TECHNICAL MANUAL

WESTERBEKE

13 - 21 - 27 - 33

MARINE DIESEL ENGINES

Edition Two

October 1981

SECTION INDEX

IMPORTANT

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INTRODUCTION

IMPORTANT

THIS MANUAL IS A DETAILED GUIDE TO THE INSTALLATION, START-UP, OPERATION AND MAINTENANCE OF YOUR WESTERBEKE MARINE DIESEL ENGINE. THE INFORMATION IT CONTAINS IS VITAL TO THE ENGINE'S DEPENDABLE, LONG TERM OPERATION. READ I T ! KEEP IT IN A SAFE PLACE ! KEEP IT HANDY FOR REFERENCE AT ALL TIMES !

FAILURE TO DO SO WILL INVITE SERIOUS RISK, NOT ONLY TO YOUR INVESTMENT BUT YOUR SAFETY AS WELL.

UNDERSTANDING THE DIESEL ....

The diesel engine closely resembles the gasoline engine inasmuch as the mechanism is essentially the same. Its cylinders are arranged above its closed crankcase; its crankshaft is of the same general type as that of a gasoline engine; it has the same sort of valves, camshaft, pistons, connecting rods, lubricating system and reverse and reduction gear.

Therefore, it follows to a great extent that a diesel engine requires the same preventative maintenance as that which any intelligent operator would give to a gasoline engine. The most important factors are proper maintenance of the fuel, lubricating and cooling systems. Replacement of fuel and lubricating filter elements at the time periods specified is a must, and frequent checking for contamination (i.e. water, sediment,etc.) in the fuel system is also essential. Another important factor is the use of the same brand of ".high detergent" diesel lubricating oil designed specifically for diesel engines.

The diesel engine does differ from the gasoline engine, however, in the method of handling and firing its fuel. The carburetor and ignition systems are done away with and in their place is a single component - the Fuel Injection Pump - which performs the function of both.

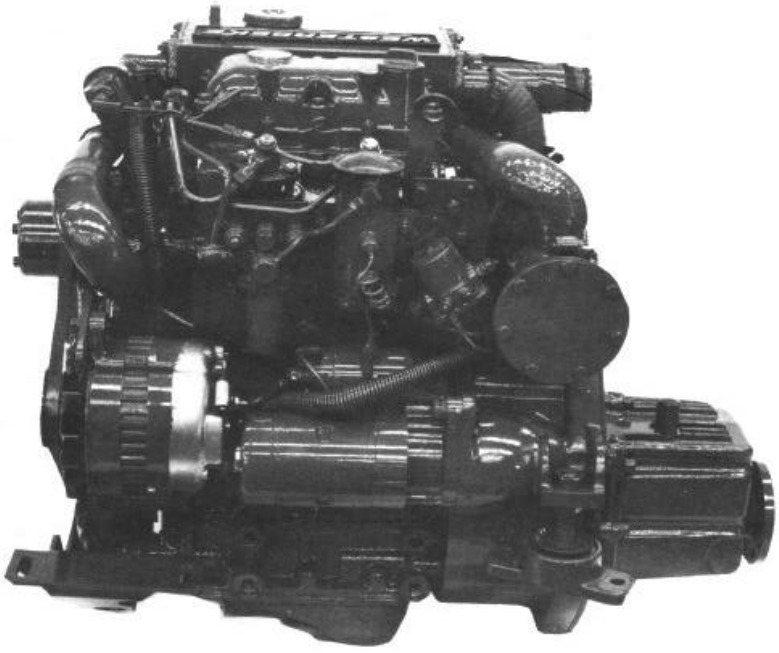
Unremitting care and attention at the factory have resulted in a Westerbeke engine capable of many thousands of hours of dependable service. What the manufacturer cannot control, however, is the treatment it receives in service. This part rests with you!

ORDERING PARTS

Whenever replacement parts are needed, always include the complete part description and part number (see separate Parts List furnished, if not part of this publication). Be sure to include the engine's model and serial number. Also, be sure to insist upon Westerbeke factory packaged parts, because "will fit" parts are frequently not made to the same specifications as original equipment`.

GENERATOR SETS

Westerbeke diesels are used for both the propulsion of boats and for generating electrical power. For generator set applications, all details of this Manual apply, except in regard to certain portions of the" Installation, Operation and Maintenance sections. Additional information is provided in the section titled Generator Sets, Section T.



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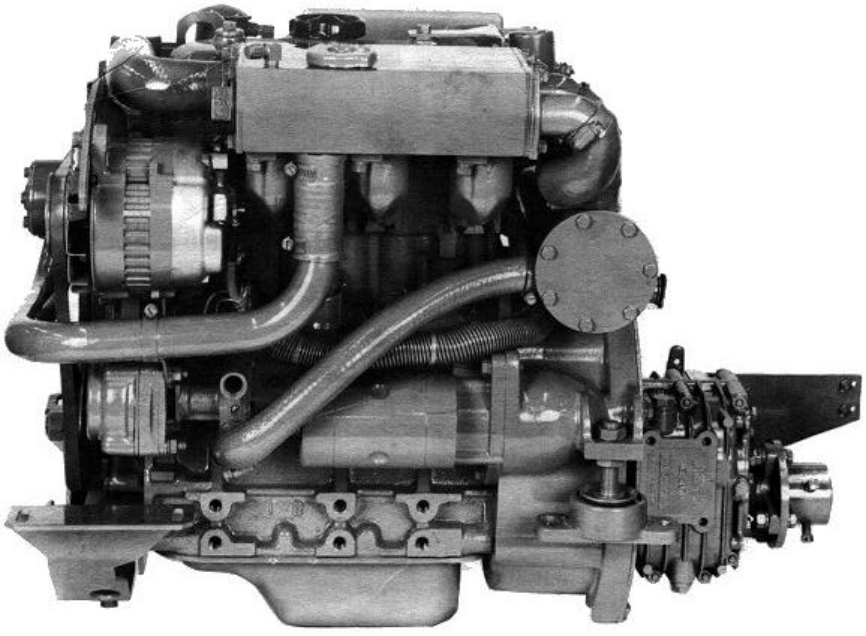

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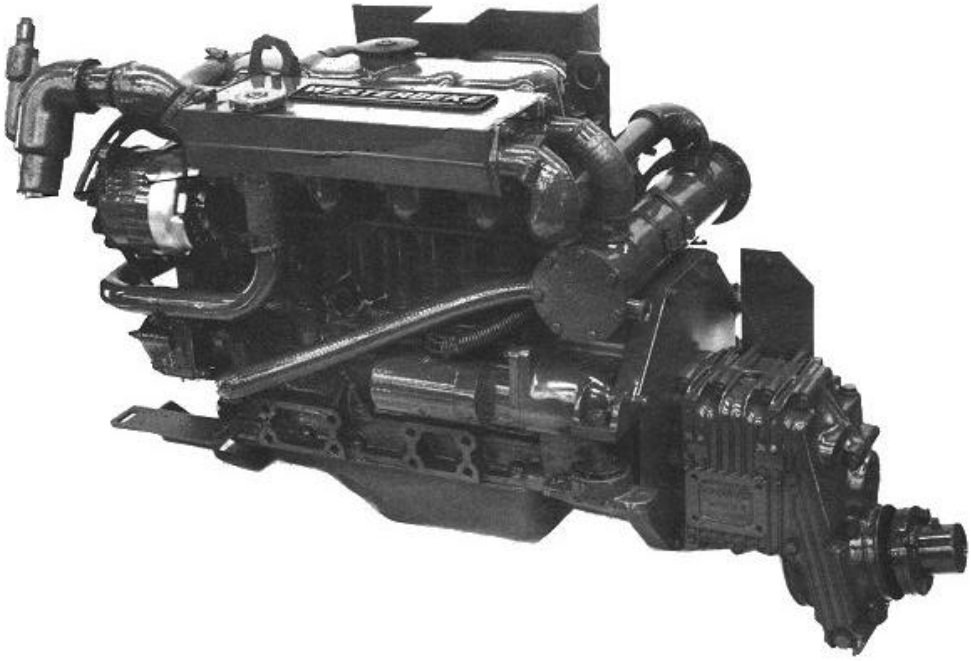

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INSTALLATION

FOREWORD

Since the boats in which these engines are used are many and varied, details of engine installation are equally so. It is not the purpose of this section to advise boatyards and engine installers on the generally well understood and well developed procedures for installation of engines. However, the following outline of general procedure is included because it is valuable in explaining the functions of each component, the reasons why, the precautions to be watched and the relationship of the installation to the operation of the engine. There are details of the installation which should have a periodic check and of which the operator should have a thorough understanding to insure good operating conditions for the engine and correct procedure for its servicing.

INSPECTION OF EQUIPMENT

The engine is shipped from the factory mounted securely and properly crated. Accessory equipment is shipped in a separate small box, usually packed with the engine crate.

Before accepting shipment from the transportation company, the crate should be opened and an inspection made for concealed damage. If either visible or concealed damage is noted, you should require the delivering agent to sign "Received in damaged condition". Also check contents of the shipment against the packing list and make sure note is made of any discrepancies. This is your protection against loss or damage. Claims for loss or damage must be made to the arrier, not to J. H. Westerbeke Corporation.

RIGGING AND LIFTING

The engine is fitted with lifting rings.

Rope or chain slings should be attached to the rings and the engine lifted by means of tackle attached to this sling. The lifting rings have been designed to carry the full weight of the engine; therefore, auxiliary slings are not required or desired.

CAUTION: Slings must not be so short as to place the engine lifting eyes in significant sheer stress: Strain on the engine lifting eyes must not be in excess of 10' from the vertical. A spacer bar must be placed between the two lifting eyes, if supported by valve cover studs.

The general rule in moving engines is to see that all- equipment used is amply strong and firmly fixed in place. Move the engine a little at a time and see that it is firmly supported. Eliminate possibility of accidents by avoiding haste. Do not lift from the propeller coupling, or pry against this with crowbar, as you may distort the coupling.

In some cases it may be necessary to lift the engine in other than the regular horizontal position. It may be that the engine must be lowered endwise through a small hatchway which cannot be made larger. If the opening is extremely restricted, it is possible to reduce, to some extent, the outside clearances such as generator, cooling piping, water tank, filters, mounting lugs, etc. This accessory equipment should be removed by a competent mechanic and special care should be taken to avoid damage to any exposed parts and to avoid dirt entering openings. The parts which have been removed should be returned to position as soon as the restriction has been passed.

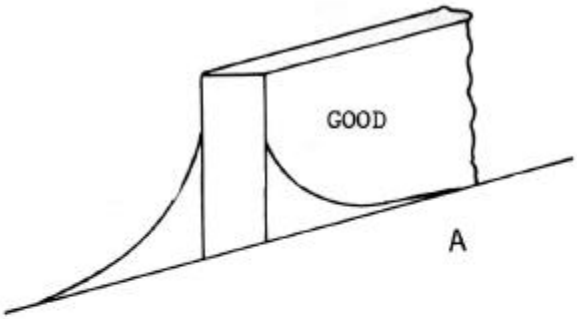
In case it is necessary to hoist the engine either front end upwards or reverse gear end upwards, the attachment of slings must be done very carefully to avoid the possibility of damage to the parts on which the weight may bear. It is best if special rigging work be done by someone experienced and competent in the handling of heavy machinery.

ENGINE BOLTS

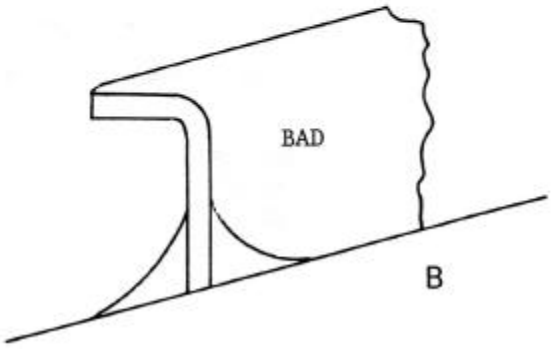
It is recommended that bronze hanger bolts of appropriate size be used through the engine flexible mounts. Lag screws are less preferred because their hold on the wood is weakened every time they are moved, whereas the lag bolt stays in position and the nut on top is used to tighten the engine down or is removed to permit the engine to be lifted. The bolt itself stays in position at all times, as a stud, and the bond between the bolt and the wood is not weakened by its removal.

FOUNDATION FOR ENGINE

A good engine bed contributes much toward the satisfactory operation of the engine. The engine bed must be of rigid construction and neither deflect nor twist when subjected to the engine weight or the position the boat may have to take under the effects of rough seas. The bed must keep the engine within one or two thousandths of an inch of this position at all times. It has to withstand the forward push of the propeller which is applied to the propeller shaft, to the thrust washer bearing in the engine and finally to the engine bolts and engine bed.



In fiberglass hulls, we recommend that similar wooden stringers as in wooden hulls be formed and fitted, then glassed to the hull securely. This allows hanger bolts to be installed firmly in wood, thus reducing~noise and transmitted vibration.



The temptation to install the engine on a pair of fiberglass "angle irons" should be resisted. Such construction will allow engine vibrations to pass through to the hull. Flexible mounts require a firm foundation against which to react if they are to do their job. When possible, follow bed design "A" and avoid bed design "B".

PROPELLER COUPLING

Each Westerbeke Diesel engine is regularly fitted with a suitable coupling connecting the propeller shaft to the engine.

The coupling must not only transmit the power of the engine to turn the shaft, but must also transmit the thrust either ahead or astern from the shaft to the thrust bearing which is built into the reduction gear housing of the engine. This coupling is very carefully machined for accurate fit.

For all engine models, a propeller half-coupling, bored to shaft size for the specific order, is supplied. The coupling either has a keyway with set screws or is of the clamping type.

The forward end of the propeller shaft has a long straight keyway. Any burrs should be removed from the shaft end. The coupling "should be a light drive fit on the shaft and the shat should not have, to be scraped down or filed in order to get a fit. It is important that the key be properly fitted both to the shaft and the coupling. The key should fit the side of the keyway very closely, but should not ,touch the top of the keyway in the hub of the coupling.

If it seems difficult to drive the coupling over the shaft, the coupling can be expanded by heating in a pail of boiling water. The face of the propeller coupling must be exactly perpendicular to the centerline or axis of the propeller shaft.

PROPELLER

The type and size of propeller varies with the gear ratio and must be selected to fit the application based upon boat tests. To utilize the full power of the engine, and to achieve ideal loading conditions, it is desirable to use a propeller which will permit the engine to reach its full rated speed at full throttle under normal load.

ALIGNMENT OF ENGINE

The engine must be properly and exactly aligned with the propeller shaft. No matter what material is used to build a boat it will be found to be flexible to some extent and the boat hull will change its serape to a greater extent than is usually realized when it is launched and operated in the water. It is therefore very important to check the engine alignment at frequent intervals and to correct any errors when they may appear.

Misalignment between the engine and the propeller shaft is the cause of troubles which are blamed often on other causes. It will create excessive bearing wear, rapid shaft wear and will, in many cases, reduce the life of the hull by loosening the hull fastenings. A bent propeller shaft will have exactly the same effect and it is therefore necessary that the propeller shaft" itself be perfectly straight.

One particularly annoying result of misalignment may be leakage of transmission oil through the rear oil seal. Check to make sure that alignment is within the limits prescribed.

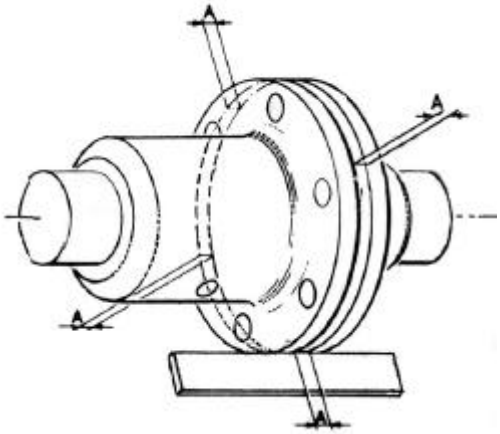
The engine should be moved around on the bed and supported on the screw-jacks or shims until the two halves of the couplings can be brought together without using force and so that the flanges meet evenly all around. It is best not to drill the foundation for the foundation bolts until the approximate alignment has been accurately determined.

Never attempt a final alignment with the boat on land. The boat should be in the water and have had an opportunity to assume its final water form. It is best to do the alignment with the fuel and water tanks about half full and all the usual equipment on board and after the main mast has been stepped and final rigging has been accomplished.

Take plenty of time in making this alignment and do not be satisfied with anything less than perfect results.

The alignment is correct when the shaft canbe slipped backward and forward into the counterbore very easily and when a feeler gauge indicates that the flanges come exactly together at all points. The two halves of the propeller coupling should be parallel within 0.002 inches (A).

In making the final check for alignment, the engine half coupling should be held in one position and the alignment with the propeller coupling tested with the propeller coupling in each of four positions, rotated 90^0 between each position. This test will also check whether the propeller half coupling is in exact alignment on its shaft. Then, keeping the propeller coupling in one position, the alignment should be checked rotating the engine half coupling to full position each 90^0 from the next one.



The engine alignment should be rechecked after the boat has been in service for one to three weeks and, if necessary, the alignment remade. It will usually be found that the engine is no longer in alignment. This is not because the work was improperly done at first but because the boat has taken some time to take its final. shape, and the engine bed and engine stringers have probably absorbed some moisture. It may even be necessary to re-align at a further period.

The coupling should always be opened up and the bolts removed whenever the boat is hauled out or moved from the land to the water, and during storage in a cradle. The flexibility of the boat often puts a very severe strain on the shaft or the coupling or both when it 'is being moved. In some cases the shaft has actually -been .bent by these strains. This does not apply to small boats that are hauled out of the water when not in use, unless they are dry for a considerable time.

EXHAUST SYSTEM

Exhaust line installations vary considerably and each must be designed for the particular job. The general requirements are to provide an outlet line with a minimum of restrictions and arranged so that sea water, rain water or condensation cannot get back into the engine. There should be a considerable fall in the line between the exhaust manifold flange and the discharge end. This slope in the pipe makes it difficult for water to be driven in very far by a wave, and a steep drop followed by a long slope is better than a straight gradual slope. Avoid any depression or trough to the line which would fill with water and obstruct the flow of exhaust gas. Also avoid any sharp bends.

Brass or copper is not acceptable for wet exhaust systems, as the combination of salt water and diesel exhaust gas will cause rapid deterioration. Galvanized iron fittings and galvanized iron pipe are recommended for the exhaust line. The exhaust line must be at least as large as the engine exhaust manifold flange and be increased in size if there is an especially long run and/or many elbows. It should be increased by 1/2" in I.D. for every 10 feet beyond the first 10 feet.

Most exhaust systems today use a water lift type muffler such as the Westerbeke "Hydro-Hush". In most installations there is a dry, insulated high loop after the engine manifold and before the muffler to prevent water flowing backwards into the engine during cranking

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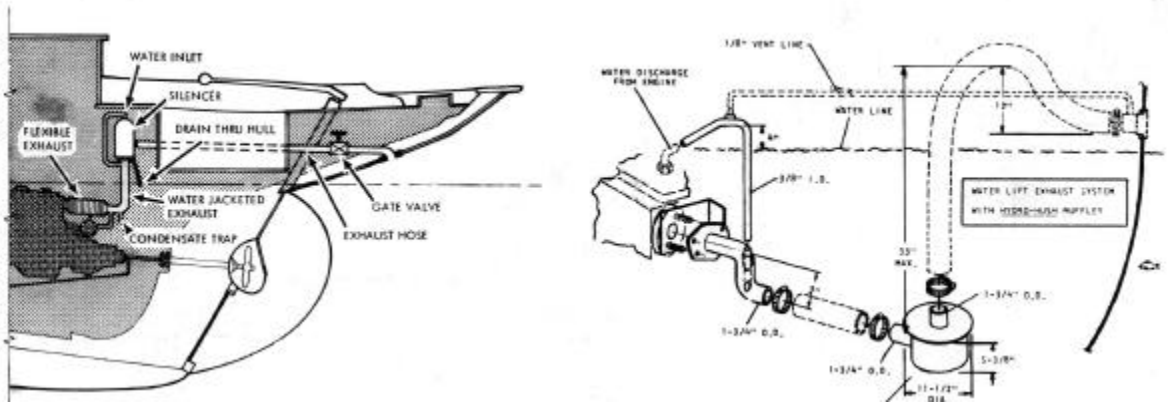
It is essential not to hang too much weight in the form of exhaust system components rigidly from the engine manifold. Generally, it is permissible to directly connect a pipe nipple and a water jacketed exhaust elbow, which two components weigh about 8 pounds (4 kg). If there are more components to be rigidly connected to each other than will weigh 8 pounds, then a flexible exhaust section must be installed between manifold outlet and the exhaust system.



The exhaust system must be supported or suspended independently of the engine manifo+d, usually using simple metal hangers secured to the overhead.:

All dry portions of the exhaust system should be wrapped in suitable insulation material to keep surface temperatures as low as possible.

Many installations use flexible rubber exhaust hose for the water cooled section of the exhaust line because of the ease of installation and flexibility. Provide adequate support for the rubber hose to prevent sagging, bending and formation of water pockets,

Always arrange the rubber hose section so that water cannot possibly flow back into the engine. Also make sure that entering sea water cannot spray directly against the inside of the exhaust piping. Otherwise, excessive erosion will occur.

MEASURING EXHAUST GAS BACK PRESSURE

Back pressure must be measured on a straight section of the exhaust line and as near as possible to the engine exhaust manifold. The engine should be run at maximum load during the measurement period. Set-up should be as shown below.

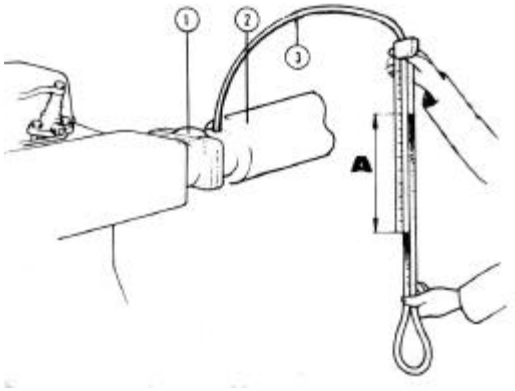
1. For normally asperated engines:

Pressure Test	Mercury Test	Water Column
1-1/2" Max PSI	3" Mercury	= 39"

2. For turbo-charged engines:

Pressure Test	Mercury Test	Water Column
0.75 Max PSI	1-1/2" Mercury	= 19-1/2"

Checking The Back Pressure
1. Exhaust pipe flange
2. Exhaust line
3. Transparent plastic hose, partly filled with water.
Measurement "A" may not exceed 39" for normally asperated engines and 19.5" for turbo-charged engines.



WATER CONNECTIONS

Seacocks and strainers should be of the full flow type at least one size greater than the inlet thread of the sea water pump. The strainer should be of the type which may be withdrawn for cleaning while the vessel is at sea.

Water lines can be copper tubing or wire-wound, reinforced rubber hose. In arty case, use a section of flexible hose that will not collapse under suction, between the hull inlet and engine and between the outlet and the exhaust system. This takes up vibration and permits the engine to be moved slightly when it is being re-aligned. Do not use street elbows in suction piping. All pipe and fittings should be of bronze. Use sealing compound at all connections to prevent air-leaks. The neoprene impeller in the sea (raw) water pump should never be run dry.

FUEL TANK AND FILTERS

Fuel tanks may be of fiberglass, monel, aluminum, plain steel or terne plate. If made of fiberglass, be certain that the interior is gel coated to prevent fibers from contaminating the fuel system. Copper or galvanized fuel tanks should not be used. It is not necessary to mount the tank above the engine level as the fuel lift pump provided will raise the fuel from the tank. The amount of lift should be kept minimum (6 feet being maximum). If a tank is already installed above the engine level, it can be utilized in this position. Great care should be taken to ensure that the fuel system is correctly installed so that air-locks are eliminated and precautions taken against dirt and water entering the fuel.

A primary fuel filter of the water collecting type should be installed between the fuel tank and the fuel lift pump. A recommended type is available from the list of accessories. The secondary fuel filter is fitted on the engine between the fuel lift pump and the injection pump and has a replaceable element. As the fuel lift pump has a capacity in excess of that required by the injection pump, the overflow is piped to the fuel tank and should be connected to the top of the tank or as near the top as possible.

To insure satisfactory operation, a diesel engine must have a dependable supply of clean diesel fuel. For this reason, cleanliness and care are especially important at the time when the fuel tank is, installed, because dirt left anywhere in the fuel lines or tank will certainly cause fouling of the injector nozzles when the engine is started for the first time.

FUEL PIPING

We recommend copper tubing together with suitable fittings, both for the supply line and the return line. Run the tubing in the longest pieces obtainable to avoid the use of unnecessary fittings and connectors. The shut off valve in the line between the fuel tank and engine should be of the fuel oil type, and it is important that all joints be free of pressure leaks.

Keep fuel lines as far as possible from exhaust pipe for minimum temperature, to eliminate "vapor locks".

The fuel piping leading from the tank to the engine compartment should always be securely anchored to prevent chafing. Usually the copper tubing is secured by means of copper straps.

The final connection to the engine should be through flexible rubber hoses.

ELECTRIC PANEL

The Westerbeke all-electric panel utilizes an electronic tachometer with a built-in hour meter. Tachometer cables are no longer required, except for the Skipper mechanical panel. Mounted on the panel are a voltmeter, water temperature gauge and oil pressure gauge. Each instrument is lighted. The all-electric panel is isolated from ground and may be mounted where visible. It is normally pre-wired.

ELECTRICAL EQUIPMENT

Most Westerbeke engines are supplied pre-wired and with plug-in connectors. Never make or break connections while the engine is running. Carefully follow all instructions on the wiring diagram supplied, especially those relating to fuse/circuit breaker requirements. Starter batteries should be located as close to the engine as possible to avoid voltage drop through long leads. It is bad practice to use the starter batteries for other services unless they require low amperage or are intermittent. In cases where there are substantial loads (from lights, refrigerators, radios, depth sounders, etc.), it is essential to have a complete, separate system and to provide charging current for this by means of a second alternator or "alternator output splitter".

Starter batteries must be of a type which permits a high rate of discharge (Diesel starting).

