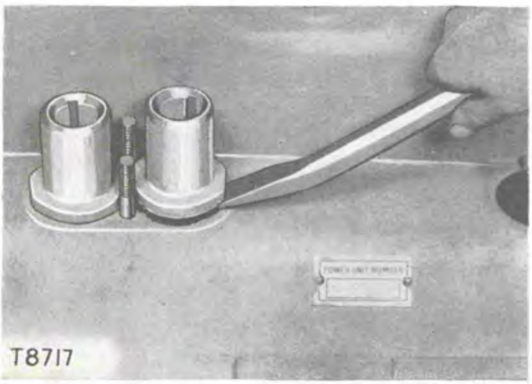


Remove the hold-down clamp **(4)**.

Loosen the valve lifter guide from the crankcase by prying with a bar and tapping lightly on the opposite side with a soft hammer.



LOOSENING GUIDE FROM CRANKCASE

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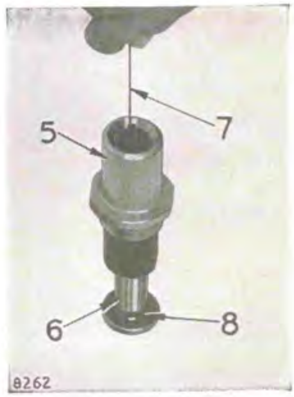
Since the lifters are not secured to the guides in any manner, the lifters and guides should be removed from the crankcase carefully, to prevent the lifters from sliding out of the guides, The lifters can be held in place by using a wire **(7)** with a short, sharp bend and hooking onto the shoulder at **(8)** and bending the upper end of the wire over the guide. Remove the lifter **(6)** and the guide **(5)**.



VALVE LIFTER AND GUIDE REMOVAL

5—Valve lifter guide. 6—Valve lifter. 7—Wire. 8—Shoulder.

♦

Check the lifter and the guides for wear or scoring.

Clean all parts and oil the lifter to assure lubrication on initial starting.

Install the lifter and guide, and assemble the remaining parts in the reverse order of removal.

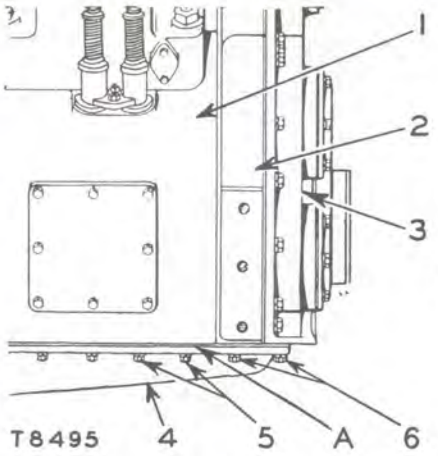
During engine operation the lifters and guide are lubricated by oil that comes down the push rods and dust tubes from the rocker arm assembly. The oil flows into the notches of the guides and then returns to the crankcase.

Timing Gears

TIMING GEAR COVER REMOVAL AND INSTALLATION (All Models)

To remove the timing gear cover, it is first necessary to remove the radiator, the fan, the water lines, the fan drive pulley, the air cleaners, the air cleaner support brackets and the damper weight. See the topics, FAN HUB ASSEMBLY REMOVAL (D17000L-E-I), WATER LINES REMOVAL (ALL MODELS), FAN DRIVE PULLEY REMOVAL (D17000L-E-I), AIR CLEANERS AND AIR CLEANER SUPPORT BRACKETS REMOVAL AS A UNIT (D17000L-E-I) and DAMPER WEIGHT REMOVAL AND INSTALLATION (ALL MODELS).

On a marine engine remove the necessary assemblies as described in their respective topics.



PREPARING FOR TIMING GEAR COVER REMOVAL

A—Location to place shims when separating oil pan from crankcase. 1—Crankcase. 2—Timing gear housing. 3—Timing gear cover. 4—Oil pan. 5—Capscrews. 6—Capscrews.

Remove all the capscrews **(6)** holding the oil pan **(4)** to the timing gear cover **(3)** and the timing gear housing **(2)**.

Loosen all the capscrews **(5)**, holding the oil pan to the crankcase **(1)**, enough to permit the oil pan to be lowered approximately 1/8". With a putty knife, carefully separate the oil pan from the crankcase, the timing gear cover, and the timing gear housing, in order to keep the oil pan gasket from being damaged.

Place approximately .060" to .070" shim stock between the oil pan and crankcase as illustrated at the arrow **(A)**.

Tighten all the capscrews **(5)**, holding the oil pan to the crankcase, finger tight to assure the shims stay in place.

Raise the forward end of the engine slightly, only enough to permit the engine front support to be removed and installed.

Support the engine with blocks under the oil pan.

Remove the engine front support.

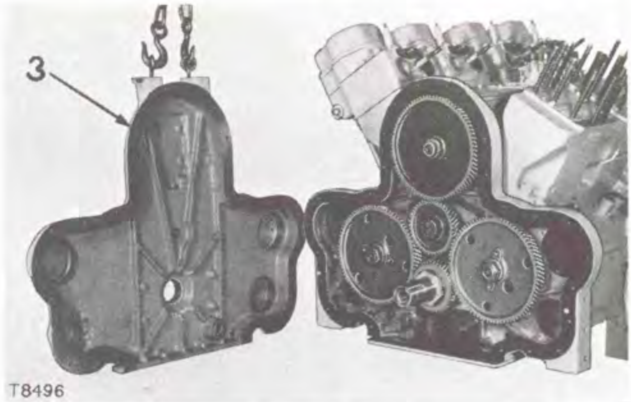
Remove the capscrews holding the timing gear cover.

Remove the timing gear cover as illustrated.

Cover the timing gear housing and the open portion of the oil pan to prevent dirt from getting into the engine.

Before installing the timing gear cover, clean the mating surfaces and install new gaskets if necessary.

Install the timing gear cover carefully in order to prevent damaging the oil pan gasket, and the crankshaft oil seal.



REMOVING THE TIMING GEAR COVER
3—Timing gear cover.

Raise the forward end of the engine. Loosen the capscrews **(5)** to permit the oil pan to be lowered slightly and remove the shim stock.

Assemble the remaining parts in the reverse order of removal.

TIMING GEARS AND TIMING MARKS (ALL MODELS)

The engine timing gears are located within the timing gear housing **(3)**. See the topic, TIMING GEAR COVER REMOVAL AND INSTALLATION (ALL MODELS), for the procedure of removing the timing gear cover.

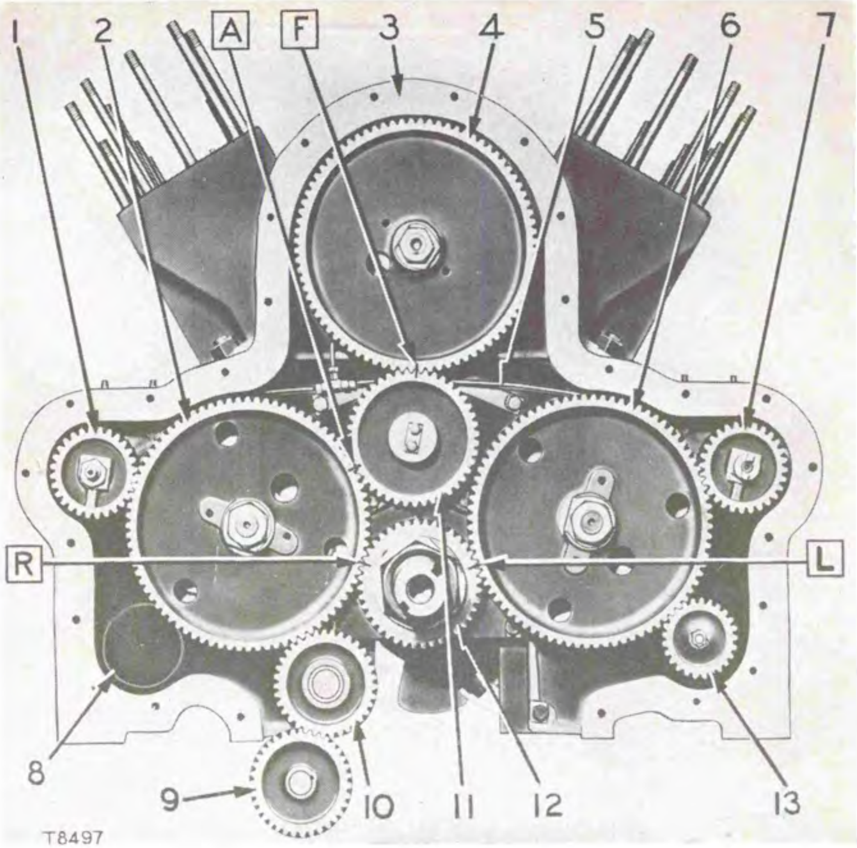
The crankshaft gear **(12)** drives both the right camshaft gear **(2)** and the left camshaft gear **(6)**.

The right camshaft gear is timed to the crankshaft gear by the mating teeth that are marked **(R)**. The right camshaft gear also drives the accessory shaft idler gear **(11)** and is timed by the mating teeth marked **(A)**.

The oil pump idler gear **(10)** is driven by the right camshaft gear, and in turn drives the oil pump drive gear **(9)**. These two gears are not timed. The gears **(9)** and **(10)** are installed on all models except the locomotive, which has the oil pump drive gear installed into the timing gear housing after the cover **(8)** has been removed. The locomotive oil pump drive gear is driven by the right camshaft gear, but is not timed.

The left camshaft gear is timed to the crankshaft gear by the mating teeth that are marked **(L)**.

The accessory shaft gear **(4)**, which drives the governor and the fuel injection pump, is driven by and timed to the accessory shaft idler gear **(11)**. The mating teeth are marked **(F)**.



TIMING GEARS AND TIMING MARKS

A—Timing marks between the gears (2) and (11).
F—Timing marks between the gears (4) and (11).
L—Timing marks between the gears (6) and (12).
R—Timing marks between the gears (2) and (12).

1—Right water pump gear. 2—Right camshaft gear. 3—Timing gear housing. 4—Accessory shaft gear. 5—Oil line. 6—Left camshaft gear. 7—Left water pump gear. 8—Cover. 9—Oil pump drive gear. 10—Oil pump idler gear. 11—Accessory shaft idler gear. 12—Crankshaft gear. 13—Fuel transfer pump drive gear.

Earlier models used two water pumps which are illustrated by the gears **(1)** and **(7)**. Later models have only the right water pump gear **(1)**. The water pump gears are not timed to the engine. The oil supply tube **(5)** is installed only on models that have two water pumps.

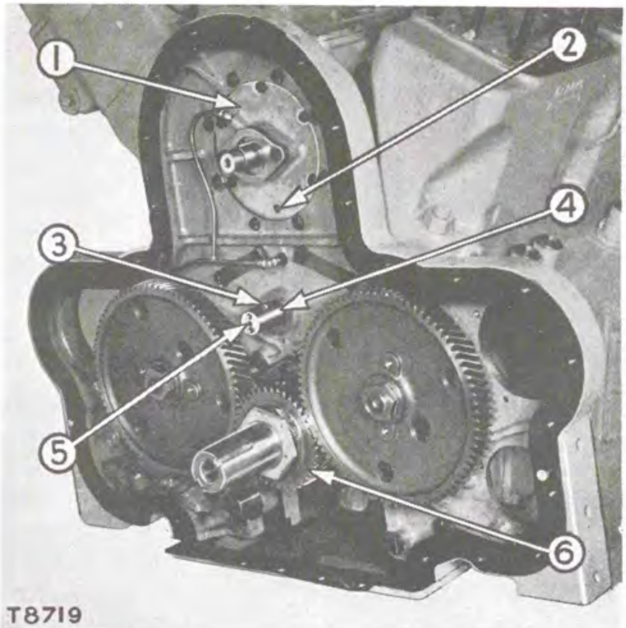
The fuel transfer pump drive gear **(13)** is driven by the left camshaft gear **(6)** and does not require timing.

TIMING GEAR LUBRICATION
(All Models)

The engine timing gears are lubricated by oil that drips onto the accessory shaft idler gear (which mounts on the idler shaft **(4)**, but is removed in the illustration) and the crankshaft gear **(6)**.

This oil drains from the hole **(2)** in the bearing assembly **(1)**. See the topic, GOVERNOR LUBRICATION (ALL MODELS).

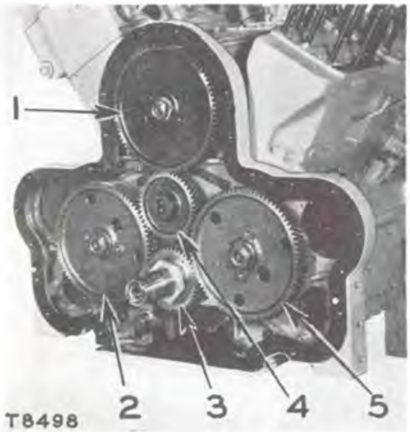
The idler gear shaft is hollow and is pressure-lubricated by oil from the oil manifold. The idler gear shaft has two outlet oil holes **(3)** and **(5)**, the top oil hole **(3)** lubricates the idler gear bushing. The oil hole **(5)** supplies oil between the forward end of the idler gear and its retaining washer. The excess oil drops down on the crankshaft gear. As the crankshaft gear is covered with oil, this oil in turn is carried onto the other gears by the mating teeth.



TIMING GEAR LUBRICATION
1—Accessory shaft front bearing assembly. 2—Drain hole. 3—Outlet oil hole (at top of idler gear shaft). 4—Idler gear shaft. 5—Outlet oil hole (at end of idler gear shaft). 6—Crankshaft gear.

REMOVING THE TIMING GEARS
(All Models)

When removing and installing the crankshaft gear **(3)**, the right camshaft gear **(2)**, the accessory shaft idler gear **(4)**, the left camshaft gear **(5)** and the accessory shaft gear **(1)**, the timing marks should be observed. See the topic, TIMING GEARS AND TIMING MARKS (ALL MODELS).



REMOVING TIMING GEARS

1—Accessory shaft gear. 2—Right camshaft gear. 3—Crankshaft gear. 4—Accessory shaft idler gear. 5—Left camshaft gear.

NOTE

The water pump gear, the oil pump drive idler gear, the oil pump drive gear and the fuel pump drive gear, are shown already removed in the illustration. For the removal of these gears see the topics in which their removal is described.

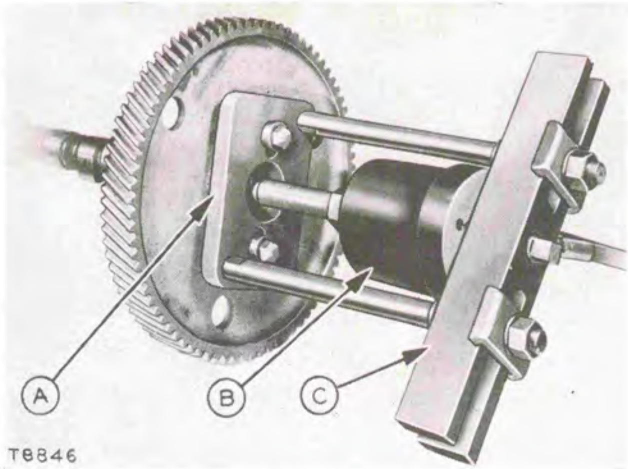
The timing gears can be removed in the following manner:

Bend the lock and remove the capscrews and washer holding the accessory shaft idler gear **(4)**.

Remove the idler gear by sliding it off the idler gear shaft.

Both the right and left camshaft gears and the accessory shaft gear can be removed in the following manner. Bend the lock, remove the nut and lock holding the gear. Using the 8F3672 Puller Plate **(A)** with the 7F9540 Hydraulic Puller **(B)** and the 8B7548 Push Puller **(C)**, remove the gear.

If a hydraulic puller is not available the gear can be removed by using the 8B7548 Push Puller and the attachments.



REMOVING CAMSHAFT GEAR
A—8F3672 Puller Plate. B—7F9540 Hydraulic Puller. C—8B7548 Push Puller.

The crankshaft gear **(3)** can be removed by using the 8B7548 Push Puller, the 8B7549 Legs and the 8B7558 Adapters. When installing the crankshaft gear, see the topic, CRANKSHAFT GEAR INSTALLATION (ALL MODELS).

REMOVING CRANKSHAFT GEAR

3—Crankshaft gear.

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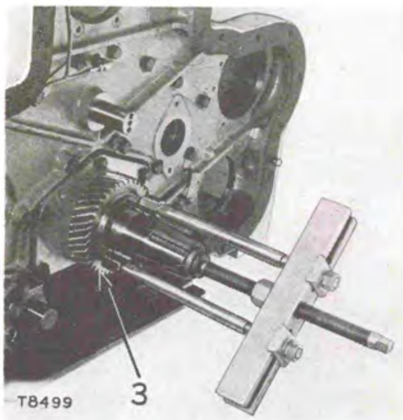

INSTALLING THE TIMING GEARS
(All Models)

Heat all gears except the accessory shaft idler gear, preferably in hot oil, to ease installation.

The camshaft gears must be pressed on the camshaft.

This can be done by either of two methods, depending on the kind of tools available.

The camshaft gear can be pressed on the camshaft using the 3B5208 Nut **(6)** and the 3B5209 Stud **(7)**.

INSTALLING CAMSHAFT GEAR
6—3B5208 Nut. 7—3B5209 Stud.

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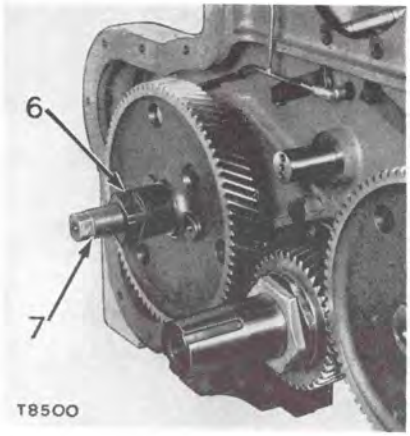
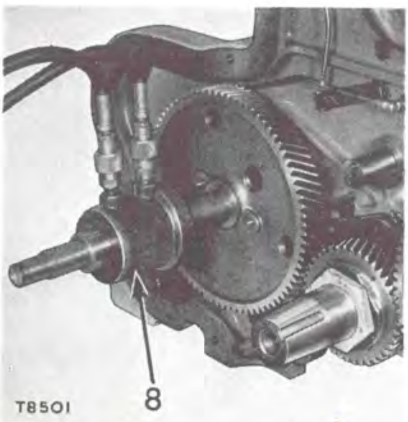


The second method uses the 8B3671 Pusher Assembly and the 7F9540 Hydraulic Puller **(8)**. The 8F3671 Pusher Assembly consists of the 8F3668 Threaded Sleeve, the 8F3667 Threaded Sleeve, the 8F3670 Stud and the 8F3669 Sleeve.

The accessory shaft gear can be installed using the 4B8267 Nut and the 4B8268 Stud.



INSTALLING CAMSHAFT GEAR
(USING HYDRAULIC PUSHER)
8—7F9540 Hydraulic Pusher.

♦

TIMING GEAR HOUSING REMOVAL AND INSTALLATION
(All Models)

To facilitate the timing gear housing removal, first remove the timing gear cover. See the topic, TIMING GEAR COVER REMOVAL AND INSTALLATION (ALL MODELS).

Remove the water pump or pumps as described in their respective topics.

Remove the fuel transfer pump drive with the fuel transfer pump attached as described in the topic, FUEL TRANSFER PUMP DRIVE REMOVAL (ALL MODELS).

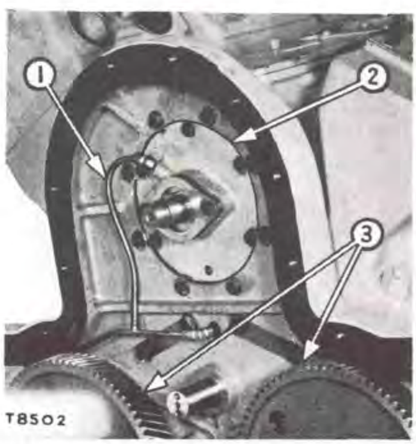
Remove the externally mounted oil pump and oil pump drive if the engine is the locomotive model. See the topics, OIL PUMP REMOVAL AND INSTALLATION (D17000L) and OIL PUMP DRIVE REMOVAL AND INSTALLATION (D17000L).

On all other models remove the oil pump drive idler gear.

Remove the oil pump drive gear and shaft, or loosen the capscrews holding the oil pump drive gear and support bracket to lower this assembly far enough to clear the timing gear housing when it is removed. See the topic, OIL PUMP DRIVE REMOVAL AND INSTALLATION (D17000E-I-M).

Remove the accessory shaft idler gear from the idler gear shaft **(9)**. Remove the accessory shaft gear as described in the topic, REMOVING THE TIMING GEARS (ALL MODELS).

The timing gear housing can be removed from the engine, either with or without the governor housing removed from the engine, in the following manner.



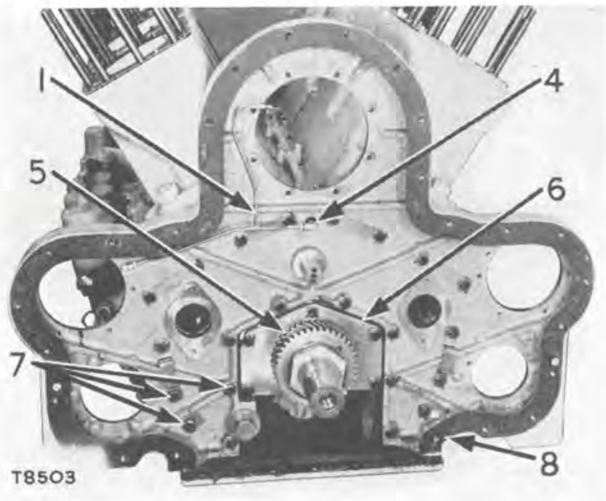
DISCONNECTING OIL TUBE

1—Oil supply tube. 2—Accessory shaft front bearing assembly. 3—Camshaft gears.

♦

Disconnect the oil supply tube **(1)** at the accessory shaft front bearing assembly **(2)**.

Remove the capscrews and locks holding the timing gear housing to the governor housing. Support the governor housing with several wooden wedges to keep it in position when the timing gear housing is removed and installed. If the governor housing and the fuel injection pump housing are to be removed, remove the fuel pump housing and the governor housing as described in the topic, FUEL PUMP HOUSING AND GOVERNOR HOUSING REMOVAL AS A UNIT (ALL MODELS).



PREPARING TO REMOVE THE TIMING GEAR HOUSING (D17000L ILLUSTRATED)
(The governor housing is removed in this illustration, although this is not necessary).
1—Oil supply tube. 4—Fitting. 5—Crankshaft gear. 6—Thrust plate. 7—Capscrews. 8—Timing gear housing.

Remove the camshaft gears **(3)** or remove the camshaft and camshaft gear as a unit.

The camshaft gear can be removed as described in the topic, REMOVING THE TIMING GEARS (ALL MODELS).

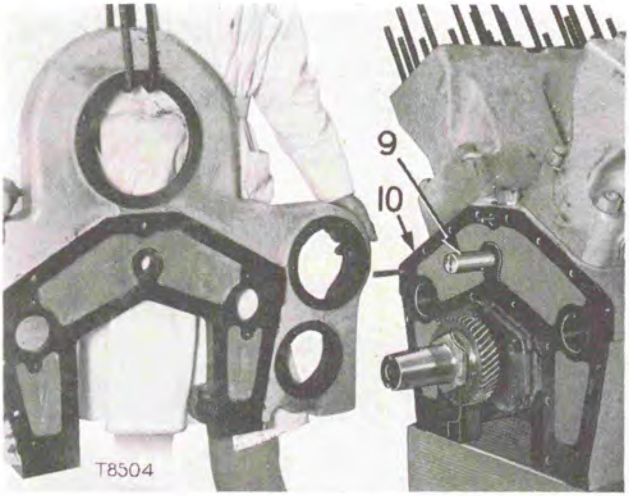
The camshaft gear need not be removed from the camshafts. If other work has been done or will be done to facilitate the removal of the camshaft, the camshafts and the camshaft gears can be removed from the engine as a unit. See the topic, REMOVING AND INSTALLING THE CAMSHAFT AND CAMSHAFT GEAR AS A UNIT (ALL MODELS).

The crankshaft gear **(5)**, the crankshaft thrust plates **(6)** and thrust washer need not be removed.

Remove the oil supply tube **(1)** which supplies oil from the oil manifold to the governor housing and the water pump. Remove the fitting **(4)**.

Before bending and removing the locks and capscrews **(7)**, take notice of the different size locks and their location and method of locking. This will be helpful when the timing gear housing is installed.

Using a suitable sling and hoist to support the timing gear housing **(8)**, remove all the capscrews and locks holding it to the crankcase **(10)**.



REMOVING TIMING GEAR HOUSING

9—Idler gear shaft.
10—Crankcase.

♦

Remove the timing gear housing.

When installing the timing gear housing, use new gaskets. Install the locks and capscrews holding the timing gear housing to the crankcase. Install the capscrews and tighten to 960 in. lb. (80 ft. lb.) torque and bend the locks. Assemble the remaining parts in the reverse order of their removal.

INSTALLING TIMING GEAR HOUSING

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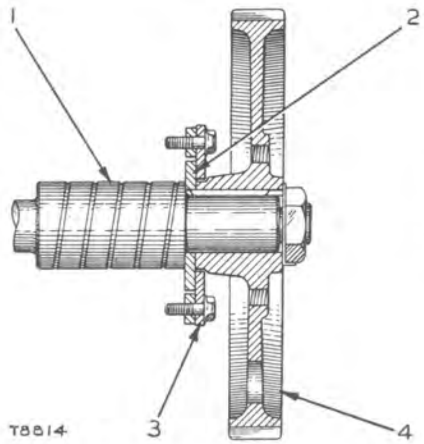
Camshaft and Camshaft Gear
(All Models)

This engine has two camshafts and two camshaft gears.

The camshaft gears can be removed from the camshafts, without removing the camshafts from the engine. See the topic, REMOVING THE TIMING GEARS (ALL MODELS).

A camshaft **(1)** and camshaft gear **(4)** can be removed as a unit with the camshaft thrust plate **(3)** and the camshaft thrust washer **(2)** installed. See the topic, REMOVING A CAMSHAFT AND CAMSHAFT GEAR AS A UNIT (ALL MODELS).



CAMSHAFT AND CAMSHAFT GEAR

1—Camshaft. 2—Camshaft thrust washer. 3—Camshaft thrust plate. 4—Camshaft gear.

♦

PREPARING TO REMOVE A CAMSHAFT AND CAMSHAFT GEAR AS A UNIT
(All Models)

Although the left camshaft and camshaft gear are different than the right camshaft and camshaft gear, their removal is the same.

A camshaft and camshaft gear can be removed from the engine as a unit in the following manner.

Remove the timing gear cover as described in the topic, TIMING GEAR COVER REMOVAL AND INSTALLATION (ALL MODELS).

Remove the rocker arm assemblies, the push rods and the push rod dust tubes as described in the topic, INDIVIDUAL CYLINDER HEAD REMOVAL (D17000L-E-I).

PREPARING TO REMOVE A CAMSHAFT AND CAMSHAFT GEAR

1—Hole. 2—Camshaft gear.

Remove the valve lifters as described in the topic, VALVE LIFTER REMOVAL (ALL MODELS).

Rotate the engine crankshaft to locate the hole **(1)** in the camshaft gear **(2)** in alignment with one of the capscrews which hold the camshaft in place.

Each camshaft is held in place by two capscrews, which are spaced 180° apart, one above and one below the camshaft.

Place a heavy piece of paper directly below the timing gears to keep anything from falling into the oil pan. Bend the lock and, using a speed wrench and a 9/16" socket as illustrated, loosen the top capscrew until there are no more threads holding it, but do not remove the capscrew.

If the capscrew is removed at this point, the spacer which is installed on the capscrew would fall into the oil pan.

Turn the crankshaft to rotate the camshaft gear 180°, to align the hole **(1)** with the bottom capscrew. Bend the lock and loosen the capscrew five or six threads. Carefully slide the camshaft and gear out enough to permit the spacers and the capscrews to be seen. Loosen the capscrew completely. Reach behind the camshaft gear and either remove the spacers or position them so they will not fall off.

For an illustration showing the capscrews and spacers which hold the camshaft in position, see the topic, REMOVING AND INSTALLING A CAMSHAFT AND CAMSHAFT GEAR AS A UNIT (ALL MODELS).

REMOVING AND INSTALLING A CAMSHAFT AND CAMSHAFT GEAR AS A UNIT
(All Models)

See the topic, PREPARING TO REMOVE A CAMSHAFT AND CAMSHAFT GEAR AS A UNIT (ALL MODELS).

Slide the camshaft and the camshaft gear out of the camshaft bearings carefully, as illustrated, so as not to damage the camshaft bearings.

When installing a camshaft, oil the camshaft journal generously.

Rotate the thrust plate **(4)** to see that it moves freely on the camshaft.

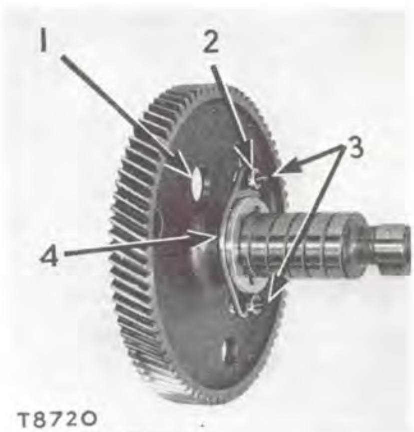
Install the camshaft hold-down capscrews and locks **(3)** through the thrust plate **(4)**.

Install the spacers **(2)** on the capscrews **(3)**.

Install the camshaft and the camshaft gear carefully so as not to damage the camshaft bearings or to permit the spacers **(2)** to fall off the capscrews.

Align the timing marks as outlined in the topic, TIMING GEARS AND TIMING MARKS (ALL MODELS). Engage the camshaft gear into the crankshaft gear part way. Start one capscrew, rotate the camshaft gear 180°, and then start the remaining capscrew. After both hold-down capscrews are started, tighten both capscrews and bend the locks, by working through the hole **(1)**.

REMOVING A CAMSHAFT AND CAMSHAFT GEAR



SPACERS AND HOLD-DOWN CAPSCREWS

1—Hole. 2—Spacer. 3—Capscrews. 4—Thrust plate.

Recheck the timing marks. Check the camshaft backlash and end clearance. See the topics, CHECKING CAMSHAFT BACKLASH (ALL MODELS) and CHECKING CAMSHAFT END CLEARANCE (ALL MODELS).

INSTALLING CAMSHAFT GEAR USING AN ARBOR PRESS
(All Models)

A camshaft gear can be installed on a camshaft, that has been removed from the engine, with the use of an arbor press in the following manner.

Install the woodruff key **(3)** into the keyway of the camshaft.

Remove any burrs from the camshaft gear **(1)**, the camshaft **(6)**, the key **(3)**, the thrust washer **(5)** and the thrust plate **(4)**.

Install the thrust washer **(5)** onto the camshaft with the chamfer **(7)** pointing in toward the bearing journal **(6)**. Guide the keyway of the washer over the key **(3)**. Push the thrust washer all the way on the camshaft until it touches the camshaft bearing journal.

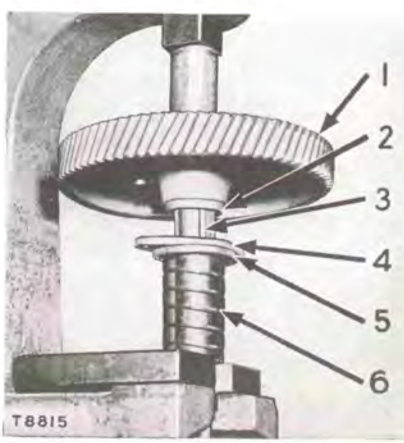
Install the thrust plate **(4)**, centering it on the camshaft.

Coat the inside bore of the camshaft gear with a lubricating compound to ease installation.

Place the camshaft gear onto the camshaft aligning the key and the keyway.

Using an arbor press and a suitable sleeve large enough to pass over the threaded end of the camshaft so as not to damage the threads, press the gear on the camshaft until it is about half-way on.

Slide the thrust plate up over the under-cut **(2)** on the camshaft gear. (The bore of the thrust plate is large enough to pass over the under-cut



INSTALLING CAMSHAFT GEAR

1—Gear. 2—Under-cut on camshaft gear. 3—Key. 4—Thrust plate. 5—Thrust washer. 6—Camshaft bearing journal.

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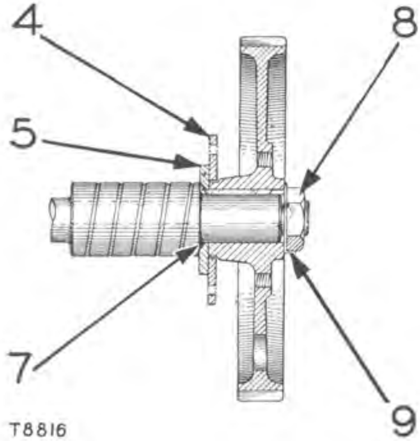


CAMSHAFT GEAR INSTALLED

4—Thrust plate. 5—Thrust washer. 7—Chamfer. 8—Nut. 9—Lock.

on the camshaft gear.) Hold the thrust plate in this position and press the gear completely on the camshaft.

Rotate the thrust plate to make sure it has no bind.

Install the lock **(9)** and nut **(8)**.

Tighten the nut and bend the lock.

Checking Camshaft Gear Backlash (All Models)

The backlash between a camshaft gear and the crankshaft gear can be checked in the following manner.

Install a dial indicator as illustrated. The backlash between a camshaft gear **(1)** and the crankshaft gear **(2)** should be .003" - .004".

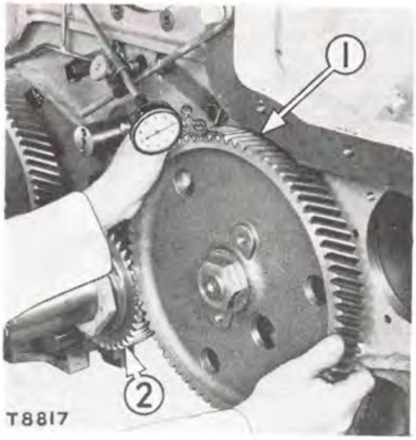
The backlash is pre-determined through machining, and cannot be adjusted.

When a dial indicator reading of .010" or more is shown, a further check must be made to determine the cause. Excessive backlash indicates that either the timing gears, the main bearings or the camshaft bearings are badly worn.

Timing gear wear can be compensated for, by adjusting the fuel injection pump lifters. See the topic, FUEL INJECTION PUMP LIFTER SETTINGS (ALL MODELS).

If either the main bearings or the camshaft bearings are badly worn they should be replaced with new ones.

If a reading of less than .003" backlash is shown, it is an indication of incorrect assembly, or a burr or rough spot on one of the gears. In this



CHECKING CAMSHAFT GEAR BACKLASH

1—Camshaft gear. 2—Crankshaft gear.

case take readings every 90° around the camshaft gear, to determine the cause. A burr can be removed from a gear tooth, by using a gear file or fine stone, without removing the gear from the camshaft. When removing a burr, cover the remaining exposed parts to keep them clean.

If a camshaft gear needs to be removed see the topic, REMOVING TIMING GEARS (ALL MODELS).

Checking Camshaft End Clearance (All Models)

When the camshaft gear **(1)** is installed on the camshaft **(6)**, the undercut **(2)** passes through the bore of the thrust plate **(7)** and touches the thrust washer **(5)**. The camshaft is secured in place by the capscrews **(3)**.

The spacers **(4)** are matched, and they are machined to the same thickness. The spacers measure .005" to .009" thicker than the thrust washer

THRUST WASHER AND THRUST PLATE

1—Camshaft gear. 2—Undercut on camshaft gear. 3—Capscrew. 4—Spacer. 5—Thrust washer. 6—Camshaft. 7—Thrust plate.

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CHECKING CAMSHAFT END CLEARANCE

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(5), thus permitting the camshaft gear, the thrust washer, and the camshaft to move forward and back in the camshaft bearing bores. The combined assembly can move forward until the thrust washer touches the thrust plate and backward until the thrust washer touches the timing gear housing.

The end clearance can be checked by installing a dial indicator as illustrated. The end clearance should be .005″ to .009″ with a maximum permissible clearance of .025″. When excessive end clearance is shown, remove the camshaft gear as described in the topic, REMOVING TIMING GEARS (ALL MODELS).

Install a new thrust plate and thrust washer.

The end clearance will be the difference of the thickness between the spacers **(4)** and the thrust washer **(5)**. These can be checked with a 0″ to 1″ micrometer before assembly.

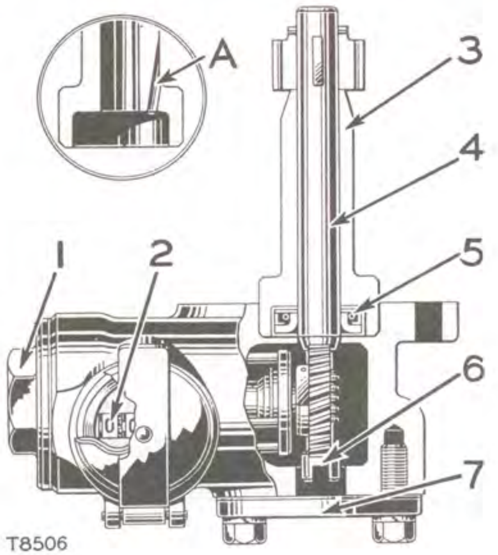
Hour Meter
(All Models)

The hour meter is mounted on the fuel transfer pump drive housing and is driven by the transfer pump drive shaft. See the topic, DISASSEMBLING THE FUEL TRANSFER PUMP DRIVE (ALL MODELS). Remove the hour meter as described in that topic. Earlier models had the hour meter mounted elsewhere.

The hour meter can be disassembled in the following manner.

HOUR METER (TOP VIEW)

1—Retainer assembly. 2—Counter assembly. 3—Bearing assembly. 4—Drive shaft. 5—Oil seal. 6—Grooved end of drive shaft. 7—Cover. A—Oil return passage on under side of bearing (3).



Remove the retainer assembly **(1)** and the counter retaining spring.

Remove the counter assembly **(2)**.

Remove the cover **(7)** or the tachometer drive assembly if installed in place of the cover. When installed, the tachometer is driven by the grooved end **(6)** of the shaft **(4)**.

Slide out the drive shaft **(4)**. The gear can be removed from the shaft, by first removing the pin which retains the gear to the shaft. Pull the gear using the 8B7547 Puller.

Place the bearing **(3)** in a vise, gripping the bearing lightly. Tap the hour meter housing gently to separate the housing and the bearing.

When installing the counter assembly, lubricate the drive gear with a suitable ball and roller bearing grease.

An oil seal **(5)** keeps oil out of the hour meter assembly. If this seal is replaced, the wiping edge should be installed toward the bearing **(3)**. The bearing should be replaced if the clearance between the shaft and the bearing exceeds .012″. The bearing **(3)** is lubricated through holes (not shown) in the bearing and the oil is returned through a drilled passage **(A)** just behind the leather seal. This drilled passage should be on the bottom when the bearing is installed, to permit the oil to drain away from the oil seal.

Connecting Rods
(All Models)

There are two connecting rod assemblies installed on each connecting rod journal. The connecting rods and connecting rod caps are numbered consecutively from front to rear as they are attached to the crankshaft.

NOTE

When facing the flywheel, the bank of cylinders on the left side is considered the left bank, and the bank of cylinders on the right side is considered the right bank.

The right bank is mounted slightly forward of the left bank, nearer the front of the engine, to facilitate installing two connecting rods on one connecting rod journal.

The bearing caps and rods are numbered consecutively, 1 to 8, from the front end of the engine on the outside so that the numbers can be seen through the inspection openings on the sides of the crankcase. The rods should be reassembled with the numbers in this position, with the odd numbers visible on the right side of the engine, the even numbers on the left.

CONNECTING ROD ASSEMBLIES

CONNECTING ROD BEARING REMOVAL AND INSTALLATION
(All Models)

The connecting rod bearings are of the precision type, aluminum alloy and are to be installed without fitting or scraping.

The bearing shells can be removed, inspected and installed without removing the connecting rods from the engine.

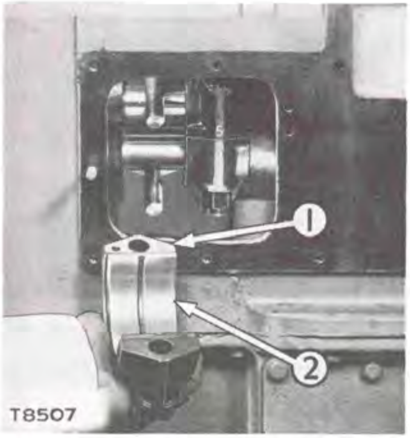
To remove the connecting rod bearing shells first remove the crankcase inspection covers or the assemblies which cover the inspection openings which are as follows: fuel filter housing, oil filter manifold, oil filler and crankcase breather. See the covering topics.

Other items to be removed are the fuel transfer pump drive and, on a locomotive, the oil pump and oil pump drive. See the covering topics.

Rotate the crankshaft to position the connecting rod near the inspection opening through which the bearing shell is to be removed.

Remove the cotter pins and the connecting rod nuts.

Remove the connecting rod cap **(1)** and the bearing shell **(2)**.



CONNECTING ROD CAP REMOVED
1—Connecting rod cap. 2—Bearing shell.

REMOVING BEARING SHELL
2—Bearing shell.

Remove the bearing shell by rolling it out of the connecting rod cap, as illustrated.

To remove the upper bearing shell, turn the crankshaft or push the connecting rod up slightly.

Clean and inspect the bearings. See the topic, CHECKING CONNECTING ROD BEARING CLEARANCE (ALL MODELS).

When installing the bearing, place the dowel hole **(4)** of the bearing shell over the dowel **(3)**, in the connecting rod cap. Place the upper bearing shell into the connecting rod with the dowel hole over the dowel in the connecting rod.

INSTALLING BEARING INTO CONNECTING ROD CAP

3—Dowel. 4—Dowel hole.

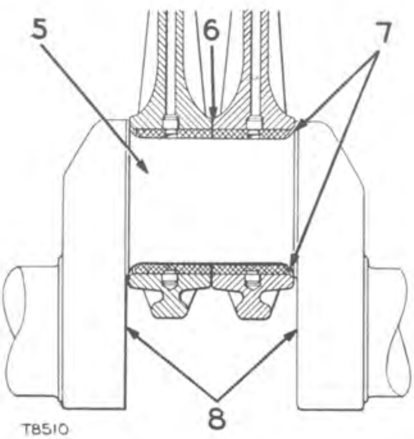
NOTE

The connecting rod bearing shells, the connecting rod caps and the connecting rods must be installed with the chamfered side **(7)** toward the crankshaft cheeks **(8)**. There are two connecting rod assemblies mounted on each connecting rod journal **(5)**. The straight sides **(6)** (the sides that are not chamfered) must be together.

Oil both the upper and lower bearings.

Install the connecting rod cap and bearing.

Replace the nuts and tighten to 1500 inch pounds (125 foot pounds). This may be exceeded to align the nearest hole to permit the cotter pin to be installed.



INSTALLING CONNECTING ROD BEARINGS

5—Connecting rod journal. 6—Straight side (side that is not chamfered). 7—Chamfered side. 8—Crankshaft cheeks.

After the connecting rod bearings have been installed, tap the connecting rod back and forth gently to see that there is side clearance, and that there is no bind. As a final check turn the crankshaft to see that it turns freely.

Checking Connecting Rod Bearing Clearance (All Models)

Connecting rod bearings on later engines and all replacement bearings are aluminum alloy.

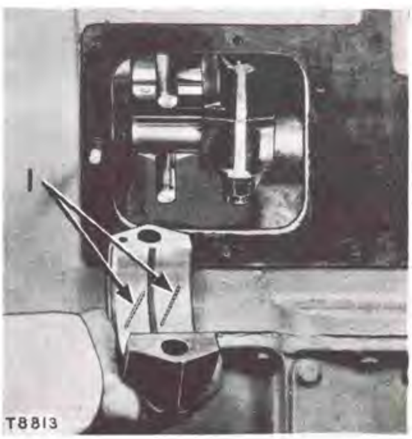
Larger particles of dirt and abrasives in the oil do not tend to embed in aluminum bearings. Such particles roll around between the bearing and crankshaft journal causing scratches in the aluminum bearing without actually becoming embedded in the aluminum. Such scratches are not necessarily harmful and do not indicate that the bearings should be replaced.

Bearings that have over .015" clearance should be replaced. If there is any question about the surface of a bearing, wash it with cleaning solvent to remove oil. Then, if the surface feels rough and abrasive to the touch, replace the bearing. Another indication of dirt in the bearing is excessive crankshaft wear.

The standard crankshaft connecting rod journal diameter is 4.000" to 3.999". In a new engine with aluminum bearings the clearance is .0065" to .009".

Earlier engines had babbitt bearings. The clearance on babbitt bearings is .005" to .007" with a maximum of .015".

The bearing clearance can be checked by using the 5B1161 Lead Wire **(1)** placed between the lower bearing shell and the crankshaft. Coat two one-inch lengths of the soft lead wire with soft grease and place them diagonally on the bearing as shown. The soft grease will



CHECKING CONNECTING ROD BEARING CLEARANCE

1—5B1161 lead wire.

◆

keep the wires in place while installing and tightening the connecting rod cap. Tighten the connecting rod bolt nuts to 1500 inch pounds (125 foot pounds) torque.

Rock the crankshaft back and forth a short distance.

Remove the bearing cap and measure the thickness of the compressed lead wire with a 0" to 1" micrometer to determine the bearing clearance.

Replace bearings having over .015" clearance due to wear on the bearings.

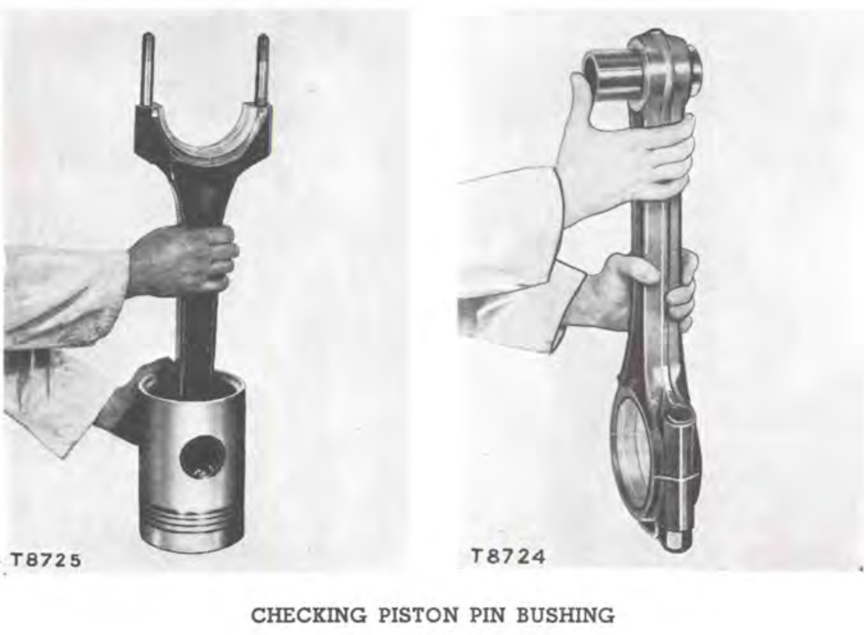
Service bearing shells, .050" undersize, can be obtained for reground crankshafts.

Bent rods should be discarded. Do not attempt to align connecting rods by bending them.

PISTON PIN BUSHING
(All Models)

It is not always necessary to replace piston pin bushings when new precision bearing shells are installed in a connecting rod. In many cases, bushings may be serviceable even though the second replacement of bearing shells has been made.

After the oil has been cleaned from the pin and bushing, it is possible to feel the clearance between them. This normal oil clearance must not be mistaken for wear.



CHECKING PISTON PIN BUSHING

A new bushing should be installed only when the clearance between the bushing and a new piston pin exceeds .006".

New connecting rods have the piston pin bushing bored in a special machine which maintains the proper center-to-center distance and parallelism of the connecting rod bearing and piston pin bore. Reconditioned rods should be machined in the same manner. A new connecting rod makes a good templet. The center-to-center distance is 16.000" ± .001".

After pressing a new bushing into place, it should be machined accurately from .001" to .002" larger than the new piston pin diameter.

Pistons and Rings
(All Models)

The first noticeable symptoms of worn piston rings and cylinder liners are increased oil consumption and excessive vapor from the crankcase breather. Extreme wear will result in poor compression, loss of power and hard starting. See the topic, CYLINDER LINERS (ALL MODELS).

The older model pistons have six rings. There are four compression rings and two oil rings.

Pistons that used six rings were not of the oil-cooled type and these pistons were used with connecting rods that were not drilled. When replacing pistons that used six rings, always install a six-ring piston unless a complete changeover to oil cooling is used.

Later pistons use four rings, consisting of three compression rings and one oil ring.

All rings are located above the piston pin bore. Holes in the piston in the oil ring groove provide for the return of oil to the crankcase. The piston pins are full floating and are held in place by retainers fitting into recesses in the pin bore. Oil is sprayed from the top of the connecting rod to lubricate the piston pin and to cool the piston. Some earlier models did not have the connecting rods drilled for this type of lubrication.

PREPARING FOR PISTON AND CONNECTING ROD REMOVAL
(All Models)

The connecting rods will not pass through the cylinder liners. There are a number of different methods by which the connecting rods and pistons can be removed. The best method in any particular case depends on the work to be done. Connecting rods and pistons can be removed from the bottom of the engine after the crankshaft is removed (preferred method when engine is to be completely reconditioned). Connecting rods can be removed through the inspection openings in the sides of the crankcase and the pistons from the tops of the liners (practical when only one piston or rod is to be removed). Two pistons and connecting rods can be removed as a unit with a cylinder block (only under unusual circumstances). If it is not necessary to remove the crankshaft, it may be desirable to remove the cylinder blocks and liners to change liners, pistons or rings.

Remove the cylinder heads as described in the topics, INDIVIDUAL CYLINDER HEAD REMOVAL (D17000L-E-I), or CYLINDER HEAD REMOVAL AND INSTALLATION WITH MANIFOLDS INSTALLED (D17000L-E-I).

In any case where assemblies or attachments interfere with the removal of the pistons or connecting rods, it would be more practical to remove them than to work around them.

When assemblies or attachments are to be removed, see the removal topic for that particular unit.

INDIVIDUAL PISTON AND CONNECTING ROD REMOVAL (All Models)

The pistons can be disconnected from the connecting rods and removed from the engine in the following manner.

Remove the crankcase inspection covers, or the assemblies which are installed on the crankcase and form the inspection cover.

Remove the cylinder head (or heads) for the particular cylinder from which the piston is to be removed. Remove the carbon from the inside surface near the top of the cylinder liner.

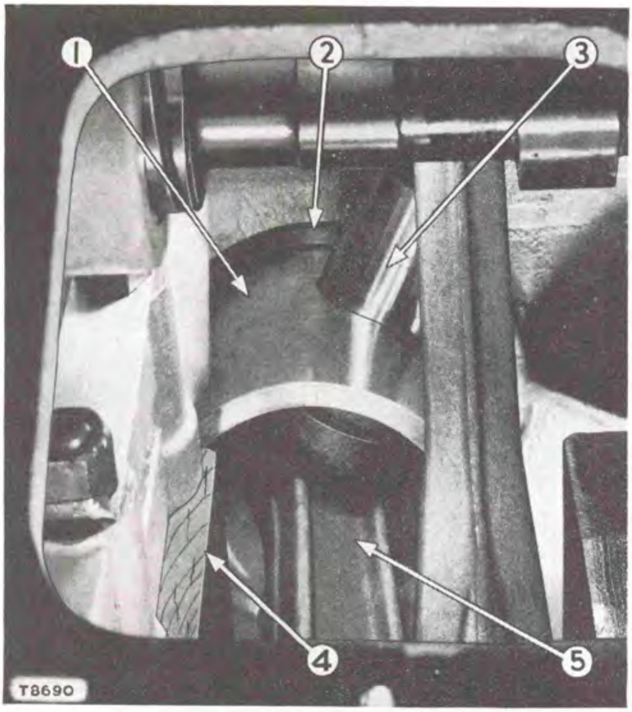
Remove the connecting rod caps as described in the topic, CONNECTING ROD BEARING REMOVAL AND INSTALLATION (ALL MODELS).

Turn the crankshaft to lower the connecting rod and the piston in the cylinder liner. After the connecting rod and piston are at the bottom of their stroke, push the connecting rod and piston upward enough to lift the connecting rod off the crankshaft journal.

Lower the connecting rod and piston enough to allow the piston pin to clear the cylinder liner **(2)**.

CAUTION

Do not lower the piston any further than necessary. The rings must remain in the cylinder liner to avoid damaging them.



REMOVING PISTON PIN
1—Piston. 2—Cylinder liner. 3—Piston pin. 4—Block of wood. 5—Connecting rod.

Rotate the connecting rod and the piston in the cylinder liner enough to allow clearance for removing the piston pin retainer.

Place a suitable block of wood **(4)** at the bottom of the piston **(1)** to support the weight of the piston and the connecting rod.

Remove the piston pin retainer on the side that has the most clearance.

Slide the piston pin **(3)** out of the piston enough to permit the connecting rod **(5)** to be removed.

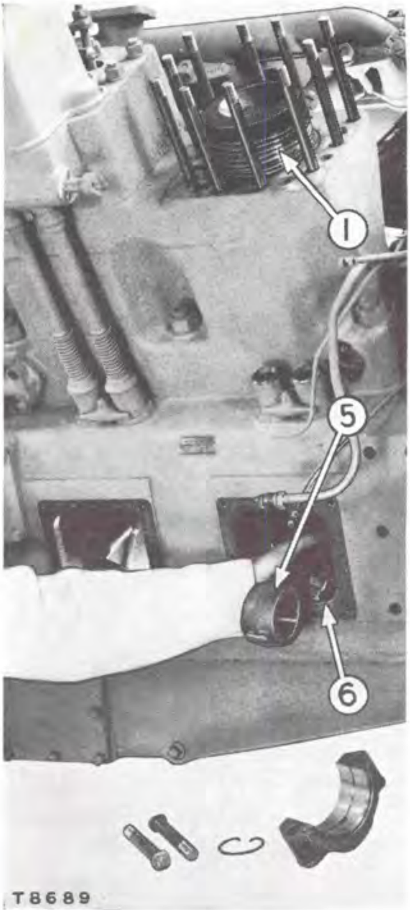
Remove the connecting rod, through the inspection opening **(6)**.

Push the piston pin back to its original position in the piston.

Push the piston upward and remove it from the top of the cylinder liner.

The illustration shows the No. 8 piston being removed, although any of the pistons can be removed and installed using this method.

When a piston and connecting rod have been removed by this method, the easiest way to reinstall them is to remove the cylinder liner, install



REMOVING CONNECTING ROD AND PISTON

(D17000 E-I-M ILLUSTRATED)
1—Piston. 5—Connecting rod. 6—Inspection opening.

the piston in the liner with the rod attached and then install the liner in the block. The connecting rod will pass through the block when the liner is removed.

REMOVING PISTONS AND CYLINDER BLOCKS AS A UNIT (All Models)

The pistons and cylinder blocks can be removed from the engine as a unit in the following manner.

See the topic, PREPARING FOR PISTON AND CONNECTING ROD REMOVAL (ALL MODELS), and remove the assemblies necessary to facilitate piston and connecting rod removal.

Rotate the crankshaft, to position the two pistons **(4)** (in the cylinder block to be removed) an equal distance from the top of their strokes in the cylinder liners.

LIFTING CYLINDER BLOCK

1—Cylinder block. 2—Lifting bar. 3—Dowel. 4—Pistons. 5—Crankcase. 6—Dowel.

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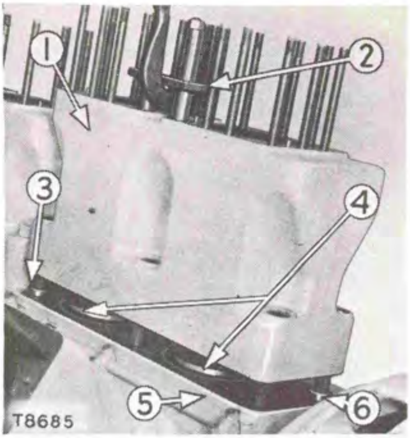
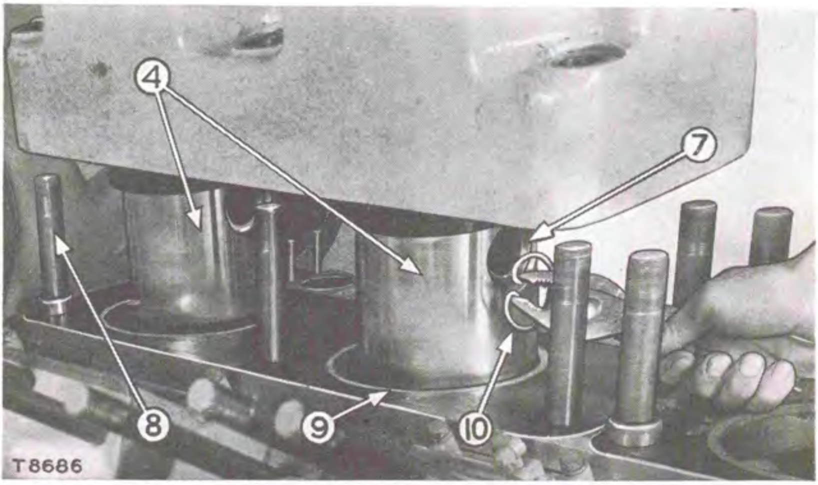


Remove the nuts holding the cylinder block **(1)** to the crankcase **(5)**.

Place a lifting bar **(2)** similar to the bar shown in the illustration over the two center cylinder head studs, using spacers made of 3/4" pipe cut to equal lengths, at the top and the bottom of the lifting bar. Install the cylinder head nuts to secure the spacers and the lifting bar in place.

The lifting bar can be made of bar stock approximately 1/2" thick, 2" wide and 6" long, with 3 1/2" centers for two 3/4" holes.

Place a suitable chain or hook around the lifting bar. A groove filed on the underside of the lifting bar is helpful in keeping a chain or hook in place.



REMOVING PISTON PIN RETAINER

4—Pistons. 7—Piston pin. 8—Stud. 9—Gasket. 10—Piston pin retainer.

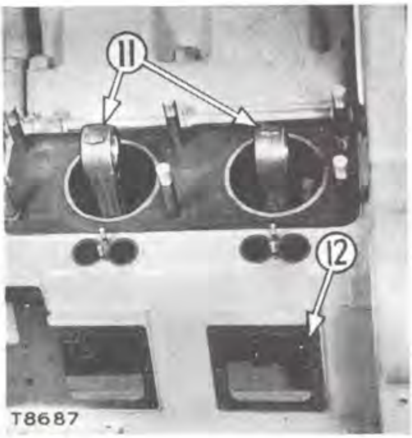
Pry the cylinder block upward to loosen it from the dowels **(3)** and **(6)** which are pressed into the crankcase **(5)**.

Raise the cylinder block carefully until it is just off the crankcase studs **(8)**.

Remove the piston pin retainer **(10)** from one side of each piston.

Remove the piston pin **(7)** from each piston and connecting rod.

Push each piston up into the cylinder liner and lay the connecting rods over against the crankcase so as not to damage the gaskets **(9)**.



REMOVING CONNECTING RODS

11—Connecting rods.
12—Inspection opening.

If it is desired, the connecting rods **(11)** can then be removed in the following manner.

Remove the crankcase inspection covers or the assemblies that are installed on the crankcase and form the inspection covers.

Remove the connecting rod caps through the inspection opening **(12)** as described in the topic, CONNECTING ROD BEARING REMOVAL AND INSTALLATION (ALL MODELS).

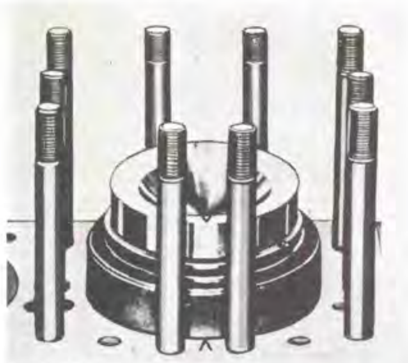
Remove the connecting rods by lifting them out through the top of the crankcase.

When installing the pistons and cylinder blocks, the crankshaft must be in the same position as during the time of removal.

PISTON INSTALLATION
(All Models)

Be sure the carbon has been removed from the inside surface at the top of the cylinder liner.

PISTON INSTALLATION



Place the 2B8184 Ring Compressor on the top of the liner in which the piston is to be installed.

Space the ring gaps evenly around the piston and thoroughly oil the piston and the rings. Center the rings on the piston so they will not protrude more on one side of the piston than on the other.

Place the piston into the ring compressor and the liner and position the V-mark on top of the piston in alignment with the V-mark on top of the cylinder block. This will place the crater of the piston directly under the opening of the pre-combustion chamber.

Apply a gentle downward pressure on the piston. If the piston and rings do not pass into the liner freely, check the rings. It is possible that a ring can be positioned so it is protruding farther out on one side of the piston than the other, thus causing the piston ring to bind and preventing it from being compressed.

INSPECTING AND CLEANING PISTONS
(All Models)

Pistons which are not worn excessively or scored badly should be cleaned and used again. The ring grooves should be square and smooth. The side clearance between a new ring and the top ring groove should not exceed .012".

A number of commercial solvents are available for cleaning pistons. A good solvent should loosen the carbon deposits sufficiently in the bottom of each ring groove to permit removal by wiping or with a soft brush. The bottom of each ring groove must be clean and the oil return holes in the oil ring grooves must be open before the installation of new rings. Never scrape the sides of the ring grooves or the contact surfaces of the piston. The area above the top ring may be filed smooth but pistons badly scored below the top ring groove should be replaced.

REWORKING PISTONS
(All Models)

Pistons with a clearance of more than .012" between the top ring and the ring land can be reworked to use a wider ring in the top groove if the remainder of the piston is in good condition.

After chucking the piston in a lathe, remove just enough material to clean up the lower surface of the top ring groove. Then remove sufficient material from the upper surface of the groove to give a clearance of .003" to .004" between the wider ring and the piston. Pistons originally equipped with a 3/16" ring should use the 1/4" ring 9B2814.

Leave a .020"-.025" radius in the inside corners of the groove and chamfer the outer corners .025"-.030" x 45°. The upper and lower surfaces of the groove on which the ring bears must have a very smooth surface.

PISTON RINGS
(All Models)

Piston rings seal compression and control the amount of oil on the cylinder walls. If oil consumption is not excessive and compression is satisfactory, pistons should not be removed or new pistons installed when an engine is dismantled for some other reason. To avoid damage to the piston and rings, remove and replace rings with a 7B7974 Ring Expander.

When installing new piston rings, it is not necessary to check the gaps because new rings are supplied only in standard size. New rings in the standard size may be used in cylinder liners worn as much as .020". Oversize rings are unnecessary.

When new piston rings are to be used in worn cylinder liners, the ridge at the top of the liner should be raised and the liner etched as recommended in the topics, RAISING THE RIDGE IN WORN CYLINDER LINERS (ALL MODELS) and ETCHING CYLINDER LINERS (ALL MODELS).

RING EXPANDING TOOL

If new rings are installed on the old pistons, be sure the ring grooves are clean and the oil return holes in the oil grooves are free of carbon and are open.

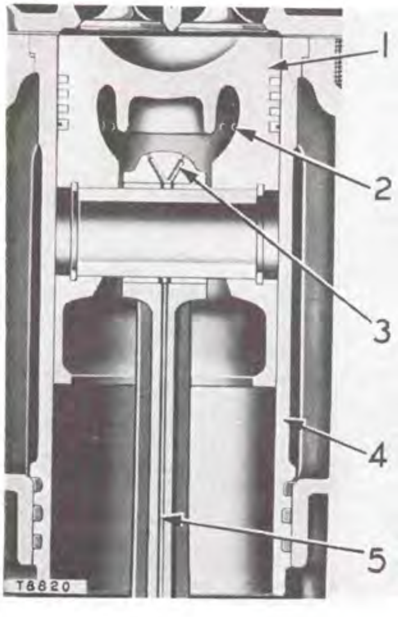
After new rings are installed, the engine should be operated on the recommended running-in schedule before a full load is assumed.

PISTON AND RING LUBRICATION
(All Models)

The pistons **(1)**, the rings and the cylinder liners **(4)** are primarily lubricated by the oil that is splashed or thrown by the crankshaft and the camshafts, while the engine is in operation.

Oil return holes **(2)** in the piston oil ring groove provide for the return of oil to the crankcase.

The drilled passages **(5)** in the connecting rods receive a supply of oil from the crankshaft to lubricate the piston pin and bushing. A portion of the oil is sprayed from the discharge holes **(3)** at the top of the connecting rods on the inside top of the piston, to aid in cooling the piston. Earlier models did not have the connecting rods drilled for oil cooling of the pistons. These engines are equipped with six-ring pistons.



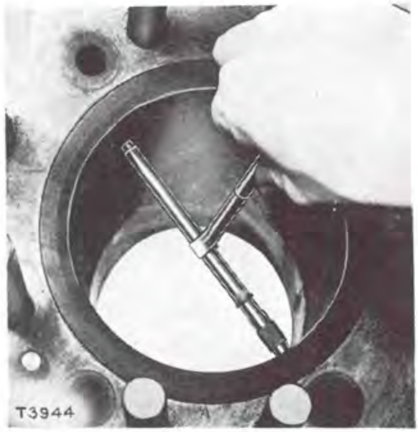
PISTON AND RING LUBRICATION

1—Piston. 2—Oil return hole. 3—Oil discharge holes at top of connecting rod. 4—Cylinder liner. 5—Drilled oil passage in connecting rod.

Cylinder Liners
(All Models)

Cylinder liner surfaces are machined, hardened, ground and finally honed to a mirror finish and chemically treated to assure proper break-in. The resultant surface is so hard that ordinary boring tools will not machine it. Cylinder liners and pistons are priced at the factory so that it is not economical to grind worn cylinder liners oversize.

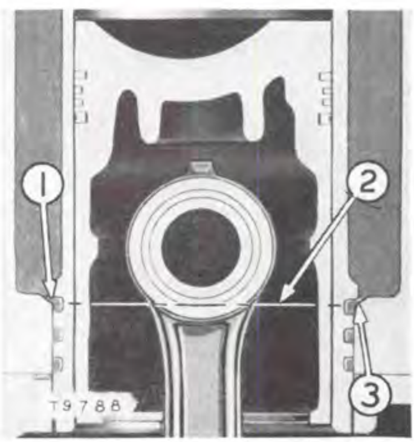
CHECKING LINER WEAR



Liners, pistons and rings are available from the factory in standard sizes only and require no fitting when they are installed.

Cylinder liners should be replaced when they are worn at the top of the ring travel more than .020" or when they are scratched or scored.

Liner wear should be checked with inside micrometers, as shown.



THREE SEAL LINER

1—Top liner seal. 2—Center line of the top seal ring groove. 3—Cylinder bore chamfer.

When installing liners, use a new copper gasket and new rubber seals. Coat the rubber seals with liquid soap to ease installation.

When three liner seals are used, the top seal **(1)** protects the cylinder bore chamfer **(3)** from rust and scale. The cylinder bore chamfer is machined to permit the lower edge of the chamfer to align with the center line **(2)** of the top seal ring groove as illustrated.

Earlier models used two liner seals and the location of the cylinder bore chamfer did not meet the top seal.

If an old liner had only two liner seals, use only two seals on the replacement liners.

LINER AND SEALS

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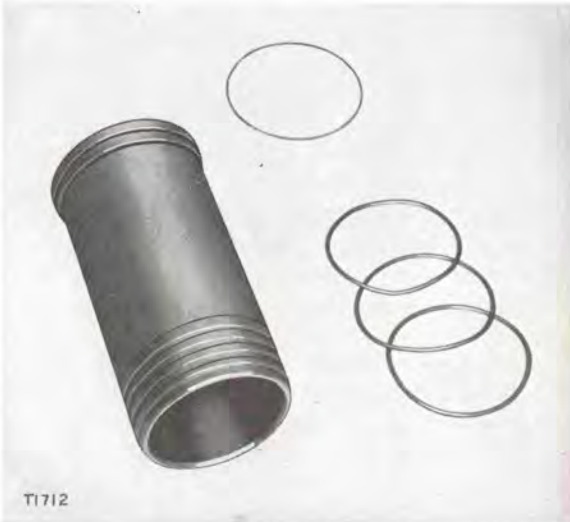


REMOVING AND INSTALLING CYLINDER LINERS
(All Models)

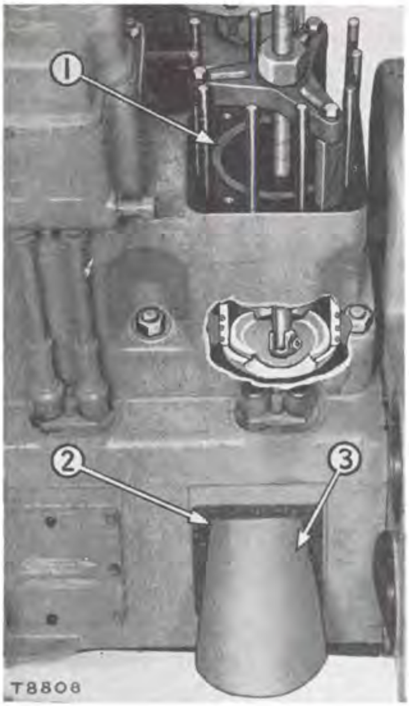
Drain the cooling system by removing the drain plugs.

Remove the heads, the connecting rods and the pistons as outlined in their respective topics.

When removing and installing the cylinder liners, rotate the crankshaft to position the crankshaft journal as far away as possible from the inspection opening for the cylinder from which the liner is being removed.

Place a piece of cardboard or heavy gasket material **(3)** into the inspection opening **(2)** as illustrated to protect the inside of the engine.

Install the 5F7346 Puller and the 5F7364 Adapter Plate.



REMOVING CYLINDER LINER

1—Cylinder liner.
2—Inspection opening.
3—Cardboard or heavy gasket material.

Remove the cylinder liner **(1)** and clean the water jacket sediment from the cylinder block.

If the cylinder block has been removed with the liners in place, it is easier to invert the block and drive out the liners. Place the adapter plate on the liner and drive it out with a block of hardwood and a heavy hammer.

When installing the cylinder liner, always use a new gasket and rubber seals. Coat the rubber seals with liquid soap to ease installation.

Lower the cylinder liner carefully into the block. The liners can be driven into place by using a suitable driver, or by placing the puller adapter on the top of the liner. A block of hard wood to be used as a driving block is then placed on the puller adapter.

Drive the liner into the cylinder block until it bottoms. Then hit the block of wood several light taps, to assure that the liner is in flush. Occasionally the liner may bounce back out a trifle, if the last blow bottoms the liner too hard.

Properly installed liners should extend slightly above the face of the cylinder block. This insures proper holding and sealing of the cylinder liner against the cylinder head gasket when the cylinder head is drawn down.

INSTALLING CYLINDER LINER

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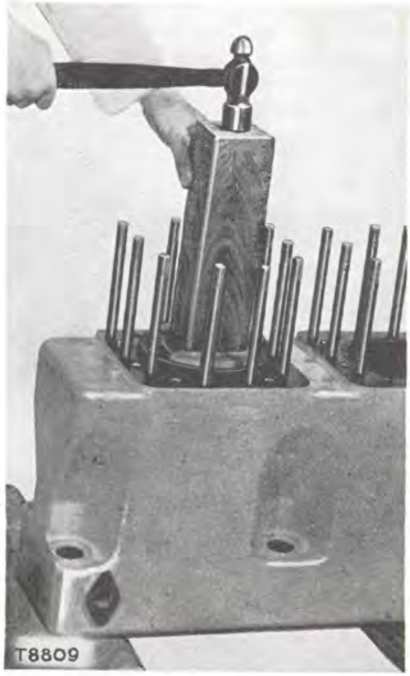


Some liners may feel slightly loose in the cylinder block, yet serve satisfactorily without water or anti-freeze leaking past the rubber seals.

Remove the cardboard and assemble the parts in the reverse order of removal.

RAISING THE RIDGE IN WORN CYLINDER LINERS
(All Models)

When new piston rings are to be used in worn cylinder liners, the ridge in the liner at the top of the ring travel should be raised to provide clearance for the new top ring. Since the liners are too hard for ordinary tools, the 9B3086 Liner Ridge Boring Tool should be used. The illustration shows how the tool is installed.

The tungsten carbide tool bit is spring loaded and specially ground so it will follow the worn contour of the liner and will not cut deeper than the worn surface. Instructions for its use accompany the tool.

CAUTION

> Be careful not to rotate the tool counterclockwise when the tool bit is against the liner wall. Doing so will break the cutting edge.

LINER RIDGE BORING TOOL

The worn liners should be etched or honed to remove the highly glazed surface. Either of these processes will shorten the running-in period and improve the performance of the rings. If the engine still does not break in properly, see the topic, BREAK-IN POWDER (ALL MODELS).

ETCHING CYLINDER LINERS
(All Models)

An inexpensive etching tool can be made similar to the one shown.

Use an etching solution composed of:

Oxalic Acid (commercial grade)—10 ounces

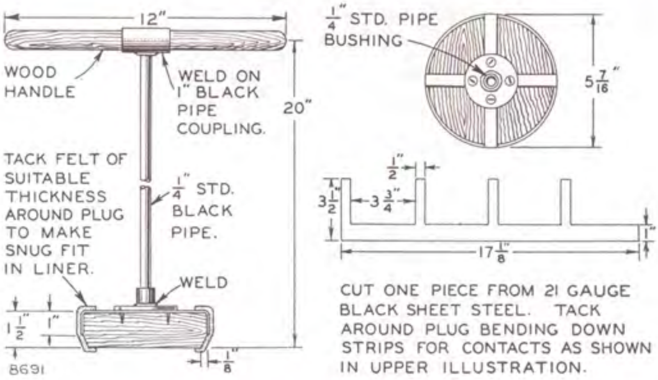
Acetic Acid (Glacial)—3/4 fluid ounce

Denatured Alcohol (Industrial)—7 fluid ounces

Add sufficient water to make one gallon.