Carefully follow the recommended wire sizes shown in the wiring diagrams. Plan installation so the battery is close to the engine and use the following cable sizes:

#1 - for distances up to 8 feet
#1/0 - for distances up to 10 feet
#2/0 - for distances up to 13 feet
#3/0 - for distances up to 16 feet

MECHANICAL CONTROLS

The recommended practice is to have the stop-run lever loaded to the run position and controlled by a sheathed cable to a push-pull knob at the pilot station. The throttle lever should be connected to a Morse type lever at the pilot station by a sheathed cable.

The transmission control lever may be connected to the pilot station by a flexible, sheathed cable and controlled by a Morse type lever. The single-lever type gives clutch and throttle control with full throttle range in neutral position. The two-lever type provides clutch control with one lever and throttle control with the other.

Any bends in the control cables should be gradual. End sections at engine and transmission must be securely mounted. After linkages are completed, check the installation for full travels making sure that, when the transmission control lever at the pilot station is in forward, neutral and reverse, the control lever on the transmission is on the respective detent. Check the throttle control lever and the stop-run lever on the fuel injection pump for full travel.

Some models do not require a stop cable because they have either a fuel solenoid or an electric fuel pump. Examples of such models are the W58 and the W52.

OPERATION

PREPARATION FOR FIRST START

The engine is shipped "dry"...with lubricating oil drained from crankcase and fluid from the transmission. Therefore, be sure to follow these recommended procedures carefully before starting the engine for the first time.

1. Remove oil filler cap and fill oil sump with heavy duty diesel lubricating oil to the highest mark on the dipstick. See table under Maintenance for an approved lubricating oil. Do not overfill. Select an approved grade from the listing and continue to use it.

2. Fill the reverse gear to the highest mark on the dipstick with TYPE A transmission fluid. Do not overfill. Refer to the `Transmission Section of this manual for details.

   Engine oil is not recommended because it can foam, and it can contain additives harmful to some transmissions.

   If the engine is equipped with a V-drive, fill to the full mark on the dipstick with the recommended lubricant specified on the data tag n the V-drive housing.

3. Fill fresh water cooling system with a 50-50 antifreeze solution only after opening all petcocks and plugs until all entrapped air is expelled.

   Fill surge tank to within one inch of the top. Check this level after engine has run for a few minutes. If trapped air is released, the water level may have dropped. If so, refill tank to within one inch, of top and replace filler cap.

4. Ensure battery water level is at least 3/8" above the battery plates and battery is fully charged so that it is capable of the extra effort that may be required on the first start.

5. Fill fuel tank with clean diesel fuel oil; No. 2 diesel fuel oil is recommended. The use of No. 1 is permissible but No. .2 is preferred because of its higher lubricant content.

   NOTE: If there is no filter in the filler of the fuel tank, the recommended procedure is to pour the fuel through a funnel of 200 mesh wire screen.

6. Fill grease cup on the sea water pump, if present, with a good grade of water pump grease.

FUEL SYSTEM

The fuel injection system of a compression ignition engine depends upon very high fuel pressure during the injection stroke to function correctly: Relatively tiny movements of the pumping plungers produce this pressure and, if any air is present inside the high pressure line, then this air acts as a cushion and prevents the correct pressure, and therefore fuel injection, from being achieved.

In consequence, it is essential that all air is bled from the system whenever any part of the system has been opened for repair or servicing.

BLEEDING PROCEDURES BY MODEL

1. Initial Engine Start-up (Engine stoppage due to lack-of fuel)
   a. Insure that the fuel tank(s) is filled with the proper grade of diesel fuel.
   b. Fill any large primary filter/water separator with-clean diesel fuel that is installed between the fuel tank and engine. To attempt to fill any large primary filter using the manual priming lever on the engine mounted fuel lift pump may prove futile or require a considerable amount of priming.
   c. Turn the fuel selector valve to "On". Systems with more than one tank insure that fuel returning is going to the tanks being used.

The above procedures are basic for all initial engine start-ups or for restarting engines stopping due to lack of fuel.

WESTERBEKE W7 AND WPD4 GENERATOR (3600 RPM) (Figure 1)

1. With the use of a 5/16 box wrench or common screw driver, open the bleed screw one or two turns on the outgoing side of the engine mounted secondary fuel filter (Bleed point A). With firm strokes on the lift pump priming lever, bleed until fuel free of air bubbles flows from this point. Stop priming and gently tighten the bleed screw.

2. With a 5/8 open end wrench loosen one to two turns the nut securing the injector line to the injector (Bleed point B).

   Decompress the engine with the lever on the top of the cylinder head. Crank the engine over with the starter. (W7: ensure that the engine stop lever is in the run position and the throttle is full open.) (4KW: use the defeat position while cranking.) Crank the engine until fuel spurts by the nut and line. Stop cranking and tighten the 5/8 nut and proceed with normal starting procedures.

WESTERBEKE W30 (Figure 2), W40 & WPO10, 12h, 15 (Figure 3), W50 & WBO 15 (Figure 4), W80 & BR 30 (Figure 5),W120 & BR 45 (Figure 5)

1. Open the banjo bolt on top of the engine mounted secondary fuel filter 1-2 turns (Bleed Point A). With firm stroke on the fuel lift pump priming lever, bleed until fuel free of air bubbles flows from this point. Stop priming and tighten the bolt.

2. On the fuel injection pump body is a 5/16 bleed screw (Bleed Point B). This may be mounted on a manifold with a pressure switch. Open this one or two turns (do not remove it) and with the priming lever bleed until fuel free of air bubbles flows. Stop priming and tighten the bleed screw.

3. On the control cover of the injection pump (Bleed Point C) is a 5/16 bleed screw. Open this screw one to two turns and proceed as in Step 2. (Note: Bypass this bleed point on the W30 injection

W50 injection pump only. Open the 5/16 bleed screw (Bleed Point D) on the injector line banjo bolt one or two turns and, with, the throttle full open and the engine stop lever in the run position, crank the engine over with the starter until clear fuel free of air flows from this point. Stop cranking and tighten this Bleed screw.

With a 5/8 wrench loosen one to two turns the injector line attaching nuts at the base of each injector and, with the throttle full open and the engine stop control in the run position, crank the engine over with the starter until fuel spurts by the nuts and injector line at each injector. Stop cranking and tighten the nut and proceed with normal starting procedures.

WESTERBEKE W13, 4.4KW, W21, 7.7KW, W27, 11.1KW, W33, 12.5KW (Figure 6)

These units are self-bleeding.

1. Turn the ignition to the ON position and wait 15-20 seconds.

2. Start the engine following normal starting procedures.

WESTERBEKE W58 & WTO 20 (Figure 7)

1. Open the bleed screw on the top inboard side of the engine-mounted secondary fuel filter one to two turns using a l0mm box wrench (Bleed Point A). This fuel filter is equipped with a hand-operated priming pump. With the palm of your hand:, pump this primer until fuel free of air flows from this point. Stop pumping and tighten the bleed screw.

2. With bleed screw A tightened, pump the hand primer several more times. This primes the injection pump which is self-bleeding. The injection pump incorporates a feed pump which keep the fuel system primed when the engine is running; thus, no external lift pump is required.

3. Loosen the four injector line attaching nuts at the base of each injector (Bleed Point B) one to two turns with a 16mm open end wrench. Place the throttle in the full open position and crank the engine over with the starter until fuel spurts by the nut and injector lines. Stop cranking and tighten each of the four nuts and proceed with normal starting procedure. "

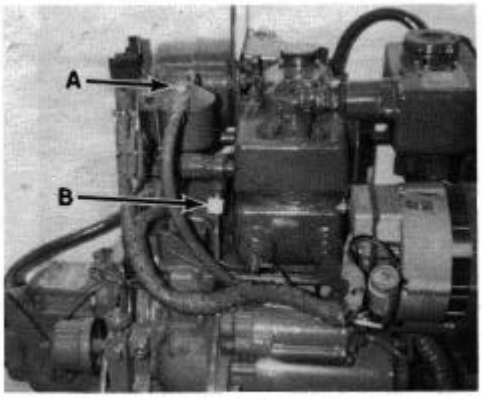


Figure 1

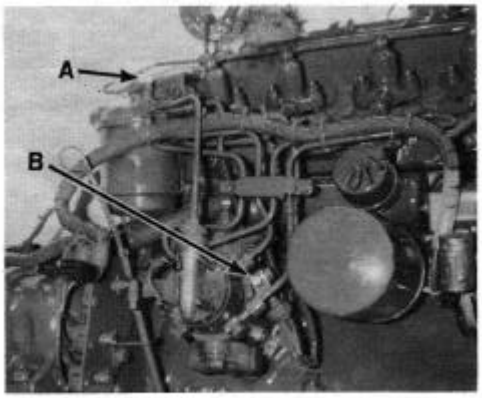


Figure 2

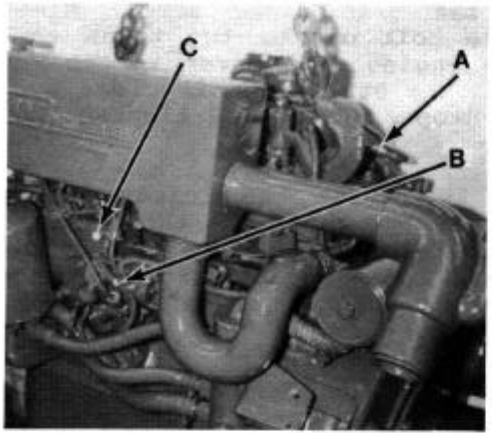


Figure 3

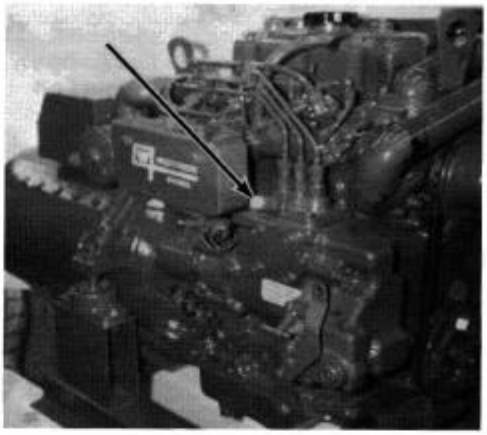


Figure 6

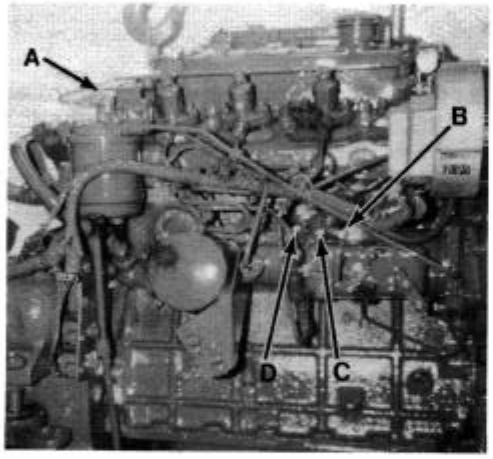


Figure 4

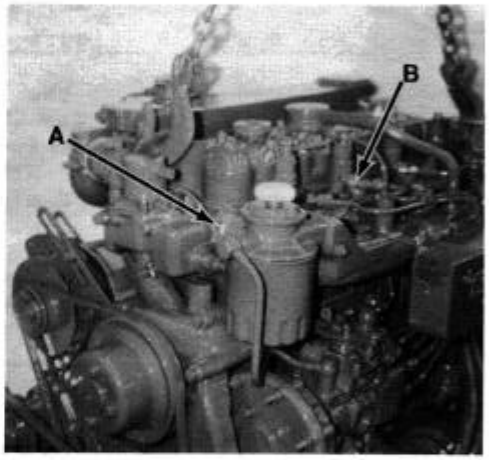


Figure 7

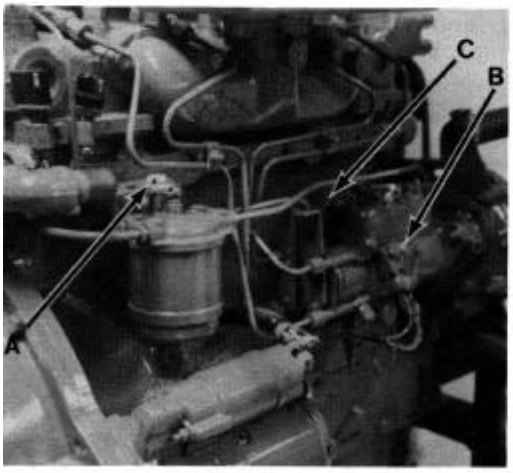
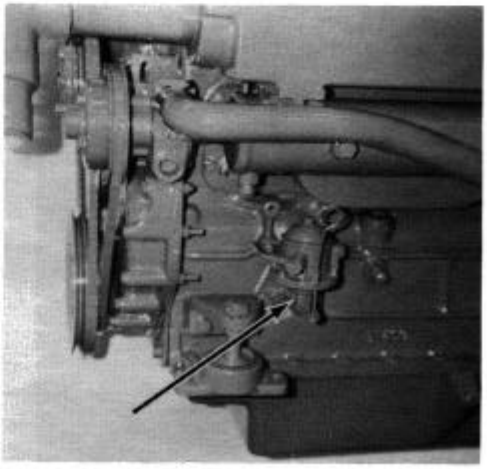


Figure 5



Typical Mechanical Fuel Lift Pump

PREPARATION FOR STARTING

1. Check water level in expansion tank. It should be lh to 2 in. below the top of the tank when cold.

2. Check the engine sump oil level.

.

3. Check the transmission fluid level.

4. See that there is fuel in the tank and the fuel shut-off is open.

5. Check to see that the starting battery is fully charged, all electrical connections are properly made, all circuits in order and turn on the power at the battery disconnect.

6. Check the seacock and ensure that it is open.

STARTING THE ENGINE (COLD)

Most Westerbeke marine diesel engines are equipped with a cold starting aid to ease in the starting of your engine when cold.

1. Check to see that the "stop" lever (if installed) is in the "run" position.

2. Place the throttle in the fully open position.

3. Press the "Preheat" button in and hold for 15 to 20 seconds.

4. While holding the "Preheat" button in, turn the key switch to the "ON" or "Run" position. This activates the panel gauges, lights and fuel solenoid or electric fuel pump if so equipped. Continue to turn the key switch to the "Start" position and hold for no more than 20 seconds. Some units may be equipped with a pushbutton start rather that the key switch and in these cases the electric system is activated by fuel pressure.

5. If the engine fails to start in 20 seconds, release start switch and preheat for an additional 15 to 20 seconds, then repeat step 4.

6. As soon as the engine starts, release the start switch and the preheat button and return the throttle to the "idle" position immediately.

CAUTION: Do not crank the engine more than 20 seconds when trying to start. Allow a rest period of at least twice the cranking period between the start cycles. Starter damage may occur by overworking the starter motor and the backfilling of the exhaust system is possible.

STARTING THE ENGINE (WARM)

If the engine is warm and has only been stopped for a short time, place the throttle in the partially open position and engage the starter as above, eliminating the preheat step.

NOTE: Always be sure that the starter pinion has stopped revolving before again re-engaging the starter; otherwise, the flywheel ring gear or starter pinion may be damaged.

Ensure that the electrical connection to the cold starting aid is correct .

Extended use of the cold starting aid beyond the time periods stated should be avoided to prevent damage to the aid.

NEVER under any circumstances use or allow anyone to use ether to start your engine. If your engine will not start, then have a qualified Westerbeke marine mechanic check your engine.

WHEN ENGINE STARTS

1. Check for normal oil pressure immediately upon engine starting. Do not continue to run engine if oil pressure is not present within 15 seconds of starting the engine.

2. Check Sea Water Flow. Look for water at exhaust outlet. Do this without delay.

3. Recheck Crankcase Oil. After the engine has run 3 or 4 minutes, subsequent to an oil change or new installation, stop the engine and check the crankcase oil level. This is important as it may be necessary to add oil to compensate for the oil that is required tote fill he engine's internal oil passages and oil filter. Add oil as necessary. Check oil level each day of operation.

4. Recheck Transmission Fluid level. (This applies only subsequent to a fluid change or new installation.) In such a case, stop the engine after running for several minutes at 800 RPM with one shift into forward and one into reverse, then add fluid as necessary. Check fluid level each day of operation.

5. Recheck Expansion Tank Water Level, if engine is fresh water cooled. (This applies after cooling system has been drained or filled for the first time.) Stop engine after it has reached operating temperature of 175'F and add water to within one inch of top of tank.

WARNING: The system is pressurized when overheated, and the pressure must be released gradually if the filler cap is to be removed. It is advisable to protect the hands against escaping steam and turn the cap slowly counter-clockwise until the resistance of the safety stops is felt. Leave the cap in this position until all pressure is released. Press the cap downward against the spring to clear the safety stops and continue turning until it can be lifted off.

6. Warm-up Instructions. As soon as possible, get the boat underway, but at reduced speed, until water temperature gauge indicates 130-150^{0}F. If necessary, engine can be warmed up with the transmission in neutral at 1000 RPM. Warming up with the transmission in neutral takes longer and tends to overheat the transmission.

Do not be alarmed if temperature gauges show a high reading following a sudden stop after engine has been operating at full load. This is caused by the release of residual heat from the heavy metal masses near the combustion chamber. Prevention for this is to run engine at idle for a short period before stopping it. High temperature reading after a stop does not necessarily signal alarm against restarting. If there is no functional difficulty, temperatures will quickly return to normal when engine is operating.

TEN MUST RULES

IMPORTANT

..for your safety and your engine's dependability.

IMPORTANT

ALWAYS -

1. Keep this Manual handy and read it whenever:;.in doubt.
2. Use only filtered fuel oil and check lube oil level daily.
3. Check cooling water temperature frequently to make sure it is 190^0 or less.
4. Close all drain cocks and refill with water before starting out.
5. Investigate any oil leaks immediately.

NEVER -

6. Race the engine in neutral.
7. Run the engine unless the gauge shows proper oil pressure.
8. Break the fuel pump seals.
9. Use cotton waste or fluffy cloth for cleaning or store fuel in a galvanized container.
10. Subject the engine to prolonged overloading or continue to run it if black smoke comes from the exhaust.

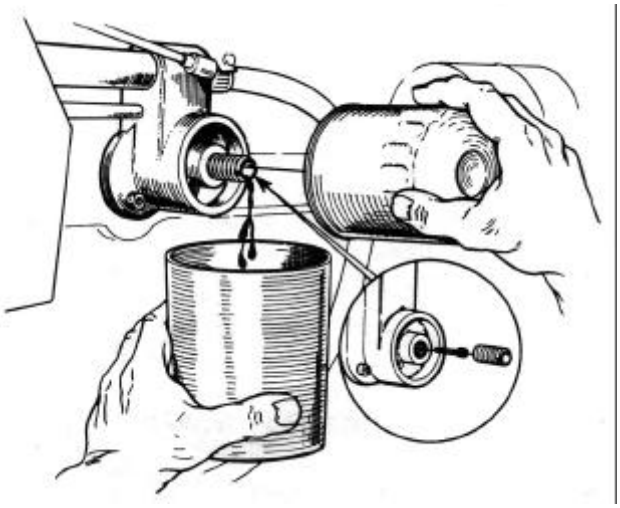
MAINTENANCE

PERIODIC ATTENTION:„

After you have taken delivery of your engine, it is important that you make the following checks right after the first fifty hours of its operation.

Note: Transmissions generally require fluid change after the first 25 to 30 hours of operation. Refer to the Transmission Section of this manual for details.

FIFTY HOUR CHECKOUT (INITIAL)
Do the following:



1. Re-torque the cylinder head bolts.
2. Re-torque the rocker bracket nuts and adjust valve rocker clearance.
3. Check and adjust, if necessary, the forward drum assembly and the reverse band on manual SAO and SA-1 transmissions.
4. Change engine lubricating oil and oil filter.
5. Check for fuel and lubricating oil leaks. Correct if necessary.
6. Check cooling system for leaks and inspect water level.
7. Check for loose fittings, clamps, connections, nuts, bolts, vee belt tensions, etc. Pay particular attention to loose engine mounts engine mount fittings. These could cause misalignment.

DAILY CHECKOUT
Do the following:

1. Check the sea water strainer, if one has been installed.
2. Check water level in cooling system.
3. Check lubricating oil level in sump. Fill to highest mark on dipstick.
4. Turn down grease cup on water pump, if used, one full turn.
5. Check fluid level in transmission. Fill to highest mark on dipstick with proper fluid.

SEASONAL CHECK-OUT (MORE OFTEN IF POSSIBLE)
Do the following:

1. Check generator, alternator and sea water pump "V" belts for proper tension.
2. Check water level in battery.
3. Change oil in sump. See Note.
4. Replace lubricating oil filter, Figure 2. See Note.
5. Fill sump with diesel lubricating oil to highest mark on dipstick. Refer to Specification page for proper quantity of oil. Do Not Overfill. See Note.

CAUTION: The use of different brands of lubricating oils during oil changes has been known to cause extensive oil sludging and may in many instances cause complete oil starvation.

6. Start engine and run for 3 or 4 minutes. Stop engine and check ,.oil filter gasket for leaks. Check oil sump level. This is important as it may be necessary to add oil to compensate for the oil that is required to fill the engine's internal oil passages and oil filter. Add oil as necessary. See Note.

IMPORTANT NOTE

IT IS MANDATORY THAT THE CHECKS 3, 4, 5 AND 6 BE ATTENDED TO WHEN TOTAL OPERATING TIME REACHES 150 HOURS. IN SOME INSTANCES, THIS TOTAL IS REACHED BEFORE END OF SEASON.

7. lean Air Filter if supplied. (Most models have an air silencer that does not require cleaning.) The time period for replacing the air filter depends on operating conditions. therefore, under extremely dirty conditions, the seasonal frequency should be increased. The correct time periods for replacing the filter will greatly assist in reducing bore wear, thereby extending the life of the engine.
8. Check engine for loose bolts, nuts, etc.
9. Check sea water pump for leaks.
10. Wash primary filter bowl and screen. If filter bowl contains water or sediment, filter bowl and secondary oil fuel filter need be cleaned more frequently.
11. Replace secondary fuel filter element.
12 Replace air filter.
13. Change the fluid in the transmission. Refer to the Transmission Section of this manual for details.

END OF SEASON SERVICE

1. Drain fresh water cooling system by removing the surge tank pressure cap and opening all water system petcocks.
2. Remove zinc rod (usually located in heat exchanger) and see if it needs replacing. The zinc rod will take care of any electrolysis that may occur between dissimilar metals. Insert new zinc if necessary.
3. Fill fresh water cooling system with antifreeze of a reputable make. (Refer to Cold Weather Precautions.)
4. Start engine. When temperature gauge indicates 175'F, shut engine down and drain lubricating oil. Remove and replace filter. Fill sump with High Detergent Lubricating Oil.
5. Carefully seal air intake opening with waterproofed adhesive tape or some other suitable medium.
6. Seal the exhaust outlet at the most accessible location as close to the engine as possible.
7. Remove injectors and spray oil into cylinders.
8. Replace injectors with new sealing washer under each injector. Turn engine slowly over compression.
9. Top off fuel tank completely so that no air space remains, thereby preventing water formation by condensation.
10. Leave fuel system full of fuel.
11. Change fuel filters before putting the engine back in service.
12. Wipe engine with a coat of oil or grease.
13. Change fluid in transmission. Refer to the Transmission Section of this manual for details.

14. Disconnect battery and store in fully charged condition. Before storing the battery, the battery terminals and cable connectors should be treated to prevent corrosion. Recharge battery every 30 days.
15. Check alignment.

LUBRICATING OILS

Lubricating oils are available for Westerbeke Diesel engines which offer an improved standard of performance to meet the requirements of modern operating conditions such as sustained high speeds and temperatures.

These oils meet the requirements of the U. S. Ordnance Specifications MIL-L-2104B (API Service CC). Any other oils which also conform to these specifications, but are not listed here, are, of course, also suitable.

		S.A.E. DESIGNATION		
COMPANY	BRAND	$0^0/45^0$F	$45^0/80^0$F	OVER 80^0F
American Oil Co.	American Supermil Motor Oil	10W	20W/20	30
BP Canada Ltd.	BP Vanellus	10W	20W/20	30
	BP Vanellus	10W/30	10W/3010W/	30
Chevron Oil Co.	RPM DELO Multi service oil	10W	20W/20	30
Cities Service Oil Co.	CITGO Extra Range	10W	20W/20	30
Continental Oil Co.	CONOCO TRACON OIL	10W	20W/20	30
Gulf Oil Corporation	Gulflube Motor Oil X.H.D.	10W	20W/20	30
Mobil Oil Company	Delvac 1200 Series	1210	1220	1230
Shell Oil Company	Shell Rotella T Oil	10W	20W/20	30
Sun Oil Company	Subfleet MIL-B	10W	20W/20	30
Texaco, Inc.	Ursa Oil Extra Duty	10W	20W/20	30

ENGINE OVERHAUL

The following sections contain detailed information relating to the proper operation characteristics of the major components and systems of the engine. Included are disassembly, rework and reassembly instructions for the guidance of suitably equipped and staffed marine engine service and rebuilding facilities. The necessary procedures should be undertaken only by such facilities.

Additional operating characteristics are included in the Operation Section of this manual.

Any replacements should be made only with genuine Westerbeke parts..

GENERAL SPECIFICATIONS

MODEL,--MARINE - GENERATOR	W13 4.4KW	W21 7.7KW	W27 11.1KW	W33 12.5KW
TYPE	4 Cycle, Water Cooled, Vertical Overhead Valve Type Diesel Engine			
NUMBER OF CYLINDERS	2	3	4	4
BORE	70mm	73mm	73mm	78mm
STROKE	78mm	78mm	78mm	78mm
TOTAL DISPLACEMENT (LITRE)	0.600	0.979	1.305	1.490
MAXIMUM HORSEPOWER @3600 RPM	13.5	21	29	33
LUBE OIL CAPACITY	2.5 litre	3.0 litre	4.0 litre	4.5 litre
COMPRESSION RATIO	23:1			
FIRING ORDER	1-2	1-3-2	1-3-4-2	1-3-4-2
COMBUSTION CHAMBER	Swirl Chamber Type			
DIRECTION OF ROTATION	Counter-Clockwise viewed from flywheel			
INCLINATION	Continuous 15^0 Temporary 20^0 (not to exceed 20 minutes)			
FUEL	Diesel Fuel Oil			
FUEL INJECTION PUMP	Bosch M Type			
NOZZLE	Throttle Type			
GOVERNOR	Mechanical Centrifugal Type			
LUBRICATING DEVICE	Forced Lubrication by Trochoid Pump			
STARTER MOTOR	12 VDC, 1.6KW			
ALTERNATOR	12VDC, 50 amp.			
REGULATOR	IC Built into Alternator			
START AID	Glow Plug - Sheathed Type			

TABLE OF TIGHTENING TORQUE		kg- m	lb ft.
Cylinder head bolt	(M10) W21, W27, W33	7-8	50.7-57.9
	(M12) W21	11-12	79.6-86.8
	W13, W27	12-13	86.8-94.0
	(M14) W33	15-16	108.5-115.7
Crank pulley nut	W13	15-20	108.5-144.6
	W21, W27, W33	20-25	108.5-180.8
Main bearing cap bolt	W21, W27, W33	5.0-5.5	36.-43.4
Connecting rod cap nut	W13, W21, W27	3.2-3.5	23.1-25.3
Connecting rod cap bolt	W33	11.5-12.5	83.2-90.4
Flywheel bolt		11.5-12.5	83.2-90.4
Oil pan drain plug		5-6	36.2-43.4
Oil filter		1.1-1.3	8.0-9.4
Delivery valve holder (injection pump)		4-5	28.9-36.2
Holder mounting bolt, nozzle		1.5-2.0	10.8-14.5
Holder body and retaining nut, nozzle		6-8	43.4-57.9
Glow plug		1.5-2.0	10.8-14.5
General screw tightening torque	M6	0.7	5.1
	M8	1.7	12.3
	M10	3.5	25.3
	M12	6.4	46.3
	M14	9.5	68.7

			STD. VALUE	REPAIR LIMIT	SERVICE LIMIT
1.	Compression pressure @ 280 RPM		32Kg/cm^2	26Kg/cm^2	32Kg/cm^2
2.	Compression pressure difference between cylinders (maximum)		2.5Kg/cm^2		
3.	Firing Order	W13	1-2		
		W21	1-3-2		
		W27 - W33	1-3-4-2		
4.	Injection Timing - BTDC of compression stroke when started"'-, at smoke set position.				
	Marine Engine		23^0 +/- 1.5^0		
	Generator		19^0 +/- 1.5^0		
5.	Cylinder Head				
	a. Bottom surface distortion		0.05mm/less	0.1mm	
	b. Valve guide ID	W13, W21, W27	6.6 mm		
		W33	8.0		
	c. Valve seat angle		45^0		
	d. Valve seat width		1.3-1.8mm	2.5mm	
	e. Valve seat sinkage				-l mm
6.	Valve Timing				
	a. Intake valve open (BTDC)				
		W13, W21, W27	18^0		
		W33	20^0		
	b. Intake valve close (ABDC)				
		W13, W21, W27	46^0		
		W33	44^0		
	c. Exhaust valve open (BBDC)				
		W13, W21, W27	46^0		
		W33	44^0		
	d. Exhaust valve close (ATDC)				
		W13, W21, W27	18^0		
		W33	80^0		
7.	Valve Clearance (engine cold)		0.25 mm		
8.	Valve				
	a. Valve head diameter (Intake)				
		W13	27.0 mm		
		W21, W27	27.2 mm		
		W33	30.0 mm		

				STD. VALUE	REPAIR LIMIT	SERVICE LIMIT
	b.	Valve head diameter (Exhaust)				
			W13	25.0 mm		
			W21, W27	25.2 mm		
			W33	28.0 mm		
	c.	Overall length	W13	103.0 mm		
			W21, W27	114.5 mm		
			W33	126.0 mm		
	d.	Stem O.D.	W13, W21, W27	6.6 mm		
		.	W33	8.0 mm		
	e.	Clearance between stem & guide				
			Intake valve	0.10 mm		
			Exhaust valve	0.15 mm		
	f.	Valve face angle		45^0		
	g.	Valve head thickness (margin)				
			W13, W21, W27	1.0 mm		0.50 mm
			W33	1.5 mm		0.50 mm
9.	Valve Spring					
	a.	Free length	W13, W21,W27	43.0 mm	41.7 mm	
			W33	45.85 mm	44.5 mm	
	b.	Installed load/length	W13	14.0kg+/-0.6/36.0mm		15%
			W21, W27	11.8kg+/-0.6/37.1mm		15%
			W33	13.2kg+/-0.7/41.8mm		15%
	c.	Squareness		1.5^0		3.0^0
10.	Rocker Arm					
	a.	Rocker arm hole I.D.		18.9 mm		
	b.	Rocker arm to shaft clearance		0.05 mm	-0.2 mm	
11.	Cylinder Block					
	Camshaft Hole I.D.					
	Front (bush)			45.0mm		
	Center			44.0mm		
	Rear	W13, W21, W27		34.0mm		
		W33		39.0mm		

	STD. VALUE	REPAIR LIMIT	SERVICE LIMIT
Cylinder bore			
W13	70.0 mm	+0.2 mm	+0.95 mm
W21, W27	73.0 mm	+0.2 mm	+0.95 mm
W33	78.0 mm	+0.2 mm	+1.20 mm
Cylinder bore oversize finish tolerance	0 to 0.03 mm for each oversize tolerance		
Taper of cylinder bore	0.01 mm or less		

12. Piston

Type	Solid type	
Material	Aluminum alloy	
O.D. (skirt end)	W13	70.0 mm
	W21, W27	73.0 mm
	W33	78.0 mm
Piston to cylinder clearance		
	W13, W21, W27	0.25, 0.50, 0.75 mm
	W33	0.25, 0.50, 0.75, 1.00 mm

13. Piston Pin

Type	W13, W21, W27	Semi-floating type	
	W33	Full-floating type	
O.D.	W13, W21, W27	19.0 mm	
	W33	23.0mm	
Piston to piston clearance			0.08mm
Piston to connecting rod clearance (Press-fit load:			
	W13, W21, W27	500 to 1500kg)	
	W33		0.10mm

14 Piston Ring

Number of rings	
Compression rings	3 (No. 1: chrome plated barrel type and semi-keystone type except W13. No. 2 & No. 3: tapered ring)
Oil ring	1 (Chrome plated: with coil expander - except W13)

			STD. VALUE	REPAIR LIMIT	SERVICE LIMIT
Ring width					
Compression rings					
W13			2. 5 mm		
W21, W27, W33 - Nos. 2 & 3			2.0 mm		
Oil ring			4.0 mm		
Ring side clearance					
Compression rings		No. 1	0.66-0.11mm		0.3 mm
		No. 2	0.05-0.09mm		0.2 mm
		No. 3	0.04-0.08mm		0.2 mm
Oil ring			0.03-0.07mm		0.2 mm
Ring gap			0.15-0.40mm		1.5 mm
15. Connecting Rod					
Type			Forged I-beam		
Bend and distortion				within 0.15 mm	
Big end thrust clearance			0.1-0.35mm		0.5 mm
16. Connecting Rod Bearing					
Type			Kelmet metal with back metal		
Oil clearance					0.15 mm
Undersize			0.25, 0.50, 0.75 mm		
17. Crankshaft					
Type			Fully counterbalanced		
Bend			0.05 mm		
End play			0.06-0.3mm		
Journal O.D.	W13		59 mm		-0.95 mm
	W21, W27		52mm	-0.15mm	-0.95 mm
	W33		57mm		
Pin O.D.	W13, W21, W27		42mm		
	W33		48mm	-0.15 mm	-0.95 mm

			STD. VALUE	REPAIR LIMIT	SERVICE LIMIT
Undersize finish dimensions					
	Journal	W13	U.S. 0.25	58.695-58.710	mm
			U.S. 0.50	58.445-58.460	mm
			U.S. 0.75	58.195-58.210	mm
		W21, W27	U.S. 0.25	51.735-51.750	mm
			U.S. 0.50	51.485-51.500	mm
			U.S. 0.75	51.235-51.250	mm
		W33	U.S. 0.25	56.695-56.710	mm
			U.S. 0.50	56.445-56.460	mm
			U.S. 0.75	56.195-56.210	mm
	Pin	W13	U.S. 0.25	41.700-41.715	mm
			U.S. 0.50	41.450-41.465	mm
			U.S. 0.75	41.200-41.215	mm
		W21, W27	U.S. 0.25	41.700-41.715	mm
			U.S. 0.50	41.450-41.465	mm
			U.S. 0.75	41.200-41.215	mm
		W33	U.S. 0.25	47.735-47.750	mm
			U.S. 0.50	47.485-47.500	mm
			U.S. 0.75	47.235-47.250	mm

18. Main Bearing

Type	Kelmet metal with back metal (flanged metal for center bearing)	
Oil clearance		0.10nn
Undersize	U.S 0.25, 0.50, 0.75	

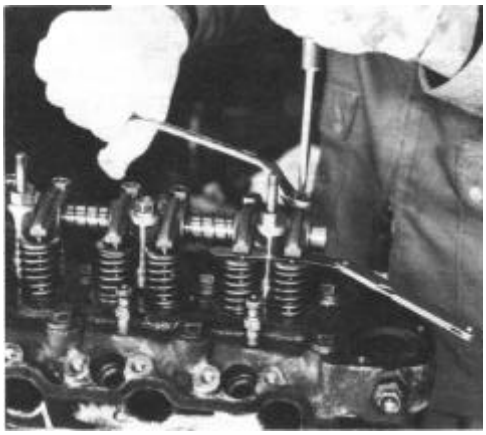
19. Camshaft

Driving method	Gear Drive	
Clearance between journal and cylinder block hole of bushing		0.15 mm
Cam lobe height (for both intake and exhaust valves)	35.76 mm	-1.0 mm
Camshaft bushing (when equipped with front bushing)		
Type	Lead bronze alloy with back metal	

		STD. VALUE	REPAIR LIMIT	SERVICE LIMIT
Oil clearance				0.15mm
20.	Pump Camshaft			
	Driving method	Gear drive		
	Bearing	Front: ball bearing Rear: cylinder block hole		
	Cam lobe height	44 mm		-1.0 mm
21.	Tappet			
	O.D.	23 mm		
	Tappet to cylinder block hole clearance			0.15 mm
22.	Push Rod			
	Bend	Within 0.3mm		
23.	Oil Pump			
	Type	Trochoid type		
	Check valve opening pressure			
	W13	3.5kg/cm2		
	W21	6.0kg/cm2		
	W27, W33	4.0kg/cm2 (@ 500 Pump RPM)		
	Outer rotor to body clearance	0.15-0.20mm 0.3 mm		
	Outer rotor to inner rotor clearance	0.05-0.12mm 0.25 mm		
	Rotor to cover clearance	0.03-0.07mm		
24.	Fuel System			
	a. Fuel supply pump	Electromagnetic type		
	Delivery rate	225 cc or more (15 seconds, 12 VDC)		
	b. Fuel injection pump rate at smoke set (ss)			
	W13	1500 RPM: 26.0 +/- 1.0mm^3/stroke		
	W21	1500 RPM: 28.0 +/- 1.0mm^3/stroke		
	W27	1500 RPM: 27.5 +/- 1.0mm^3/stroke		
	W33	1500 RPM: 30.0 +/- 1.0mm^3/stroke		

		STD. VALUE	REPAIR LIMIT	SERVICE LIMIT
c.	Fuel injection pump rate at start set (MS)			
	W13	150 RPM: 33.5 +/- 5.0mm^3/stroke		
	W21	150 RPM: 37.5 +/- 5.0mm^3/stroke		
	W27	150 RPM: 34.0 +/- 5.0mm^3/stroke		
	W33	150 RPM: 36.0 +/- 7.5mm^3/stroke		
d.	Difference from reference cylinder	2mm^3/rev. cylinder or less e		
e.	Pre-stroke	2.2 +/- 0.1 (within 0.1 for . difference from reference cylinder)		
f.	Timing - see service text			
g.	Nozzle			
	Type	Throttle type		
	Model	ND-DN4 SD 24		
	Injection start pressure	120kg/cm^2 +10 -0 kg/cm^2		
h.	Governor	Centrifugal weight type		
25.	Starter Motor			
	No load terminal voltage	11.5 VDC		
	No load current	90a or less		
	No load speed	3600 RPM or more		
	Brush length	17mm	11.5 mm	
	Spring pressure	1.5 kg	0.7 kg	
	Pinion gap	0.5-2.0 mm		
26.	Alternator			
	Voltage	12 VDC		
	Current	50 amp		
	Rotation (viewed from pulley)	Clockwise		
	Regulator (Internal IC type)	14.4 VDC +/- 0.3 v		
	No load output			
	Terminal voltage	13.5 VDC		
	Current	24 amp		
	Speed	1300 RPM or less		
Load	output			
	Terminal voltage	13.5 VDC		
	Current	50 amp		
	Speed	2500 RPM		
27.	Glow Plug			
	Type	Sheath type - conventional		
	Current	10 amp		
	Resistance	1 - 1.2 ohm		

ADJUSTMENTS



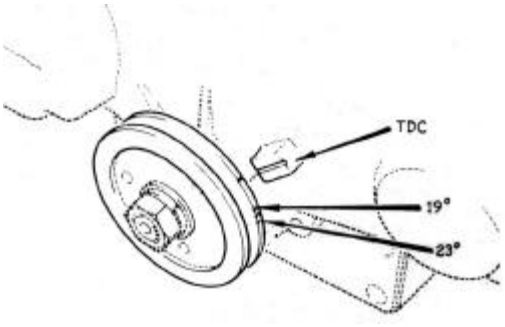
(1) **Adjustment of Valve Clearance**

Pull off the air breather from the rocker cover, and then loosen off rocker cover bolts. Adjust the valve clearance at top dead center of compression stroke (cold) of each cylinder. Prior to the measurement of the valve clearance, re-tighten cylinder head bolts to specified torque. Give care to exact alignment of the timing mark of the gear case with that on the crankshaft pulley; if not, the valve may be hushed up by the piston, depending on the position of the cam lobe.

(2) **Adjustment of Injection Timing**

Incorrect fuel injection timing will result in hard engine starting and poor engine performance. Adjust the injection timing in the following manner. First remove No. 1 delivery valve holder. Pull off the delivery valve and spring. Install the delivery valve holder only. Subsequently turn the crankshaft, and find an instant when the fuel flowing out of the outlet port of the holder stops. This instant is the injection timing to be obtained. The injection timing differs with engine specifications; be sure to adjust the timing to specification. (Align with the timing mark on the crankshaft pulley.)

Marine engines 230 BTDC
Generator sets 190 BTDC

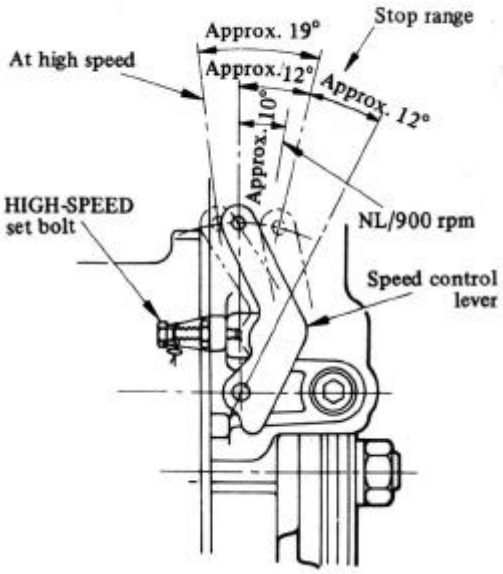


Angles between timing marks on the crankshaft pulley are illustrated at right.

When the specified injection timing cannot be obtained, adjust by increasing or decreasing the thickness of the injection pump mounting shim. Changing the shim thickness by 0.l mm changes the injection timing by about 1 degree. If this adjustment cannot be made, adjust by the following method without removing the delivery valve and spring. First disconnect No. 1 injection pipe at the nozzle holder side. Then, using a wrench on the crankshaft pulley nut, gradually turn the nut. The instant the fuel in the forward end of the pipe expands is the injection timing. In this case, the injection timing takes place about 1 degree later than the specified.

Adjustments of High Speed (No Load)

Set the engine to a no-load high speed with the HIGH SPEED set bolt. This speed is set by the factory and should not require adjustment. Should adjustment be required after the accuracy of the tachometer has been verified by mechanical means, loosen the HIGH SPEED sit bolt lock nut and turn the set bolt clockwise to lessen no load speed and counter-clockwise to increase no load speed. Re-tighten the lock nut. Consult model specifications for no load high speed setting.



CONSTRUCTION AND SERVICING OF CYLINDER HEAD

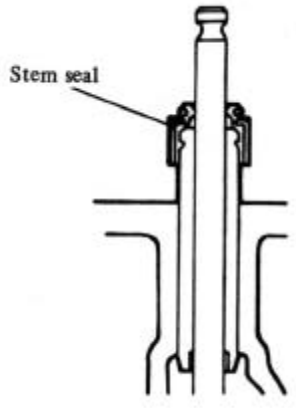
CONSTRUCTION

1. **Cylinder Head**

The cylinder head is an overhead valve head produced from a high rigidity special cast iron having an excellent cool-effect. Intake end exhaust ports are of a cross-flow type which insures good 'intake and exhaust efficiency. The combustion chamber is a swirl chamber produced from heat resisting steel and is press-fitted in the cylinder head. This chamber, therefore, requires no disassembly. Intake and exhaust valve guides are made of sintered alloy and are commonly usable in either ports. The valve guides are oil-impregnated to provide greater wear resistance.

2. **Cylinder Head Gasket**

The cylinder head gasket is an alloy-asbestos gasket and is fitted with stainless steel sheet grommets around the bores to provide greater heat and pressure resistance. Both sides of the gasket are coated with a sealant and therefore does not require further application of the sealant. New gaskets are made of carbon called "grafoil".



3. **Valve and Valve Spring**

The intake valve is a heat-resisting steel valve having a large diameter head to provide great intake efficiency. The exhaust valve has a special heat-resisting steel head welded to the valve stem so the valve may have adequate resistance to high temperatures.

Valve springs are made of spring steel and are closed at the upper end. They carry a red enamel mark on the upper part (rocker arm side) for easy identification of the upper and lower ends. The retainer and retainer lock are commonly usable with intake and exhaust valves. In the top of the valve guide, a valve stem seal is fitted to prevent downward seepage of oil along the valve stem.

4. **Rocker Arm, Rocker Shaft and Stay**

Rocker arms are make of special cast iron and are gas-carburized on the entire surface. Each arm has an oil hole in the upper part. The rocker arm shaft is produced from a carbon steel tube, the interior of which forms a lubricant passage. The rocker arm area of the shaft is induction-hardened. The rocker shaft stay is an aluminum alloy casting. The rear stay is provided with an oil hole into which the oil from the head flows for lubrication of the rocker shaft.

5. **Crankcase Ventilating System**

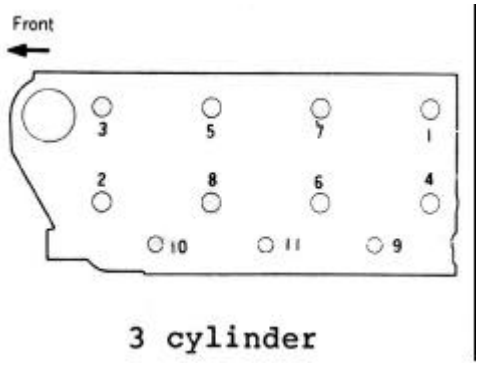
The crankcase ventilating system leads blow-by fumes from the cylinder block up into the rocker without discharging the fumes out into the atmosphere. The fumes flow into the cover through tappet holes and push rod holes and further into the cylinders for recombustion through the air breather hose (rubber hose) and inlet pipe.

SERVICING THE CYLINDER HEAD

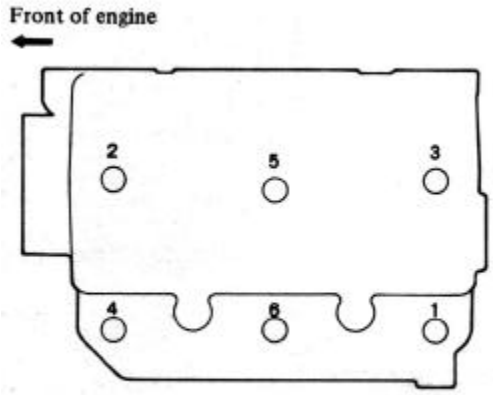
DISASSEMBLY

Disconnect the air breather hose.
Disconnect the fuel injection pipes.
Remove the air intake silencer, intake manifold and exhaust manifold.
Remove the rocker cover.
Remove the rocker arms and rocker shaft assembly.
Remove the push rods.
Remove the cylinder head assembly by loosening the head bolts in the sequence shown in the figure.

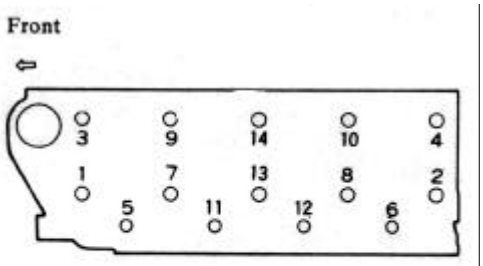
Remove the cylinder head gasket.
Partly disassemble the cylinder head assembly in the following manner. Remove the nozzle holder. Remove the glow plug lead wire, then remove the glow plug. Using a valve lifter, compress the spring. Remove the retainer lock, and then remove the retainer, spring and valve. Place the removed valves and other parts in order by each cylinder. Remove the thermostat housing and thermostat.



3 cylinder

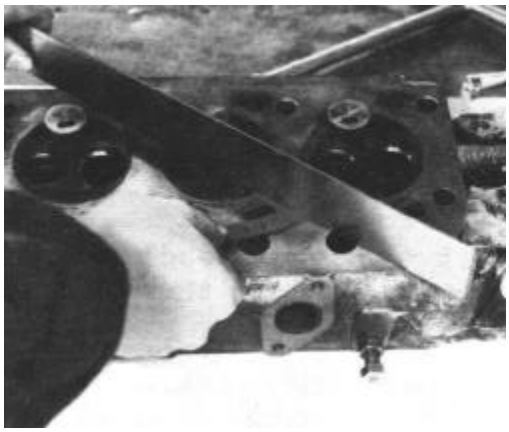


2 cylinder



4 cylinder

INSPECTION



1. **Cylinder Head**

Prior to washing the cylinder head, check for cracks, damage and water leaks.

Check to see if the oil passageway feeding lube oil to the rocker shaft is clean.

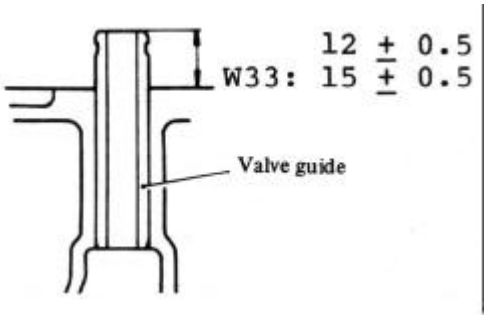
Using a straight edge and a feeler gauge, check the lower surface of cylinder head for distortion as shown.

2. **Valve Guide**

Check a valve stem to guide clearance. If the clearance exceeds the service limit, replace the valve guide and valve.

To remove the existing guide, press it upward using a driver from under the cylinder head.

To install a new guide, press it in to the illustrated size using a suitable driver from above the head.

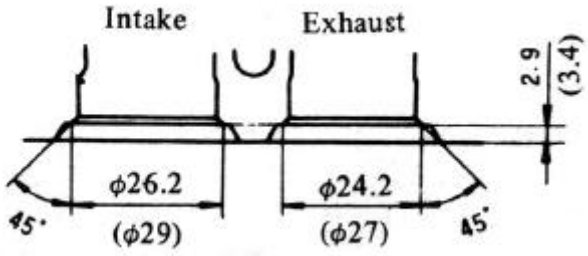


After installing the valve guide, check the guide to stem clearance. If the clearance is smaller than the correct to the standard size by using a suitable reamer.

3. **Valve Seat**

Check the valve seat for damage and incorrect contact. Correct as shown if defective. After correction, lap the valve to the seat using a lapping compound.

n case of excessive valve seat sinkage over the service limit, replace the cylinder head.



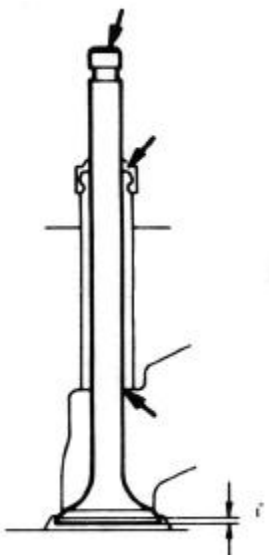
Check the valve seat sinkage by measuring the installed length of the spring. When measuring the size up to the top of the valve spring retainer, include retainer thickness (at the collar) of 2.0mm+/-0.25mm for the W21 and W33 and 1.7mm+0.03,-0mm for the W27.

4. **Valve**

Check the valve face and stem for excessive wear, damage and deformation. Correct or replace if defective.

If valve head thickness has decreased over the service limit, replace the valve.

Check the tip of the valve stem for wear and pitting. Correct if defective. Replace if the tip is worn over the service limit.



5. **Valve Spring**

Check for cracks and damage.

Measure the free length and load of the spring.

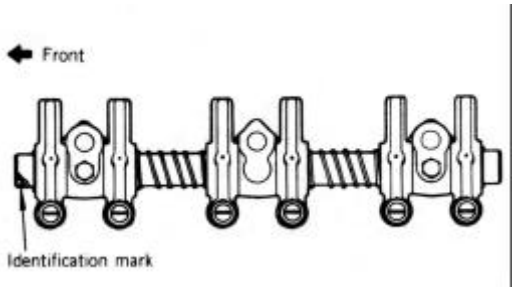
Replace if the spring is deteriorated.

Check the squareness of the spring. Replace if it tilts too much.

6. **Rocker Arm and Rocker Shaft**

Check the rocker arm face for wear and damage. Replace the rocker arm if excessively worn or damaged. Also check the adjusting screw. If its push rod contact surface is worn or damaged, replace.

Measure the rocker arm I.D. and shaft O.D. In the event of excessive clearance, replace the rocker arm.