To prepare the etching solution, dissolve the oxalic acid crystals in approximately one-half gallon of water in a glass container. Add the acetic acid and stir until well mixed. Add the denatured alcohol and water to make one gallon. The solution can be kept indefinitely in a tightly closed glass container.

Clean the liner with cleaning solvent and flush with carbon tetrachloride to remove all traces of oil. Cover the crankshaft beneath the liner to



CYLINDER LINER ETCHING TOOL

protect it from the etching solution, by using a similar method as described in the topic, REMOVING AND INSTALLING CYLINDER LINERS (ALL MODELS).

Saturate the felt on the tool with the etching solution and place the tool in the liner bore and force it to the bottom.

Connect the positive (+) terminal of a 6 volt storage battery to one of the cylinder block studs and the negative (—) terminal to the shank of the tool using wires and battery clips. Move the tool up and down the liner bore with a spiral movement for eight or ten minutes with the current at 15 to 20 amperes. Etching solution should be added while the tool is in the liner to keep the felt well saturated.

Care should be taken to see that the tool is kept in motion while the electrical circuit is complete.

After the etching process, remove the tool from the liner, wipe the liner clean and dry and coat it with oil. Flush out the crankcase before assembling the engine.

Running-in Schedule (All Models)

The following is a reproduction of the label that accompanies pistons and rings sent out from the "Caterpillar" Parts Department.

CAUTION

Whenever new rings, piston assemblies or liners are installed be sure to run-in the engine on at least a 4-hour conditioning schedule before operating at normal load and speed. Avoid operating the engine at high speed idle at any time during the conditioning process. The following schedules are indicated as safe procedures to follow:

	DIESEL TRACTOR	DIESEL POWER UNITS
Period 1: $\frac{1}{2}$ hour	Operate the engine at low idle speed.	Operate the engine at low idle speed.
Period 2: $\frac{1}{2}$ hour	Operate the tractor in 4th gear without load at $\frac{3}{4}$ rated speed.	Operate the engine on work approximating $\frac{1}{4}$ maximum load at $\frac{3}{4}$ rated speed.
Period 3: 2 hours	Operate the tractor at $\frac{3}{4}$ rated speed on light work.	Operate the engine on work approximating $\frac{1}{2}$ maximum load at $\frac{3}{4}$ rated speed.
Period 4: 1 hour	Operate the tractor at full rated speed on medium work.	Operate the engine on work approximating $\frac{3}{4}$ maximum load at full rated speed.

These periods may be impractical to maintain in all cases; however, at least three hours should be accumulated before operating at full rated speed.

CATERPILLAR TRACTOR CO.

T4351

Do not run the engine idle for a long period after installing new rings or liners. **Rings will not seat during idle operation.** Place some load on the engine after $\frac{1}{2}$ hour of operation and put a full load on the engine if at all possible, after 4 hours of operation.

Break-in Powder (All Models)

Besides honing or etching the cylinder liners, a third method has frequently been used to hasten the seating of new rings to worn liners. This method uses 7F5225 Bon Ami Powder. The procedure is as follows:

> After assembling and starting the engine, loosen the air cleaner on each bank of cylinders to allow a gap between the flange and the inlet manifold. Run the engine at about 800 RPM and allow the powder to be sucked slowly through the gap and into the engine. Use $1\frac{1}{4}$ teaspoonfuls of powder per cylinder and then tighten the air cleaner. Run the engine idle at 800 RPM for thirty minutes, and it is then ready for service.

This method of break-in has been used successfully when facilities were not available for honing or etching the liners. It has also been successful when, for some unknown reason, new rings and liners have failed to break-in in a reasonable length of time. If the first powder treatment is not effective, a second one may be. However, if the second treatment is not effective, a thorough investigation should be made to determine the cause of the oil consumption.

Cylinder Blocks
(All Models)

Four identical cylinder blocks are mounted on the crankcase. Each contains two removable wet-type cylinder liners. As a rule the blocks should not be removed from the crankcase unless they have been accidentally damaged or unless there is oil leakage between the block and crankcase.

Each cylinder bore in the crankcase is counterbored for an oil seal made of cork. New seals should be installed whenever the blocks are removed, but otherwise, only if leakage should develop.

The blocks can be removed after the engine is disassembled by removing six hold-down nuts for each block and lifting it off the crankcase and studs. The blocks can also be removed individually or as units with the pistons. See the topic, REMOVING PISTONS AND CYLINDER BLOCKS AS A UNIT (ALL MODELS).

TURNING ENGINE OVER
(All Models)

The engine can be rolled over and placed on its side in the following manner.

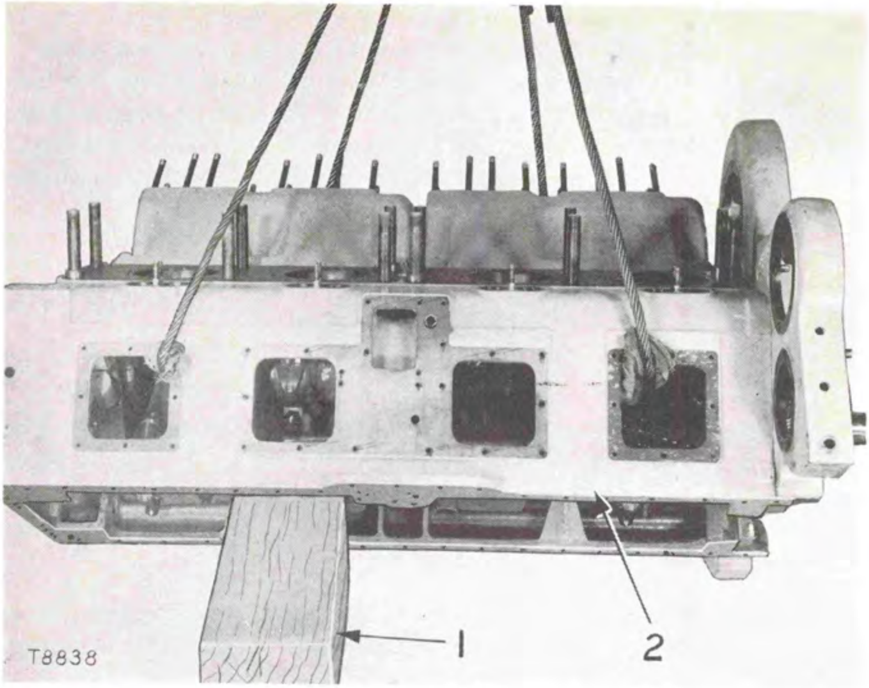
(The right bank of cylinders has been removed here for better illustration only.)

Position the crankshaft so the front and rear crankshaft journals are at the bottom of their strokes.

Place cables through the crankcase and protect the crankcase with cloths as illustrated.

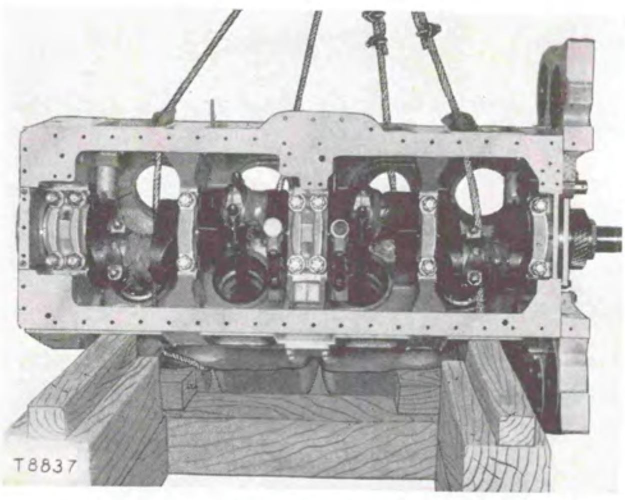
Raise the engine to a height of approximately three feet off the floor.

Place a large heavy wooden block **(1)** on the floor directly below the engine.



TURNING ENGINE OVER
1—Wooden block. 2—Crankcase.

Lower the engine carefully so one side of the crankcase **(2)** will rest on the wooden block.



SUPPORTING ENGINE WITH WOODEN BLOCKS

Continue lowering the engine slowly, permitting the engine to roll in the cables to the desired position.

Place wooden blocks under the engine to support it and provide safe working conditions.

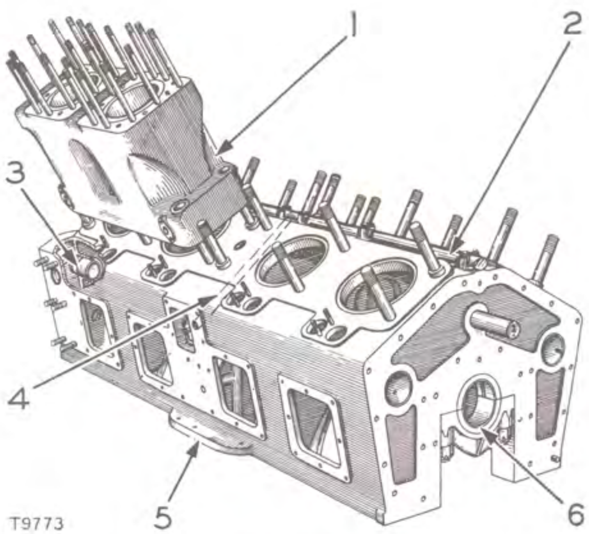
Crankcase
(All Models)

The crankcase **(5)** has four cylinder blocks **(1)** attached to it, and each cylinder block has two cylinders within it.

The camshaft bearings **(3)** are pressed into the crankcase and they are replaceable.

The main bearings **(6)** support the crankshaft in the crankcase.

Filtered oil under pressure from the oil filters enters the oil tube **(4)** (which is pressed into the crankcase) and flows into the oil manifold **(2)**. The oil manifold supplies the engine with the oil necessary for lubrication. See the topic, OIL MANIFOLD (ALL MODELS).



CRANKCASE
1—Cylinder block. 2—Oil manifold. 3—Camshaft bearing. 4—Oil tube (pressed in crankcase). 5—Crankcase. 6—Main bearing.

Main Bearings
(All Models)

The main bearings support the crankshaft in place in the crankcase.

Earlier models used babbitt bearings with shims and these bearings were not of the precision-type. A field changeover group is available which makes possible the installation of later precision-type main bearings in earlier engines. These groups include installation instructions. This information is also given in the following topic.

Later model engines use the precision-type main bearings and shims are not required.

The bearing changeover groups for earlier engines can be obtained for a standard crankshaft or for a .050" undersized crankshaft.

There are five main bearings, each consisting of upper and lower halves. The upper halves have drilled holes which are aligned with drilled passages in the crankcase.

The lower halves locate in the main bearing caps, which are held to the crankcase by studs and nuts. The lower halves are held in place by dowels in the main bearing caps, while the lower halves and the upper halves are kept in alignment with each other by dowels at their parting surfaces.

Oil under pressure enters the drilled passages in the crankcase from the oil manifold, which is mounted on top of the crankcase. See the topic, OIL MANIFOLD (ALL MODELS).

The main bearings are lubricated by this supply of oil. The oil is then carried through the drilled passages in the crankshaft to lubricate the connecting rod bearings.

The main bearings can be removed without removing the crankshaft. See the topic, REMOVING MAIN BEARINGS (ALL MODELS).

INSTRUCTIONS FOR INSTALLATION OF 5F367 OR 5F368 MAIN BEARING CHANGEOVER GROUPS IN ENGINES ORIGINALLY EQUIPPED WITH NON-PRECISION BEARINGS
(All Models)

The 5F368 Main Bearing Changeover Group is available for a standard crankshaft, and the 5F367 for use with a .050" undersize crankshaft.

These changeover groups permit the installation of precision-type bearings into early model engines that did not originally use a precision-type bearing.

A changeover group consists of aluminum main bearings of the precision-type, laminated shim packs, main bearing packing plate assembly, cork seals and dowels.

If a changeover group is to be installed, the crankshaft should always be inspected for wear unless a new crankshaft is being installed at the same time as the changeover group.

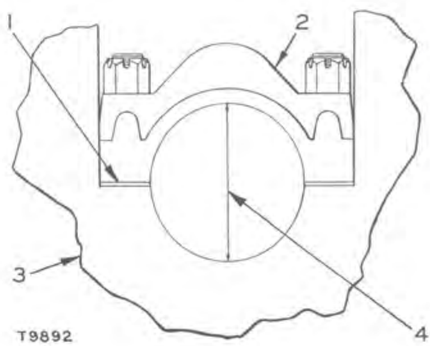
These instructions should be followed closely when installing a changeover group:

a. Remove the main bearing caps and shims and the crankshaft as described in their respective topics. Discard the original shims.

b. Remove the hollow dowels that are pressed into the main bearing bores in the crankcase **(3)**, if they have not already been removed. (This will permit the upper halves of the main bearings to be removed at a later time by merely rolling them out without removing the crankshaft).

c. Install an equal amount of the new shims **(1)** at each side of the bearing caps **(2)**. Install the main bearing caps and nuts without the bearings.

d. Tighten the bearing cap nuts evenly using 440 foot pounds torque.



MEASURING BEARING BORE

1—Shims. 2—Bearing cap. 3—Crankcase. 4—Bore.

◆

e. With a micrometer, measure the diameter of each bore **(4)** vertically as illustrated, and record these diameters. **This dimension is critical and must be measured carefully.**

f. Remove the bearing caps, being sure that the shims remain in their present location.

g. The diameter of the main bearing bore should be 5.123" - 5.124". Enough laminations should be removed from each side to provide this dimension for each bearing bore.

Example: If the measured vertical bore is 5.127", remove a .003" shim from each side of the bearing bore (5.127" minus .003" equals 5.124"). The shims are .002" and .003" thick.

h. After a shim adjustment has been made, install the caps and nuts. Tighten the nuts again to 440 foot pounds torque. Measure the bore again to see that it is actually 5.123" - 5.124".

i. Remove the bearing caps. Remove the original dowels from the main bearing caps carefully so as not to damage the caps. Install the new dowels.

j. Be sure the bearing backs are clean and dry. Install the upper bearing shells aligning the oil holes with the drilled oil passages in the crankcase.

k. Lubricate the main bearing journals generously and install the crankshaft, the lower halves of the main bearings, the main bearing caps and nuts. Tighten the nuts to 440 foot pounds torque. Check the crankshaft end clearance as described in the topic, CHECKING CRANKSHAFT END CLEARANCE (ALL MODELS).

l. Install the cork seals between the crankcase and the packing plate. Install the new rear main bearing packing plate as described in its respective topic.

NOTE

After the changeover group has once been installed the main bearing bores in the crankcase are then suitable for precision bearings. Then in the future the precision-type bearings can be replaced when necessary with the 5F444 Bearing group for a standard crankshaft, or the 5F443 Bearing group for a .050" undersize crankshaft. These groups only include the bearing shells. The original changeover shims, must be reassembled with the same bearing caps from which they were removed to obtain the bore reading of 5.123" - 5.124".

REPLACEMENT MAIN BEARING SHELLS
(All Models)

Precision main bearing shells, machined to provide proper clearance, are obtainable in complete sets and should be installed without fitting, scraping, filing or reaming.

Single replacement bearings, upper and lower shells, may also be obtained and installed without special fitting. As a rule, however, it is good practice to replace the complete set if any one of the bearings needs to be replaced. If only one new bearing is installed and the other bearings are worn to any extent, the new bearing will carry more than its normal share of load and damage to it or the crankshaft can result.

Precision main bearings are also obtainable for use with crankshafts reground to .050" undersize.

REMOVING MAIN BEARINGS
(All Models)

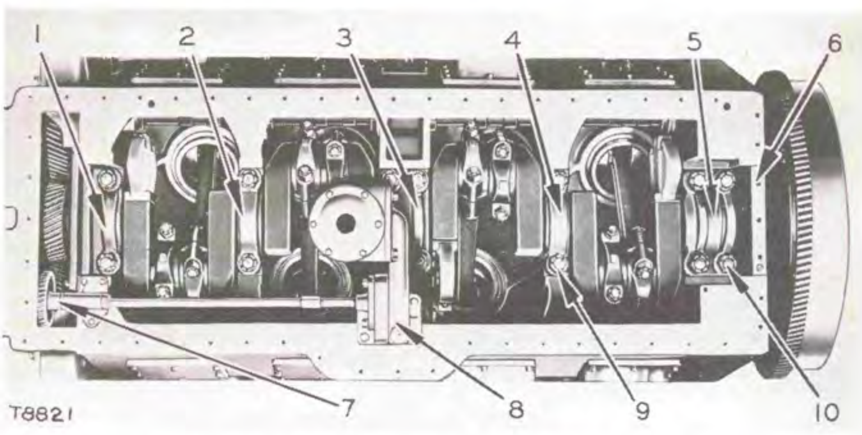
Remove the oil pan as described in the topics, OIL PAN REMOVAL AND INSTALLATION (D17000L) or (D17000E-I-M).

Remove the oil pump **(8)** and the oil pump drive **(7)** on all models except the locomotive engine. The locomotive engine has an externally mounted oil pump drive and oil pump and they need not be removed.

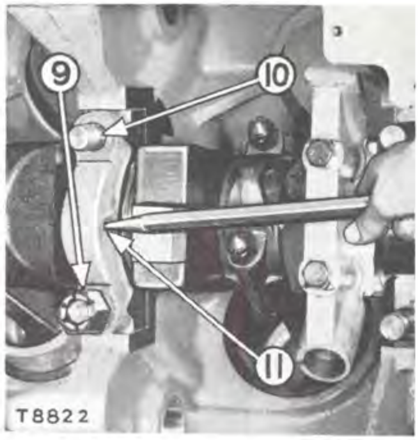
The main bearings (upper and lower halves) and the main bearing caps are numbered consecutively from 1 to 5, with No. 1 main bearing located at the forward end of the engine. The numbers are marked on the forward side of the bearings and the main bearing caps.

When removing the main bearings for inspection or replacement, remove no more than two sets at a time, in order to permit the remaining main bearings to support the crankshaft. See the topic, CHECKING MAIN BEARING CLEARANCE (ALL MODELS).

The front main bearing **(1)** and the intermediate main bearings **(2)**, and **(4)** and the center main bearing **(3)** can be removed as follows:



MAIN BEARING CAPS (D17000 E-I-M ILLUSTRATED)
1—No. 1 main bearing cap. 2—No. 2 main bearing cap. 3—No. 3 main bearing cap. 4—No. 4 main bearing cap. 5—No. 5 main bearing cap. 6—Rear main bearing packing plate. 7—Oil pump drive. 8—Oil pump. 9—Nut. 10—Stud.



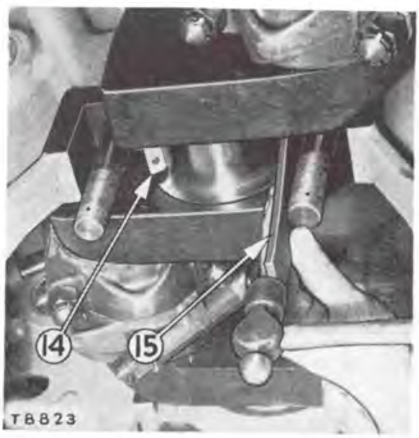
REMOVING MAIN BEARING CAP
9—Nut. 10—Stud. 11—Hole.

♦

Remove the cotter pins and nuts **(9)** and remove the main bearing cap and the lower half of the main bearing.

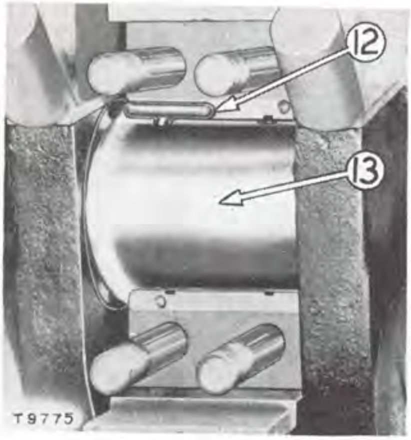
The rear main bearing packing plate **(6)** must be removed, before the rear main bearing can be removed. The rear main bearing is held in place by both the rear main bearing cap **(5)** and the packing plate **(6)**. See the topics, REMOVING AND INSTALLING REAR MAIN BEARING PACKING PLATE WITH FLYWHEEL HOUSING INSTALLED (ALL MODELS) and REMOVING AND INSTALLING REAR MAIN BEARING PACKING PLATE WITH FLYWHEEL HOUSING REMOVED (ALL MODELS).

Some bearing caps may fit too snugly to permit their removal by hand. In this case the bearing cap can be removed as illustrated. Install a nut **(9)** loosely on a stud **(10)** to stop the cap from falling off as it becomes loosened. Place a small block of wood on the crankshaft flange. Insert a pinch bar in the horizontal drilled hole **(11)** in the bearing cap, pry outward, tapping the cap with a soft hammer.

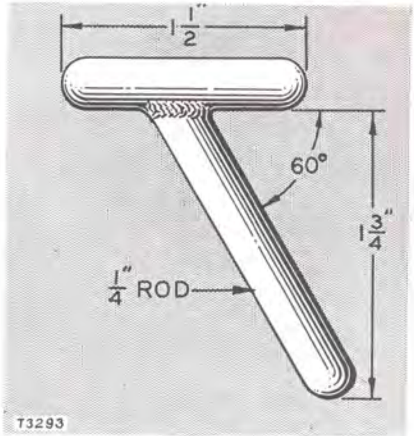


REMOVING UPPER BEARING HALF
14—Upper half of main bearing.
15—Fiber or heavy leather.

♦



REMOVING UPPER MAIN BEARING
12—Tool. 13—Crankshaft journal.



TOOL FOR REMOVING AND INSTALLING MAIN BEARINGS

The upper half of the main bearing **(14)** can be removed by rolling it out as illustrated, using a piece of fiber or heavy leather **(15)**, flexible enough to bend, (approximately 8" long x 1½" wide x ¼" thick), on the parting surface of the upper bearing half and tapping it out. Another method of removing the upper halves is by the use of a tool **(12)** as shown in the illustration. Place the tool into the drilled oil passage of the crankshaft and turn the crankshaft enough to permit the tool to touch the bearing.

Before turning any further, make sure the tool is all the way into the crankshaft journal **(13)**.

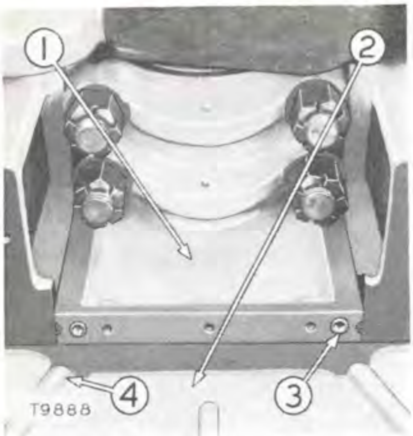
Turn the crankshaft slowly to roll the upper shell around to permit it to be lifted out.

Remove the bearing and the tool. The upper main bearings can be installed by either method described above.

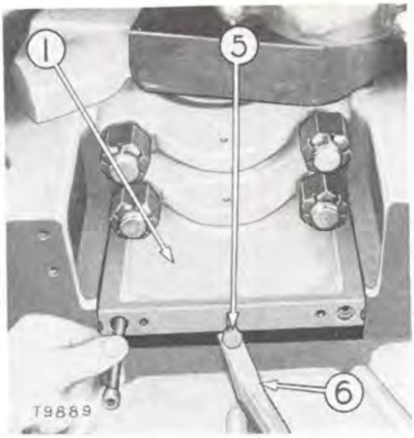
REMOVING AND INSTALLING THE REAR MAIN BEARING PACKING PLATE WITH THE FLYWHEEL HOUSING INSTALLED (All Models)

The rear main bearing packing plate **(1)** can be removed in the following manner when the flywheel housing **(2)** is installed.

Make a mark on the forward side of the packing plate so that it can be installed correctly.



PREPARING FOR PACKING PLATE REMOVAL WITH THE FLYWHEEL HOUSING INSTALLED
1—Packing plate. 2—Flywheel housing. 3—Hollow-head screws.4—Support ribs.



PRYING PACKING PLATE AWAY FROM FLYWHEEL HOUSING
1—Packing plate. 5—Capscrew. 6—Pinch bar.

Remove the hollow-head screws **(3)** from the crankcase. The screws cannot be removed from the packing plate at this time, because of the support ribs **(4)** of the flywheel housing.

Install an oil pan capscrew **(5)** into the packing plate.

Using a pinch bar **(6)**, pry on the capscrew to loosen the packing plate and move the packing plate outward and away from the rear main bearing.

Pry the packing plate away from the flywheel housing enough to permit the hollow-head screws to be removed.

Install two $3/8''$ eyebolts **(7)** as illustrated.

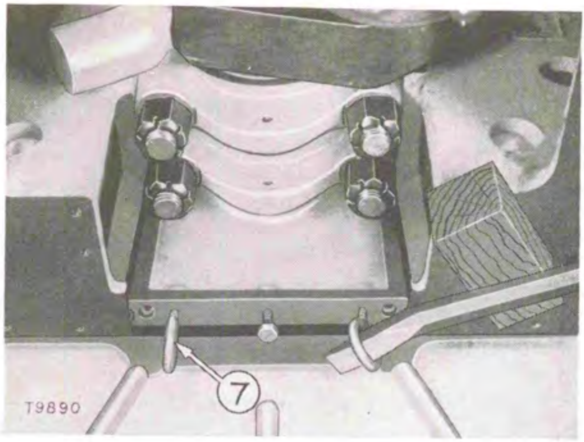
Remove the packing plate by using a pinch bar. Place a block of wood between the crankcase and the pinch bar and bump the bar sharply.

When removing the packing plate guide the plate forward and away from the support ribs.

Clean the packing plate grooves.

Remove the rear main bearing cap and the rear main bearings as described in the topic, REMOVING MAIN BEARINGS (ALL MODELS).

When installing the packing plate, use the identification mark to locate the packing plate correctly.



REMOVING PACKING PLATE WITH FLYWHEEL HOUSING INSTALLED
7—Eyebolt.

Install the packing plate into the crankcase in the reverse order or removal.

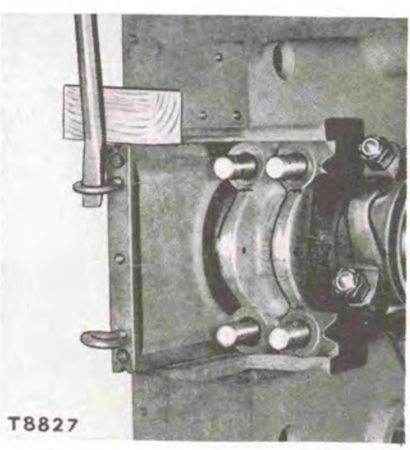
See the topic, REMOVING AND INSTALLING THE REAR MAIN BEARING PACKING PLATE WITH THE FLYWHEEL HOUSING REMOVED (ALL MODELS), and repack the packing plate as described.

REMOVING AND INSTALLING THE REAR MAIN BEARING PACKING PLATE WITH THE FLYWHEEL HOUSING REMOVED (All Models)

The rear main bearing packing plate can be removed in the following manner when the flywheel housing is removed from the engine.

LOOSENING REAR MAIN BEARING PACKING PLATE

◆



Remove the long hollow-head screws.

The packing plate can be removed by using 3/8" eyebolts and a pinch bar. Place a block of wood between the crankcase and the pinch bar and bump the bar sharply to loosen the packing plate.

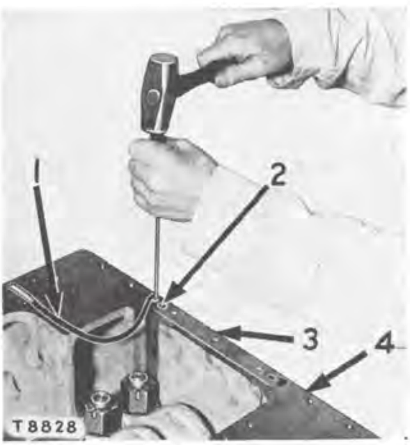
Before installing the packing plate, clean out the packing grooves.

Install the packing plate into the crankcase. Using a soft hammer, align the outside face **(3)** of the packing plate with the rear face **(4)** of the crankcase. The packing plate must be aligned correctly, since the flywheel housing is mounted to the rear face of the crankcase.

Install the hollow-head screws **(2)** and tighten.

Dip the packing **(1)** in pitch or paint and start it into the packing grooves.

Using a suitable driver (which will fit into the packing groove in the packing plate) and hammer, feed the packing into the groove until the groove is filled.



ALIGNING PACKING PLATE AND INSTALLING PACKING

1—Packing. 2—Hollow-head screw. 3—Outside face of packing plate. 4—Rear face of crankcase.

When the grooves are filled correctly, they will be packed solid and the packing will protrude from the packing plate and the crankcase approximately 1/8".

MAIN BEARING INSPECTION
(All Models)

Although fine dirt and abrasives in the oil affect aluminum and babbitt bearings somewhat alike, coarser particles act quite differently. While the softer babbitt bearing may permit large particles to become embedded in the bearing, these same size particles may merely roll around between the bearing and crankshaft journal causing scratches in the aluminum bearing without actually becoming embedded in the aluminum. Such scratches are not necessarily harmful and do not indicate that the bearings should be replaced.

If there is any question about the surface of a bearing, wash it with cleaning solvent to remove the oil. Then, if the surface feels rough and abrasive to the touch, replace the bearing. Another indication of dirt in the bearing is excessive crankshaft wear.

Checking Main Bearing Clearance (All Models)

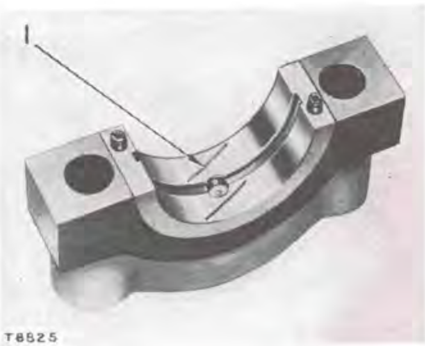
The main bearing clearance can be checked without removing the crankshaft.

If the engine is in an upright position, the crankshaft must be held against the upper main bearings when checking main bearing clearance, otherwise the weight of the crankshaft will compress the lead wire slightly and indicate a lesser clearance than really exists.

The crankshaft can be held against the upper main bearings by placing paper, approximately .025" thick, between the lower bearing and the crankshaft journal of the bearing or bearings next to the one to be checked and tightening those bearing caps. For example, place paper between No. 2 and No. 4 lower main bearings and their crankshaft journals, and then check the bearing clearance of No. 1, No. 3 and No. 5 bearings.

The bearing clearance can be checked by placing soft lead wire **(1)** between the lower bearing and the crankshaft. Lead wire for this purpose can be obtained from the Parts Department by ordering part number 5B1161.

Coat two one-inch lengths of the wire with soft grease and place them diagonally on the bearing as shown. The soft grease will keep the wires in position while installing and tightening the cap.



CHECKING MAIN BEARING CLEARANCE

1—5B1161 lead wire.

Tighten the main bearing stud nuts to 5300 in. lb. (442 ft. lb.) torque.

Remove the bearing cap and lower bearing and check the thickness of the lead wire with a 0" to 1" micrometer to determine the bearing clearance.

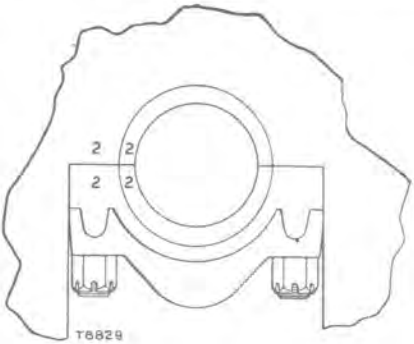
The main bearing clearance for aluminum bearings should be .0065"-.009" with a maximum permissible clearance of .015".

Earlier models had babbitt bearings, with a clearance of .0045"-.0065" and a maximum permissible clearance of .015".

INSTALLING MAIN BEARING
(All Models)

After the main bearings have been cleaned, inspected, checked for wear and determined suitable for use, they should be installed in the following manner.

All bearings and bearing caps are numbered and they should be installed in their original locations.



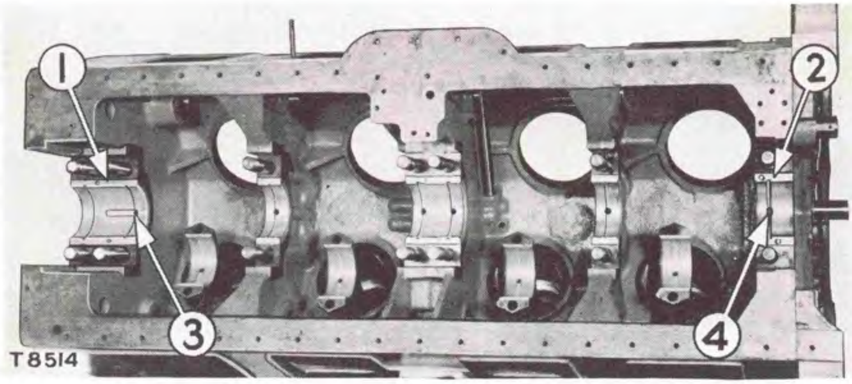
IDENTIFICATION NUMBERS FOR MAIN BEARING

◆

NOTE

Install the upper main bearing halves by rolling them into place as described in the topic, REMOVING MAIN BEARINGS (ALL MODELS), with the oil hole **(3)** of the rear main bearing **(1)** and the oil hole **(4)** of the front main bearing **(2)** located as shown in the illustration. The oil holes in the remaining bearings are located on-center and cannot be installed incorrectly.

The oil holes will be automatically aligned with the drilled passages in the crankcase if the bearings are installed in their original location with the number toward the front of the engine.



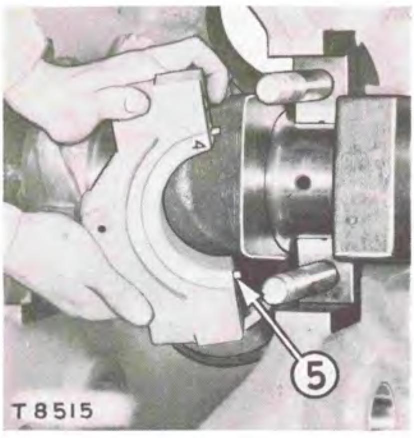
LOCATION OF OIL HOLES IN UPPER MAIN BEARING (CRANKSHAFT REMOVED FOR BETTER VIEW)
1—Rear main bearing (upper). 2—Front main bearing (upper.) 3—Oil hole. 4—Oil hole.

Locate the upper bearings centrally in the crankcase.

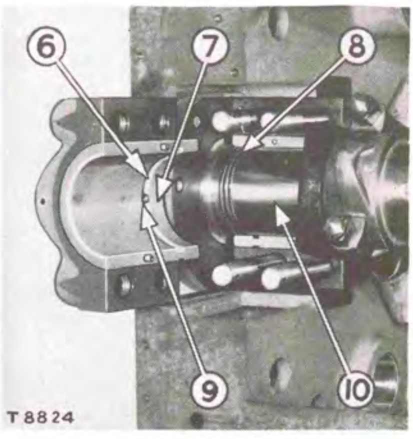
Install the lower bearing half into the bearing cap, aligning the dowels with the dowel holes. The dowels in the bearing caps are located off-center, which causes the lower bearing halves to fit into the bearing caps only in the correct position.

Lubricate the lower bearing generously with oil.

Install the bearing cap and the lower half of the bearing, matching the numbers on the bearing and cap with the number stamped in the crankcase as shown in the illustration. Guide the dowels **(5)** of the lower



INSTALLING INTERMEDIATE MAIN BEARING AND BEARING CAP
5—Dowel.



INSTALLING REAR MAIN BEARING AND BEARING CAP
6—Oil groove. 7—Large diameter of rear bearing. 8—Oil return threads on crankshaft. 9—Oil hole. 10—Crankshaft.

bearings into the dowel holes located in the upper half of the bearing.

If new bearings are installed, they should be marked for identification.

Install the main bearing stud nuts and tighten to 5300 in. lb. (442 ft. lb.) torque.

The front main bearing (which is marked No. 1), and the intermediate main bearings (which are marked No. 2 and No. 4) and the center main bearing (which is marked No. 3) are installed in the same manner.

The rear main bearing (which is marked No. 5) is held in place by both the rear bearing cap and the rear main bearing packing plate.

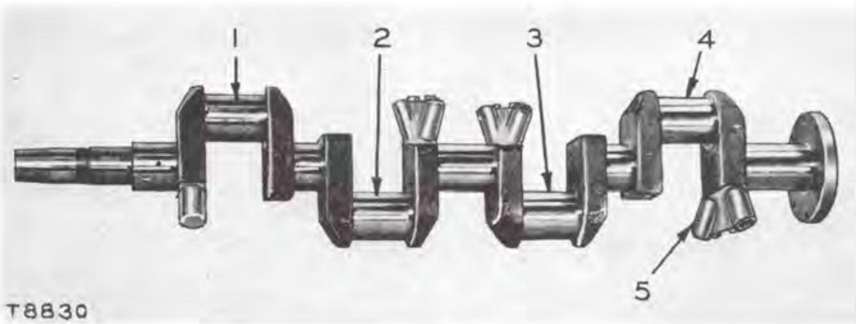
The flywheel end of the rear main bearing is bored from .002"-.003" larger in diameter at **(7)**, and consequently the crankshaft should not touch this part of the bearing. This counterbore provides for oil control by permitting the oil return threads **(8)** cut on the crankshaft **(10)** to transmit oil to the oil groove **(6)**. Oil from the oil groove **(6)** enters the hole **(9)** in the bearing and cap, through which it is returned to the crankcase.

Crankshaft
(All Models)

The crankshaft is of the forged-steel type, with four counterweights **(5)** bolted to the crankshaft.

There are five main bearing journals and four connecting rod journals with two connecting rods attached to each connecting rod journal.

The main bearings and journals are lubricated by a supply of oil from the oil manifold. The drilled passages in the crankshaft transmit the oil to the connecting rod bearings and journals.



CRANKSHAFT

1—Connecting rod journal for No. 1 and No. 2 connecting rods. 2—Connecting rod journal for No. 3 and No. 4 connecting rods. 3—Connecting rod journal for No. 5 and No. 6 connecting rods. 4—Connecting rod journal for No. 7 and No. 8 connecting rods. 5—Counterweight.

The connecting rod journals **(2)** and **(3)** are located on the same angle, but 180° opposite the journals **(1)** and **(4)**.

The crankshaft end thrust is taken at the front by a thrust washer and two thrust plates. See the topic, CHECKING CRANKSHAFT END CLEARANCE (ALL MODELS).

CRANKSHAFT GEAR REMOVAL
(All Models)

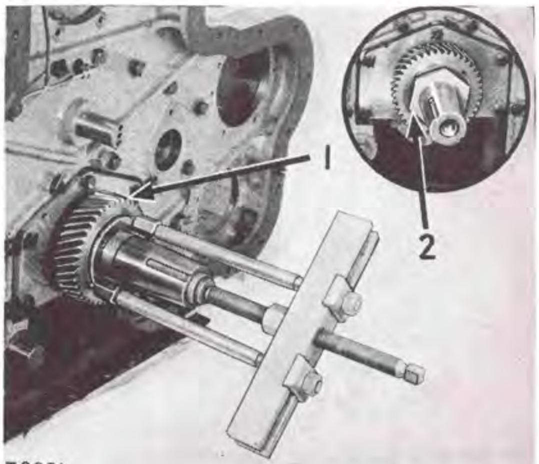
The crankshaft gear can be removed from the crankshaft without removing the crankshaft from the engine. The crankshaft gear can be removed in the following manner.

Remove the timing gear cover as described in the topic, TIMING GEAR COVER REMOVAL AND INSTALLATION (ALL MODELS).

Remove the camshaft gears as described in the topic, REMOVING THE TIMING GEARS (ALL MODELS), or remove the camshafts and the camshaft gears as a unit as described in the topic, REMOVING AND INSTALLING A CAMSHAFT AND CAMSHAFT GEAR AS A UNIT (ALL MODELS), depending on what other work is to be done.

Bend the lock and remove the nut **(2)** and lock.

Remove the crankshaft gear **(1)** as illustrated by the use of the 8B7548 Puller with the 8B7558 Adapters.



CRANKSHAFT GEAR REMOVAL

1—Crankshaft gear.
2—Nut.

♦

CRANKSHAFT GEAR INSTALLATION
(All Models)

Install the crankshaft gear key.

Remove all burrs or rough edges from the crankshaft, the crankshaft gear and the crankshaft gear key.

Heat the crankshaft gear **(2)** (preferably in hot oil) to ease installation.

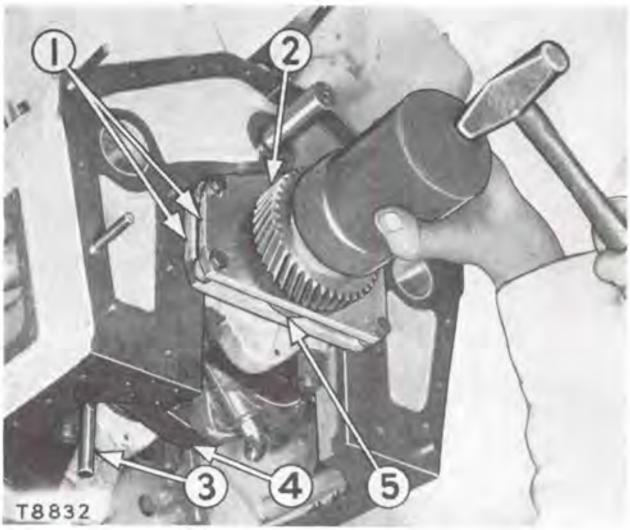
Place a common cold chisel **(3)** (or another suitable metal wedge), between a crankshaft flange **(4)** and the crankcase near a main bearing cap, as illustrated.

Pry the crankshaft forward toward the thrust plates **(1)**. Tap the cold chisel lightly to wedge it in place.

When the gear is installed it touches a spacer which passes through the thrust plate nearer the crankshaft gear and touches the thrust washer **(5)**.

Place the gear on the crankshaft with the timing marks to the outside and with the key and the key-way aligned. With a suitable driver and hammer, as shown, drive the gear all the way on.

Install the lock and the crankshaft gear retaining nut.



INSTALLING CRANKSHAFT GEAR
1—Thrust plates. 2—Crankshaft gear. 3—Cold chisel (or another suitable metal wedge). 4—Crankshaft flange. 5—Thrust washer.

Tighten the retaining nut before the gear cools, to assure that the gear has been installed onto the crankshaft completely and that it will remain in this position.

Bend the lock and remove the cold chisel.

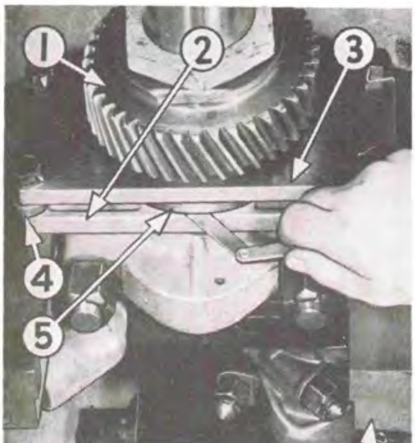
Check the crankshaft end clearance as described in the topic, CHECKING CRANKSHAFT END CLEARANCE (ALL MODELS).

CHECKING CRANKSHAFT END CLEARANCE
(All Models)

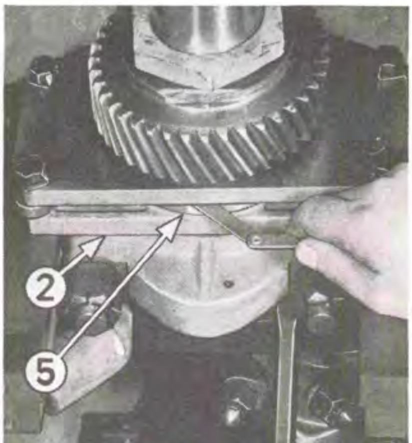
The thrust washer **(5)** is keyed to the crankshaft. A spacer (not shown) touches the crankshaft gear **(1)**, passes through the thrust plate **(3)** and touches the thrust washer. Thus, the crankshaft, the crankshaft gear, the spacer and the thrust washer will move together as a unit.

The thrust plates are held to the crankcase **(7)** by capscrews and separated from each other by the spacers **(4)**.

The spacers **(4)** are machined to be .016"-.020" thicker than the thrust washer.



MOVING CRANKSHAFT FORWARD AND CHECKING END CLEARANCE
1—Crankshaft gear. 2—Thrust plate (rear). 3—Thrust plate (front). 4—Spacer. 5—Thrust washer. 6—Pinch bar. 7—Crankcase.



MOVING CRANKSHAFT BACKWARD AND CHECKING END CLEARANCE
2—Thrust plate (rear). 5—Thrust washer.

The crankshaft, the crankshaft gear and the thrust washer can move forward until the thrust washer touches the thrust plate **(3)** and backward until the thrust washer touches the thrust plate **(2)**.

The crankshaft end clearance should be .016"-.020", which is the difference in thickness between the thrust washer **(5)** and the spacers **(4)**.

The maximum permissible end clearance is .025", and then the thrust washer should be replaced. See the topic, CRANKSHAFT THRUST WASHER AND THRUST PLATES (ALL MODELS).

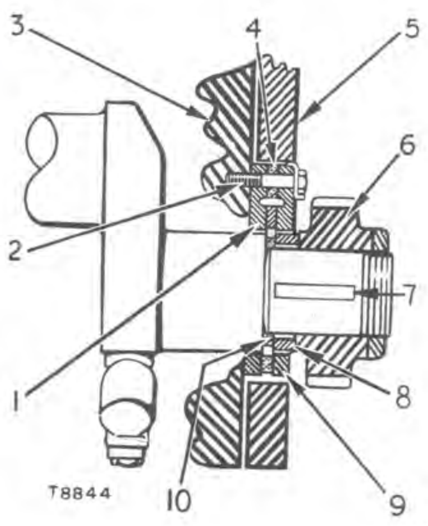
The crankshaft end clearance can be checked by using a pinch bar **(6)**, moving the crankshaft forward until the thrust washer touches the thrust plate **(3)** and checking the clearance between the thrust washer and the thrust plate **(2)** as shown.

Move the crankshaft backward as shown and check the clearance between the thrust plate **(3)** and the thrust washer. The clearance should be the same as found in the first check, and this will be a true measurement of the crankshaft end clearance.

CRANKSHAFT THRUST WASHER AND THRUST PLATES
(All Models)

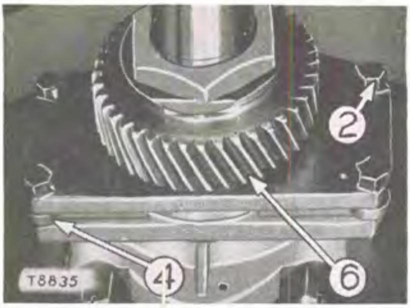
The crankshaft thrust washer and the thrust plates can be removed in the following manner, without removing the timing gear housing **(5)** from the crankcase **(3)**.

Remove the crankshaft gear **(6)** as described in the topic, CRANKSHAFT GEAR REMOVAL (ALL MODELS).



THRUST WASHER AND THRUST PLATES

1—Thrust plate (rear). 2—Capscrew. 3—Crankcase. 4—Spacer. 5—Timing gear housing. 6—Crankshaft gear. 7—Crankshaft gear key. 8—Spacer. 9—Thrust plate (front). 10—Thrust washer.



REMOVING THRUST WASHER AND THRUST PLATES

2—Capscrew. 4—Spacer. 6—Crankshaft gear.

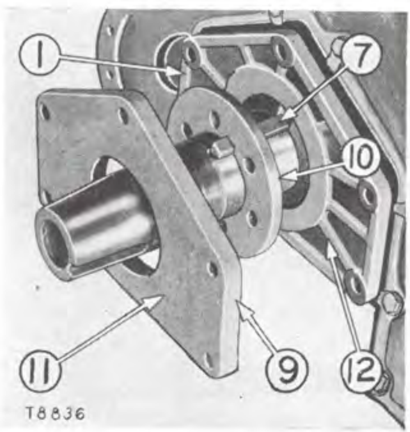
Bend the locks and loosen the capscrews **(2)**. Slide the capscrews out carefully and remove the spacers **(4)**. If the oil pan has not been removed, it is a good idea to protect the oil pan to keep the spacers from falling into it, in case one is dropped.

Remove the thrust plate **(9)**, the spacer **(8)**, the thrust washer **(10)**, the key **(7)** and the thrust plate **(1)**.

When installing the thrust washer and the thrust plates, remove all burrs from the thrust plates, the thrust washer and the spacers, since the crankshaft end clearance is controlled by these parts.

The thrust plates **(1)** and **(9)** are identical, both having a smooth machined face **(11)** and a ribbed face **(12)**. The thrust plates are originally installed in the following manner:

The ribbed faces **(12)** are installed toward each other with the smooth-machined face of the rear thrust plate **(1)** toward the crankcase **(3)** and the smooth-machined face **(11)** of the front thrust plate **(9)** toward the crankshaft gear. Always install the thrust washer with the chamfered side of the inner diameter toward the crankcase.



INSTALLING THRUST WASHER AND THRUST PLATES

1—Thrust plate (rear). 7—Crankshaft gear key. 9—Thrust plate (front). 10—Thrust washer. 11—Smooth-machined face (of thrust plate). 12—Ribbed face (of thrust plate).

If excessive wear is shown between the thrust washer and the thrust plates, install a new thrust washer. The thrust plates can be turned over to provide a new wearing surface against the thrust washer if they are in good condition.

After all parts are assembled, check the crankshaft end clearance as described in the topic, CHECKING CRANKSHAFT END CLEARANCE (ALL MODELS).

CRANKSHAFT REMOVAL
(All Models)

When the crankshaft is to be removed, it is first necessary to remove the following parts.

Remove the radiator or the heat exchanger, whichever is installed.

Remove the oil pan. See the topics, OIL PAN REMOVAL AND INSTALLATION (D17000L) or (D17000E-I-M).

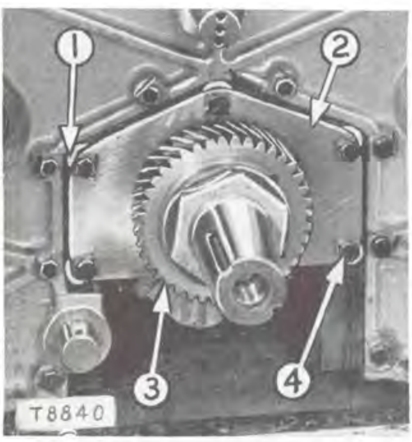
Remove the oil pump and the oil pump drive. See the topics, OIL PUMP REMOVAL (D17000E-I-M) and OIL PUMP DRIVE REMOVAL (D17000E-I-M). The locomotive engine has an externally mounted oil pump and oil pump drive and they need not be removed.

Remove the timing gear cover. See the topic, TIMING GEAR COVER REMOVAL AND INSTALLATION (ALL MODELS).

Remove the oil pump idler gear.

The timing gear housing need not be removed.

Remove the camshaft gears. See the topic, REMOVING THE TIMING GEARS (ALL MODELS).



PREPARING FOR CRANKSHAFT REMOVAL

1—Spacer. 2—Thrust plate. 3—Crankshaft gear. 4—Capscrew.

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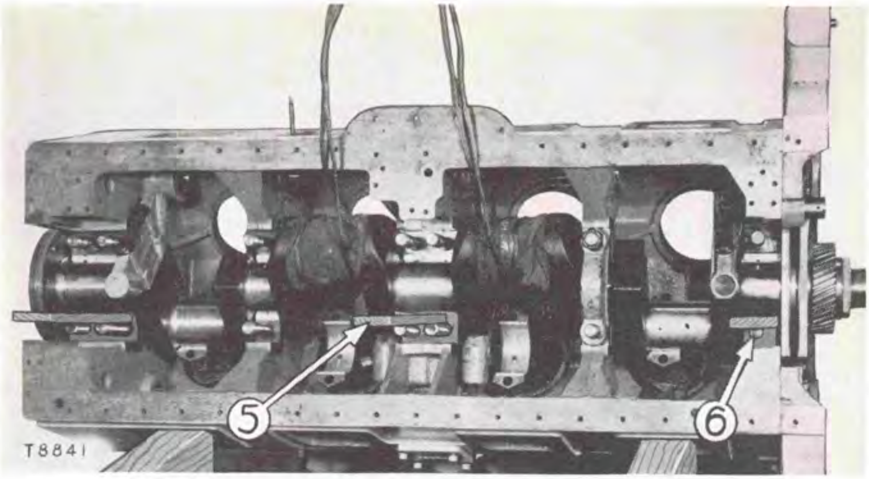


REMOVING CRANKSHAFT
5—Wooden block. 6—Main bearing stud.

Remove the flywheel and the flywheel housing. See the topics, FLYWHEEL REMOVAL AND INSTALLATION (ALL MODELS) and FLYWHEEL HOUSING REMOVAL AND INSTALLATION (ALL MODELS).

Turn the engine on its side as illustrated in the topic, TURNING ENGINE OVER (ALL MODELS). The crankshaft can be removed without turning the engine on its side, but for most practical purposes it would be easier to remove the crankshaft if the engine is on its side.

The crankshaft gear **(3)** need not be removed.

Remove the capscrews **(4)** and the spacers **(1)** which hold the thrust plates **(2)** to the crankcase.

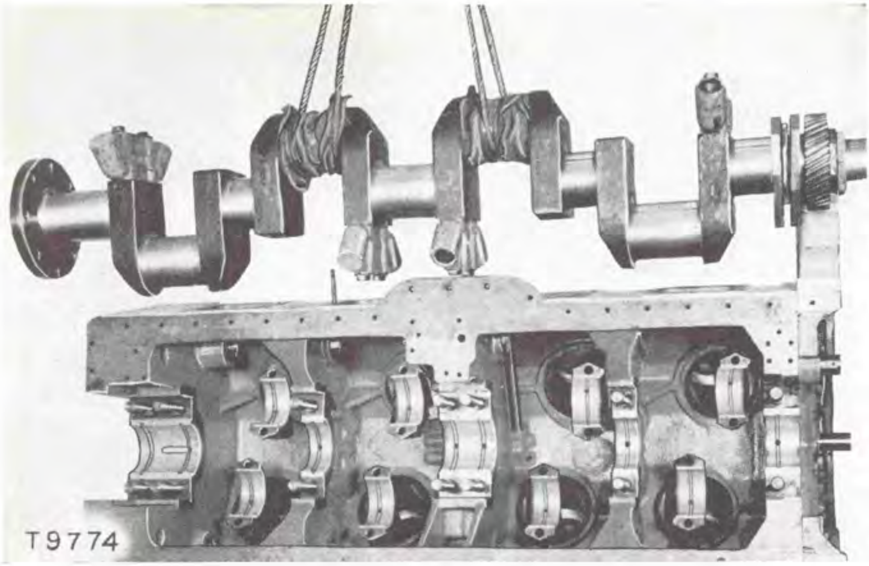
Remove the connecting rod caps, as described in the topic, CONNECTING ROD BEARING REMOVAL AND INSTALLATION (ALL MODELS).

Push the connecting rods and the pistons upward in the liners so they will not interfere with crankshaft removal.

Wrap the connecting rod journals with suitable cloths to protect them. Place cables around the crankshaft as illustrated.

Remove the main bearing caps and the rear main bearing packing plate as described in the topics, REMOVING MAIN BEARINGS (ALL MODELS) and REMOVING AND INSTALLING THE REAR MAIN BEARING PACKING PLATE WITH THE FLYWHEEL HOUSING REMOVED (ALL MODELS).

Place several wooden blocks **(5)**, approximately 3/4" thick, 3" wide and 6" long, between the main bearing studs **(6)** and the crankshaft as



CRANKSHAFT REMOVED

illustrated to keep the crankshaft from bumping the studs as it is being removed.

Remove the crankshaft with the crankshaft gear, the thrust plates and the thrust washer installed.

Place the crankshaft on a wooden bench. Cover the crankshaft to prevent dirt from entering the drilled passages.

Before installing, clean the crankshaft and check that all drilled passages are open.

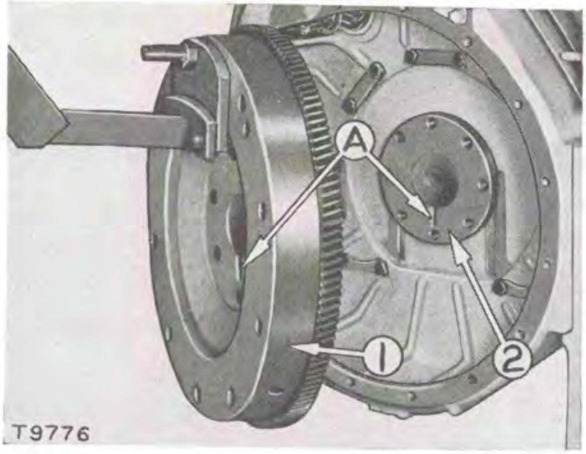
FLYWHEEL REMOVAL AND INSTALLATION
(All Models)

To facilitate the flywheel removal, first disconnect whatever attachment is connected to and driven by the flywheel. Since there are many different models, they are not illustrated here.

The flywheel can be removed as follows.

Attach a chain or sling to the flywheel to support it while the capscrews are being removed.

Locate the timing marks **(A)** on the flywheel **(1)** and the crankshaft flange **(2)**. If they are not visible, clean the surface of the flywheel and locate the marks. With a piece of chalk, heavy up the original marks.



FLYWHEEL INSTALLATION
A—Timing marks. 1—Flywheel. 2—Crankshaft flange.

Bend the locks and remove the capscrews holding the flywheel to the crankshaft.

Remove the flywheel.

When installing the flywheel, clean the mating surfaces of both the crankshaft bolting flange and the flywheel.

Remove any burrs on the mating surfaces.

Using a capscrew that is used to attach the flywheel, check all the capscrew holes in the flywheel, to see that they are free of roughness and burrs.

Install the flywheel **(1)** to the crankshaft flange **(2)** matching the timing marks **(A)** when doing so.

Using a soft brass bar, bump the flywheel to assure its being flat against the mating surface of the crankshaft flange.

Install the locks and capscrews through the holes in the flywheel, and start each capscrew before tightening any of them.

After it has been determined that all capscrews have been started correctly, tighten them evenly and diametrically.

If for some reason it is suspected the flywheel mating surface is not in true alignment with the crankshaft flange, the flywheel run-out should be checked with a dial indicator. The indicator reading should not exceed .006" for both the bore and the face.

FLYWHEEL HOUSING REMOVAL AND INSTALLATION
(All Models)

To permit the flywheel housing to be removed, first remove the flywheel as described in the topic, FLYWHEEL REMOVAL AND INSTALLATION (ALL MODELS).

Place suitable cables or chains onto the flywheel housing to support the housing during its removal.

Some installations may require supporting the engine with blocks during the time the flywheel housing is removed.

Bend the locks and remove the capscrews holding the flywheel housing to the crankcase.

On engines that have a starting engine installed, it may be advisable to first remove the starting engine, although it is not necessary. The flywheel housing can be removed with the starting engine installed, by merely disconnecting the starting engine from the Diesel engine, and using the same procedure for the flywheel housing removal as described in this topic.

Bump the flywheel housing in order to remove it from the dowels. Remove the flywheel housing.

When installing the housing, clean the mating surface of both the flywheel housing and the crankcase. Check closely for any burrs.

Check to be sure the rear packing plate is aligned correctly with the crankcase as described in the topic, REMOVING AND INSTALLING THE REAR MAIN BEARING PACKING PLATE WITH THE FLYWHEEL HOUSING REMOVED (ALL MODELS).

INSTALLING FLYWHEEL HOUSING (D17000L ILLUSTRATED)

1—Dowel holes. 2—Dowels.

Install the flywheel housing guiding the dowel holes **(1)** in the housing over the dowels **(2)** in the crankcase.

Using a soft brass bar or similar object, bump the housing all the way onto the dowels so the mating surfaces are together.

Install the locks and capscrews.

Tighten the capscrews evenly, to 150 foot pounds torque and bend the locks.

Check the flywheel housing run-out with a dial indicator as described in the topic, PROCEDURE FOR CHECKING FLYWHEEL HOUSING RUN-OUT (ALL MODELS).

PROCEDURE FOR CHECKING FLYWHEEL HOUSING RUN-OUT (All Models)

If an engine is in an upright position the flywheel housing run-out can be checked in the following manner.

Checking Flywheel Housing Bore Run-Out (All Models)

To assure accurate results, always have the flywheel removed when checking flywheel housing run-out.

Clean the face and counterbore surfaces of the flywheel housing, where the dial indicator will be in contact, to assure a correct reading.

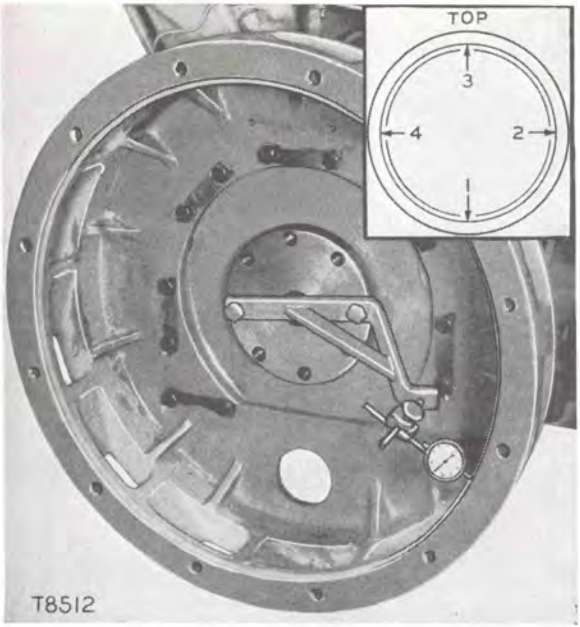
Install a dial indicator to the crankshaft flange using a rigid support bracket for the indicator as illustrated. Turn the crankshaft to position the dial indicator at the starting point **(1)**.

Adjust the dial indicator to read .000". (Since the crankshaft is resting on the lower halves of the main bearing shells, this is used as a starting point.)

Turn the crankshaft 90° to position the dial indicator at **(2)**. Carefully pry the crankshaft toward the location **(2)** to permit the crankshaft to touch the halves of the main bearings. Take the indicator reading.

Turn the crankshaft to position the dial indicator at point **(3)**. Pry the crankshaft upward to permit the crankshaft to touch the upper halves of the main bearings and take the indicator reading at this point.

Turn the crankshaft to position the dial indicator at point **(4)**. Take indicator readings at point **(4)** as described for point **(2)**. (On flywheel housings that have the starting engine bendix mechanism installed, the crankshaft must be turned in the opposite direction to avoid bumping the dial indicator.)



CHECKING FLYWHEEL HOUSING BORE RUN-OUT (D17000L ILLUSTRATED)
1—Bottom. 2—Right side. 3—Top. 4—Left side.

The indicator readings should not exceed .007″ total run-out for the flywheel housing bore, for single-bearing generator installations, and .010″ for other models.

NOTE

If any method is used other than the method described here for checking the run-out, always allow for bearing clearances in order to obtain correct readings.

Checking Flywheel Housing Face Run-Out (All Models)

Install a dial indicator as illustrated and turn the crankshaft to position the dial indicator at point **(A)**.

Pry the crankshaft forward and adjust the indicator to read .000″.

Turn the crankshaft and take readings at points **(B)**, **(C)** and **(D)**. Always pry the crankshaft forward before taking readings to be sure the end clearance is always in the same direction.

The readings should not exceed .007″ total run-out for the flywheel housing face, on single-bearing generator installations.

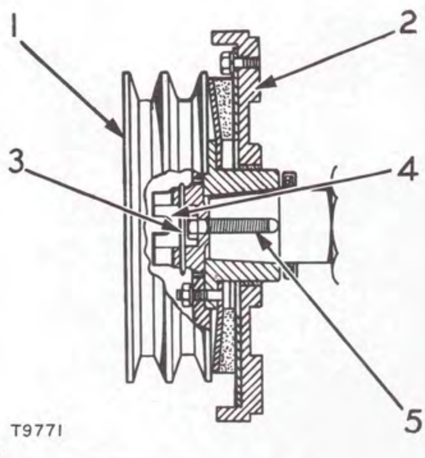
On other installations the total run-out for the flywheel housing should not exceed .010″.

CHECKING FLYWHEEL HOUSING FACE RUN-OUT
(D17000L ILLUSTRATED)
A—Bottom. B—Right side. C—Top. D—Left side.

VIBRATION DAMPER WEIGHT REMOVAL AND INSTALLATION (D17000L)

The vibration damper weight **(2)** is mounted on the forward end of the crankshaft and it can be removed in the following manner.

Remove the fan drive pulley **(1)** as described in the topic, FAN DRIVE PULLEY REMOVAL (D17000L-E-I).



VIBRATION DAMPER WEIGHT REMOVAL

1—Fan drive pulley.
2—Vibration damper weight.
3—Lock pin. 4—Crankshaft jaw nut.
5—Capscrew (locking).

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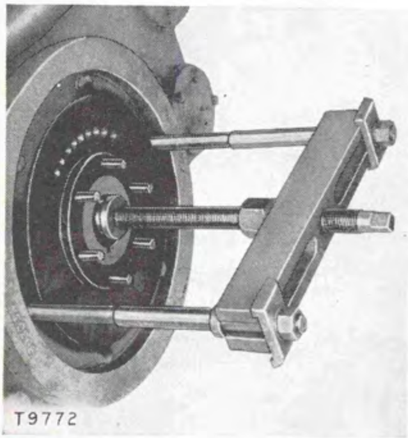
Remove the lock pin **(3)**.

Remove the crankshaft jaw nut **(4)** (right hand thread).

Remove the capscrew **(5)** by turning it in a clockwise rotation. This capscrew has a left hand thread, and is used to lock the crankshaft jaw nut to keep it from becoming loose.

Remove the damper weight by using the 8B7548 Puller and suitable attachments as illustrated.



PULLING DAMPER WEIGHT

DIESEL ENGINE—PART II

This section covers the topics not explained in DIESEL ENGINE—PART I. These additional topics pertain to the marine engine, or to the electric set, industrial and marine engines.

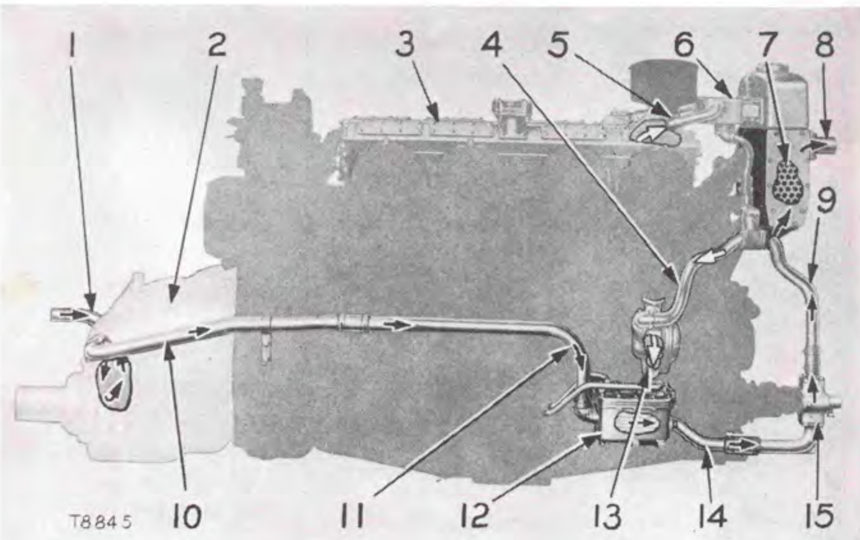
Heat Exchanger Cooling System

(D17000M)

The flow of the raw water in a marine installation is as follows.

The raw water pump draws the raw water from the source of supply through the inlet pipe **(1)** into the water compartment of the reverse and reduction gear unit **(2)**. As the raw water passes through the water compartment, it cools the lubricating oil in the reverse and reduction gear unit.

The raw water then passes through the water lines **(10)** and **(11)** into the raw water compartment of the oil cooler **(12)**. See the topic, OIL COOLER (D17000M).



HEAT EXCHANGER COOLING SYSTEM

(White arrows indicate fresh water, and black arrows indicate raw water.)

1—Inlet pipe (raw water). 2—Reverse and reduction gear unit. 3—Water-cooled exhaust manifold. 4—Pipe (fresh water return to water pump). 5—Fresh water elbow (outlet from water-cooled exhaust manifold to water regulator housing). 6—Regulator housing. 7—Heat exchanger core assembly. 8—Outlet pipe. 9—Pipe (discharge from raw water pump to heat exchanger). 10—Water line. 11—Water line (inlet to oil cooler). 12—Oil cooler. 13—Fresh water pump. 14—Pipe (outlet from oil cooler to raw water pump). 15—Raw water pump.

The tube **(14)** transmits the raw water from the oil cooler to the raw water pump **(15)**.

The raw water is pumped through the pipe **(9)** into the heat exchanger core assembly **(7)** where it cools the fresh water. The raw water is then discharged by the outlet pipe **(8)** into the source of supply.

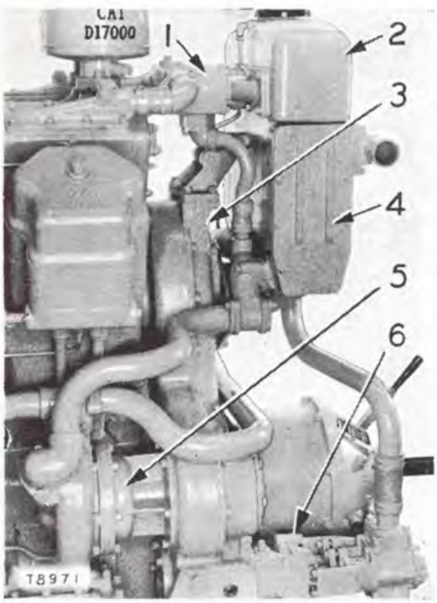
The fresh water pump **(13)** delivers the fresh water coolant throughout the engine, and then into the water-cooled exhaust manifold **(3)**, the elbow **(5)** and the regulator housing **(6)**, which are located on the right side of the engine. The fresh water coolant is also delivered through the left manifold and elbow into the regulator housing, but they are not shown in this illustration. See the topic, WATER REGULATOR HOUSING AND WATER TEMPERATURE REGULATORS (D17000L-E-I).

After the fresh water coolant has been cooled, it flows through the pipe **(4)** and then to the suction side of the fresh water pump.

HEAT EXCHANGER (D17000M)

Marine engines use a heat exchanger **(2)** to cool the fresh water coolant, instead of a radiator.

The heat exchanger is mounted at the front of the engine on the timing gear cover **(3)**.



HEAT EXCHANGER

1—Regulator housing. 2—Heat exchanger. 3—Timing gear cover. 4—Clean-out cover. 5—Fresh water pump. 6—Raw water pump.

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The raw water pump **(6)** delivers raw water under pressure into the heat exchanger, where it passes through the passageways of the heat exchanger core assembly.

The fresh water which is used for engine cooling is admitted to the heat exchanger from the water regulator housing **(1)** and flows around the outside the heat exchanger core assembly and is cooled. Then it is returned to the fresh water pump **(5)**.

Zinc plates (which are replaceable) are installed in the raw water compartment for the purpose of localizing any electrolytic action which may be set up.

The zinc plates are mounted on the clean-out cover **(4)**, and can be inspected in the following manner. Close the sea valve and drain the raw water system. Remove the clean-out cover.

The zinc plates should be inspected at least once a month to determine their condition.

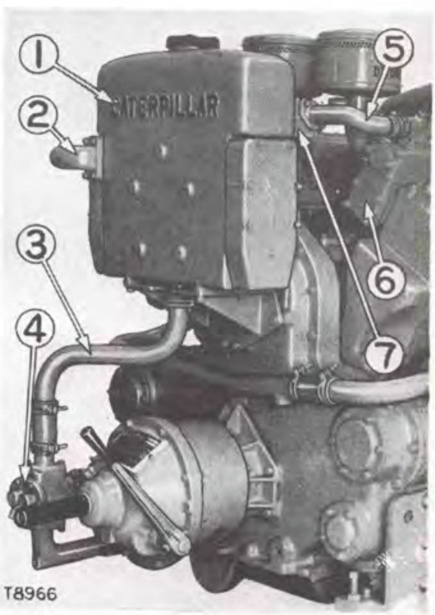
Heat Exchanger Removal (D17000M)

The heat exchanger can be removed in the following manner.

Close the sea valve, and drain the raw water system.

Drain the fresh water system.

Disconnect the heat exchanger outlet pipe **(2)**.



PREPARING FOR HEAT EXCHANGER REMOVAL

1—Heat exchanger. 2—Heat exchanger outlet pipe (raw water). 3—Heat exchanger inlet pipe (raw water). 4—Raw water pump. 5—Elbow (fresh water). 6—Water-cooled exhaust manifold (left side). 7—Regulator housing.

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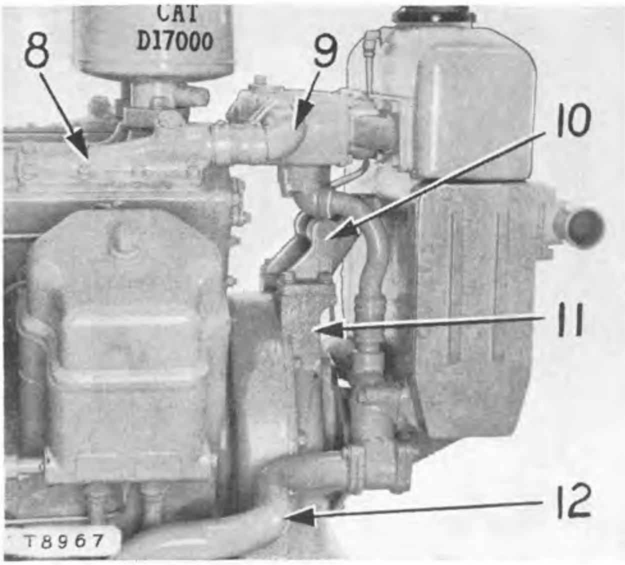
Disconnect and remove the raw water inlet pipe **(3)** which carries the raw water from the raw water pump **(4)** to the heat exchanger **(1)**.

Cover the raw water pump to prevent foreign matter from falling into it.