REASSEMBLY

Reassembly can be done by reversing the order or disassembly. reassembling keep in mind the following items.

1. Partial Assembly of Cylinder Head Assembly

Press in the valve guide to the specified height. (For installation, see 2. Valve Guide Inspection.)

Install the valve stem seal properly#in the valve guide.

Apply oil to the valve stem and insert the valve stem into the valve guide. Install the spring, retainer and retainer lock in order of mention.

To assemble the rocker arms and shaft, first place the rocker shaft in such a manner that the identification mark (3 mm hole) at the front end of the shaft faces toward the front of engine. Install the frontmost rocker arm and retain it with a snap ring. Then, install the assembly in the cylinder head. When tightening the front and rear stays, be sure to install bolt seats and washers.

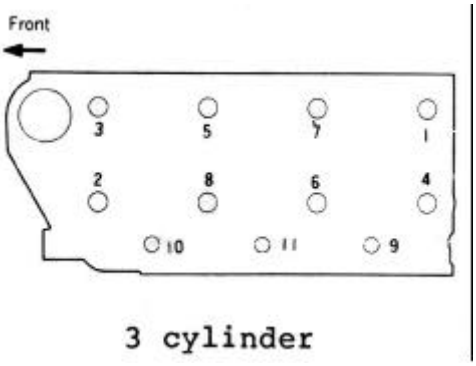
Tighten the glow plugs to their specified torque.

Install the nozzle holders and tighten bolts temporarily. After installing the injection lines, tighten the bolts evenly to the specified torque. Do not reuse injector sealing washers.

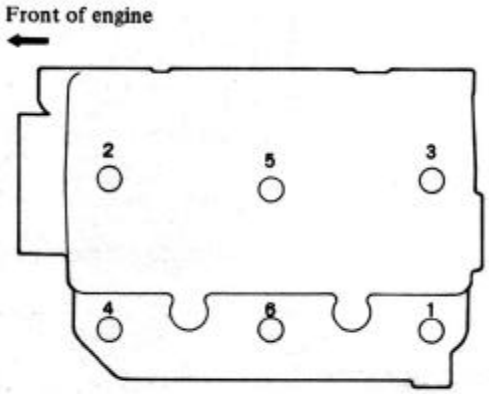
Install the glow plug lead wire. (The glow plug, being a taper sealed type, does not require a gasket.)

2. The cylinder head gasket has already been coated with sealant and therefore must not be further sealed.

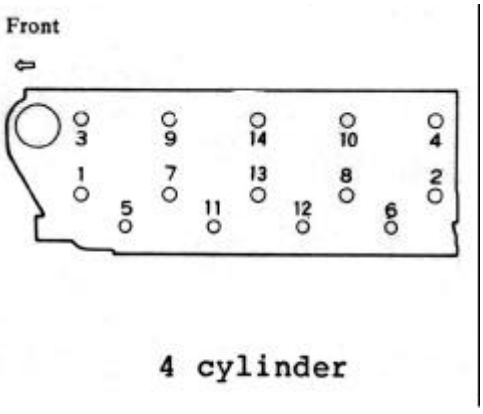
3. Tighten cylinder head bolts to the specified torque in the illustrated sequence in two to three stages, first slightly and finally firmly to specification.



3 cylinder



2 cylinder



4 cylinder

4. Replace gaskets and packings with new ones. Apply sealant to specified sealing points.

5. Adjust valve clearance. For adjustment procedures, see "Adjustment of Valve Clearance" under ADJUSTMENTS.

CONSTRUCTION AND SERVICING OF CYLINDER BLOCK ASSEMBLY

1. Cylinder Block

The cylinder block is a special cast iron casting and is of a full jacket type formed integral with cylinder liners.

Main bearings are metal-backed copper sintered alloy (kelmet) bearings and are coated with lead and tin alloy plating on the journal surface and flash-plated over the entire bearing surface to insure good run-in. Crankshaft thrust is received by the flanged bearing. On the front bearing area of the camshaft, a metal-backed special copper alloy rolled bushing is installed. (In engines produced in the initial period of production, this bushing is not used.) .

2. Crankshaft

The crankshaft is a precision-forging of carbon steel and is supported on bearings to provide great ridigity. Journals, pins and oil seal areas have been induction-hardened to improve wear resistance and durability.

3. Flywheel and Ring Gear

The flywheel is produced from iron casting.

The ring gear is produced from a carbon steel and shrinkage-fitted on the flywheel; the gear teeth are induction-hardened.

4. Piston, Pin and Piston Ring

Aluminum alloy pistons are used for the purpose of reducing engine weight and decreasing bearing load during high-speed operation. The piston is cam-ground and tapered so it may become nearly round to obtain the best contact with the cylinder wall during normal operation.

The piston pin is a hollow, carburized forging, and retains the connecting rod small end to the piston by a semi-floating system. The piston pin is pressed in the rod. The W33 uses a snap ring to retain the pin.

Piston rings are made of a special cast iron. Each piston is provided with three compression rings and one oil ring. The outside surface of the top and oil rings are hard chrome-plated. The engine uses a semi-keystone type top ring and an oil ring with coil expander.

5. Connecting Rod

The connecting rod is an I-beam section rod with a horizontal split-type big end to provide greater rigidity.

The connecting rod bearing is a metal-backed special copper alloy bearing and is flash-plated.

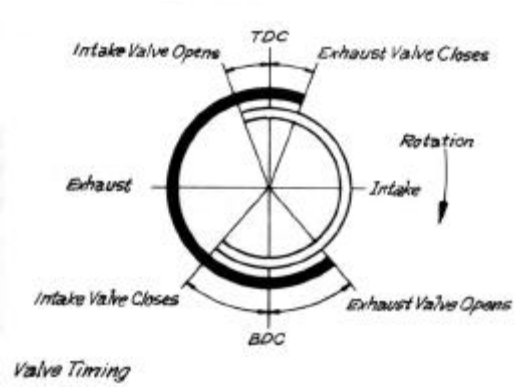
6. Front Plate and Gear Case

The front plate is a steel plate and positioned by a dowel pin located in the upper part of the camshaft gear and a dowel pin in the lower part of the injection pump gear. It is attached by bolts to the cylinder block. On the left end rear surface, the high-pressure pump gear housing is installed together with the gear case.

The gear case is an aluminum casting and is attached on the front end of the cylinder block through the front plate. The case houses the injection pump front bearing and related parts of the governor and further serves as a camshaft and idler gear thrust surface.

7. **Camshaft and Timing Gear**

The camshaft is a high carbon steel forging. The cam surface and journals are induction-hardened to improve wear resistance. The shaft is supported on three bearings. Each journal is supported in a bore made in the cylinder block and is lubricated by a forced lubrication system. A camshaft journal has a slot to intermittently lubricate the rocker arms through the cylinder head.



Valve Timing

Further, the shaft has an oil escape hole at the rear end to let excess oil return to the oil pan.

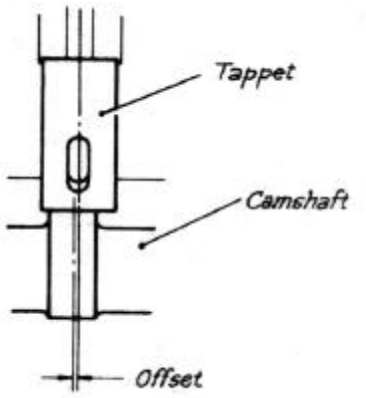
Timing gears are helical gears which have been finished by shaving and crowning to provide a greater durability and to reduce gear noise.

The valve timing is as shown in the specification section.

8. **Lubricating Oil Pump Gear**

The lubricating oil pump gear is mounted on the left side of the engine's front gear case. This also serves as the drive gear for the injection pump camshaft. When the oil pump is mounted, it is driven by the rotation of the injection pump cam by means of an Oldham's coupling.

9. **Tappet and Push Rod**



The tappet is a tubular tappet which has .been chill-hardened at the bottom and gas-carburized at low temperature over the entire surface to provide a great wear resistance. The tappet is offset from the cam center to prevent uneven wear of the tappet bottom.

The push rod is produced from bar steel; both ends of the rod are flame hardened.

10. **Fuel Injection Pump Cam**

The pump camshaft is produced from high carbon steel. Its cam surfaces are induction-hardened to provide great wear resistance.

The front end of the shaft supported on a ball bearing is connected with the governor shaft. The rear end is provided with an Oldham's coupling groove for connecting with the oil pump drive shaft.

11. **Oil Pan**

The oil pan is made of steel and is equipped with a drain hose assembly attached where normally the oil drain plug would be found.

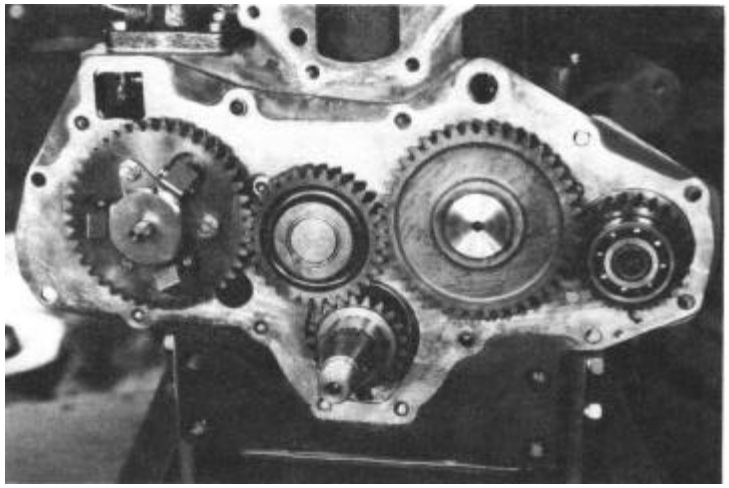
SERVICING

Disassembly

For removal of the cylinder head and related parts, refer to "Cylinder Head".
For the removal of the water pump and electrical equipment, refer to their respective items.

Pull off the push rod, then pull out the tappet upward..
Remove the fuel filter.
Loosen the crankshaft pulley nut, then take out the pulley and washer.
With flywheel bolts loosened, remove the flywheel.
Remove the rear plate and the rear oil seal case.
Place the engine upside down, then remove the oil pan and the oil screen.
Remove the injection pump gear bearing housing. Remove the gear case. Remove the inspection window cover located at the right front (beside the injection pump) of the cylinder block, the stopper spring and tie rod from the control rack of the pump prior to removal of the gear case.

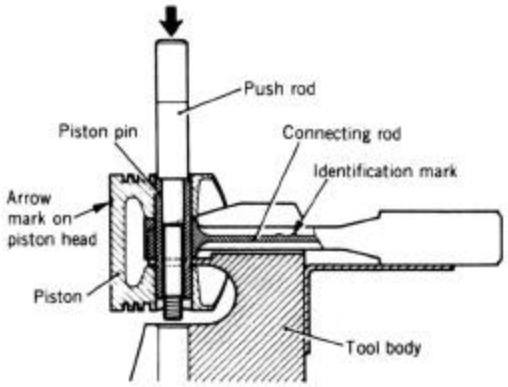
CAUTION: PRIOR TO REMOVING THE GEAR CASE, BE SURE TO SEPARATE THE INJECTION PUMP RACK AND TIE ROD. THE FRONT PLATE IS BOLTED TO THE CYLINDER BLOCK FROM INSIDE THE GEAR CASE; THEREFORE BE CAREFUL NOT TO DRIVE OUT THE GEAR CASE TOGETHER WITH THE FRONT PLATE.



Remove the fuel injection pump.
Remove governor weight bolts, then remove the weight.
Remove the pump camshaft bolt.
Remove the oil filter and the oil pump assembly, and then draw out the pump camshaft.
Remove the gears, and then remove the front plate. Only for the W33 engines, use the following procedure to remove the front plate: pull out the crankshaft front bearing with a puller and, then, remove the front plate. To remove the front plate without drawing the front bearing out, remove five bearing caps to let the crankshaft float, draw the idle gear out and remove the other gears.
Draw out the camshaft. Prior to removing the camshaft, remove the pushrod, tappet and tachometer drive unit.

Remove the connecting rod big end bolt nuts (bolts on the W33), then remove the bearing cap. Push tie piston and connecting rod assembly upward out of the cylinder block. (Mark each piston with its respective cylinder prior to its removal.) Arrange the removed parts by each cylinder. When pushing out the piston and connecting rod assembly, use a wooden block on the mating surface of cap so as not to impair the metal.

When disassembling the piston and connecting rod assembly, use the following procedure. Keep the disassembled parts by each set. Be careful to prevent confusion, especially for each set of the piston and pin.



W13, W21 and W27: Set the piston and connecting rod assembly on the special tool (Piston Pin Setting Tool) body. Insert the push rod of tool into the piston pin hole and then press the pin out.

CAUTION: DO NOT ATTEMPT TO REMOVE A PISTON PIN BY STRIKING IT WITH A HAMMER. A STUCK PISTON PIN WHICH REQUIRES EXCESSIVE PULLING FORCE SHOULD BE REPLACED.

CAUTION: DO NOT PLACE A LOAD OF MORE THAN 3,000kg ON THE PISTON SETTING TOOL.

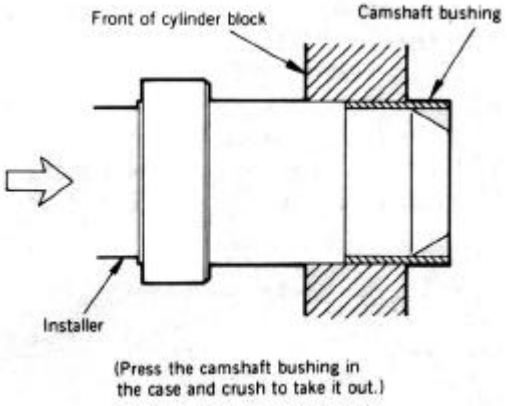
Remove the main bearing caps. Arrange the removed caps and bearings by each cylinder. Before removing the cap, measure the crankshaft end play. (See paragraph 4 in INSPECTION below.)

Remove the crankshaft.

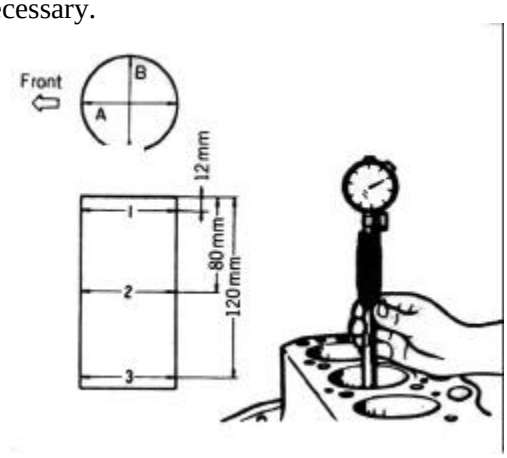
INSPECTION

1. **Cylinder block**

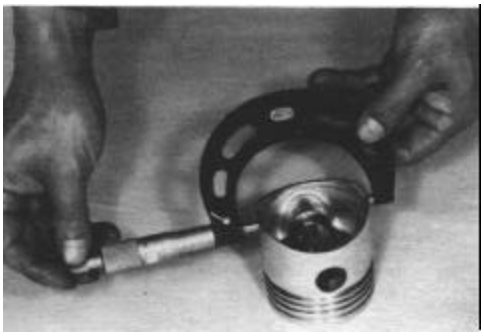
Check the cylinder block for cracks and damage. Replace if defective. Check the camshaft front journal bushing for wear and damage. If defective, replace using a special tool.



Check the water jacket for scales and rust. Clean if necessary.
Check the cylinder wall for scratches, damage and wear. If defective, correct the cylinder by honing or reboring. Measure the cylinder bore size at three levels in the directions of A and B.
In case of slight wear of cylinder bore and when only the piston rings require replacement, check the upper part of the cylinder for groove wear. If there is groove wear, remove it by reaming or, when necessary, by honing.



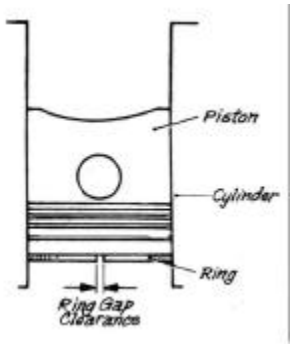
2. **Piston, Pin and Rings**



Check the piston for seizure, nicks and wear. Replace if defective.
Measure the piston O.D. If the piston is excessively worn, replace. Also check the clearance between the piston and the cylinder wall. The piston O.D. should be measured at the lower end of the skirt, across the thrust faces.

Measure the piston ring side clearance. Replace the ring if necessary. In the case of a taper ring (No. 1), measure the side clearance between the lower side of the ring and the ring groove with the ring outside surface held flush with the piston outside surface.

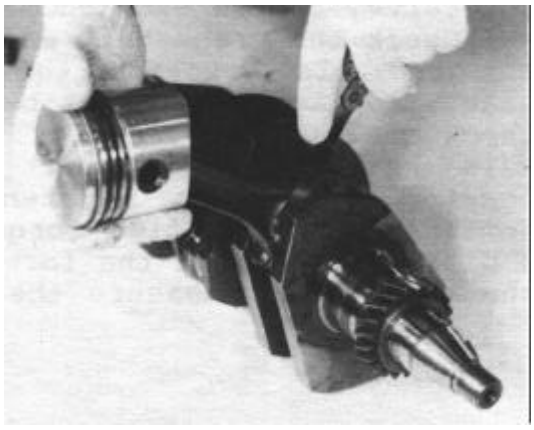
Measure the piston ring gap clearance. Replace the ring if the gap is too large. To measure, insert the ring into the least worn place of the cylinder bore (skirt) using a piston as shown, and measure the gap with a feeler gauge.
When the clearance between the piston pin and piston or connecting rod small end bushing for the W33 engine is excessive, replace the piston and pin assembly or the connecting rod.



3. **Connecting Rod**

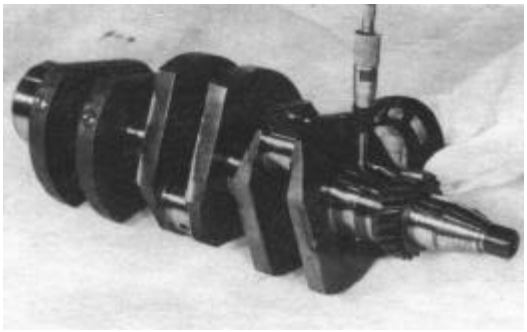
Using a connecting rod aligner, check bend and distortion of the rod.
If excessive.

Measure the connecting rod thrust clearance with the rod assembled on the crankshaft. If the clearance is excessive, replace the rod assembly.

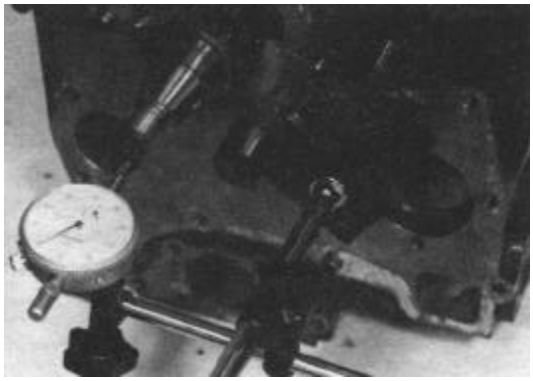


4. **Crankshaft**

Measure crankshaft bend. If excessive, replace the crankshaft.
Check the journals and pins for damage, seizure and other faults. If the journals and pins are seriously worn, or damaged, correct them to undersize. In this case, it is necessary to replace the main bearings and connecting rod bearings to the same undersize parts. When correcting the crankshaft journals and pins undersize, finish each end to R2.5 mm.

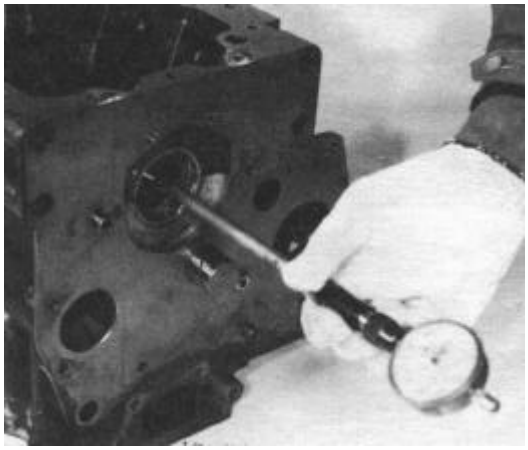


Check the crankshaft end play. If the end play exceeds the specified value, replace the thrust bearing. To check the end play, first install the main bearings, crankshaft and main bearing caps then tighten the cap bolts to the specified torque. Using a dial indicator on the forward end of the crankshaft, measure the end play.

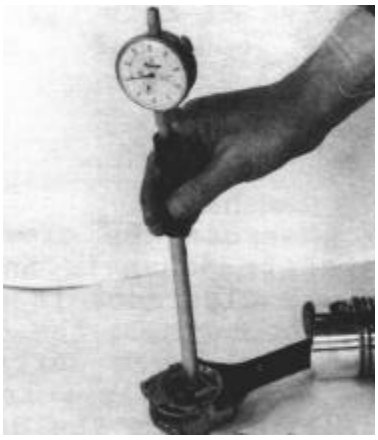


5. **Main Bearings and Connecting Rod Bearings**

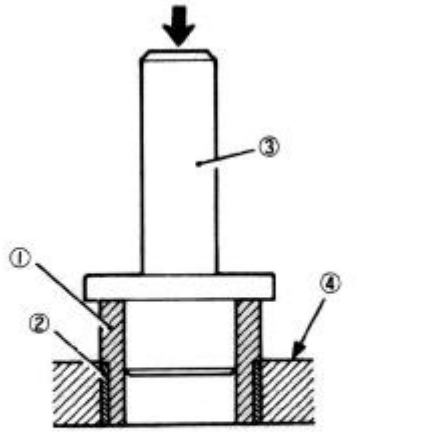
Check the bearing surface for spalling, melt, seizure and incorrect contact. If defective, replace.



Install the main bearings and connecting rod bearings to the cylinder block and connecting rod respectively. Tighten bolts to specification and measure the bearing I.D. Subsequently measure the crankshaft journal and pin O.D. to obtain an oil clearance. (A plasti-gauge may be used.) In case of excessive oil clearance, replace the bearing. If the standard clearance cannot be obtained even after replacement of the bearing, grind the crankshaft undersize and install bearings of the same size.

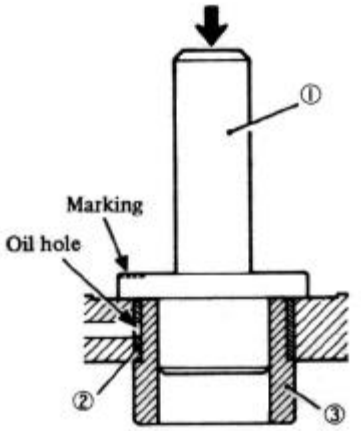


W13 and W33: To remove the main bearing, install the guide ring to the installer body as illustrated. Remove the main bearing from the bearing housing by pushing from the front toward the rear. Also remove the main bearing from the rear of the crankcase by pushing inward from the rear after the removal of the oil seal.



1. Guide Ring
2. Main Bearing
3. Bearing Installer
4. Bearing housing (front) or crankcase (rear)

Removing the Main Bearing



1. Bearing installer
2. Main bearing
3. Guide ring

Installing the Main Bearing

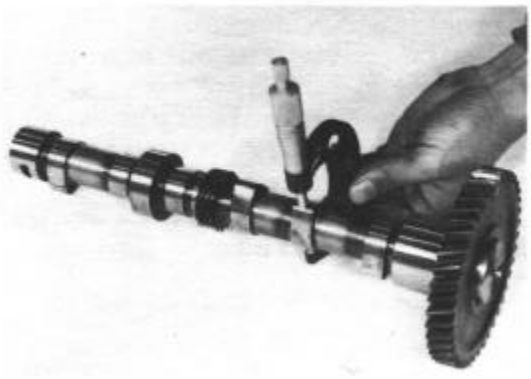
To install the main bearing, assemble the main bearing to be installed, to the installer body and guide ring as illustrated, and the press in the bearing in the same direction of removal. Insure any oil supply holes are properly aligned with oil galley holes in the block. In W33 engines, main bearings are pressed in 1 mm deep below the crankcase surface. Be careful not to confuse them with bearings for W13 engines.

6. **Timing Gears and Injection Pump Gear**

Check each gear for incorrect tooth contact, wear and damage. Replace if defective. Also check the Oldham's coupling groove at the rear end of the injection pump camshaft for faults.

7. **Camshaft**

Measure the clearance between the camshaft journals and cylinder block. If the clearance is excessive, replace the camshaft or the cylinder block.
If the cam surface is damaged or the cam lobe is worn over the service limit, replace the camshaft.



8. **Fuel Injection Pump Camshaft**

If the camshaft cam surface is badly worn or damaged, or if the Oldham's coupling is damaged, replace the camshaft.

9. Tappet

Check the bottom of tappets for cracks, spalling and nicks. Replace a tappet if it is seriously defective.
Check the tappet to cylinder block clearance. If the clearance exceeds the specified value, replace the tappet.

10. **Tachometer Drive Unit**

Check the gear and shaft for wear and damage. Also check the 0ring for damage. This unit is generally not used for a mechanical tachometer connection.

REASSEMBLY

CAUTION: CLEAN EACH PART SUFFICIENTLY. CLEAN OIL HOLES, SLIDING SURFACES AND ROTATING PARTS CAREFULLY.

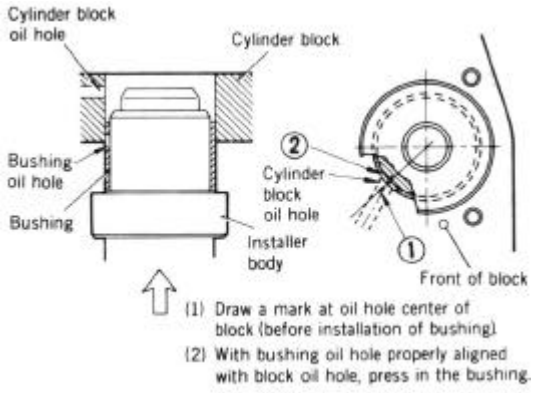
BEFORE ASSEMBLING, APPLY ENGINE OIL TO ALL SLIDING AND ROTATING PARTS SUCH AS BEARINGS AND CYLINDER INNER WALLS.