Disconnect and remove the elbow **(5)** that transmits the fresh water from the left water-cooled exhaust manifold **(6)** to the regulator housing **(7)**.

Remove the elbow **(9)** which connects the right water-cooled exhaust manifold **(8)** to the regulator housing.

Disconnect the fresh water pipe **(12)**. This pipe transmits the fresh water from the heat exchanger back to the fresh water pump.



DISCONNECTING HEAT EXCHANGER

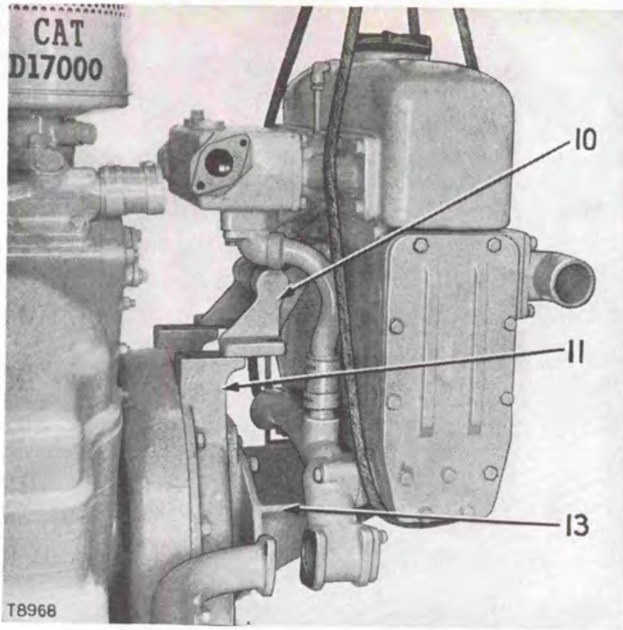
8—Water-cooled exhaust manifold (right side). 9—Elbow (fresh water). 10—Heat exchanger brace. 11—Timing gear cover. 12—Fresh water pipe (discharge from heat exchanger to fresh water pump).

Remove the capscrews holding the heat exchanger brace **(10)** to the timing gear cover **(11)**.

Attach a cable or sling to the heat exchanger as illustrated.

Remove the capscrews holding the heat exchanger to the lower support bracket **(13)**.

Remove the heat exchanger, with the remaining parts installed, by sliding it off the support bracket.



REMOVING HEAT EXCHANGER
10—Heat exchanger brace. 11—Timing gear cover.
13—Support bracket.

The support bracket can be removed and installed with the heat exchanger if desired. It is mounted on studs which are installed into the timing gear cover. The support bracket can be removed by removing the nuts and lockwashers **(14)**.

SUPPORT BRACKET

13—Support bracket. 14—Nut and lockwasher.

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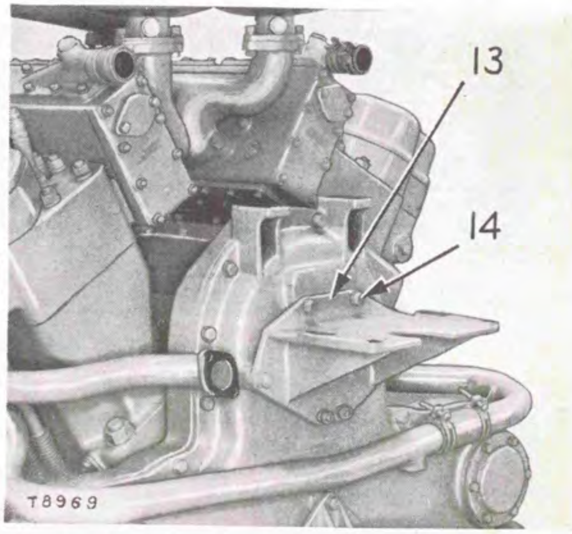
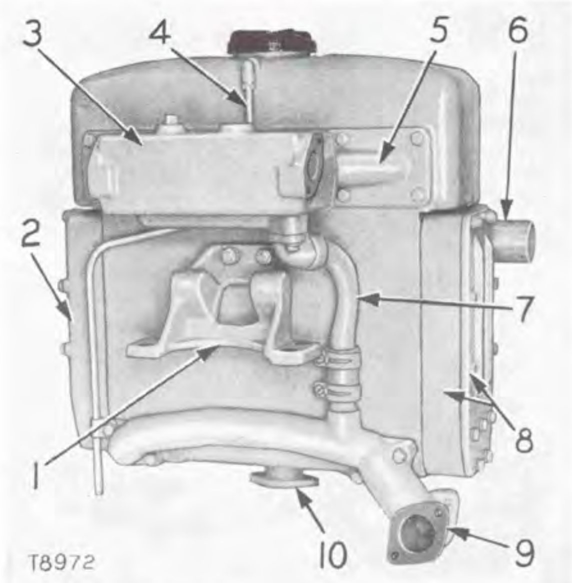


Heat Exchanger Disassembly (D17000M)

The heat exchanger can be disassembled either on or off the engine. In most cases it would be more practical to disassemble the heat exchanger while it is installed on the engine.

The following parts can be removed while the heat exchanger is on the engine: the regulator housing **(3)**, the adapter housing **(5)**, the cover **(2)**, the cover assembly and the heat exchanger core assembly **(8)**, the brace **(1)**, the overflow tube **(4)**, the raw water outlet pipe **(6)** and the fresh water lines **(7)** and **(9)**.

The elbow **(10)** cannot be removed from the heat exchanger unless the heat exchanger is off the engine. See the topic, HEAT EXCHANGER INSTALLATION (D17000M), for further information on the elbow **(10)**.

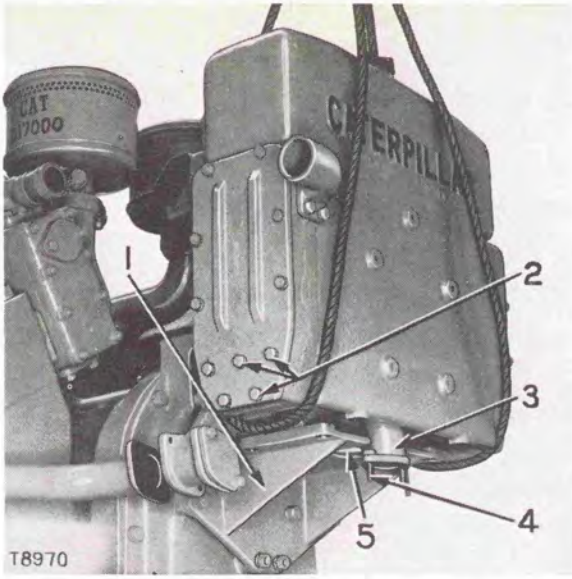


HEAT EXCHANGER DISASSEMBLY
1—Brace. 2—Cover. 3—Regulator housing. 4—Overflow tube. 5—Adapter housing. 6—Raw water outlet pipe. 7—Fresh water by-pass line. 8—Cover assembly and heat exchanger core assembly. 9—Fresh water line. 10—Elbow.

Heat Exchanger Installation (D17000M)

Install the heat exchanger by sliding it on the support bracket **(1)** permitting the elbow **(3)** and the bolts **(4)** to fit into the cut-out portion **(5)** of the support bracket as illustrated.

The raw water elbow **(3)** is held in place by the three capscrews **(2)**. This elbow can be removed or installed only while the heat exchanger is off the engine.

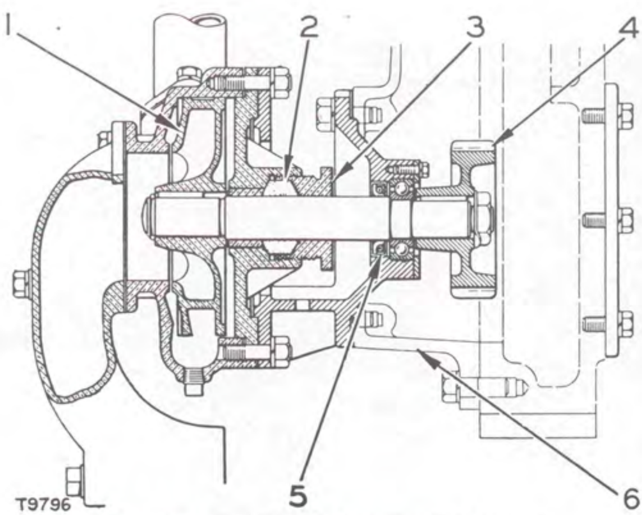


INSTALLING HEAT EXCHANGER
1—Support bracket. 2—Capscrews. 3—Elbow. 4—Bolts. 5—Cut-out portion of support bracket.

Install the remaining parts in the reverse order of removal.

RAW WATER PUMP — CENTRIFUGAL TYPE (D17000M)

The raw water is circulated throughout the heat exchanger cooling



RAW WATER PUMP—CENTRIFUGAL TYPE
1—Impeller. 2—Packing. 3—Packing nut. 4—Gear. 5—Oil seal. 6—Timing gear cover.

system by the impeller **(1)**. See the topic, HEAT EXCHANGER COOLING SYSTEM (D17000M).

The centrifugal type pump is mounted on the timing gear cover **(6)** and is driven by the right camshaft gear. The pump is lubricated by oil from the timing gear housing, which is retained by the oil seal **(5)**.

The raw water packing **(2)** can be adjusted by tightening the nut **(3)**, using the 1B1909 Packing Nut Wrench.

Tighten the nut only enough to stop the raw water leakage, then loosen the nut slightly.

When it becomes necessary to replace the packing, it can be replaced in the following manner.

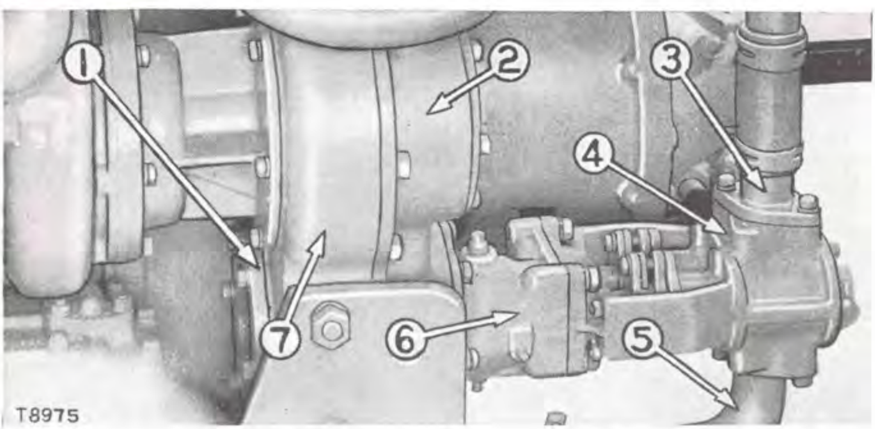
Loosen the nut **(3)** and slide it toward the gear **(4)**. The packing can be removed by using a hook and pulling it out. Install new packing and tighten the nut only enough to prevent leakage.

RAW WATER PUMP — GEAR TYPE (D17000M)

Raw Water Pump Removal (D17000M)

The gear type raw water pump **(4)** is mounted to the adapter housing **(6)**, which in turn is mounted on the lower right side of the timing gear cover **(2)**.

The raw water pump is driven by, and connected to, the raw water pump drive assembly **(1)** by a coupling.



RAW WATER PUMP REMOVAL
1—Raw water pump drive assembly. 2—Timing gear cover. 3—Outlet pipe. 4—Raw water pump. 5—Inlet pipe. 6—Adapter housing. 7—Timing gear housing.

The raw water pump drive assembly is installed into the timing gear housing **(7)** and is driven by the right camshaft gear.

The raw water pump can be removed in the following manner.

Remove the outlet pipe **(3)**.

Disconnect the inlet pipe **(5)**.

Remove the capscrews holding the raw water pump to the adapter housing and remove the raw water pump.

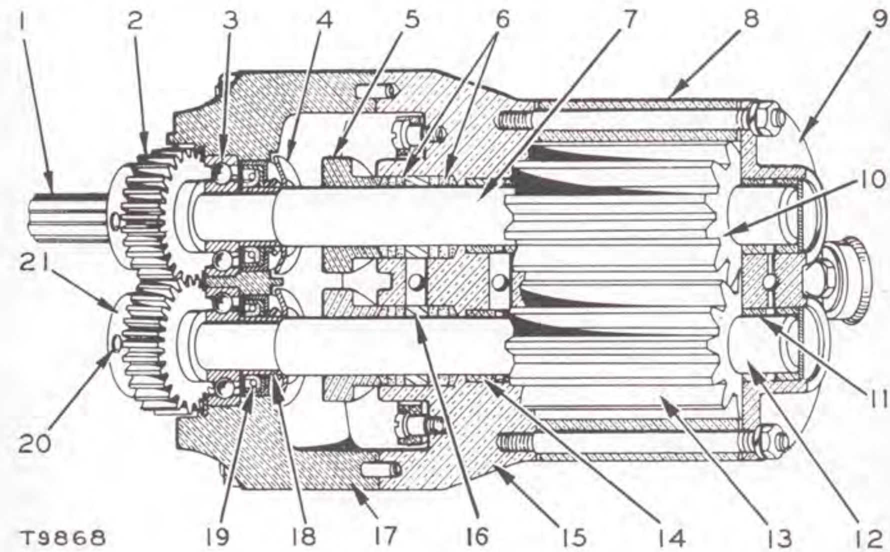
Cross-Section of Raw Water Pump (D17000M)

The raw water pump is attached to, and driven by, the raw water pump drive. See the topic, RAW WATER PUMP DRIVE (D17000M).

The raw water pump consists of the following: the shafts **(7)** and **(12)**, which are installed in the cover assembly **(9)**, the housing assembly **(8)**, the bracket assembly **(15)** and the body assembly **(17)**.

The brass gear **(10)** is installed on the shaft **(7)** and the brass gear **(13)** is installed on the shaft **(12)**. Each gear is driven by its respective shaft, and these gears are not in contact with each other.

Each shaft has a taper pin **(20)**, bearing **(3)**, oil seal **(19)**, sleeve **(18)**, slinger **(4)**, gland **(5)**, packing **(6)**, packing bushing **(16)** and bushings **(11)** and **(14)**.



CROSS-SECTION OF RAW WATER PUMP

1—Splined end of shaft (7). 2—Drive gear. 3—Bearing. 4—Slinger. 5—Gland. 6—Packing. 7—Shaft. 8—Housing assembly. 9—Cover assembly. 10—Brass gear. 11—Bushing. 12—Shaft. 13—Brass gear. 14—Bushing. 15—Bracket assembly. 16—Packing bushing. 17—Body assembly. 18—Sleeve. 19—Oil seal. 20—Taper pin. 21—Drive gear.

When the splined end **(1)** of the shaft **(7)** which is connected to the raw water pump drive by couplings is rotated, it turns the drive gear **(2)**.

The drive gear **(2)** meshes with, and drives, the drive gear **(21)** which, in turn, drives the shaft **(12)**.

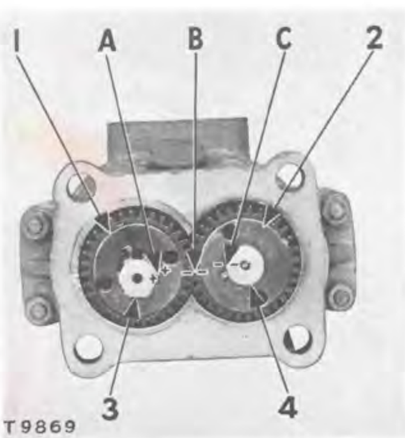
All gears should be installed on their respective shafts. For this reason they should be marked and identified as described in the topic, RAW WATER PUMP DISASSEMBLY (D17000M), at the time of disassembly.

Raw Water Pump Disassembly (D17000M)

If it becomes necessary to replace the raw water pump packing, it can be removed in the following manner. Remove the capscrews **(6)**. Remove the gland **(9)**. The packing can then be removed by using a hook and pulling it out. The packing can be installed as described in the topic, ASSEMBLING THE RAW WATER PUMP (D17000M).

The raw water pump can be disassembled in the following manner.

Before removing the gears **(1)** and **(2)** mark them and the shafts **(3)** and **(4)** as illustrated so the gears can be returned to the correct location on their respective shafts and also in the proper relationship to each other. This is necessary because the gears look identical, although they are actually different.



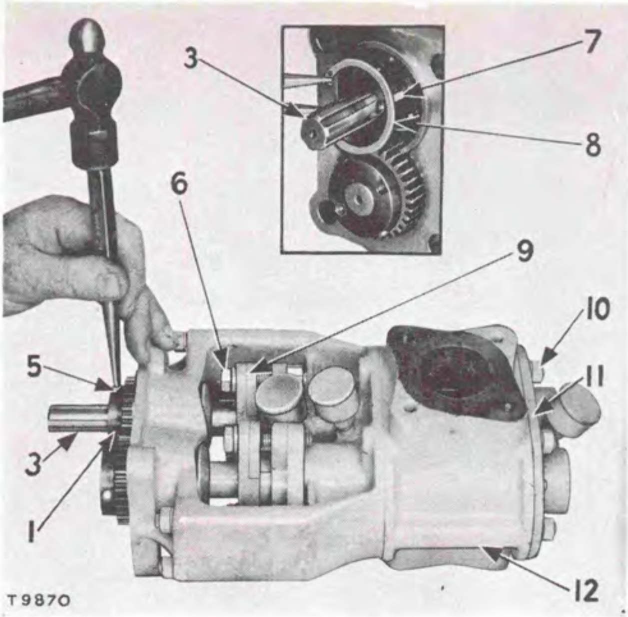
MARKING GEARS AND SHAFTS FOR IDENTIFICATION AND ASSEMBLY PURPOSES

A—Identification marks between the gear (1) and the shaft (3). B—Identification marks between the gear (1) and the gear (2). C—Identification marks between the gear (2) and the shaft (4).

Remove the taper pin **(5)**.

Remove the gear **(1)** and its key **(7)** from the shaft **(3)**.

Loosen the capscrews **(6)** holding the packing gland **(9)** enough to remove the tension from the packing.

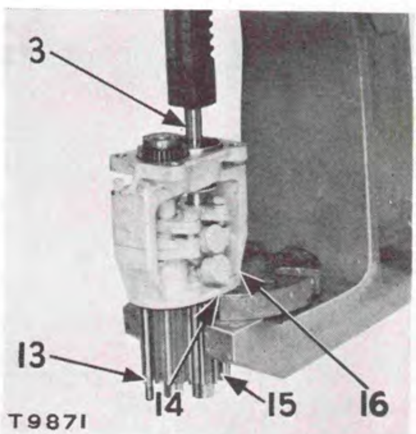


REMOVING TAPERED PIN
1—Gear. 3—Shaft. 5—Taper pin. 6—Capscrew. 7—Key. 8—Retaining ring. 9—Packing gland. 10—Nut. 11—Cover. 12—Housing assembly.

Remove the nuts **(10)**, the end cover **(11)** and the housing assembly **(12)**.

Remove the bearing retaining ring **(8)**.

Remove several studs **(13)** from the bracket assembly **(16)** to allow the flat surface **(14)** of the bracket assembly to lay evenly on the press and not damage the pump.



PRESSING OUT SHAFT
3—Shaft. 13—Stud. 14—Flat surface of the bracket assembly (16). 15—Gear. 16—Bracket assembly.

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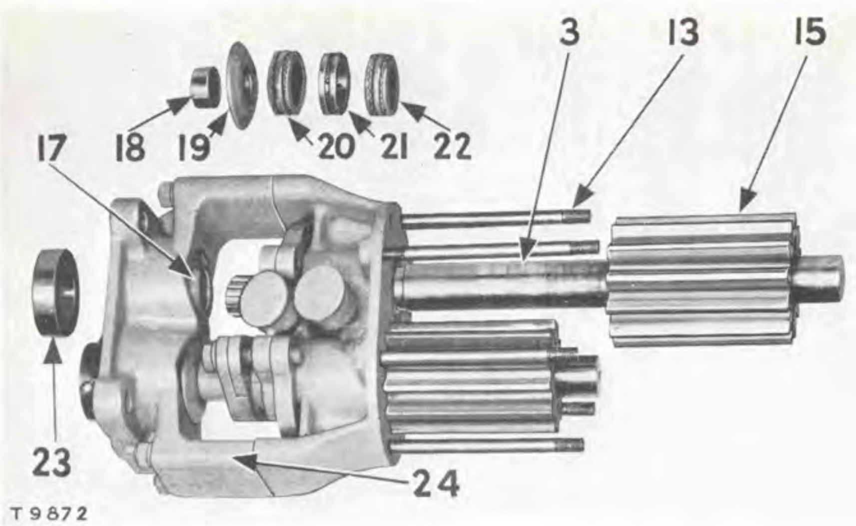


REMOVING SHAFT

3—Shaft. 13—Stud. 15—Gear. 17—Seal. 18—Sleeve. 19—Slinger. 20—Packing. 21—Bushing. 22—Packing. 23—Bearing. 24—Body assembly.

Press the shaft **(3)** from the assembly with the pump gear **(15)** attached as illustrated thus making it possible to remove the sleeve **(18)**, the slinger **(19)**, the packing **(20)**, the bushing **(21)** and the packing **(22)**.

Inspect, and replace if necessary, the seal **(17)**, in the body assembly **(24)** and the bushings in the cover **(11)** and in the bracket assembly **(16)**.

The bearing **(23)** can be removed from the body assembly **(24)** by placing a brass bar against the bearing race and tapping the bar lightly.

Measure or mark the location of the gear **(15)** on the shaft **(3)** so that the gear can be reassembled in the same location.

Press the shaft **(3)** from the gear **(15)**.

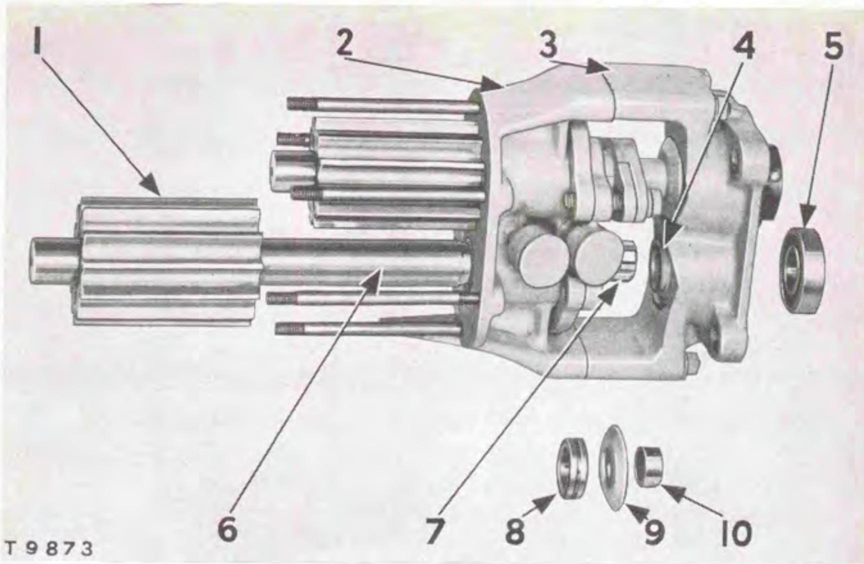
The shaft **(4)** has similar parts and it can be removed in the same manner as the shaft **(3)**.

The body assembly **(24)** can be removed from the bracket assembly **(16)** after both shafts **(3)** and **(4)** have been removed.

Assembling the Raw Water Pump (D17000M)

Since both shaft assemblies can be assembled in the same manner, the installation of one shaft assembly only is described in this topic.

Press the gear **(1)** on its respective shaft **(6)** and key, to the proper location, as described in the topic, RAW WATER PUMP DISASSEMBLY (D17000M).



INSTALLING SHAFT

1—Gear. 2—Bracket assembly. 3—Body assembly. 4—Seal. 5—Bearing. 6—Shaft. 7—Splined end of shaft (6). 8—Bushing. 9—Slinger. 10—Sleeve.

Insert the splined end **(7)** of the shaft **(6)**, through the bushing in the bracket assembly **(2)**.

When the splined end **(7)** protrudes from the bracket assembly **(2)** slightly, and before it enters the body assembly **(3)** install the bronze bushing **(8)**, the slinger **(9)** (with the concave side away from the bronze gear), and the sleeve **(10)**, in that order.

Slide the shaft into the body assembly **(3)** through the seal **(4)** until the sleeve **(10)** begins to enter the seal.

Install the bearing **(5)** into the body assembly **(3)**.

PRESSING SHAFT INTO COMBINED ASSEMBLIES

1—Gear. 2—Bracket assembly. 6—Shaft. 11—Pressing sleeve.

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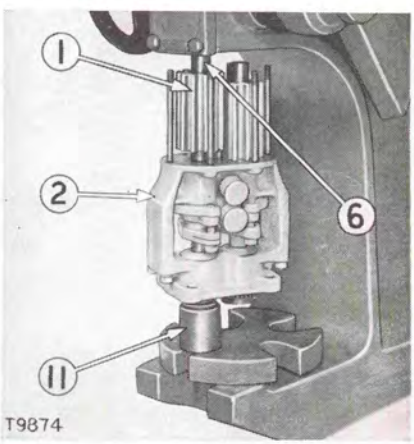


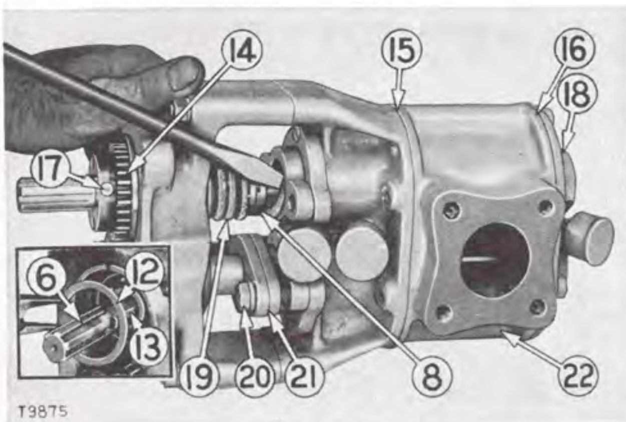
Position the combined assembly on a press as illustrated with a pressing sleeve **(11)** that will slide over the shaft and press on the inner race of the bearing **(5)**. (The pressing sleeve is not part of the raw water pump and is used only for assembly purposes.)

Press on the shaft **(6)** until the gear **(1)** touches the bracket assembly **(2)**.

Install the bearing retaining ring **(12)** into the body assembly as illustrated.

Insert the key **(13)** into the shaft **(6)**. Install the gear **(14)** on the shaft **(6)** using the identification marks as described in the topic, RAW WATER PUMP DISASSEMBLY (D17000M). Secure with the taper pin **(17)**.

Install new packing **(19)** with three rings of packing on each side of the bronze spacer **(8)** and insert them in the counterbore with a screwdriver or a suitable blunt object as illustrated.



INSTALLING PACKING
6—Shaft. 8—Bushing. 12—Bearing retaining ring. 13—Key. 14—Gear. 15—Gasket. 16—Gasket. 17—Taper pin. 18—Cover. 19—Packing. 20—Capscrew. 21—Gland. 22—Housing assembly.

Install the gland **(21)** and capscrews **(20)** on the shaft assembly as illustrated and tighten only slightly. The final tightening should be made during engine operation.

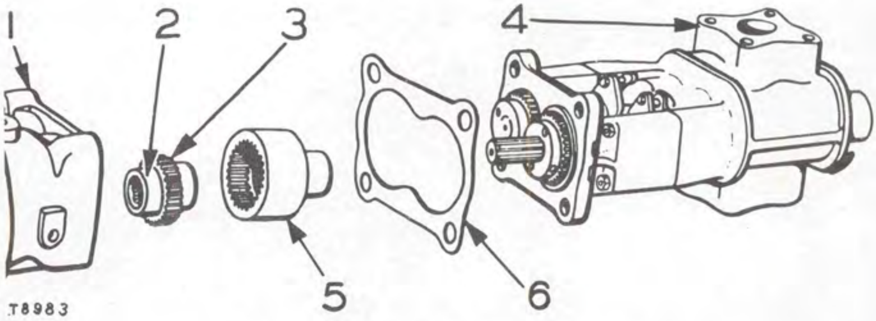
Install the gasket **(15)**, the housing assembly **(22)**, the gasket **(16)** and the end cover **(18)**. Install the locks and nuts and tighten securely.

Rotate by hand, to see that the pump shafts will turn.

Raw Water Pump Installation (D17000M)

Install the coupling **(3)** on the raw water drive shaft and into the adapter housing with the long shoulder **(2)** toward the adapter housing **(1)**.

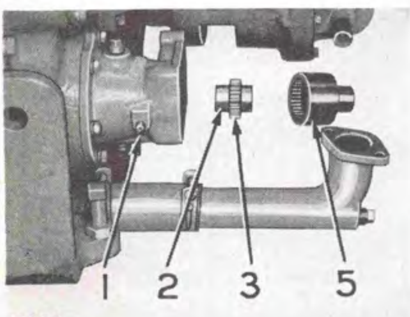
Slide the coupling **(5)** over the coupling **(3)**.



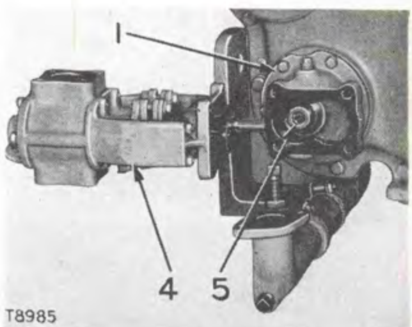
RAW WATER PUMP INSTALLATION
1—Adapter housing. 2—Long shoulder of coupling (3). 3—Coupling. 4—Raw water pump. 5—Coupling. 6—Gasket.

Install the gasket **(6)** and the raw water pump **(4)**.

The shafts and couplings all have mating splines and are a slip fit. If any of the splines fit tightly, they should be checked for burrs or roughness.



INSTALLING COUPLINGS
1—Adapter housing. 2—Long shoulder of coupling (3). 3—Coupling. 5—Coupling.



INSTALLING RAW WATER PUMP
1—Adapter housing. 4—Raw water pump. 5—Coupling.

RAW WATER PUMP DRIVE
(D17000M)

Raw Water Pump Drive Removal and Installation (D17000M)

The raw water pump drive can be removed in the following manner.

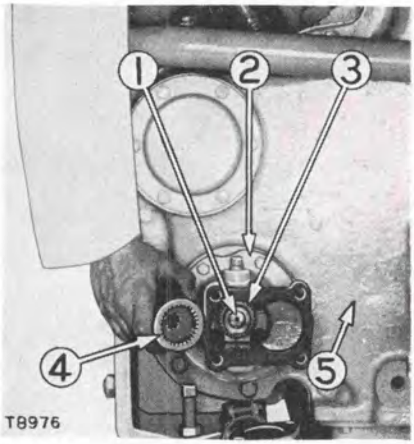
Remove the raw water pump as described in the topic, RAW WATER PUMP REMOVAL (D17000M).

Remove the coupling **(4)**. This coupling is a connection between the raw water pump and coupling **(3)**.

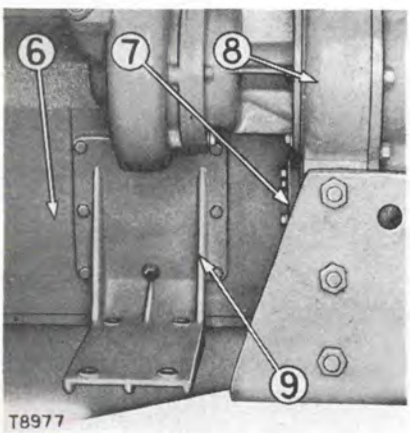
Remove the coupling **(3)**. This coupling is a connection between the shaft **(1)** of the raw water pump drive and the coupling **(4)**.

PREPARING FOR RAW WATER PUMP DRIVE REMOVAL

1—Shaft of the raw water pump drive. 2—Adapter housing. 3—Coupling. 4—Coupling. 5—Timing gear cover.



Remove the capscrews holding the adapter housing **(2)** to the timing gear cover **(5)** and remove the adapter housing.



REMOVING OIL COOLER SUPPORT BRACKET

6—Crankcase. 7—Raw water pump drive. 8—Timing gear housing. 9—Oil cooler support bracket.

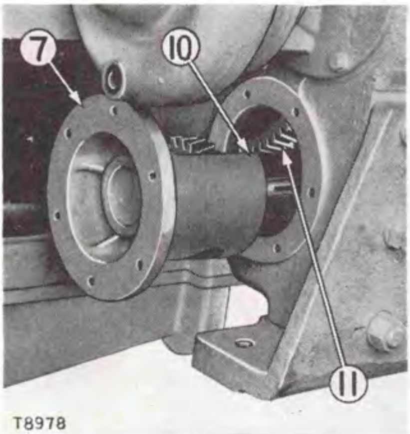
Remove the oil cooler as described in the topic, OIL COOLER REMOVAL (D17000M).

Remove the capscrews holding the oil cooler support bracket **(9)** to the crankcase **(6)** and remove the support bracket.

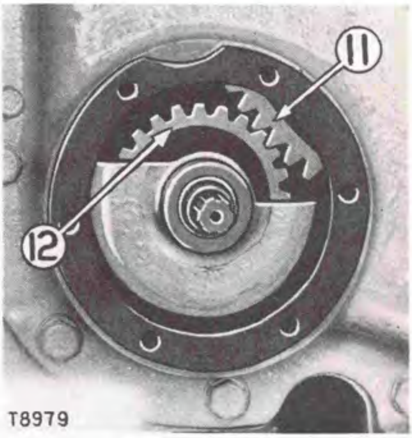
Remove the capscrews holding the raw water pump drive **(7)** to the timing gear housing **(8)**.

Remove the raw water pump drive by positioning as shown in the illustration in order to permit the forward end of the pump drive **(10)** to pass by the right camshaft gear **(11)**.

The raw water pump drive must be positioned as illustrated in order to install the pump drive into the timing gear housing.



REMOVING RAW WATER PUMP DRIVE
7—Raw water pump drive.
10—Forward end of pump drive.
11—Right camshaft gear.



CHECKING BACKLASH
11—Right camshaft gear.
12—Gear.

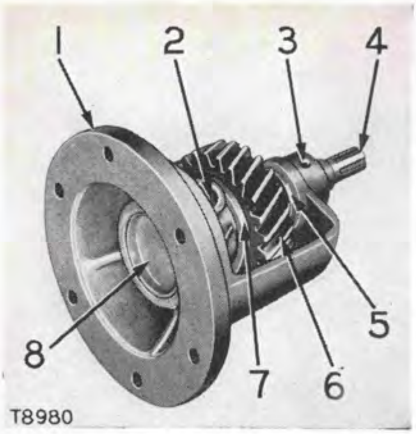
After the pump drive is installed, see that there is backlash between the gear **(12)** and the camshaft gear **(11)**. There is no adjustment between these gears, and this check is merely to see that the pump drive is located properly and does not bind.

Raw Water Pump Drive Disassembly (D17000M)

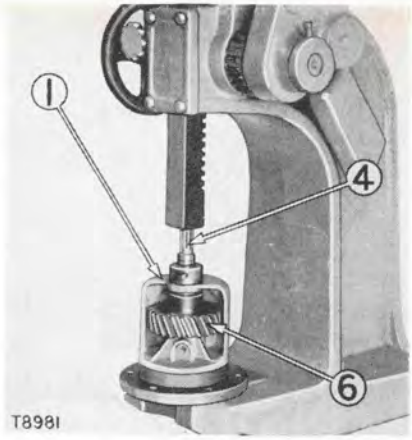
The gear **(6)** is a press fit onto the shaft **(4)**.

The shaft rotates in the bushings **(5)** and **(7)**.

The bushings are lubricated by oil that is splashed into the pockets **(2)** and **(3)**.



RAW WATER PUMP DRIVE
1—Housing. 2—Oil pocket. 3—Oil pocket. 4—Shaft. 5—Bushing. 6—Gear. 7—Bushing. 8—Plug.



PRESSING OUT SHAFT
1—Housing. 4—Shaft. 6—Gear.

The raw water pump drive can be disassembled in the following manner.

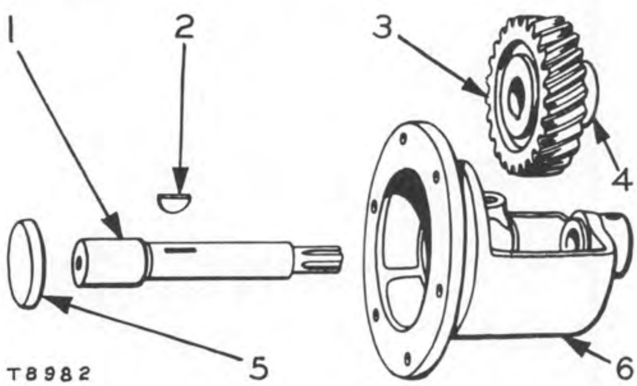
Using an arbor press as illustrated, press the shaft **(4)** out of the gear **(6)**, permitting the shaft to press out the plug **(8)** at the same time.

Remove the gear from the housing **(1)**.

Place the shaft in the housing and check the bushings for wear. The bushings can be replaced with new ones by the use of an arbor press.

Assembling the Raw Water Pump Drive (D17000M)

When assembling the pump drive, install the key **(2)** into the shaft and be sure it has no burrs.



ASSEMBLING THE RAW WATER PUMP DRIVE
1—Shaft. 2—Key. 3—Gear. 4—Long shoulder of gear. 5—Plug. 6—Housing.

Place the gear **(3)** into the housing **(6)** with the long shoulder **(4)** toward the small end of the housing as illustrated.

Place the shaft **(1)** into the gear, aligning the key with the keyway.

Press the shaft into the gear.

Rotate the shaft and gear to see that they turn freely.

Coat the outside diameter of the plug **(5)** with a suitable sealing compound to prevent leaking.

Install the plug into the housing.

Fresh Water Cooling System
(D17000M)

The fresh water cooling system of a marine engine is similar to the cooling system as described in the topic, FLOW OF COOLANT (D17000L-E-I).

The chief differences are that in the marine engine the fresh water coolant is cooled in the heat exchanger core instead of a radiator and the marine engine is equipped with water-cooled exhaust manifolds. See the topic, HEAT EXCHANGER COOLING SYSTEM (D17000M) for a description of the combined cooling systems of a marine engine.

The flow of coolant through the water temperature regulators and the regulator housing is similar to the flow as described in the topic, WATER REGULATOR HOUSING AND WATER TEMPERATURE REGULATORS (D17000L-E-I), although the regulator housing is installed differently.

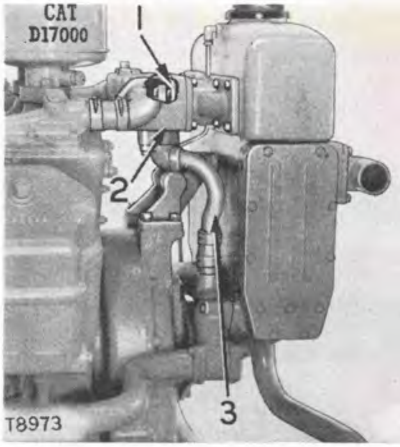
WATER REGULATOR HOUSING AND WATER TEMPERATURE REGULATORS (D17000M)

The water regulator housing **(2)** and the water temperature regulators **(1)** on the marine engine are similar to those on the other engines differing only in the method of mounting. See the topics, WATER REGULATOR HOUSING AND WATER TEMPERATURE REGULATORS (D17000L-E-I) and FLOW OF COOLANT THROUGH WATER TEMPERATURE REGULATORS (D17000L-E-I) for complete information.

On the marine engine the fresh water by-pass line **(3)** is attached as shown.

WATER REGULATOR HOUSING AND FRESH WATER BY-PASS LINE

1—Water temperature regulator. 2—Water regulator housing. 3—Fresh water by-pass line.



Water Regulator Housing Removal and Installation (D17000M)

Drain the fresh water cooling system down far enough to permit the water regulator housing **(1)** to be removed without loss of cooiant.

Disconnect the elbows **(2)** and **(3)** from the regulator housing.

Disconnect the fresh water by-pass line **(5)** from the regulator housing.

Remove the capscrews holding the regulator housing to the adapter housing **(4)** and remove the regulator housing.

The water temperature regulators can be removed from the regulator housing as described in the topic, WATER TEMPERATURE REGULATOR REMOVAL (D17000L-E-I).

Before installing the regulators, clean and test them as described in the topics, TESTING WATER TEMPERATURE REGULATORS (ALL MODELS) and CLEANING WATER TEMPERATURE REGULATORS (ALL MODELS).

WATER REGULATOR HOUSING REMOVAL

1—Water regulator housing. 2—Elbow. 3—Elbow. 4—Adapter housing. 5—Fresh water by-pass line.

WATER-COOLED EXHAUST MANIFOLD (D17000M)

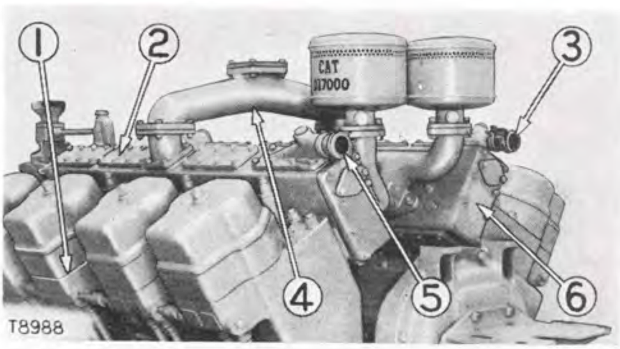
Marine engines are equipped with two water-cooled exhaust manifolds **(2)** and **(6)**, with each manifold serving a bank of cylinders.

The manifolds are cooled by the fresh water coolant.

The fresh water coolant passes under pressure into the manifolds from the cylinder heads **(1)**. The fresh water pump in turn supplies the cylinder heads with fresh water coolant.

The fresh water coolant cools the engine exhaust gases as they pass through the water-cooled exhaust manifolds **(2)** and **(6)** and then into the exhaust manifold Y-pipe **(4)**.

The fresh water coolant is discharged at the outlets **(3)** and **(5)**, from where it is delivered into the regulator housing. See the topic, WATER REGULATOR HOUSING AND WATER TEMPERATURE REGULATORS (D17000M).

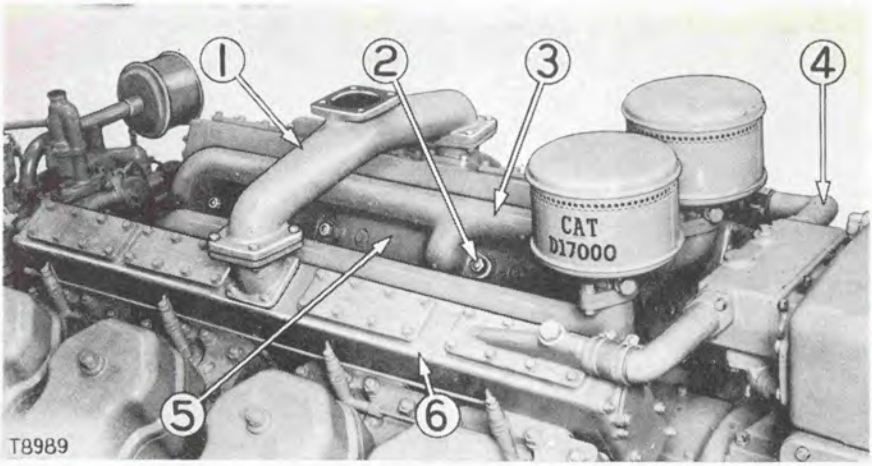


WATER-COOLED EXHAUST MANIFOLDS
1—Cylinder head. 2—Water-cooled exhaust manifold (right side). 3—Outlet. 4—Exhaust manifold Y-pipe. 5—Outlet. 6—Water-cooled exhaust manifold (left side).

Water-Cooled Exhaust Manifold Removal and Installation (D17000M)

The removal of the left and right water-cooled exhaust manifolds **(5)** and **(6)** can be performed in the same manner except that the elbow **(12)** must be disconnected and the fumes disposal tube **(8)** must be disconnected from the inlet manifold **(10)** when removing the right manifold.

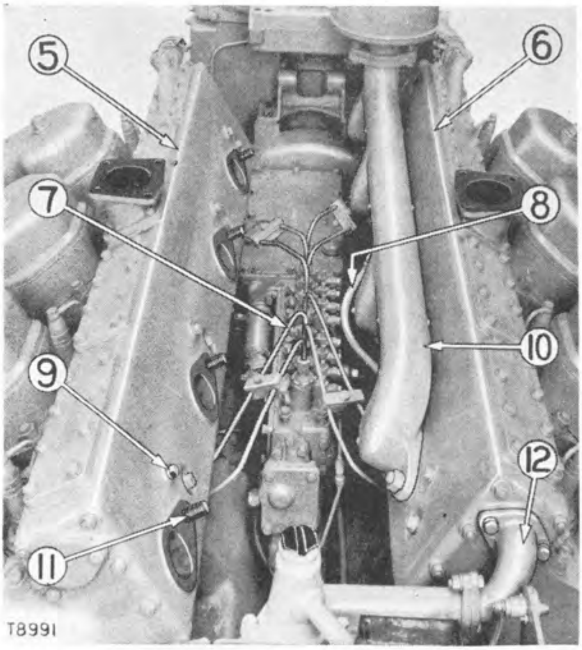
The removal of the left manifold is illustrated and described as follows.



PREPARING FOR WATER-COOLED EXHAUST MANIFOLD REMOVAL
1—Exhaust manifold Y-pipe. 2—Nut. 3—Inlet manifold (left side). 4—Water elbow. 5—Water-cooled exhaust manifold (left side). 6—Water-cooled exhaust manifold (right side).

Drain the fresh water cooling system.

Remove the exhaust manifold Y-pipe **(1)**.



REMOVING FUEL INJECTION LINES
5—Water-cooled exhaust manifold (left side). 6—Water-cooled exhaust manifold (right side). 7—Fuel injection lines. 8—Fumes disposal tube. 9—Long capscrew. 10—Inlet manifold (right side). 11—Stud. 12—Elbow.

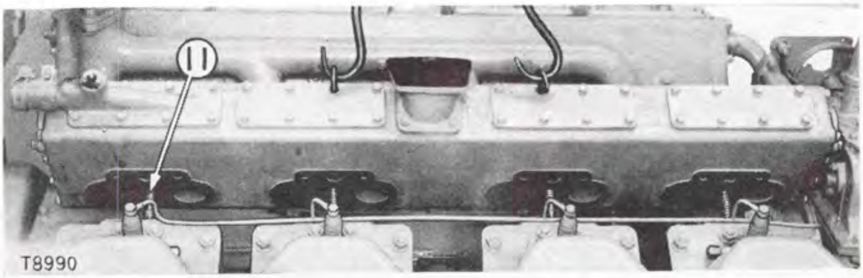
Remove the fuel injection lines **(7)**.

Remove the water elbow **(4)**, which transmits the fresh water coolant into the regulator housing.

Remove the nuts **(2)** holding the inlet manifold **(3)** and remove the inlet manifold.

Remove the long capscrews **(9)** which hold the manifold to the cylinder heads.

Using two 3/8"–16 (NC) eyebolts and a chain, as illustrated, with a suitable hoist, lift the water-cooled exhaust manifold and slide it off the studs **(11)**.



REMOVING WATER-COOLED EXHAUST MANIFOLD
11—Stud.

After the manifolds have been removed, cover the cylinder heads to prevent anything from falling into the inlet or exhaust ports.

When installing the manifolds, check that each port is clean.

Install new gaskets, and centrally locate the gaskets over the ports, to eliminate the possibility of restriction of the ports.

Flow of Lubricating Oil

(D17000E-I-M)

The flow of oil for all engines except the locomotive engine is as follows:

a. The oil pump **(21)** is driven by the oil pump drive gear **(17)** and the oil pump idler gear **(16)**, which in turn are driven by the right camshaft gear **(13)**. The oil pump is attached to the crankcase and is located inside the oil pan **(18)**.

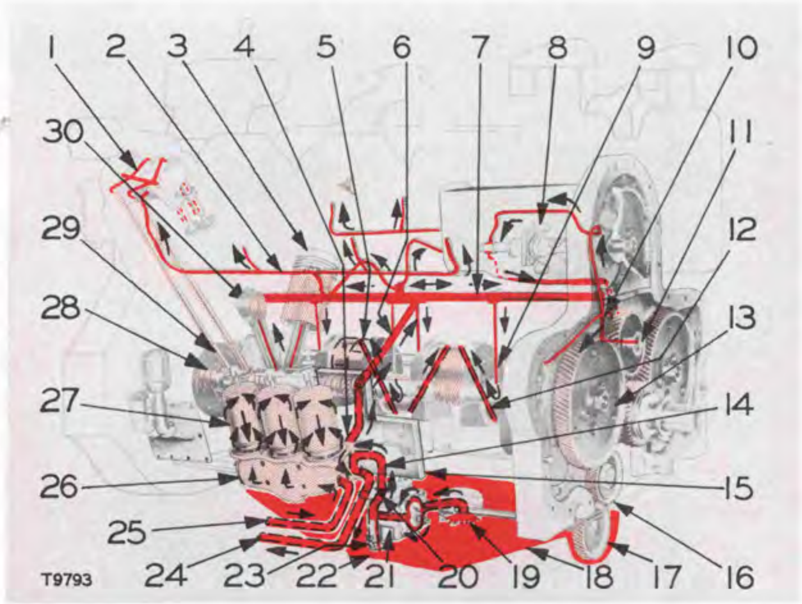
b. The oil settles in the sump **(22)** of the oil pan and is drawn into the suction bell **(19)** by the oil pump. See the topic, OIL PUMP AND OIL PUMP DRIVE (D17000E-I-M).

c. An oil pressure control by-pass valve **(23)** is installed in the oil pump and as the oil is delivered through the oil pump, the by-pass valve controls the amount of oil to be by-passed into the sump **(22)**. See the topic, FLOW OF OIL THROUGH THE OIL PUMP (D17000E-I-M).

d. The outlet passage **(20)** in the oil pump discharges the oil under pressure into the vertical drilled passage **(14)** in the crankcase, and delivers the oil into the oil filter manifold **(15)** which is mounted on the crankcase.

e. The oil filter manifold transmits the oil into the oil filter base **(26)**.

f. The oil tube **(24)** transmits the oil from the oil filter base to the oil



FLOW OF LUBRICATING OIL (D17000 E-I-M)

1—Rocker arm assembly. 2—Oil tube (supply for rocker arms). 3—Piston and rings. 4—Passage (in oil filter manifold). 5—Connecting rod bearing. 6—Oil tube (pressed into crankcase). 7—Oil manifold. 8—Governor. 9—Drilled passage in crankcase. 10—Oil line (supply to water pump and governor). 11—Idler gear shaft. 12—Drilled passage in crankshaft. 13—Right camshaft gear. 14—Vertical drilled passage (in crankcase). 15—Oil filter manifold. 16—Oil pump idler gear. 17—Oil pump drive gear. 18—Oil pan. 19—Suction bell. 20—Outlet passage (of oil pump). 21—Oil pump. 22—Sump. 23—By-pass valve assembly. 24—Oil tube (to oil cooler). 25—Oil tube (from oil cooler). 26—Oil filter base. 27—Oil filter. 28—Camshaft bearing journal. 29—Valve lifter. 30—Piston pin bushing.

cooler. The lubricating oil is cooled, then delivered back to the oil filter base by the oil tube **(25)**.

NOTE

g. The oil filter base has mounted within it, the oil cooler by-pass valve. If the oil cooler should become clogged or the passages become restricted in some manner, the pressure will unseat the by-pass valve and permit the oil to by-pass the oil cooler. See the topic, FLOW OF OIL THROUGH OIL FILTER BASE AND OIL FILTERS (D17000E-I-M).

h. The oil passes into the oil filters **(27)** which are mounted on the oil filter base. The oil is then filtered and delivered into the oil filter manifold **(15)** through the passage **(4)** and then into the oil tube **(6)** which is pressed into the crankcase. See the topic, OIL FILTER MANIFOLD (D17000E-I-M).

NOTE

i. The oil filters have by-pass valves installed, to permit the oil to by-pass the filters if they should become clogged. See the topic, FLOW OF OIL THROUGH OIL FILTER BASE AND OIL FILTERS (D17000E-I-M).

j. The oil tube **(6)** supplies oil to the oil manifold **(7)**. See the topic, OIL MANIFOLD (ALL MODELS).

k. The oil manifold supplies oil to the drilled passage **(9)** in the crankcase, which delivers the oil to the main bearings and drilled passages in the crankshaft.

l. The crankshaft has drilled passages **(12)** to deliver oil from the main bearings to the connecting rod bearings **(5)**.

m. Grooves in the connecting rod bearings are in alignment with a drilled passage in the connecting rods. The oil passes through these passages to the piston pin bushing **(30)**. A portion of the oil is sprayed onto the inside top of each piston **(3)** from holes in the top of the connecting rod.

n. The oil tubes **(2)** are connected to the oil manifold and they transmit the oil to the rocker arm assemblies **(1)**, valve stem bushings and the push rods. Oil from the rocker arm assemblies drains down onto the push rods, and then to the valve lifters **(29)** to lubricate the valve lifters as they operate in the valve lifter bushings and on the camshaft.

o. The camshaft bearings are lubricated by oil splashed onto the camshaft bearing journals **(28)** and carried into the bearings by the grooves in the journals.

p. The oil line **(10)** is connected to the oil manifold **(7)** by a passage in the crankcase. This oil line supplies oil to the governor **(8)** and the water pump. See the topics, GOVERNOR LUBRICATION (ALL MODELS) and WATER PUMP LUBRICATION (ALL MODELS).

q. The idler gear shaft **(11)** receives a supply of oil from the oil manifold and this lubricates the idler gear and drains onto the timing gears. See the topic, TIMING GEAR LUBRICATION (ALL MODELS).

r. The pistons and rings **(3)** are lubricated by oil that is splashed or thrown by the crankshaft and the camshafts. See the topic, PISTON AND RING LUBRICATION (ALL MODELS).

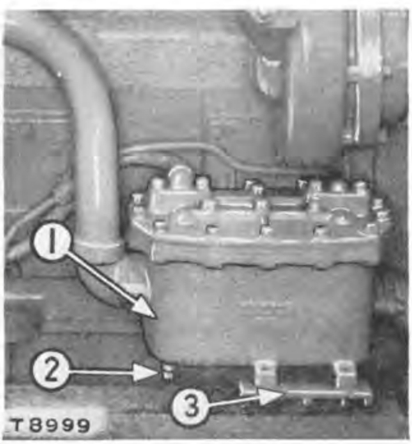
s. After the oil has been delivered throughout the engine for lubrication, it then drains into the oil pan, and settles into the sump of the oil pan, thus completing the oil circuit.

OIL COOLER
(D17000M)

The oil cooler **(1)** for a marine engine is cooled by raw water.

The oil cooler has been mounted in various locations on the engine. Late model engines have the oil cooler mounted to a support bracket **(3)** which also serves as the crankcase inspection cover on the right forward side of the engine.

A zinc plug **(2)** is installed into the raw water compartment of the oil cooler to localize any electrolytic action within the raw water compartment. This plug should be inspected once a month. It can be cleaned or replaced.



OIL COOLER

1—Oil cooler. 2—Zinc plug. 3—Support bracket.

Flow of Lubricating Oil and Flow of Raw Water Coolant through Oil Cooler (D17000M)

The engine lubricating oil flows through the oil cooler in the following manner.

The oil tube **(2)** transmits the uncooled oil from the oil filter base into the pocket **(4)** of the cover **(5)**.

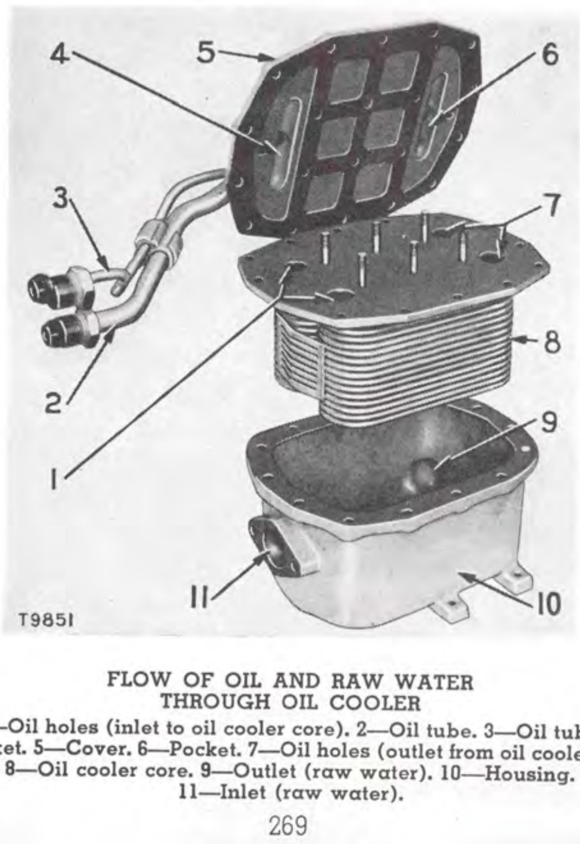
The oil passes into the oil holes **(1)**, then through the oil cooler cores **(8)**.

The oil is cooled and then expelled through the oil holes **(7)** into the pocket **(6)**.

The oil tube **(3)** returns the cooled oil to the oil filter base.

The raw water enters the housing **(10)** at the inlet **(11)**, and flows around the outside of the oil cooler cores.

The raw water is expelled at the outlet **(9)**, where it is drawn into the suction side of the raw water pump.



FLOW OF OIL AND RAW WATER THROUGH OIL COOLER

1—Oil holes (inlet to oil cooler core). 2—Oil tube. 3—Oil tube. 4—Pocket. 5—Cover. 6—Pocket. 7—Oil holes (outlet from oil cooler core). 8—Oil cooler core. 9—Outlet (raw water). 10—Housing. 11—Inlet (raw water).

Oil Cooler Removal (D17000M)

The oil cooler **(4)** can be removed in the following manner.

Close the sea valve.

Remove the zinc plug **(6)** to drain the raw water coolant from the oil cooler.

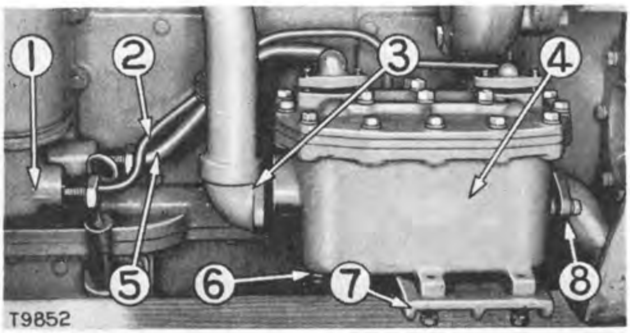
Drain the oil from the oil filter base **(1)** to permit any oil pressure which is retained in the system to be released from the oil cooler and oil lines.

Disconnect the raw water inlet line **(3)** and the outlet line **(8)**.

Disconnect and remove the oil tube **(5)**, which transmits the uncooled oil from the oil filter base to the oil cooler.

Disconnect and remove the oil tube **(2)**, which transmits the cooled oil from the oil cooler to the oil filter base.

Remove the capscrews holding the oil cooler to the support bracket **(7)** and lift off the oil cooler.



OIL COOLER REMOVAL
1—Oil filter base. 2—Oil tube (cooled oil). 3—Raw water inlet pipe. 4—Oil cooler. 5—Oil tube (uncooled oil). 6—Zinc plug. 7—Support bracket. 8—Raw water outlet line.

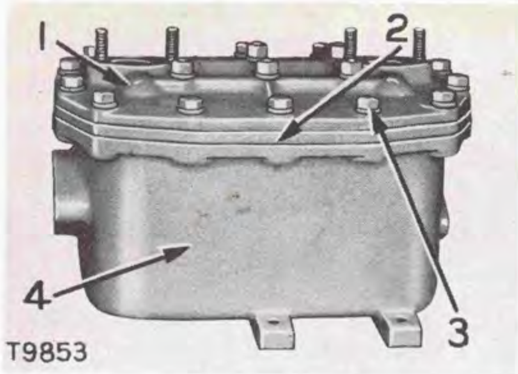
Oil Cooler Disassembly and Assembly (D17000M)

Remove the capscrews **(3)** and the nuts holding the cover **(1)** to the core assembly **(2)** and remove the cover.

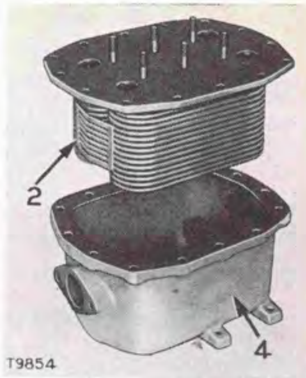
Lift out the core assembly **(2)**.

Clean the housing **(4)** and the core assembly thoroughly.

When assembling the oil cooler, clean the mating surfaces and install new gaskets between the housing and the core assembly, and between the cover and the core assembly.



REMOVING COVER
1—Cover. 2—Core assembly. 3—Capscrew. 4—Housing.

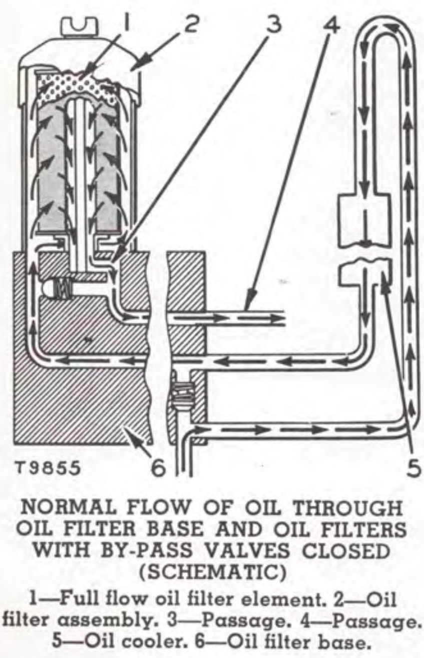


REMOVING CORE ASSEMBLY
2—Core assembly. 4—Housing.

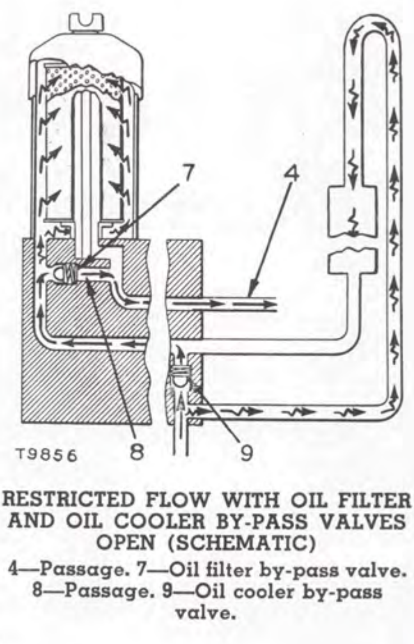
OIL FILTERS AND OIL FILTER BASE—FULL FLOW SYSTEM (D17000E-I-M)

Flow of Oil Through Oil Filter Base and Oil Filters — Full Flow System (D17000E-I-M)

The lubricating oil is delivered under pressure into the oil filter base **(6)** from the oil pump.



NORMAL FLOW OF OIL THROUGH OIL FILTER BASE AND OIL FILTERS WITH BY-PASS VALVES CLOSED (SCHEMATIC)
1—Full flow oil filter element. 2—Oil filter assembly. 3—Passage. 4—Passage. 5—Oil cooler. 6—Oil filter base.



RESTRICTED FLOW WITH OIL FILTER AND OIL COOLER BY-PASS VALVES OPEN (SCHEMATIC)
4—Passage. 7—Oil filter by-pass valve. 8—Passage. 9—Oil cooler by-pass valve.

The oil is transmitted to the oil cooler **(5)** where it is cooled and delivered to the filter base from which it goes into the oil filter assembly **(2)**.

The oil passes through the full flow filter elements **(1)** to the passages **(3)** and **(4)**, which deliver the filtered oil to the oil manifold. See the topic, OIL MANIFOLD (ALL MODELS).

If the oil cooler should become clogged or restricted in any manner, the increased oil pressure will unseat the oil cooler by-pass valve **(9)** and permit the oil to by-pass the oil cooler.

If the filters should become clogged or restricted, the increased oil pressure will unseat the oil filter by-pass valves **(7)** and permit the oil to pass through the passage **(8)** and then into the passage **(4)**.

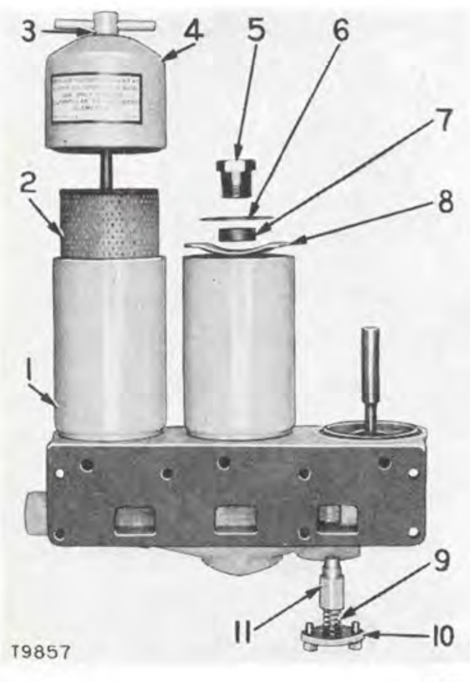
The by-pass valves assure the engine of a supply of lubricating oil at all times.

Disassembling the Oil Filters and Oil Filter Base — Full Flow System (D17000E-I-M)

Remove the cover **(4)** by turning the screw **(3)** in a counterclockwise rotation.

Lift out the full flow filter element **(2)**.

Remove the nut **(5)**, the washer **(6)**, the spacer **(7)** and the clamp **(8)**.



DISASSEMBLING OIL FILTER

1—Case. 2—Full-flow filter element. 3—Screw. 4—Cover. 5—Nut. 6—Washer. 7—Spacer. 8—Clamp. 9—Spring. 10—Capscrews and plate. 11—Plunger.

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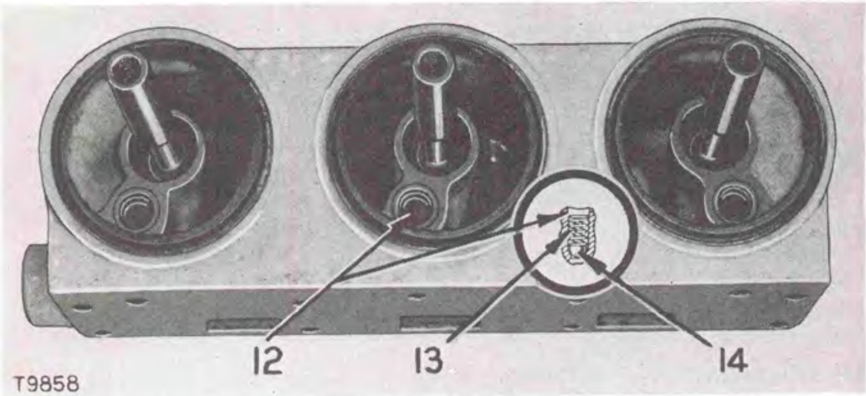
Lift off the case **(1)**.

Remove the capscrews and the plate **(10)**, the spring **(9)** and the plunger **(11)**. The spring and plunger together form the oil cooler by-pass valve.

Remove the plug **(12)** and lift out the spring **(13)** and the ball **(14)**. The spring and ball together form the oil filter by-pass valve.



LOCATION OF OIL FILTER BY-PASS VALVE
12—Plug. 13—Spring. 14—Ball.

Assembling the Oil Filter Base and Oil Filters — Full Flow System (D17000E-I-M)

Clean the filter base, filter case and cover thoroughly and check all passages to be sure they are open.

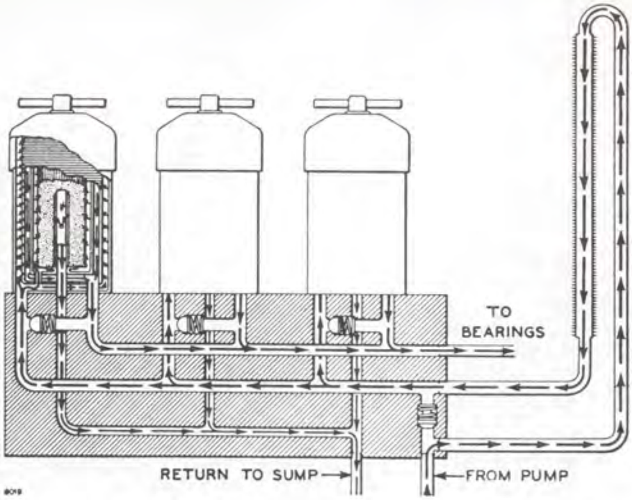
Install new filter elements and new gaskets and assemble in the reverse order of disassembly.

OIL FILTERS AND OIL FILTER BASE — BY-PASS SYSTEM (D17000E-I-M)

Each oil filter has an edge-type metal element surrounding an absorbent type element. As shown in the following sketch, the oil filtered by the outer element goes to the bearings while the oil filtered by the inner element is returned through the metering hole in the stud to the oil pan.

If the oil is cold and viscous, a by-pass valve in the filter base opens to permit oil to flow directly to the filters from the pump without passing through the oil cooler.

If the outer element becomes clogged, another by-pass valve opens to permit oil to flow directly to the bearings without passing through the



FLOW OF OIL—BY-PASS SYSTEM (SCHEMATIC)

filter elements. These by-pass valves should be checked to insure that they are functioning properly.

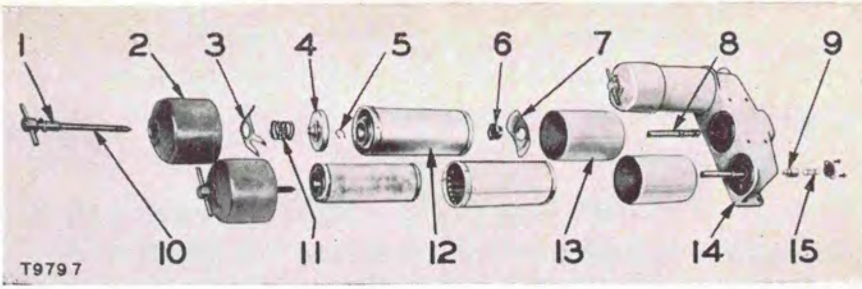
Remove the plug adjacent to the stud and inspect the ball check and spring. If the ball check and spring are corroded, replace them. Smooth the seat if rough.

The outer element may be clogged internally even when the outside surface has been carefully cleaned. Occasionally the gums and lacquers that clog the inside of the elements cannot be removed with any solvent or cleaner. Under these conditions the elements should be discarded if they are clogged too much. To check the internal condition, plug the holes in the bottom of the element in question and a new element, and then immerse both elements to the top rim in some noninflammable fluid such as Diesel fuel. Compare the rate at which the fluid level rises in each element. Discard the used element if its flow rate is less than three-fourths the flow rate of the new element. In other words, if the used element is not at least three-fourths full in the time required to fill a new element, the used element should be discarded.

Disassembly — By-Pass System (D17000E-I-M)

The accompanying illustration shows the filter housings and base completely disassembled.

The screw assembly **(10)**, gasket, springs **(3)** and **(11)**, and plate assembly **(4)** are held in place in the top cover **(2)** by a snap ring **(5)**



OIL FILTER ASSEMBLY

1—Groove. 2—Top cover. 3—Spring. 4—Plate assembly. 5—Snap ring. 6—Nut. 7—Retainer clamp. 8—Filter stud. 9—Plunger. 10—Screw assembly. 11—Spring. 12—Filter element. 13—Case. 14—Filter base. 15—Spring.

that fits in a groove **(1)** on the screw assembly **(10)**. They in turn hold the filter elements **(12)** in position.

With the top cover assembly and filter elements removed, an 8B2444 Socket Wrench should be used to remove the nut **(6)** at the bottom of the filter stud **(8)**. This nut holds the retainer clamp **(7)** that secures the filter element case **(13)** to the base **(14)**. Remove the filter stud **(8)**, taking care not to damage the metering hole in the stud.

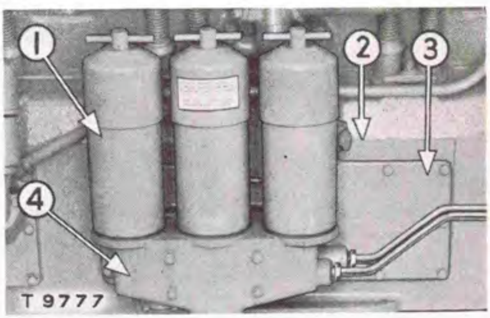
The plunger **(9)** and spring **(15)** should be removed and cleaned whenever the filter assembly is taken apart. The plunger permits oil to flow directly to the oil filters when the oil in the system is too cold or viscous to flow through the oil cooler. Thoroughly clean the oil passages in the filter base **(14)** and stud **(8)**.

OIL FILTER MANIFOLD
(D17000E-I-M)

The oil filter manifold **(3)** is mounted onto the crankcase **(2)**. The oil filter base **(4)** and oil filters **(1)** are mounted on the oil filter manifold.

OIL FILTER MANIFOLD

1—Oil filter. 2—Crankcase. 3—Oil filter manifold. 4—Oil filter base.



The oil filter manifold transmits the uncooled, unfiltered oil from the oil pump to the oil filter base.

After the oil has been cooled and filtered, the oil filter manifold returns the oil to the crankcase for engine lubrication.

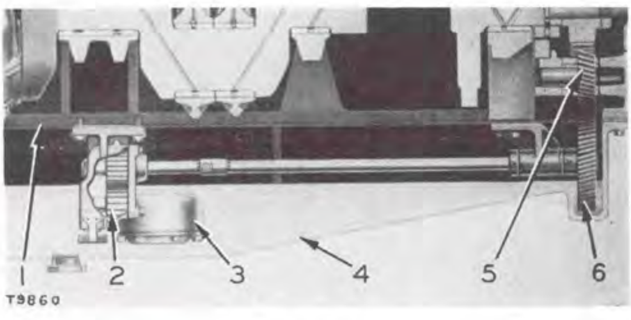
The flow of oil through the oil filter manifold for the full flow system is similar to the flow through the locomotive engine oil filter manifold. The removal is also similar. See the covering topics.

The flow of oil through the oil filter manifold for the by-pass system is also similar except that a portion of the filtered oil is by-passed through the base and manifold to the crankcase.