REPLACE GASKETS, PACKINGS AND OIL SEALS WITH NEW ONES. REUSE OF THESE PARTS IS NOT PERMITTED.

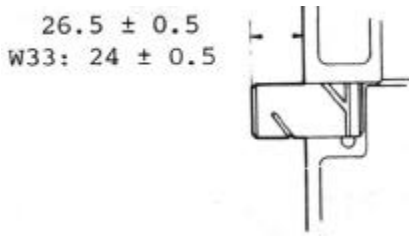
APPLY SEALANT TO GASKETS AND PACKINGS AND TO THE SPECIFIED SEALING POINTS.

OBSERVE TIGHTENING TORQUE AND SEQUENCE WHERE SPECIFIED. IN OTHER PARTS TIGHTEN TO THE GENERAL TORQUE SPECIFICATION FOR THE BOLT SIZE.
CHECK CLEARANCES AND END PLAYS WHEN INSTALLING.

(1) When the camshaft front bushing needs to be pressed in, align the bushing oil hole with the oil hole in the cylinder block as illustrated. To align the oil holes, draw an oil hole mark (with marking ink) on the front end of the cylinder block. After installing the bushing, make certain the oil holes are properly aligned.

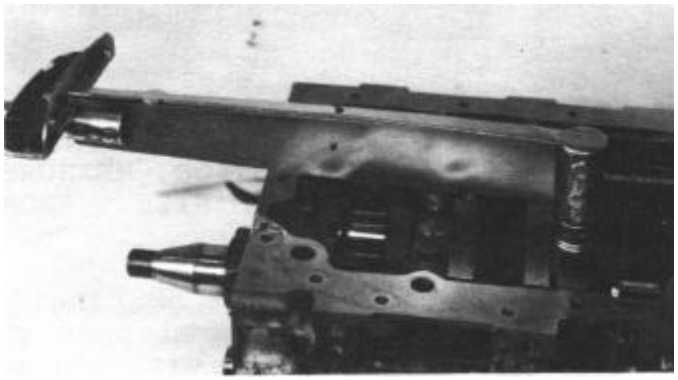


(2) When the idler gear shaft needs to be pressed in, observe the illustrated direction of installation and length of protrusion.



(3) Install the main bearings to the cylinder block and main bearing caps.

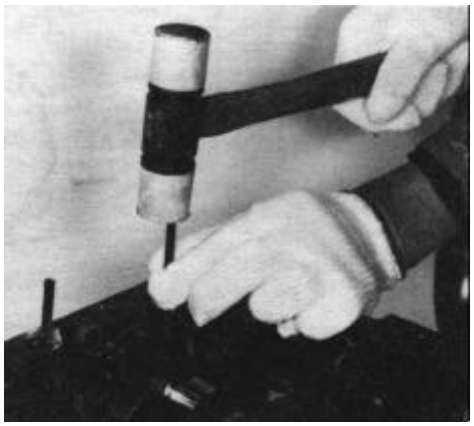
(4) Install the crankshaft. Apply engine oil to journals and pins.

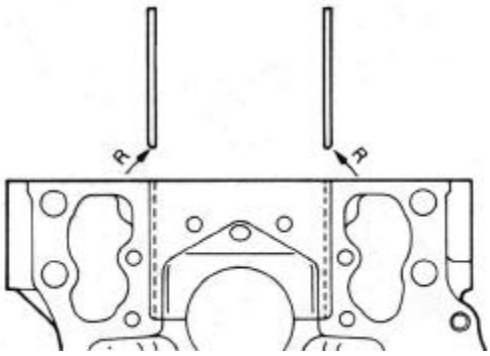


(5) Install the main bearing caps, then tighten cap bolts to the specified torque. Each cap carries an embossed arrow mark and numeral to prevent incorrect installation of the caps. When installing the No. 1 and last caps, apply sealant to the upper surface (cylinder block mating surface). For the W33 with its crankshaft front bearing previously fitted, however, first install bearings temporarily without sealant and, after performing step (12), carry out steps (5) and (7).

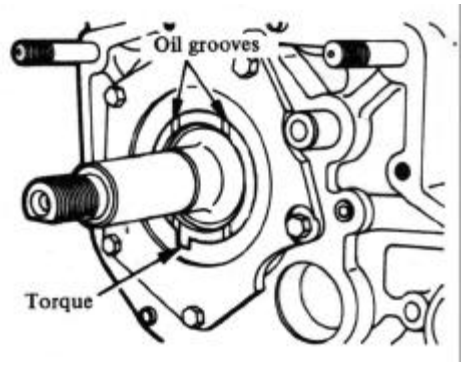
(6) Check the crankshaft end play.

(7) Apply sealant to outside surface of side seals. Press the side seals into the front and rear caps. (Insure the radius ends are installed first and the radius faces towards the outside of the block.) This completes the reassembly of the crankshaft.





On the W13 insert the crankshaft into the crankcase. Apply engine oil to the main bearings and crankshaft journals. Be careful not to damage the main bearings. Install the bearing housing with the tongue of the inside thrust bearing properly fitted in a notch in the bearing housing.

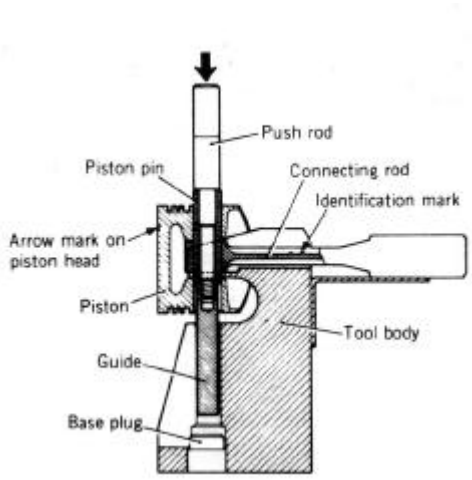


CAUTION: THRUST BEARINGS, INSIDE AND OUTSIDE, ARE IDENTICAL. HOWEVER, BEFORE INSTALLATION, MEASURE THEIR THICKNESS TO CONFIRM THEIR BEING WITHIN THE STANDARD SIZE. FROM THIS THE CRANKSHAFT END PLAY CAN BE SPECIFIED.

Install the outside thrust bearing in the bearing bore in the bearing housing, then install the stopper plate, crankshaft gear and sleeve. Install the stopper plate with the chamfered side directed toward the rear of the engine. Install the crankshaft gear with the stepped side directed toward the rear of the engine. Also install the sleeve with the chamfered square end toward the front of the engine.

(8) Insert the oil seal into the crankshaft rear oil seal case. Install the seal case to the cylinder block. Remember to install the gasket.

(9) The piston and the connecting rod should be assembled as described below using Piston Pin Setting Tool (Special Tool), except the W33. (See below.)



Insert the piston pin into the push rod of the tool, then screw the guide fully into the push rod.

Insert the assembled push rod, piston pin and guide into the piston pin hole from the guide side, and into the small end of the connecting rod. In this case, make certain the front mark(arrow) on the piston head and the identification mark on the connecting rod are on the same side, or face up. Before insertion, apply engine oil sufficiently to the piston pin O.D. and the connecting rod small end I.D.

Set the piston, connecting rod and tool on the tool body. To set, insert the pin and connecting rod assembly and the tool into the tool body with the cut of the guide properly aligned with that of the tool body, and them turn the guide a 90 degree turn. After setting, make certain the small end of the connecting rod rests properly on the tool body. Also check to see if the front mark on the piston head and the connecting rod identification mark face up.

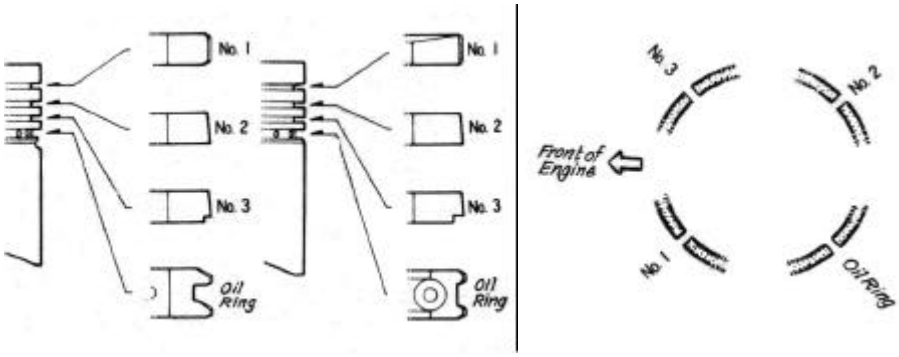
Press in the piston pin with 500 to 1,500 kg pressure. If the piston pin is easily pressed in with a less pressure than the above, or if the pin needs a greater pressure, replace the connecting rod or the piston and piston pin assembly. The piston pin is pressed into the specified position by the guide. After installation, turn the push rod 90 degrees until the guide and. tool body cuts match up, and then detach the piston and connecting rod assembly from the tool body.

CAUTION:
AFTER ASSEMBLING THE PISTON AND CONNECTING ROD, MAKE CERTAIN THE CONNECTING ROD SMALL END IS PROPERLY POSITIONED IN THE CENTER OF THE PISTON PIN. IN THE EVENT OF EXCESSIVE SHIFT OF THE PISTON PIN FROM ITS PROPER POSITION, CORRECT IT. IN THIS CASE, CHECK THE SPECIAL TOOL ALSO.

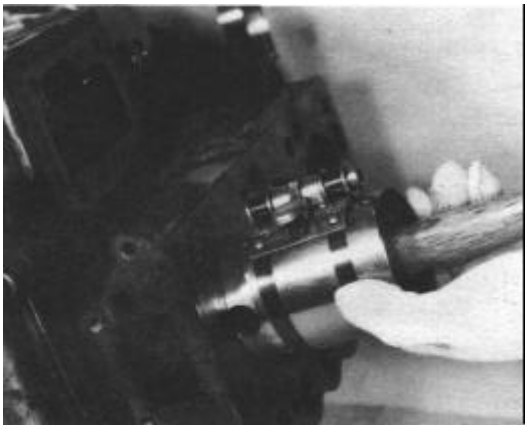
THE PISTON AND PISTON PIN ARE MATCHED PARTS AND THEREFORE MUST NOT BE MIXED WITH OTHER PARTS. PISTONS AND PISTON PINS TO BE USED IN ONE ENGINE MUST BE OF THE SAME SIZE (SAME MARK).

When assembling the piston and connecting rod for the W33 engine, heat the piston at 80 degrees C for about 5 minutes in oil using a piston heater. After installing the piston pin, lock with a snap ring at each end of the pin to prevent it from loosening.

(10) The piston rings differ in shape from one another. Be careful to install them in proper positions and directions as illustrated and with the stamped manufacturer mark and size mark facing up. In case of the oil ring with coil expander, the gap clearance of the ring should be positioned 180 degrees away from that of the expander.



(11) Insert the piston and connecting rod assembly from above into the cylinder block using a ring band. In this case, make certain the piston ring gaps are properly positioned and the piston arrow mark is directed to the front of the engine. After insertion, properly install the connecting rod bearing and tighten rod cap bolts to the specified torque.

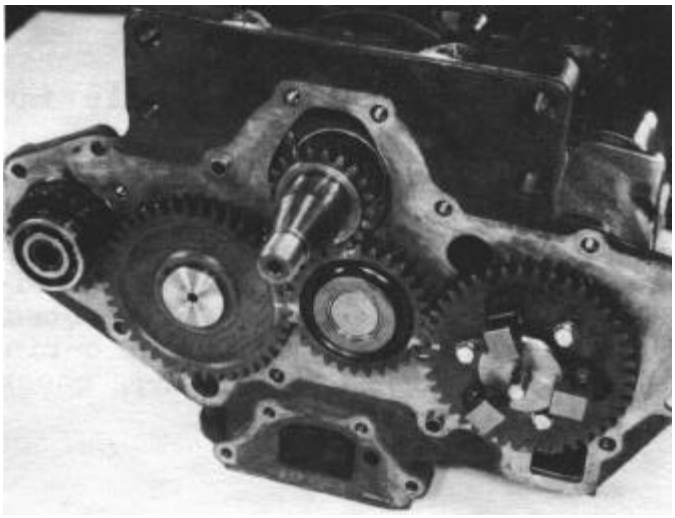


(12) Install the front plate. Remember to install the gasket and dowel pin. For the W33 engine in which its crankshaft front ball bearing has already been press-fitted, raise the crankshaft main bearing cap, and insert the front plate. Then, proceed to the next step.

(13) Turn the crankshaft until No. 1 piston is in top dead center.

(14) Drive the key into the crankshaft and then install the crankshaft gear onto the shaft (except the W33 engine with its crankshaft gear previously installed).

(15) With the idler gear mating mark "1" properly aligned with the crankshaft mating mark "1", install the idler gear onto the idler shaft. When the crankshaft front bearing has already been installed, the mating mark "1" on the front side of the crankshaft is invisible.



Align the idler gear mating mark "1" with a mark line on the side of the gear boss. In this case, after installing the idler gear, press the sealant-coated guide seal into the front and rear main bearing caps. Note position of radius ends - install first and outboard. Tighten to the specified torque.

Insert the camshaft and gear assembly into the cylinder block and align the idler gear mark "2" with the camshaft gear mating mark "2".

Subsequently insert the injection pump camshaft assembly into the cylinder block and align the idler gear mating mark "3" with the pump gear mark "3". Finally install the high-pressure pump drive shaft gear assembly.

(16) Confirm that mating marks on the gears are in proper alignment with each other. For the W33 engine in which its crankshaft front bearing has not been installed, press the bearing inner race in.

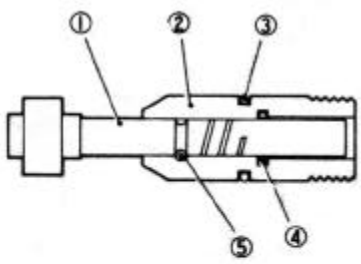
(17) Install the governor weight assembly to the injection pump cam gear.

(18) Install the gear case (after installing governor and related parts) and gasket. When installing the gear case, insert the governor tie rod and tie-rod stopper spring into a hole in the cylinder block.

(19) Insert the crankshaft pulley. Install the washer and nut. Tighten to the specified torque.

(20) Install the combination backplate/flywheel housing. Be sure to install the gasket.

(21) After installing the oil screen, install the oil pan.



(1) Driven gear shaft
(2) Sleeve
(3) O-ring (big)
(4) O-ring (small)
(5) Spring pin

(22) Place the engine upside down. Install the tachometer drive unit while turning the camshaft or the gear shaft. Install the o-ring properly. Apply silicone sealant to the outside surface of the sleeve beforehand. Assemble drive gear unit components in the following manner.

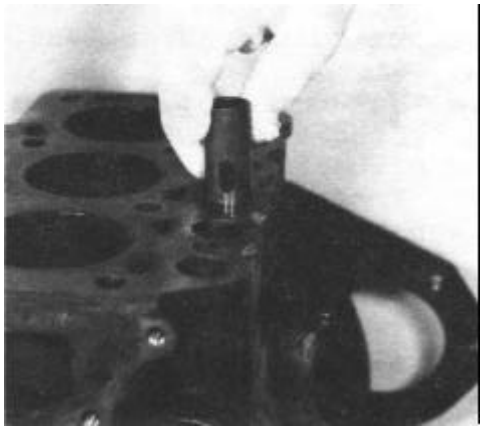
Insert the o-ring properly into the o-ring groove in the drive gear sleeve.

Apply white lube to the outside surface of drive gear shaft (specially to the o-ring area), and then insert the shaft into the sleeve.

Keep the gear unit and sleeve in position with a spring pin. The spring pin groove must be directed outward in relation to the shaft center. The pin end must not protrude out of the sleeve outside surface.

Install the o-ring in the o-ring groove in the outside surface of the sleeve. After assembling, check to see if the gear shaft rotates smoothly.

(23) Apply oil to the outside surface of tappet, and then insert the tappet into the cylinder block. Insert the push rod properly into the tappet hole. Check to see if tappet lightly moves.

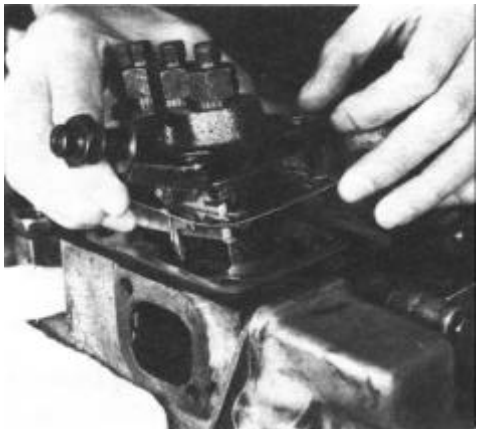


(24) Install the cylinder head assembly. (Refer to "Reassembly of Cylinder Head".)

(25) Install the injection pump assembly. (Refer to FUEL SYSTEM.)

(26) Install the oil pump and oil filter. (Refer to LUBRICATION SYSTEM.) (27) Install the fuel filter.

(28) Install the water pump.



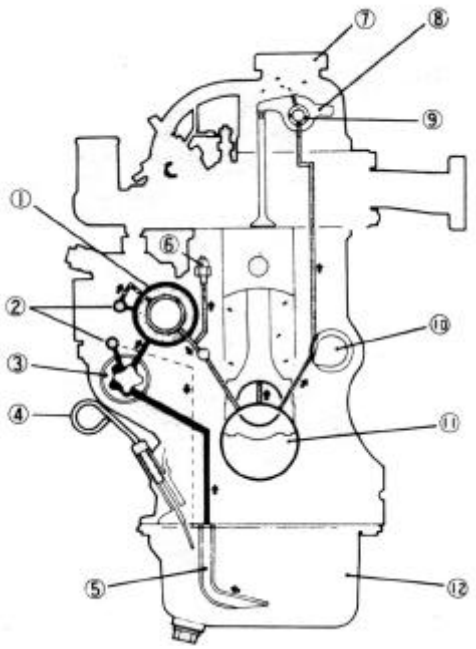
(29) Install flywheel using special bolts and lockwashers. Tighten to specified torque.

(30) Install the starter and alternator. (Refer to ELECTRICAL SYSTEM.)

(31) Install the oil pressure alarm switch and oil pressure gauge sender. Apply a sealant (liquid) to their threads before installing.

LUBRICATION SYSTEM

The lubrication system is a full-force type using a trochoid gear pump fitted with a full-flow oil filter. The oil pump is driven through the Oldham's coupling at the rear end of the fuel injection pump camshaft. The oil from the oil pump flows into the cartridge type oil filter via the relief valve. After being filtered in this filter, the oil passes through the oil gallery hole in the cylinder block, being delivered to each part of the engine.



(1) Oil filter
(2) Check valve
(3) Oil pump
(4) Oil level gauge
(5) Oil screen
(6) Oil pressure switch
(7) Oil filler cap
(8) Rocker arm
(9) Rocker shaft
(10) Camshaft
(11) Crankshaft
(12) Oil pan

Lubricating System

(1) **Oil Filter**

The oil filter is of the spin-on cartridge type that the filter body is integral with the filter element to insure easy handling.

The oil from the oil pump is fed into the filter element. When a pressure difference between before and after the element exceeds 1 kg/cm2 due to excessive clogging of the element, the check valve in the element will open to allow the passage of the oil through the valve to each part of the engine. In this case, as the oil is not filtered, it is important to change the oil regularly. This oil filter does not require cleaning of the interior, but must be replaced after the first 50 hours of operation and thereafter every 100 hours of operation.

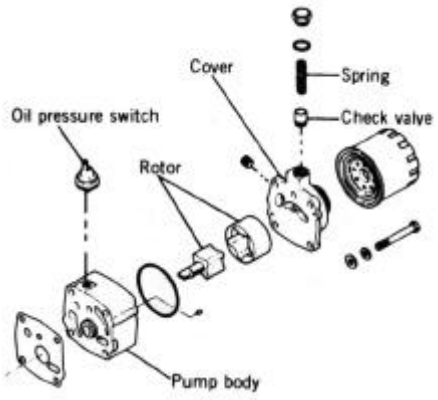
(2). **Oil Pump**

The oil pump is a trochoid gear type and is mounted at the rear of the fuel injection pump on the right-hand side of the cylinder block. The oil pump houses a relief valve, which, when the delivery, pressure exceeds 6 kg/cm2, will open to let the oil flow into the oil pan, thus preventing oil pressure rise.

SERVICING

Disassembly

(1) **0i1 Filter**
If the oil filter is on too tight to remove by hand, remove using a filter wrench (commercially obtainable).



(2) **Oil Pump**
Remove the oil filter.
Remove the pump cover assembly body, o-ring and gasket.

Inspection

(1) Oil Pump

Outer Rotor to Body Clearance: Using a feeler gauge, check an outer rotor to body clearance. If excessive, replace the rotor assembly.

Rotor Clearance: Check an outer rotor to inner rotor clearance using the feeler gauge. If excessive, replace the rotor assembly.

Rotor to Cover Clearance: With the outer rotor inserted in the filter body, measure the clearance between the rotor and straight edge using the feeler gauge. In case of excessive clearance, replace either the rotor or the body.

Pump Body O-ring: Check pump body o-ring for cracks and damage.

REASSEMBLY

(1) Oil Pump

Install the gasket. Install the pump body, o-ring, rotor assembly and cover assembly in order of mention. Apply oil to rotating parts.

(2) Oil Filter

Install the filter and tighten fully by hand. (Reference: Tightening torque 1.1 to 1.3 kg/cm2).
When installing, check to see if the o-ring is properly fitted in the o-ring groove. Apply a small amount of oil to the o-ring.
Start the engine and check for oil leaks and proper pressure.

FUEL SYSTEM

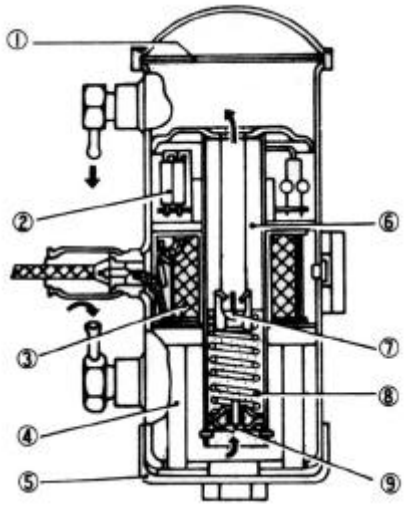
Fuel from the fuel tank is drawn to the engine by means of an engine mounted 12 volt electric fuel pump/filter. It is also filtered by an engine mounted secondary fuel filter and delivered to the fuel injection pump. The injection pump then delivers a portion of the fuel to each injector through the connecting injection lines where the injector sprays the fuel into the combustion chamber for ignition. The remaining fuel carrying heat with it is returned to the tank through the fuel return system.

(1) **Fuel Filter**

The fuel filter encloses the paper element with high filtering efficiency and is provided with one air vent screw.

(2) **Fuel Pump**

This is the electromagnetic (transistor type) fuel pump, which uses reciprocation of a plunger under the control of the transistor circuit. The hollow plunger is actuated by the oscillator which encloses the transistor, diode, resistor, etc. When the transistor is "ON", the exited solenoid coil attracts the plunger downward against the spring, thus allowing fuel to push the outlet valve to open the passage through which the ful is led into the plunger. When the transistor is turned to "OFF", the plunger is pushed upward by the spring, thus the fuel in the plunger is forced to flow out of the outlet port. At the same time, the inlet valve opens to suck fuel into the cavity under the plunger.



(1) Diaphragm
(2) Oscillator
(3) Solenoid coil
(4) Filter
(5) Filter cover
(6) Plunger
(7) Outlet Valve
(8) Spring
(9) Inlet Valve

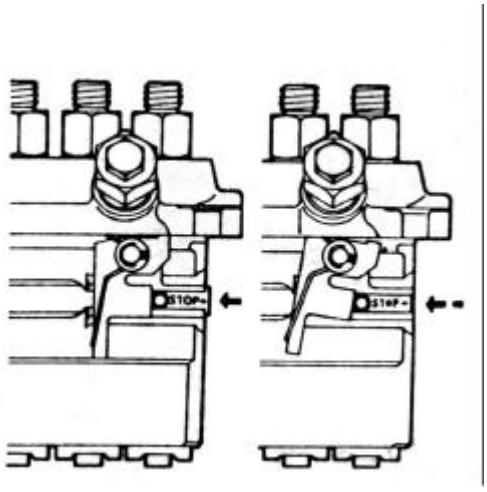
Fuel Pump

(3) **Fuel Injection Pump**

This built-in type cylinder injection pump is mounted on the right hand side of the cylinder block. It consists of the pump elements (plunger assemblies), delivery valves, tappets, smoke set unit, etc. As the pump camshaft rotates, the plungers are moved up and down through the fixed stroke, delivering fuel to each cylinder's injector.

(a) **Fuel Injection Control**

Fuel injection rate is controlled by changing the relative positions of the plunger lead and barrel. The plunger is rotated by the control pinion which is mounted on the plunger barrel. This pinion is in mesh with the plunger lower collar to directly turn the plunger. As the engine runs, the injection pump camshaft rotates to move the control rack through the centrifugal type governor weight, governor sleeve and lever. The control rack slides to turn this pinion. Rightward movement (STOP - mark) of the control rack decreases the fuel injection rate and leftward movement does the reverse.



(b) **Smoke Set Unit**

The smoke set unit restricts the maximum fuel injection rate from the injection pump. The stopper is held by a spring in the illustrated position. This position is the smoke set position. When starting the engine, pull the speed control lever fully toward the maximum speed, and the tie rod (with the stopper spring) moves the control rack, which overcomes the spring force and moves in the direction of the arrow, thus allowing over-injection for easy engine starting.

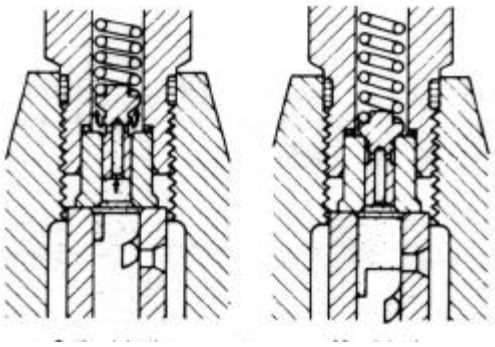
(c) **Inter-Cylinder Injection Control**

Fuel injection control among the cylinders is performed by the adjusting plates having a cam mechanism. These adjusting plates are located on the opposite side of the control rack and as these plates are turned, the plunger barrel is also turned, thus controlling the fuel injection. THESE ADJUSTING PLATES SHOULD NOT BE TAMPERED WITH.

(d) **Delivery Valve Operation**

The delivery valve functions to deliver the fuel to the injection pipe after the fuel pressure has increased sufficiently high and also to prevent "after-drip" from the nozzle.

When the fuel pressure above the plunger has decreased after injection, the delivery valve piston closes the delivery valve seat. At this time the - compressed fuel remaining in the injection pipe drips from the nozzle. To prevent this "after-drip", the delivery valve piston makes a stroke to draw back the fuel before the delivery valve reaches the seat, reducing the fuel pressure in the injection pipe to nearly zero.



(4) **Nozzle and Nozzle Holder**

Fuel from the fuel injection pump flows through the passage in the body of each nozzle holder and is injected from the nozzle into the combustion chamber. Fuel overflowing from the nozzle enters the nozzle holder and returns to the fuel tank through the banjo bolt, banjo and overflow pipe.

SERVICING

Disassembly

(1) Fuel Filter (Secondary)

Remove the retaining nut.

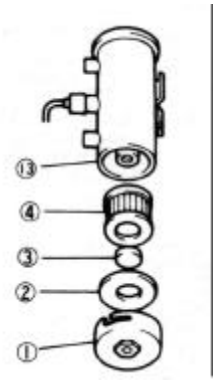
Remove the O-ring and element.

(2) Fuel Pump

The wholly sealed transistor type fuel pump does not require any inspection and adjustment except cleaning of the cover and plunger assembly and changing the filter element.

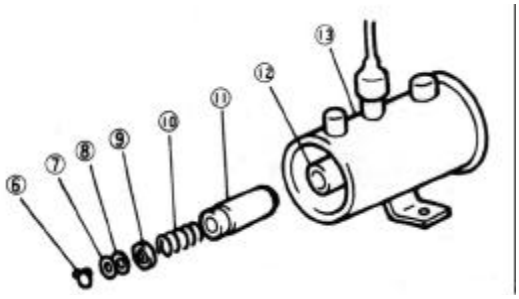
(a) Remove the cover (1) with a 17mm wrench. Remove the cover gasket (2) , magnet (3) and filter(4) from the pump body.

Remove the cover gasket if damaged. Clean the magnet and cover satisfactorily.



Removing Filter

(1) Cover
(2) Cover gasket
(3) Magnet
(4) Filter
(5) Body
(6) Spring retainer
(7) Washer
(8) O-ring
(9) Valve
(10) Plunger spring
(11) Plunger
(12) Plunger tube
(13) Body



Removing Plunger

(b) When removing the plunger, first take out the spring retainer (6) from the plunger tube (12). Then remove the washer (7), 0-ring seal (8), valve (9), plunger spring (10) and plunger (11) from the tube. Wash the removed parts with detergent and blow off dirt with compressed air.

CAUTION: THE TUBE (12) HAS VERY SMALL WALL THICKNESS. BE CAREFUL NOT TO DEFORM THE TUBE DURING REMOVAL OF THE PLUNGER AND THE RELATED PARTS.

CAREFULLY HANDLE THE PLUNGER TO PREVENT IT FROM BEING DENTED OR OTHERWISE DAMAGED.

(3) **Fuel Injection Pump**

(a) Remove the fuel injection pipes.

(b) Remove bolts fastening the injection pump and remove the pump assembly.
Prior to removal of the pump, be sure to remove the pump side cover and disconnect the tie rod and spring from the rack.

(c) Record the thickness and number of pump adjusting shims to facilitate adjustment at the time of reassembly.

(d) Partly disassemble the fuel injection pump using the following procedure:

CAUTION:

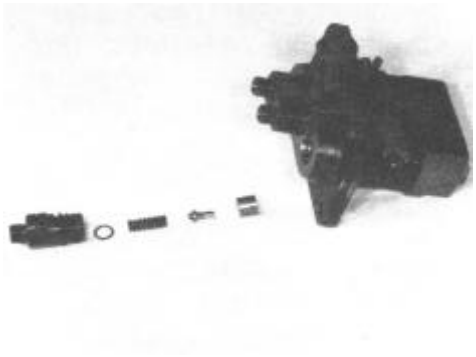
DO NOT ATTEMPT TO DISASSEMBLE THE FUEL INJECTION PUMP UNLESS IT IS NECESSARY. SINCE THE ADJUSTMENT OF AN INJECTION PUMP REQUIRES A PUMP TESTER AND TRAINED PERSONNEL, DISASSEMBLY, REASSEMBLY AND ADJUSTMENT OF A PUMP SHOULD NOT BE PERFORMED IF SUCH A TESTER AND TRAINED PERSONNEL SKILLED HAND ARE NOT AVAILABLE.

BEFORE DISASSEMBLY, PLUG THE FUEL INLET AND OUTLET AND CLEAN THE OUTSIDE.

PREPARE VESSELS FILLED WITH CLEAN DIESEL OIL TO KEEP DISASSEMBLED PARTS IMMERSED IN THE OIL.

KEEP DISASSEMBLED PARTS NEATLY ARRANGED, EXCEPT FOR THOSE TO BE REPLACED, TO PREVENT CONFUSION OF A SET OF PARTS REMOVED FROM A UNIT WITH ANOTHER SET OF PARTS.

(1) Remove the delivery valve holder.



(2) Take out the valve spring, valve and O-ring.

(3) Take out the gasket and valve seat.

(4) Spread the lock plate of the tappet guide pin. Push the tappet slightly in and pull off the guide pin using a pincette. Then remove the tappet.

(5) Remove the spring and upper seat.

(6) Remove the pinion.

(7) Pull out the plunger barrel upward from the pump housing. Assemble the removed plunger barrels and plungers by each cylinder. (Do not mix plungers and barrels of other cylinders.)

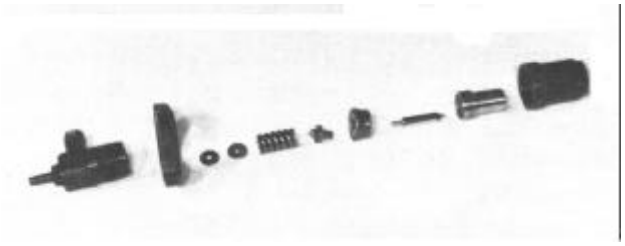
(8) Pull off the split pin. Remove the washer, return spring and smoke set stopper. Draw out the control rack. Remove the Andreich set spring and plate, if equipped, before taking out the control rack.

(4) **Nozzle Holder**

(a) Disconnect the overflow pipe from the nozzle holder upper nipple.

(b) Disconnect the fuel injection pipe from the nozzle holder.

(c) Loosen the nozzle holder attaching bolt and remove the holder assembly.



(d) Partly disassemble the nozzle holder assembly using the following procedure:

(1) Holding the retaining nut in a vise, remove the nozzle holder body with a wrench. When holding in the vise, be sure to use an aluminum or copper plate adapter.

(2) Remove the shim, pressure spring, flange, pressure pin and spacer.

(3) Take out the nozzle from the retainer nut. If the nozzle is hard to remove, remove it by applying light taps with a wooden block. Be careful not to impair the nozzle needle valve.

INSPECTION

(1) **Fuel Filter (Secondary)**

Check the element for clogging and dirtiness. Replace if it is, seriously damaged. Regular element replacement interval is 200 hours. Replace the element more frequently if engine operating condition is severe.

(2) **Fuel Pump**

(a) Filter and Valve

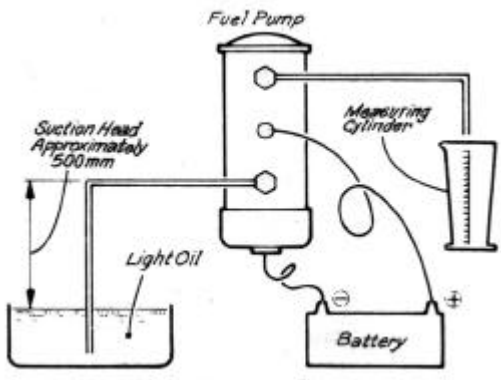
Check the filter element for clogging and dirtiness and the valve plunger and spring for damage and dirtiness. Element replacement interval is same as above.

(b) Checking for Normal Function

Turn the ignition switch to ON and confirm that the fuel pump clicks. If no click is heard, try connecting a 12V battery to the fuel pump directly. If still silent, replace the fuel pump assembly. If the fuel pump clicks when directly connected to the battery, check the fuse, connectors and wiring for defects.

(c) Checking Pump Delivery

Test the pump by connecting a battery and fuel lines as illustrated. Fuel delivery must be 225cc or more every 15 seconds.



(3) **Fuel Injection Pump**

(a) Delivery Valve Seat

Check the contact surface of the delivery valve. To test, assemble the delivery valve and seat and apply a 150kg/cm2 fuel pressure to the assembly. The fuel pressure must not drop within five seconds.

(b) Plunger Barrel

(1) To test the fuel-tightness of the plunger, use a tester. Increase fuel pressure up to 300kg/cm2 and check the time required for fuel pressure to drop from 200kg/cm2 to 100kg/cm2. The time must not be less than six seconds.

(2) Check the plunger for seizure, damage and rust. Also check to see if the plunger slides smoothly when inserted into the barrel. If defective, do not repair it but replace as a matched set with a new set.

(c) Control Rack and Pinion
If the rack and pinion have any worn or damaged teeth, replace.

(d) Tappet
Check the tappet O.D. roller and shaft for wear and damage. If defective, replace.

(4) **Nozzle**

(a) Check the nozzle for incorrect contact and damage. Replace the nozzle as an assembly if defective.

(b) Check the pressure spring for damage.

(5) **Others**
Check the set plates and set springs for wear and damage.

REASSEMBLY

(1) **Fuel Filter (Secondary)**

(a) Install the element and filter cup 0-ring properly in place. Tighten the retaining nut securely. Care should be taken when assembling the fuel filter retaining nut; it is fine threaded and care should be taken not to cross thread.

(b) Install the filter assembly on the support.

(2) **Fuel Pump**

(a) Install the plunger, plunger spring, valve, O-ring and washer in that order into each pump cylinder. Finally install the retainer to prevent them from jumping up out of the pump. (See illustration.)

(b) Install a new filter in the pump body. Fit the magnet and gasket in the cover. Using a 17mm wrench, turn in the cover to the pump body until the cover comes into contact with the stopper, so that the pump body is maintained air-tight.

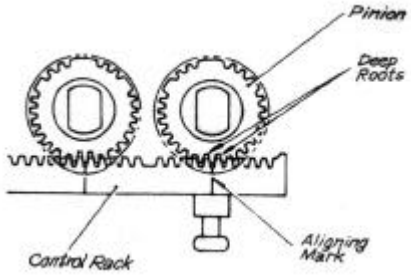
(3) **Partial Reassembly of Fuel Injection Pump Assembly**

(a) Insert the plunger barrel with the dowel pins projecting in the pump housing aligned with the slots in the barrel.

(b) Install the O-ring in the valve holder.

(c) Install the spring seat gasket and the valve assembly in holder. Tighten the holder to the pump housing. In this case, make certain that the 0-ring has been properly installed.

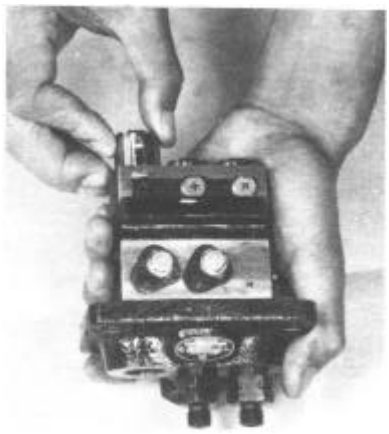
(d) Install the control rack.



(e) Install the pinion with its deep root tooth aligned with an aligning mark on the rack.

(f) Install the spring upper seat and spring.

(g) Assemble the spring lower seat to the plunger. Insert the Mark "L" area of the plunger collar into the control rack side.

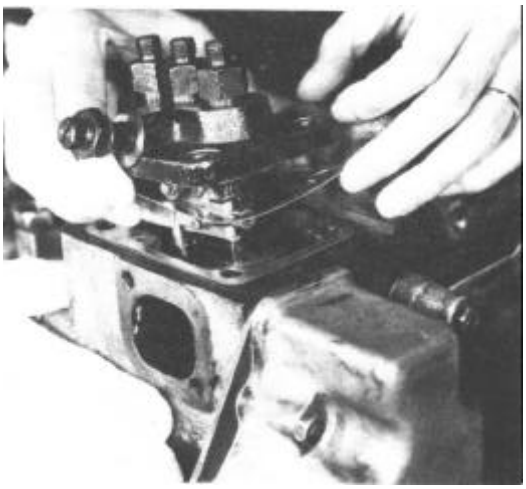


(h) Insert the tappet, using care not to drop the shim. Align the tappet guide hole with the dowel pin hole of the housing and insert the tappet guide pin. Install the lock plate before installing the tappet guide pin and bend the lock plate after inserting the pin.

(i) Install the smoke set stopper, return spring and washer. Then, insert the split pin.

(j) Install the Angreich set plate and spring when equipped.

(4) **Installation and Adjustment of Fuel Injection Pump**



(a) When installing the pump assembly, select and install the adjusting shim. After installing the pump, fit the tie rod from the governor lever to the control rack. Install the tie rod spring in place.

For proper 'selection of shim thickness, temporarily install a shim having the same thickness as before removal when installing the pump assembly. When adjusting fuel injection timing, replace the current shim with the proper one selected from nine kinds of shims, thickness of them ranging from 0.2mm to 1.0mm at intervals of 0.lmm.

(b) Install the tie rod cover.

(c) Connect the fuel feed line and fuel return hose.

(d) Check fuel injection timing. For adjustment procedure, refer to Adjustment in the GENERAL section.

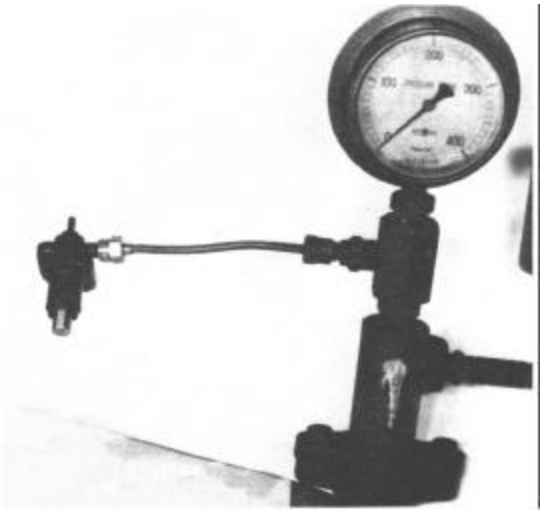
(5) **Partial Reassembly of Nozzle and Nozzle Holder Assembly**

CAUTION:
THOROUGHLY CLEAN ALL PARTS WITH DIESEL OIL. DO NOT WIPE THEM WITH RAGS. WHEN TIGHTENING THE RETAINING NUT ON THE NOZZLE .HOLDER BODY, BE SURE TO TIGHTEN IT TO THE SPECIFIED TORQUE. INSUFFICIENT TORQUE WILL CAUSE POOR COMPRESSION. IF TORQUED EXCESSIVELY, THE NOZZLE NEEDLE WILL DRAG, AFFECTING INJECTION CHARACTERISTIC.

(a) Install the nozzle assembly, spacer and pressure pin in the retaining nut.

(b) Install the shim, spring and flange to the body. Install the retaining nut on the body and tighten to the specified torque.

(6) **Adjustment and Installation of Nozzle Holder Assembly**

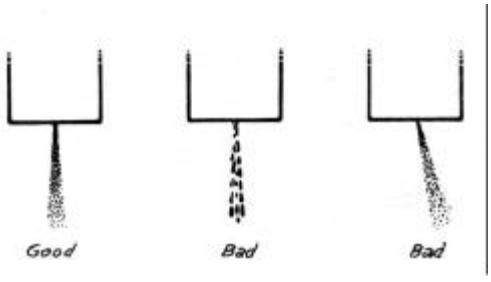


(a) **Injection Start Pressure Test**

1) Using a nozzle tester, measure the injection start pressure. If the pressure is different from the standard value, adjust to the specified pressure by increasing or decreasing the thickness of adjusting shim.

2) Increasing or decreasing shim thickness by 0.1mm will vary the pressure by approximately 10kg/cm2. When replacing the shim, hold the retaining nut in the vise and remove the body with a wrench. Tighten the retaining nut to the specified torque.

(b) **Injection Test**



For the chattering test, operate the lever of the tester slowly. If the nozzle makes a spasm of injection, the nozzle is considered good. The nozzle should inject fuel straight in its axial direction. A nozzle is defective if it injects fuel in a wrong direction or in several separate strips. Also, a spray in the form of particles indicates a defect. These defects may be sometimes caused by clogging with dust and, therefore, all parts should be carefully cleaned before reassembly. (Care should be taken not to expose one's skin to this spray as it may penetrate the skin and cause infection.)

(c) **After-spilling Test**

An injection nozzle is considered defective if it spills fuel accumulated on the bottom of the nozzle after chattering test. Replace such a nozzle. A very small amount of fuel may sometimes remain on the tip of the nozzle. This is due to chattering and is not a faulty nozzle.

(d) Install the tested nozzle holder assembly in the cylinder head. Tighten bolts to the specified torque. Be sure to install the assembly together with a new gasket.

GOVERNOR SYSTEM

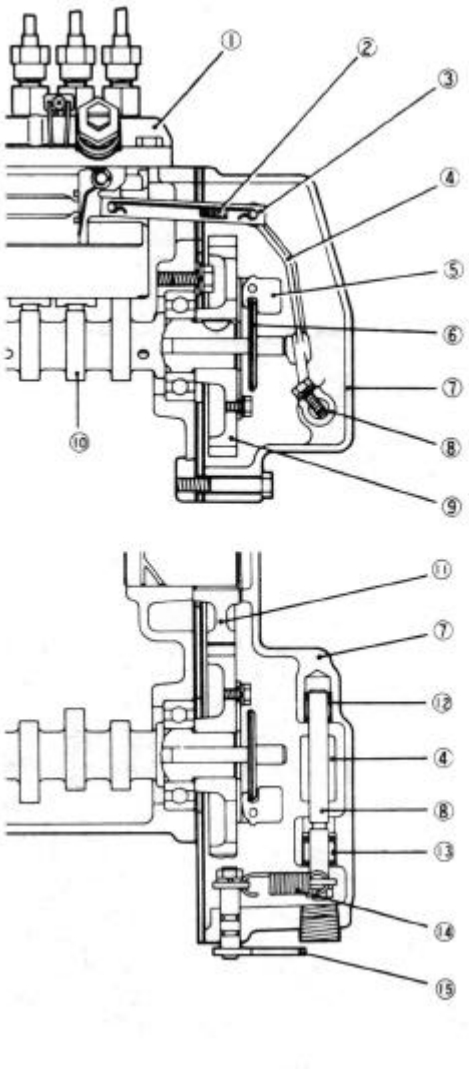
l: CONSTRUCTION

Operation of the governor maintains the engine speed constant as the centrifugal force acting on the governor weights, according to the engine speed balances with the tension of the governor spring.

If the engine speed increases, the governor weights will open, forcing the sliding shaft forward. Therefore, the injection pump control rack, linked to the sliding shaft through the governor lever assembly, tie rod and spring, is moved in the direction that less fuel is injected. The movement of the governor lever is stopped at a point where the centrifugal force of the governor weight balances with the tension of the governor spring.

When engine speed is decreased by an overload, the control rack is pushed against the small set spring in the direction that more fuel is injected.

(1) Injection pump
(2) Stopper spring
(3) Tie rod
(4) Governor lever
(5) Governor weight
(6) Sliding shaft
(7) Gear case
(8) Governor shaft
(9) Pump gear
(10) Pump camshaft
(11) Idle gear
(12) Needle bearing
(13) Needle bearing
(14) Governor spring
(15) Speed control lever

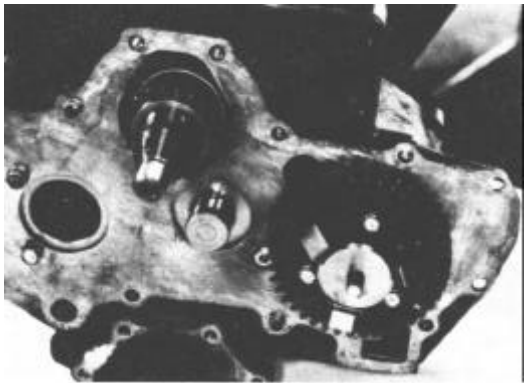


2. **SERVICING**

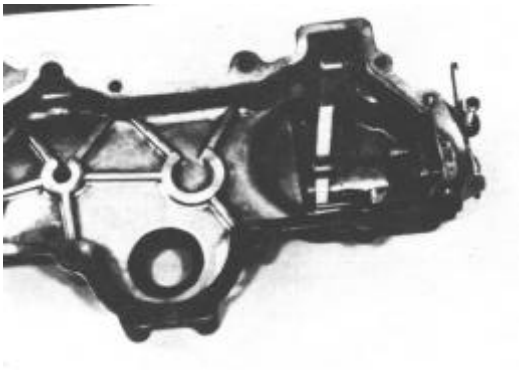
Disassembly

1. Remove the alternator belt. (Refer to COOLING SYSTEM.)
2. Remove the crankshaft pulley nut, and then remove the pulley.
3. Remove the fuel injection pump. (Refer to "Fuel Injection Pump.)
4. Remove gear case mounting bolts, then remove the gear case. (See CAUTION in "Removal" of cylinder block gear case.)
5. Remove the governor spring.
6. Remove the nut, washer and lever C. Remove the speed control lever from the gear case.
7. Remove the nut, washer and spring lever, then remove the governor lever set bolt. Remove the governor lever.
8. Remove the governor weight assembly and the sliding shaft from the pump camshaft.
9. Remove the tie rod and spring from the governor lever.

Servicing



1. Governor Assembly
   a. Check the governor weights for wear and damage and replace if defective.
   b. Check the operating part of the sliding shaft for damage. Also check to see if the shaft operates smoothly when placed in the camshaft holder. Replace if defective.



2. Governor Lever
   Check the sliding shaft contact area of the governor lever, and tie rod and spring connecting the governor lever to the control rack; replace if defective.

3. Governor Spring
   Check the spring for deterioration and breakage. Replace if defective.

Reassembly

4. Needle Bearing
   Check the needle bearing supporting the governor lever shaft in the gear case for damage.

   Reassembly is just the reverse of disassembly. After reassembly, check the governor for smooth movement.

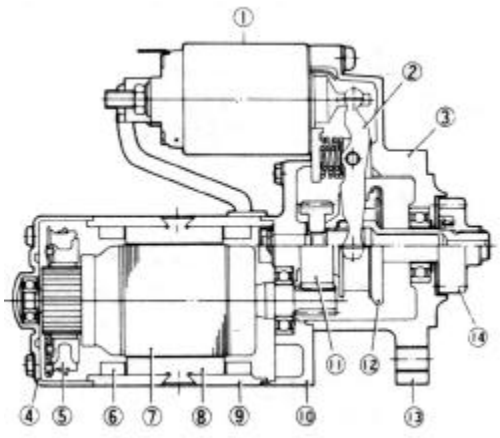
ELECTRICAL SYSTEM

CONSTRUCTION

1. **Starter**

The starter can be roughly divided into the following sections:

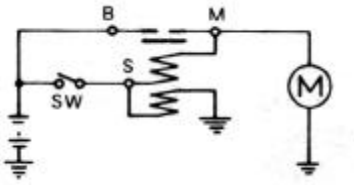
(a) A motor section which generates a drive power.
(b) An overrunning clutch section which transmits an armature torque, preventing engine overrun after starting
(c) A switch section which is operated when actuating the overrunning clutch through a lever and which supplies load current to the motor.



(1) Magnetic Switch
(2) Shift Lever
(3) Front Bracket
(4) Rear Bracket
(5) Brush
(6) Field Coil
(7) Armature
(8) Pole Piece
(9) Yoke
(10) Center Bracket
(11) Gear
(12) Clutch
(13) Front Bracket
(14) Pinion Gear

Section View of Starter

The starter used with this engine is a new type of small, light-weight starter called a high-speed internal reduction starter. Its differences in construction from conventional starters are as follows.



(a) In conventional starters, the pinion slides on the motor shaft (armature shaft). In the new type of starter, however, the pinion shaft is separate from the motor shaft; the pinion slides only on the pinion shaft.

(b) A reduction gear is installed between the motor shaft and a pinion shaft.

(c) The pinion sliding part is not exposed outside the starter so that the pinion may slide smoothly without becoming fouled with dust and grease.

(d) The motor shaft is supported at both ends on ball bearings. The lever mechanism, switch and overrunning clutch inner circuit are identical to conventional ones.
(e) The starter wiring is as shown.

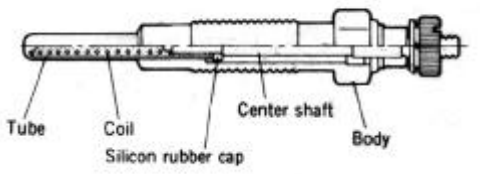
2. **Alternator (50 amp 12 volt)**

The alternator is a three phase AC generator with a diode rectifier and is driven by the crankshaft through a pulley and a V-belt.

It can also be roughly divided into rotor and stator sections. The rotor section consists of a rotor, ball bearings and pulley with a fan, while the stator section consists of an armature, front and rear brackets, fin complete and brushes. Three diodes (+) and three diodes (-) are fixed on the fin heat sink.

3. **Glow Plug**

The glow plug employed is a sheathed type; its construction is as illustrated.



NOTE: In addition to the conventional type of glow plug, a new quick-heat glow plug has come in use for engines of late. Be careful not to confuse them with each other for proper handling and part replacement. It is not recommended to use the quick-heat type. See table below.