OIL PUMP AND OIL PUMP DRIVE (D17000E-I-M)

The oil pump **(2)** is mounted to the crankcase **(1)** and is located inside the oil pan **(4)**.

The right camshaft gear **(7)** drives the idler gear **(5)** which in turn drives the oil pump drive gear **(6)**.



OIL PUMP
1—Crankcase. 2—Oil pump. 3—Suction bell. 4—Oil pan. 5—Oil pump idler gear. 6—Oil pump drive gear.

The suction bell **(3)** filters the oil as it is drawn through it and removes any large particles that may be present.

The oil is delivered by the oil pump into the oil filter manifold. See the topic, OIL FILTER MANIFOLD (D17000E-I-M).

OIL PUMP IDLER GEAR

5—Oil pump idler gear.
6—Oil pump drive gear.
7—Right camshaft gear.

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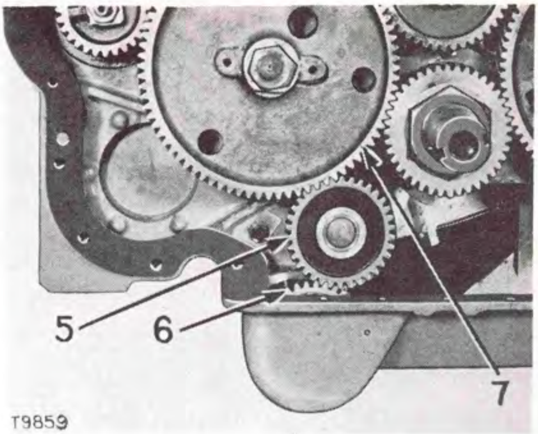
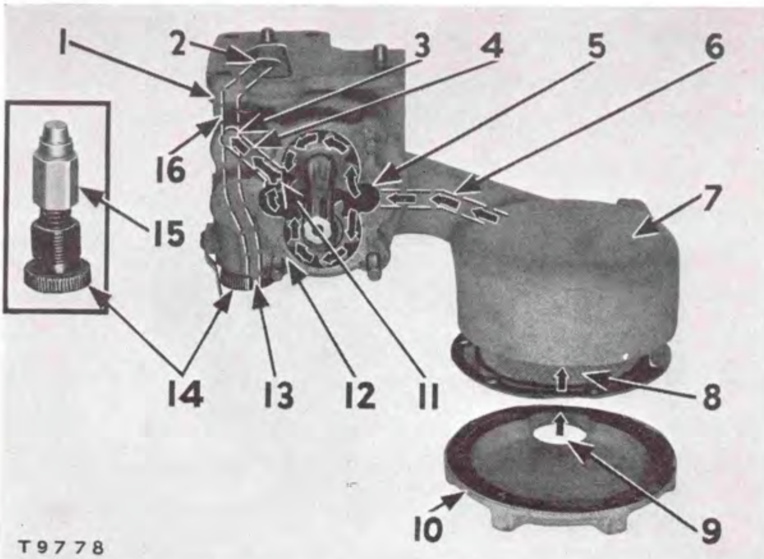


Flow of Oil Through the Oil Pump (D17000E-I-M)

The flow of oil through the oil pump is as follows:

The oil is drawn through the inlet hole **(9)** of the suction bell cover **(10)** and is filtered as it passes through the screen assembly **(8)**. It then goes through the suction bell **(7)** and the passage **(6)** of the bracket **(1)** to the pump body inlet **(5)**.



FLOW OF OIL THROUGH THE OIL PUMP (D17000E-I-M)
1—Bracket. 2—Oil outlet. 3—Passage (in bracket). 4—Passage (in body). 5—Pump body inlet. 6—Passage (in bracket). 7—Suction bell. 8—Screen assembly. 9—Inlet hole. 10—Suction bell cover. 11—Pump body outlet. 12—Body. 13—Passage (in body). 14—By-pass valve assembly. 15—Plunger. 16—Passage (in bracket).

The pump drive gear and the pump idler gear then delivers the oil, under pressure, to the pump body outlet **(11)** and it flows through the passages **(4)**, **(3)** and **(16)** to the oil outlet **(2)**.

The oil pump delivers more oil than is necessary for engine lubrication. The oil control by-pass valve assembly **(14)** is provided to by-pass the excess oil through the passage **(13)** in the body **(12)** to the oil pan sump. The assembly consists of the adjusting screw, the spring and the plunger **(15)** which seats in the passage **(3)**.

When the plunger **(15)** is unseated by pressure of the oil in the passage **(3)** part of the oil is returned to the oil pan sump and the rest goes to lubricate the engine. See the topic, ASSEMBLING THE OIL PUMP (D17000E-I-M) for the adjustment of the oil control by-pass valve assembly.

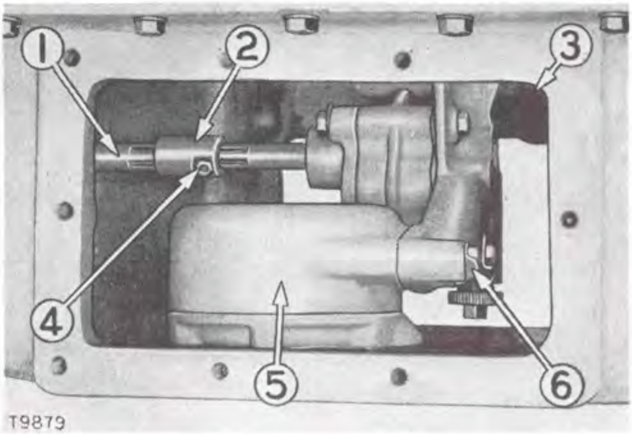
Oil Pump Removal and Installation Through the Oil Pan Inspection Opening (D17000E-I-M)

Drain the lubricating oil.

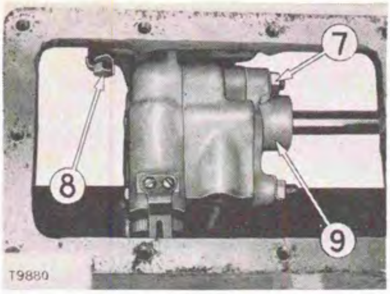
Remove the oil pan inspection covers.

Bend the locks and remove the capscrews **(6)** holding the suction bell **(5)**, and remove the suction bell through an inspection opening **(3)** of the oil pan.

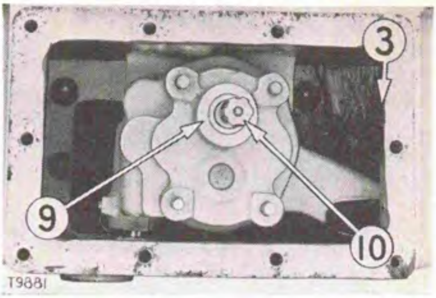
Remove the cotter pin, nut and bolt **(4)**. Slide the coupling **(2)** all the way on the oil pump drive shaft **(1)**.



REMOVING SUCTION BELL
1—Oil pump drive shaft. 2—Coupling. 3—Inspection opening (of oil pan). 4—Cotter pin, nut and bolt. 5—Suction bell. 6—Capscrew and lock.



DISCONNECTING OIL PUMP FROM CRANKCASE
7—Nut. 8—Capscrew. 9—Cover assembly.



POSITIONING PUMP TO REMOVE COVER ASSEMBLY
3—Inspection opening. 9—Cover assembly. 10—Oil pump shaft and gear assembly.

Bend the locks and remove the nuts **(7)** holding the cover assembly **(9)**.

Bend the locks and remove the capscrews **(8)** holding the oil pump to the crankcase.

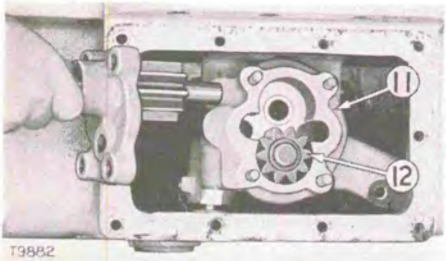
Remove the oil pump from the crankcase and position the pump by an inspection opening of the oil pan.

Slide off the cover assembly **(9)** and the oil pump shaft and gear assembly **(10)** as illustrated.

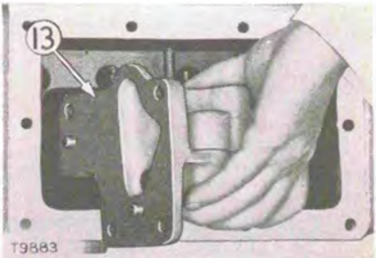
The idler gear **(12)** and body **(11)** can be lifted off at this time, although it is not necessary to do so.

The bracket assembly **(13)** can now be removed through the inspection opening as shown.

The oil pump can be installed in the reverse order of removal.



REMOVING COVER ASSEMBLY
11—Body. 12—Idler gear.

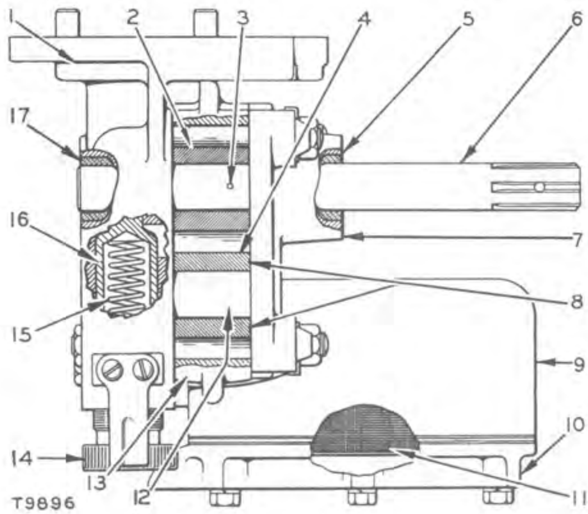


REMOVING BRACKET ASSEMBLY
13—Bracket assembly.

Oil Pump Disassembly (D17000E-I-M)

The oil pump can be disassembled in the following manner.

Make an identification mark on the outside surfaces of the oil pump bracket **(1)**, the body **(13)** and the cover **(7)** to assure the correct location of these parts at the time of assembly.



OIL PUMP CROSS-SECTION

1—Bracket. 2—Gear. 3—Pin. 4—Idler gear. 5—Bushing. 6—Shaft. 7—Cover. 8—Oil groove. 9—Suction bell. 10—Cover. 11—Screen assembly. 12—Idler gear shaft. 13—Body. 14—Adjusting screw. 15—Spring. 16—Plunger. 17—Bushing.

Bend the locks and remove the nuts holding the cover **(7)** to the bracket **(1)** and the body **(13)** and lift off the cover.

Bend the locks and remove the capscrews holding the cover **(10)** to the suction bell **(9)**.

Remove the cover.

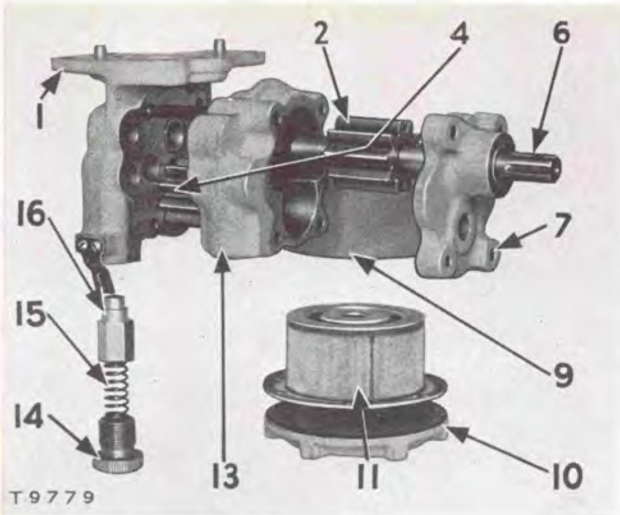
Remove the screen assembly **(11)**.

Bend the locks and remove the capscrews that connect the suction bell **(9)** to the bracket and remove the suction bell.

Slide out the shaft **(6)** and the gear **(2)**. The gear is held in place by the pin **(3)**.

Remove the idler gear **(4)** from the idler gear shaft **(12)** noting the position of the oil groove **(8)**.

Lift off the body **(13)** noting the position in which the body was located on the bracket assembly.



DISASSEMBLING OIL PUMP
1—Bracket. 2—Gear. 4—Idler gear. 6—Shaft. 7—Cover. 9—Suction bell. 10—Cover. 11—Screen assembly. 13—Body. 14—Adjusting screw. 15—Spring. 16—Plunger.

The by-pass valve assembly consists of the adjusting screw **(14)**, the spring **(15)** and the plunger **(16)**.

Before removing the adjusting screw, measure the distance the screw is protruding from the bracket, and use this measurement as a guide when installing the screw. The method of adjusting the screw is described in the topic, ASSEMBLING THE OIL PUMP (D17000E-I-M).

The bushings **(5)** and **(17)** can be replaced with new ones by the use of an arbor press, if excessive wear is shown.

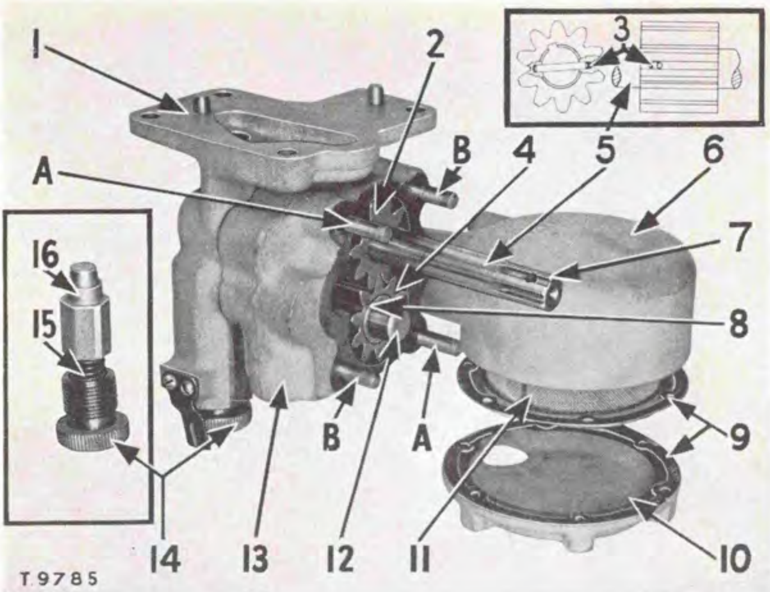
The pin **(3)** can be removed from the gear **(2)** and the shaft **(6)** in the same manner as described for the oil pump of the locomotive engine. See the topic, OIL PUMP DISASSEMBLY (D17000L).

Assembling the Oil Pump (D17000E-I-M)

Clean all parts and inspect for excessive wear. Replace any parts necessary.

Install the gear **(2)** on the shaft **(5)** and secure the gear with the pin **(3)**. The pin can be installed into the gear and shaft in the same manner as described for the locomotive oil pump. See the topic, ASSEMBLING THE OIL PUMP (D17000L). Check the splined end **(7)** of the shaft **(5)** to be sure it is free from any roughness or burrs.

Install the idler gear **(4)** on the idler gear shaft **(12)** which is pressed



ASSEMBLING THE OIL PUMP
A—Studs. B—Capscrews. 1—Bracket. 2—Gear. 3—Pin. 4—Idler gear. 5—Shaft. 6—Suction bell. 7—Splined end of shaft (5). 8—Oil groove. 9—Gaskets. 10—Cover. 11—Screen assembly. 12—Idler gear shaft. 13—Body. 14—Adjusting screw. 15—Spring. 16—Plunger.

into the bracket **(1)**. The oil groove **(8)** in the idler gear should be pointing away from the bracket.

Slide the body **(13)** onto the studs **(A)** matching the identification mark on the body with the identification mark on the bracket, as described in the topic, OIL PUMP DISASSEMBLY (D17000E-I-M).

Install the capscrews **(B)** which act as dowels in keeping the bracket, the body and the cover in alignment.

Install the suction bell **(6)**, gasket **(9)** and the screen assembly **(11)**. Install a gasket **(9)** and the cover **(10)** with the inlet opening of the cover pointing toward the bracket as illustrated.

Install the plunger **(16)**, the spring **(15)** and the adjusting screw **(14)**. Use the measurement obtained at the time of disassembly as a guide for adjusting the screw.

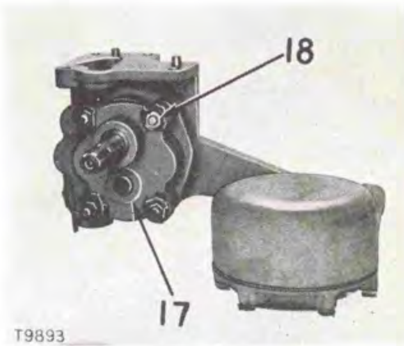
When the adjusting screw is turned in a clockwise direction the spring pressure becomes greater and holds the plunger tightly on its seat, thus raising the oil pressure which causes a greater amount of oil to go directly to the engine for lubrication.

Turning the adjusting screw in a counterclockwise direction releases the spring pressure, and permits the plunger to be lifted off its seat easier by the lubricating oil. When the plunger is lifted off its seat a portion of the lubricating oil by-passes into the sump.

Install the cover **(17)**, the locks and nuts **(18)** locating the cover by means of identification marks made at disassembly.

INSTALLING COVER
17—Cover. 18—Nut.

♦



Tighten the nuts evenly and diametrically.

Rotate the shaft to see that it turns freely before bending the locks. If the shaft binds, loosen the nuts slightly and tap the body with a suitable object to properly locate the parts. Tighten the nuts and bend the locks.

Oil Pump Drive Removal and Installation (D17000E-I-M)

The oil pump drive cannot be removed until the oil pan has been removed.

Remove the oil pan **(11)** as described in the topic, OIL PAN REMOVAL (D17000E-I-M).

Remove the cotter pin, the nut and the bolt **(7)**.

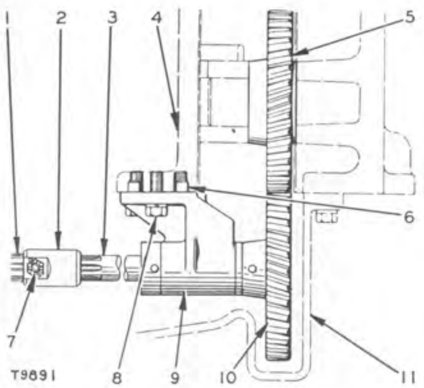
Slide the coupling **(2)** toward the rear, onto the oil pump shaft **(1)**, or forward, onto the oil pump drive shaft **(3)**.

Remove the capscrews **(8)** and remove the oil pump drive assembly **(9)**.

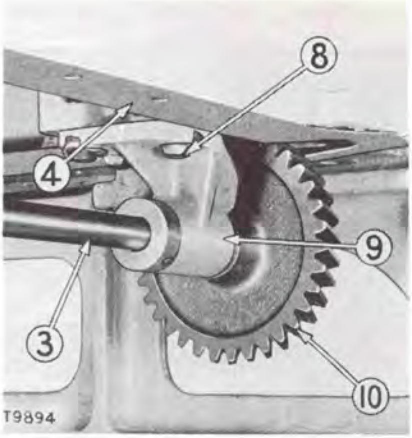
When installing the oil pump drive assembly, engage the oil pump drive gear **(10)** into the oil pump idler gear **(5)** and guide the dowel pins **(6)** into the dowel holes in the crankcase **(4)**.

Install the capscrews **(8)** and connect the coupling to the shafts **(1)** and **(3)**.

If a new oil pump drive assembly is installed on an engine, always check the backlash between the gears **(10)** and **(5)**. The backlash should be approximately .002″ to .003″. If an oil pump drive assembly has no



OIL PUMP DRIVE
1—Oil pump shaft. 2—Coupling. 3—Oil pump drive shaft. 4—Crankcase. 5—Oil pump idler gear. 6—Dowel pin. 7—Cotter pin, nut and bolt. 8—Capscrew. 9—Oil pump drive assembly. 10—Oil pump drive gear. 11—Oil pan.



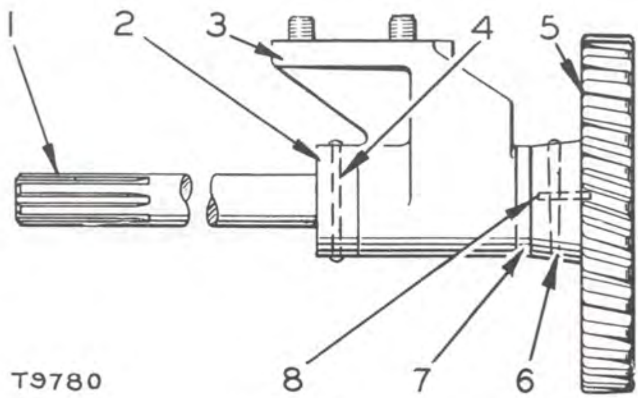
OIL PUMP DRIVE REMOVAL
3—Oil pump drive shaft. 4—Crankcase. 8—Capscrew. 9—Oil pump drive assembly. 10—Oil pump drive gear.

backlash, remove the assembly and place shims between the mating faces of the crankcase and the oil pump drive assembly to obtain the correct backlash.

Disassembling and Assembling the Oil Pump Drive (D17000E-I-M)

The oil pump drive can be disassembled in the following manner.

Using a file, smooth up one end of the straight pin **(4)**, which has been peened, in order to permit the pin to be removed.



OIL PUMP DRIVE
1—Shaft. 2—Collar. 3—Bracket. 4—Straight pin. 5—Gear. 6—Taper pin. 7—Bushing. 8—Key.

Drive out the straight pin.

Slide the collar **(2)** off the shaft **(1)**.

Slide the gear **(5)** and the shaft **(1)** out of the bracket **(3)** and the bushing **(7)**.

Drive out the taper pin **(6)**.

Press the shaft out of the gear and remove the key **(8)**.

Inspect the bushing for wear. If excessive wear is shown the bushing can be replaced by using an arbor press.

Assemble the parts in the reverse order of disassembly and peen the straight pin **(4)** on both ends.

Place a feeler gauge between the gear and the bushing at point **(A)** to check the end clearance. Bump the shaft and gear forward and backward in the bracket and bushing.

The end clearance should be .003″ to .010″ with a maximum permissible clearance of .025″.

DISASSEMBLING OIL PUMP DRIVE

A—Location to check end clearance. 1—Shaft. 2—Collar. 3—Bracket. 4—Straight pin. 5—Gear. 6—Taper pin. 7—Bushing.

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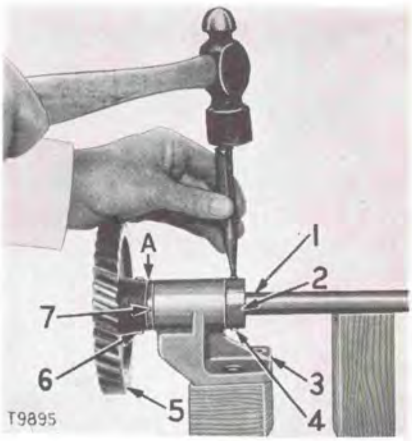
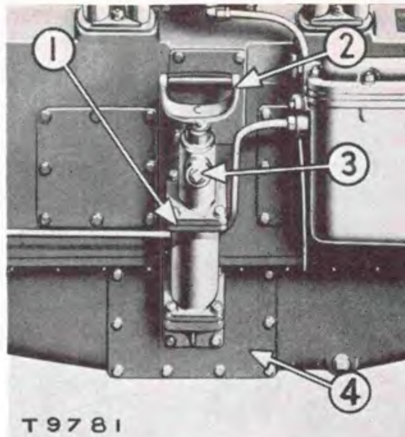


HAND SUMP PUMP
(D17000M)

The hand sump pump **(1)** is used to drain the lubricating oil from the oil pan on installations where the oil pan drain plug is not accessible.

The hand sump pump is attached to an oil pan inspection cover **(4)**.

To use the sump pump it is necessary to remove the plug **(3)** and attach a suitable pipe to carry the oil to a drain pan. Operating the handle **(2)** pumps the oil out of the oil pan.

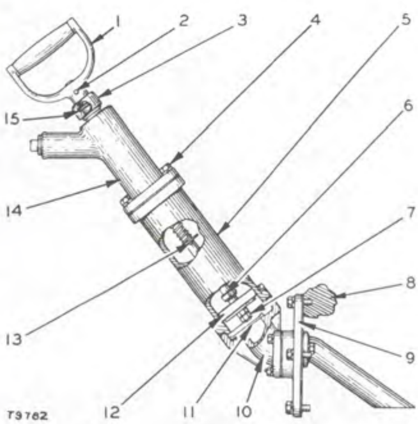


HAND SUMP PUMP

1—Hand sump pump. 2—Handle. 3—Plug. 4—Oil pan inspection cover.

Disassembling and Assembling the Hand Sump Pump (D17000M)

The hand sump pump can be disassembled and assembled in the following manner.



DISASSEMBLING THE HAND SUMP PUMP

1—Handle. 2—Pin. 3—Nut. 4—Capscrew. 5—Cylinder. 6—Cylinder assembly. 7—Nuts. 8—Crankcase. 9—Inspection cover. 10—Body. 11—Valve. 12—Retainers, valve and cup. 13—Shaft and spring. 14—Head. 15—Seal.

Remove the capscrews holding the cylinder assembly **(6)** to the body **(10)**.

Lift off the cylinder assembly permitting the body and the oil pan inspection cover **(9)** to remain attached to the crankcase **(8)**.

Lift out the valve **(11)**.

Cover the body to prevent anything falling into it.

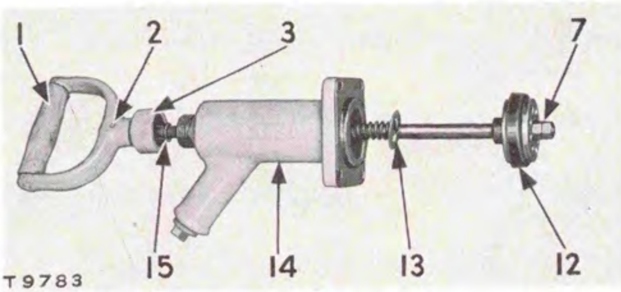
Place the cylinder assembly on a clean bench.

Drive out the pin **(2)** and remove the handle **(1)**.

Unscrew the nut **(3)** and remove the nut and seal **(15)**.

Remove the capscrews **(4)** holding the head **(14)** to the cylinder **(5)** and remove the head.

Remove the nuts **(7)** and remove the retainers, the valve and the cup **(12)**.



REMOVING SHAFT
1—Handle. 2—Pin. 3—Nut. 7—Nut. 12—Retainers, valve and cup. 13—Shaft and spring. 14—Head. 15—Seal.

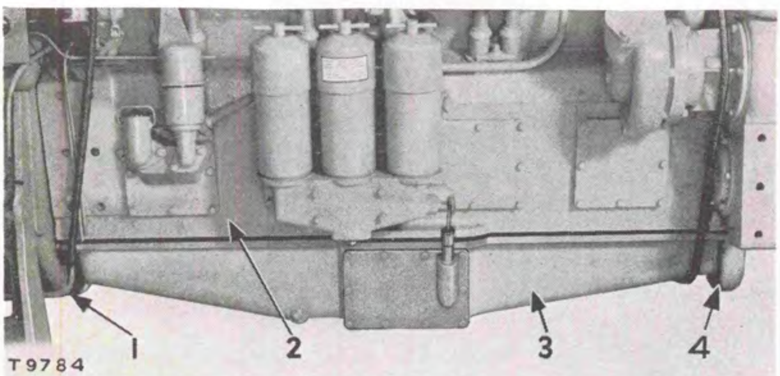
Slide out the shaft **(13)** and spring.

Clean and inspect all parts, and install a new seal **(15)** and cup **(12)** if necessary.

OIL PAN
(D17000E-I-M)

Oil Pan Removal and Installation (D17000E-I-M)

The oil pan **(3)** can be removed in the following manner.



REMOVING OIL PAN
1—Support ribs. 2—Crankcase. 3—Oil pan. 4—Forward end.

Drain the lubricating oil.

Place slings or cables around the oil pan as illustrated. Position the slings or cables so as not to damage the engine.

Remove all capscrews holding the oil pan to the crankcase **(2)**.

Using a putty knife, separate the oil pan from the crankcase. Protect and save the oil pan gasket if a new gasket is not available.

With a suitable hoist lower the forward end **(4)** of the oil pan enough to clear the oil pump drive gear.

Move the oil pan forward enough to clear the flywheel housing support ribs **(1)** and remove the oil pan.

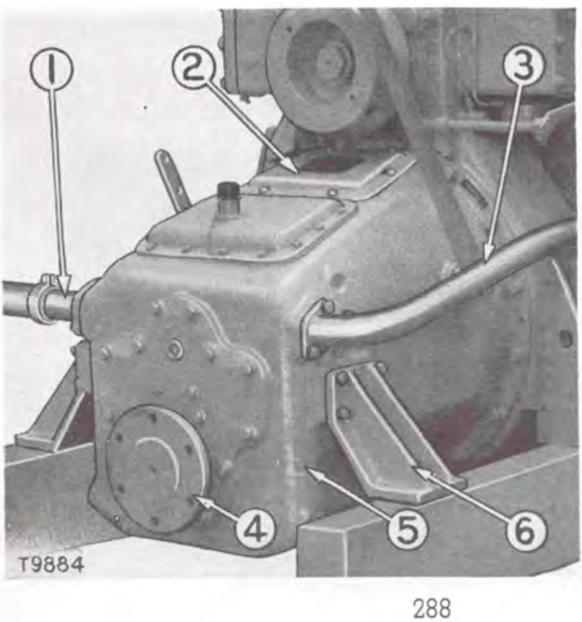
Clean the oil pan thoroughly and install new gaskets if necessary.

Reverse and Reduction Gear Unit
(D17000M)

REVERSE AND REDUCTION GEAR UNIT REMOVAL AND INSTALLATION
(D17000M)

The reverse and reduction gear unit **(5)** can be removed in the following manner.

Close the sea valve.



DISCONNECTING RAW WATER PIPES

1—Raw water inlet pipe.
2—Top inspection cover.
3—Raw water outlet pipe.
4—Flange. 5—Reverse and reduction gear unit.
6—Support.

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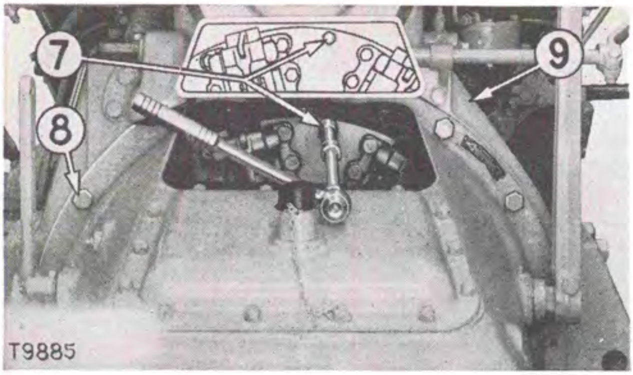

DISCONNECTING UNIT FROM FLYWHEEL
7—Capscrew. 8—Capscrew. 9—Flywheel housing.

Drain the raw water from the reverse and reduction gear unit by removing the drain plug at the bottom.

Remove the raw water inlet pipe **(1)**.

Remove the raw water outlet pipe **(3)**.

Disconnect and remove the coupling between the propeller shaft and the flange **(4)**.

Disconnect or remove the supports **(6)**, depending on the type of installation.

PULLING UNIT USING PULLER SCREWS
9—Flywheel housing.
10—Puller screws.

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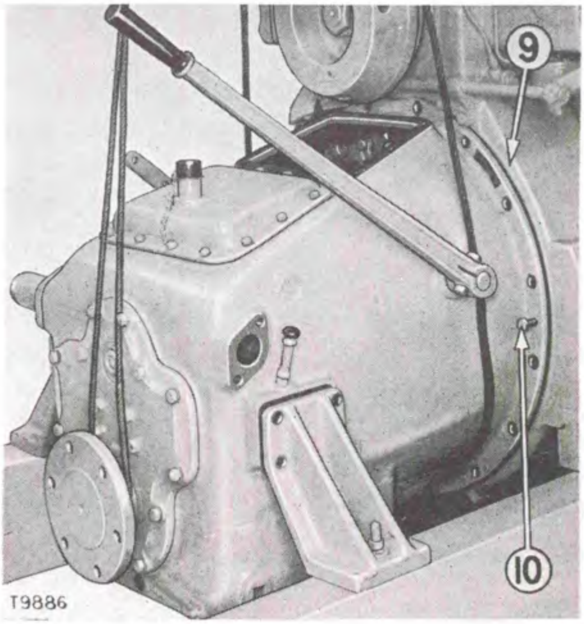


Remove the top inspection cover **(2)**.

Remove the capscrews **(7)** which connect the unit to the flywheel.

Place suitable cables around the unit as illustrated.

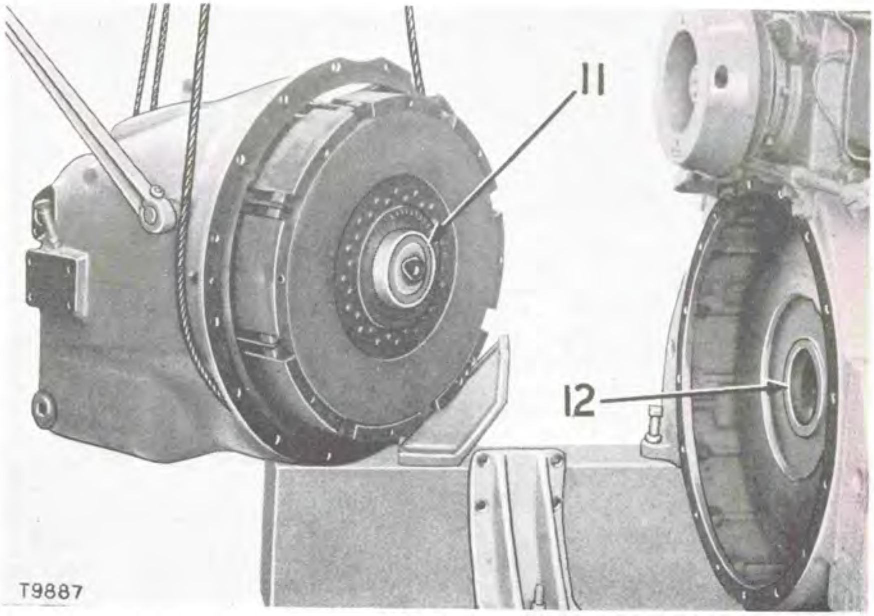
Remove the capscrews **(8)** holding the unit to the flywheel housing **(9)**.

Using two $\frac{1}{2}''$–13 (NC) capscrews as puller screws **(10)**, pull the unit from the flywheel and the flywheel housing **(9)** and lift out as shown.

Before installing the unit, always clean the flywheel to be sure it is free of dirt or grease.

Inspect the pilot bearing **(11)**. Replace if necessary and pack the bearing with ball and roller bearing grease.

When installing, guide the pilot bearing into the pilot bearing bore **(12)** of the flywheel.



PILOT BEARING
11—Pilot bearing. 12—Pilot bearing bore.

Start all the capscrews connecting the unit to the flywheel as well as those holding the unit to the flywheel housing before any are tightened.

Tighten all capscrews diametrically and evenly.

Install the inspection cover.

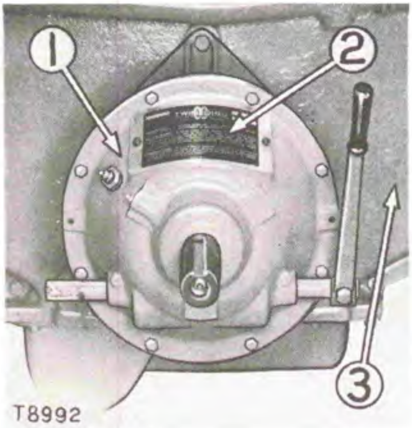
Front Power Take-Off
(D17000M)

FRONT POWER TAKE-OFF REMOVAL
(D17000M)

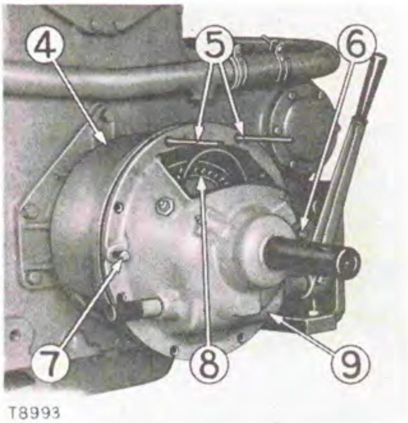
The front power take-off **(1)** is mounted on the timing gear cover **(3)**, and is attached to and driven by the crankshaft.

The front power take-off can be removed in the following manner.

Remove the inspection cover **(2)**.



FRONT POWER TAKE-OFF
1—Front power take-off.
2—Inspection cover.
3—Timing gear cover.



REMOVING CLUTCH COVER ASSEMBLY
4—Housing. 5—Guide pins. 6—Puller capscrew. 7—Puller capscrew. 8—Driving plates. 9—Clutch cover assembly.

Engage the clutch to lock the driving plates **(8)** in place. This will be helpful if the clutch assembly is not disassembled, and will keep the plates aligned.

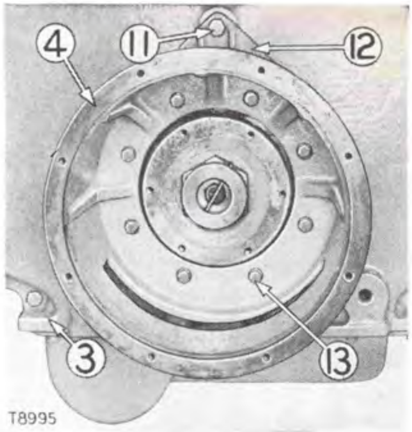
Remove two of the capscrews holding the clutch cover assembly **(9)** to the housing **(4)** and install two 3/8″–16 (NC) guide pins **(5)**.

Remove the remaining capscrews holding the cover assembly **(9)**.

Install two 3/8″–16 (NC) capscrews **(6)** and **(7)** as illustrated and pull the cover assembly. The guide pins **(5)** will support the cover assembly while pulling is being done.

Remove the capscrews holding the coupling **(10)** and remove the coupling.

REMOVING COUPLING
10—Coupling.



REMOVING ADAPTER AND HOUSING
3—Timing gear cover. 4—Housing. 11—Capscrews. 16—Adapter. 13—Capscrew.

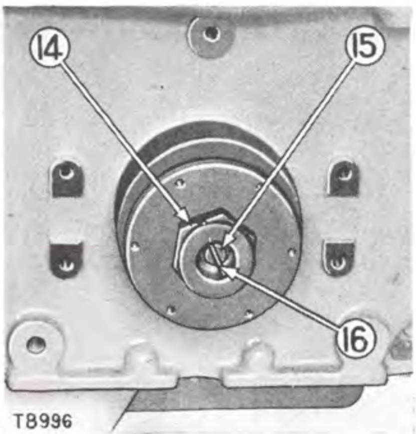
Remove the capscrews **(11)** holding the adapter **(12)** to the timing gear cover **(3)**.

Remove the adapter and the housing **(4)** as a unit.

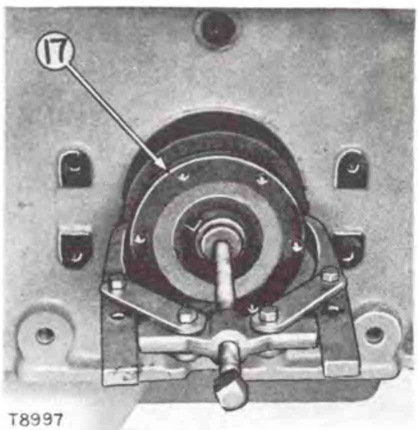
The housing can be removed from the adapter by removing the capscrews **(13)** if desired.

Remove the pin **(16)**.

Remove the capscrew **(15)**, which has left-hand threads.



REMOVING CRANKSHAFT NUT
14—Crankshaft nut. 15—Capscrew with left hand threads. 16—Pin.



PULLING HUB
17—Hub.

Remove the crankshaft nut **(14)**.

Pull the hub **(17)** using the 8B7545 Puller and Step Plate as illustrated.

FRONT POWER TAKE-OFF INSTALLATION (D17000M)

The procedure for installing the front power take-off is as follows.

Install the hub **(5)** on the crankshaft, mating the key-way of the hub with the crankshaft key.

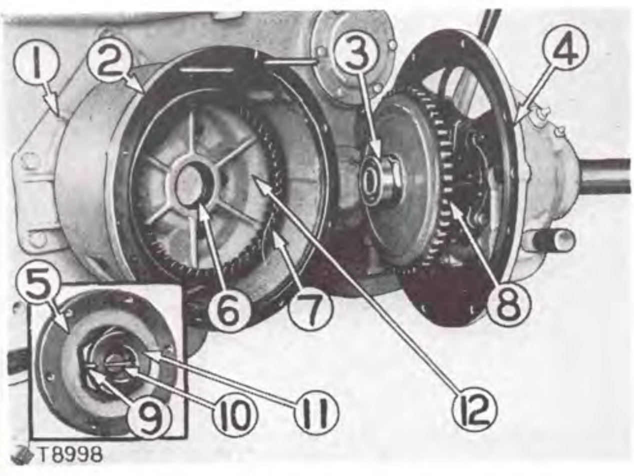
Install the crankshaft nut **(11)**, the capscrew **(10)** which has a left-hand thread and the pin **(9)**.

Install the adapter **(1)** and the housing **(2)**.

The driving plates **(8)** must be centrally located (on the clutch assembly) to move freely in the splines **(7)** of the coupling **(12)** when these assemblies are installed to the engine.

The alignment of the splines can be checked and positioned in the following manner.

Slide the coupling **(12)** over the driving plates before it is installed on the hub **(5)**, mating the splines carefully. If the driving plates do not slide into the coupling freely, disengage the clutch and position the splines to be in correct alignment. Then slide the coupling over the driving plates. Engage the clutch to lock them in place. Remove the coupling from the driving plates and install the coupling to the hub **(5)**.



INSTALLING FRONT POWER TAKE-OFF

1—Adapter. 2—Housing. 3—Bearing. 4—Clutch cover assembly. 5—Hub. 6—Bore. 7—Splines. 8—Driving plates. 9—Pin. 10—Capscrew with left hand thread. 11—Crankshaft nut. 12—Coupling.

Using two guide pins as illustrated, install the clutch cover assembly **(4)**, mating the driving plates with the splines **(7)** and the bearing **(3)** into the bore **(6)** of the coupling.

Install the capscrews holding the clutch cover assembly to the housing. Remove the guide pins and install the inspection cover.

Aligning Attachments to Flywheel

(All Models)

Attachments that are connected to the flywheel can be classified into two general types: the self-aligning coupling which needs only to be installed with no check necessary to determine the alignment of the attachment with the flywheel; and the flexible drive coupling which is not rigidly attached to the engine and which must be aligned in relationship to the flywheel.

SELF-ALIGNING COUPLING

(All Models)

The self-aligning coupling incorporates a pilot bearing which is installed into the pilot bearing bore and is rigidly connected to the flywheel, the flywheel housing or both. This automatically aligns the drive shaft of the attachment to the crankshaft, and allows the rear main bearing of the engine to serve as a front bearing for the attachment. The attachments that have pilot bearings are connected to and driven by the flywheel either by a rigid connection or a flexible link connection.

Examples of the self-aligning couplings which need only to be installed to the engine are as follows: the Marine reverse and reduction gear unit, the regulating type generator set, the enclosed type clutch (for use without pillow blocks) and the multiple disc clutch.

FLEXIBLE DRIVE COUPLING

(All Models)

The flexible drive coupling type does not have a rigid connection between either the flywheel or the flywheel housing and the attachment. The open face clutch (for use with pillow blocks) is of this type, and it must be aligned with the engine.

A flexible drive coupling can be aligned to the engine by removing or adding shims, and the alignment can be checked as described in the following topics.

Bore Alignment (All Models)

When checking the bore alignment, install a dial indicator **(A)** as illustrated. Rotate the crankshaft to locate the indicator at position No. 1 and adjust it to read .000".

Rotate the crankshaft to check the readings at the positions 2, 3 and 4.

CHECKING POINTS

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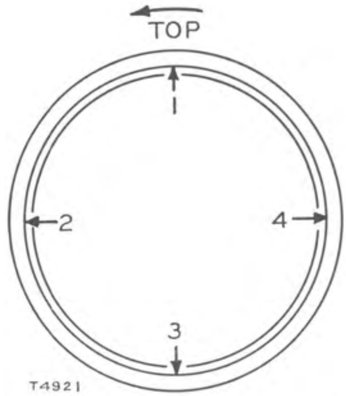
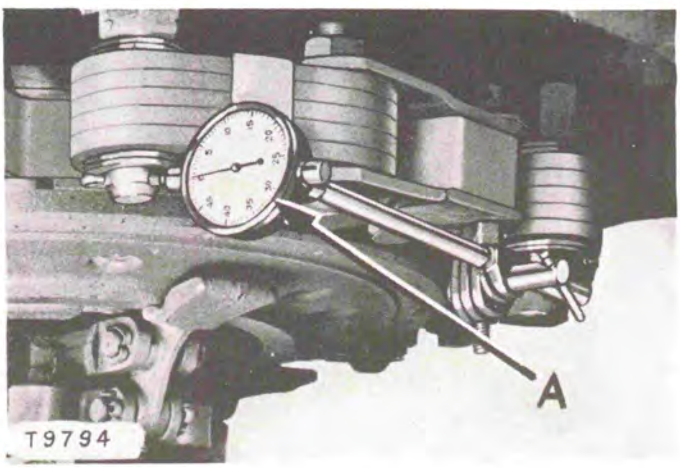


The difference in readings between positions No. 1 and 3 and positions No. 2 and 4, should not be more than .010" total indicator movement.

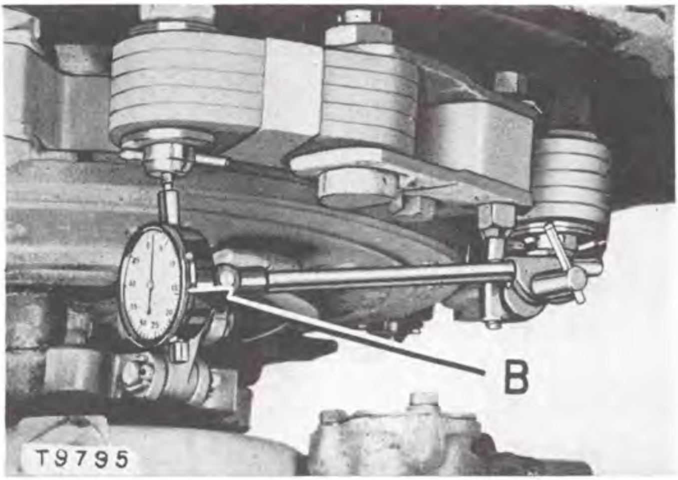
If shims are inserted or removed or if the attachment has been shifted, the hold-down bolts should be tightened firmly before taking further readings.



CHECKING BORE RUN-OUT
A—Dial indicator used for checking bore alignment.

Face Alignment (All Models)

When checking the face alignment install a dial indicator **(B)** as illustrated.

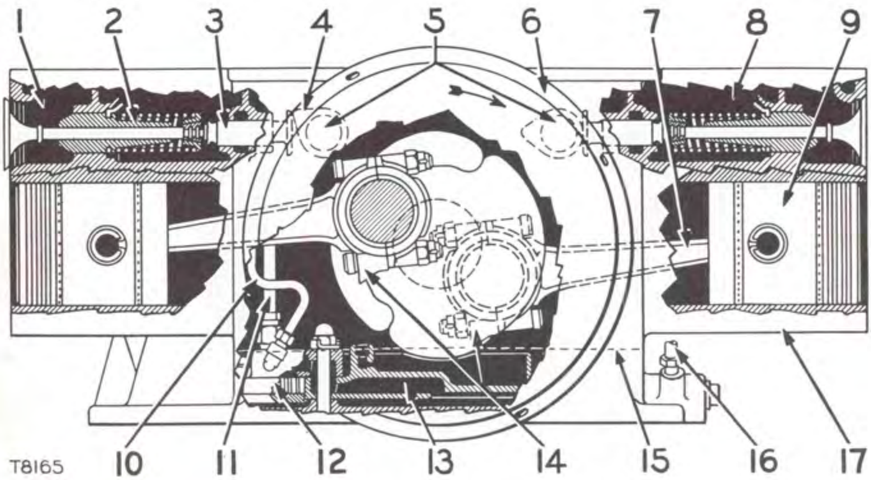


CHECKING FACE RUN-OUT
B—Dial indicator used for checking face alignment.

Start at position No. 1 with the dial indicator adjusted to zero, take readings at No. 2, 3 and 4. Always pry the crankshaft either forward or backward when taking readings so the end clearance will always be in the same direction.

Face alignment should not exceed .010" total indicator movement.

Repeat bore and face alignment operations until the desired results are obtained. Never take for granted that the face alignment is satisfactory after bore alignment is correct, or that bore alignment is satisfactory after re-aligning the face. A finished alignment is only established when satisfactory readings on both face and bore may be obtained without further movement of the attachment.



STARTING ENGINE CUT-AWAY
VIEW FROM REAR — LOWER PART

1. Exhaust Port
2. Valve Assembly
3. Valve Lifter
4. Camshaft Lobe
5. Camshafts
6. Flywheel
7. Connecting Rod
8. Valve Chamber
9. Piston
10. Pressure Oil Line (Magneto)
11. Pressure Oil Line (Main Bearings)
12. Oil Pump
13. Suction Bell
14. Connecting Rod Oil Scoops
15. Oil Level (Full)
16. Valve Chamber Oil Drain Line
17. Cylinder Block

STARTING ENGINE

(All Models So Equipped)

The starting engine **(1)** is mounted at the rear of the Diesel engine on top of the flywheel housing **(3)**. The starter pinion mechanism **(2)** is located within the flywheel housing and is driven by the starting engine. When the pinion is in the engaged position, it meshes with the ring gear on the flywheel and turns the Diesel engine in correct engine rotation.

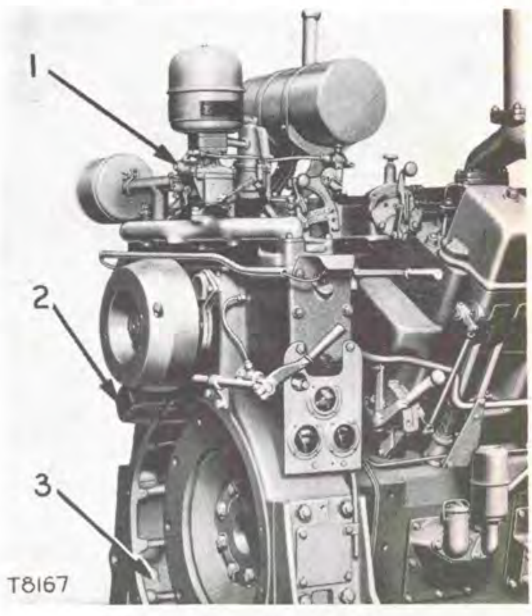
The starting engine contains an oil pump and lubricating system independent of the Diesel engine. See the topic, STARTING ENGINE LUBRICATION.

The cooling system is interconnected with the cooling system of the Diesel engine. See the topics, DIESEL ENGINE COOLING SYSTEM, (D17000L-E-I) and DIESEL ENGINE COOLING SYSTEM (D17000M) for the flow diagram and description of the combined cooling of the engines.

Most reconditioning work can be done more readily by first removing the starting engine. See the topic, STARTING ENGINE REMOVAL AND INSTALLATION. However, an inspection can be made to determine the general condition of the engine by removing the top cover. See the topic, TOP COVER REMOVAL.

Whenever it is possible, before disassembling the starting engine, check the clearances and compare them with the original clearances as listed under the topic, SPECIFICATIONS. Many times this check will eliminate the unnecessary removal of parts. Also by this check it may be possible to determine which parts or assemblies need to be replaced or reconditioned.

The starting engine has a bore of 3¾ inches and a stroke of 4 inches.



STARTING ENGINE

1—Starting engine. 2—Starter pinion mechanism. 3—Flywheel housing.

◆

Starting Engine Removal and Installation

Drain the coolant and the lubricating oil from the starting engine.

On the right side of the engine disconnect or remove the following:

Remove the inlet water line **(2)** from the Diesel engine to the starting engine, and the outlet water line **(1)** from the starting engine to the Diesel engine.

Remove the nuts **(3)** holding the instrument panel **(5)** to the starting engine.

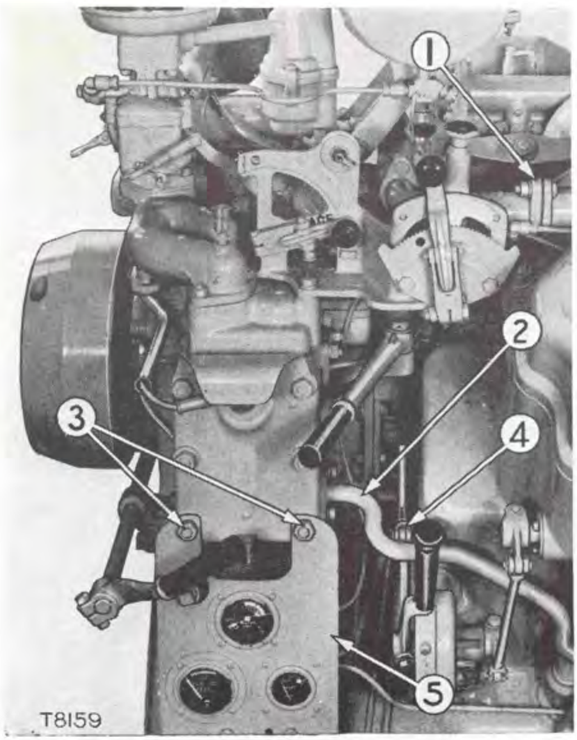
Disconnect the compression release control rod **(4)**.

On the left side of the engine, disconnect and remove the compression release control rod from lever **(10)** and the Diesel engine fuel supply line **(11)** at the fuel filter housing.

Disconnect the Diesel engine governor control rod **(6)** and the fuel pump control rod **(7)** from the starting engine.

Remove the inlet water line **(8)**.

Remove all capscrews holding the starting engine to the Diesel engine flywheel housing.



STARTING ENGINE REMOVAL (Right Side)

1—Water outlet line. 2—Water inlet line. 3—Nuts. 4—Compression release control rod. 5—Instrument panel.

◆

STARTING ENGINE REMOVAL (Left Side)

6—Governor control rod. 7—Fuel pump control rod. 8—Inlet water line. 9—Clutch idler gear. 10—Compression release lever. 11—Diesel engine fuel supply line.

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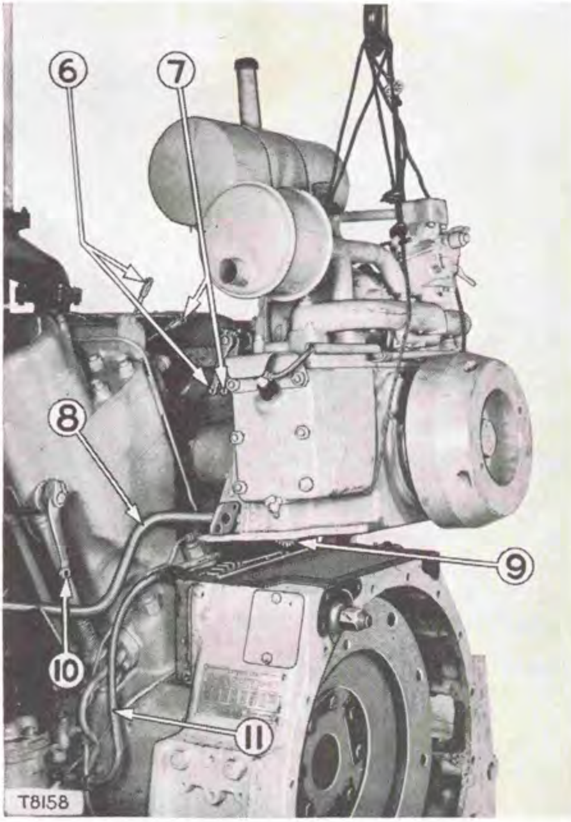


Lay the instrument panel clear so as not to cause interference.

With a pry bar, pry slightly to make certain that the starting engine is free and that all the capscrews are removed.

Place cables around the cylinder block as slings and lift off the starting engine.

Before installing the starting engine, clean the gasket surfaces on the top of the Diesel engine flywheel housing and on the bottom of the starting engine block. Cement a new gasket in place on the flywheel housing and allow it to set. Coat the top of the gasket with grease.

Attach cables to the starting engine in a manner to balance the engine, to permit it to be lowered into place so as not to damage the gasket. Guide the starting engine down over the dowels in the flywheel housing and also engage the teeth of the clutch idler gear **(9)** with the starter pinion gear teeth. (The starter pinion assembly is mounted on the Diesel engine flywheel housing). A rocking motion will assist the gear teeth to become engaged and will permit the starting engine to settle down into place. When the engine is fully seated by its own weight, install the capscrews at the base of the starting engine and tighten evenly and securely. The remaining connections are made in the reverse order of removal.

Cooling System

The starting engine cooling system is interconnected with the Diesel engine. See the topics, DIESEL ENGINE COOLING SYSTEM, (D17000L-E-I) and DIESEL ENGINE COOLING SYSTEM (D17000M), for the flow diagram and description of the combined cooling systems. Also, see the topic, WATER PUMP OPERATION, in the Starting Engine section of this book.

Lubrication System

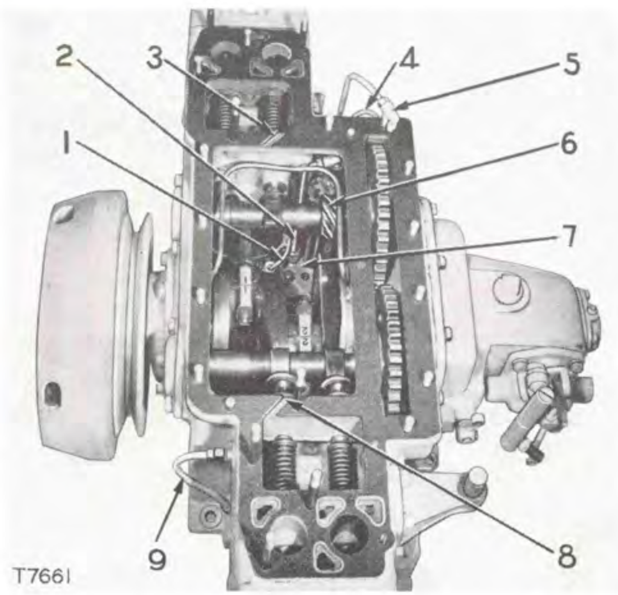
The oil pump **(7)** is located inside the crankcase and is driven by a gear **(6)** which is integral with the left camshaft. See the topic, OIL PUMP.

Oil is drawn through the suction bell into the gear pump which expels the oil through two pressure oil lines **(2)** and **(1)**.

The larger line **(2)** from the oil pump supplies oil to the main bearings.

The smaller line **(1)** from the oil pump is connected to an external oil line **(5)** which sprays oil on the magneto drive gear, the camshaft gears and the crankshaft drive gear.

There is an opening cast into the crankcase near the bottom of the timing gear housing that permits surplus oil to drain back into the crankcase.



LUBRICATION SYSTEM
1—Small oil line. 2—Large oil line. 3—Slot in gasket. 4—Valve compartment oil drain line. 5—External oil line. 6—Integral gear. 7—Oil pump. 8—Slot in gasket. 9—Valve compartment oil drain line.

The connecting rod bearings are splash-lubricated. To facilitate this there is a scoop attached to each connecting rod. A portion of the oil picked up by the scoops is forced through drilled holes in the connecting rods, to the connecting rod bearings. See the topic, CONNECTING ROD BEARING ASSEMBLY, The scoops also throw the oil against the cylinder walls and all internal parts of the crankcase.

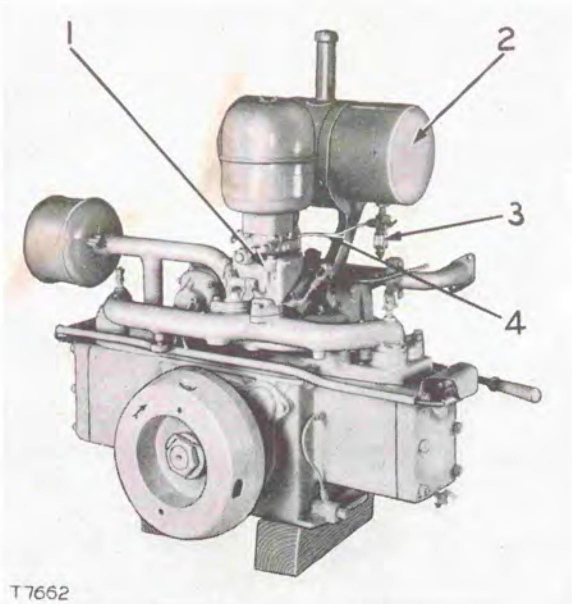
Oil is splashed against the top cover and into the camshaft bearing wells.

Oil is splashed through the two slots **(3)** and **(8)** in the gasket into the valve chambers. Surplus oil is returned to the crankcase through external oil drain lines **(4)** and **(9)** from each valve compartment.

The starter pinion has a separate lubrication system in conjunction with the clutch. See the topic, STARTER PINION LUBRICATION.

Fuel System

The fuel system of the starting engine consists of the carburetor **(1)**, the fuel tank **(2)**, the sediment bulb **(3)** and the fuel line **(4)**. These assemblies are mounted on the top cover. They can be removed individually. See the topics, TOP COVER REMOVAL, and CARBURETOR REMOVAL and INSTALLATION.



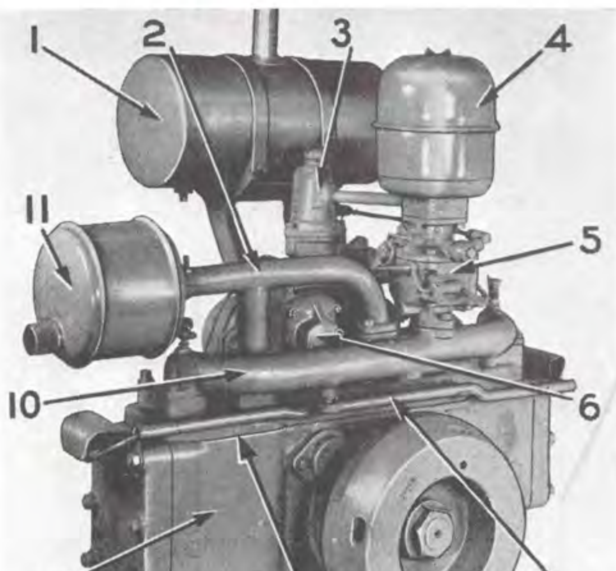
FUEL SYSTEM
1—Carburetor. 2—Fuel tank. 3—Sediment bulb. 4—Fuel line.

Top Cover

For assembly and identification purposes, the housing, which is mounted on top of the cylinder block, is considered the top cover **(8)**. It contains integrally cast ports and passages which form a part of the inlet and exhaust manifold systems and also part of the cooling system of the starting engine. The inlet manifold pipe **(10)**, the exhaust manifold pipe **(2)** and the muffler **(11)** are connected to the top cover to complete the manifold system. Passages connect the water pump (which is mounted on the top cover) to other passages which transmit the coolant to the starting engine.

The top cover **(8)** has the following assemblies mounted on it, and they can be removed without removing the top cover from the cylinder block **(9)**: the gasoline tank **(1)** the exhaust manifold pipe **(2)**, the oil filler **(3)**, the air cleaner **(4)**, the carburetor **(5)**, the magneto **(6)**, the ignition wiring and metal conduit **(7)** and the inlet manifold pipe **(10)**.

The water pump, the governor and the accessory shaft can also be removed with the top cover in place. See the topic, ACCESSORY SHAFT, WATER PUMP AND GOVERNOR REMOVAL.



STARTING ENGINE -REAR-VIEW
1—Fuel tank. 2—Exhaust manifold pipe. 3—Oil filler. 4—Air cleaner. 5—Carburetor. 6—Magneto. 7—Ignition wiring and metal conduit. 8—Top cover. 9—Cylinder block. 10—Inlet manifold pipe. 11—Muffler.

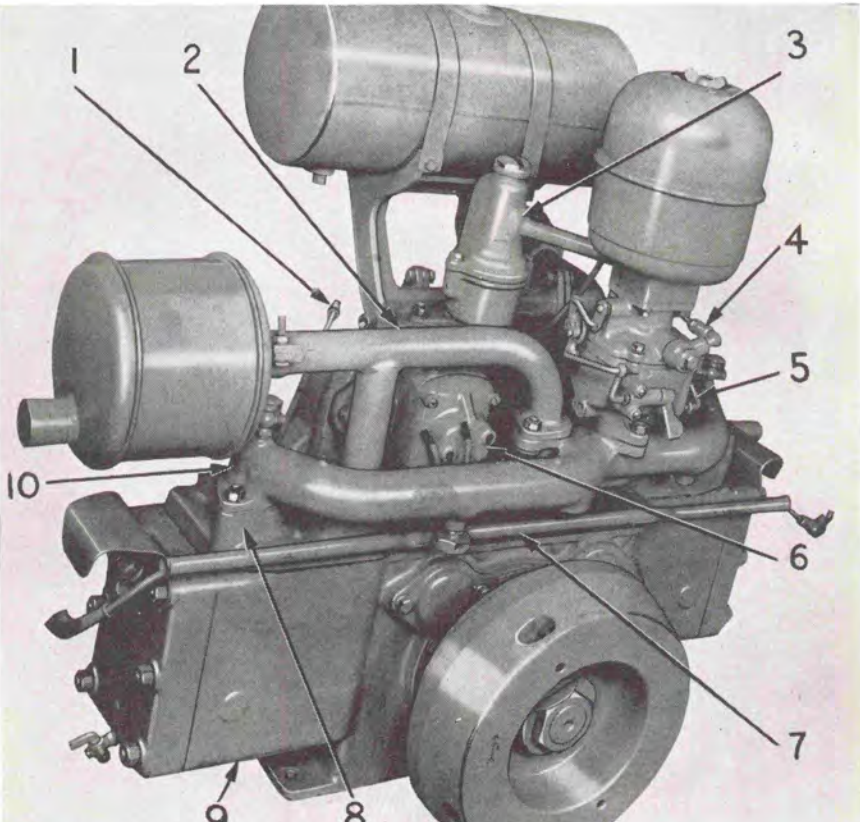
The magneto drive gear is mounted inside the top cover and can only be removed by first removing the top cover, because the gear will not pass through the openings of the top cover.

TOP COVER REMOVAL

If it is desired to inspect the starting engine connecting rod bearings for wear and clearances, and to determine the general condition of the starting engine, it can be accomplished by removing the top cover in the following manner.

Drain the cooling system.

Drain the lubricating oil from the starting engine.



PREPARING FOR TOP COVER REMOVAL

1—Oil tube. 2—Exhaust manifold pipe. 3—Breather and oil filler. 4—Fuel line. 5—Carburetor throttle linkage. 6—Magneto. 7—Metal conduit. 8—Top cover. 9—Cylinder block. 10—Inlet manifold pipe.

Remove the nuts holding the exhaust manifold pipe **(2)** to the top cover **(8)** at No. 2 cylinder.

Remove the capscrews holding the breather and oil filler **(3)** to the top cover.

Disconnect the fuel line **(4)** at the carburetor.

Disconnect the throttle linkage **(5)** at the carburetor.

Remove the nuts holding the inlet manifold pipe **(10)** to the top cover **(8)**.

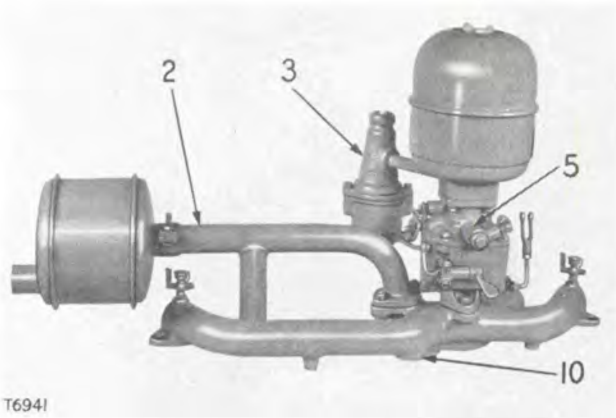
Disconnect and remove the oil tube **(1)** which supplies oil to the magneto drive gear.

Disconnect the ignition wires at the magneto **(6)** and at both spark plugs, noting the position of the wires as they are disconnected and also that they can remain in the metal conduit **(7)** if desired.

Disconnect the water manifold at the starting engine water pump.

Disconnect all Diesel engine controls.

Lift off the inlet manifold pipe, **(10)**, the exhaust manifold pipe **(2)**, the breather and oil filler **(3)**, the carburetor **(5)** and the air cleaner as a unit as illustrated.



MANIFOLD UNIT REMOVAL
2—Exhaust manifold pipe. 3—Breather and oil filler.
5—Carburetor. 10—Inlet manifold.

Remove the nuts holding the metal conduit assembly **(7)** to the top cover and remove the conduit assembly.

Remove all the nuts and capscrews holding the top cover **(8)** to the cylinder block **(9)**.

TOP COVER REMOVAL

8—Top cover. 9—Cylinder block.

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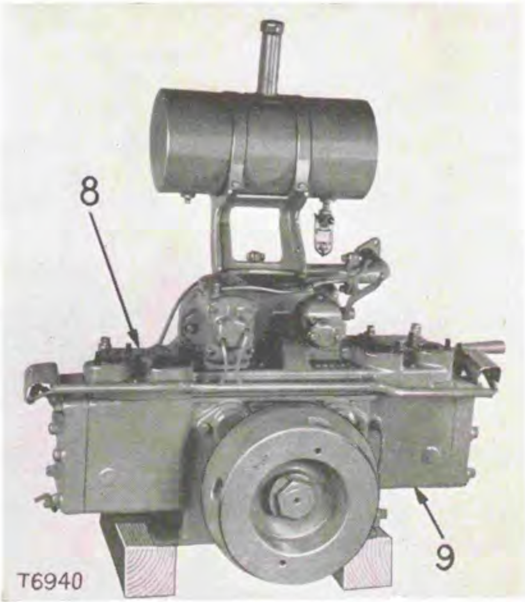
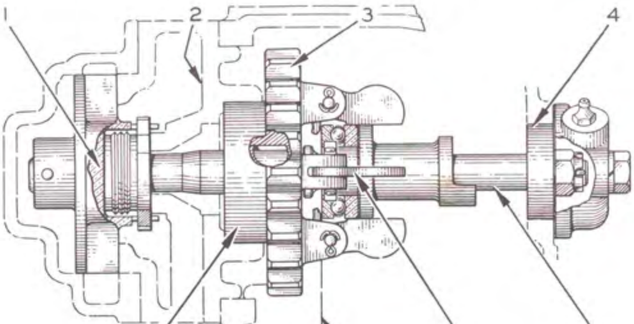


With a suitable hoist, remove the combined assemblies mounted on the top cover as a unit.

Accessory Shaft, Water Pump and Governor

The accessory shaft **(8)** is located in the top cover **(6)** and turns in the bearings **(4)** and **(5)**.

The water pump impeller **(1)** and the governor assembly **(7)** are mount ed on the accessory shaft so all three parts turn as a unit.



ACCESSORY SHAFT, WATER PUMP AND GOVERNOR (VIEW FROM LEFT SIDE)

1—Water pump impeller. 2—Water pump bearing cage. 3—Governor gear. 4—Bearing. 5—Bearing 6—Top cover. 7—Governor assembly. 8—Accessory shaft.

The governor drive gear **(3)** is driven by the camshaft gear and in turn drives the accessory shaft and the water pump impeller.

The accessory shaft must be removed from the top cover before the governor assembly **(7)** is accessible. It is possible however, to remove the water pump impeller with the accessory shaft in the top cover. See the topic, ACCESSORY SHAFT, WATER PUMP AND GOVERNOR DISASSEMBLY.

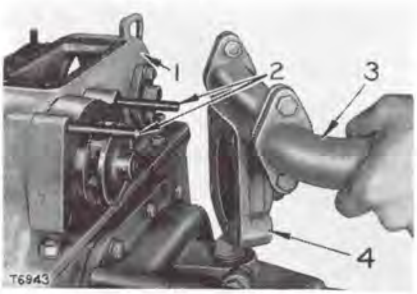
ACCESSORY SHAFT, WATER PUMP AND GOVERNOR REMOVAL

Remove the water pump body **(4)** with the water pipe **(3)** attached.

Disconnect the governor control lever **(5)** allowing the lever to drop back.

Remove the studs **(2)**.

The accessory shaft assembly (including the governor assembly) can be lowered enough, as it is removed from the top cover **(1)**, for the small bearing to clear the governor control fork.



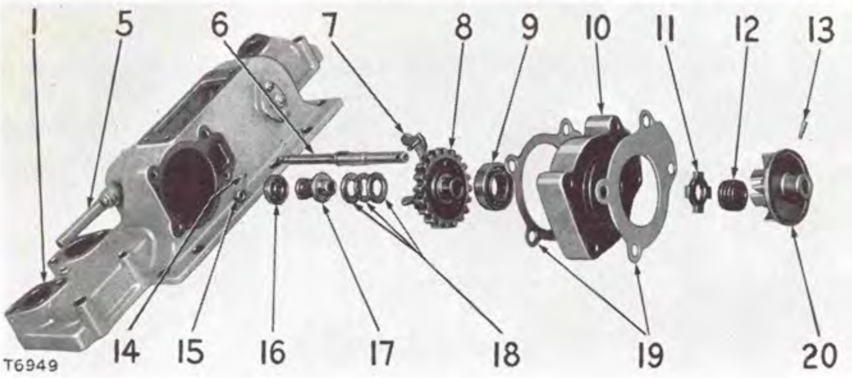
REMOVING THE WATER PUMP BODY
1—Top cover. 2—Studs. 3—Water pipe. 4—Water pump body.

ACCESSORY SHAFT, WATER PUMP AND GOVERNOR REMOVAL
1—Top cover. 5—Governor control lever.

ACCESSORY SHAFT, WATER PUMP AND GOVERNOR DISASSEMBLY

With the governor control lever **(5)** attached to the top cover **(1)** remove the accessory shaft assembly as described in the topic, ACCESSORY SHAFT, WATER PUMP AND GOVERNOR REMOVAL.

Remove the following from the small end of the accessory shaft **(6)**: the cotter pin **(14)**, the nut **(15)**, the bearing **(16)** and the sleeve **(17)** with the thrust bearing **(18)** installed.



ACCESSORY SHAFT, WATER PUMP AND GOVERNOR DISASSEMBLY
(Top cover shown removed for illustration only)
1—Top cover. 5—Governor control lever. 6—Accessory shaft. 7—Weight. 8—Governor drive gear. 9—Bearing. 10—Bearing cage. 11—Carbon thrust washer. 12—Bellows assembly. 13—Taper pin. 14—Cotter pin. 15—Nut. 16—Bearing. 17—Sleeve. 18—Thrust bearing. 19—Gaskets. 20—Impeller.

Remove the thrust bearing **(18)** from the sleeve **(17)**.

Remove the weights **(7)**.

To permit removal of the governor drive gear **(8)**, the bearing **(9)** or of the bearing cage **(10)**, the water pump must first be disassembled.

Remove the taper pin **(13)**, the impeller **(20)**, the carbon thrust washer **(11)**, the bellows assembly **(12)** and the bearing cage **(10)**.

When driving the taper pin out of the impeller **(20)**, support the end of the accessory shaft **(6)** as illustrated to prevent bending the shaft.

Remove the gear **(8)** from the accessory shaft **(6)** using the 8B7549 Puller as illustrated.

REMOVING TAPER PIN

6—Accessory shaft. 8—Governor drive gear. 10—Bearing cage. 20—Impeller.

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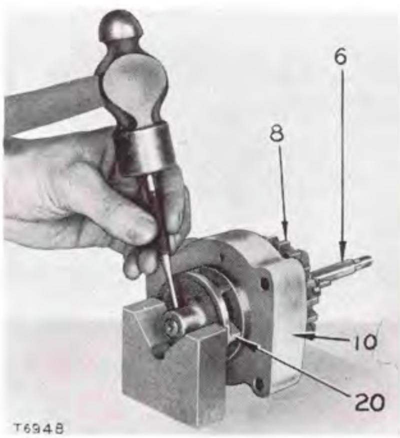

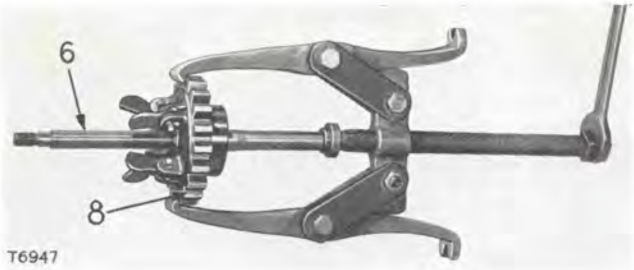

PULLING GOVERNOR DRIVE GEAR

6—Accessory shaft.
8—Governor drive gear.

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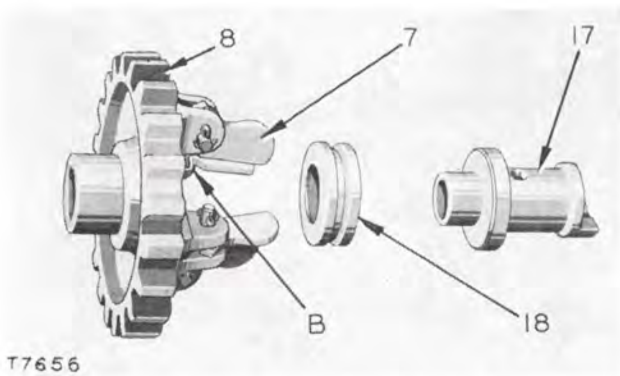
GOVERNOR OPERATION

The governor gear **(8)**, mounted on the accessory shaft, is driven by the camshaft gear.

Centrifugal force moves the weights **(7)** out, causing point **(B)** to move the bearing **(18)** and the sleeve **(17)** away from the gear **(8)**.

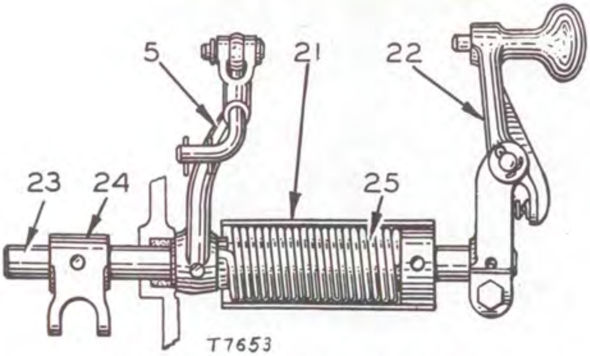


GOVERNOR WEIGHT OPERATION
B—Thrust point of weight. 7—Weight. 8—Governor gear. 17—Sleeve. 18—Bearing.

The sleeve presses against the yoke **(24)**, which is pinned to the shaft **(23)**, and thus moves the governor control lever **(5)** (also pinned to the shaft) in opposition to the tension in the spring **(25)** when the lever **(22)** is in high idle position.

The movement of the governor control lever is transmitted to the carburetor throttle shutter by means of the rod connecting the two.

When the lever **(22)** is moved to the low idle position the tension on the spring **(25)** is released and the governor now holds the carburetor throttle shutter closed against the set screw rather than trying to close it against the spring tension.



GOVERNOR CONTROL MECHANISM
5—Governor control lever. 21—Sleeve. 22—Lever. 23—Shaft. 24—Yoke. 25—Spring.

GOVERNOR CONTROL LOCATION
5—Governor control lever. 21—Sleeve.
22—Lever.

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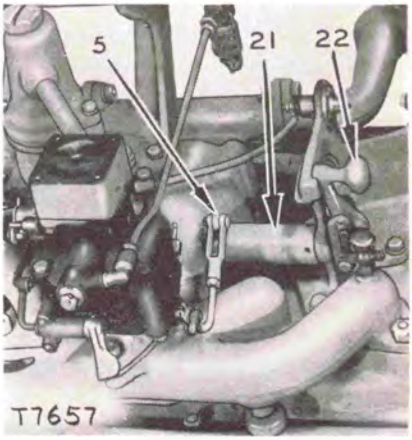


Low Idle Speed

The low idle speed of the engine is adjusted by the idling speed adjusting screw on the carburetor. Turning the screw in or out will adjust the low idle speed to the desired setting. See the topic, IDLING JET.

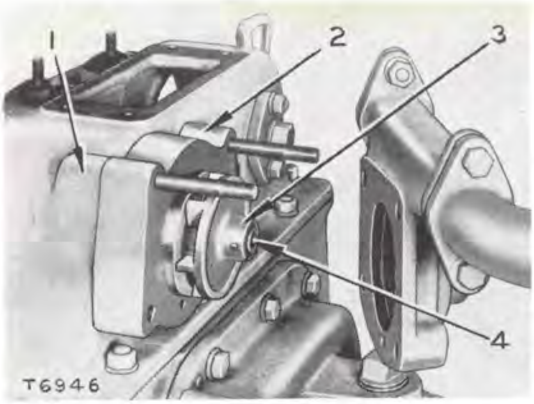
High Idle Speed

To change the tension on the governor spring, remove the cotter pin from the control rod connecting the governor control lever **(5)** and the carburetor throttle shutter. Then lengthen or shorten the control rod as necessary, locking in place by means of the lock nut provided.

The control rod should be adjusted to permit the engine to operate at the high idle speed of 3350 RPM. This can be checked by the use of a hand tachometer, checking off the flywheel end of the crankshaft.

WATER PUMP OPERATION

The water pump impeller **(3)** is mounted on, and driven by the accessory shaft **(4)**. The accessory shaft locates in the top cover **(1)** and the water pump bearing cage **(2)**.



WATER PUMP
1—Top cover. 2—Water pump bearing cage. 3—Water pump impeller. 4—Accessory shaft.

The water pump delivers the coolant from the starting engine into the Diesel engine water manifold. The starting engine and the Diesel engine cooling systems are interconnected. See the topics, DIESEL ENGINE COOLING SYSTEM (D17000L-E-I) and DIESEL ENGINE COOLING SYSTEM (D17000M) for further details.

For the removal and disassembly of the water pump, see the topics, ACCESSORY SHAFT, WATER PUMP AND GOVERNOR REMOVAL and ACCESSORY SHAFT, WATER PUMP AND GOVERNOR DISASSEMBLY. Also see the topic, TOP COVER.

ACCESSORY SHAFT, WATER PUMP AND GOVERNOR ASSEMBLY

Governor Assembly

Install the governor drive gear before the water pump as it assembles over the water pump end of the shaft.

Install the parts on the small end of the shaft in the reverse order of disassembly.

The sleeve assembly thrust bearing faces the gear.

Weights must move freely on the pins after assembly.

Water Pump Assembly

Clean and inspect all parts and install a new bellows seal **(3)** and carbon washer **(4)**.

Clean the drain hole **(2)** before assembling to permit water to drain out should the seal fail. Otherwise the water may enter the lubricating system

The thrust surface of the bearing cage **(1)** must be smooth so that the new carbon washer **(4)** will not be damaged.

WATER PUMP ASSEMBLY

1—Thrust surface of bearing cage. 2—Drain hole. 3—Bellows seal assembly. 4—Carbon washer.

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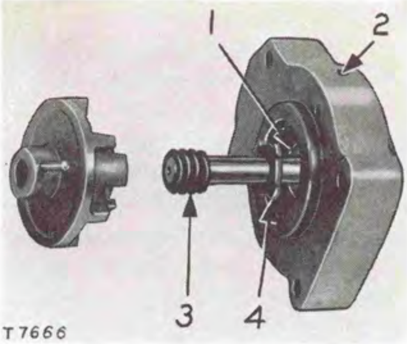


Magneto Drive Gear

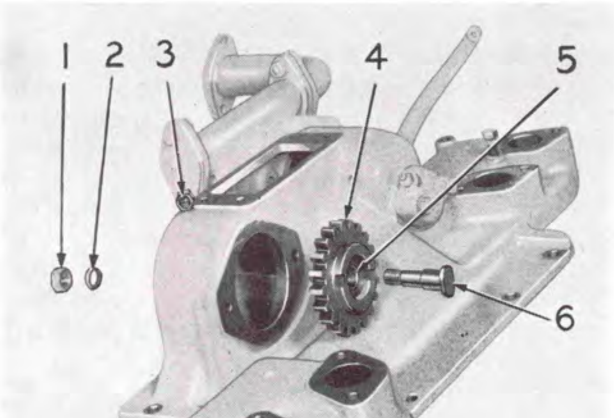
MAGNETO DRIVE GEAR REMOVAL

Remove the top cover **(7)** as described in the topic, TOP COVER REMOVAL.

Remove the magneto in accordance with the topic, MAGNETO REMOVAL.

Remove the nut **(1)** and lockwasher **(2)**, the shaft **(6)**, and remove the gear **(4)** through the bottom opening of the top cover **(7)**.

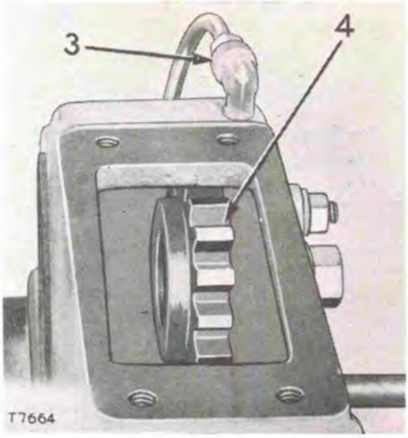
Clean and inspect the bushing **(5)** for excessive wear.



REMOVING MAGNETO DRIVE GEAR
1—Nut. 2—Lockwasher. 3—Elbow fitting. 4—Magneto drive gear. 5—Bushing. 6—Shaft. 7—Top cover.

LUBRICATION OF THE MAGNETO DRIVE GEAR (VIEW LOOKING THROUGH OIL FILLER OPENING)

3—Elbow fitting. 4—Magneto drive gear.



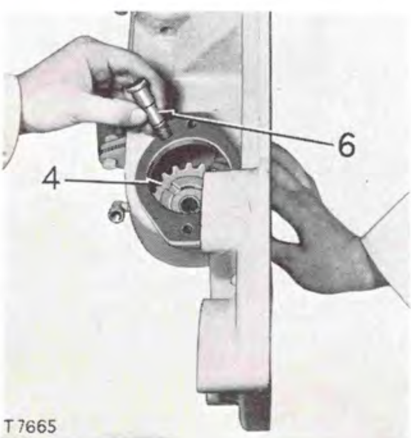
The magneto drive gear **(4)** is pressure-lubricated by oil delivered through the elbow fitting **(3)** from a pressure line connected directly to the oil pump.

MAGNETO DRIVE GEAR ASSEMBLY

Insert the gear **(4)** through the bottom opening of the top cover and install the shaft **(6)** as illustrated.

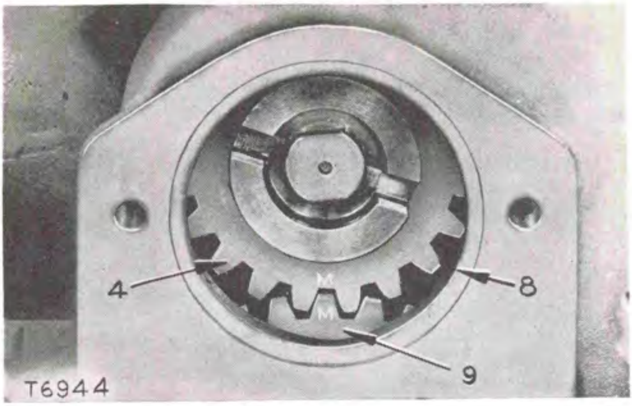
Install lockwasher and nut.

When installing the top cover to the cylinder block, check through the magneto opening **(8)** to align the timing mark **(M)** on the magneto drive gear **(4)** with the timing mark **(M)** on the camshaft gear **(9)** as the top cover is lowered into place.



ASSEMBLING MAGNETO DRIVE GEAR

4—Magneto drive gear. 6—Shaft.

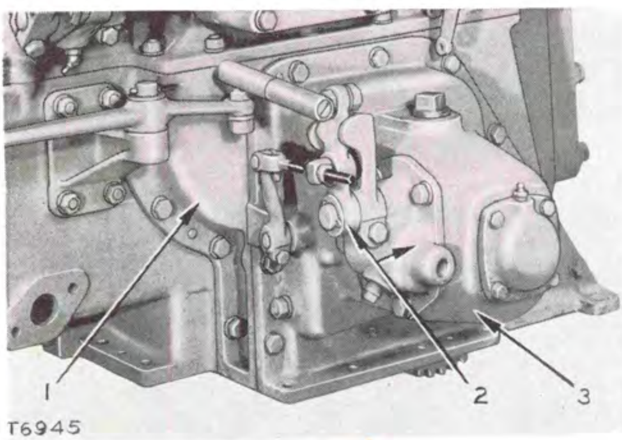


ALIGNING MAGNETO DRIVE GEAR TIMING MARKS
4—Magneto gear. 8—Magneto opening. 9—Camshaft gear.

Clutch

CLUTCH HOUSING

The clutch housing **(3)** is dowelled to the timing gear cover **(1)** which is mounted on the rear of the starting engine. The clutch and brake assemblies are located within the clutch housing and the clutch and brake control mechanism **(2)** is mounted on the clutch housing.



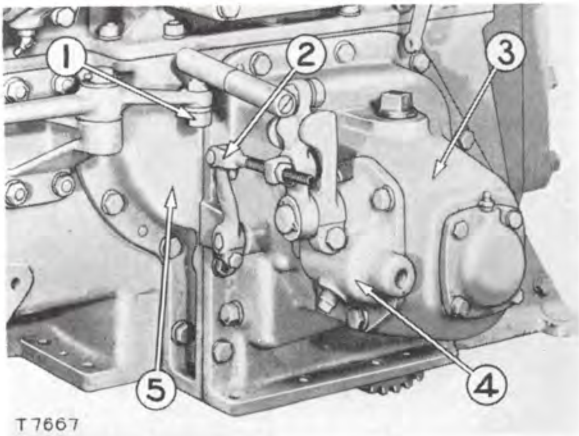
CLUTCH HOUSING
1—Timing gear cover. 2—Clutch and brake control mechanism. 3—Clutch housing.

Clutch Housing Removal and Installation

To remove the clutch housing **(3)**:

Disconnect the clutch control mechanism at **(1)**.

Disconnect the brake band lever at **(2)**.



CLUTCH HOUSING REMOVAL AND INSTALLATION

1—Point of disconnecting clutch control mechanism. 2—Point of disconnecting brake band lever. 3—Clutch housing. 4—Yoke housing assembly. 5—Timing gear cover.

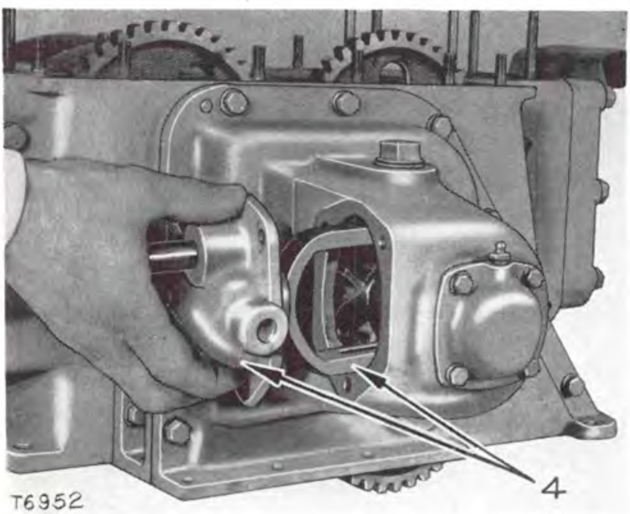
Remove the capscrews holding the yoke housing assembly **(4)** to the clutch housing.

Remove the yoke housing assembly **(4)** as illustrated.

Remove the capscrews and bolts holding the clutch housing **(3)** to the timing gear cover **(5)**.

Remove the clutch housing.

Before installing the clutch housing, clean all parts, check the clutch brake band for wear. See the topic, CLUTCH AND CLUTCH BRAKE REMOVAL AND INSTALLATION.



YOKE HOUSING REMOVAL

4—Yoke housing assembly.

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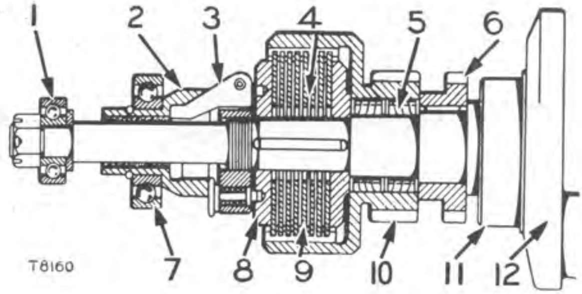
CLUTCH AND CLUTCH BRAKE OPERATION

The clutch is of the multiple-disc wet-type and is mounted directly onto the crankshaft **(12)** next to the crankshaft gear **(6)**. It is supported by the main bearing **(11)** and the bearing **(1)** pressed on the end of the crankshaft and located in the clutch housing.

The clutch operates as follows: When the clutch lever is moved to engage the clutch, it transmits the action through the yoke to the bearing **(7)** and the collar assembly **(2)**. The internal cone of the collar actuates the fingers **(3)** creating pressure on the adjusting pressure plate **(8)**, thus compressing the discs and engaging the clutch. The driven discs **(9)** directly drive the drum and gear **(10)**. When the clutch is disengaged, the shaft (and the drive discs **(4)** which are keyed to it) rotate freely in the bearing **(1)** and the rear main bearing **(11)**, the gear and the driven discs remain stationary.

When the clutch control lever is released, neither the brake or the clutch is actuated. If the lever is moved farther in the released direction, it applies the brake stopping the clutch drum and gear from rotating to permit the starter pinion to be engaged while the starting engine is running.

The clutch drum and gear **(10)** are integral and rotate on the bearing **(5)**. The drum has internal teeth which mesh with the teeth in the driven discs **(9)**. The machined outer surface serves as a drum for the brake band. The gear section of this part drives the clutch idle gear which drives the starter pinion assembly. See the topic, STARTER PINION.



CLUTCH

1—Bearing. 2—Collar assembly. 3—Finger. 4—Drive disc. 5—Bearing. 6—Crankshaft gear. 7—Bearing. 8—Adjusting pressure plate. 9—Driven disc. 10—Drum and gear. 11—Crankshaft main bearing. 12—Crankshaft.

CLUTCH AND CLUTCH BRAKE REMOVAL AND INSTALLATION

Remove the clutch housing. See the topic, CLUTCH HOUSING REMOVAL AND INSTALLATION.

The clutch brake **(6)** is removed from the clutch housing by removing the nut **(5)** and rotating the brake band **(6)** away from the shaft **(4)**.

To disassemble the clutch, remove the cotter pin and the castellated nut **(7)**.

Pull the bearing **(3)**, using the 8B7546 Puller.

Remove the spacer (not shown) and the collar assembly **(2)**.

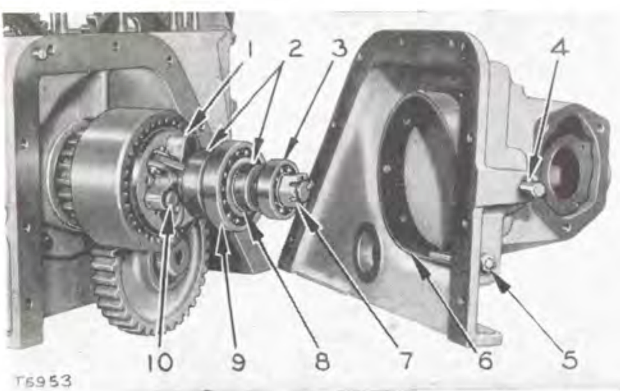
The snap ring **(8)** holds the bearing **(9)** on the collar **(2)**.

To remove the spider **(1)**, pull out the spider lock pin **(10)** and turn the spider counterclockwise away from the adjusting pressure plate directly behind it.

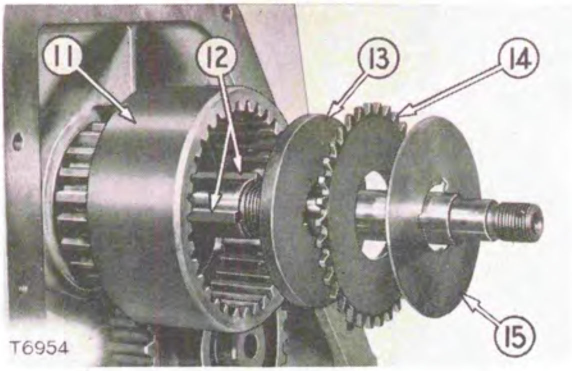
Remove the adjusting pressure plate, the clutch drum and gear **(11)**, the driven discs **(14)** and the drive discs **(15)**.

Remove the drive keys **(12)** and the clutch gear bearings. Replace any worn parts.

Assemble in reverse order of removal. The driven discs **(14)** are assembled alternately with the drive discs **(15)**, starting with a driven disc **(14)** next to the pressure plate **(13)** as illustrated.



CLUTCH AND CLUTCH BRAKE REMOVAL AND INSTALLATION
1—Spider. 2—Collar. 3—Bearing. 4—Shaft. 5—Nut. 6—Brake band. 7—Cotter pin and nut. 8—Snap ring. 9—Bearing. 10—Lock pin.



CLUTCH ASSEMBLY
11—Clutch drum and gear. 12—Key. 13—Pressure plate. 14—Driven disc. 15—Drive disc.

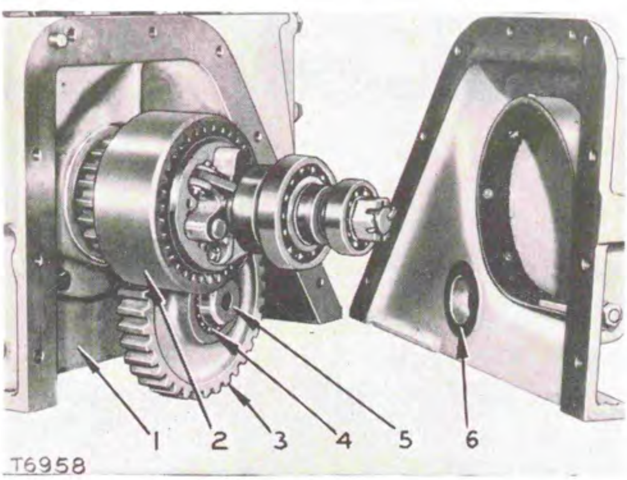
CLUTCH IDLER GEAR AND SHAFT

The clutch idler gear shaft **(5)** is a press fit into the cylinder block **(1)** and a slip fit into the clutch housing bore in the machined boss **(6)**.

The roller bearings **(4)** and the clutch idler gear **(3)** locate on the idler gear shaft.

The machined boss **(6)** of the clutch housing limits the end clearance of the idler gear.

To facilitate the idler gear removal, first remove the clutch assembly **(2)**. See the topic, CLUTCH AND CLUTCH BRAKE REMOVAL AND INSTALLATION.



CLUTCH IDLER GEAR AND SHAFT LOCATION
1—Cylinder block. 2—Clutch assembly. 3—Clutch idler gear. 4—Roller bearings. 5—Clutch idler gear shaft. 6—Machined boss (clutch housing).

Remove the idler gear and bearings.

The clutch housing is splash-lubricated. See the topic, STARTER PINION LUBRICATION.

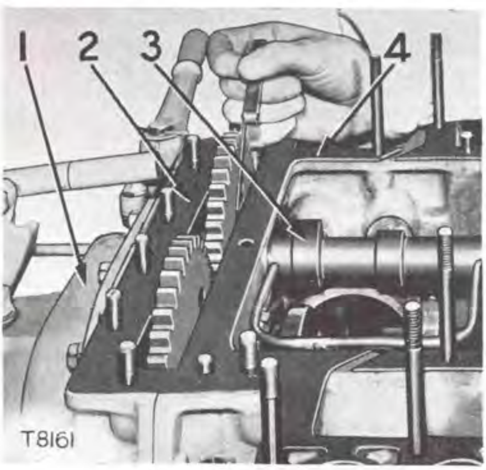
Timing Gears

TIMING GEAR HOUSING

The timing gear housing **(2)** is mounted between the cylinder block **(4)** and the clutch housing **(1)**.

Machined bosses inside the timing gear housing limit the end clearance of the camshafts **(3)**. The end clearance should be .011″ to .018″.

Check the end clearance with a feeler gauge between the gear and the machined face of the cylinder block as shown.



CHECKING TIMING GEAR END CLEARANCE

1—Clutch housing. 2—Timing gear housing. 3—Camshaft. 4—Cylinder block.

TIMING GEAR HOUSING REMOVAL AND INSTALLATION

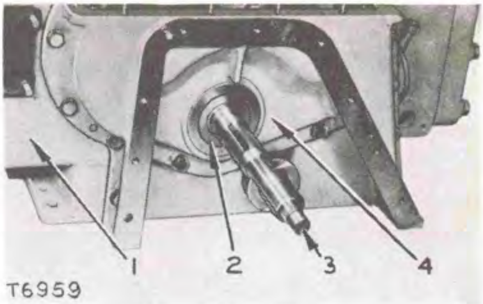
To permit timing gear housing removal, remove the following as described in their respective topics: top cover, clutch housing, clutch and clutch idler gear.

Remove the capscrews holding the timing gear housing **(4)** to the cylinder block **(1)** and remove the timing gear housing.

When installing the timing gear housing, wash all parts, install new gaskets and a new seal **(2)** on the crankshaft **(3)**. The lip of the seal should face the crankshaft throws.

TIMING GEAR HOUSING REMOVAL

1—Cylinder block. 2—Seal. 3—Crankshaft. 4—Timing gear housing.



TIMING THE GEARS

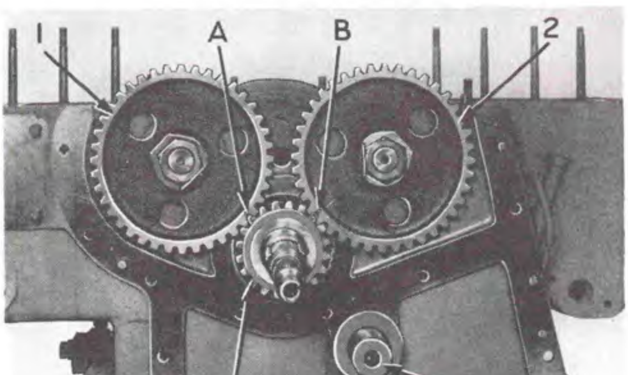
If either camshaft gears **(1)** or **(2)**, or the crankshaft gear **(3)** are removed, the timing marks must be aligned as the gears are replaced.

Align the teeth marked "C" on the camshaft gears with the C-mark on the crankshaft gear. The camshaft gear **(1)** is timed to the crankshaft gear at **(A)** and the camshaft gear **(2)** is timed to the crankshaft gear at **(B)**.

NOTE

> The clutch idler gear (not shown) mounts on the clutch idler gear shaft **(4)**. This gear is driven by the clutch drive gear which is mounted on the crankshaft. These two gears are not timed.

The camshaft gear **(2)** drives the magneto and is timed to it. See the topic, MAGNETO. The timing mark "M" is located on the rear side of the camshaft gear **(2)**.



TIMING GEARS

A—Timing marks, camshaft gear (1) and crankshaft gear (3). B—Timing marks, camshaft gear (2) and crankshaft gear (3). 1—Camshaft gear. 2—Camshaft gear. 3—Crankshaft gear. 4—Clutch idler gear shaft.

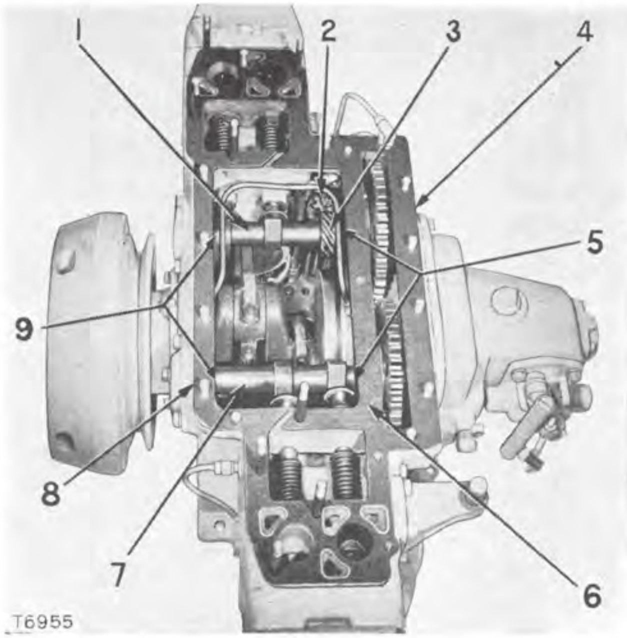
Camshafts

The starting engine has two camshafts **(1)** and **(7)** which rotate in opposite directions and are driven by the crankshaft gear. The camshafts rotate in the bushings **(9)** located in the rear of the cylinder block **(8)** and the bushings **(5)** located in the front of the cylinder block **(6)**. These bushings can be replaced if necessary.

End clearance of the camshaft is limited by the bosses on the inside of the timing gear housing **(4)**.

The helical gear **(3)**, an integral part of the left camshaft **(1)**, is used to drive the oil pump **(2)**. See the topic, OIL PUMP.

The camshaft front bearing journal diameter is 2.2455"-2.2465" and a bearing clearance of .0025"-.0045" is provided. The rear bearing journal diameter is 1.496"-1.497" and the bearing clearance is .002"-.004".



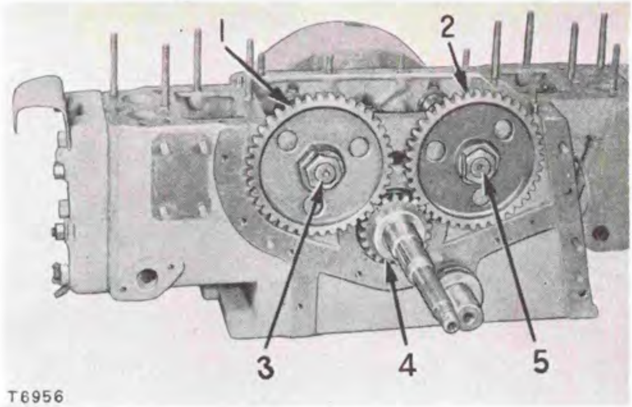
CAMSHAFTS

1—Left camshaft. 2—Oil pump. 3—Helical gear (machined integral with the camshaft). 4—Timing gear housing. 5—Bushings. 6—Front of cylinder block. 7—Right camshaft. 8—Rear of cylinder block. 9—Bushings.

CAMSHAFT REMOVAL AND INSTALLATION

To remove the camshafts remove the timing gear housing as described in the topic, TIMING GEAR HOUSING REMOVAL AND INSTALLATION.

Remove the camshaft **(5)** and camshaft gear **(2)** together, by pulling them out by hand enough to clear the camshaft gear from the crankshaft gear **(4)**.



CAMSHAFTS AND CAMSHAFT GEARS
1—Camshaft gear. 2—Camshaft gear. 3—Camshaft. 4—Crankshaft gear. 5—Camshaft.

Rotate the camshaft to position the camshaft lobes to clear the lifter assemblies.

Care must be used during the removal and installation of the camshaft to avoid damage to the bushings.

The camshaft **(3)** and the gear **(1)** are removed and installed in the same manner.

The camshaft gears are timed to the crankshaft gear. See the topic, TIMING THE GEARS.

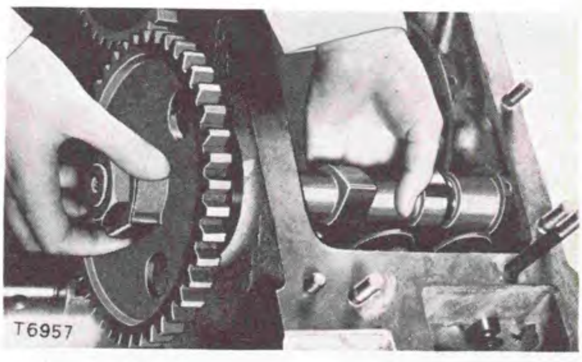
Check the end clearance as described in the topic, TIMING GEAR HOUSING.

NOTE

Each camshaft has two lobes and by rotating the camshaft, it is possible to position the lobes away from the lifters. This is also the correct position of the camshaft lobes for adjusting valve clearance. See the topic, VALVE CLEARANCE ADJUSTMENT.

REMOVING CAMSHAFT

◆



Flywheel

The flywheel is keyed to, and locked on, the tapered end of the crankshaft. It is machined on all surfaces to assure balance. Some models have a V-belt groove for attachments that may be installed.

FLYWHEEL REMOVAL AND INSTALLATION

Remove the nut and lock holding the flywheel to the crankshaft.

Pull the flywheel **(1)** using the 8B7548 Push Puller with 8B7550 Legs and the 8B7559 Adapter. Use the L1774 Centering Spacer to prevent damage to the crankshaft.

CAUTION

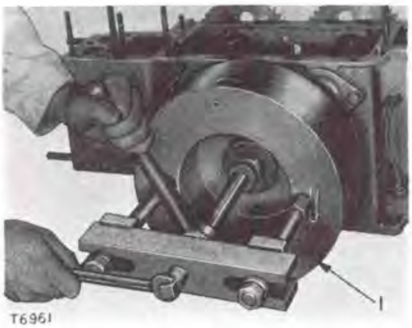
> Support the flywheel so that it will not slip from the tapered end of the crankshaft and cause personal injury.

Remove the woodruff key.

When installing the flywheel, install the woodruff key in the crankshaft.

Place the flywheel on the crankshaft (it can be installed in only one position). A slight tap on the flywheel will assist the flywheel to go onto the tapered crankshaft.

Install the lock and the nut, tighten securely and lock.



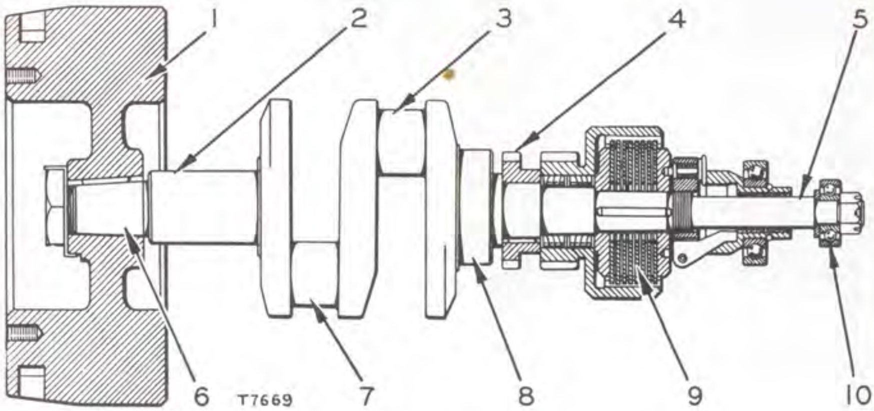
PULLING FLYWHEEL

1—Flywheel.

◆

Crankshaft

This starting engine has a single-piece drop-forged crankshaft. The correct measurements for a standard crankshaft are as follows: The rear main journal **(2)**, next to the flywheel **(1)**, is 2.875"-2.874". The front main journal **(8)** is 3.750"-3.749". The connecting rod journals **(3)** and **(7)** are 2.000"-1.999". The maximum journal out-of-roundness permissible is .003".



CRANKSHAFT

1—Flywheel. 2—Rear main journal. 3—No. 2 connecting rod journal. 4—Crankshaft drive gear. 5—Front end of the crankshaft. 6—Rear end of the crankshaft. 7—No. 1 connecting rod journal. 8—Front main journal. 9—Clutch assembly. 10—Bearing.

NOTE

For assembly and identification purposes, the flywheel end of the crankshaft is considered the rear end **(6)** of the crankshaft and the clutch is installed on the front end **(5)** of the crankshaft. The journal **(7)** is the No. 1 connecting rod journal, and the journal **(3)** is the No. 2 connecting rod journal.

The following parts are located on the front end **(5)** of the crankshaft: The crankshaft drive gear **(4)**, the clutch assembly **(9)** and the crankshaft end support bearing **(10)** (which is located in the clutch housing when installed).

The earlier crankshafts were entirely splash-lubricated and taper roller main bearings were used.

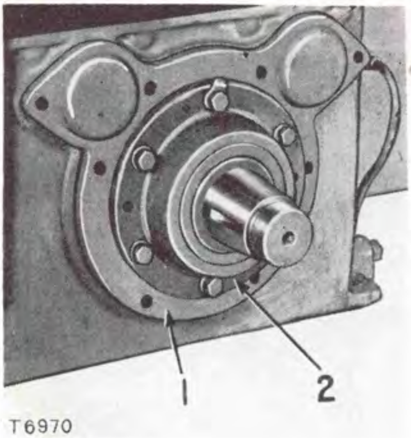
Later crankshafts used aluminum alloy main bearings and were drilled to allow for pressure oil to lubricate the connecting rods.

Still later crankshafts are not drilled and are pressure-lubricated to the main bearings only. The connecting rods are splash-lubricated and use oil scoops to assure lubrication.

A drilled crankshaft can be used in the latest system by installing plugs in the drilled holes.

CRANKSHAFT AND CRANKSHAFT GEAR REMOVAL

To remove the crankshaft, first remove the following assemblies as described in their respective topics: the top cover, the flywheel, the clutch, and the clutch idler gear.



REMOVING END COVER AND BEARING CAGE

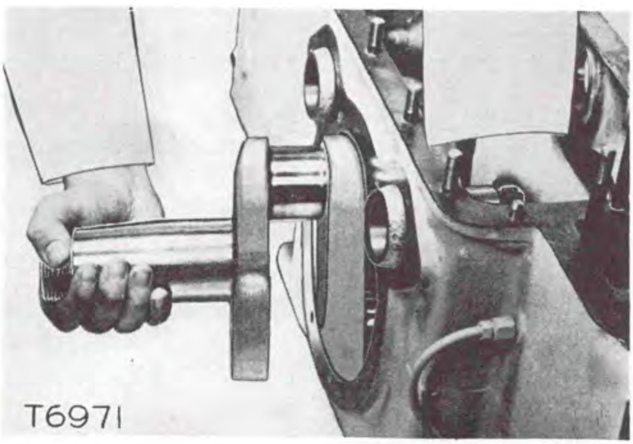
1—End cover. 2—Bearing cage.

◆

Remove the capscrews holding the end cover **(1)** to the cylinder block. Remove the end cover and the bearing cage **(2)** as a unit so that the shims between them are not disturbed.

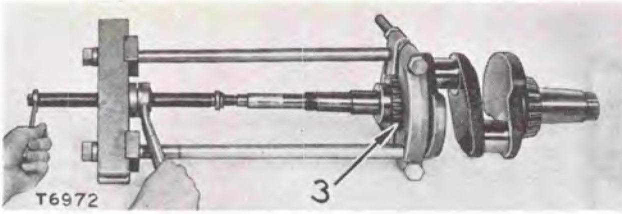
Disconnect the connecting rods and push the connecting rods away from the crankshaft.

Lift the crankshaft out by hand as shown.



CRANKSHAFT REMOVAL
(Aluminum Bearing Type)

To remove the crankshaft gear **(3)** as well as the bearing (taper bearing type) apply the 8B7548 Push Puller with the 8B7551 Adapter, the two 8B7549 Legs ($16\frac{1}{2}$ inches long) and centering spacer L1774 as illustrated.



REMOVING CRANKSHAFT DRIVE GEAR AND TAPER ROLLER MAIN BEARINGS
3—Crankshaft drive gear.

CRANKSHAFT INSTALLATION

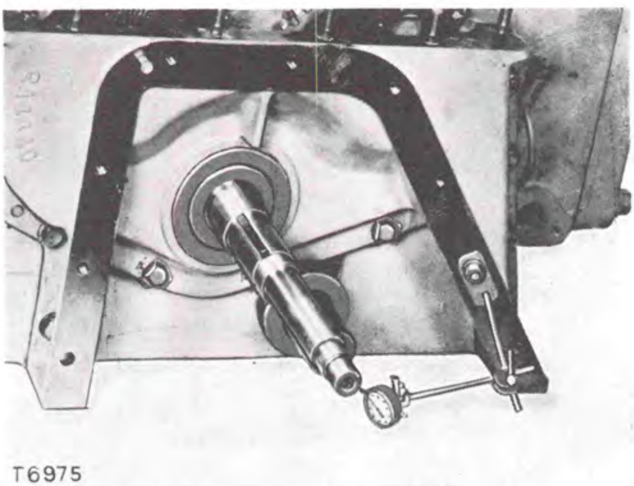
Insert the crankshaft into the cylinder block using shim stock as an aid to slide the clutch end of the crankshaft through the seal in the timing gear housing.

Place the end cover **(1)** and the bearing cage **(3)** over the end of the crankshaft, secure with capscrews and check the end clearance as shown. The proper end clearance for aluminum bearings is .010″ to .018″ with a maximum clearance of .025″.

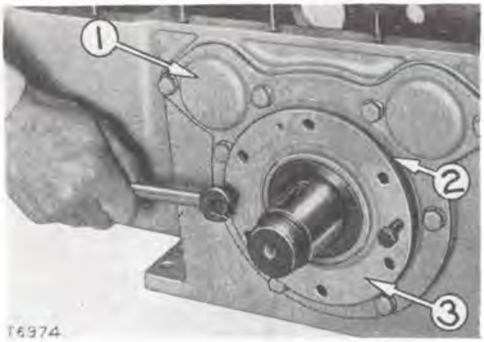
The end clearance can be checked after assembly by mounting an indicator as illustrated and prying the crankshaft endwise.

Adjustments are made by adding or removing shims **(2)** between the bearing cage **(3)** and the cover **(1)**. Adding shims increases the end clearance and removing shims decreases the end clearance.

Remove the bearing cage to make this adjustment. Remove the capscrews from the flange of the bearing cage. Use two capscrews in the tapped holes of the bearing cage as puller screws to force the bearing cage off.



CHECKING CRANKSHAFT END CLEARANCE



REMOVING BEARING CAGE FOR ADJUSTMENT

1—End cover. 2—Shims. 3—Bearing cage.

◆

Remove or install the shims necessary to obtain the correct adjustment.

In starting engines with aluminum main bearings the top capscrew hole in the rear main bearing cage flange intersects the oil passage. The correct choice of capscrews is important during assembly because a long capscrew in this hole can reduce oil flow to the rear main bearing. The correct capscrew is 1″ long. A copper gasket is used under the capscrew to prevent oil leakage, and a metal lock secures the capscrew.

NOTE

> The same method of adjustment is used in the older model starting engines having the taper roller main bearings. The proper end clearance is .0005″-.002″. Rotate the crankshaft by hand, before assembling the connecting rods. It must move freely.

MAIN BEARINGS (ALUMINUM)

The main bearings are of the single-piece type and are made of aluminum alloy. The front main bearing **(5)** locates in the cylinder block **(1)** and the rear main bearing **(2)** locates in the bearing cage **(3)**, when installed.

The proper clearance between the crankshaft and the front main bearing is .007″ to .011″. The clearance between the crankshaft and the rear main bearing is .006″ to .010″.

The maximum permissible bearing clearance is .017″.

Earlier models were equipped with a tapered roller bearing, which is replaceable by an aluminum main bearing changeover group.

Removal

Remove the crankshaft **(4)** as described in the topic, CRANKSHAFT REMOVAL.

Press the front main bearing **(5)** from the crankcase **(1)**.

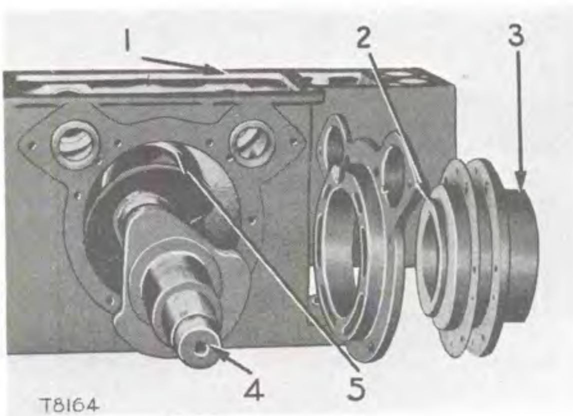
Press the rear main bearing **(2)** from the bearing cage **(3)**.

Installation

Apply a lubricant to the outside of the new bearings and install with a suitable press.

NOTE

When new bearings are installed, check the crankshaft end clearance as described in the topic, CRANKSHAFT INSTALLATION, and adjust accordingly.



MAIN BEARINGS (ALUMINUM)
1—Crankcase. 2—Rear main bearing. 3—Bearing cage. 4—Crankshaft. 5—Front main bearing.

MAIN BEARINGS (TAPER ROLLER)

Taper roller bearings were used in the earlier models. One bearing race was located in the block and the other in the bearing cage.

Removal

Remove the crankshaft. See the topic, CRANKSHAFT AND CRANKSHAFT GEAR REMOVAL. With the 8B7548 Push Puller, the 8B7551 Bearing Pulling Attachment, the two 8B7549 Legs and the centering spacer L1774, pull the crankshaft drive gear and one bearing. Use the same tools with the $9\frac{1}{2}''$ legs for the other bearing.

Installation

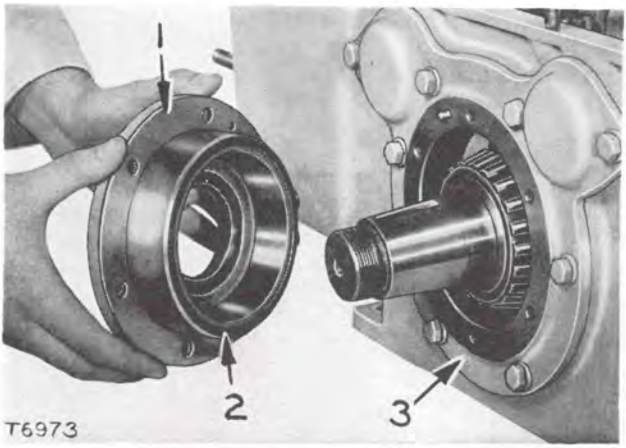
The taper roller cones are pressed onto the crankshaft with the small diameter toward its respective end of the crankshaft, as illustrated.

NOTE

The tapered cups **(2)** are pressed in the cylinder block and bearing cage **(1)** with the large opening of the bearing cup toward the cover **(3)**, as illustrated.

The methods of installing, adjusting, and checking the taper roller type bearings are the same as the aluminum type bearings.

The end clearance is .0005″ to .002″. See the note on CRANKSHAFT INSTALLATION.



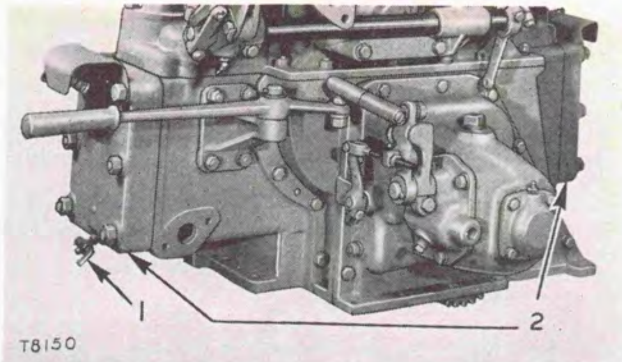
MAIN BEARING INSTALLATION (TAPER ROLLER)
1—Bearing cage. 2—Tapered roller bearing cup. 3—Cover.

Cylinder Heads

The starting engine cylinder heads **(2)** are provided with drain cocks **(1)**. These cocks can be used to drain condensation or excess gasoline from the cylinder when it is flooded.

When they are open, the compression is released from the cylinder.

The cylinder head gasket provides both a compression seal and a water seal.



CYLINDER HEADS
1—Drain cock. 2—Cylinder heads.

CYLINDER HEAD REMOVAL

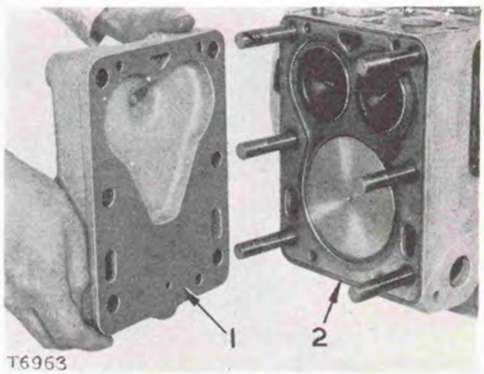
Drain the coolant.

Disconnect the ignition wire from the spark plug and remove the guard.

Remove the nuts and the cylinder head **(1)**, taking care not to damage the gasket **(2)**.

CYLINDER HEAD REMOVAL
1—Cylinder head. 2—Gasket.

◆



CYLINDER HEAD INSTALLATION

Clean the carbon from the heads and inspect all parts.

Position the gasket on the studs properly.

Install the cylinder head, the guard and the nuts.

Tighten the nuts securely and uniformly to the torque specifications 960 lb. in.

Connect the spark plug wire.

Valves and Valve Mechanism

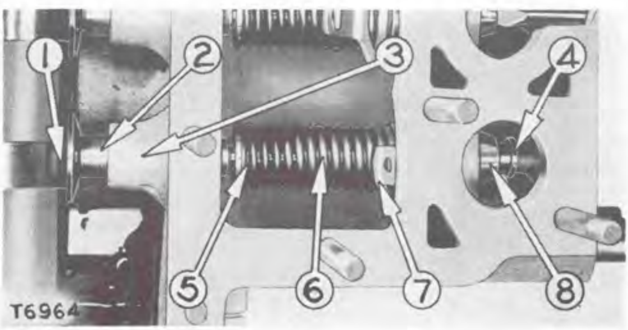
Compression pressure losses occur when the valve faces and seats become pitted. Valves should be checked occasionally to see that they are seating properly. This may be done by rocking the starting engine against compression. If the cylinder head gaskets and piston rings are in good condition and the engine does not "rock back" against compression, it is likely that the valves and seats should be refaced and reground.

The camshaft lobe **(1)** operates the lifter **(2)** which moves in and out in a bore machined in the cylinder block **(3)**.

The valve **(4)** is lifted from its seat by the lifter **(2)** and is returned by the spring **(6)**. The valve is guided by the valve stem bushing **(8)** which is replaceable. The valve spring has a pressure of 54 to 60 pounds when compressed to 2¾ inches.

The valve stem bushing retainer **(7)** holds the valve assembly in the cylinder block.

The retainer **(5)** and locks secure the valve, the valve stem bushing and the spring together, forming the valve assembly.

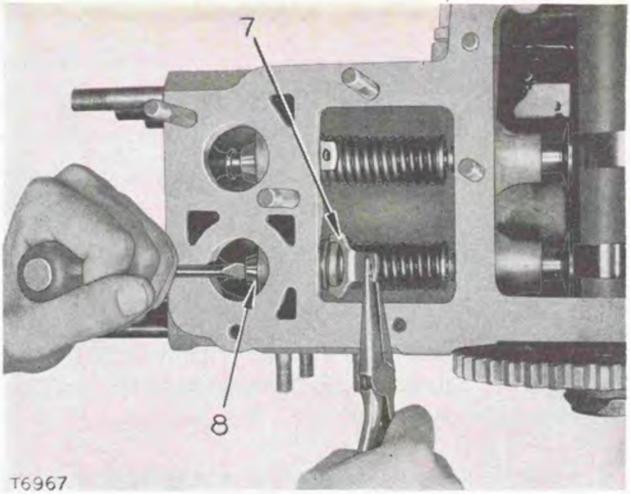


VALVE AND VALVE MECHANISM
1—Camshaft lobe. 2—Lifter. 3—Cylinder block. 4—Valve. 5—Retainer. 6—Spring. 7—Valve stem bushing retainer. 8—Valve stem bushing.

VALVE AND VALVE MECHANISM REMOVAL AND DISASSEMBLY

Remove the top cover, the top cover gasket and the cylinder heads. See the topics, TOP COVER REMOVAL and CYLINDER HEAD REMOVAL.

To remove the valve mechanism, place a screwdriver in the valve port opening and pry against the valve stem bushing **(8)** toward the camshaft and lift out the valve stem bushing retainer **(7)** as illustrated.



REMOVING VALVE STEM BUSHING RETAINER
7—Valve stem bushing retainer. 8—Valve stem bushing.

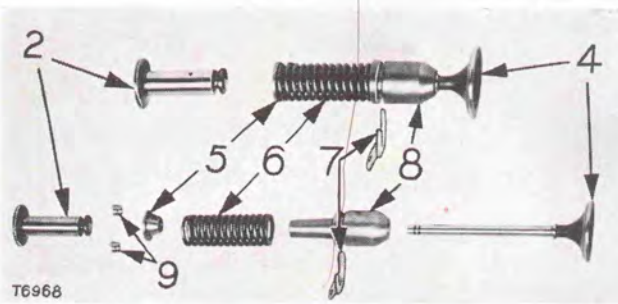
Remove the valve **(4)**, the valve stem bushing **(8)**, the spring **(6)**, the retainer **(5)** and the locks **(9)** as a unit by sliding them out away from the valve lifter **(2)**.

Press down on the retainer **(5)** to compress the valve spring and remove the locks **(9)**, after which the parts of the valve assembly can be separated.

The valve lifters **(2)** can be removed after taking out the camshaft as described in the topic, CAMSHAFT REMOVAL AND INSTALLATION.

Valve stem to bushing clearances are:

	New Clearance	Wear Limits
Inlet	.0015″-.003″	.005″
Exhaust	.003″ -.005″	.007″



VALVE ASSEMBLY REMOVED AND DISASSEMBLED
2—Lifter. 4—Valve. 5—Retainer. 6—Spring. 7—Valve stem bushing retainer. 8—Valve stem bushing. 9—Locks.

These clearances are obtained with a new valve.

The faces of the valves should always be inspected and refaced if necessary. If the faces are pitted or warped, the valves may need to be replaced.

The valve seats in the cylinder block should be inspected, reconditioned if necessary, and checked as outlined in the Diesel engine section.

VALVE MECHANISM ASSEMBLY

Carefully clean the parts of the valve mechanism and reassemble in the reverse order of disassembly. Be sure the locks are correctly installed in the lock retainer. Installation can be facilitated by coating the inside of the locks with heavy grease.

VALVE CLEARANCE ADJUSTMENT

The clearance between the inlet and exhaust valve lifters and the base circle of the cam on the camshaft should be .007″ to .010″ when the engine is cold. The adjustment should be made by grinding the end of the valve stem as required to obtain the proper clearance. Check the clearance with a feeler gauge as shown.

CHECKING VALVE CLEARANCE

Pistons, Rings and Connecting Rods

CONNECTING ROD BEARINGS

The starting engine connecting rod has replaceable, precision, babbitt-lined bearing shells, machined to provide proper clearance.

These bearings do not require fitting, scraping, reaming or filing.

The clearance between the connecting rod bearings and the crankshaft is .0025″ to .0043″ with a maximum of .009″.

CONNECTING ROD BEARING REMOVAL

Remove the top cover. See the topic, TOP COVER REMOVAL.

Remove the cotter pins, nuts, oil scoops and bolts from the connecting rod bearing caps and remove the caps from the connecting rods.

Rotate the crankshaft to push the pistons and the connecting rods far enough into the cylinder so the bearing shells clear the crankshaft sufficiently to allow their removal from the connecting rod.

Remove the bearing shells from the connecting rod bearing caps.

CONNECTING ROD BEARING ASSEMBLY

Clean and inspect all parts. Check them in accordance with information contained in the topic, SPECIFICATIONS.

The connecting rod bearings are lubricated by oil picked up by the scoops (mounted on the connecting rods) and forced through the holes **(3)** drilled in the bearing caps and the connecting rods to the bearings.

CAUTION

The oil scoops and bearing shells with the oil grooves are installed in different positions on each connecting rod. Follow these instructions and the illustration carefully to insure proper lubrication to the connecting rod bearings.

When replacing the bearing shells, see that the protruding portion on the back of each shell lines up with its corresponding groove in the connecting rod and the bearing cap. This locks the bearing in place and keeps it from rotating.

The connecting rods and connecting rod caps come in mated pairs and are marked on the top side with matching numbers.

Oil the bearing shells on assembly to protect them until the engine is started.

The No. 1 connecting rod **(1)** is near the rear of the cylinder block on the flywheel side.

Insert a bearing shell without an oil groove in the No. 1 connecting rod.

Place a bearing shell with an oil groove in the No. 1 connecting rod cap.

Slip the oil scoop on a connecting rod bolt with the scoop facing the piston. Place this bolt and oil scoop on the bottom of the No. 1 connecting rod and another bolt on the top.

Position the connecting rod and shell on the crankshaft and add the proper bearing cap.

Install the nuts, tighten and lock with cotter pins.

Insert a bearing shell with an oil groove in the No. 2 connecting rod **(2)**.

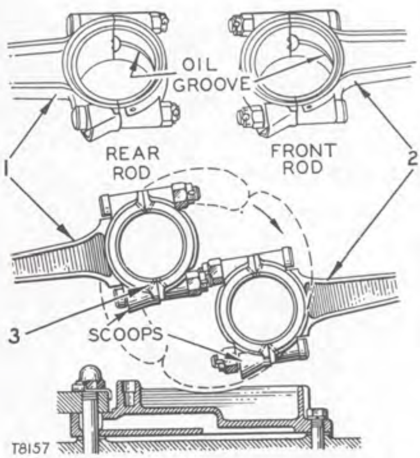
Place a bearing shell without an oil groove in the No. 2 connecting rod cap.

Position the connecting rod on the crankshaft.

Install the bolts and the proper bearing cap and shell.

Place an oil scoop on the bottom bolt with the scoop facing away from the piston.

Install the nuts, tighten and lock with cotter pins.



INSTALLING CONNECTING ROD BEARINGS AND SCOOPS

1—Connecting rod No. 1. 2—Connecting rod No. 2. 3—Oil holes.

CONNECTING ROD REMOVAL AND INSTALLATION

The connecting rods are drop-forged steel and may be removed in the following manner.

Remove the connecting rod bearings and the cylinder heads as described in their respective topics.

Remove the carbon from the inside top surface of the cylinder.

Slide the rod and piston assembly out the top of the cylinder.

Remove the piston pin.

If new parts are installed raise the ring ridge as described for the Diesel engine before assembly.

PISTON PINS AND BUSHINGS

It is not always necessary to replace piston pin bushings whenever new precision bearing shells are installed in a conecting rod. In many cases, bushings may be serviceable even though the second replacement of bearing shells has been made.

After the oil has been removed from the pin and bushing, check the clearance between them. The proper clearance is .0008" to .0013". New bushings and pins should be installed when the clearance exceeds .003".

A piston pin bushing furnished from stock must be finished to the correct size after it is pressed into the connecting rod, and the oil hole drilled.

New connecting rods have the piston pin bushing bored in a special machine which maintains the proper center-to-center distance and parallelism of the connecting rod bearing and piston pin bore. Reconditioned rods should be machined in the same manner. A new connecting rod makes the best templet. The center-to-center distance is 8.499"-8.501".

The piston pin should be a thumb push fit in the connecting rod bushing and piston at normal room temperature (70° F.). The piston pin must never be forced.

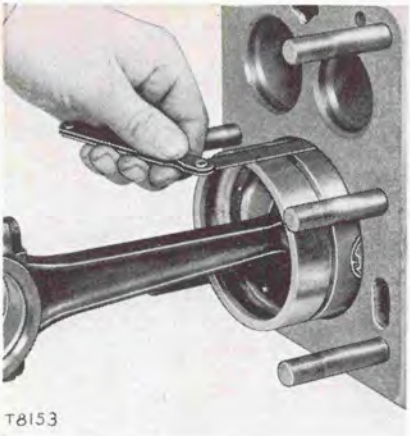
The piston pin to piston clearance is .0004" to .001" with a maximum of .0025".

FITTING PISTON PIN

PISTON REMOVAL AND INSTALLATION

Remove the piston as a unit with the connecting rod and piston pin. See the topic, CONNECTING ROD REMOVAL AND INSTALLATION.

Piston clearance should be measured by a thickness gauge on the thrust side of the piston. The piston skirt clearance of a new piston should be .006" to .008". See the illustration.



T8153

CHECKING PISTON CLEARANCE

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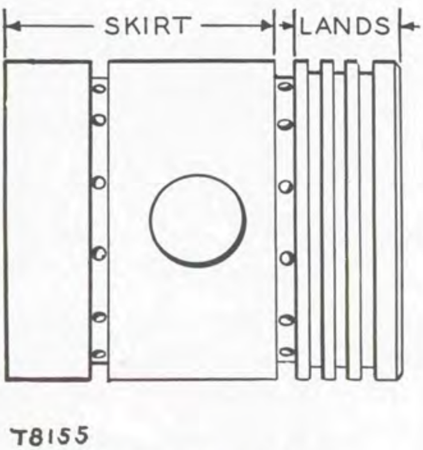
The piston surfaces and ring grooves should be thoroughly cleaned before installing rings or replacing pistons in the cylinder. The most satisfactory method of cleaning pistons is to follow the same recommendations as outlined for cleaning the Diesel engine pistons.

Piston assemblies should be replaced in the same cylinders from which they are removed. The connecting rods are marked on the camshaft side to assure correct assembly.

Cylinder No. 1 is located nearest to the flywheel.

While the piston is removed, it is good practice to gauge the cylinder bore for possible out-of-round (eccentricity) and wall taper as shown. To obtain a true reading, the bore must be checked below the piston ring ridge. If the cylinder bore shows an out-of-round of more than .003″ or a taper of .005″, the cylinder bore should be reconditioned and new pistons and rings installed. Cylinder bore diameter is 3.751″ to 3.752″.



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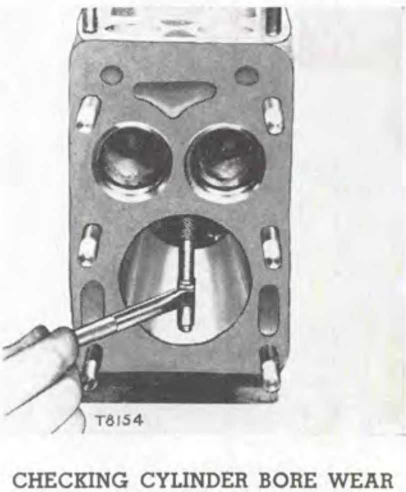
PISTON NOMENCLATURE



T8154

CHECKING CYLINDER BORE WEAR

Semi-finished pistons may be obtained that can be finish-turned up to .060″ over standard, according to the following chart:

CYLINDER AND PISTON DIAMETERS FOR REBORING THE STARTING ENGINE

.020″ Oversize			.040″ Oversize			.060″ Oversize		
Cylinder Dia.	Piston Dia. Aluminum		Cylinder Dia.	Piston Dia. Aluminum		Cylinder Dia.	Piston Dia. Aluminum	
	Skirt	Lands		Skirt	Lands		Skirt	Lands
3.772	3.764	3.742	3.792	3.784	3.762	3.812	3.804	3.782
3.771	3.763	3.741	3.791	3.783	3.761	3.811	3.803	3.781

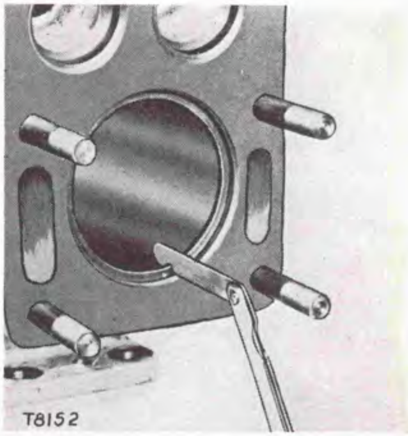
RINGS

The aluminum alloy pistons have three compression rings and two oil rings. One oil ring is located below the piston pin bore.

Piston rings are machined to the exact size required and then cut at one point. After being cut they are peened, or hammered, on the bottom (or inside of ring) to expand the ring diameter. When the completed ring is compressed to cylinder size, it returns to its original machined shape, a true circle, but it now has a tendency to expand when inserted in the cylinder. The force with which a ring presses against the cylinder wall is the ring tension.

Piston rings are divided into two classifications with respect to their use, compression rings and oil control rings.

PISTON RING SIDE CLEARANCE
1—Compression rings. 2—Oil control rings.



CHECKING RING GAP

Compression rings **(1)** are the top three rings on the piston and serve mainly to form the compression seal.

The oil control rings **(2)** are the fourth and fifth rings from the top and serve not only to improve compression but to prevent the lubricating oil on the cylinder wall from working into the combustion chamber.

These oil control rings have small holes or slots which allow the oil accumulating in the groove of the ring to drain into the piston ring groove, and to return to the crankcase through small holes in the piston.

New compression rings **(1)** should have .0015″ to .003″ side clearance in the ring groove and oil rings **(2)** should have .001″ to .0025″. The maximum permissible clearance between a new ring and the ring groove is .009″. After the rings have been installed on the piston, it should be possible to rotate the rings around the piston without binding.

The ring gap for the compression rings should be .012″ to .022″ and the ring gap for the oil control rings should be .012″ to .020″. This measurement should be taken at the smallest diameter of the cylinder bore.

PISTON ASSEMBLY AND INSTALLATION

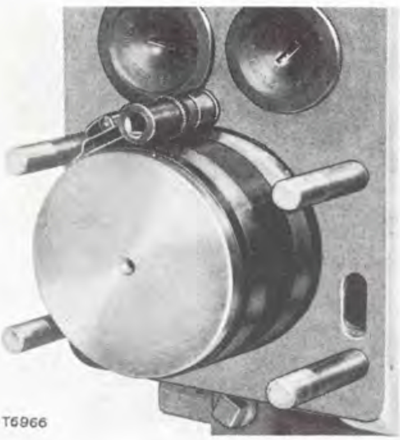
Install one piston pin retainer **(5)**.

Assemble the connecting rod **(2)**, the piston **(3)** and the piston pin **(4)**.

Install the other piston pin retainer.

Install the piston rings **(6)** using a suitable ring expander.

Raise the ridge around the top of the cylinder bore with a ridge remover before installing new rings.



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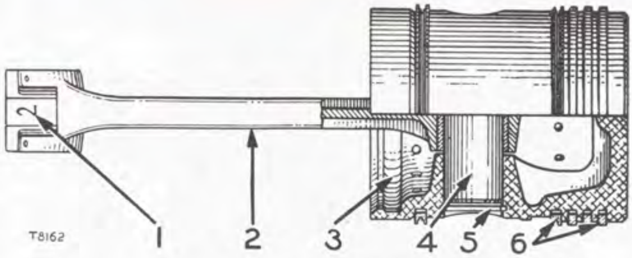
PISTON ASSEMBLY INSTALLATION (RING COMPRESSOR INSTALLED)



PISTON ASSEMBLY
1—Rod number. 2—Connecting rod. 3—Piston. 4—Piston pin. 5—Piston pin retainer. 6—Piston rings.

Apply a suitable ring compressor and install the assembly, as illustrated inserting connecting rod **(2)** first, with the rod number **(1)** up.

See the topics, RINGS, PISTON PINS AND BUSHINGS, and CONNECTING RODS.

Oil Pump

The oil pump is located on the bottom of the crankcase under the left camshaft and is driven by a helical gear on the left camshaft.

The oil pump supplies the pressure oil for the starting engine only.

REMOVAL AND INSTALLATION

The oil pump **(2)** may be removed as follows.

Remove the crankshaft and the left camshaft, as described in their respective topics.

Remove the internal oil lines.

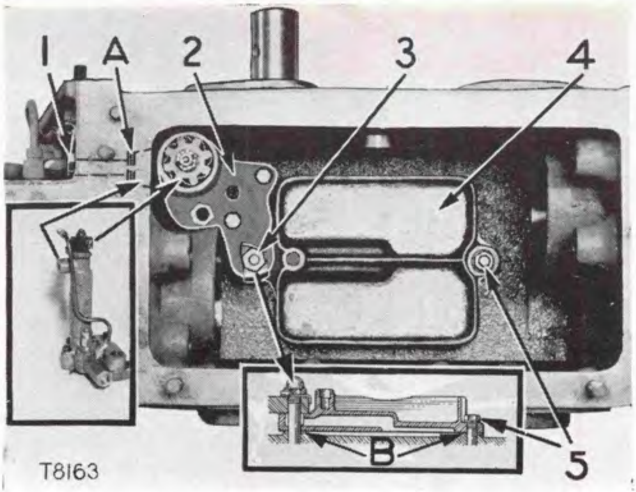
Remove the nut and lock **(3)**.

Remove the capscrew **(1)** holding the oil pump to the cylinder block noting if there are any shims **(A)** between them.

Lift out the oil pump **(2)**.

Remove the nut **(5)** and lift out the suction bell **(4)** noting any shims **(B)** between the cylinder block and the suction bell.

Clean the bell **(4)** and pump **(2)**. Assemble in the reverse order of removal. Shims **(A)** are sometimes used to decrease the backlash which should be .004" to .008", between the camshaft gear and oil pump drive gear. This is set at the factory and need be changed only if a new pump is installed.



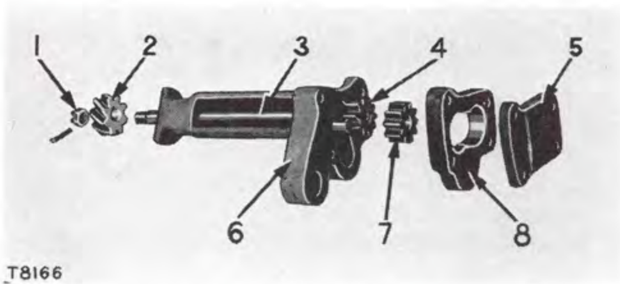
OIL PUMP REMOVAL (TOP VIEW)
A—Shims. B—Shims. 1—Capscrew. 2—Oil pump. 3—Nut and lock. 4—Suction bell. 5—Nut.

If a new pump **(2)** or suction bell **(4)** is to be used, place the suction bell **(4)** in the housing and then install the oil pump **(2)**. Draw the pump upper mounting capscrew **(1)** up tight. With the suction bell resting on the two small spot-faced bosses in the engine housing, check with a feeler gauge for any space between the pump and suction bell. Shims **(B)** may be necessary to raise the suction bell to prevent binding the pump when the nut **(3)** is pulled down tight.

OIL PUMP DISASSEMBLY AND ASSEMBLY

Remove the cotter pin and nut **(1)**.

Remove the gear **(2)**.



OIL PUMP DISASSEMBLY
1—Nut. 2—Drive gear. 3—Shaft. 4—Gear. 5—End cover. 6—Pump bracket. 7—Gear. 8—Body.

Remove the capscrews from the oil pump bracket **(6)**.

Remove the pump end cover **(5)**, body **(8)** and the idler gear **(7)**.

Remove the drive gear **(4)** and the shaft **(3)**, together from the pump bracket.

Assemble in the reverse order of removal.

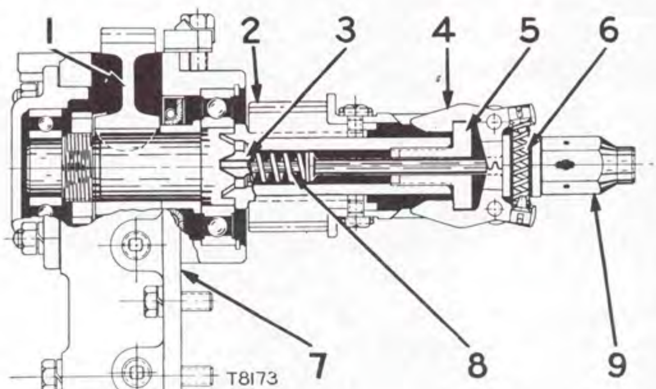
Rotate the gear **(2)** to check that the pump rotates freely.

Starter Pinion

The starter pinion is meshed with the ring gear on the Diesel engine flywheel. When the starter pinion is engaged, it forms a conection between the starting engine and the Diesel engine. The starter pinion will remain in an engaged position until the Diesel engine starts and the pinion is automatically released by centrifugal force acting upon the pinion latches.

When the hand control lever is actuated it applies pressure on the end of the nut **(9)**, the action is transmitted through to the pinion **(2)** which slides on the splined shaft **(3)**. The latches **(4)** catch on the spring-loaded stop **(5)**. The spring **(6)** maintains pressure on the latches, and holds the pinion in the engaged position until the latches are released by centrifugal force. The springs **(8)** return the pinion to the disengaged position, when the latches move away from the stop.