Description/Type	General Use	Quick-heat Type
Glow plug	Y-110	Y-114^{m}
Lead wire code color	Black (conventional type)	White stripes on black background
Length of time operation:		
Normal	Approx. 20 seconds	Approx. 20 seconds
Cold weather	Approx. 60 seconds	Approx. 30 seconds
Limit of continuous use	2 minutes maximum	1 minute maximum

SERVICING

CAUTION: WATER AND HEAT ARE ENEMIES OF ELECTRICAL DEVICES. SPECIAL CARE SHOULD BE TAKEN WHEN CLEANING THE ENGINE. INTRUSION OF WATER INTO THE STARTER AND ALTERNATOR WILL CAUSE RUSTING OF BRUSH SPRINGS, ETC.

CAUTION: BE CAREFUL TO PREVENT INTRUSION OF SAWDUST AND FIBREGLASS ALSO.

DISASSEMBLY

1. **Starter**

(a) Turn the engine battery selector switch to the off position.
(b) Disconnect wiring from Band S terminals on the starter.
(c) Remove attaching nuts, then remove the starter.

2. **Alternator**

(a) Turn the engine battery selector switch to the off position.
(b) Loosen the alternator adjusting strap bolts, then remove the belt.
(c) Disconnect electrical connections from back of alternator. (Note connections for proper reassembly.)
(d) Remove alternator support bolt.

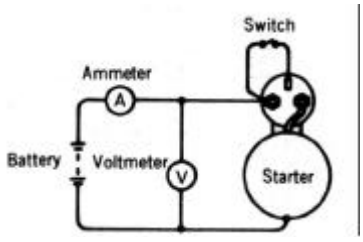
INSPECTION AND SERVICING

1. **Starter**

CAUTION: HARD ENGINE STARTING IS NOT NECESSARILY CAUSED BY STARTER TROUBLE. A CAUSE OF TROUBLE WILL SOMETIMES EXIST IN ANOTHER PART, FOR EXAMPLE, IN THE STARTER SWITCH OR ENGINE. IN THE EVENT OF HARD STARTING, CHECK THE STARTER CIRCUIT WITH THE STARTER IN PLACE ON THE ENGINE. IF NO ABNORMALITY IS FOUND WITH THE CIRCUIT, REMOVE THE STARTER FROM THE ENGINE AND TEST IT.

(a) Starter Circuit
Check condition of the battery and be sure it is properly charged. Clean and tighten battery terminals and connections
Clean and check connection of starter terminal connections Clean and check connection at battery selector switch
Check condition of all wiring, especially from the battery to the engine
Check engine mounted circuit breaker

(b) No-load Test
Connect the starter with the battery as illustrated and close the switch to turn the starter.
The starter must turn lightly at the following current and speed when the battery voltage is 11.5V.
Current: 90A or less
Speed: 3600 rpm or higher
If any abnormality has been found, make the following inspections.



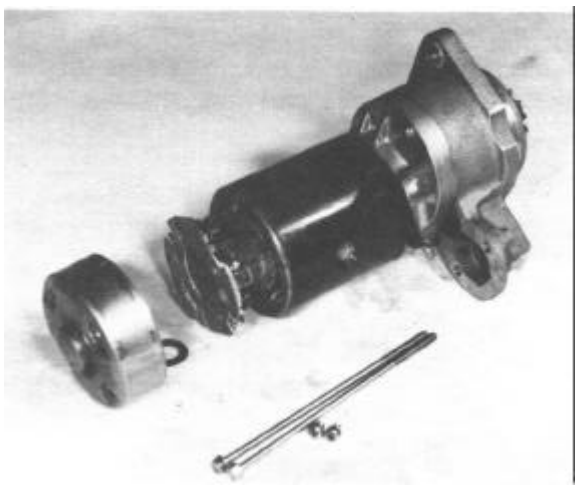
(c) **Brushes and Brush Holders**

(i) Check brushes. If the brushes are worn over the service limit, replace. (See "Service Standards".)

(ii) With the holders assembled to the commutator, check spring tension. If spring tension has decreased over the service limit, replace.

(iii) Check continuity between the positive brush holder and the brush holder base. In case of continuity, replace the holder assembly.

(iv) Check the brush holder caulk.



(d) **Armature**

(i) Check the armature coil using a growler tester. If the armature is shorted, replace.

(ii) Measure the commutator O.D. and the depth of the undercut. Correct or replace the commutator if defective. Also check the commutator outside surface for dirtiness and roughness. Polish the commutator, if rough, with sandpaper No. 300 to 400.

(e) **Field Coil**

(I) Check for continuity at both ends of coil (between brushes). If no current is flowing, the coil is broken. Replace the yoke assembly.

(ii) Check for continuity between the connector and the yoke. If current is flowing, the coil is grounded. In this case, check the insulated condition and correct. Replace the yoke assembly if not repairable.

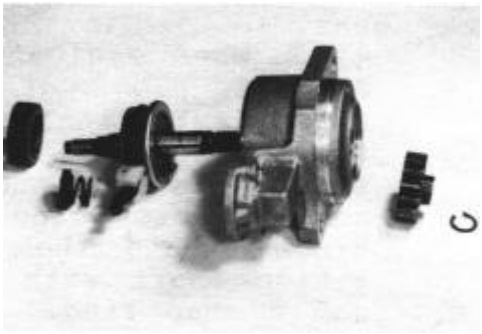
(iii) Check the staked condition of poles and check the coil and other parts for looseness.

(f) **Solenoid Switch**

The solenoid switch must be conducting between S and M terminals and between S terminal and body.

(g) **Overrunning Clutch**

If the pinion is worn or damaged, replace.



(h) **Reduction Gear**

Replace the reduction gear if it is worn or damaged.

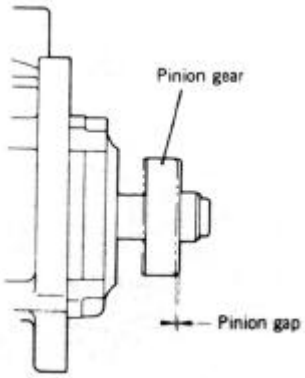
(i) **Front Bracket**

If the ball bearing seat or pinion shaft bushing is worn, replace the bracket assembly.

(j) **Pinion Gap**

(i) Remove the connector from M terminal.

(ii) Insert the battery between the S terminal and the starter motor (connect the positive cable of battery to the S terminal*),and the pinion moves out and stops. Lightly push the pinion back toward the armature to measure a pinion gap. If the pinion gap is not within the standard range (0.5 to 2.0 mm), adjust by increasing or reducing the number of adjusting shim washers between the solenoid switch and the front bracket. Increasing the number of washers reduces the gap. If the pinion does not move out, or if the pinion gap is too large or too small, the shift lever has been installed in a wrong direction or the solenoid magnet switch is defective.

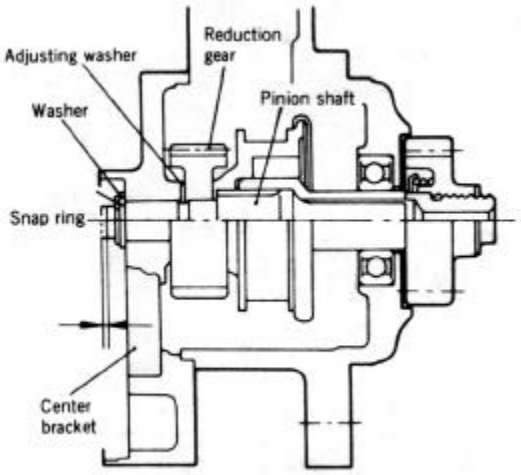


CAUTION:

*IN THIS CHECK, DO NOT APPLY THE CURRENT FOR OVER 20 SECONDS TO PREVENT SWITCH COIL FROM OVERHEATING.

(k) **Pinion Shaft Thrust Gap**

A pinion shaft thrust gap is an axial play of the shaft. Adjust the gap to less than 0.5 mm by the adjusting washer between the center bracket and the reduction gear.



(i) When Pinion has been Removed
After installing the reduction gear to the pinion shaft, insert the pinion shaft into the center bracket, and then fix the pinion shaft with a washer and a snap ring. With the pinion shaft pressed to one side, measure the thrust gap and adjust by the adjusting shim.

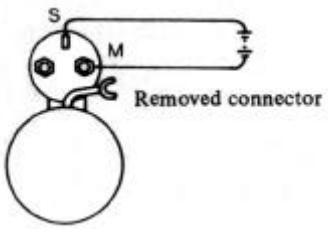
(ii) When Pinion has not been Removed
Insert the pinion shaft and reduction gear between the front bracket and the center bracket and tighten the bolt. Move the pinion shaft to one side and measure the thrust gap.

CAUTION:

PRIOR TO MEASURING THE THRUST GAP WHEN THE PINION HAS NOT BEEN REMOVED, REMOVE THE LEVER SPRING.

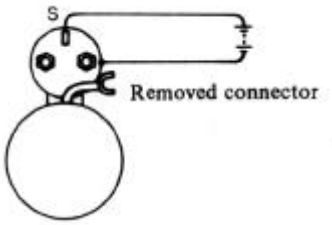
2. **Solenoid Switch**

(i) To Test Pull In of Solenoid
Connect the battery between the S and M terminals of the solenoid switch. If the plunger is pulled in and the pinion moves out, then the switch is good.



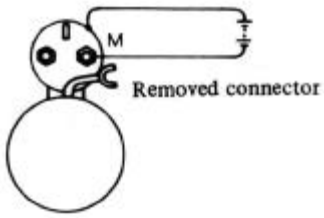
(ii) Holding Test

With the battery connected between the S terminal of the solenoid switch and the body, manually move the pinion out of the stopper position. If the pinion does not move back to its original position, the switch is good.



(iii) Return Test

With the battery connected between the M terminal of the solenoid switch and the body, manually move the pinion out of the stopper position. If the pinion returns to its original position as soon as it is released, the switch is good.



In the above tests, do not supply current for more than 10 seconds.

3. **Alternator**

CAUTION:

DO NOT USE A HIGH-VOLTAGE TESTER SUCH AS A MEGGER; OTHERWISE A DAMAGED DIODE RESULTS.

DURING HIGH-SPEED OPERATION OF THE ENGINE, DO NOT DISCONNECT THE POSITIVE OR NEGATIVE TERMINAL OF THE BATTERY FROM THE (A) TERMINAL OF THE REGULATOR. A VOLTAGE SURGE WILL OCCUR THAT WILL DAMAGE ALTERNATOR DIODES SHOULD THESE CONNECTIONS BE OPENED.

DO NOT RUN THE ENGINE WITH THE LEAD DISCONNECTED FROM THE (B) TERMINAL OF THE ALTERNATOR. THE INTERNAL REGULATOR VOLTAGE COIL WILL BE DAMAGED.

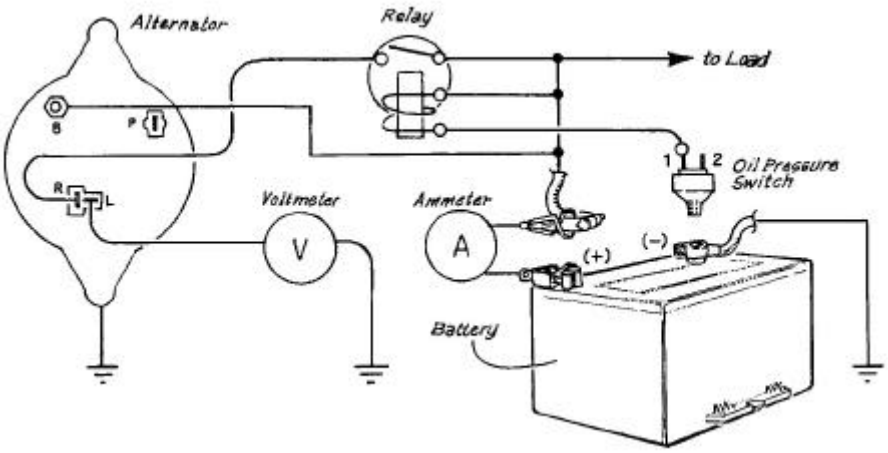
WHEN MAKING A RAPID CHARGE OF BATTERY USING A QUICK CHARGER, BE SURE TO DISCONNECT THE BATTERY CABLES; OTHERWISE DAMAGED ALTERNATOR DIODES WILL RESULT.

WHEN USING A STEAM CLEANER, BE CAREFUL NOT TO ALLOW DIRECT CONTACT OF STEAM WITH THE ALTERNATOR.

The charging system consists of an alternator with internal voltage regulator, engine mounted circuit breaker, battery and connecting wires.

Because of the use of IC's (integrated circuits), the electronic voltage-regulator is very compact and is built in the rear bracket of the alternator.

Charging Voltage Test



1. Turn key switch off on marine engines or disconnect the oil pressure switch wire on generator sets.
2. Disconnect cable from positive (+) terminal of battery and connect an ammeter in series between the cable and positive (+) terminal of the battery.
3. Connect a voltmeter between terminal (L) of alternator and ground. Check to ensure that the voltmeter reading is zero. If the pointer of the voltmeter deflects (a voltage present), a defective alternator or wiring is suspected.
4. Turn key switch on or connect the oil pressure switch terminal to ground, but do not start the engine. The voltmeter reading should be considerably lower than the battery voltage. If the voltmeter reading is much the same as the battery voltage, a defective alternator is suspected.
5. With the ammeter terminals short-circuited, start the engine.

CAUTION:
MAKE SURE THAT WHEN THE ENGINE IS STARTED, NO STARTING CURRENT IS APPLIED TO THE AMMETER.

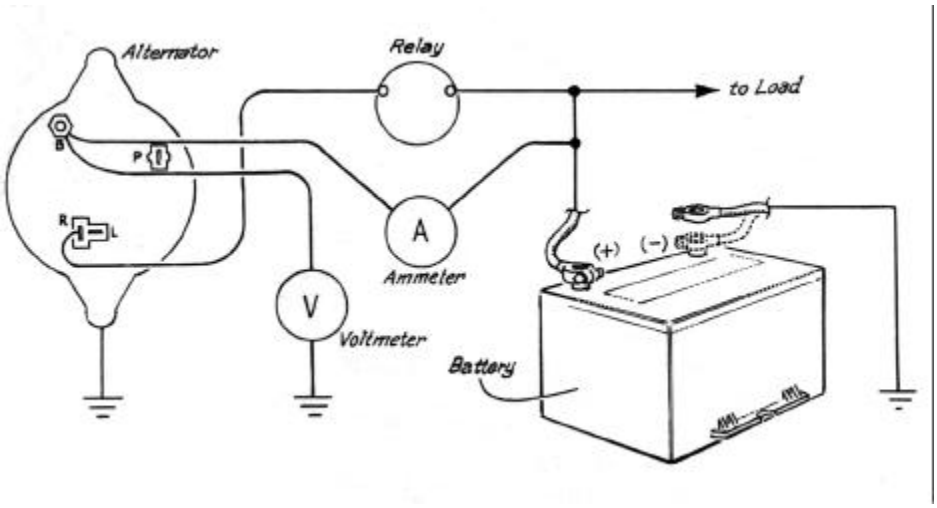
6. Remove the short circuit across the ammeter terminals and increase the engine speed immediately to approximately 2,000 to 3,000 rpm. Take the ammeter reading.
7. If the ammeter reading is 5A or less, take the voltmeter reading without changing the engine speed (2,000 to 3,000 rpm). The reading is the charging voltage.

NOTE: Since the electronic voltage regulator is a temperature compensation type, the charging voltage varies with temperature. Therefore, the temperature around the rear bracket of the alternator must be measured and the charging voltage corrected to the temperature.

Description	Standard value
Charging voltage	14.4 +0.3V at 20'C (68'F)
Temperature compensation gradient	-O.1V/10'C (50'F)

8. If the ammeter reading is more than 5A, continue to charge the battery until the reading falls to less than 5A or replace the battery with a fully charged one. An alternative method is to limit the charging current by connecting 1/4 ohm (25W) resistor in series with the battery.

Output Test



1. Disconnect the battery ground cable.
2. Disconnect the cable from terminal "B" of alternator and connect an ammeter between terminal "B" and this cable.
3. Connect a voltmeter between terminal "B" (+) and ground (-).
4. Set the engine tachometer.
5. Connect battery ground cable to battery. The voltmeter should indicate the battery voltage.
6. Start the engine.
7. Turn on the 12 volt accessories equalling the amperage output of the alternator, accelerate the engine to the specified speed (2000 to 3000 RPM) and measure the output current. The output current should be close to alternator maximum output.

Output current	1300 RPM	2500 RPM	5000 RPM
Hot	16 amp	41 amp	48 amp
Cold	24 amp	50 amp	--

Note: The RPM is that of the alternator. The pulley ratio (alternator vs. crank pulley) is 1.78 to 1. All readings are at 13.5 VDC.

Disassembly

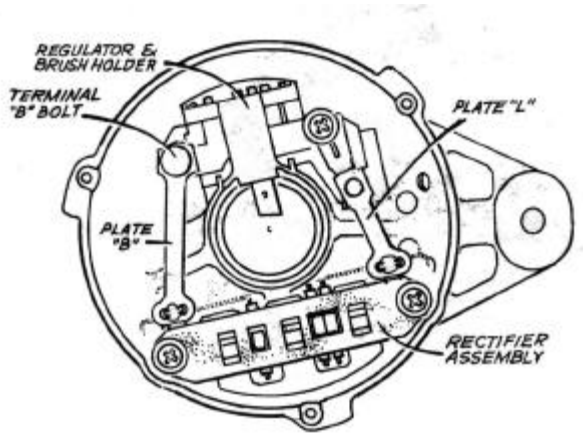
1. After removing the three through bolts, insert a screwdriver between the front bracket and stator. While prying it, remove the front bracket and rotor.

   NOTE: If the screwdriver is inserted too deep, the stator coil might be damaged.

2. Hold the rotor in a vise and remove the pulley nut. Then remove the pulley, fan, spacer and seal. Next, remove the rotor from the front bracket and remove the seal.
3. Unsolder the rectifier from the stator coil lead wires and remove the stator assembly.

   NOTE: Make sure that the solder is removed quickly (in less than five seconds). If a diode is heated to more than 150^0C (310^0F), it might be damaged.

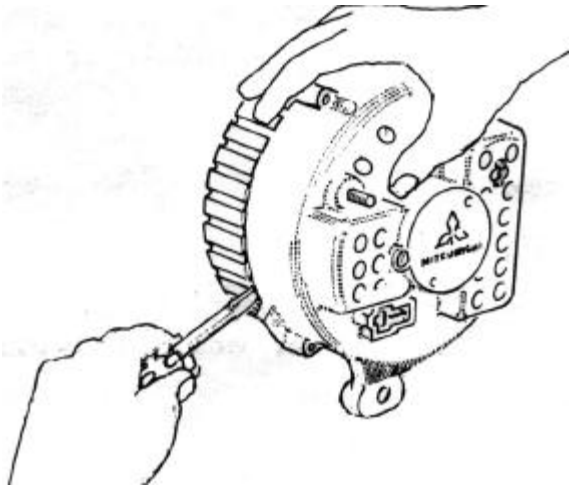
4. Remove the condenser from terminal "B".
5. Unsolder the plates "B" and "L" from the rectifier assembly.
6. Remove the mounting screw and "B" terminal bolt and remove the electronic voltage regulator and brush holder. The regulator and brush holder cannot be separated.
7. Remove the rectifier assembly.
8 Brush and brush spring. When only a brush or brush spring is to be replaced, it can be replaced without removing the stator, etc. With the brush holder assembly raised as shown, unsolder the pig-tail of the brush.



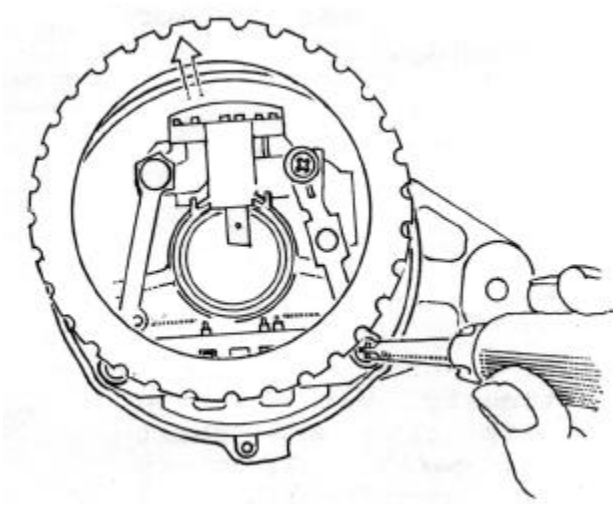
   NOTE: If the terminals "L" and "B" of the rectifier assembly are bent, damage might result to the rectifier molding. Therefore, the plates "B"and "L" should be gently bent at the center.

   Alternative method for disassembling the stator winding, brush holder/regulator unit and the integrated circuit/diode rectifier assembly from the rear bracket. Once the front bracket and rotor assembly are separated from the rear half of the alternator:

1. Insert a flat-bladed screwdriver between the stator core and the edge of the rear bracket on the same side as the brush-holder. Raise this side of the stator core away from the bracket so as to open a gap of about 1/2 inch. BE CAREFUL NOT TO ALLOW THE SCREWDRIVER BLADE TO ENTER FAR ENOUGH TO TOUCH THE STATOR WINDING.
2. Maintaining the 1/2 inch gap, insert the screwdriver between the stator core and the bracket on the rectifier side and move the stator laterally towards the brush-holder for a distance of 1/2 to 3/4 of an inch without lifting it from the bracket.



3. Insert a #2 Philips screw driver through this opening and remove the two screws holding the rectifier.
4. Remove the nut anchoring the "B" terminal bolt and the capacitor mounted thereto on the outside rear of the bracket. Then remove the third Philips screw holding the brush-holder to the bracket.
5. Carefully withdraw stator, brush-holder and rectifier from the rear bracket as one loosely connected unit.



With the bracket out of the way, it is easy to unsolder the stator winding leads from the rectifier quickly to avoid heat damage to the diodes and I.C. chips. It is also easier to renew brushes because there is no need to-bend the connecting plates between the brush-holder and the rectifier and possible damage the rectifier molding.

When reversing this procedure, make sure that the stator winding leads are gently pushed back (from possible contact with the rotor body) after seating the stator into the rear bracket.

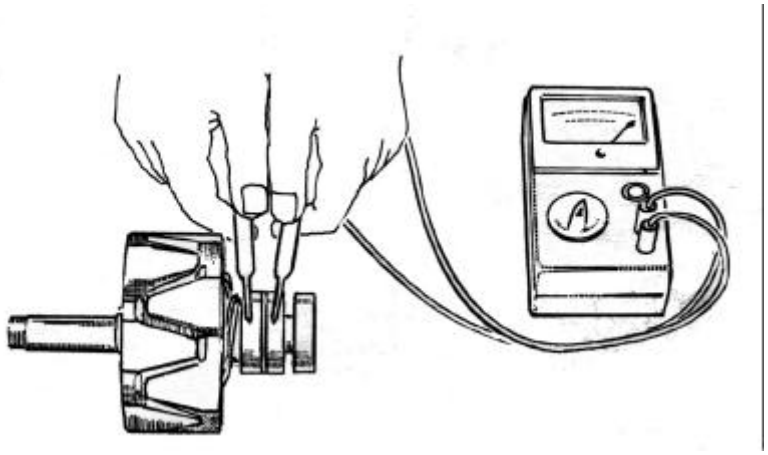
Inspection

Rotor Assembly

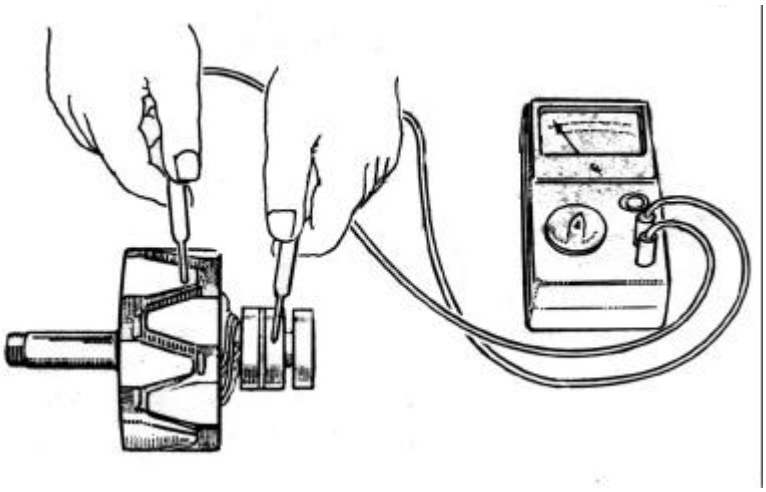
1. Check the outside circumference of the slip ring for dirtiness and roughness. Clean or polish with fine sandpaper, if required. A badly roughened slip ring or a slip ring worn down beyond the service limit should be replaced.

Description	Standard value mm (in.)	Service limit mm (in.)
Slip ring O.D.	33 (1.2992)	32.2 (1.2677)
Runout	0.03 (.0012) or less	0.2 (.008)

2. Check for continuity between the field coil and slip ring. If there is no continuity, the field coil is defective. Replace the rotor assembly.

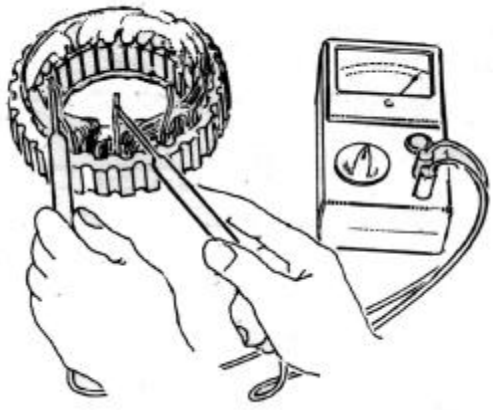


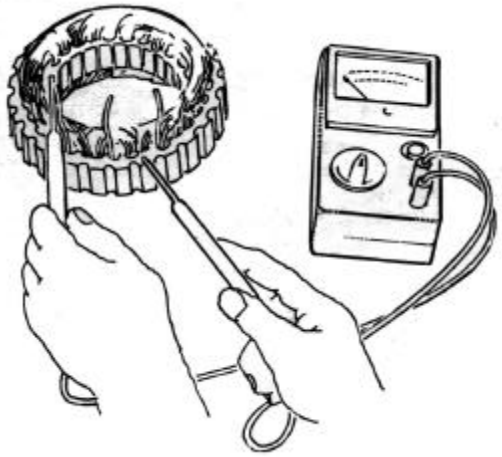
3. Check for continuity between the slip ring and shaft (or core). If there is continuity, it means that the coil or slip ring is grounded. Replace the rotor assembly.