The starter pinion drive gear **(1)** is located in the starter pinion housing **(7)** and is driven by the clutch idler gear. See the topic, STARTER PINION LUBRICATION, for further details.

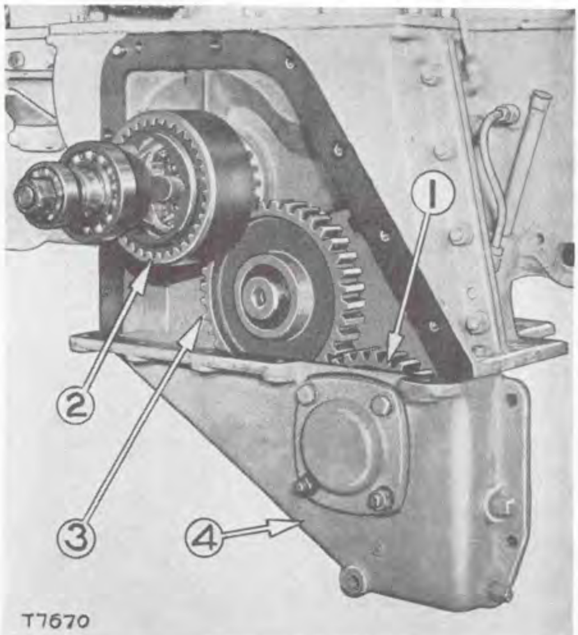


STARTER PINION (ENGAGED POSITION)
1—Starter pinion drive gear. 2—Pinion. 3—Splined shaft. 4—Latches. 5—Stop. 6—Spring. 7—Starter pinion housing. 8—Spring. 9—Nut.

STARTER PINION LUBRICATION

The starter pinion has an oil system in conjunction with the clutch, separate from the crankcase lubricating system.

The starter pinion drive gear **(1)** is located in the starter pinion housing **(4)**. The housing also acts as an oil reservoir. As the drive gear rotates, the gear teeth pick up the oil and in turn distribute oil to the mating teeth on the idler gear **(3)** and the clutch drum and gear. The clutch assembly **(2)** is lubricated by oil that is splashed or thrown by the gears.

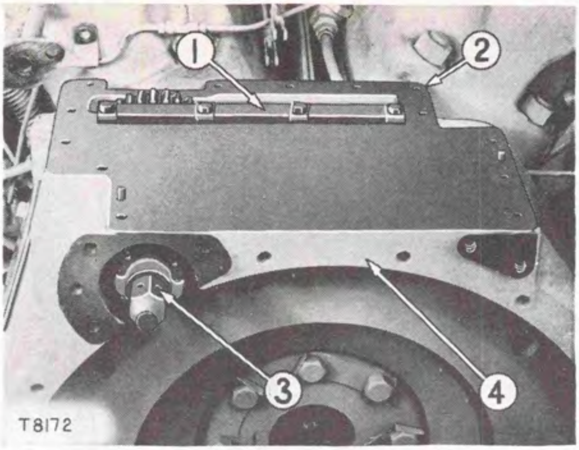


PARTS LUBRICATED BY STARTER PINION
1—Pinion drive gear. 2—Clutch assembly. 3—Idler gear. 4—Starter pinion housing.

STARTER PINION REMOVAL AND INSTALLATION

To remove the starter pinion assembly **(3)**, first remove the starting engine. See the topic, STARTING ENGINE REMOVAL. Remove the Diesel engine flywheel housing, see the topic, FLYWHEEL HOUSING REMOVAL. Remove the capscrews holding the retaining plate **(1)** to the starter pinion housing **(2)** and the flywheel housing **(4)**. Remove all the capscrews holding the starting pinion housing to the flywheel housing and remove the starter pinion assembly.

When installing the starter pinion housing to the flywheel housing, install the capscrews and tighten them slightly and check the alignment of the top faces of the two housings. A light tap with a block of wood will align the top faces. Tighten the capscrews to secure the starter pinion housing. Install a new gasket and the retaining plate.



REMOVING STARTER PINION
1—Retaining plate. 2—Starter pinion housing. 3—Starter pinion mechanism. 4—Flywheel housing.

STARTER PINION DISASSEMBLY

Before disassembling the starter pinion locate the pinion in the disengaged position.

Remove the bearing cage **(1)** and gasket. The bearing **(2)** is a light press fit on the shaft **(16)**. Using a small bar on each side of the bearing, pry the bearing off the shaft. Bend the lock **(12)** to release the nut **(3)** and remove the nut and lock. The nut can also be used to force the bearing **(2)** off the shaft while the nut is being removed if desired. Remove the

REMOVING DRIVE GEAR
4—Drive gear. 13—Starter pinion housing.

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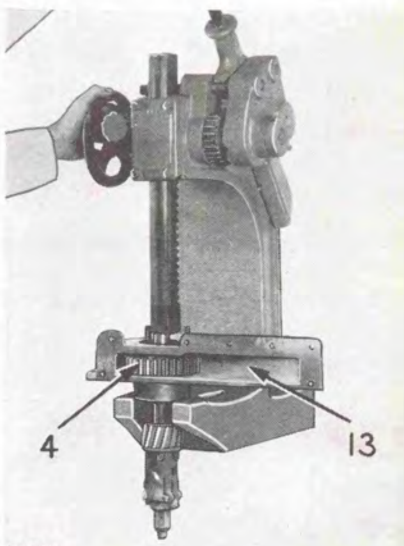
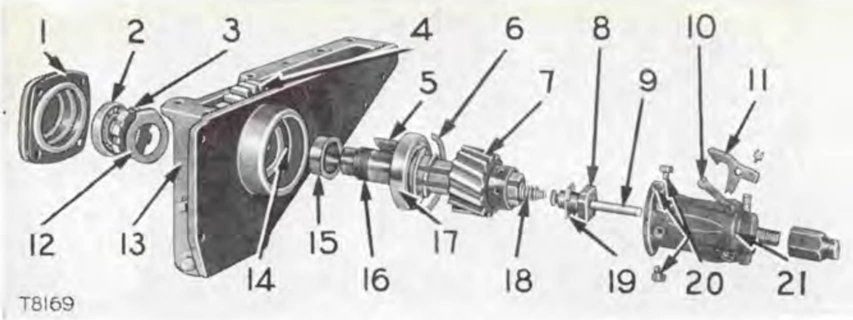




STARTER PINION DISASSEMBLY
1—Bearing cage. 2—Bearing. 3—Nut. 4—Drive gear. 5—Key. 6—Retainer ring. 7—Gear. 8—Stop. 9—Plunger. 10—Pin. 11—Latches. 12—Lock. 13—Housing. 14—Oil seal. 15—Sleeve. 16—Splined shaft. 17—Bearing. 18—Springs. 19—Lock. 20—Capscrews. 21—Latch housing.

retainer ring **(6)** from the housing and slide it up on the pinion gear **(7)**. Press the shaft from the drive gear **(4)** and housing **(13)** as shown. Inspect the oil seal **(14)**. Remove the key **(5)**, the sleeve **(15)**, the bearing **(17)** and the retainer ring **(6)** from the shaft.

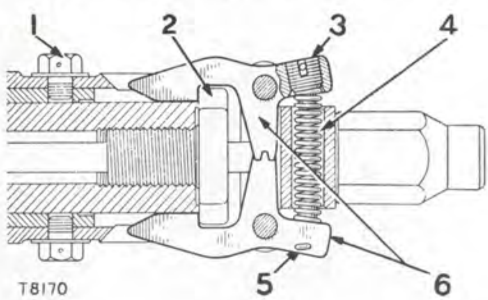
Remove the wire and the capscrews **(20)** from the latch housing **(21)** and slide the latch housing off. The latches **(11)** can be removed by removing the retaining pins **(10)**.

Bend the lock **(19)** and remove the stop **(8)**, the plunger **(9)** and springs **(18)** from the splined shaft **(16)**. Remove the pinion gear **(7)**.

STARTER PINION ASSEMBLY AND ADJUSTMENT

Install the latch housing assembly on the splined shaft in a position to permit the latches **(6)** to catch on the wide shoulders of the stop **(2)**. The latches will not catch if installed in alignment with the narrow shoulders of the stop. Thus, the pinion would not remain engaged long enough to permit the Diesel engine to be started.

Safety wire the capscrews **(1)** when they are secured.



STARTING PINION ASSEMBLY
1—Capscrew. 2—Stop. 3—Adjusting screw. 4—Spring. 5—Adjusting screw. 6—Latch.

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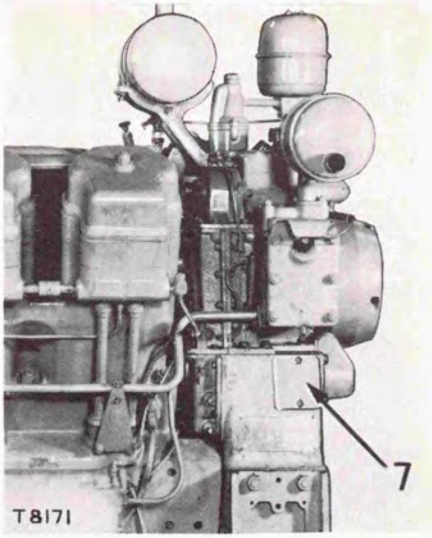
ADJUSTMENT LOCATION
7—Inspection plate.



The speed at which the pinion releases is controlled by the compression of the spring **(4)** between the two adjusting screws **(3)** and **(5)**. Turning each screw clockwise one-half turn increases the releasing speed by 100 to 150 RPM. Care should be taken not to raise the releasing speed too high which might cause damage to the starting engine by overspeeding when the Diesel engine starts.

If the starter pinion requires adjustment, remove the plate **(7)** and adjust the latches through the opening in the flywheel housing.

ELECTRICAL EQUIPMENT, CARBURETOR AND AIR STARTING

Generator

(Delco-Remy 1102536)

This is a third-brush, 12-volt generator. The current output is regulated by the setting of the third brush and the voltage is regulated internally by the step-voltage control. The third brush should be set so that the current cannot exceed the generator's maximum safe output and the step-voltage control will control the output to conform with the requirements of the battery and the connected load.

The recommended output of the generator is shown in the following chart:

Field Current at 12V. at 80° F.	Cold Output			Hot Output After 15 Minutes Operation		
Amps	Amps	Volts	Approx. RPM	Amps	Volts	Approx. RPM
2.5 – 3.0	11 – 13	15.0 – 15.6	1800	7 – 10	14.2 – 14.8	2000

The generator should be checked and adjusted at the voltage specified in the chart, since the generator output increases with generator voltage. Normally if the generator is checked with an accurate ammeter and a fully charged battery, the proper voltage will be developed. If a fully charged battery is not available, it will be necessary to cut in resistance until the proper voltage is obtained. This can be done by inserting in the charging circuit a $1\frac{1}{2}$-ohm variable resistance of sufficient current carrying capacity to handle the load. See the topic, STEP-VOLTAGE CONTROL. Connections for checking the output are shown in a sketch under that topic.

CAUTION

Never operate a generator on an open circuit.

Excessive output will result in an overcharged battery, burned contact points and burned generator windings.

If the brushes are in good condition, the third brush properly adjusted and the regulator functioning as it should, and yet the generator output does not check with the specified current and voltage values, the unit should be disassembled and inspected.

Disassembly

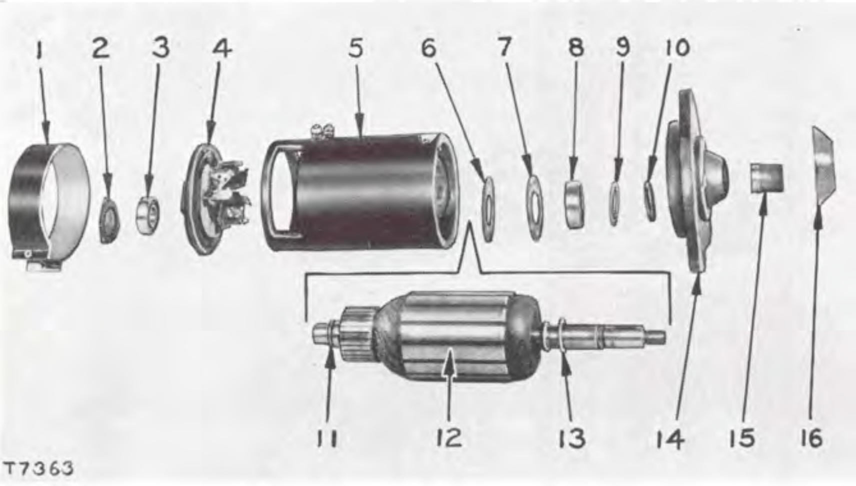
Remove the cotter pin and nut and pull the drive gear using an 8B7546 Puller. Remove the key and take off the slinger **(16)** and spacer **(15)**. Take off the cover **(1)** and disconnect the field lead from the third brush. Remove the two through bolts and separate the brush holder plate **(4)** and drive end flange **(14)** from the housing **(5)**. Remove the armature **(12)** from the housing. Take the spacer **(11)** from the commutator end of the armature and the washer **(13)** from the drive end.

The field and pole shoes can be removed from the housing by removing the screws securing them to the housing.

Remove the plate and gasket **(2)** from the brush holder plate **(4)** and tap out the bearing **(3)**. Remove the bearing retainer **(6)**, gasket **(7)**, bearing **(8)**, washer **(9)** and felt washer **(10)** from the drive end flange **(14)**.

CAUTION

When assembling the generator, the drive gear must be pressed tightly on the armature. Failure to do so will result in premature wear of the brush holders caused by drifting of the armature.



DISASSEMBLING GENERATOR

1—Cover. 2—Plate and gasket. 3—Bearing. 4—Brush holder plate. 5—Housing. 6—Bearing retainer. 7—Gasket. 8—Bearing. 9—Washer. 10—Felt Washer. 11—Spacer. 12—Armature. 13—Washer. 14—Drive end flange. 15—Spacer. 16—Slinger.

Brushes

The generator has an adjustable third brush **(1)** in addition to two fixed brushes **(3)**. To vary the generator output, loosen the locking screw on the rear cover of the generator and rotate the third brush **(1)** in the same direction that the armature rotates. As the third brush moves closer to the main brush, the amperage will increase. Move it in the reverse direction to decrease the amperage output. Tighten the locking screw after making the adjustment.

GENERATOR BRUSHES

1—Third brush. 2—Screws. 3—Main brushes.

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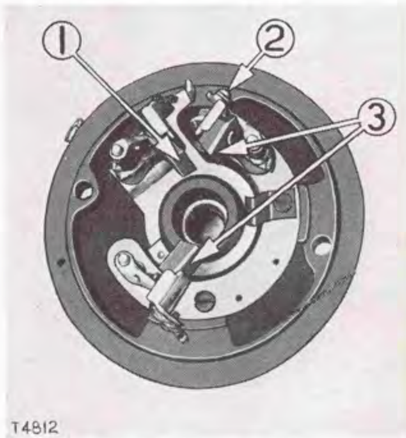

Remove all carbon dust from the brush holders and cover to insure that the brushes are not grounded. Check the lead from each carbon brush for loose or broken connections.

If the brushes are worn or covered with oil, they should be replaced. New brushes may be installed through the opening in the generator housing after removing the cover. Remove the screw **(2)** from each brush lead and install the new brushes.

After new brushes are installed, they should be seated to the commutator with a bedding stone. With the engine operating at low idle speed, press the bedding stone firmly against the commutator and move it back and forth along the commutator to cover the entire area contacted by the brushes. It takes only a few seconds to seat the brushes. Blow out the generator with compressed air to remove all of the particles of abrasive. Never use emery cloth on brushes or commutator.

Brush Holder Springs

The brush holder springs should be replaced if they have lost their tension and they can be checked with a pull scale. The two main springs should have a tension of 25 ounces while the third brush spring should have a tension of 17 ounces.

TESTING

Armature

With the armature removed from the generator, connect a battery and a 6-volt lamp in series. Place one lead on the armature shaft and the other lead on each segment of the commutator in succession. If the test lamp lights between any one segment and the shaft, the armature is grounded and should be replaced.

To test the armature for a short, clean out between the commutator bars, place the armature on a growler with a hacksaw blade over the armature core and rotate the armature. If the blade does not vibrate the armature is not shorted. If the blade vibrates, the armature is short-circuited and should be replaced.

Commutator

Check the commutator for roughness. If rough, it should be turned down in a lathe just enough to remove the roughness and then sanded with 00 sandpaper. The commutator should be checked for concentricity. Undercut the mica between each segment 1/32" with a hacksaw blade. If the surface of the commutator is only glazed or darkened, polish with 00 sandpaper. Clean out generator with air to remove abrasives.

Field Winding

The fields should be tested for a continuous circuit, ground and coil balance.

To test for a continuous circuit, connect a battery and a 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the brush lead. If the lamp does not light, the field coils are open-circuited and should be replaced.

To test for a ground, connect a battery and 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the generator housing. If the test lamp lights, the fields are grounded and should be replaced.

The field coils should be balanced, to test for this condition, connect a 6-volt battery and ammeter in series. Slide the insulation off the wire connection between the two field coils. Connect the lead from the battery to this wire connection. First place the other lead on the field (F) terminal of the generator and note the ammeter reading. Second, place the same lead on the brush terminal of the windings and note the ammeter reading. If one field coil draws more current than the other, there is an internal short in that field coil and it should be replaced.

Use rosin flux in making all soldered connections. Check to make sure that the coils are installed in the same position as the coils which were taken out.

Polarizing the Generator

After the generator has been installed on the engine and reconnected, always connect momentarily a jumper lead between the (GEN) terminal and (BAT) terminal of the regulator before starting the engine. This allows a momentary surge of current to pass from the battery to the generator which will automatically give the generator the correct polarity with respect to the battery which it is to charge. Failure to do this will result in a discharged battery, burned contact points and possibly serious damage to the generator.

Never operate the generator on an open circuit as this will allow the generator voltage to build up dangerously high and result in complete generator failure.

Step-Voltage Controls
(Delco-Remy 5901)

The step-voltage control used with the 12-volt, 125-watt system consists of a step-voltage control unit and a cutout relay. This unit is designed for use with a third brush generator, such as the Delco-Remy 1102536 generator, which has the field circuits insulated in the generator but grounded in the step-voltage control.

STEP-VOLTAGE CONTROL

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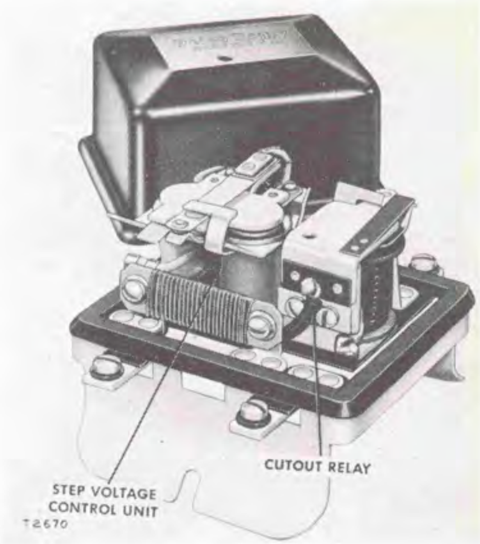


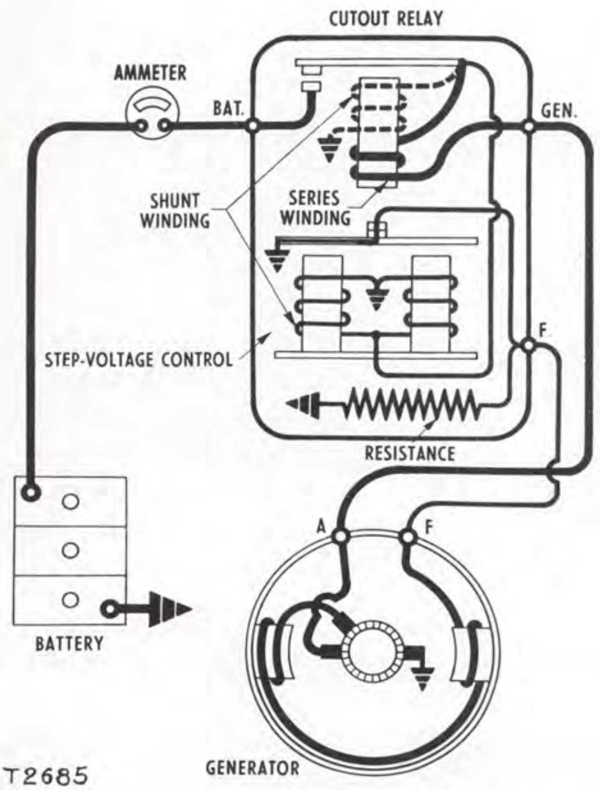
Cutout Relay

When the generator voltage builds up to a value great enough to charge the battery, the magnetism induced in the relay windings is sufficient to overcome the armature spring tension and pull the armature toward the core so that the contact points close. This completes the circuit between the generator and the battery. The current which flows from the generator to the battery passes through the series winding in the proper direction to add to the magnetism holding the armature down and the contact points closed.

When the generator slows down or stops, current begins to flow from the battery to the generator. This reverses the direction that the current flows through the series windings, thus causing a reversal of the series winding magnetic field. The magnetic field of the shunt winding does not reverse. Therefore, instead of helping each other, the two windings now magnetically oppose each other so that the resultant magnetic field becomes insufficient to hold the armature down. The flat spring pulls the armature away from the core so that the points separate; this opens the circuit between the generator and battery. See wiring diagram under the topic, STEP-VOLTAGE CONTROL.

Step-Voltage Control

The purpose of the step-voltage control is to cut down generator output a substantial amount by inserting a resistance into the generator field circuit when the generator voltage reaches a pre-determined maximum.



WIRING DIAGRAM

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When the battery approaches a fully charged condition and electrical units such as lights are turned off, the circuit voltage will increase. This increasing voltage causes a corresponding voltage increase on the shunt windings in the step-voltage control unit with a consequent increase in strength of the magnetic field produced by these windings. When the voltage reaches the value for which the step-voltage control is set, the magnetic field will be strong enough to overcome the armature spiral spring tension. The armature will be pulled down toward the armature core so that the contact points will be separated. This causes the resistance to be inserted into the generator field circuit so that generator output is substantially reduced. There is no vibrating action. The resistance remains in the generator field circuit as long as the battery remains in a fully charged condition, and the electrical load demand is small.

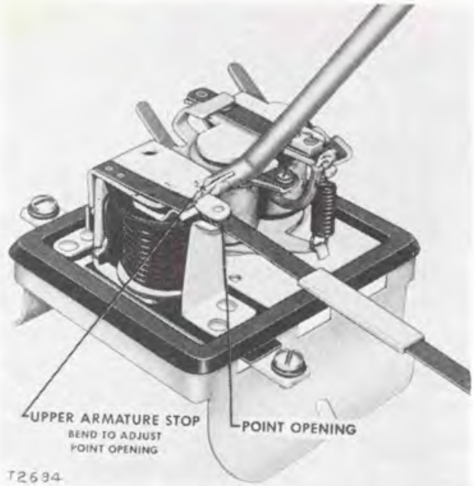
Cutout Relay Checks and Adjustments

The cutout relay requires three checks and adjustments: air gap, point opening, and closing voltage. The air gap and point opening adjustments must be made with the battery disconnected.

The air gap adjustment is made by holding the armature down so the contact points are closed and measuring the gap between the armature and the center of the core as shown. The air gap should be .015". Adjust by loosening the two screws on the back of the relay and raise or lower the armature as required. Tighten the screws after adjustment.

CHECKING AND ADJUSTING CUTOUT RELAY AIR GAP

Check the point opening and adjust by bending the upper armature stop as shown. The point opening should be .020".



CHECKING AND ADJUSTING CUTOUT RELAY POINT OPENING

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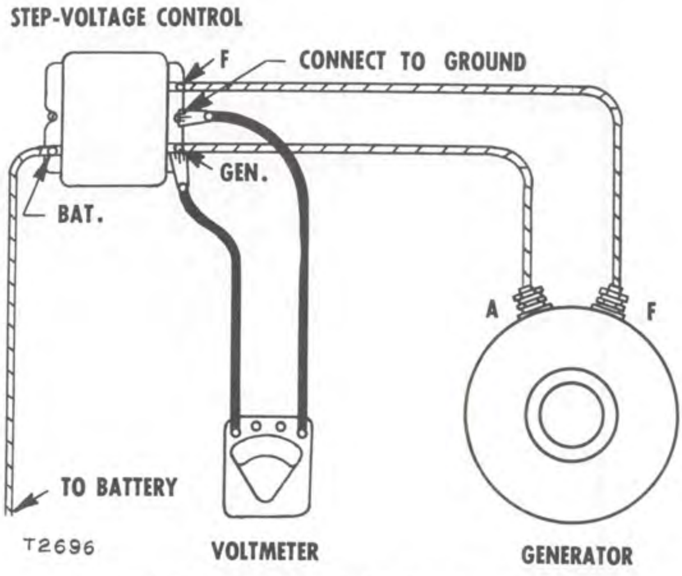
Check the closing voltage of the cutout relay by connecting the step-voltage control to the generator and battery and connect a voltmeter between the step-voltage control (GEN) terminal and ground as shown. Slowly increase the generator speed and note the relay closing voltage. Adjust the closing voltage by bending the armature spring post as shown. The closing voltage should be 12.5 to 14.0 volts. If the voltage is not in this range, adjust to 13.3 volts by bending the armature spring post up to increase tension and closing voltage and down to decrease voltage as shown.



CHECKING VOLTAGE OF CUTOUT RELAY

ADJUSTING CLOSING VOLTAGE OF CUTOUT RELAY

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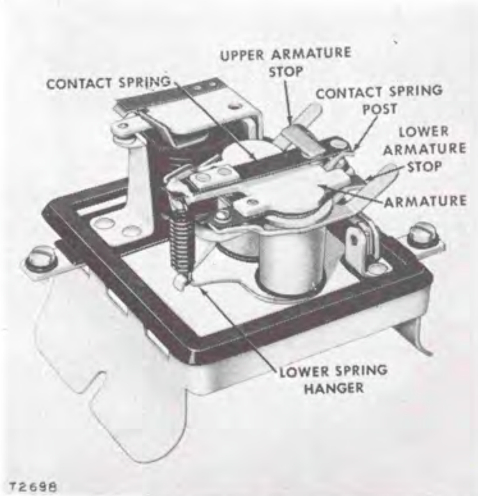
Step-Voltage Control Unit Checks and Adjustments

Five checks and adjustments are required on the step-voltage control unit: flat spring tension, air gap, armature travel, point opening and voltage setting. The various points of adjustment and the posts and stops which must be bent to make adjustments are shown in the following illustration.

STEP-VOLTAGE CONTROL SHOWING POINTS OF ADJUSTMENTS, ADJUSTING POSTS AND STOPS

◆



The flat spring tension determines the amount of pressure between the step-voltage contact points. This spring tension should be 3/4 ounce at the instant the points separate. This can be measured by pushing the armature down until the points almost open and then using a spring gauge to measure the upward pull required to open the points. Adjustment is made by bending the flat spring.

CHECKING CONTACT SPRING TENSION OF STEP-VOLTAGE CONTROL

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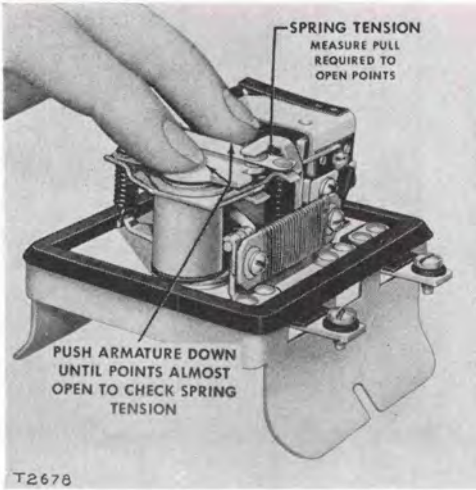
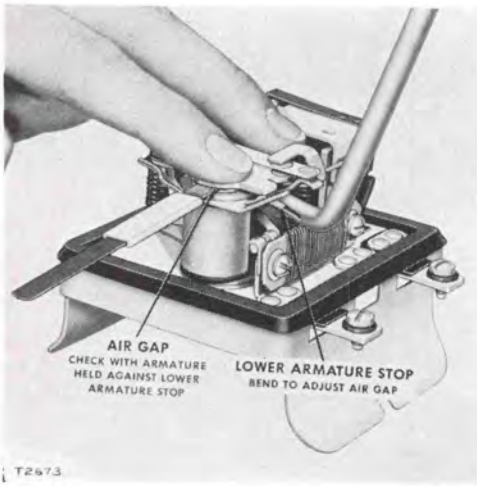


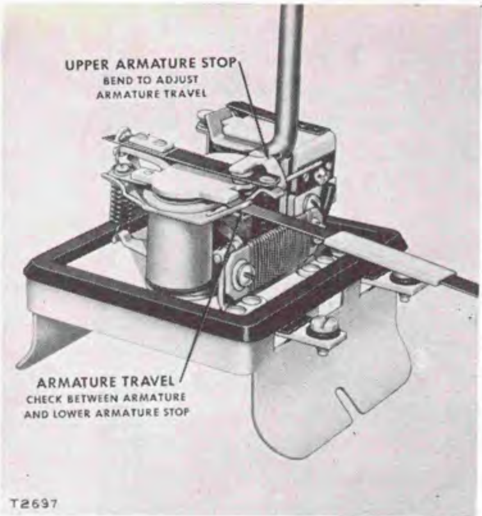
Check the air gap by holding the armature down against the lower armature stop by placing the fingers on either side of the flat contact spring as shown. Adjust the air gap by bending the lower armature stop as shown. The air gap should be .030".



CHECKING AND ADJUSTING AIR GAP OF STEP-VOLTAGE CONTROL

♦

Check the armature travel by releasing the armature so that it moves up against the upper armature stop and then measure the gap or armature travel between the armature and lower armature stop. The armature travel should be .030". Adjust by bending the upper armature stop as shown.



CHECKING AND ADJUSTING ARMATURE TRAVEL ON STEP-VOLTAGE CONTROL

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Check the point opening by holding the armature down against the lower armature stop with the fingers placed on either side of the flat contact spring and measure the contact point opening. The opening should be .010". Adjust the point opening by bending the contact spring post as shown.

CHECKING AND ADJUSTING CONTACT POINT OPENING OF STEP-VOLTAGE CONTROL

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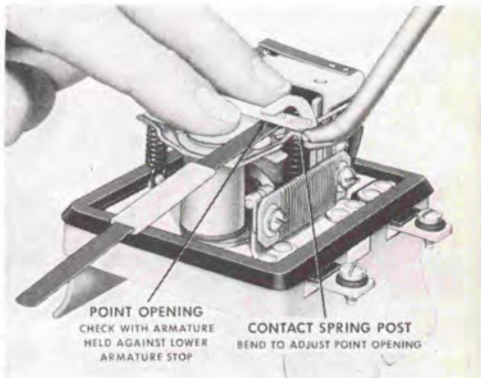
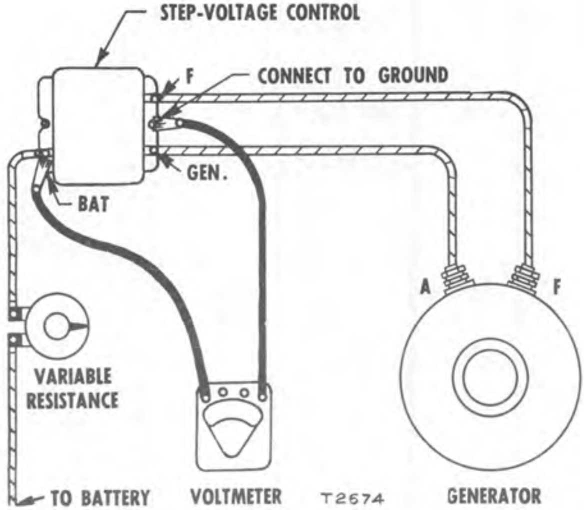


Check the voltage setting at which the contact points open by connecting a voltmeter between the step-voltage control (BAT) terminal and ground, and connect a ¼-ohm variable resistance into the charging circuit at the (BAT) terminal as shown. Gradually increase the generator speed and note the voltage at which the contact points of the step-voltage control opens. Decrease speed and note the voltage at which the contacts close. The step-voltage control must be at operating temperature and the cover must be in place. Should the battery be in a low state of charge, the voltage will not increase sufficiently to cause the step-voltage control contact points to open. Under this condition, it will be necessary to slowly cut in resistance by means of the variable resistance with the engine running at medium speed to cause the voltage to increase and the points to open.



WIRING DIAGRAM SHOWING SET UP FOR CHECKING OPENING AND CLOSING VOLTAGES OF STEP-VOLTAGE CONTROL

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The step-voltage control contact points satisfactory opening range is 14.0–15.5 volts. If they do not open in this range, adjust to 14.7 volts by bending the lower spring hanger down to increase spring tension and opening voltage and bend up to decrease the opening voltage as shown. Check the voltage adjustment by stopping the generator and slowly bringing it up to speed.

ADJUSTING STEP-VOLTAGE CONTROL OPENING RANGE

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The voltage at which the step-voltage control contact points will close is adjusted by adjusting the air gap as previously explained. Increasing the air gap increases the closing voltage while decreasing the air gap lowers the closing voltage. After this adjustment, it may be necessary to re-adjust the contact point opening slightly to keep it within specifications. The closing voltage should be within a range of 12.5 to 14.0 volts. The minimum difference between the opening and the closing voltage is 1.5 volts.

Maintenance of Step-Voltage Controls

Mechanical checks such as air gaps and point openings must be made with the battery disconnected and the step-voltage control preferably off the engine.

CAUTION

> The cutout relay contact points must never be closed by hand with the battery connected to the step-voltage control. This will cause damage to the contact points and other electrical equipment.

Electrical checks and adjustments can be made with the step-voltage control off or on the engine. The step-voltage control must be at operating temperature and the cover must be in place when the operating voltage is checked.

The generator must be re-polarized before the engine is started. After reconnecting the leads and before attempting to start the engine, momentarily connect a jumper lead between the (GEN) and (BAT) terminals of the step-voltage controls. This allows a momentary surge of current to flow through the generator which correctly polarizes it. Severe damage may result if this is not done.

Generator
(Delco-Remy 1102734)

This generator is a 6-volt, 115-watt generator and rotates clockwise looking at the drive end of the generator. It is a two brush, two pole shunt type generator with externally grounded field circuits. The generator is prevented from exceeding its rated maximum by an externally mounted voltage regulator. The generator output is checked and adjusted by checking the voltage regulator. See the topic, REGULATOR (DELCO-REMY 1118377).

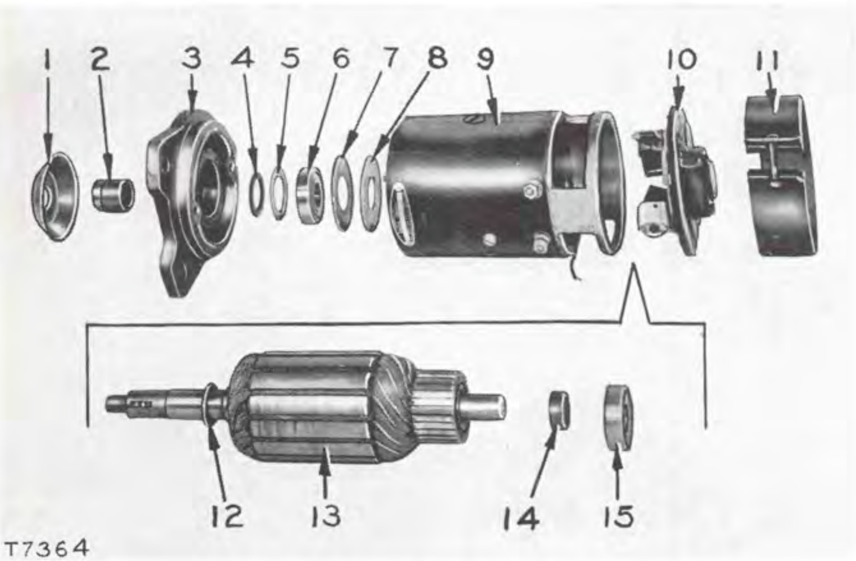
REMOVAL

Disconnect the leads between the generator and voltage regulator. Remove the fastenings securing the generator mounting flange to the engine and remove the generator.

DISASSEMBLY AND ASSEMBLY

Remove the nut and washer and pull the drive gear (not shown) with an 8B7546 Puller. Take off the band **(11)**. Remove the key and slinger **(1)** from the drive end of the armature shaft. Remove the spacer **(2)**. When replacing the spacer **(2)**, the threaded end faces away from the armature. Disconnect the field lead from the brush lead. Remove the two through bolts and separate the commutator end assembly **(10)** and the drive end flange **(3)** from the housing **(9)**. The armature **(13)** will come out with the drive end flange.

Remove the safety wire from the screws securing the bearing retainer **(8)** to the drive end flange. Take out the screws and remove the bearing retainer **(8)** and gasket **(7)**. The bearing **(6)** is a light press fit and can be removed by tapping against the backside of the bearing. Remove the washer **(5)** and felt washer **(4)**. When reassembling the felt washer **(4)** should be replaced. Remove the washer **(12)** from the drive end of the armature. Pull the bearing **(15)** from the armature using the 8B7547 Puller. Remove the spacer **(14)**.



GENERATOR DISASSEMBLY

1—Slinger. 2—Spacer. 3—Drive end flange. 4—Felt washer. 5—Washer. 6—Bearing. 7—Gasket. 8—Bearing retainer. 9—Housing. 10—Commutator end assembly. 11—Band. 12—Washer. 13—Armature. 14—Spacer. 15—Bearing.

INSPECTION AND TESTING

Brushes

Remove all carbon dust from the brush holder and cover. Check the lead from each carbon brush to see that they are not damaged or loose.

If the brushes are worn or covered with oil, they should be replaced with new brushes. New brushes may be installed by removing the cover band or by removing the brush holder plate.

After new brushes have been installed, they should be seated to the commutator by using a bedding stone. With the engine operating at low speed, press the bedding stone firmly against the commutator and move it back and forth along the commutator to cover the area contacted by the brushes. The brushes should be seated in a few seconds. Blow out the generator with air to remove all abrasives. Never use emery cloth on brushes and commutator.

Brush Holder Spring Tension

If the brush holder springs have lost their tension, they should be replaced with new springs. The brush spring tension should be 28 ounces.

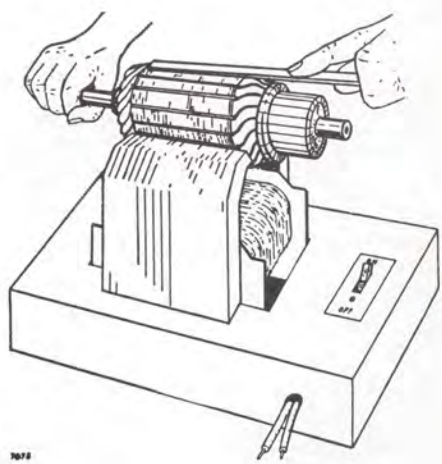
Bearings

The armature bearings should be replaced if they are worn or damaged. Before replacing, pack them with high melting point lubricant.

Armature

With the armature out of the generator, connect a battery and 6-volt lamp in series. Place one lead on the armature shaft and the other lead on each segment of the commutator in succession. If the test lamp lights

CHECKING WITH GROWLER



between any one segment and the shaft, the armature is grounded and should be replaced.

To test the armature for a short, clean out between the commutator bars, place the armature on a growler with a hacksaw blade over the armature core and rotate the armature. If the blade vibrates, the armature is short-circuited and should be replaced.

Commutator

Check the commutator for roughness. If rough, it should be turned down in a lathe just enough to remove roughness and then sanded with 00 sandpaper. Check the commutator for concentricity. Undercut the mica between each segment 1/32" with a hacksaw blade. Clean out generator with air to remove abrasives.

Field Winding

The field windings should be tested for a continuous circuit, ground and coil balance.

To test for a continuous circuit, connect a battery and 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the brush lead. If the lamp fails to light, the field coils are open-circuited and should be replaced.

To test for a ground, connect a battery and 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the generator case. If the test lamp lights the fields are grounded and should be replaced.

To test the field coils for balance, connect a 6-volt battery and ammeter in series. Slide the insulation off the wire connections between the two fields. Connect the lead from the battery to this wire connection. First, place the other lead on the field (F) terminal of the generator and note the ammeter reading. Second, place the same lead on the brush terminal of the field coils and note the ammeter reading. If one field coil draws more current than the other, there is an internal short in that field coil and the coil should be replaced.

To replace the field coils, remove the screws and pole shoes and take out the field coils. When replacing, make sure that the coils are installed in the same positions as the coils that were removed. Use rosin flux in making all soldered connections.

Polarizing the Generator

After a generator has been reconditioned and reinstalled on an engine or at any time after the generator has been tested, it must be repolarized to make sure that it has the correct polarity with respect to the battery it is to charge. This generator has externally grounded field circuits and is polarized by connecting a jumper lead momentarily between the armature and battery terminals of the regulator after all leads have been connected but before the engine is started. This allows a momentary surge of current to flow through the generator which correctly polarizes it in respect to the battery it is to charge. Failure to do this will result in a discharged battery, burned contact points and possibly serious damage to the generator.

Regulator

(Delco-Remy 1118377)

The three unit regulator is designed for use with Delco-Remy shunt type generators, such as the Delco-Remy 1102734 generator, with externally grounded field circuits. The regulator contains a cutout relay, a voltage regulator and a current regulator.

Cutout Relay

The cutout relay closes the generator to battery circuit when the generator voltage is sufficient to charge the battery, and it opens the circuit when the generator slows or stops. The cutout relay action is the same as the cutout relay action of the step-voltage control. See the topic, CUT-OUT RELAY under the topic, STEP-VOLTAGE CONTROLS.

Voltage Regulator

The voltage regulator is a voltage limiting device that prevents the voltage from exceeding a specified maximum and reduces generator output to the value required for any particular condition of battery charge and electrical load.

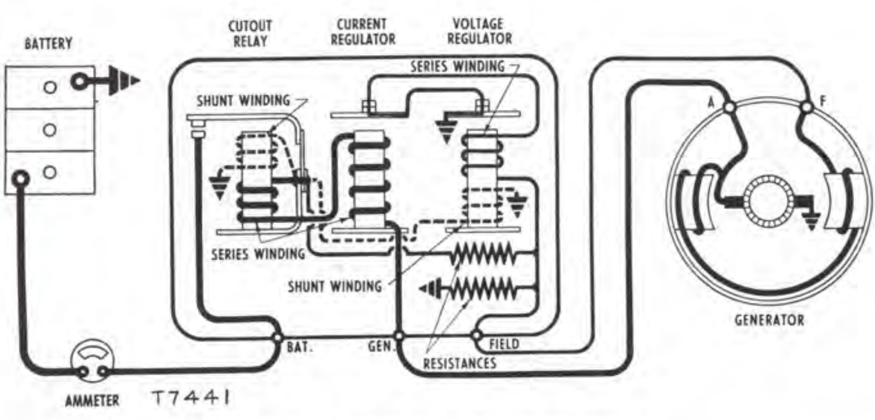
When the generator voltage reaches the value for which the voltage regulator is adjusted, the magnetic field produced by the two windings (shunt and series) overcomes the armature spring tension and pulls the armature down so that the contact points separate. This inserts resistance into the generator field circuit so that the generator field current and voltage are reduced. Reduction of the generator voltage reduces the magnetic field of the regulator shunt winding. Also, opening the regulator points opens the regulator series winding circuit so that its magnetic field is reduced sufficiently to allow the spiral spring to pull the armature away from the core so that the contact points again close. This directly grounds the generator field circuit so that the generator voltage and output increase. The above cycle of action again takes place and the cycle continues at a rate of 150 to 250 times a second, regulating the voltage to a predetermined value. With the voltage thus limited the generator supplies varying amounts of current to meet the varying states of battery charge and electrical load.

Current Regulator

All of the generator output is carried by the current regulator through the series winding. When the current regulator is not operating the tension of the spiral spring holds the armature away from the core so that the points are in contact. In this position the generator field circuit is completed to ground through the current regulator contact points in series with the voltage regulator contact points.

When the load demands are heavy, as for example when electrical devices are turned on and the battery is in a discharged condition, the voltage may not increase to a value sufficient to cause the voltage regulator to operate. Consequently, the generator output will continue to increase until the generator reaches its rated output, this ouput, flowing through the current regulator winding, creates sufficient magnetism to pull the current regulator armature down and open the contact points. With the points open, resistance is inserted into the generator field circuit so that the generator output is reduced. As soon as the generator output starts to fall off, the magnetic field of the current regulator winding is reduced, the spiral spring tension pulls the armature up and the contact points close and directly connect the generator field to ground. Output increases and the above cycle is repeated. The cycle continues to take place while the current regulator is in operation 150 to 250 times a second, preventing the generator from exceeding its rated maximum.

When the electrical load is reduced (electrical devices turned off or battery comes up to charge), then the voltage increases so that the voltage regulator begins to operate and reduces the generator output. This prevents the current regulator from operating. Either the voltage regulator or the current regulator operates at any one time, the two do not operate at the same time.



WIRING DIAGRAM OF REGULATOR

Regulator Maintenance

Mechanical checks and adjustments (air gap, point opening) must be made with the battery disconnected and the regulator preferably off the engine.

CAUTION

> The cutout relay contact points must never be closed by hand with the battery connected to the regulator. This would cause a high current to flow through the regulator units which would seriously damage them.

The regulator must be mounted in the operating position when electrical settings are checked and adjusted and it must be at operating temperature.

After any tests or adjustments the generator on the engine must be repolarized after the leads are connected and before the engine is started. This is accomplished by momentarily connecting a jumper lead between the (GEN) and (BAT) terminals of the regulator. This allows a momentary surge of current to flow through the generator which correctly polarizes it. Failure to do this will result in severe damage to the equipment.

The contact points of a regulator will not operate indefinitely without some attention. The points should be cleaned with a spoon or riffler file. Never use sandpaper or emery cloth to clean the contact points.

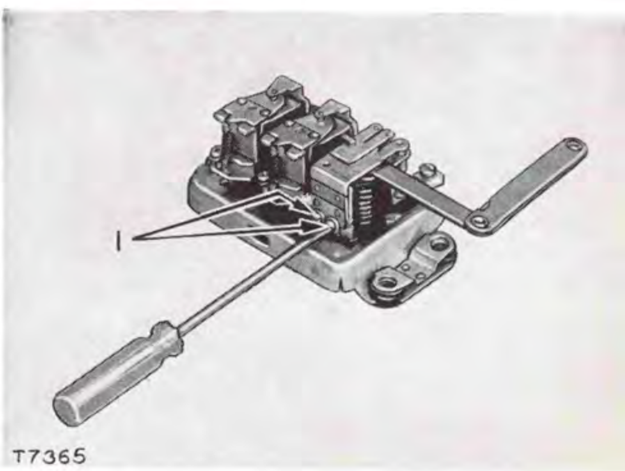
Cutout Relay Checks and Adjustments

The cutout relay requires three checks and adjustments: air gap, point opening and closing voltage. The air gap and point opening adjustments must be made with the battery disconnected.

CHECKING AND ADJUSTING CUTOUT RELAY AIR GAP

1—Two screws.

♦



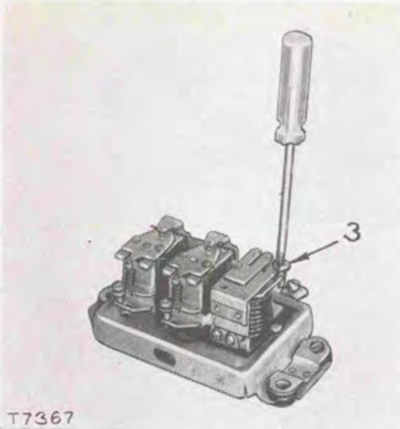
Check the air gap by placing the fingers directly above the core and press the armature down until the contact points just close and then measure the air gap between the armature and the center of the core as shown. Make sure that both sets of contact points close simultaneously. If they do not, bend spring finger so they do. To adjust the air gap, loosen the two screws **(1)** at the back of the cutout relay and raise or lower the armature as required. The air gap should be .020". Tighten the two screws after making the adjustment.

Check the point opening of the cutout relay. The point opening should be .020". Adjust the point opening by bending the upper armature stop **(2)**.

CHECKING AND ADJUSTING CUTOUT RELAY POINT OPENING

2—Armature stop.

Check the closing voltage of the cutout relay by connecting the field terminal of the generator to the field terminal of the regulator, connect the armature lead of the generator to the generator lead of the regulator. Connect the battery lead of the regulator to the battery. Connect a voltmeter between the regulator (GEN) terminal and the regulator base. Slowly increase the speed and note the cutout relay closing voltage. The closing voltage should be in a range of 5.9 to 6.8 volts. Decrease the generator speed and make sure the contact points open. An alternate method is to use a variable resistor (15 ohms–25 watt) connected in the field circuit. With the generator operating at medium speed and resistance all in slowly decrease the resistance until the cutout relay points close and note the closing voltage. If the closing voltage is not in the given range, adjust it to 6.4 volts by turning the adjusting screw **(3)**. Turn the screw clockwise to increase the spring tension and the closing voltage, and counterclockwise to decrease the spring tension and to decrease the closing voltage.



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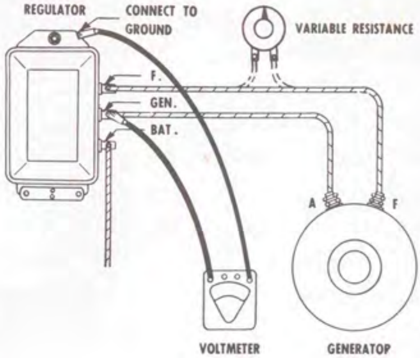


T7443

CHECKING AND ADJUSTING CLOSING VOLTAGE OF THE CUTOUT RELAY
3—Adjusting screw.

Voltage Regulator Checks and Adjustments

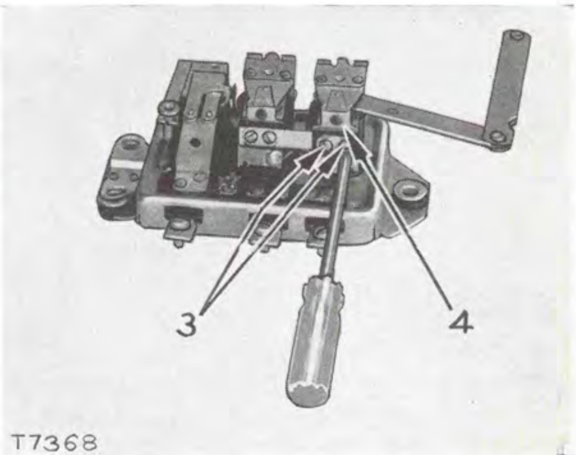
Two checks and adjustments are required on the voltage regulator: air gap and voltage setting.

The air gap is checked by pushing the armature down until the points are just touching and then measure the air gap between the bottom of the armature and the center of the core. Adjust by loosening the contact mounting screws **(3)** and raising or lowering the contact bracket **(4)** as required. The air gap should be .075". Be sure the points are lined up, tighten the screws after adjustment.

CHECKING AND ADJUSTING VOLTAGE REGULATOR AIR GAP

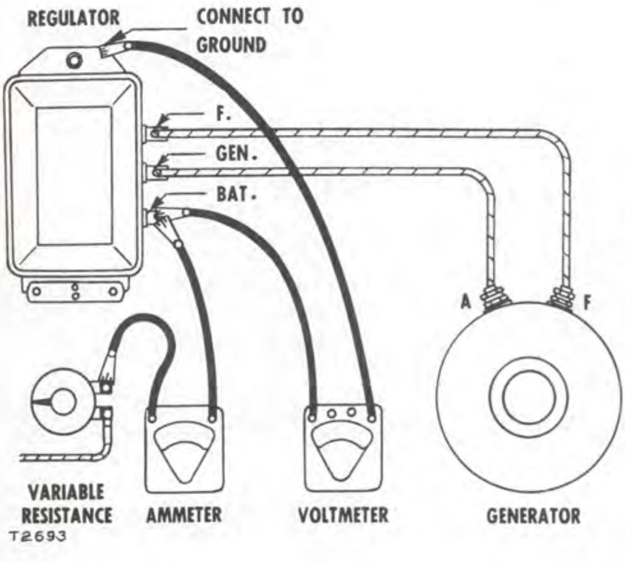
3—Mounting screws.
4—Contact bracket.

♦



T7368

The voltage setting of the voltage regulator can be checked by the variable resistance method. Connect an ammeter into the charging circuit (BAT) terminal of the regulator with a 1/4-ohm variable resistance in series. Connect a voltmeter from the regulator (BAT) terminal to ground as shown. Increase the generator to the specified speed (approx. 1300 RPM). If less than 8 amperes is obtained, throw a load on to permit increased generator output. Cut in resistance until output is reduced to 8–10 amperes. Operate until regulator reaches operating temperature. Retard the generator until the relay points open, then bring the generator back to specified speed and note the voltage setting. The voltage setting should be in a range of 7.0 to 7.7 volts. Voltage readings must be taken with the cover in place, regulator at operating temperature and with 8–10 amperes flowing.



CHECKING VOLTAGE REGULATOR SETTING BY VARIABLE RESISTANCE METHOD

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To adjust the voltage setting, turn the adjusting screw **(5)** clockwise to increase voltage setting and counterclockwise to decrease the voltage setting.

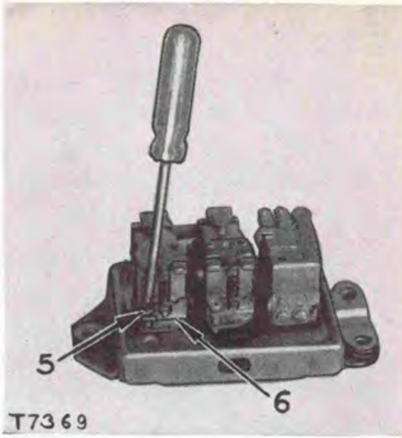
CAUTION

> If the adjusting screw is turned down (clockwise) beyond normal adjustment range, spring support **(6)** may fail to return when pressure is relieved. In such cases, turn screw counterclockwise until sufficient clearance develops between screw head and spring support, then bend spring support upward carefully with small pliers until contact is made with the screw head. Final setting of the unit should always be approached

ADJUSTING VOLTAGE REGULATOR SETTING

5—Adjusting screw.
6—Spring support.

◆

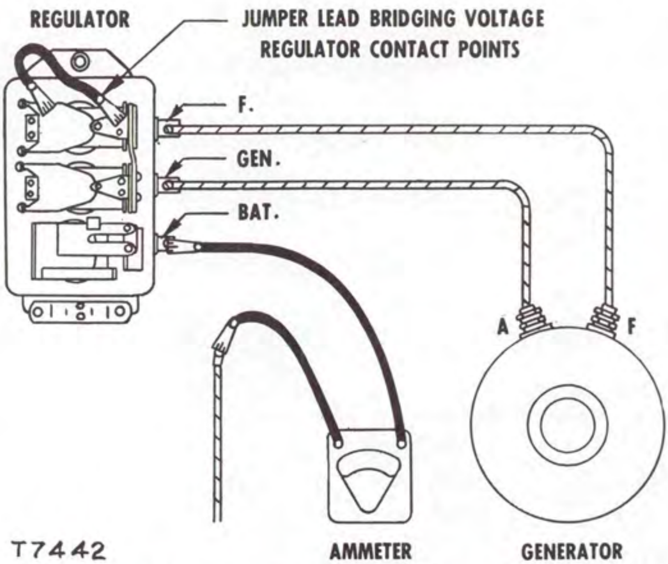


by increasing spring tension, never reducing. If the setting is too high, adjust unit below the required value, and then raise to exact setting by increasing spring tension.

After each adjustment and before taking voltage reading, replace the regulator cover, reduce generator speed until relay points open and then bring the generator back to speed again.

Current Regulator Checks and Adjustments

Two checks and adjustments are required on the current regulator: air gap and current setting. The air gap on the current regulator is .075" and is adjusted in the same manner as the voltage regulator. To check



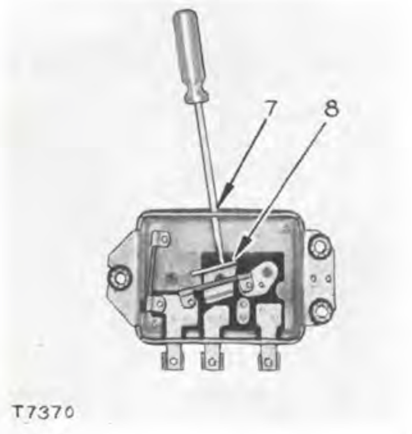
CHECKING CURRENT REGULATOR SETTING BY THE JUMPER LEAD METHOD the current regulator setting, it is necessary to prevent the voltage regulator from operating. There are four methods of preventing the voltage regulator from operating, however only two are given here. Regardless of the method used, an ammeter must be connected into the charging circuit at the regulator (BAT) terminal. The first method should be used for preliminary checks whenever possible since it does not require removal of the regulator cover.

The quick check method is to insert a screw driver through the oblong hole **(7)** in the base of the regulator until contact is made with the shield **(8)** around the resistor. Be sure the screw driver is held firmly in place during the check so that the blade touches the regulator base and shield at the same time. This temporarily cuts out the voltage regulator unit. Turn on accessories to prevent high voltage during the test. With the ammeter connected and at operating temperature, operate generator at approximately 1300 RPM and note current setting. It should be in a range of 17–21 amperes. If necessary to adjust, remove cover and adjust in the same manner as the voltage regulator unit by turning the screw clockwise to increase current setting and counterclockwise to decrease current setting. It should be set at 19 amperes. See, CAUTION, under VOLTAGE REGULATOR CHECKS AND ADJUSTMENT.

Another method is to remove the regulator or cover and connect a jumper lead across the voltage regulator contact points. Turn on accessories to prevent high voltage during the test. With the generator operating at approximately 1300 RPM and with the regulator at operating temperature, note the current setting.

NOTE

When testing current regulator, the generator must be operated at a speed sufficient to produce current in excess of the specified setting.



CUTTING OUT VOLTAGE REGULATOR TO CHECK CURRENT SETTING OF CURRENT REGULATOR

7—Oblong hole. 8—Shield.

Generator

(Leece-Neville 1960G 15235)

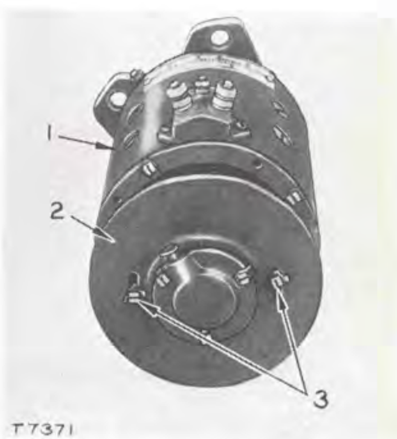
This is a third-brush, 24-volt generator and rotates clockwise looking at the drive end. The current output is regulated by setting the third brush and the voltage is controlled by the voltage regulator control unit. The third brush should be set so that the current cannot exceed the generator's maximum safe output and the voltage regulator control unit will control the output to conform with the requirements of the battery and the connected load.

Periodic inspections and good maintenance will prevent service interruptions. Connect units according to terminal markings for correct performance and to prevent damage to the windings. Keep all connections clean and tight.

DISASSEMBLY

Remove the cotter pin and nut and pull the drive gear. Remove the key from the armature shaft. Take off the cover band and disconnect the two field leads from the two brushes. Disconnect the third lead from the end of the safety fuse bracket. It is wise to mark the leads as they are disconnected. Marking them will facilitate reassembly.

Open the locks and remove the screws securing the brush holder assembly cage **(2)** to the housing **(1)**.

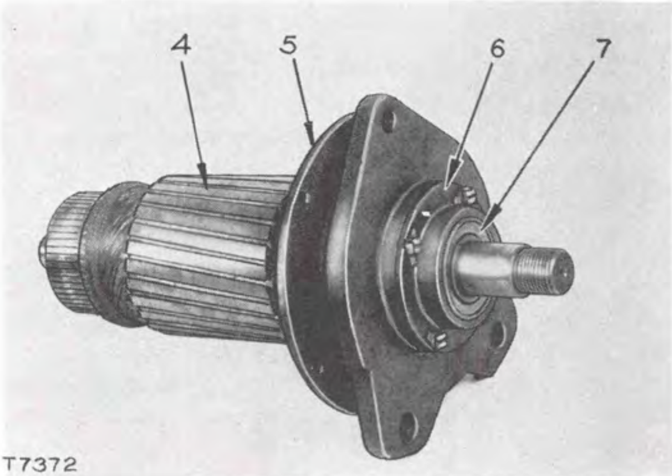


REMOVING BRUSH HOLDER ASSEMBLY CAGE

1—Housing.
2—Brush holder assembly cage.
3—Screws.

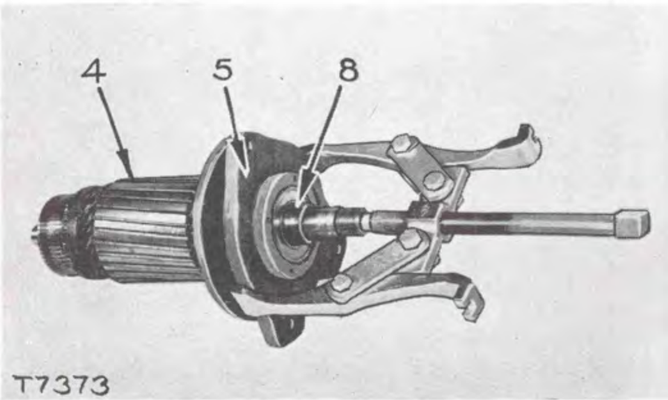
It may be necessary to open the locks and loosen the two screws **(3)** in order to disconnect the field leads from the brushes. If so, mark the position of the screws **(3)**, so the brush holder ring can be rotated back to its original position in the brush holder assembly cage when reassembling the generator. The position of the brush holder ring is determined at the factory and shouldn't be altered. Only the third brush is to be moved and it is moved on the brush holder ring to alter ampere output.

Open the locks and remove the capscrews securing the drive end flange **(5)** to the housing **(1)**. Remove the armature **(4)** and the drive end flange **(5)** from the housing as a unit. Remove the screws securing the cover **(6)** to the flange **(5)** using extreme care to prevent damaging of the seal **(7)**.



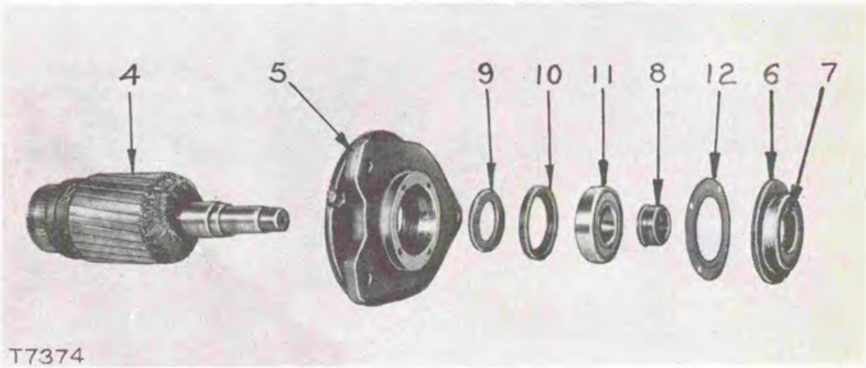
REMOVING ARMATURE AND DRIVE END FLANGE AS A UNIT
4—Armature. 5—Drive end flange. 6—Cover. 7—Seal.

The spacer **(8)** is a tight press fit and must be pulled from the armature shaft. This can be accomplished by pulling the drive end flange **(5)** from the armature **(4)** with the 8B7546 Puller. This will force the spacer **(8)** from the armature shaft.



PULLING DRIVE END FLANGE FROM THE ARMATURE
4—Armature. 5—Drive end flange. 8—Spacer.

After removing the cover **(6)** and gasket **(12)** and pressing off the spacer **(8)**, remove the bearing **(11)**. The shielded side of the bearing **(11)** faces away from the armature. Pry out the retainer **(10)** and remove the felt seal **(9)**. The counterbored side of the retainer **(10)** faces out. The flange of the spacer **(8)** should be facing the bearing **(11)** when the generator is reassembled. The seal **(7)** can be driven from the cover **(6)** if it is damaged and needs replacing. The lip of the seal is turned away from the armature.



DISASSEMBLING DRIVE END FLANGE
4—Armature. 5—Drive end flange. 6—Cover. 7—Seal. 8—Spacer. 9—Felt seal. 10—Retainer. 11—Bearing. 12—Gasket.

Disassemble the brush holder cage assembly **(2)** by removing the screws securing the cover **(14)**. Mark the position of the fiber brush holder ring in relation to its position on the brush holder assembly cage **(2)** before removing the two screws **(3).** The fuse **(13)** protects the field windings. A 3-ampere fuse should always be used. The fuse capacity is specified on the cover band.

DISASSEMBLING BRUSH HOLDER ASSEMBLY CAGE

2—Brush holder assembly cage. 3—Screws. 13—Fuse. 14—Cover.

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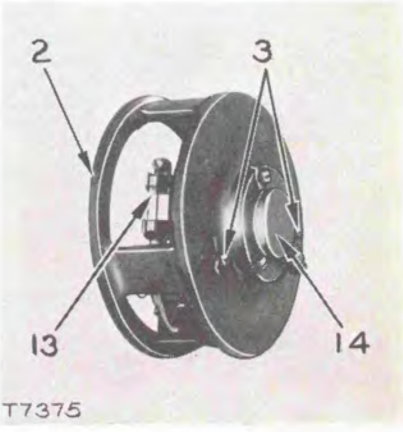
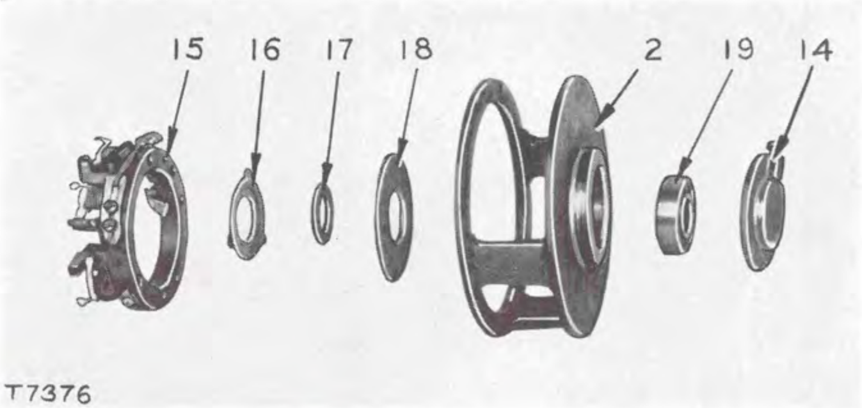
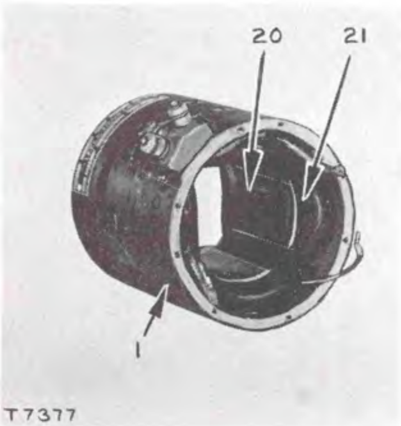


After the cover **(14)** and the brush holder ring **(15)** have been removed from the brush holder cage, remove the three machine screws located under the cover **(14)**. This will permit removal of the seal retainer **(16)**, felt seal **(17)** and plate **(18)**. The bearing **(19)** is a light press fit and can be driven from the brush holder assembly cage **(2)**.



DISASSEMBLING BRUSH HOLDER CAGE
2—Brush holder assembly cage. 14—Cover. 15—Brush holder ring. 16—Seal retainer. 17—Felt seal. 18—Plate. 19—Bearing.

The field windings **(21)** and pole shoes **(20)** can be removed from the housing **(1)** by removing the pole shoe screws. When replacing the field windings, the same field windings should be put back in the place from which they were removed.



REMOVING FIELD WINDINGS
1—Housing. 20—Pole shoes. 21—Field windings.

♦

Adjusting Generator Third Brush

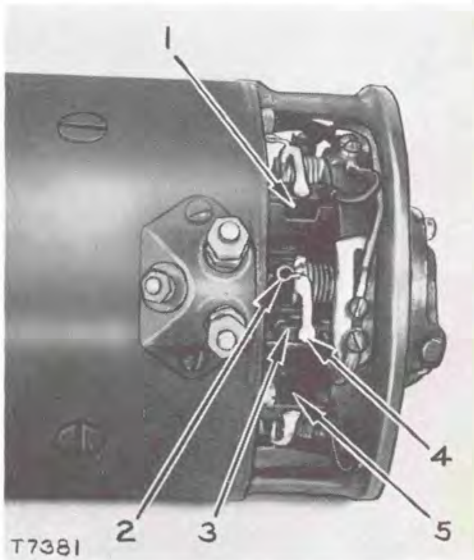
See the covering topic under, VOLTAGE CONTROL UNIT (Leece-Neville 3204-R12).

Brushes and Brush Springs

Blow all dirt and carbon dust out of generator with compressed air. The third brush **(3)** is smaller than the two main brushes **(1)** and **(5)**. Lift up the lever **(4)** and disconnect the leads to remove brushes. If brushes are worn down or damaged they should be replaced. Seat new brushes with 00 sandpaper. As the brushes wear, the spring pressure can be increased by lifting the spring **(2)** and placing it in the next notch. There will be excessive arcing when the brushes are worn and the generator will eventually quit charging. The two main brush springs can be changed in the same manner as the third brush spring.

BRUSHES AND BRUSH SPRINGS

1—Main brush. 2—Spring. 3—Third brush. 4—Lever. 5—Main brush.



TESTING

Armature

With the armature out of the generator, test for a ground by connecting a battery and 6-volt lamp in series. Place one lead on the armature shaft and the other lead on each segment of the commutator in succession. If the test lamp lights between any one segment and the shaft, the armature is grounded and should be replaced.

To test the armature for a short, clean out between the commutator bars, place the armature on a growler with a hacksaw blade over the armature core and rotate the armature. If the blade vibrates, the armature is short-circuited and should be replaced.

Commutator

Check the commutator for roughness. If rough, it should be turned down on a lathe just enough to remove the roughness and then sanded with 00 sandpaper. Undercut the mica between each segment with a hacksaw blade. Clean out the generator with air to remove all abrasives.

Field Coils

To test for a continuous circuit, connect a battery and a 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the third brush lead. If the lamp does not light, the field coils are open-circuited and should be replaced.

To test for a ground, connect a battery and 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the generator housing. If the test lamp lights, the fields are grounded and should be replaced.

To test for balance between the four field coils, connect an ammeter and a six-volt battery in series. Remove part of the insulation from the connecting wires between each field coil. Connect the lead from the battery to one side of the field coil and the other lead on the opposite side of the same field coil and note the ammeter reading. Repeat the same test on all four field coils, recording each reading. If any one field coil draws more current than the others, there is an internal short in that field coil and it should be replaced. Each field coil should give the same reading.

Use rosin flux in making all soldered connections. Make sure that the coils are installed in the same position as the coils which were taken out.

Voltage Regulator Control Unit

(Leece-Neville 3204-R12)

This is a voltage regulation control unit for a 12-cell battery and is used with a 24-volt, 250-watt Leece-Neville generator (1960G-15235). It is a two-unit control consisting of a voltage regulator and a cutout relay.

Voltage Regulator

The purpose of voltage regulation is to automatically control and limit generator voltage in order to properly charge a battery and to provide a source of controlled energy for other electrical units that may be connected. The voltage regulator permits a comparatively high charging current when the battery is in a discharged condition and not only needs the higher current, but can take it without damage. It will also cause this current to gradually decrease as the battery becomes charged, thereby protecting the battery from possible damage by higher current. By means of voltage regulation, the charging current will be adjusted automatically to agree with the battery throughout the charging cycle.

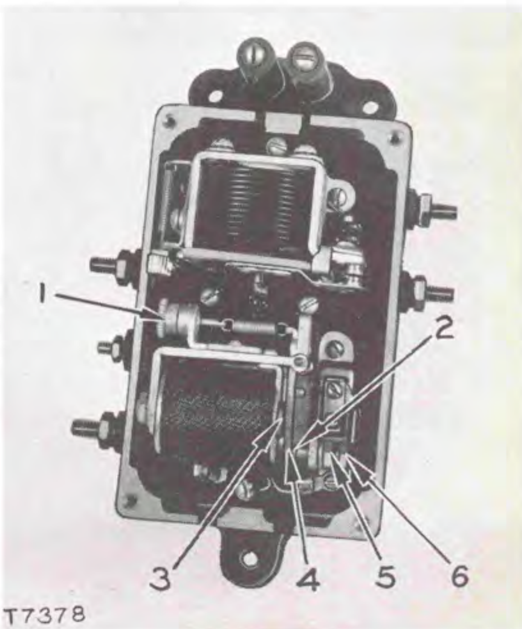
Cutout Relay

The cutout relay acts as an automatic switch between the generator and the battery. When generator speed and voltage have increased sufficiently to begin to charge the battery, the cutout relay armature is magnetically attracted toward its coil to close the contacts and thus automatically connect the generator to the battery for charging. When the generator speed and voltage decrease below charging values and also when the generator is not running, the cutout relay automatically disconnects the generator from the battery to prevent the battery from discharging back through the generator.

TESTING

When testing the units, use accurate test meters. Adjust while hot; after running 15 minutes or more to heat up. Do not close cutout relay contacts while the battery is connected or while the generator is not running. Disconnect battery from control unit terminal (B—) before removing the cover or while cleaning contact points.

Voltage Regulator



TESTING VOLTAGE REGULATOR

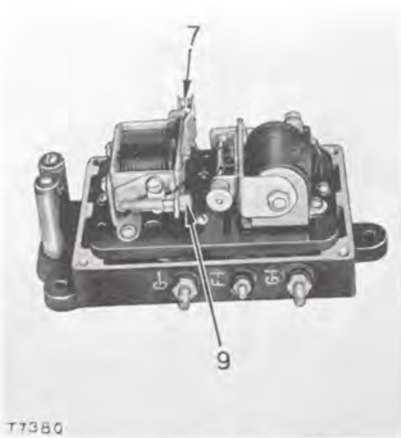
1—Regulator spring adjusting nut. 2—Regulator contact points. 3—Coil core. 4—Regulator armature. 5—Lock nut. 6—Screw.

Disconnect the battery wire from the control unit terminal (B—). Connect a test voltmeter to terminals (G—) and (G+) and run generator at 2500 RPM. At this speed, test voltmeter should indicate open circuit volts of 28.4 to 28.6. If not turn regulator spring adjusting nut **(1)** right to increase or left to decrease until open circuit volts are correct. Open regulator contact points **(2)** by hand (do not use metal) after each adjustment. Repeat adjustment and opening of contact points until open circuit volts are correct. The regulator contact point gap should be .020" to .025" when the regulator armature **(4)** is held against the coil core **(3)**. They are checked with a thickness gauge and adjusted by loosening the lock nut **(5)** and turning the screw **(6)**. After adjustment is correct, tighten the lock nut.

Cutout Relay

Disconnect the battery wire from the control unit terminal (B—) and connect a test voltmeter to (G—) and (G+). From a very slow speed where the cutout relay contacts **(8)** are open, slowly increase the generator speed and at the instant the cutout relay contacts close, the voltmeter should read 22.0 to 22.5 volts, which is the correct voltage to close the contact points. A 24-volt bulb temporarily attached to (B—) and (B+) will light the instant that the contact points close, and if held near the voltmeter, will aid in observing the exact voltage when the contacts close. If correct closing voltage is indicated by the voltmeter, no adjustment is necessary, otherwise, turn the cutout relay spring adjusting nut **(9)** clockwise to increase the voltage or counterclockwise to decrease the voltage until a reading of 22.0 to 22.5 volts is obtained.

TESTING CUTOUT RELAY
7—Auxiliary contact gap.
8—Cutout relay contacts.



TESTING CUTOUT RELAY
7—Auxiliary contact gap.
9—Cutout relay spring adjusting nut.

A discharge of 0–3 amperes is necessary to open the cutout relay contact points. Connect a test ammeter from (B—) to the wire disconnected from (B—). Decrease the generator speed or bring to a complete stop and at the instant the cutout relay contacts open, the test ammeter should read 0 to 3 amperes, otherwise, recheck the closing voltage adjustment. The gap of the contacts **(8)** should be .070" to .075" and the auxiliary contact gap **(7)** should be .040" to .045". The hinge gap should be .005" to .010".

Adjusting Generator Third Brush

Connect a test ammeter from (B—) terminal to the battery wire removed from (B—). The battery specific gravity must be 1.250 or over. Run the generator at 2000 RPM on bench test. On engine test, gradually increase engine speed and observe that the test ammeter indication will move up to a certain point and then start to fall back as speed is further increased, therefore, drop speed back to point where ammeter indicated the highest reading, adjustment should be made at this speed. This point represents the peak of ampere output and the same can be duplicated on the test bench.

While running at this speed, hold the regulator contacts closed and test ammeter should read 10 amperes. Do not adjust higher. The third brush moved in direction of rotation increases amperage and opposite to rotation decreases amperage.

After adjustment, run generator at all speeds and output must not exceed 10 amperes at any speed. Readjust if necessary until correct. Tighten third brush holder screws and recheck, readjust if necessary.

Recheck the voltage regulator open circuit voltage (28.4 to 28.6) after adjusting the generator third brush.

Connections for Reconnecting Units

Connect generator (G—) terminal to control unit (G—) terminal, also (G+) to (G+) and (F+) to (F+). Connect control unit (B—) to battery negative (—) and control unit (B+) to battery positive (+).

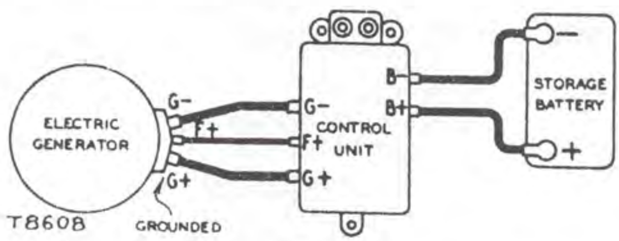


DIAGRAM FOR CONNECTING UNITS

Generators

(Leece-Neville 24 volt 1910G 15272)
(Leece-Neville 32 volt 1912G 15272)

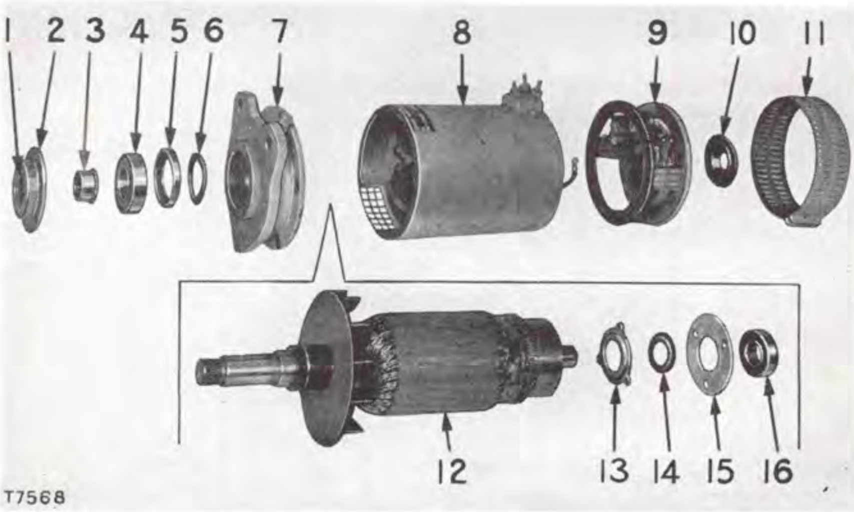
These are third brush generators and rotate clockwise looking at the drive ends. Since these generators are similar in construction and design, they will be discussed together. The illustrations are of the 24-volt, 1910G generator.

The current output is regulated by setting the third brush and the voltage is controlled by voltage regulator control units. The third brush should be set so the current cannot exceed the generator's maximum safe output and the voltage regulator control unit will control the output to conform with the requirements of the battery and the connected load.

Periodic inspections and good maintenance will prevent service interruptions. Connect units according to terminal markings for correct performance and to prevent damage to the windings. Keep all connections tight and clean.

DISASSEMBLY

Remove cotter pin and nut, then remove the drive gear. Remove the key from the armature shaft. Mark the position of the flange housing **(7)**, housing **(8)** and brush holder housing **(9)** in relation to each other to



DISASSEMBLING GENERATOR
1—Seal. 2—Seal retainer. 3—Collar. 4—Bearing. 5—Collar. 6—Felt washer. 7—Flange housing. 8—Housing. 9—Brush holder housing. 10—Cover. 11—Cover band. 12—Armature. 13—Retainer. 14—Felt washer. 15—Plate. 16—Bearing.

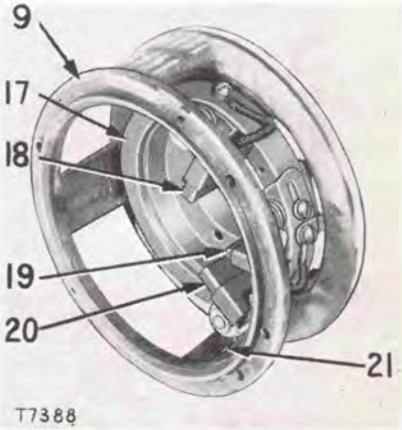
facilitate assembly. Remove the cover band **(11)** and disconnect the two field leads, marking them as they are disconnected. Disconnect the third lead from the end of the safety fuse bracket. It may be necessary to open the locks and loosen the two screws securing the brush holder ring to the brush holder housing in order to disconnect the field leads. If so, mark the position of the brush holder ring in relation to the brush holder housing so that it can be rotated back to its original position when assembling the generator. The position of the brush holder ring is determined at the factory and should not be altered. Only the third brush is to be moved and it is moved on the brush holder ring to alter ampere output.

Remove the cover **(10)** from brush holder housing **(9)**. Remove the machine screws under cover **(10)** and the small capscrews securing the brush holder housing **(9)** to the housing **(8)**. Remove the brush holder housing and pull the bearing **(16)** from the armature **(12)** with the 8B7547 Puller. Remove the plate **(15)**, felt washer **(14)** and retainer **(13)**.

Remove the capscrews securing the flange housing **(7)** to the housing **(8)**. Remove the flange housing **(7)** and armature **(12)** as an assembly. Take off the seal retainer **(2)** and pull the flange housing **(7)** from the armature shaft using the 8B7546 Puller. This will force the collar **(3)** from the armature shaft. Drive the bearing **(4)** from the housing and remove the collar **(5)** and felt washer **(6)**. When assembling the unit, the shielded side of bearing **(4)** faces out. The counterbored side of the collar **(5)** faces out. The lip of the seal **(1)** also faces out.

Brush and Brush Springs

Blow all dirt and carbon dust out of the generator with compressed air. The brush holders are attached to a fiber brush holder ring **(17)**. The brushes can be inspected and replaced without removing the brush holder housing **(9)** from the generator housing. The third brush **(19)** is



BRUSHES AND BRUSH SPRINGS

9—Brush holder housing.
17—Brush holder ring. 18—Main brush.
19—Third brush. 20—Main brush.
21—Brush spring.

◆

smaller than the two main brushes **(18)** and **(20)**. If brushes are worn down or damaged, they should be replaced. The brushes can be replaced by lifting the spring **(21)**, disconnecting the lead and removing. Each brush has a spring which is identical to spring **(21)**. As the brushes wear, lift the spring and place in the next notch. Seat new brushes with 00 sandpaper.

Adjusting Third Brush

For adjusting the third brush, see the covering topic under, VOLTAGE REGULATOR CONTROL UNITS (Leece-Neville 3192-R12 and 3194-R15). This covers both generators 1910G and 1912G.

Armature

With the armature out of the generator, connect a battery and 6-volt lamp in series. Place one lead on the armature shaft and the other lead on each segment of the commutator in succession. If the test lamp lights between any one segment and the shaft, the armature is grounded and should be replaced.

To test the armature for a short, clean out between the commutator segments, place the armature on a growler with a hacksaw blade over the armature core and rotate the armature. If the blade vibrates, the armature is short-circuited and should be replaced.

Commutator

Check the commutator for roughness. If rough, it should be turned down on a lathe just enough to remove the roughness and then sanded with 00 sandpaper. Undercut the mica between each segment with a hacksaw blade. Clean out the generator with air to remove all abrasives.

Field Coils

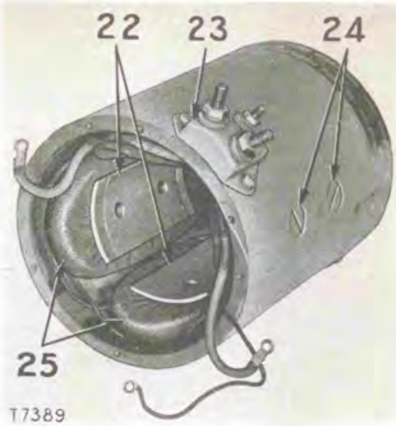
To test for continuous circuit, connect a battery and a 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the third brush lead. If the lamp does not light, the field coils are open-circuited and should be replaced.

To test for a ground, connect battery and 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the generator housing. If the test lamp lights, the fields are grounded and should be replaced.

To test for balance between the four field coils, connect an ammeter and a six-volt battery in series. Remove part of the insulation from the connecting wires between each field coil. Connect the lead from the battery to one side of the field coil and the other lead on the opposite side of the same field coil and note the ammeter reading. Repeat the

REMOVING FIELDS

22—Pole shoes. 23—Carrier assembly. 24—Pole shoe screws. 25—Field coils.



same test on all four field coils, recording each reading. If any one field coil draws more current than the other, there is an internal short in that field coil, however the four field coils are furnished as a unit and must be installed as such.

Use rosin flux in making any soldered connections.

The field coils **(25)** can be removed by removing the pole shoe screw **(24)** and pole shoes **(22)**. (Only two of each are pointed out in the illustration.) Remove the carrier assembly **(23)** and disconnect the leads.

Voltage Regulator Control Units

(Leece-Neville 3192-R12)
(Leece-Neville 3194-R15)

The two voltage regulation control units are similar and will be discussed together. The Leece-Neville 3192-R12 Control Unit is for a 12-cell battery and is to be used with the 24-volt, 400-watt Leece-Neville generator (1910G-15272). The Leece-Neville 3194-R15 Control Unit is for a 15-cell battery and is to be used with a 30-volt, 350-watt Leece-Neville generator (1912G-15272).

Voltage Regulator

The purpose of voltage regulation is to automatically control and limit generator voltage in order to properly charge a battery and to provide a source of controlled energy for other electrical units that may be connected. The voltage regulator permits a comparatively high charging current when the battery is in a discharged condition and not only needs the higher current, but can take it without damage. It will also cause this current to gradually decrease as the battery becomes charged, thereby protecting the battery from possible damage by higher current. By means of voltage regulation, the charging current will be adjusted automatically to agree with the battery throughout the charging cycle.

Cutout Relay

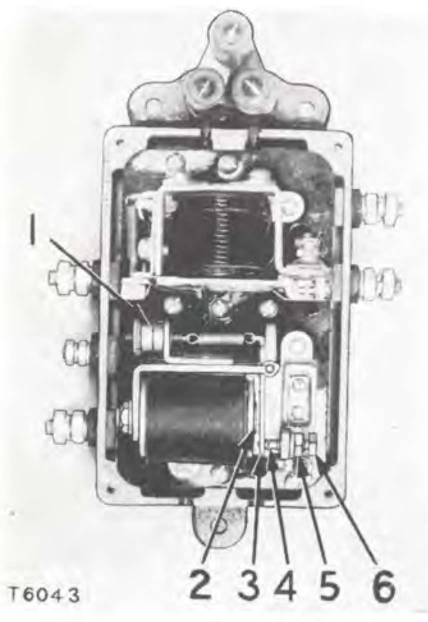
The cutout relay acts as an automatic switch between the generator and the battery. When the generator speed and voltage have increased sufficiently to begin to charge the battery, the cutout relay armature is magnetically attracted toward its coil to close the contacts and thus automatically connect the generator to the battery for charging. When the generator speed and voltage decrease below charging values and also when the generator is not running, the cutout relay automatically disconnects the generator from the battery to prevent the battery from discharging back through the generator.

TESTING

When testing the units, use accurate test meters. Adjust while hot; after running 15 minutes or more to heat up. Do not close cutout relay contacts while the battery is connected or while the generator is not running. Disconnect the battery from the control unit terminal (B—) before removing the cover or while cleaning the contact points.

Voltage Regulator

Disconnect the battery wire from the control unit terminal (B—). Connect a test voltmeter to terminals (G—) and (G+) and run the generator at 2500 RPM. At this speed, test voltmeter should indicate open circuit volts of 28.4 to 28.6 for the 24-volt regulator and open circuit volts of 35.5 to 36.0 for the 30-volt regulator. If not, turn the regulator spring adjusting



TESTING VOLTAGE REGULATOR
(Leece-Neville 3192-R12)
(24 Volt)
(This also applies to 3194-R15—30 Volt)

1—Regulator spring adjusting nut. 2—Coil core. 3—Armature. 4—Contact points. 5—Lock nut. 6—Screw.

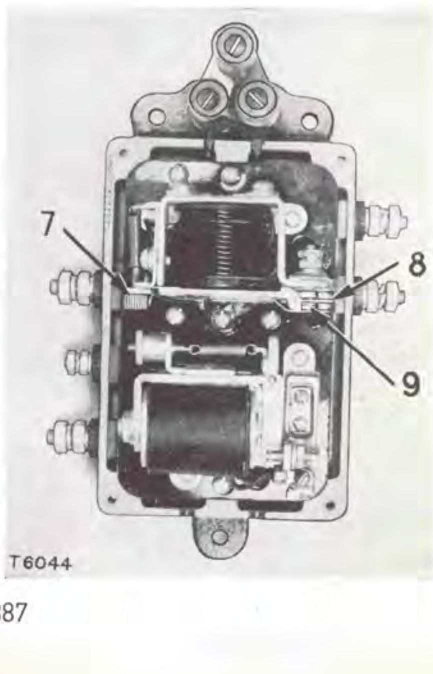
nut **(1)** to the right to increase or left to decrease until open circuit voltage is correct. Open the regulator contact points **(4)** by hand (do not use metal) after each adjustment. Repeat adjustment and opening of contact points until open circuit voltage is correct. The regulator contact point gap on the 24-volt regulator should be .020" to .025" and .027" to .030" on the 30-volt regulator when the regulator armature **(3)** is held against the coil core **(2)**. They are checked with a thickness gauge and adjusted by loosening the lock nut **(5)** and turning the screw **(6)**. After adjustment is correct, tighten the lock nut.

Cutout Relay

Disconnect the battery wire from the control unit terminal (B—) and connect a test voltmeter to (G—) and (G+). From a very slow speed where the cutout relay contacts at **(9)** are open, slowly increase the generator speed and at the instant the cutout relay contacts close, the voltmeter should read 22.0 to 22.5 volts for the 24-volt regulator and 27.0 to 28.0 volts for the 30-volt regulator, which is the correct voltage to close the contact points of the two cutout relays. A 24-volt bulb temporarily attached to (B—) and (B+) will light the instant the contact points close (32-volt bulb for 30-volt regulator), and if held near the voltmeter, will aid in observing the exact voltage when the contacts close. If correct closing voltage is indicated by the voltmeter, no adjustment is necessary, otherwise, turn the cutout relay spring adjusting nut **(7)** clockwise to increase the voltage or counterclockwise to decrease the voltage until a reading of 22.0 to 22.5 volts is obtained for the 24-volt regulator and a reading of 27 to 28 volts for the 30-volt regulator.

TESTING CUTOUT RELAY
(Leece-Neville 3192-R12)
(24-Volt)
(This also applies to 3194-R15 – 30-Volt)

7—Adjusting nut. 8—Auxiliary gap. 9—Contact gap.



A discharge of 1-5 amperes is necessary to open the cutout relay contact points of either regulator. Connect a test ammeter from (B—) to the wire disconnected from (B—). Decrease the generator speed or bring to a complete stop and at the instant the cutout relay contacts open, the test ammeter should read 1 to 5 amperes, otherwise recheck the closing voltage adjustment. The contact gap **(9)** should be .070" to .075" and the auxiliary gap **(8)** should be .040" to .045" on the cutout relays of both units. The hinge gap should be .005" to .010".

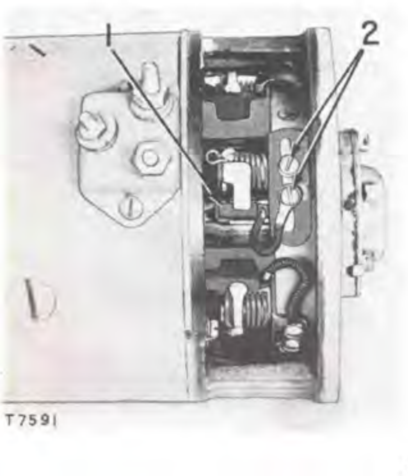
Adjusting Generator Third Brush

Connect a test ammeter from (B—) terminal to the battery wire removed from (B—). The battery specific gravity must be 1.250 or over. Run the generator at 2000 RPM on bench test. On engine test, gradually increase engine speed and observe that the test ammeter indication will move up to a certain point and then start to fall back as speed is further increased, therefore, drop speed back to point where the ammeter indicated the highest reading, adjustment should be made at this speed. This point represents the peak of ampere output and the same can be duplicated on the test bench.

While running at this speed, hold the regulator contacts closed and test ammeter should read 10 amperes for both units. Do not adjust higher. The third brush **(1)** moved in the direction of rotation increases amperage and opposite to rotation decreases amperage.

After adjustment, run the generator at all speeds and output must not exceed 10 amperes at any speed. Readjust if necessary, until correct. Tighten third brush holder screws **(2)** and recheck, readjust if necessary.

Recheck the voltage regulator open circuit voltage 28.4 to 28.6 for the 24-volt unit and 35.5 to 36.0 for the 30-volt unit after adjusting the generator third brush.



ADJUSTING THIRD BRUSH

1—Third brush.
2—Third brush holder screws.

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Connections for Reconnecting Units

Connect generator (G—) terminal to control unit (G—) terminal, also (G+) to (G+) and (F+) to (F+). Connect control unit (B—) to battery negative (—) and control unit (B+) to battery (+). See the illustration under the topic, CONNECTIONS FOR RECONNECTING UNITS, which is under the topic, VOLTAGE REGULATOR CONTROL UNIT (LEECE-NEVILLE 3204-R12).

Generator

(Leece-Neville 1946G-15052)

This is a third brush, 30-volt generator and rotates clockwise looking at the drive end. The current output is regulated by setting the third brush and the voltage is controlled by the voltage regulator control unit. The third brush should be set so that the current cannot exceed the generator's maximum safe output and the voltage regulator control unit will control the output to conform with the requirements of the battery and the connected load.

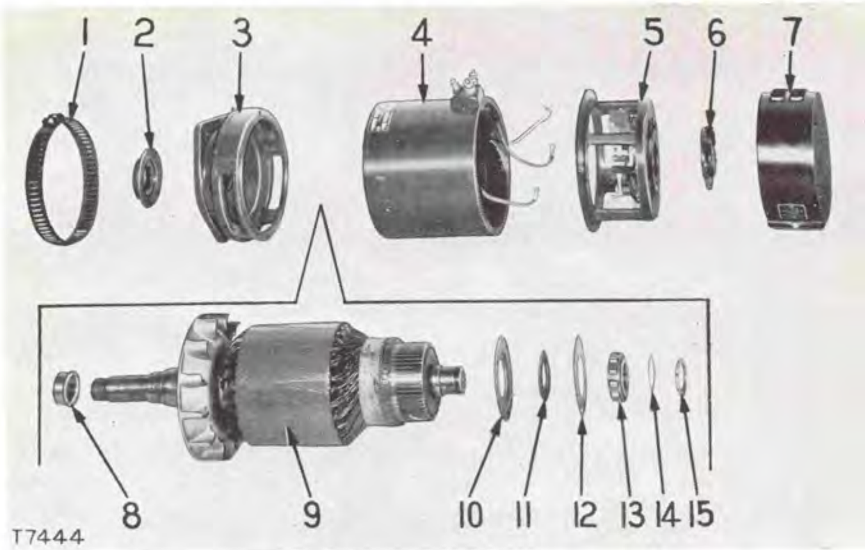
Periodic inspections and good maintenance will prevent service interruptions. Connect the units according to terminal markings for correct performance, and to prevent damage to the windings. Keep all connections tight and clean.

DISASSEMBLY AND ASSEMBLY

Remove the cotter pin and nut and pull the drive gear. Remove the key from the armature shaft. Take off the cover band **(7)** and disconnect the two field leads from the two brushes. The brush holders are mounted on a fiber ring and secured to the brush holder cage by two screws. The holes in the brush holder cage are elongated, this permits the fiber ring to be rotated a short distance. When disconnecting the two field leads from the two main brush leads it is necessary to rotate the fiber ring in order to get to the screws securing the field leads to the brush leads. The position of the fiber ring should be marked and it must be returned to its original position. This position is determined at the factory and should not be changed. Only the third brush is to be moved and it is moved on the fiber ring to vary the ampere output.

Disconnect the third lead from the end of the safety fuse bracket. Marking the leads as they are disconnected will facilitate assembly.

Open the locks and remove the screws securing the brush holder cage **(5)** to the field ring **(4)**.



GENERATOR ASSEMBLY

1—Band. 2—Seal retainer. 3—Housing. 4—Field ring. 5—Brush holder cage. 6—Cover. 7—Cover band. 8—Collar. 9—Armature. 10—Retainer. 11—Felt washer. 12—Washer. 13—Bearing. 14—Lockwasher. 15—Spanner nut.

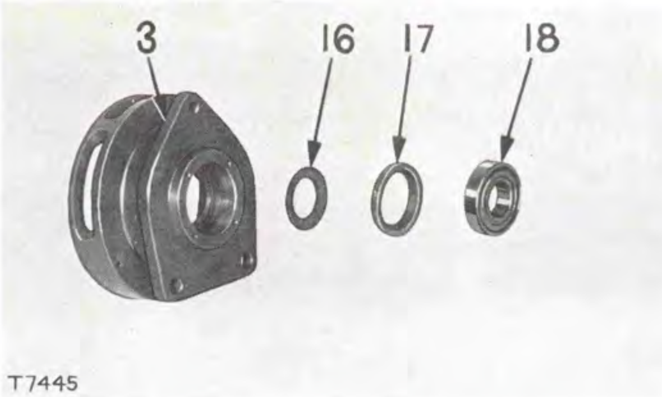
Remove the cover **(6)** and remove the spanner nut **(15)** and lockwasher **(14)**. Remove the four machine screws securing the bearing retainer **(10)**, felt washer **(11)** and washer **(12)** to the brush holder cage **(5)**. Remove the brush holder cage.

Remove the band **(1)** from the housing **(3)**. Take off the seal retainer **(2)** and remove the screws and locks securing the housing **(3)** to the field ring **(4)**. Remove the housing **(3)** from the field ring **(4)** and remove the armature **(9)** from the field ring.

The leather lip type seal in the seal retainer **(2)** should be replaced if damaged. The seal should be installed with the leather lip facing out. A new gasket should be installed between the seal retainer **(2)** and the housing **(3)**.

Remove the collar **(8)** from the armature shaft. The bearing **(13)** can be pulled from the armature shaft with the 8B7548 Puller, two 8B7550 Legs and the 8B7551 Bearing Pulling Attachment. After the bearing **(13)** has been pulled, remove the washer **(12)**, felt washer **(11)** and the retainer **(10)**.

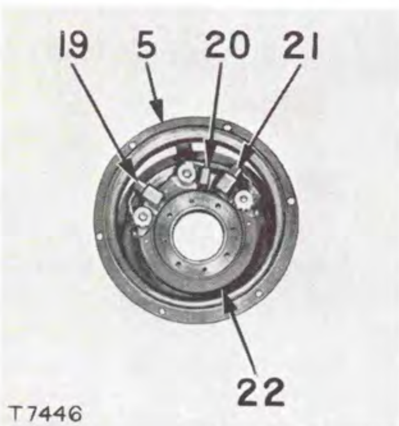
The bearing **(18)** is a light press fit and can be tapped out of the housing **(3)**. Remove the collar **(17)** and felt washer **(16)**. The counterbored portion of the collar **(17)** faces out. The felt washer **(16)** should be replaced if damaged. Soak felt washer in engine oil before installing.

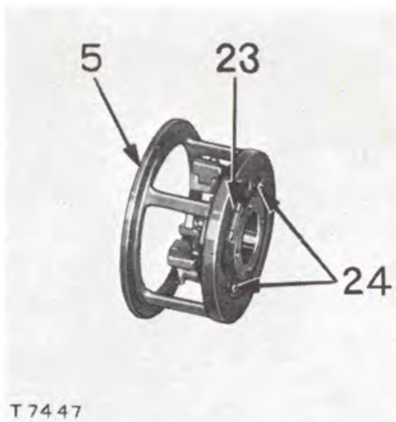


REMOVING BEARING FROM HOUSING
3—Housing. 16—Felt washer. 17—Collar. 18—Bearing.

The fiber brush holder ring **(22)** can be removed from the brush holder cage **(5)** by removing the two screws **(24)**. Mark the position of the brush holder ring **(22)** in relation to its position in the brush holder cage **(5)**. The two screw holes in the brush holder cage are elongated. The position of the brush holder ring is determined at the factory and should not be altered.

Blow all dirt and carbon dust out of the assembly with compressed air. The third brush **(20)** is smaller than the two main brushes **(19)** and **(21)**. Lift up the spring lever and disconnect the brush leads to remove the brushes. If the brushes are worn down or damaged, they should be replaced. Seat new brushes with 00 sandpaper. As the brushes wear, the spring pressure can be increased by lifting the spring and placing it in the next notch.





DISASSEMBLING BRUSH HOLDER ASSEMBLY
5—Brush holder cage. 19—Main brush. 20—Third brush. 21—Main brush. 22—Brush holder ring. 23—Fuse. 24—Two screws.

The fuse **(23)** is a five-ampere fuse and protects the field windings.

The brushes can be changed without disassembling the generator. They are accessible with the cover band removed.

The field windings **(25)** and pole shoes **(26)** can be removed from the field ring **(4)** by disconnecting the terminals and removing the pole shoe screws. There are four field windings and four pole shoes, however, only two of each are pointed out in the illustration.

REMOVING FIELD WINDINGS
4—Field ring. 25—Field windings. 26—Pole shoes.

Adjusting Generator Third Brush

See the topic, GENERATOR THIRD BRUSH CHECK AND ADJUSTMENT, under the topic, VOLTAGE REGULATION CONTROL UNIT (Leece-Neville 3196-R15).

TESTING

Armature

With the armature removed from the generator, connect a battery and 6-volt lamp in series. Place one lead on the armature shaft and the other lead on each segment of the commutator in succession. If the test lamp lights between any one segment and the shaft, the armature is grounded and should be replaced.

To test the armature for a short, clean out between the commutator segments, place the armature on a growler with a hacksaw blade over the armature core and rotate the armature. If the blade vibrates, the armature is short-circuited and should be replaced.

Commutator

Check the commutator for roughness. If rough, it should be turned down on a lathe just enough to remove the roughness and then sanded with 00 sandpaper. Undercut the mica between each segment of the commutator with a hacksaw blade. Clean out the generator with compressed air to remove all abrasives.

Field Coils

To test for a continuous circuit, connect a battery and a 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the third brush lead. If the lamp does not light, the field coils are open-circuited and should be replaced.

To test for a ground, connect a battery and 6-volt lamp in series. Place the lead from the battery on the field (F) terminal of the generator and the lead from the lamp on the generator housing. If the test lamp lights, the fields are grounded and should be replaced.

To test for balance between the four field coils, connect an ammeter and 6-volt battery in series. Remove part of the insulation from the connecting wires between each field coil. Connect the lead from the battery to one side of the field coil and the other lead on the opposite side of the same field coil and note the ammeter reading. Repeat the same test on all four field coils, recording each reading. If any one field coil draws more current than the others, there is an internal short in that field coil and it should be replaced. Each field coil should give the same reading.

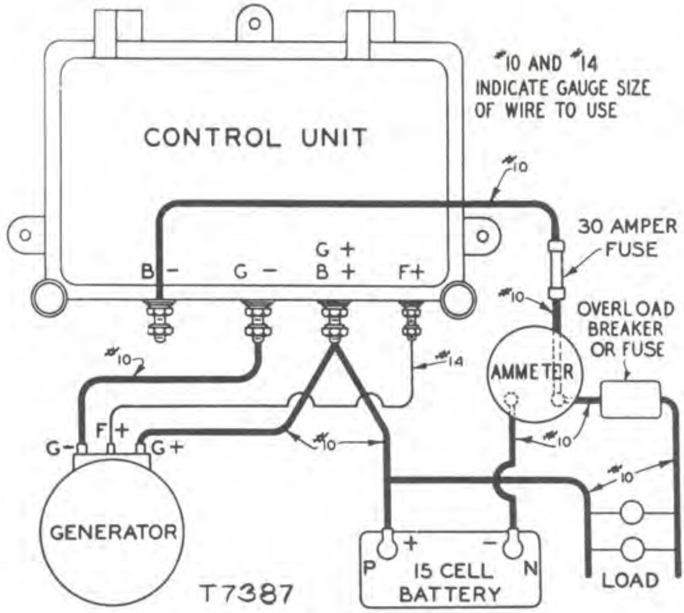
Use rosin flux in making all soldered connections. Check to make sure that the coils are installed in the same position as the coils which were taken out.

Voltage Regulation Control Unit
(Leece-Neville 3196-R15)

This voltage regulation control unit is to be used with a 1946G-15052 Leece-Neville generator. It is set for use with a 15-cell battery installation. The checks and adjustments used and the values given are for a 15-cell battery. If 16 cells are used, it is necessary to procure different adjustment values.

CAUTION

Disconnect the battery from the control unit terminal (B—) while cleaning or working on interior parts. This prevents short circuiting and burning of these parts.



WIRING DIAGRAM

> Do not close cutout relay contact points while the generator is running below charging speeds or while standing still. This avoids possible damage by back current from the battery.

Brush away any dust or other accumulations from the interior. Keep the terminals and external connections clean and tight.

Clean the contacts at least once each month. Contacts will last longer if adjustments are correct and they are properly cleaned. Clean contacts by drawing crocus cloth between them while being held together under slight pressure. Blow away the dust after cleaning. Be careful not to leave any lint from crocus cloth between contacts as this can prevent functioning. Snapping of contacts open and closed may dislodge any lint or loose particles. A clean piece of bond paper drawn between the contacts will help dislodge any particles. A file should be used only when removing projections or extreme roughness and then only use a very fine mill cut file.

The wires between the generator and control unit must be in good condition and their connections clean and tight.

Check and adjust when the control unit and generator are operated together. Both units should be hot before final adjustment is made. If the control unit has been repaired, and all gaps are correct, and it is ready to be adjusted, it should be given preliminary adjustment before heating up, then make final adjustments after units are hot.

The control unit contains two units that must be checked and adjusted, the voltage regulator and the cutout relay.

CHECKS AND ADJUSTMENT

Voltage Regulator, Check and Adjustment

1. Disconnect the battery wire from the terminal (B—). Check and adjustment of the voltage regulator must be made on open circuit, that is, while battery is disconnected.

2. Connect a test voltmeter to (G—) and to (G+, B+).

3. Run generator at 2500 RPM.

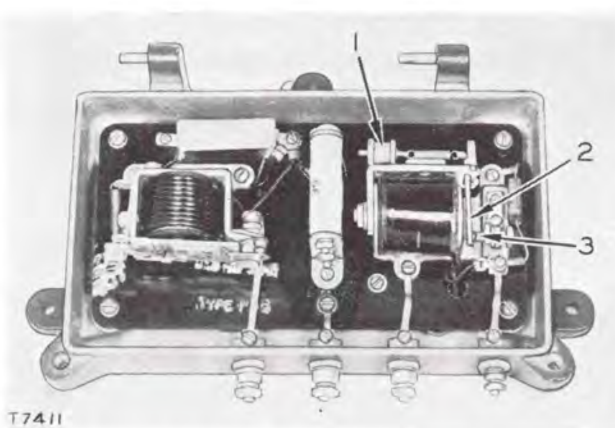
4. Voltmeter should indicate 35.5 to 36 volts while generator is running at 2500 RPM, and if so, no adjustment is necessary.

5. If the voltmeter indicates more than 36.0 volts, turn adjusting nut **(1)** counterclockwise to lower to 35.5 to 36.0 volts. If less than 35.5 volts, turn adjusting nut **(1)** clockwise to raise to 35.5 to 36.0 volts.

NOTE

After each change of the adjusting nut **(1)** position, press on armature **(2)** to open contacts **(3)** for a moment and then release armature, and if voltmeter indicates 35.5 to 36.0 volts, the adjustment is correct, otherwise repeat operation No. 5 and opening of contacts **(3)** until adjustment is correct.

6. The voltage regulator must be checked and readjusted if necessary, after the cutout relay and generator third brush have been adjusted and



CHECKING AND ADJUSTING VOLTAGE REGULATOR
1—Adjusting nut. 2—Armature. 3—Contact point.

this final adjustment of the voltage regulator should be made after the generator and control unit are hot.

7. As a final check on the correctness of final adjustment, stop the generator, then start up and bring speed up to 2500 RPM and voltmeter should indicate 35.5 to 36.0 volts, otherwise the entire voltage regulator adjustment should be repeated until corrected.

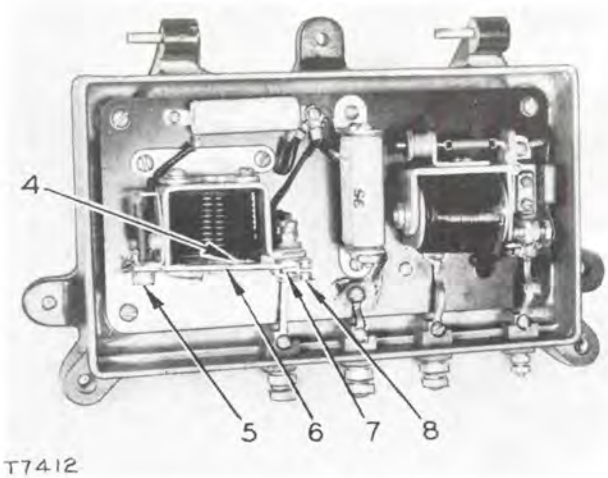
Cutout Relay Check and Adjustment

1. Disconnect battery wire from terminal (B—) and connect test voltmeter to (G—) and (G+, B+).

2. Stop generator or decrease its speed until both sets of contacts **(7)** and **(8)** are completely open.

3. Carefully and slowly increase generator speed and observe that the voltmeter indicates gradually increasing voltage. Continue to increase speed carefully and at the instant that contacts **(7)** and **(8)** close, the voltmeter should indicate 27.0 to 28.0 volts for the contact closing voltage. Repeat the operation several times to be sure of the reading. If correct, no adjustment is necessary.

4. If voltmeter indicates more than 28.0 volts, make one or two turns of the adjusting nut **(5)** counterclockwise, which decreases spring tension to permit contacts **(7)** and **(8)** to close at a lower voltage. If voltmeter indicates less than 27 volts, make one or two turns of the adjusting nut **(5)** clockwise which increases the spring tension to cause contacts to close at a higher voltage.



CHECKING AND ADJUSTING CUTOUT RELAY
4—Gap between armature and core. 5—Adjusting nut. 6—Armature. 7—Contact points. 8—Contact points.

NOTE

After each change of the adjusting nut **(5)** position, it is necessary to repeat operations No. 2, No. 3 and No. 4 until contacts close at 27.0 to 28.0 volts, when generator speed is increased to the closing point. Repeat several times until sure of the results.

The operations No. 5, No. 6 and No. 7 are to check the reverse current to open contacts **(7)** and **(8)** and at the same time to check the accuracy of adjustment for closing contact voltage.

5. Reconnect the battery but with a test ammeter connected between the (B—) of the control unit and the (N—) of the battery.

6. Increase the generator speed until contacts **(7)** and **(8)** are closed then decrease generator speed down to a dead stop and at the instant both sets of contacts open, the ammeter should indicate 2 to 5 amperes discharge. Repeat several times until certain of results.

7. If discharge current is more than 5 amperes, the contact closing voltage is adjusted too low and operations No. 2, No. 3 and No. 4 should be repeated to check for accuracy. If armature **(6)** is too close to coil core at gap **(4)**, the discharge current may also go above 5 amperes and core gap **(4)** should be checked and corrected if necessary.

Generator Third Brush Check and Adjustment

The generator third brush controls the ampere output and this check or adjustment is to determine that the third brush is correctly adjusted for rated amperage output. The third brush is the smaller one between the two main brushes which are larger.

CAUTION

Do not move main brushes to alter ampere output or attempt to alter cut-in speed. Do not loosen brush rigging retaining screws.

1. Connect control unit (B—) terminal to one side of the test ammeter and the battery (N—) terminal to the other side of the test ammeter.

CAUTION

Battery specific gravity must be 1.250 or over for check and adjustment. Specific gravity under this will cause overadjustment and subsequent damage to the parts.

2. Run generator at 1500 RPM. This speed can be closely approximated while generator is mounted on the engine, by gradually increasing engine speed and observing that test ammeter indication will increase up

to a peak ampere reading, then will begin to decrease as speed is further increased, therefore decrease speed to point where ammeter indicates highest amperes because check and adjustment should be made at this speed and highest amperes.

3. While running at 1500 RPM or where ampere indication is highest, hold voltage regulator contacts **(3)** together and test ammeter should indicate 25 amperes. If 25 amperes are indicated, no further adjustment is necessary.

CAUTION

Hold voltage regulator contacts closed only long enough to read ammeter and thus avoid overloading.

Observe that if battery is nearly discharged, the ammeter pointer may remain at approximately 25 amperes, but if battery is fully charged the pointer may drop back to lower amperes. This is correct for voltage regulation.

4. If, while holding voltage regulator contacts closed, the ammeter indicates more than 25 amperes, loosen the third brush holder screws, then move the generator third brush opposite to the generator armature rotation to decrease amperes. If indication is less than 25 amperes, move third brush in direction of rotation to increase amperes. After each movement of third brush, tighten screws, then repeat operation No. 3 to observe result of the adjustment by ammeter indication. Repeat until adjustment is correct.

5. If the battery overheats and causes excessive gassing or requires frequent addition of water, reduce ampere output by adjusting third brush until battery can be charged without overheating.

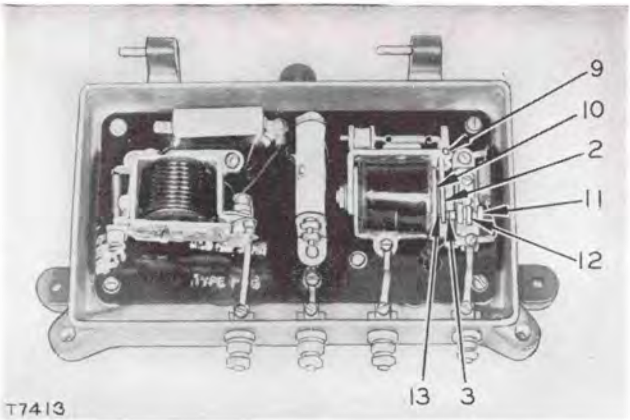
6. After adjusting cutout relay and generator third brush, make a final check of the voltage regulator adjustment and readjust it if check indicates necessity.

GAP SPECIFICATIONS

The battery must be disconnected while measuring and adjusting gaps. Use feeler gauges for measuring and adjusting gaps.

Voltage Regulator Gaps

1. Core gap **(13)** should be .027″ to .033″ between armature **(2)** and coil core **(10)** when the armature is held with contacts full open. This gap is determined by the thickness of the head of a small pin on the face of armature **(2)**. The thickness of this pin head should be checked and filed to the correct dimension of .027″ to .033″ when installing a new armature.



CHECKING VOLTAGE REGULATOR GAPS
2—Armature. 3—Contact gap. 9—Hinge pin. 10—Coil core. 11—Contact screw. 12—Locknut. 13—Core gap.

2. Contact gap **(3)** with the contacts open, should be .045″ to .051″. Adjust this by means of the contact screw **(11)** and locknut **(12)** while holding the armature **(2)** against the coil core **(10)**.

3. The hinge pin **(9)** should be replaced with a new one if it is bent, rough or worn. A damaged pin can prevent correct operation.

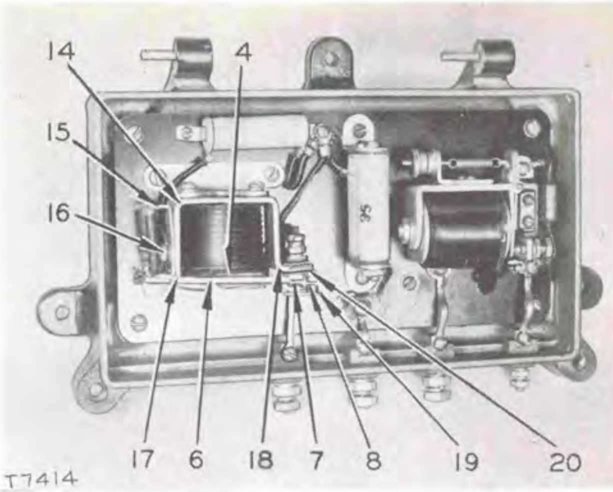
Cutout Relay Gaps

1. Hinge gap **(17)** should be .005″ to .010″. This gap is between armature **(6)** and yoke **(14)**. Adjust by first loosening screws **(16)** and then move bracket **(15)** which is slotted for screws **(16)**.

2. Main contact gap **(7)** should be .070″ to .075″ with armature **(6)** against stop **(18)**. Contacts are nearest to the coil. Adjust by means of the armature stop **(18)**.

3. Auxiliary contact gap **(8)** should be .040″ to .045″ with armature **(6)** against stop **(18)**. Adjust by bending the thin spring contact carrier **(19)**. Bend at a point near where it is fastened, otherwise contacts **(8)** may not come squarely together. These auxiliary contacts must come together before main contacts **(7)** and open after contacts **(7)**.

4. Core gap **(4)** should be .020″ to .025″ when the main contacts **(7)** are closed. This gap will be correct if the hinge gap **(17)** is correct, if armature is not bent and if stationary contact holder **(20)** with its insulators have been assembled correctly.



CHECKING CUTOUT RELAY GAPS
4—Core gap. 6—Armature. 7—Main contact gap. 8—Auxiliary contact gap. 14—Yoke. 15—Bracket. 16—Screws. 17—Hinge gap. 18—Armature stop. 19—Spring contact carrier. 20—Stationary contact holder.

Electric Starting Motor

(Leece-Neville 1223M)
(32 Volts)

The electric starting motor described in the following paragraphs is a heavy duty type used for cranking the Diesel engine at speeds sufficient to permit starting.

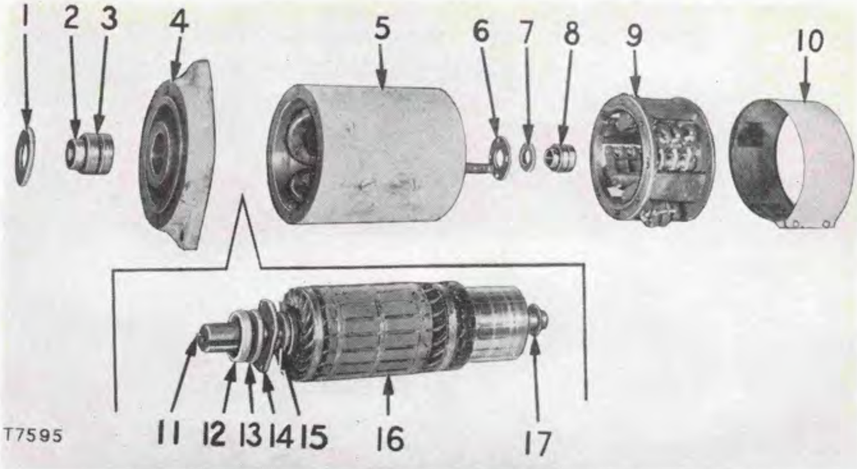
DISASSEMBLY OF STARTING MOTOR

Before starting disassembly mark the position of the flange housing **(4)**, housing **(5)** and brush holder housing **(9)**.

Remove the cover band **(10)**. Take off the small plate on the drive end of the armature **(16)** and remove the drive gear and key. Disconnect the field leads from the brushes and remove the brush holder housing **(9)**. Pull the brush holder housing from the end of the armature **(16)**, leaving the thrust washer **(17)** on the shaft.

Remove the machine screws securing the retainer **(6)** to the brush holder cage. Remove the seal **(7)** and bearing **(8)**. When replacing the seal **(7)** the lip faces the housing **(9)**.

Remove the machine screws securing the flange housing **(4)** to the housing **(5)** and remove the armature **(16)** and flange housing **(4)** as a unit. Remove the retainer **(1)** from the flange housing **(4)**. Remove the screws securing the retainer **(14)** to the back of the housing **(4)**.



DISASSEMBLING STARTING MOTOR
1—Retainer. 2—Bearing race. 3—Bearing. 4—Housing. 5—Housing. 6—Retainer. 7—Seal. 8—Bearing. 9—Brush holder housing. 10—Cover band. 11—Pin. 12—Seal. 13—Seal. 14—Retainer. 15—Thrust washer. 16—Armature. 17—Thrust washer.

Place the plate previously removed over the end of the armature shaft to protect the pin **(11)** and press the armature out. Pull the bearing race **(2)** from the end of the shaft and remove the seal **(12)**, seal **(13)**, retainer **(14)** and thrust washer **(15)**. When replacing the seal **(12)**, the lip faces out. The lip on seal **(13)** faces the center of the armature. Press the bearing **(3)** out of the housing.

Brushes

The brushes **(18)** can be removed by removing the cover band. There are 12 brushes. Blow out all carbon dust with compressed air. Check the brushes for loose connections and replace worn brushes. If brushes wear

REPLACING BRUSHES
18—Brushes. 19—Springs.

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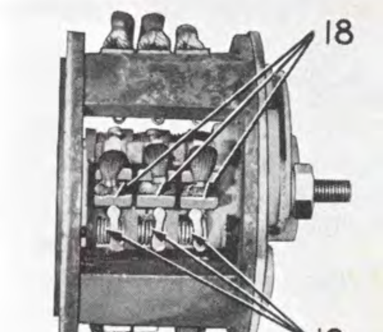


rapidly, check for roughness or high mica on the commutator or excessive brush spring tension. The springs **(19)** should be moved to the next notch as the brushes wear. Insufficient brush spring pressure will cause high temperature arcing between brushes and commutator until the solder is melted from the commutator risers.

Clean brushes and brush holders. If new brushes are installed, seat with 00 sandpaper. Blow out all dust and abrasives.

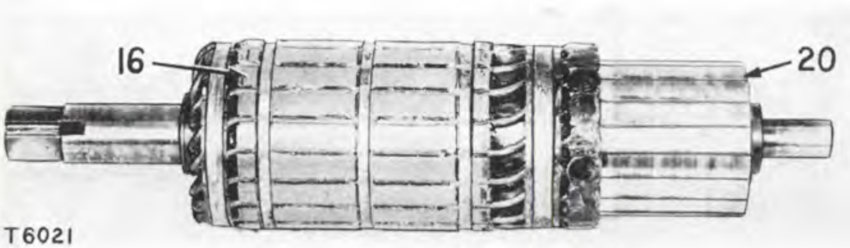
TESTING

Armature

The armature **(16)** should be tested when it is removed from the housing.

With a battery and 6-volt lamp connected in series, place one lead on the armature shaft and the other lead on each segment of the commutator **(20)** in succession. If the test lamp lights between any one segment and the shaft, the armature is grounded and should be replaced.

To test the armature **(16)** for a short, place the armature on a growler with a hacksaw blade over the armature core and rotate the armature. If the blade vibrates, the armature is short-circuited and should be replaced.



ARMATURE
16—Armature. 20—Commutator.

Commutator

If the commutator is rough or out-of-round, it should be turned down in a lathe just enough to remove the eccentricity and then sanded with 00 sandpaper. Never use emery cloth. Clean out the starting motor with compressed air to remove all abrasives.

Field Coils

Connect a battery and 6-volt lamp in series to test the field coils for a continuous circuit. Place the test leads on the field coil leads, if the test lamp lights, the field coils have a continuous circuit. If the test lamp does

REMOVING FIELD COILS

21—Pole shoe. 22—Nut.
23—Field coil.

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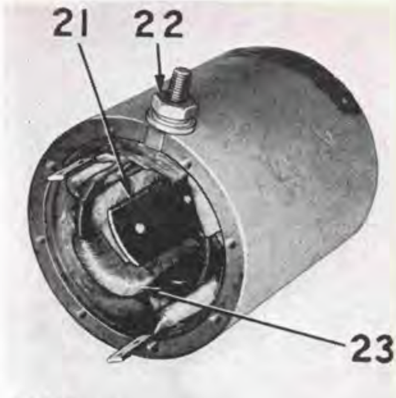

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not light, there is an open circuit in one or all of the field coils. The field coils are installed as a unit and it is necessary to replace all four.

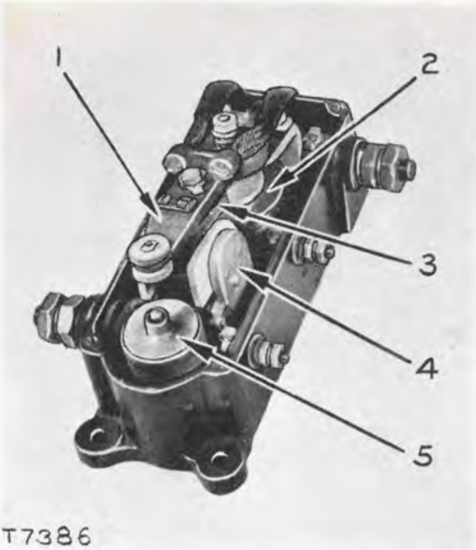
To test for grounded field coils place one lead to the housing and the other test lead to a field coil lead. If the test lamp lights, the field coils are grounded and must be replaced.

The field coils **(23)** are removed by removing the pole shoe screws and the pole shoe **(21)**. Only one of the field coils and one of the pole shoes are pointed out in the illustration. Loosen the nut **(22)** and slide the four fields out as a unit.

Magnetic Switch

OPERATION

The magnetic switch has a hinged armature **(1)** that carries one set of contacts **(3)**. The other set of contacts are stationary and located between the pole pieces of the magnetic blow out **(4)**. The operating coil **(2)** completes an electromagnet, when energized by current from the battery through the hand switch, and draws the armature **(1)** toward the iron coil core to close the contacts. When the contacts open, the electric arc is broken up by magnetic reaction since the arc forms in the magnetic field between the iron pole pieces of the magnetic blowout. The circuits between the magnetic switch and the hand switch are so arranged that if the magnetic switch contacts tend to cling together, when the hand switch lever is moved to the OFF position, the operating coil of the magnetic contact opener **(5)** is energized to complete a solenoid magnet and its plunger pushes on the end of the armature assembly to open the magnetic switch contacts. This restores all circuits to normal. The magnetic switch contacts are made of a combination of two contact metals and are especially produced for the purpose intended.



OPERATION OF MAGNETIC SWITCH

1—Hinged armature. 2—Operating coil. 3—Contacts. 4—Magnetic blowout. 5—Magnetic contact opener.

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MAINTENANCE

Maintenance does not involve much care other than proper attention to wiring and connections including ground connections. No lubrication is necessary. The battery should be checked periodically to determine that it is in good condition.

At least once each year, the contacts of the magnetic switch should be inspected and resurfaced if necessary. If these contacts are not pitted too deeply, they can be resurfaced with a file, but make certain to file so as to retain maximum contact surface. If badly pitted, the contacts will have to be ground to resurface. Replace with new contacts if they cannot be resurfaced.

If the magnetic switch fails to close its contacts it may be because the battery is too low in charge or under capacity, or there is an open in the hand switch circuit or in the switch itself and any of these conditions should be corrected.

Hand Switch

OPERATION

The hand switch is used to operate the magnetic switch. The first purpose of the hand switch is to close a low voltage circuit from three cells of the battery directly through the cranking motor to cause its automatic drive pinion to mesh gently with the engine flywheel gear. This first purpose position is marked by number "1" between OFF and ON positions cast on the face of the switch. The position "1" is indicated by a click.

The second purpose is to close a full voltage circuit from the entire battery through the magnetic switch operating a coil to close the main cranking circuit through the magnetic switch contacts for energizing the cranking motor from the battery to crank the engine. This second purpose position is the ON position.

When operating the hand switch, move the lever to the "1" position and hold for not more than two seconds, then move lever promptly to the ON position and hold firmly during cranking. Release lever quickly when engine starts or within 15 seconds. Do not operate the switch in a loose or jerky manner, to do so will damage the contacts of the magnetic switch.

MAINTENANCE

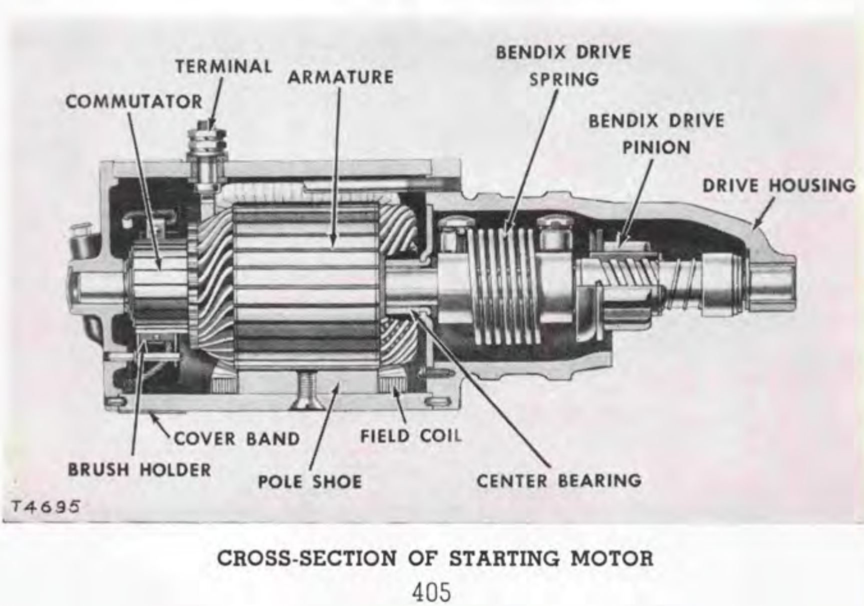
The only maintenance necessary on the hand switch is keeping all connections clean and tight. Bad connections cause loss of voltage or low voltage and may not only prevent prompt starting, but may also cause burning of motor brushes and commutator. Switch contacts also may be unnecessarily burned because they cannot be held tightly together.

Electric Starting Motor

(Delco-Remy 1107436, 6 Volt)

(Delco-Remy 1107822, 12 Volt)

The Delco-Remy 1107436, 6-volt starting motor and the Delco-Remy 1107822, 12-volt starting motor are similar in design and operations, therefore, both will be covered in the following topics.



CROSS-SECTION OF STARTING MOTOR

The electric starting motor described in the following paragraphs is a heavy duty type used for cranking the Diesel engine at speeds sufficient to permit starting.

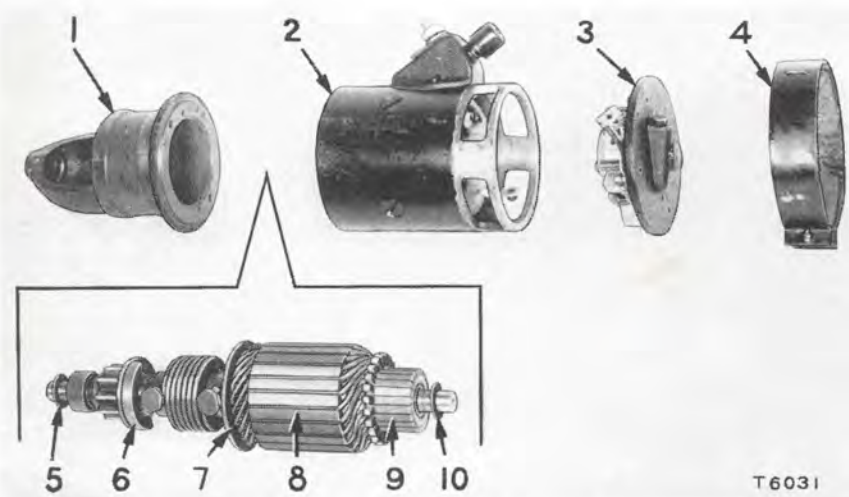
The starting motor armature must revolve at a high rate of speed to produce a strong cranking effort. To accomplish this, the cranking motor is equipped with a small drive pinion which meshes with teeth on the engine flywheel so that a gear reduction of up to 16–1 or higher is attained (the actual ratio varies on different applications). The drive pinion is engaged by the Bendix drive and after the engine starts, the same device disengages the drive pinion.

DISASSEMBLY

Brushes

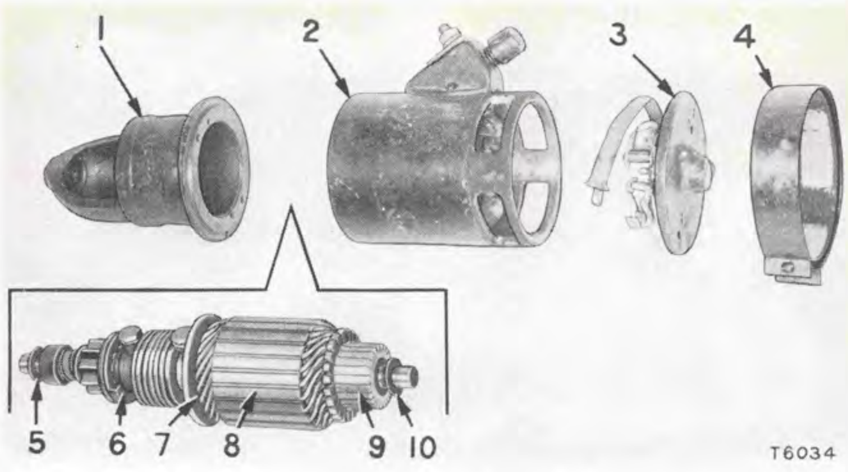
Remove the cover band **(4)** and blow out all carbon dust with compressed air. Check the brush leads for loose connections. Replace worn brushes. If brushes wear rapidly, check for roughness or high mica on the commutator or excessive brush spring tension.

Brush holder springs should be replaced if the spring tension is less than 24 ounces or more than 28 ounces. This applies to both the 6-volt and 12-volt starting motor. To replace the springs, remove the two through bolts and take off the end plate **(3)** to which the brush holders are attached.



STARTING MOTOR ASSEMBLY
(6-Volt Delco-Remy 1107436)

1—Bendix drive housing. 2—Housing. 3—End plate. 4—Cover band. 5—Thrust washer. 6—Bendix drive assembly. 7—Center bearing support plate. 8—Armature. 9—Commutator. 10—Thrust washer.



STARTING MOTOR ASSEMBLY
(12-Volt Delco-Remy 1107822)
1—Bendix drive housing. 2—Housing. 3—End plate. 4—Cover band.
5—Thrust washer. 6—Bendix drive assembly. 7—Center bearing support plate.
8—Armature. 9—Commutator. 10—Thrust washer.

New brushes may be installed through the openings in the frame without removing the end plate. Remove the cover band and take out screws holding the brush lead and the screw securing the brush to the brush holder. After installing the new brushes, they should be seated to the commutator. This may be done by holding a brush seating stone against the commutator while rotating the armature. Blow out all dust and abrasives.

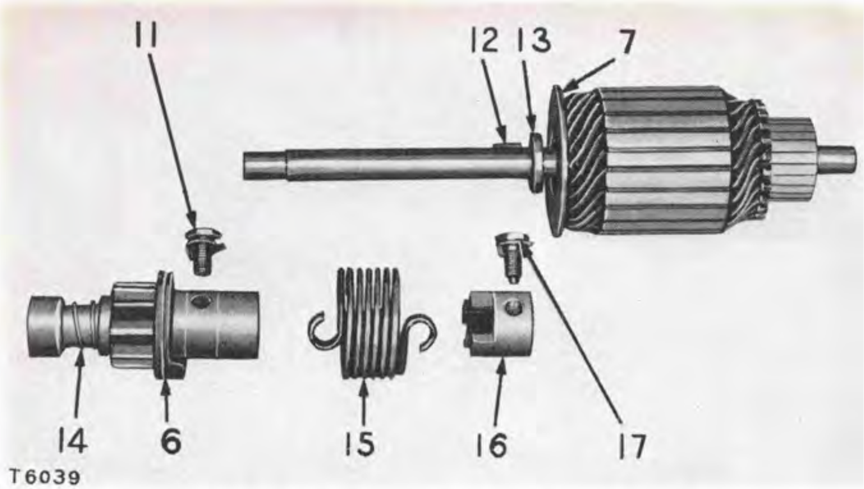
Bendix Drive

With the cover band **(4)** and the two through bolts removed, disconnect the field leads from the brushes. Remove the armature **(8)** and Bendix drive housing **(1)** from the starting motor housing **(2)** as a unit.

Remove the two screws securing the center bearing support plate **(7)** to the drive housing **(1)**.

Remove the armature **(8)** and Bendix drive assembly **(6)** from the drive housing. Take off the thrust washer **(10)** next to the commutator **(9)**. Remove the thrust washer **(5)** from the drive end.

Remove the head spring screw **(17)** and the shaft spring screw **(11)** and remove the Bendix drive **(6)** and spring **(15)** from the armature shaft. Remove the drive head **(16)**, key **(12)** and the felt seal **(13)**. This seal should be replaced if damaged. Remove the center bearing support plate **(7)**.



ARMATURE AND BENDIX DRIVE ASSEMBLY
(This covers both the 6-volt and 12-volt starting motor.)
6—Bendix drive. 7—Center bearing support plate. 11—Shaft spring screw. 12—Key. 13—Felt seal. 14—Anti-drift spring. 15—Spring. 16—Drive head. 17—Head spring screw.

Wash the spring and drive assembly in some non-inflammable cleaning fluid. Clean the end of the armature drive shaft of any accumulations of dirt or grease. The spiral upon which the pinion operates should be kept free from dirt and grease.

If the pinion teeth are chipped or damaged, replace the pinion. Check the anti-drift spring **(14)** as the pinion will have a tendency to mesh with the drive gear when the starting motor is not in use if the spring is weak. Before installing the drive, lubricate the threaded sleeve and the bushing in the housing with a few drops of light oil.

Armature

The armature should be tested while it is removed from the housing.

With a battery and 6-volt lamp connected in series, place one lead on the armature shaft and the other lead on each segment of the commutator in succession. If the test lamp lights between any one segment and the shaft, the armature is grounded and should be replaced.

To test the armature for a short, place the armature on a growler with a hacksaw blade over the armature core and rotate the armature. If the blade vibrates, the armature is short-circuited and should be replaced.

Commutator

If the commutator is rough or out-of-round, it should be turned down in a lathe just enough to remove the eccentricity and then sanded with

00 sandpaper. Never use emery cloth. Clean out the starting motor with compressed air to remove all abrasives.

Field Coils

Connect a battery and 6-volt lamp in series to test the field coils for a continuous circuit. Place the test leads on the field coil leads, if the test lamp lights, the field coils have a continuous circuit. If the test lamp does not light, there is an open circuit in one or all of the field coils. Check each one separately until the open circuit is located and replace the defective field coil or field coils. The field coils are replaced in pairs and it will be necessary to replace the pair if one is defective.

To test for grounded field coils, place one test lead to the housing and the other test lead to the field coil lead. The test lamp will not light if the field coil is not grounded. Should the test lamp light, one or all of the field coils are grounded. To test for individual grounded field coils, break the soldered connection between each field coil and test separately, replacing the defective field coil and the one that was connected to it with a new pair.

The field coils are removed by removing the pole shoe screws securing the field coils and pole shoe to the housing. Use rosin flux in making all soldered connections. When a field coil is removed, the new one should be installed in the same position as the one removed.

Battery

The electrolyte level in the battery should be checked every other day during warm weather and at least once a week during cold weather. The electrolyte in the battery should be maintained at a level 3/8" above the top of the plates by adding pure distilled water or "approved water" (water free from impurities by analysis) to each cell. Failure to maintain the proper electrolyte level will cause damage to the plates and reduce the capacity of the battery.

When water is added to the battery during freezing weather, operate the generator for ten or fifteen minutes to thoroughly mix the water with the electrolyte in the battery. This will eliminate the possibility of the water freezing and cracking the battery case.

WARNING

Never add acid, patent solutions or charging liquids to the battery electrolyte.

The state of charge of a battery should be checked with a hydrometer every 60 hours. The following hydrometer readings indicate the charge condition:

Full charge	1.275 — 1.290
Half charge	1.225
Dangerously low	1.150

In order to prevent freezing during cold weather, the hydrometer reading should be at least 1.250.

Keep the battery and its compartment clean and dry. Clean all accumulations of dust and dirt from the top of the battery.

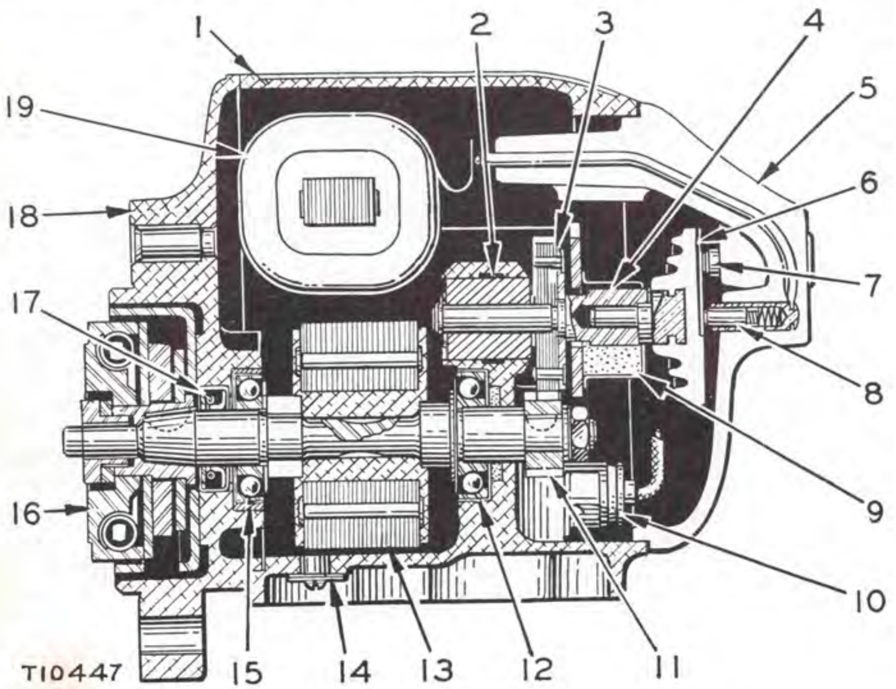
Keep the battery terminals and leads clean and tight. To clean corrosion from the battery terminals, scrub them with a weak solution of bicarbonate of soda (baking soda) and water. Dry the battery thoroughly. Coat the terminals with petrolatum to prevent corrosion.

Disconnect, thoroughly clean and inspect the other terminals of the battery cables periodically to insure good connections. Securely tighten the terminals when finished.

Magneto

(American Bosch)

An American Bosch model MJK magneto is used on the starting engine.



MAGNETO CROSS-SECTION

1—Magneto housing. 2—Distributor gear bearing. 3—Distributor gear. 4—Cam. 5—Distributor plate. 6—Distributor rotor. 7—Distributor plate terminal brush. 8—Distributor plate center brush. 9—Cam wick. 10—Condenser. 11—Magnet rotor gear. 12—Rotor bearing. 13—Magnet rotor. 14—Plate. 15—Rotor bearing. 16—Impulse coupling. 17—Seal. 18—Drive end plate. 19—High tension coil.

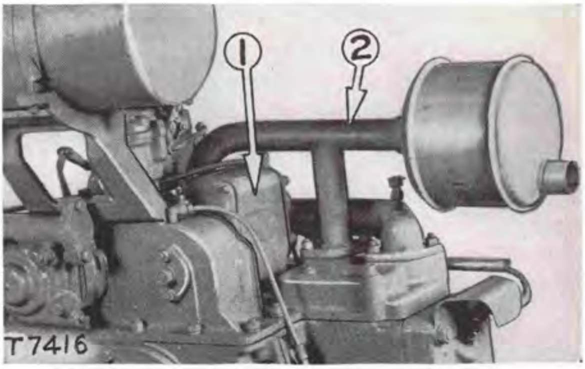
SERVICE TOOLS FOR MJK SERIES MAGNETOS

The special service tools listed here and later mentioned by part number are available from authorized American Bosch Service Stations or from the American Bosch Corp., Springfield, Massachusetts.

American Bosch Number	Use
TSE5267	Coupling Hub Puller
TSE5265	Ball Bearing Puller
TSE76108	Split Jaws For Ball Bearing Puller
TSE76101	Ball Bearing Puller
TSE7916	Ball Bearing Puller
TSE76112	Pressing Tool For Ball Bearing Inner Race
TSE5269	Pressing Tool For Ball Bearing Outer Race
TSE5289	Pressing Tool For Distributor Rotor Ball Bearings

REMOVAL

Pull the spark plug wires out of the distributor plate and disconnect the wire to the switch. Remove the exhaust manifold **(2)**. Remove the capscrews securing the magneto **(1)** and lift off the magneto.



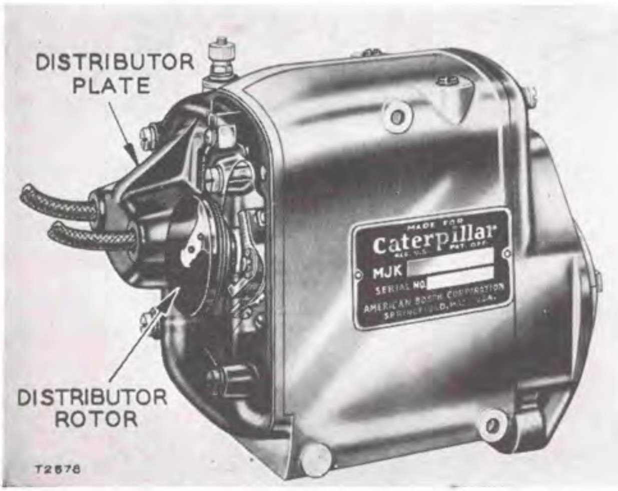
REMOVING MAGNETO
1—Magneto.
2—Exhaust manifold.

DISTRIBUTOR PLATE

The distributor plate is held in place by four screws and care should be exercised in removing the plate not to damage the gasket. Clean any carbon dust from the inside of the plate using a soft cloth, dampened with a non-inflammable cleaning solvent.

Removing Distributor Plate

Replace brushes and springs if the carbon is less than 3/16" long. Pull the old ones from their sockets, discarding both the springs and brushes. Insert a new spring, with brush attached, into the hole with a twisting motion so that the spring bottoms in the hole. Make sure that the brushes move freely and protrude evenly from their sockets.



REMOVING DISTRIBUTOR PLATE

DISTRIBUTOR ROTOR

Pull the distributor rotor out of the bore in the cam. Clean both sides of the rotor, but replace if brass is burned or pitted, the rotor cracked, or the face is grooved.

BREAKER PLATE

Remove the two screws holding the breaker plate **(1)** and pry loose the breaker plate assembly. Take out the screw which connects the ground wire **(3)** and the condenser wire **(2)** to the breaker plate assembly and remove the breaker plate. Remove the second screw holding the ground wire and remove the wire. It is not necessary to loosen the two screws which clamp the spark advance adjustment in order to remove the breaker plate, however, the edge distance must be reset when the breaker plate is removed.

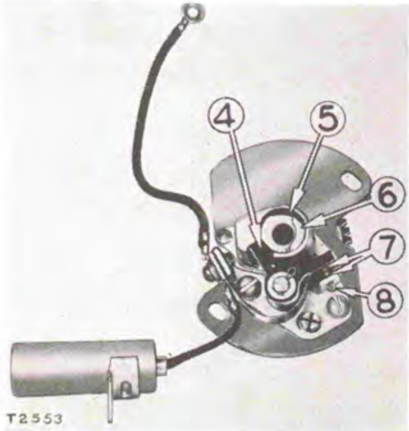
REMOVING BREAKER PLATE

1—Breaker plate. 2—Condenser wire. 3—Ground wire.

♦

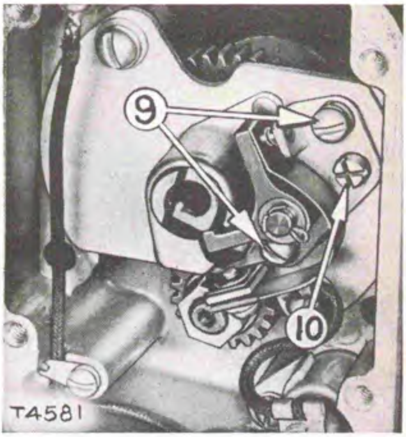
CONTACT POINT ASSEMBLY

Remove the contact point assembly **(8)** from the breaker plate by loosening the two fastening screws. Inspect the contact points for pitting or craters. The contact points **(7)** may be dressed with a suitable stone, but do not use a file, sandpaper or emery cloth, as they will leave minute particles embedded in the contact area of the points to cause a greater amount of pitting and arcing than is normally the case. Contact points are replaced by installing a new contact point assembly. The air gap between the points must then be set and the edge distance checked as described in the topic, EDGE DISTANCE.



REMOVING CONTACT POINT ASSEMBLY

4—Fiber bumper. 5—Felt wick. 6—Cam. 7—Contact points. 8—Contact point assembly.



ADJUSTING BREAKER CONTACT POINTS

9—Fastening screws. 10—Eccentric screw.

The breaker contact points should be adjusted to an opening of .014"–.018" when the fiber breaker lever bumper **(4)** rests on the high point of the cam **(6)**. This is obtained by means of the adjustable contact bracket which can be shifted by an eccentric screw **(10)** until the correct opening has been reached. After adjustment, the bracket must be secured by means of the fastening screws **(9)**.

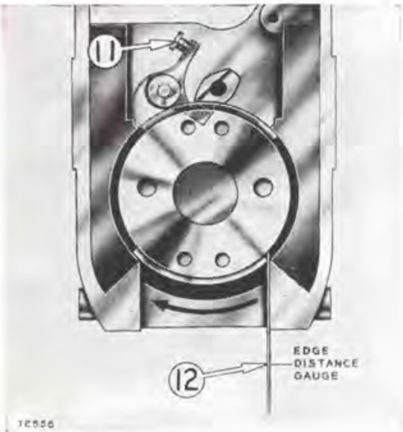
The cam lubricating felt wick **(5)** should be lubricated when dry with a drop of S.A.E. 50 or 60 oil or American Bosch bearing oil US-511. Contact points must be free from oil or grease and in proper alignment so that the entire surfaces of both contact points meet squarely.

EDGE DISTANCE

The edge distance is very important since it insures maximum spark efficiency. An improper edge distance will cause hard starting and loss of power. Therefore, make sure that the edge distance is correctly set whenever new breaker contact points are installed.

The edge distance is the dimension between the pole shoe and the edge of the magnet rotor. This is the most desirable point at which to break the primary circuit in the high tension coil to obtain the maximum magnetic disturbances or change in flux. The edge distance is always measured when the magnet leaves the pole shoe, never when it approaches the pole. The proper edge distance for the MJK American Bosch Magneto is .068" (1.75 Mm.) as shown.

To correctly set the edge distance, first adjust the breaker points **(11)** to the proper opening of .014"–.018" as described previously. Remove the small plate and gasket from the bottom of the magneto housing and carefully insert a .068" (1.75 Mm.) edge distance gauge **(12)** as shown. Turn the magnet rotor in the opposite direction that the magneto is driven



SETTING EDGE DISTANCE
11—Breaker points. 12—Gauge.

♦

until the magnet rotor contacts the gauge. The gauge must be properly located between the pole shoe and the first steps of the magnet rotor.

The edge distance is correct when the breaker contact points just begin to separate. If the edge distance is not correct, hold the gauge in position and loosen the breaker plate fastening screws. Move the complete breaker plate assembly in either a clockwise or anti-clockwise direction until the contact points just begin to separate, then tighten the breaker assembly fastening screws.

CONDENSER

Remove the condenser fastening screw and take out the condenser **(13)**. Check the condenser for leakage, shorting or damage with a neon light. If a neon testing light is not available, either a 6-volt or 110-volt circuit may be used with the proper voltage light. Place one terminal of the testing device on the metal covering of the condenser and the other terminal on the center post. If a short flash shows in the neon light, the condenser is satisfactory for further use. Should the neon light show repeated flickering, the condenser is leaking, or if the light registers continually, the condenser is short circuited. In either case the condenser should be replaced.

REMOVING AND TESTING CONDENSER

13—Condenser.

DISTRIBUTOR GEAR AND CAM

Pull the distributor gear and cam assembly **(14)** out of the supporting bearings by hand. Be careful not to damage the fiber teeth of the gear or the polished finish of the cam.

The brass grounding brush **(15)** at the rear of the supporting gear shaft prevents high tension currents from arcing through the ball bearings, thus eliminating possibilities of pitting the balls and races. If the brush is worn

REMOVING DISTRIBUTOR GEAR AND CAM

14—Gear and cam assembly.
15—Grounding brush.

or the tension of the spring is weak, they can be replaced by pulling the brush and spring assembly out of the shaft and replacing them with a new assembly. The brush protrudes from the end of the shaft about 3/16" and should be free to move in and out without binding.

On later magnetos the distributor gear and cam assembly is held in place by a ring behind the gear. It is necessary to remove this ring before the distributor gear and cam can be removed.

Replacing Distributor Gear and Cam

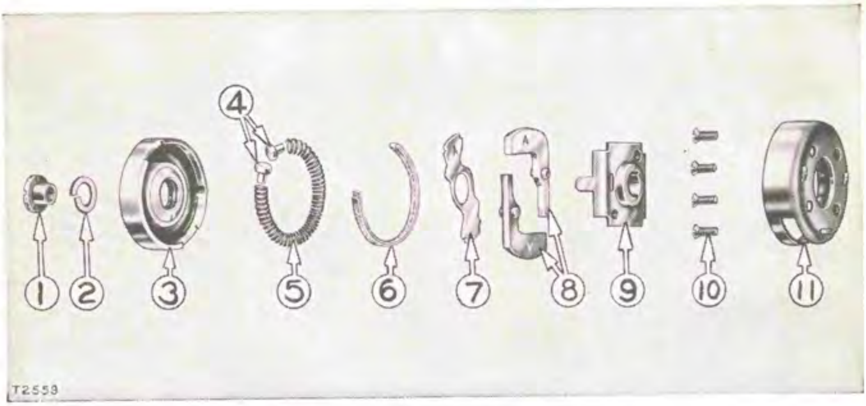
Individual replacements of the gear and cam should not be made. Because of the exact relationship between the cam and gear, the complete assembly must be replaced. Remember that distributor gear and cam assemblies which are marked with the white letter "A" cannot be used in place of those marked with a "C". Gears marked with an "A" are to be used only in magnetos rotating in an anti-clockwise direction. Those marked with a "C" are to be used only in magnetos rotating in a clockwise direction such as the one used on this engine. The direction of rotation is shown by an arrow on the top of the magneto viewed from the drive end.

Install distributor gear shaft in the distributor rotor ball bearings. The punch mark on the rotor gear must line up with either the letter "C" or "A" on the distributor gear.

IMPULSE COUPLING

Operation

The magneto is driven through an impulse coupling. The primary function of the impulse coupling is to intensify the ignition spark at low rotative speeds in order to facilitate engine starting without the aid of an auxiliary ignition system. Through its construction, it also automatically



IMPULSE COUPLING OPERATION
1—Nut. 2—Lockwasher. 3—Coupling housing. 4—Spring stop buttons. 5—Spring. 6—Felt wick. 7—Cam. 8—L-shaped weights. 9—Impulse member hub. 10—Screws. 11—Arrestor plate.

retards the ignition spark during the starting period, reducing the possibility of damage to the engine or danger to the operator by back-firing. It automatically disengages when the magneto reaches a speed of 180 RPM and then acts as a positive drive only.

The impulse couplings on the MJK magnetos employ sliding L-shaped weights **(8)** and a coil type spring **(5)** which absorbs the shock after impulsing. The vertical movement of the L-shaped weights **(8)** is guided by the impulse member hub **(9)** which engages the housing **(3)** into which are assembled the spring **(5)**, spring stop buttons **(4)** and the cam **(7)**. The coupling is released by the arrester plate **(11)** which is mounted at the shaft end of the magneto frame.

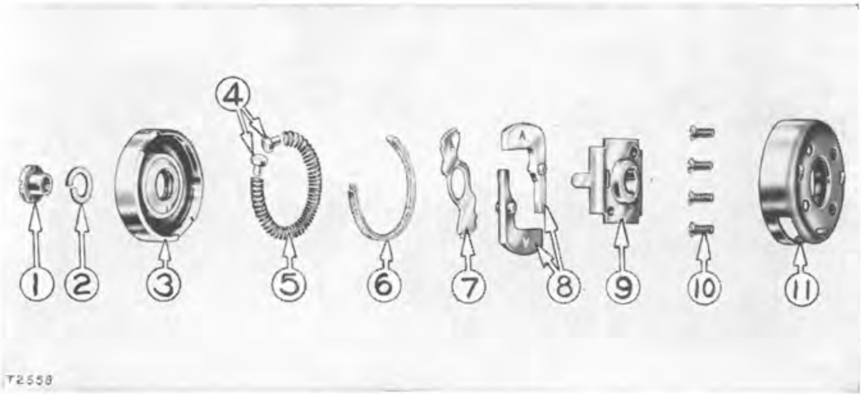
The first step in the operation of the impulse coupling occurs when the sliding weight **(8)** engages the slot in the arrester plate **(11)**, at which point the magnet rotor is prevented from further rotation, while the coupling housing **(3)** continues to rotate. During this period the mechanical energy supplied to the magneto is stored in the impulse coupling by the wind up of the spring **(5)**.

The second step of the impulse coupling action occurs just as the wind up of the spring **(5)** is completed and the lug of the sliding weight **(8)** is tripped by the cam **(7)**.

In the third step the drive spring of the coupling functions to snap the housing of the coupling together with the magnet rotor through its wind up angle, the magnet rotor passing through the entire spark angle including the edge gap distance. Since the speed of this action is determined by the strength of the drive spring, a very strong ignition spark can be produced.

Disassembling Impulse Coupling

Take off the round nut **(1)** and lockwasher **(2)**, then pull out the impulse housing **(3)** with its related parts. Notice that the weights **(8)** and cam **(7)** have been assembled with the same letter which appears on the distributor gear facing outward. They should be reassembled in the same way in order for the magneto to function properly. Check to see that the weights **(8)** are not unduly worn and move freely.



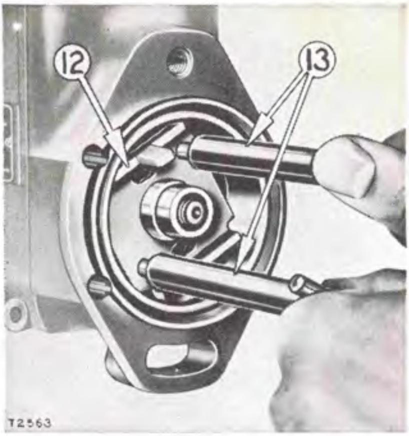
IMPULSE COUPLING
1—Nut. 2—Lockwasher. 3—Coupling housing. 4—Spring stop buttons. 5—Spiral spring. 6—Felt wick. 7—Cam. 8—Weights. 9—Coupling hub. 10—Screws. 11—Arrestor plates.

If necessary the assembly of the spring **(5)** and stop buttons **(4)** may be removed from the impulse housing **(3)**. The wick **(6)** should be lightly saturated with S.A.E. 50 or 60 oils or American Bosch US-511 oil.

Removing Coupling Hub

Using the TSE5267 Pulling Tool **(13)** or two $1/4''$–28 (NF) screws, pull the coupling hub **(12)** from the magneto rotor shaft. Some American Bosch MJK Magnetos have been manufactured with two keyways in the coupling hub, lettered "A" and "C" respectively. Re-assemble the hub with the C-markings aligned.

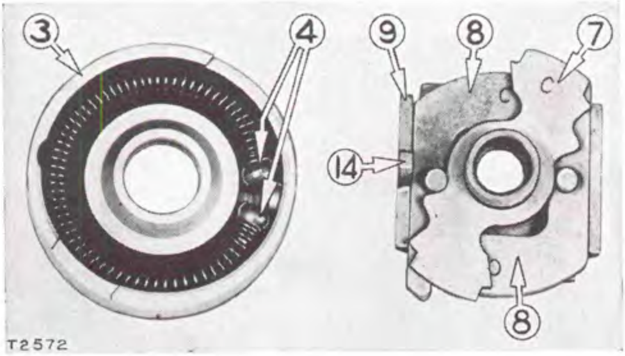
Loosen the fastening screws **(10)** and remove the arrestor plate **(11)**. However, the arrestor plate need not be removed in order to take off the drive flange. If the arrestor plate is taken off, the fastening screws **(10)** must be restaked.



REMOVING COUPLING HUB
12—Coupling hub.
13—TSE5267 Pulling Tool.

Assembling Impulse Coupling

To re-assemble the impulse coupling first place the coupling hub **(9)** on the tapered seat, lining up the proper keyway with the key. Then lay the weights **(8)** in place with the same letter facing outward. These parts must have the same letter facing outward as that which appears on the face of the fiber distributor rotor gear. Then place the ear **(14)** of the coupling hub **(9)** between the stop buttons **(4)** and press the two assemblies together. The lockwasher and nut should then be installed. The impulse housing **(3)** has a slight amount of free play to allow proper alignment.



ASSEMBLING IMPULSE COUPLING
3—Coupling housing. 4—Stop buttons. 7—Cam. 8—Weights.
9—Coupling hub. 14—Ear on coupling hub.

MAGNET ROTOR

In order to remove the magnet rotor it is first necessary to take off the impulse coupling as described in the topic, IMPULSE COUPLING.

REMOVING DRIVING END FLANGE AND MAGNET ROTOR **REMOVING MAGNET ROTOR**

1—Drive end flange. 2—Key. 3—Seal. 4—Lockwasher. 5—Magnet rotor. 6—Nut. 7—Flat washer. 8—Gear.

Remove the key **(2)** from the tapered diameter, take out the six screws and remove the drive end flange **(1)**. As the drive end flange is removed, exercise care to prevent damage to the seal **(3)** by the magnet rotor **(5)** threads. Remove the rotor gear nut **(6)**, the lockwasher **(4)** and the flat washer **(7)** from the opposite end of the magnet rotor shaft. The magnet rotor **(5)** can be removed by tapping gently on the end of the magnet rotor shaft with a piece of wood or a soft drift. The gear **(8)** will be forced from the shaft.

CAUTION

Do not exert too much force on the end of the shaft since there is danger of cracking the thin wall of the magneto housing.

Installing Magnet Rotor

Install the magnet rotor in the magneto housing with hand pressure. Replace the rotor drive gear on the distributor plate end of the shaft, being certain that the rotor drive gear is installed with the punch mark facing upward. Replace the flat washer, lockwasher and nut, seating the rotor drive gear securely by tightening the nut. Replace the drive end flange, exercising care so as to prevent damage to the seal. Secure the flange with the six screws previously removed. Replace the small key in the magnet rotor.

Remagnetizing Rotor

The magnet rotor is of the permanent type, however, abuse or careless handling can cause most of the magnetism to be lost and thus make remagnetizing necessary. The American Bosch TSE5210 Magnetizer **(1)**

REMAGNETIZING ROTOR

1—Magnetizer. 2—Jaws. 3—Magnet rotor.

utilizing a set of TSE5238 Jaws **(2)**, has sufficient capacity to saturate these magnets. After removing the magnet rotor from the magneto, determine polarity of both the magnet rotor and the magnetizer by means of a compass. Place the magnet rotor **(3)** between the jaws of the magnetizer and put them on the magnetizer stand as shown.

NOTE

The unlike poles of both the magnet rotor and the magnetizer must be placed together. The jaw of the north pole end of the magnet rotor must rest on top of the south pole of the magnetizer. With the magnetizer properly connected to the foot switch allow the current to flow through the magnet for approximately five seconds, remove foot from switch for about three seconds, then repeat the procedure three or four times.

Removing Rotor Shaft Bearings and Races

Clean the magnet rotor and bearings thoroughly in an approved cleaning solution; then dry the assembly, preferably with compressed air. Examine the bearings and races for discoloration, pitting and wear. Rough, loose or worn bearings should be replaced. If replacement of the ball bearings are necessary, pry off the ball cages from the inner races on the rotor shaft. Remove the inner races from the rotor shaft by using TSE5265 Puller, with TSE76108 Split Jaws, as shown. Take the felt washer out of the rotor bearing bore in the magneto housing. Then press the lip type lubricant seal out of the drive end flange.

REMOVING MAGNET ROTOR BEARING INNER RACE

PRESSING OUT MAGNETO ROTOR OIL SEAL

Pull the outer bearing races from both the magneto housing and drive end flange using TSE76101 Ball Bearing Puller as shown.

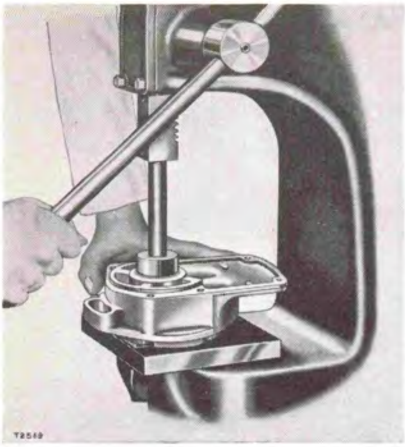
REMOVING MAGNET ROTOR BEARING OUTER RACE

◆

Installing Rotor Shaft Bearings and Races

Before installation make certain that all of the parts are clean before installing bearings. The bearings should be packed in a special ball bearing lubricant, such as American Bosch US-510, immediately after cleaning. Before pressing in the outer race, insert the insulating washers at the bottom and the insulating strips around the sides of the bore in both the magneto housing and the drive end flange.

Center the bearing outer race over the bearing bore and inside the ring of the packing strip. Press the race into position, using an arbor press and TSE5269 Pressing Tool, as shown. After the outer races have been



INSTALLING MAGNET ROTOR BEARING OUTER RACE

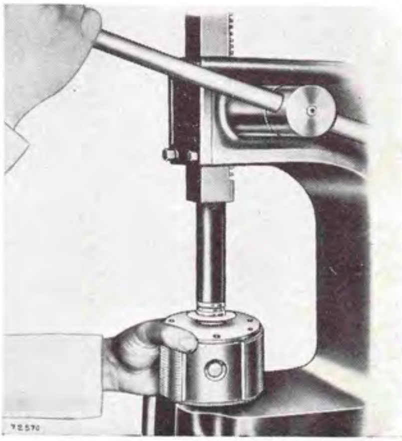
◆

installed, trim off the excess portion of the insulating strips with a sharp knife or razor blade.

To install the bearing and inner race, center the inner race on the magneto rotor shaft and press into place using TSE76112 Pressing Tool and an arbor press as shown.

PRESSING ON BEARING INNER RACE

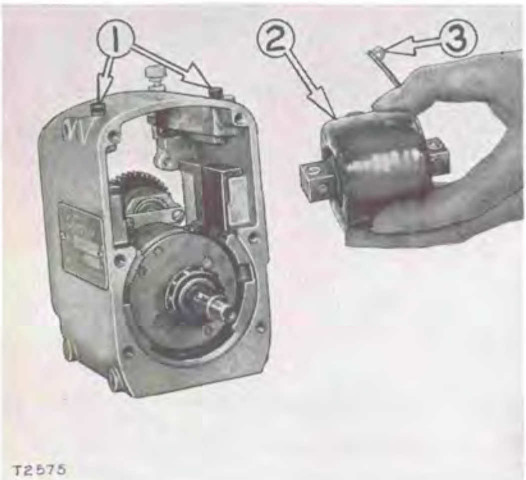
◆



If necessary, replace the felt washer at the back of the bearing bore in the magneto housing. If the lip-type lubricant seal has been removed from the drive end flange because of wear or damage, replace it also, using TSE76112 Pressing Tool and an arbor press. Install the seal with the lip toward the bearing.

HIGH TENSION COIL

To remove the high tension coil **(2)**, remove the coil lead **(3)** from the ground post by removing the screw and washer. Back out the setscrews **(1)** on top of the magneto housing enough to allow the coil winding to be pulled out of the housing.



REMOVING COIL

1—Setscrews.
2—Coil. 3—Coil lead.

Testing High Tension Coil

Inspect the coil for insulation cover breaks, loose core, and loose primary cable connections, as well as all soldered connections. Check the continuity of the secondary winding and test the coil on an approved test stand incorporating a three-electrode, needle-pointed spark gap. The coil should be capable of firing a 10 mm. gap at 1000 RPM cam speed and with a 12-volt input without missing. While this test is being run, explore the outer covering at each end with a ground wire to make sure there are no high voltage leaks.

Installing High Tension Coil

Upon installing, carefully clean the coil, as well as the top of the magnetic pole shoes, of any dirt or magnetized metal particles to insure good electrical contact. See that the copper strip protruding from the coil is dry and free from corrosion so that a good contact will be made. Slide the coil into the magneto housing with the countersunk holes facing upward and the core resting on top of the magneto pole shoes. Turn the pointed coil setscrews down into the countersunk holes and tighten them securely. Apply a coating of shellac to the protruding end of each screw to prevent the entrance of moisture. Reconnect the leads to the ground post at the distributor end of the magneto.

DISTRIBUTOR GEAR SHAFT BEARINGS

Single-row bearings support and position the distributor gear shaft. The two bearings are separated by a spacer and are not insulated from the magneto housing. Since they are shielded on one side only, they must be installed with the open side to the interior, facing each other.

Removing Distributor Gear Shaft Bearings (Earlier Models)

Remove the brush holding plate by taking out the two fastening screws at the rear of the distributor gear shaft. Each bearing is pulled from the side it faces, using the TSE7916 Pulling Tool. The handle of the pulling tool must be bent upward at a 90° angle in order to clear the magneto housing as shown. The spacer between the two ball bearings can be taken out by drawing the two ends together with a small pair of needle-nosed pliers and then withdrawing the spacer from the bore. Later models use an oilite bushing.

REMOVING DISTRIBUTOR ROTOR BALL BEARINGS

♦

Installing Distributor Gear Shaft Bearings

Install the spacer for the two distributor rotor ball bearings in the magneto housing. Be certain that the spacer fits into the counterbore since the bearing fitting snugly up against the spacer determines the proper position of the cam and gear.

The bearing which faces the breaker end (bearing nearest coil) must be installed first so that it may be used as a guide in properly positioning the other bearing. Using an arbor press and TSE5289 Tool press the bearing in until it contacts the spacer. Do not exert too much pressure against the spacer. Then press in the bearing at the opposite end using the same tools.

PRESSING IN DISTRIBUTOR ROTOR BEARINGS

REPLACING BRUSH HOLDING PLATE
1—Brush holding plate.

This bearing does not contact the spacer, but should be flush with the face of the boss. Replace the brush holding plate **(1)** which is held in place by the two screws.

MAGNETO PERFORMANCE FAILURES

Assuming that the magneto is properly timed internally and properly timed to the engine (See the topic, TIMING MAGNETO TO ENGINE), performance failures may be narrowed down by visual inspection and testing.

Initial Test

A magneto may be tested when coupled to the engine by turning the switch "on", removing the cable from a spark plug, and holding the terminal 1/8" (3.17 Mm.) away from the metal part of the plug while turning the engine flywheel. If no spark passes from the terminal to the plug body, disconnect the magneto switch wire from the magneto (connected to the terminal on top of magneto housing) and test again. If the magneto fires with the switch wire removed, the cable running from the magneto to the switch has become grounded or the switch requires replacement. If the magneto still does not fire with the switch off, proceed with the inspection under the topic, VISUAL INSPECTION.

Visual Inspection

Before disassembling the magneto, carefully examine the spark plugs and ignition cables.

(1) Check spark plug gap.

(2) Check for the spark plugs being short-circuited. This is usually caused by a cracked or porous insulator or by fouling of the electrodes or insulator. Any of these conditions will cause misfiring by permitting the current to stray from its intended path.

Ignition Cables

Misfiring of one cylinder, either continuously or intermittently, may be due also to a chafed or broken cable or a loose cable connection. The metal terminals of the cables must not come in contact with any metal parts of the engine or the magneto, except those designated as being correct according to instructions.

If the cable and plugs are in good condition, the trouble is probably in the magneto.

(1) Check the distributor plate for cracks or broken brushes.

(2) Examine condition of the rotor.

(3) Inspect the breaker assembly to see that it moves freely and that the contact points are clean and in correct alignment.

(4) Check the rotor drive gear, the distributor gear, bearings, wiring, connections and coil terminals.

Test

If all the parts pass a visual inspection, the trouble may be narrowed down to three simple tests.

(1) Check the magnetism of the rotor. If it is weak, re-magnetize or replace.

(2) Using the coil tester, determine if the coil is satisfactory.

(3) Using the condenser tester, determine whether the condenser is bad. A condenser that is of too small capacity or an open condenser will cause arcing at the breaker points. A shorted condenser will render the system inoperative.

REVERSING MAGNETO ROTATION

The magneto for this engine is counterclockwise viewing it from the drive end. However, the majority of the parts are so designed that they may be assembled for either clockwise or anti-clockwise rotation. In order to change a clockwise rotating magneto or vice-versa, two parts must be changed, plus changing the arrow on the magneto housing.

Change the distributor gear assembly which includes the rotating breaker cam to the one suitable to the rotation desired. See the covering topic.

Change the impulse coupling housing. See the covering topic. Housings with the American Bosch part number ending in an even number are for clockwise rotation and those with a part number ending in an odd number are for anti-clockwise rotation.

Magneto
(Eisemann)

An Eisemann Magneto Model RC-2Q with an impulse starter and non-adjustable drive hub is used on the starting engine of earlier engines.

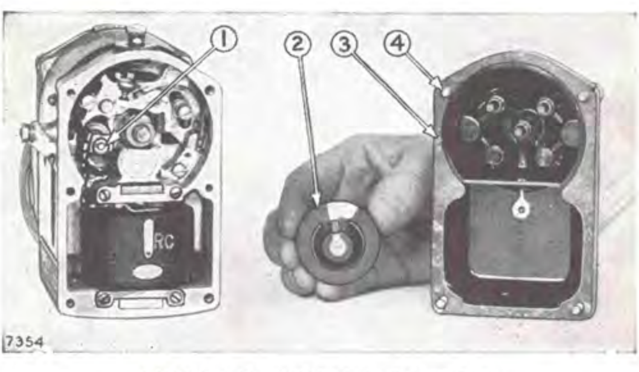
The Eisemann tools mentioned on the following pages for servicing the magneto are available from the distributors or service stations handling the products of Jack & Heintz Precision Industries, Inc., Cleveland 1, Ohio.

REMOVAL

Pull the spark plug wires out of the distributor plate, disconnect the wire to the switch and then disconnect the spark advance control rod from the side of the magneto. Take out the capscrews that hold the magneto in place and remove the magneto.

DISTRIBUTOR PLATE

Remove the distributor plate by loosening the screws **(4)**. Using a clean soft cloth dampened with non-inflammable cleaning fluid, carefully clean the inside of the plate of carbon dust. The gasket **(3)** should be replaced if damaged.



REMOVING DISTRIBUTOR PLATE
1—Slotted nut. 2—Rotor. 3—Gasket. 4—Screws.

BRUSHES

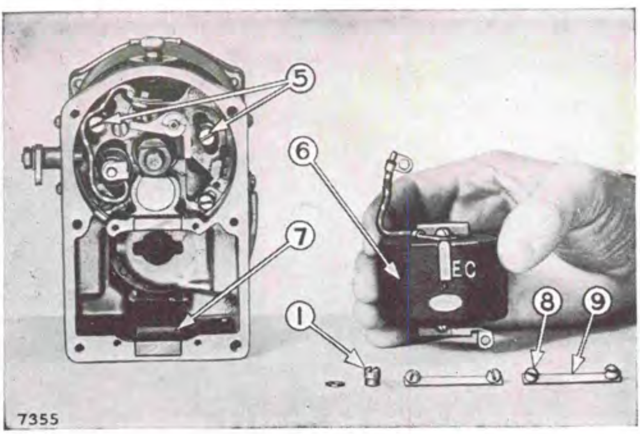
To install a new brush after the old ones have been pulled out of their sockets, place the small end of the coil spring on the brush. Press the spring straight into the socket and twist the brush a few turns clockwise. Again compress the spring by pressing the carbon brush into the socket. The brushes should move freely and protrude uniformly from their sockets.

ROTOR

Pull the rotor **(2)** from the shaft and clean both sides. Replace the rotor if the brass insert is burned, the rotor cracked, or the face is grooved.

WINDING

The winding **(6)** may be removed by taking off the slotted nut **(1)** and washer and removing the winding lead. Remove the screw **(8)** holding the straps **(9)** in position and slide out the winding. Check the winding with an Eisemann winding tester or other suitable device.



MAGNETO DISASSEMBLY
1—Slotted nut. 5—Slotted head screws. 6—Winding. 7—Pole-shoes. 8—Screws. 9—Straps.

When replacing, press firmly on the winding to seat the core ends in the tapered pole-shoes **(7)** before replacing the clamps.

BREAKER ASSEMBLY

In order not to disturb the spark advance fork stops **(10)** when removing the breaker assembly, take off the spark advance lever **(17)**, the plate **(16)** and then the lever assembly **(15)**. Remove the slotted head screws **(5)**, and pull out the breaker assembly **(12)** after removing the lead **(11)** from the condenser post.

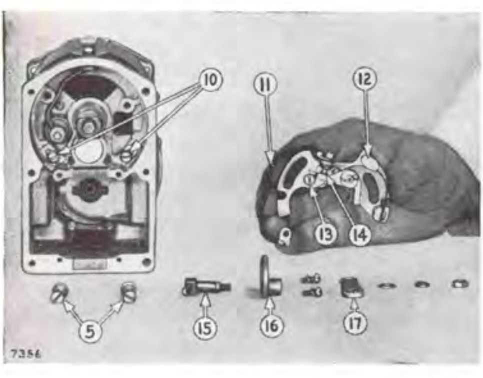
CONTACT POINTS

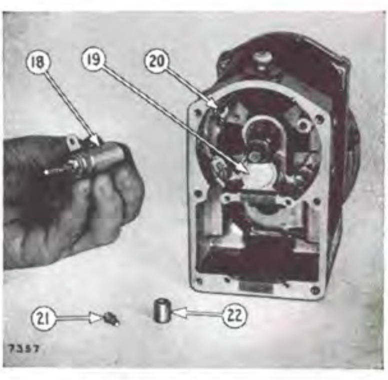
If the contact points wear unevenly or become pitted, a fine carborundum stone instead of a steel file should be used to smooth them. Replace the contact points if badly pitted or worn.

Remove all dust particles with a clean, dry cloth.

Adjustment

Insert a .020" feeler gauge between the contact points **(14)** after positioning the breaker lever bumper block on a high point of the cam. To adjust the gap, loosen the screw **(13)** which secures the adjustable contact point bracket and move the bracket by inserting a screwdriver in the space between the head of the screw and the lip on the bracket. Move the bracket to obtain .020" gap. Tighten the screw **(13)**.





MAGNETO ADJUSTMENT

5—Slotted head screws. 10—Stop screws. 11—Lead. 12—Breaker assembly. 13—Screw. 14—Contact points. 15—Lever assembly. 16—Plate. 17—Spark advance lever. 18—Condenser. 19—Plug. 20—Lead. 21—Screw. 22—Spacer.

TIMING

To obtain maximum spark intensity when the breaker points separate and to insure proper timing, the induction rotor should be properly positioned with respect to the breaker plate.

Remove the plate and gasket covering the inspection holes in the base of the housing. With the magneto lying on its side so the top is toward the operator and the impulse starter is to the right, insert the shank of a No. 31 drill (.120" dia.) or a $1/8$" drill through the upper hole. Turn the impulse starter the reverse of the operating direction until the drill is locked lightly between the induction rotor and lower pole-shoe. Loosen the fork stop screws **(10)** and shift the breaker plate until the contact points just start to separate. To check this, use a 6-volt "split lamp circuit" or draw a piece of cigarette paper between the contact points. This is the maximum spark advance position. Lock the fork stop against the breaker plate on the opposite side of the magneto from the advance lever. This limits the travel of the breaker plate.

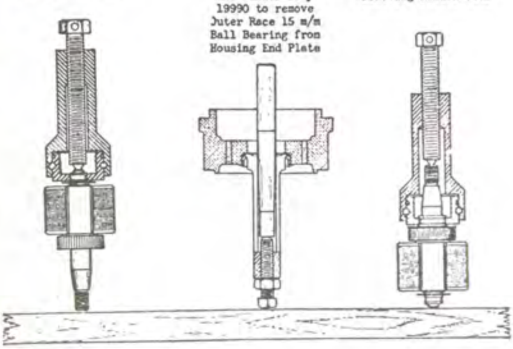
To obtain the retard position, rotate the breaker plate counterclockwise $3/8$" or 15° and lock the fork stop adjacent to the advance lever.

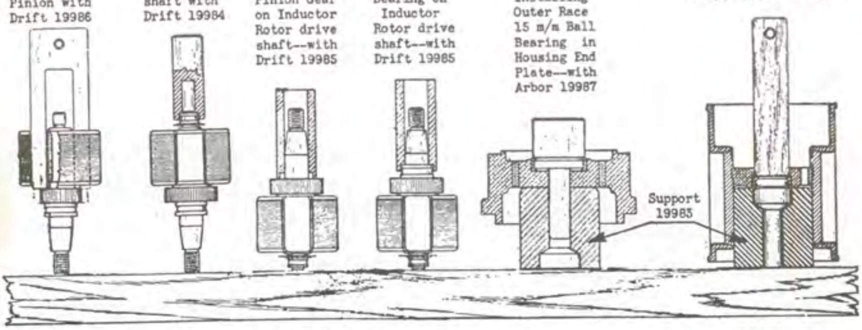
CONDENSER

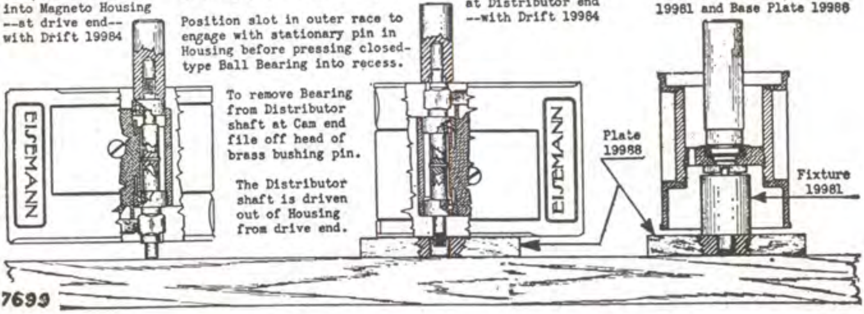
To replace the condenser, remove the breaker assembly as outlined. Slip off the spacer **(22)** and remove the lead **(20)** from the condenser post. Remove the screw **(21)** and slide out the condenser **(18)**. To check the condenser use the post as one terminal and the condenser case as the other terminal in series with a lamp on 110-volt circuit. If the lamp lights, the condenser is burned out. A 6-volt battery circuit may be used if 110-volt is not available.

EISEMANN MAGNETO SERVICE TOOLS

The tools shown on this page for servicing the magneto are available from the distributors or service stations handling the products of Jack & Heintz Precision Industries, Inc., Cleveland 1, Ohio.







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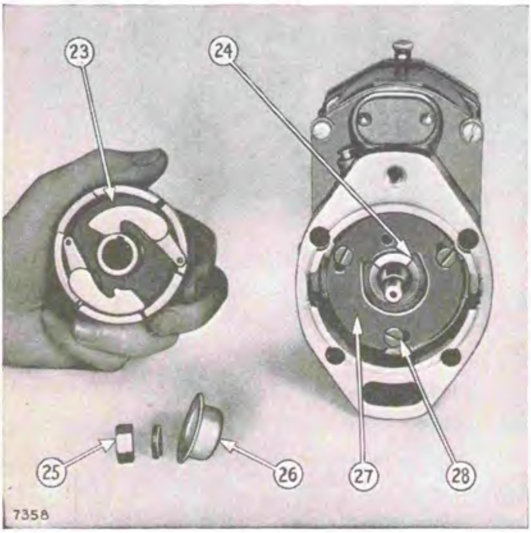
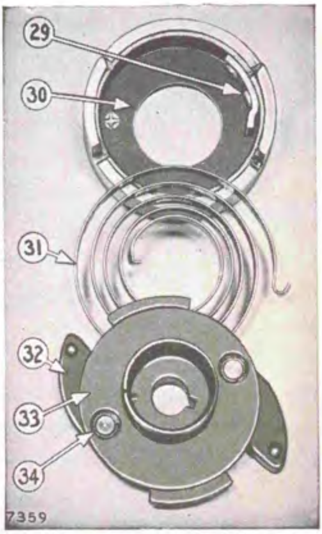
IMPULSE STARTER

The impulse starter **(23)** may be removed by removing the nut **(25)** and prying with two screwdrivers between the catch plate and flange.

The catch plate **(27)** can be removed by taking out the screws **(28)**. It should be replaced if the pawl engagement edge **(24)** is rough or worn. When replacing the catch plate, stake the screws securely.





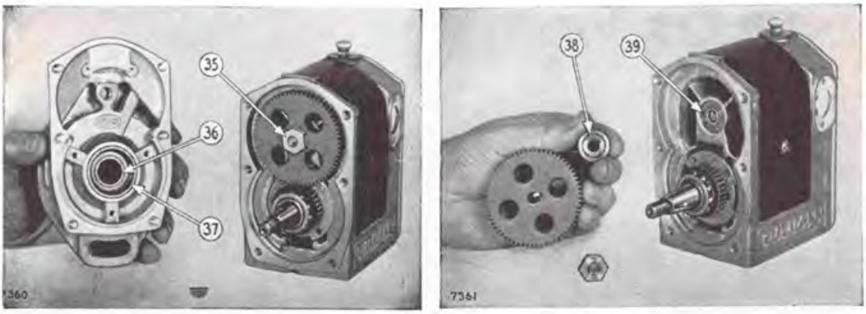
IMPULSE STARTER REMOVAL AND DISASSEMBLY
23—Impulse starter. 24—Pawl engagement edge. 25—Nut. 26—Retaining cup. 27—Catch plate. 28—Screws. 29—Post. 30—Drive cup. 31—Compression spring. 32—Pawls. 33—Flange. 34—Snap ring.

The compression spring **(31)** may be pried out of the flange **(33)** with a screwdriver. To replace the pawls **(32)**, rest the edges of the flange across a vise and drive out the pawls with a punch. Use the blunt end of a punch to spread the snap ring **(34)** into place on the stud of a new pawl. To install a new spring, grip the drive cup lugs in a vise, hook the outer end of the spring to the post **(29)**, wind up the inner coil with pliers and seat the spring in the drive cup **(30)**. Apply a very light coat of non-corrosive dripless oil having adhesive characteristics, over the compression spring before installing the flange. Hook the inner end of the spring to the slot in the hub of the flange and wind up tight with fingers, at the same time lifting the flange to clear the high walls of the drive cup.

If the impulse starter drive cup binds against the flange after assembly, install a spacing washer under the retaining cup **(26)** to prevent contact between the two assemblies.

DISTRIBUTOR GEAR AND SHAFT

Pry out the plug **(19)** holding the oil wick which lubricates the breaker cam and remove the oil wick. Impregnate the oil wick with ball and roller bearing lubricant.



DISTRIBUTOR GEAR AND SHAFT
35—Cotter pin and nut. 36—Seal. 37—Outer race. 38—Spacer. 39—Distributor gear bearing.

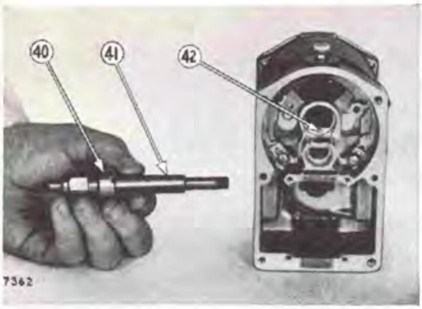
Remove the cotter pin and nut **(35)** on the shaft and gently tap the shaft out of the gear. Be sure to align the timing marks on the rotor gear **(43)** and distributor gear when reassembling. The shaft will now slide out of the magneto. The spacer **(38)** is used to properly locate the distributor gear bearing **(39)**. If damaged, this bearing should be tapped out and replaced using 19984 Drift. The breaker cam bearing **(40)** may be removed after the pin in the brass bushing **(41)** has been driven out. If the cam is scored, replace the shaft and cam assembly. Line up the slot in the outer race with the pin **(42)** in the housing before pressing the bearings into position. Before installation, pack the bearings with ball and roller bearing lubricant.

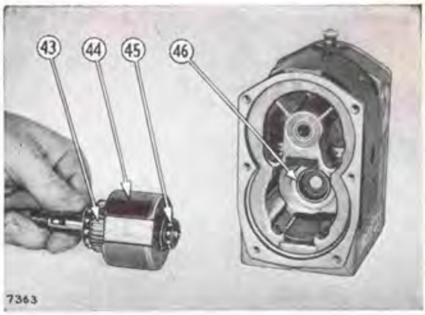
The seal **(36)** should be replaced if damaged to prevent starting engine oil fumes from entering the magneto.

INDUCTION ROTOR AND GEAR

With the distributor gear removed, the induction rotor will slide out. The rotor gear and bearing **(43)** may be driven off by using forked 19986 Drift. The race alone can be removed by pulling with the universal puller with 19973 Chuck. The 19985 Drift will install either the race or the gear.

Use 22413 Wedge and 19990 Puller Body to remove the outer race **(37)** from the housing. 19987 Arbor and 19983 Support should be used to install this outer bearing race.





DISTRIBUTOR SHAFT **INDUCTION ROTOR AND GEAR**

40—Breaker cam bearing. 41—Bushing. 42—Pin. 43—Rotor gear and bearing. 44—Inductor rotor. 45—Bearing race. 46—Outer race.

The bearing race **(45)** can be pulled using the universal puller with 19971 Chuck. 19984 Drift should be used to install this race. 19982 Drift with 19983 Support will remove the outer race **(46)** from the housing. 19980 Arbor, 19981 Fixture, and 19988 Base Plate should be used to install the race.

The bearings should be packed with ball and roller bearing lubricant.

MAGNET

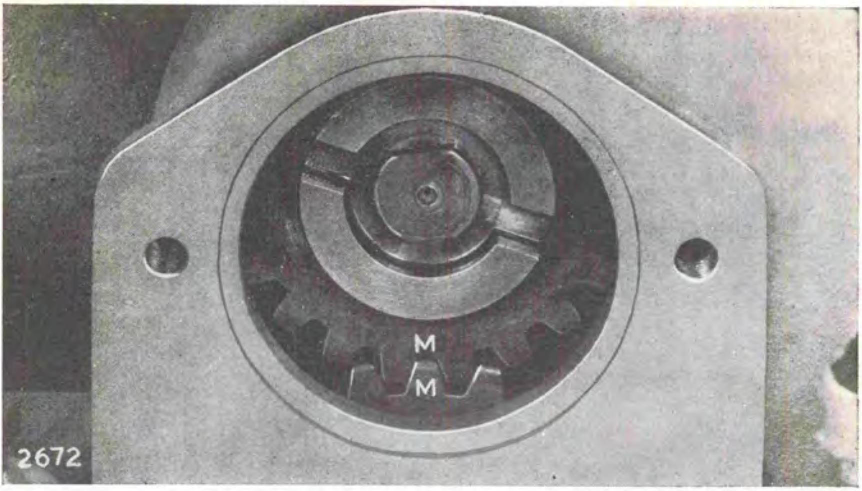
Remove the magnet only when replacing the housing by taking out the screws. Reinstall the end marked "N" on the side of the housing with the cast "N" on it.

TIMING MAGNETO TO ENGINE

Bosch Magneto

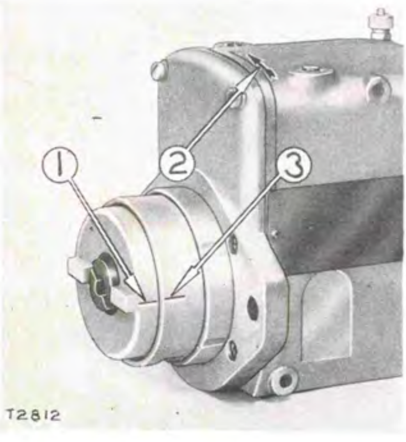
To time the magneto to the engine, first check the adjustment of the contact points. Then open the cylinder head drain cock of No. 1 (rear or left) cylinder and turn the engine flywheel slowly until a rush of air is noted coming from the cylinder. This indicates that the piston is coming up on the compression stroke. Continue to turn the flywheel slowly until the marked teeth of the timing gears are in line.

The crank of No. 1 cylinder is now 25° ahead of top center on the compression stroke, which is the correct firing point. With the magneto off of the engine, remove the distributor plate from the magneto and rotate the impulse coupling in the opposite direction from drive which is indicated by an arrow **(2)** on the top of the magneto housing (this will prevent the coupling weights from engaging) until the red mark **(1)** on the coupling lines up with the red mark **(3)** on the arrester plate and the distributor rotor contact **(4)** is in the position as shown. The breaker points should be just beginning to open, with the coupling rotating in the drive direction.



MARKED TEETH OF TIMING GEARS

Install the magneto on the engine and replace the distributor plate.



TIMING MARKS
1—Timing mark on coupling. 2—Arrow.
3—Timing mark on arrester plate.

ROTOR POSITION TO TIME MAGNETO TO ENGINE
4—Rotor contact.

Eisemann Magneto

To time the magneto to the engine, first check the adjustment of contact points. Open the cylinder head drain cock No. 1 (rear of left) cylinder and turn the flywheel slowly until a rush of air is noted coming from the cylinder. This indicates that the piston is coming up on the compression stroke. Continue to turn the flywheel slowly until the marked teeth of the timing gears are in line. (See illustration of marked teeth in Bosch Magneto information.)

MAGNETO TIMING MARKS

Remove the small cover from the end plate by taking out the two small fastening screws. Turn the magneto shaft backwards to prevent the impulse pawls catching until the white line on the distributor gear is in line with the mark on the end plate casting. Also on later machines a mark across the edge of the rotor should be on top. In this position the distributor rotor contact should be in line with the brush which is connected by the cable to the spark plug of No. 1 cylinder and the contact points should be barely separated. Install the magneto on the engine and replace cover.

Carburetor

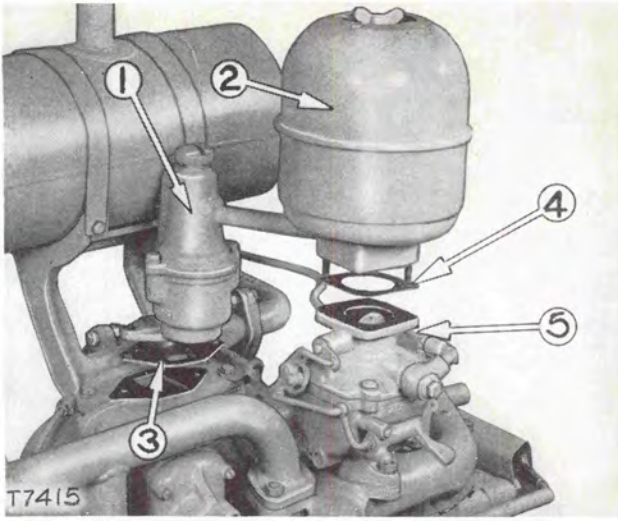
A Zenith 22 Series Carburetor of the downdraft type with a double venturi is used.

The illustrations cover the carburetor used in earlier engines and apply equally well to the later carburetor except where noted.

REMOVAL AND INSTALLATION

Disconnect the fuel line **(5)** from the inlet body. Drain the bowl by removing the plug in the base. Remove the air cleaner **(2)** and filler **(1)** as a unit. Disconnect the throttle control rod. Remove the nuts which attach the carburetor to the inlet manifold and lift off the carburetor.

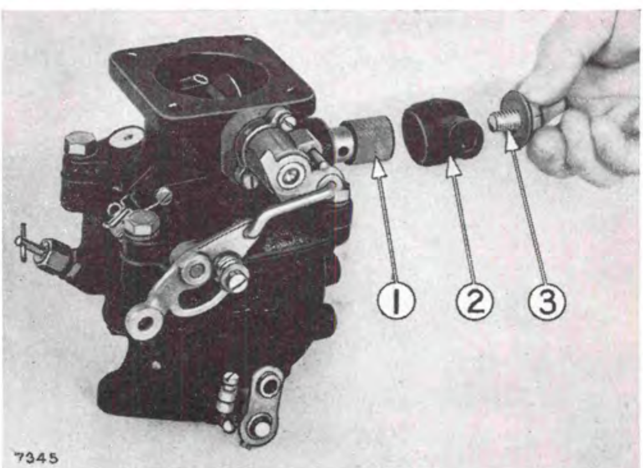
Replace gasket **(3)** and **(4)** when reinstalling unit.



CARBURETOR REMOVAL AND INSTALLATION
1—Filler. 2—Air cleaner. 3—Gasket.
4—Gasket. 5—Fuel line.

INLET BODY

Remove the inlet body **(2)** and screen **(1)** by taking out the stud **(3)**. Clean the screen and inspect the soldered joint to see that there are no cracks.



CARBURETOR INLET BODY REMOVAL
1—Screen. 2—Inlet body. 3—Stud.

AIR SHUTTER OR CHOKE CONTROL

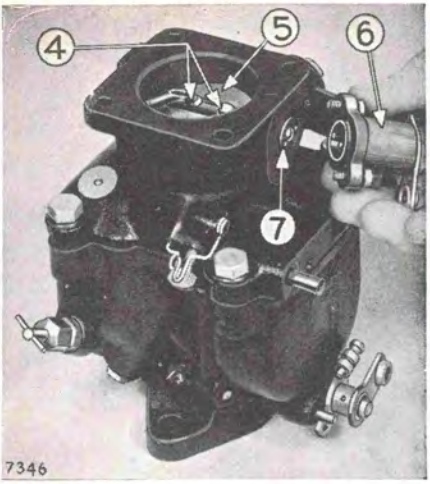
Remove the air shutter lever assembly **(6)**. This lever assembly provides a positive connection between the choke control rod and the air shutter so that when the control rod is pulled out three-fourths of the way, the shutter is completely closed mechanically. In pulling the lever the last fourth of its travel, the positive control is tripped and the shutter is held closed by the spring. In this position, the shutter will be opened by the force of the air stream as soon as the engine starts. This permits the engine to continue running without flooding until the choke control rod can be pushed in. To place the air shutter in the positive control position, push the control rod all the way in.

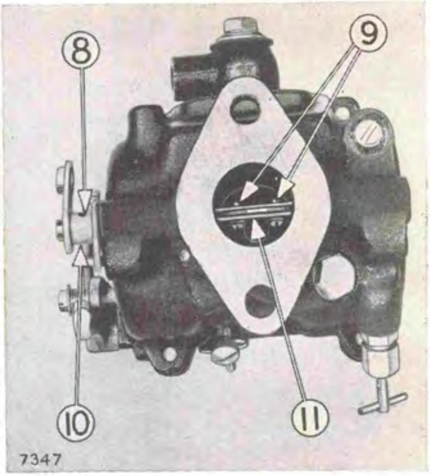
CARBURETOR USED ON LATER ENGINES

A—Spring loaded poppet valve.

The later model is recognizable by the absence of the air shutter lever assembly **(6)**, as on the new model this is not a removable part but cast with the balance of the carburetor housing. The new lever assembly provides a positive connection between the choke control rod and the air shutter at all times. A spring-loaded poppet valve **(A)**, located in the air shutter, will be opened by the force of the air stream as soon as the engine starts. This permits the engine to continue running without flooding until the choke control rod can be pushed in.

Take out the screws **(4)** after melting the solder away from the screws and shutter plate **(5)**. Slip out the shutter and then the air shutter shaft assembly **(7)**. Replace the shaft bushings in the housing if worn.





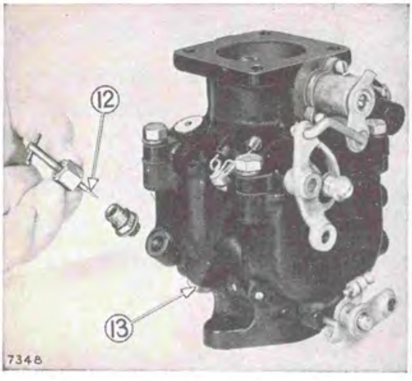
CARBURETOR DISASSEMBLY
4—Screws. 5—Shutter plate. 6—Air shutter lever assembly. 7—Air shutter shaft assembly. 8—Taper pin. 9—Screws. 11—Shaft.

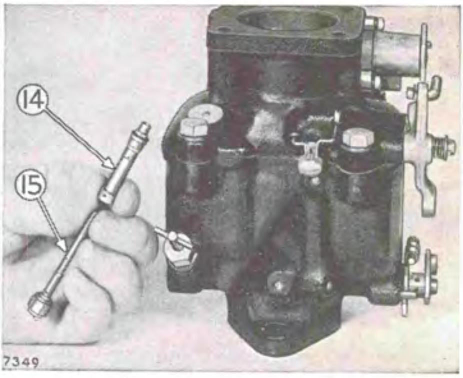
THROTTLE SHUTTER

Remove the screws **(9)**. The shutter will slide out of the shaft and the shaft **(11)** can be withdrawn. Drive the taper pin **(8)** out of the stop assembly. The stop assembly **(10)** will now come off the shaft. The shaft packing in the housing should be replaced.

MAIN OR HIGH SPEED JET

Remove the main jet adjustment screw **(12)**. If the screw is worn near the tip replace it with a new one as this screw regulates the fuel flow at speeds above idling. The amount of fuel is reduced by turning the screw clockwise.





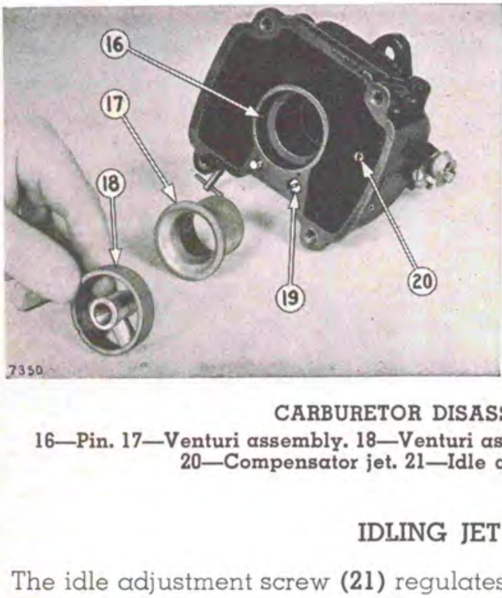
CARBURETOR DISASSEMBLY
12—Main jet adjustment screw. 13—Capscrew. 14—Cap jet assembly. 15—Main jet.

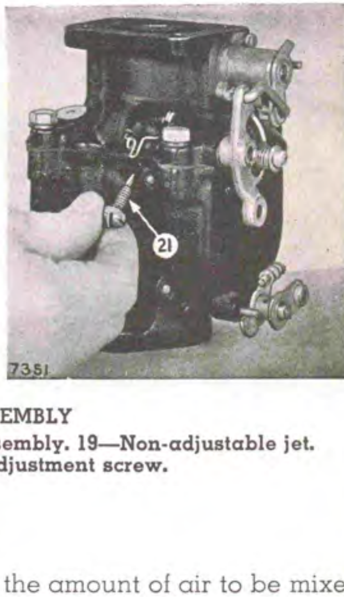
The main jet assembly may be removed by taking out the capscrew **(13)** and screwing the assembly out. This jet assembly is non-adjustable. Carefully wash the main jet **(15)** and cap jet assembly **(14)** and clean with compressed air. The cap jet assembly, by means of the size and shape of its openings, determines the rate of fuel discharge when the engine is operating.

The compensator jet **(20)** which admits the fuel for the idling jet and also for the main jet may be removed with a screwdriver.

VENTURI

The venturi assemblies **(17)** and **(18)** can be removed by hand. The pin **(16)** should register with the notches in each venturi.





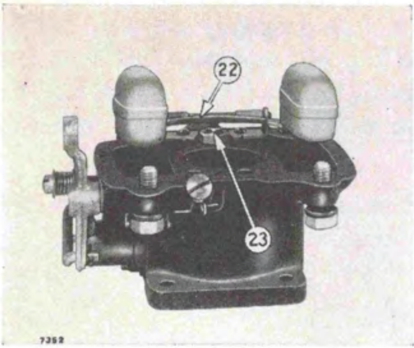
CARBURETOR DISASSEMBLY
16—Pin. 17—Venturi assembly. 18—Venturi assembly. 19—Non-adjustable jet. 20—Compensator jet. 21—Idle adjustment screw.

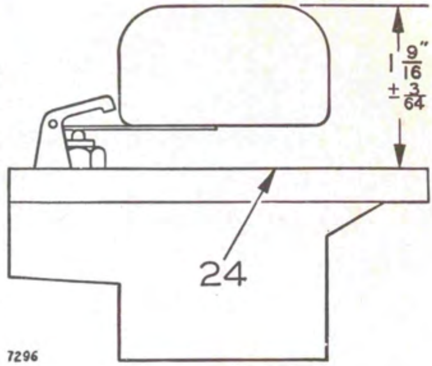
IDLING JET

The idle adjustment screw **(21)** regulates the amount of air to be mixed with the fuel at the idling jet. The non-adjustable jet **(19)** controls the amount of fuel taken from the compensator well. The fuel and air pass through the priming plug located in the carburetor throat adjacent to the idling position of the throttle shutter. There is an opening near jet **(19)** which is closed off on this application by the gasket. Do not make a hole in the gasket at this point, however in later engines this hole will be plugged.

FLOAT ASSEMBLY

If the fuel valve **(23)** leaks as evidenced by fuel leaking out of the intake manifold breather on the starting engine, inspect the seat of the valve assembly after removing the pin **(22)** and float assembly. Clean any foreign material from the seat or if worn, replace the valve assembly.





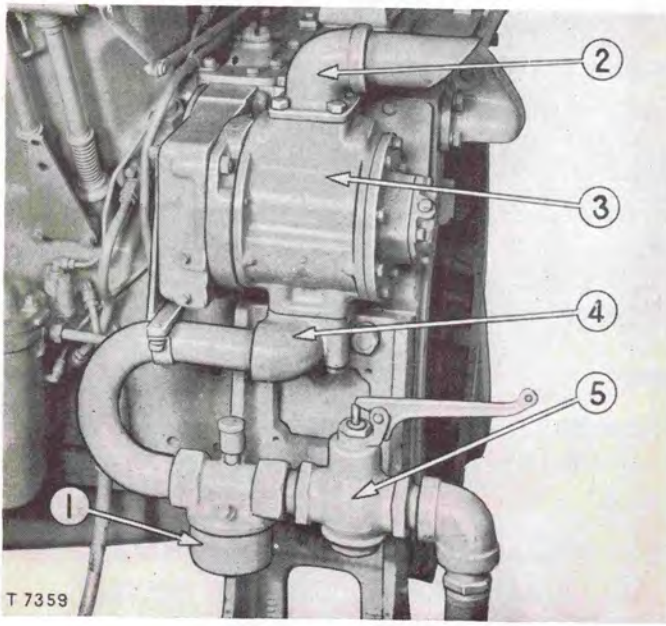
FLOAT ASSEMBLY
22—Pin. 23—Fuel valve. 24—Face of inlet assembly.

If a measurement of 1-9/16" plus or minus 3/64" does not exist between the face **(24)** of the air inlet assembly (without gasket) and the float as shown, replace the float assembly.

Air Starting System

INTRODUCTION

The air starting system shown is mounted on the left side of the engine. Air from an auxiliary compressor is stored in a receiver. This air is delivered to the whistle type control valve **(5)** which controls the air going into the air motor **(3)**. After the air leaves the control valve **(5)**, it passes through the oiler **(1)** and picks up oil spray, then into the air motor inlet **(4)**, where it is directed against the vanes. The air pressure being directed against the vanes causes the rotor to turn. As the air passes through the air motor it leaves a deposit of oil on the vanes, rotor and the air motor housing and exhausts through the outlet **(2)**.

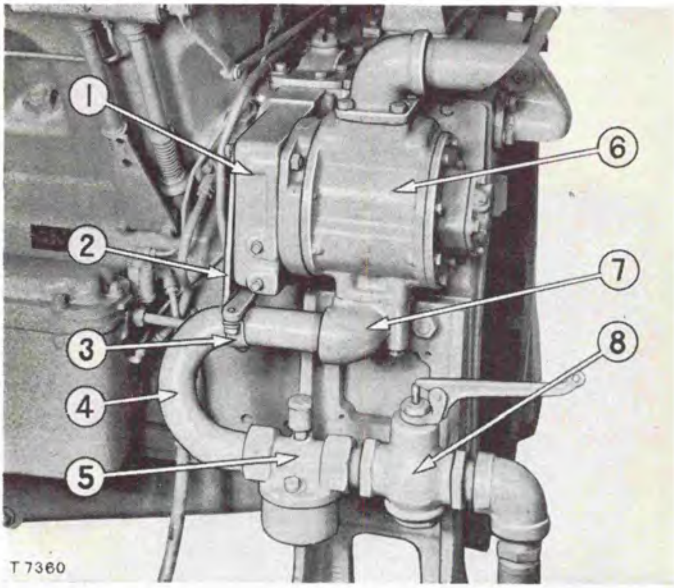


AIR STARTING SYSTEM
1—Oiler. 2—Air motor outlet. 3—Air motor.
4—Air motor inlet. 5—Control valve.

When the air pressure supply exceeds 120 PSI, it is necessary to mount a pressure regulator ahead of the control valve to control the pressure of air going into the air motor. See the topic, DISASSEMBLY AND ASSEMBLY OF THE PRESSURE REGULATOR, for additional information on the pressure regulator.

REMOVAL OF AIR MOTOR, CONTROL VALVE AND OILER FROM THE ENGINE

Remove the two capscrews securing the clamp **(3)** to the bracket **(2)**. Remove the three nuts securing the air motor **(6)** to the housing **(1)** and remove the air motor, oiler and control valve as a unit. Remove the capscrews securing the elbow **(7)** to the air motor and remove the elbow. Remove the elbow from the control valve **(8)** and remove the control valve from the oiler **(5)**. Remove the elbow **(7)** from the pipe **(4)** and remove the pipe from the oiler.



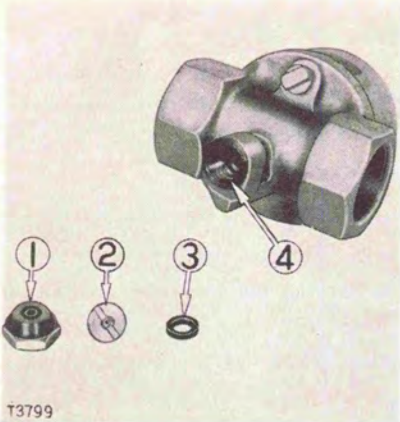
REMOVING AIR MOTOR, CONTROL VALVE AND OILER
1—Housing. 2—Bracket. 3—Clamp. 4—Pipe. 5—Oiler. 6—Air motor. 7—Elbow. 8—Control valve.

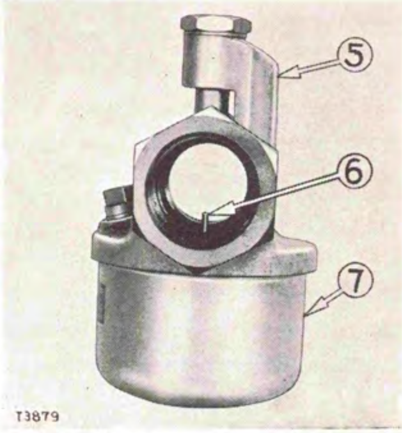
DISASSEMBLY AND ASSEMBLY OF OILER AND THE CONTROL VALVE

Oiler

The air passing through the venturi section of the oiler, over the top of a tube **(6)** in the center of the air passage causes air to pass down into the body **(7)** of the oiler and force oil up through a passage **(5)** in the top of the oiler where it is metered into the air stream. It forms into a spray and passes into the air motor to lubricate the vanes.

Remove the plug **(1)** and the oil drip gland **(2)**. If the rubber gasket **(3)** is damaged it should be replaced. Install the gasket **(3)** and oil drip gland **(2)**. When installing the oil drip gland, screw it down below the oil



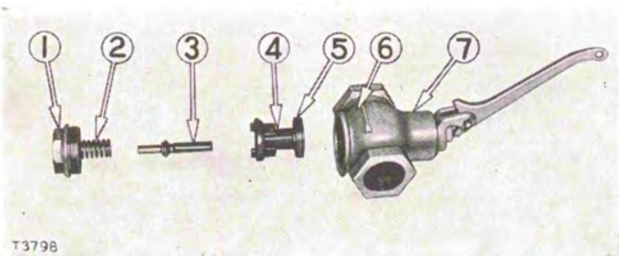


OILER
1—Plug. 2—Drip gland. 3—Gasket. 4—Oil hole. 5—Passage. 6—Tube. 7—Body.

hole **(4)** located in the top of the oiler. The oiler must be mounted so that the air flows through it in the direction indicated by the arrow on the oiler body.

Control Valve

The control valve releases the air from the receiver and allows it to pass through the system to the air motor. It is disassembled by removing the cap **(1)** and spring **(2)**. The plunger **(3)** and piston **(4)** can be removed from the body **(7)**. When reassembling the control valve, extreme care should be exercised in installing the piston **(4)** so the ring **(5)** will not be damaged. The control valve body must be installed so the air passes through the control valve in the direction designated by the arrow **(6)**.

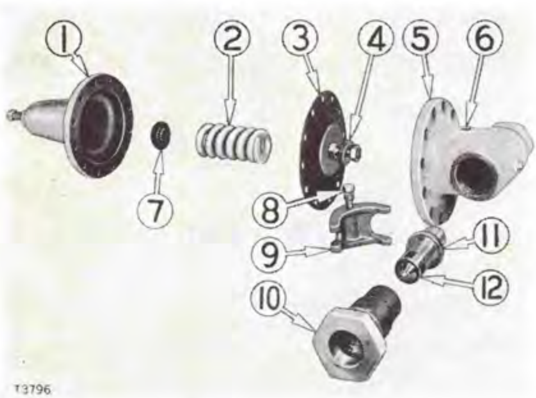


CONTROL VALVE
1—Cap. 2—Spring. 3—Plunger. 4—Piston. 5—Ring.
6—Arrow on valve body. 7—Valve body.

DISASSEMBLY AND ASSEMBLY OF PRESSURE REGULATOR

When air pressure exceeds 150 PSI, it is recommended that an air pressure regulator be used between the reservoir and control valve to regulate the air delivered to the air motor.

Remove the bolts holding the chamber **(1)**, diaphragm **(3)**, and body **(5)** together. Disengage the top of the arm **(9)** from the top of the collar **(4)** located on the diaphragm stud. The spring **(2)** and button **(7)** will drop out of the chamber **(1)** when it is lifted from the body **(5)**. Remove the shaft **(8)** from the hole **(6)** in the body. This will permit removal of the arm **(9)**. With the shaft removed, the arm can be disengaged from the collar **(11)** located on the piston **(12)**. The piston is removed by first removing the cylinder **(10)**. The piston can be further disassembled by removing the screw **(13)**. The disc **(14)** is rubber and should be replaced if damaged. The jet **(15)** can be unscrewed from the piston and the collar **(11)** removed.



DISASSEMBLY OF PRESSURE REGULATOR

1—Chamber. 2—Spring. 3—Diaphragm. 4—Collar. 5—Body. 6—Hole in body. 7—Button. 8—Shaft. 9—Arm. 10—Cylinder. 11—Collar. 12—Piston.

The regulator should be reassembled in the following order. Reassemble piston **(12)** in the cylinder **(10)**. Screw the cylinder into the body **(5)**. Install the arm **(9)**. Inspect the diaphragm **(3)** and replace it if it is damaged or broken. Install button **(7)** and spring **(2)**. Install the chamber **(1)** on the body and bolt them together.

The regulator can be adjusted by turning the adjusting screw located on top of the chamber **(1)**. With the regulator disconnected from the control valve, and connected to the air supply line, connect a gauge reading in P.S.I. to the outlet side of the regulator and check the P.S.I. In cold weather it may be necessary to raise the P.S.I. delivered by the regulator. After the pressure has been set, install the regulator.

DISASSEMBLY OF CYLINDER
13—Screw. 14—Disc. 15—Jet.

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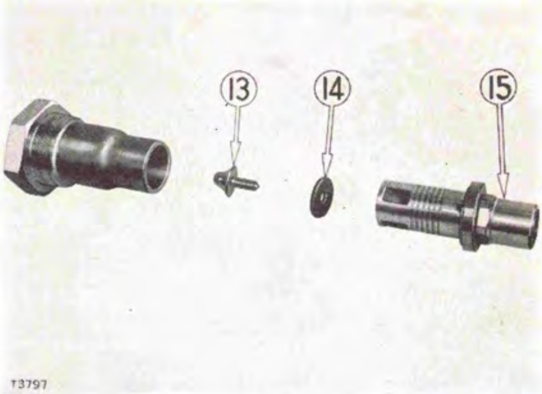


DISASSEMBLY OF AIR MOTOR

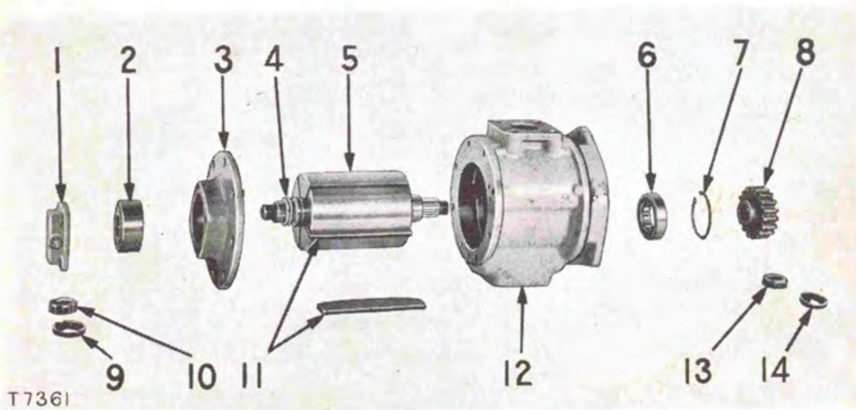
Wash the exterior of the air motor in some non-inflammable cleaning fluid. Mark all parting surfaces with punch marks or chisel marks to aid in reassembling unit.

Remove the nut **(13)** and lock **(14)** from the rotor shaft and take off the drive gear **(8)**. The drive gear **(8)** is splined to the rotor shaft and it is a light press fit.

Remove the capscrews securing the plate **(3)** to the housing **(12)** and pull the plate **(3)** and rotor **(5)** from the housing **(12)** as a unit.

The bearing **(6)** is a single row ball bearing held in place by the snap ring **(7)**. It is a light press fit and easily removed.

Remove the vanes **(11)** from the rotor **(5)**.

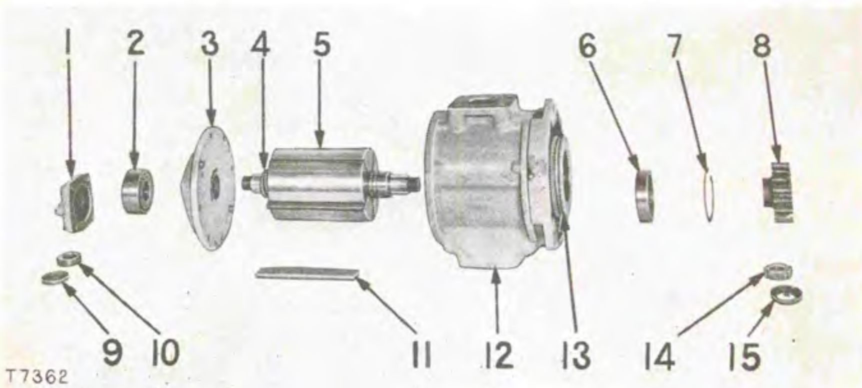


DISASSEMBLY OF AIR MOTOR
1—Cover. 2—Bearing. 3—Plate. 4—Shims. 5—Rotor. 6—Bearing. 7—Snap ring. 8—Drive gear. 9—Lock. 10—Nut. 11—Vanes. 12—Housing. 13—Nut. 14—Lock.

Remove the cover **(1)** from the plate **(3)**, remove the nut **(10)** and lock **(9)** from the rotor shaft. Pull the plate **(3)** from the rotor shaft using the 8B7546 Puller. The bearing **(2)** is a double row ball bearing, shielded on the side facing the rotor. Press the bearing out of the plate. The shims **(4)** should be tied together and reinstalled when reassembling the unit.

ASSEMBLY OF AIR MOTOR

Place the shims **(4)** that were previously removed on the rotor shaft. Place the plate **(3)** over the end of the rotor shaft and install the bearing **(2)** with the shielded side facing the rotor. Check the clearance between the plate and the end of the rotor with a thickness gauge. This clearance should be .004"-.006". This clearance is increased by adding shims and decreased by removing them. Install the lock **(9)** and nut **(10)**. Replace the cover **(1)**. Inspect the vanes **(11)** for cracks, wear or distortion which might cause them to stick. Place them in the slots in the rotor **(5)**. Install the rotor and plate in the housing **(12)** and secure with the capscrews previously removed. Install the bearing **(6)** and snap ring **(7)**. Install the drive gear **(8)**, lock **(15)** and nut **(14)**. Bend the locks and replace the rubber ring seal **(13)** before installing the air motor on the engine.



ASSEMBLING AIR MOTOR
1—Cover. 2—Bearing. 3—Plate. 4—Shims. 5—Rotor. 6—Bearing. 7—Snap ring. 8—Drive gear. 9—Lock. 10—Nut. 11—Vanes. 12—Housing. 13—Seal. 14—Nut. 15—Lock.

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