Stator Assembly

1. Check for continuity between the leads of the stator coil. If there is no continuity, the stator coil is defective. Replace the stator assembly.





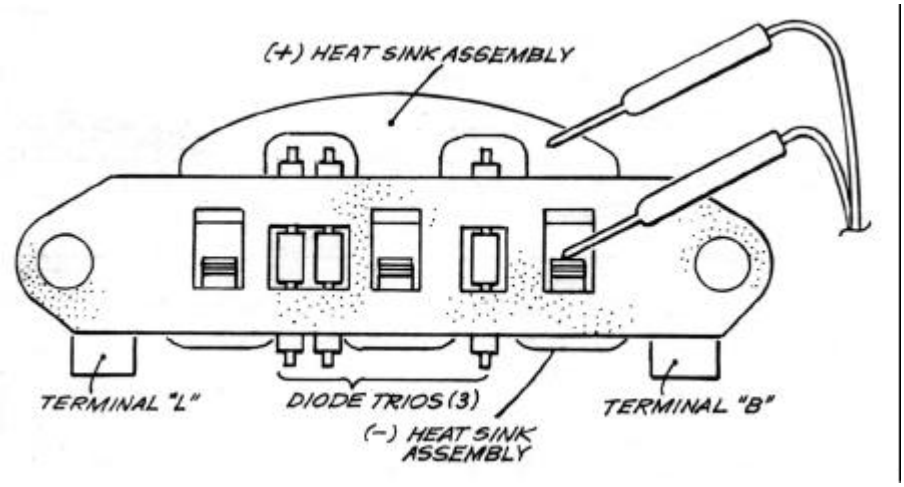
2.

Check for an open circuit between the stator coil leads and the stator core.

Rectifier Assembly

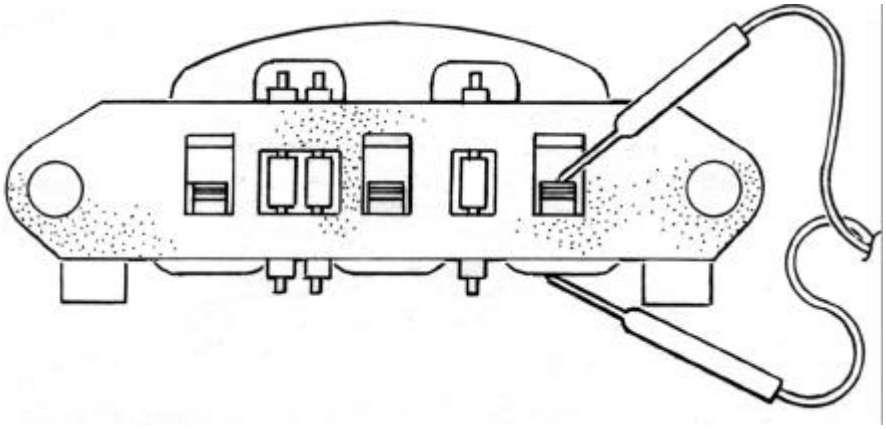
(+) Heatsink Assembly Test

Check for continuity between the (+) heatsink and stator coil lead connection terminal with an ohm-meter. If there is continuity in both directions, the diode is short circuited. Replace the rectifier assembly.



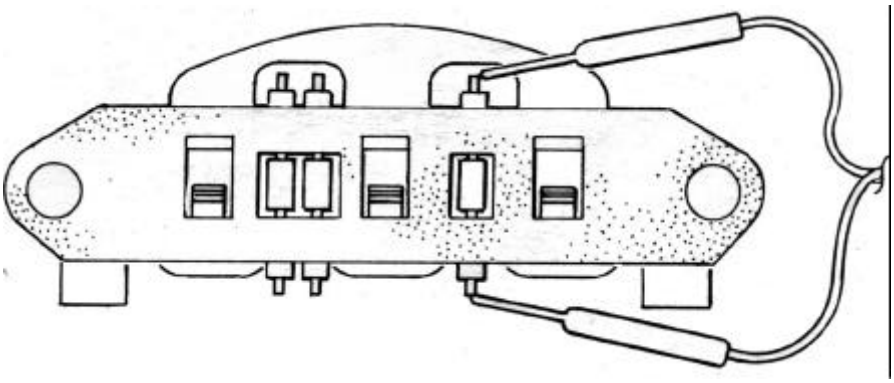
(-) Heatsink Assembly Test

Check for continuity between the (-) heatsink and stator coil lead connection terminal. If there is continuity in both directions, the diode is shortcircuited. Replace the rectifier assembly.



Diode Trio Test

Using an ohm meter, check the three diodes for continuity in both directions. If there is either continuity or an open circuit in both directions, the diode is defective. Replace the rectifier assembly.



Brush and Brush Rig

1. Check the length of the brush. A brush worn down to the service limit line should be replaced.

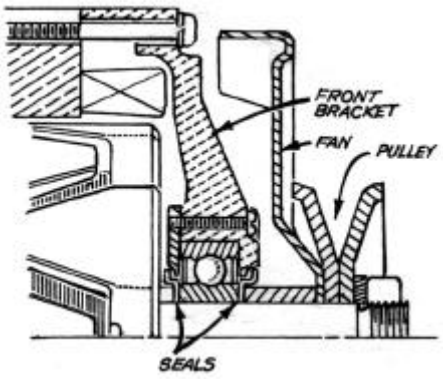
Description	Standard value	Service limit
Length of brush	18 mm (.709 in.)	8 mm (.315 in.)
Load of brush spring	3.04 to 4.22 N (.7 to 1 lbs.)	2.06 N (.5 lbs.)
	---	

2. Check the brush spring pressure to make sure the brush moves smoothly in the brush holder.

Reassembly

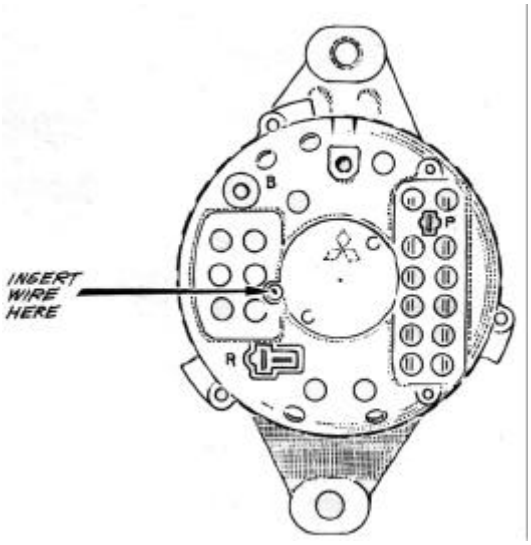
Reverse the disassembly procedure but pay special attention to reassembly of the following.

1. Install seals in front and rear of the front bearing as shown.



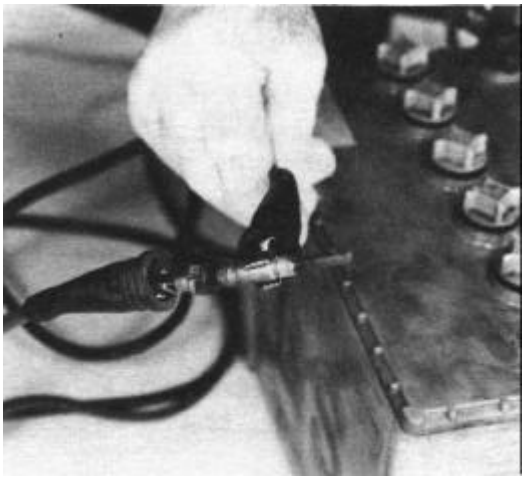
2. To install the rotor assembly in the rear bracket, push the brushes into the brush holder, insert a wire to hold them in raised position, and then install the rotor.

   NOTE: After installation, remove the wire.



4. **Glow Plug**

'When the positive cable of the battery is connected to the glow plug terminal and the negative cable of the body, the glow plug must glow red hot.



Reassembly

1. Starter

CAUTION:
PRIOR TO INSTALLATION, CLEAN THE STARTER FLANGE AND CRANKCASE MOUNTING SURFACE THOROUGHLY BY REMOVING ALL OIL, PAINT AND RUST.
THE STARTER PERFORMANCE LARGELY DEPENDS ON THE QUALITY OF WIRING. USE WIRE OF SUFFICIENT SIZE AND GRADE BETWEEN THE BATTERY AND THE STARTER AND FULLY TIGHTEN EACH TERMINAL.

2. Alternator

CAUTION:
CONNECT THE ALTERNATOR AND BATTERY PROPERLY. SHOULD THE BATTERY POLARITY BE REVERSED, A TREMENDOUS CURRENT WOULD FLOW FROM THE BATTERY INTO THE ALTERNATOR, DAMAGING THE DIODES AND WIRING HARNESS.

a. Align hole in the alternator leg with hole in gear case and insert the alternator support bolt from the front bracket side.
b. Install the adjusting strap.
c. Install the belt.
d. Push the alternator toward the rear of the engine and check clearance between alternator leg and gear case. If the clearance is more than 0.2 mm (.008 in.), insert spacers, 0.198 mm (.0078 in.) thick, as required.
e. Remove alternator support bolt, insert the spacers as selected in step (d), reinsert the bolt and tighten the nut.
f. Adjust the belt tension.
g. Tighten the alternator support bolt nut and adjusting strap to the specified torque.

Alternator support bolt nut	20 - 24 Nm (15 - 18 ft-lbs.)
Adjusting strap bolt	12 - 14 Nm (9 - 10 ft-lbs.)

MAINTENANCE

1. Judging , Engine Overhaul Period

Generally the time at which an engine should be overhauled is determined by lowered engine power, decreased cylinder compression pressure and increased fuel and lubricating oil consumption.

The lowered engine power, in the case of diesel engines, is not necessarily due to a trouble of the engine itself but is sometimes caused by worn or damaged injectors and/or worn or damaged injection pump. It is most reasonable to judge by a decrease in compression pressure. The decrease in compression pressure is caused by many factors. It is, therefore, necessary to determine a cause or causes of the trouble on the basis of data of periodic inspection and maintenance.

When the trouble is caused by a worn cylinder or piston ring, the following symptoms will occur:

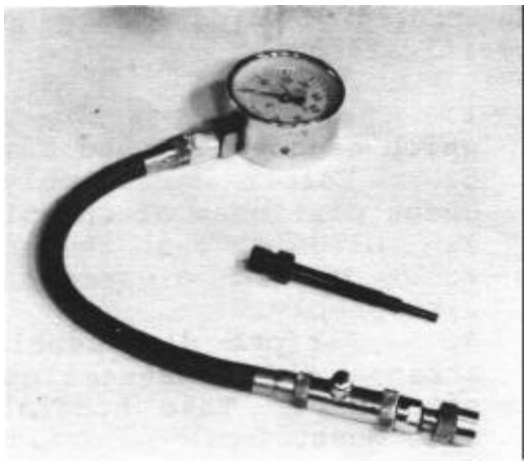
1. Low engine power, and a decrease in compression pressure.
2. Increased fuel consumption.
3. Increased lubricating oil consumption.
4. Poor engine starting.
5. Loud noise in engine parts.

Actually these symptoms often appear together. The symptoms (2) and (4) result also from excessive fuel injection, improper injection timing, and wear of plunger and nozzle. Defective electrical parts, such as the battery, alternator, starter and glow plug will become a major cause of engine trouble. Therefore, it is desirable to judge the period to overhaul the engine by the lowered compression pressure caused by worn cylinders and pistons plus increased oil consumption and other.

In diesel engines, satisfactory combustion is obtained only when the fuel and air are compressed sufficiently. When sufficient compression pressure is not obtained, incomplete combustion of fuel will take place even if other parts of engine are operating properly.

To judge the period of engine overhaul, it is important to measure the engine compression pressure regularly. Since the compression pressure varies with engine rpm, check the speed also. The engine rpm can be measured at the front end of the crankshaft.

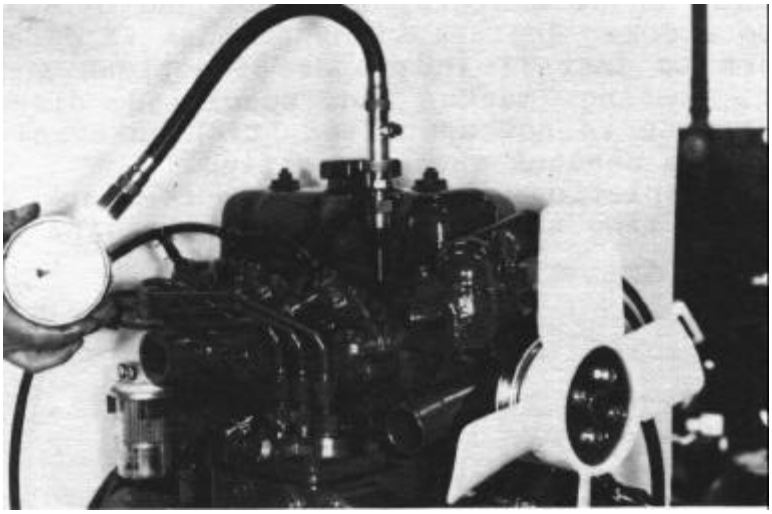
2. **Measuring Compression Pressure**



1. Remove the glow plug of cylinder to be measured.
2. Attach a pressure gauge adapter in the screw hole of the glow plug and connect a pressure gauge.
3. Operate the starter. Read the engine rpm and pressure gauge when the starter speed has become constant.

Standard value is 32kg/cm2 at 280 RPM. Cylinder and/or valve overhaul may be required should this value fall to 26kg/cm2 or below.

4. Measure the compression pressure of other cylinders in a similar manner.



CAUTION: IT IS NOT A PROPER WAY TO DETERMINE THE CONDITIONS OF THE OTHER CYLINDERS FROM A RESULT OF MEASUREMENTS OF ONE CYLINDER. BE SURE TO MEASURE THE COMPRESSION PRESSURE IN ALL CYLINDERS.

3. **Judgement of Engine Conditions by Compression Pressure**

1. The compression pressure tends to increase a little in a new engine until piston rings and valve seats are broken in, and thereafter gradually decreases with the wear of these parts.
2. If the compression pressure has decreased below the repair limit, overhaul the engine.

4. **Increased Lubricating Oil Consumption**

The engine requires overhaul when oil consumption has increased over about 150%.

5. **Disassembling Cautions**

When disassembling, keep in mind the following cautions. Note that the order of disassembly and reassembly will vary with change of specifications.

1. Before disassembly and cleaning, carefully check for defects which cannot be found after disassembly and cleaning.
2. Before disassembly, drain all drain water, oil and fuel. Check dirtiness of the oil.
3. Clean or wash the engine exterior.
4. Do not disassemble or remove the parts that require no disassembly.
5. Perform disassembly in a proper order using proper tools. Arrange the disassembled parts in good order. Apply oil when necessary. Take special care to keep parts of the fuel system from dust.

6. **Reassembly Cautions**

1. Service all parts needed for reassembly.
2. Clean or wash the parts, and apply oil where specified.
3. Carefully check gaskets, packings and oil seals even if not specified to check. Replace with new ones if defective.
4. Be sure to install in proper directions and positions (see dowel pins, mating marks and specified directions). When tightening torque is not specified, tighten evenly to an ordinary torque. Apply a sealant where specified.
5. After completion of reassembly, re-check for abnormality. Prepare for starting the engine. Run the engine idle sufficiently for test run.

OTHER OVERHAUL

CONTENTS SECTION

SECTION Q

MARINE ENGINE ELECTRICAL SYSTEM

ACTIVATION BY KEY SWITCH

This system is supplied on most Westerbeke engines beginning May, 1980. Essentially, activation of the circuit is accomplished by the ignition position of the keyswitch. No oil pressure switch is required. The engine is preheated by turning the keyswitch to the ON position, then depressing the key. The engine is cranked by turning the keyswitch to the right-most momentary position.

Voltage is maintained to the instruments, fuel solenoid or fuel lift pump, if supplied, and to other electrical devices via the ON position of the keyswitch.

Models which have a fuel solenoid may be turned off via the keyswitch. Models with mechanical fuel lift pumps or no fuel solenoid are stopped by pulling a stop cable. Some models have a combined throttle/shut-off control.

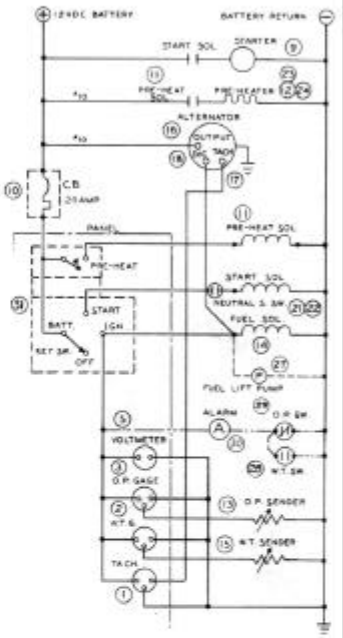
The circuit is protected by a circuit breaker located on the engine. Any time excessive current flows, the circuit breaker will trip. This is a manual reset breaker which must be reset before the engine will operate electrically again.

CAUTION: The builder/owner must ensure that the instrument panel, wiring and engine are installed so that electrical devices cannot come in contact with sea water.

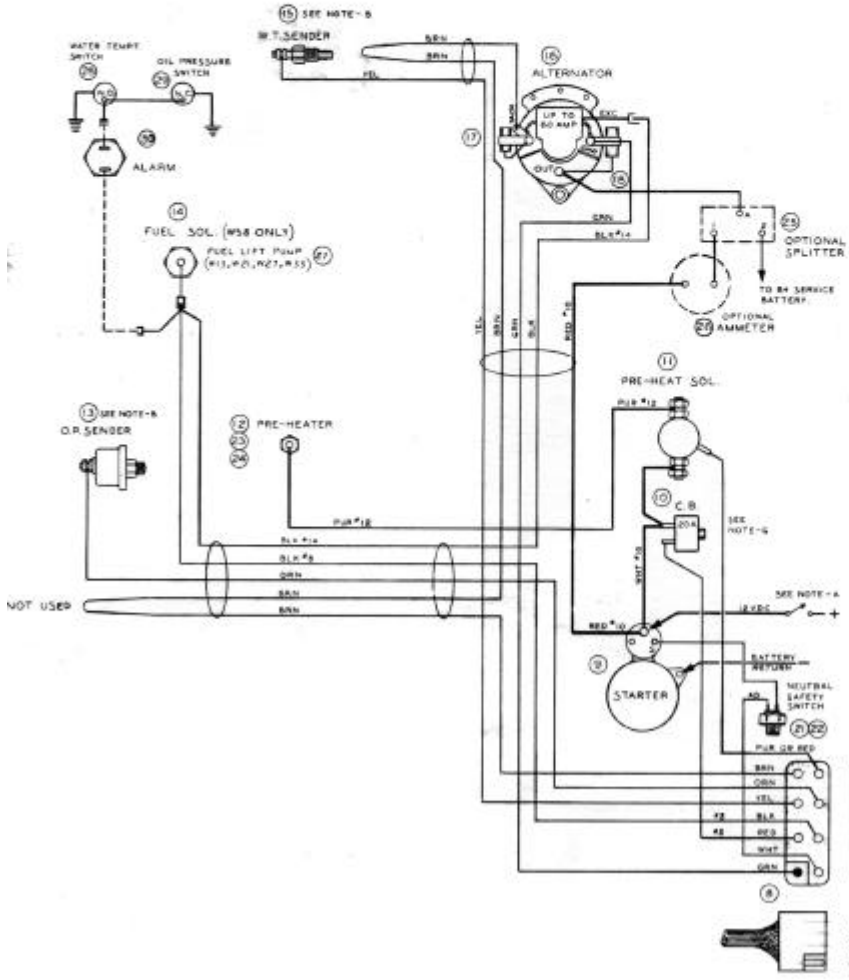
The latest information regarding your engine's electrical system is included on the wiring diagram shipped with the engine. Be sure to study this wiring diagram and all notes thereon.

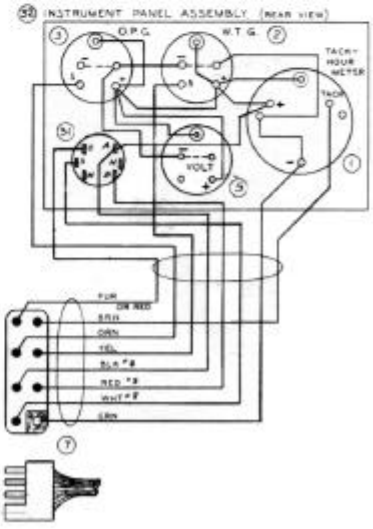
ACTIVATION BY KEYSWITCH

SCHEMATIC DIAGRAM



WIRING DIAGRAM





SECTION R

COOLING SYSTEM (EXTERNAL)

1. DESCRIPTION

Westerbeke marine diesel engines are equipped with fresh water cooling. Transfer of heat from engine fresh water to sea water is accomplished by a heat exchanger, similar in function to an automotive radiator. Sea water flows through the tubes of the heat exchanger while fresh water flows around the tubes. The sea water and fresh water never mix with the result that the cooling water passages in the engine stay clean.

2. FRESH WATER CIRCUIT

Heat rejected during combustion, as well as heat developed by friction, is absorbed by the fresh water whose flow is created by a fresh water circulating pump. The fresh water flows from the engine through a fresh water cooled exhaust manifold, a heat exchanger, in most cases an oil cooler, and returns to the suction side of the fresh water circulating pump. The flow is not necessarily in this order in every model. When starting a cold engine, most of the external flow to the heat exchanger is prevented by the closed thermostat. Some amount of by-pass is maintained to prevent overheating in the exhaust manifold. As the engine warms up, the thermostat begins to open up allowing full flow of engine fresh water through the external cooling system.

3. SEA WATER CIRCUIT

The sea water flow is created by a positive displacement neoprene impeller pump (gear pump in certain special cases). Normally the pump draws sea water directly from the ocean via the sea cock and sea water strainer. Sometimes a transmission oil cooler, or perhaps a V-drive, will be piped on the suction side of the sea water pump. Generally, it is better to have as few devices on the suction side of the sea water pump as possible to preclude priming difficulties. Usually sea water flows directly from the discharge of the sea water pump to the heat exchanger sea water inlet. After passing through the tubes of the heat exchanger, the sea water may enter a transmission oil cooler, if present and if sea water cooled. Ultimately, the sea water enters a water injected, wet exhaust system, the most popular type of exhaust system in use. In the case of larger engines the sea water flow is divided prior to entering the exhaust systems so that a portion is used to cool the exhaust system. Full sea water flow would create unnecessary exhaust back pressure.

4. SEA WATER PUMP

The sea water pump is self priming and positive displacement. It is a rotary pump with a non-ferrous housing and a neoprene impeller. The impeller has flexible vanes which wipe against a curved cam plate within the impeller housing, producing the pumping action. On no account should this pump be run dry. There should always be a spare impeller and impeller cover gasket aboard.

5. SEA WATER PUMP IMPELLER REPLACEMENT

The following instructions are general and indicative only. Specific instructions where applicable may be packaged with your replacement impeller.

a. Remove the front cover gasket taking care to salvage the gasket.
b. Remove the impeller by pulling straight outwards, parallel to the pump shaft. This is best done with a pair of pliers applied to the impeller hub.
c. Coat the replacement impeller and the chamber into which it mounts with grease.
d. Carefully align the impeller key way, or other locking mechanism, with the shaft. Take care that all the impeller blades bend in the same direction and trailing.
e. Inspect the front cover for wear. A worn front cover should ultimatelybe replaced. Sometimes it can be reversed as an emergency measure, but not when stamped markings would break the seal between the cover and the impeller blades.
f. Reinstall the end cover with a new gasket.
g. Be doubly sure to check quickly for sea water flow when starting the engine. The absence of flow indicates that the pump may not be priming itself properly. This situation must be investigated immediately or damage to the new impeller will result from overheating.

6. ENGINE FRESH WATER

It is preferable to fill your engine with a 50% antifreeze-water mixture. This precludes the necessity of draining coolant in the winter. Since most antifreezes contain preservative agents of one kind or another, rusting within the engine is minimized. Also, the antifreeze mixture boils at a higher temperature than water, giving cooling system "head room".

When draining the engine, open the pressure cap first to relieve the vacuum created by draining.

7. FILLING THE FRESH WATER SYSTEM

It is very important to completely fill the fresh water system before starting the engine. It is normal for air to become trapped in various passages so all high points must be opened to atmosphere to bleed entrapped air. When an engine is started after filling with coolant, the system may look deceptively full until the thermostat opens. At this time when water flows through the external cooling circuit for the first time, pockets of air can be exposed and rise to the fill point. Be sure to add coolant at this time.

8. **THERMOSTAT**

Generally, thermostats are of two types. One is simply a choking device which opens and closes as the engine temperature rises and falls. The second type has a by-pass mechanism. Usually this is a disc on the bottom of the thermostat which moves downward to close off an internal by-pass passage within the head. Both types of thermostats, from 1980 onwards, have a hole punched through them to serve as a by-pass while the engine is warming up. This prevents overheating in the exhaust manifold during engine warm-up. Replacement thermostats must be equal in this design characteristic.

When replacing a thermostat, be sure that it is rotated so as to not strike the thermostat housing, projections inside the head, temperature senders or temperature switches which may be installed close to the thermostat. Also insure the by-pass hole is not blocked by any part of the housing. A thermostat can be checked for proper operation by placing it in a pan of cold water and then raising the temperature of the water to a boil. The thermostat should open noticeably (with travel on the order of 1/4" - 1/2") and be fully opened when the water is boiling.

9. **ENGINE LUBE OIL COOLER**

Lubricating oil carries heat away from the engine bearings and other friction surfaces. The oil circulates from the lube oil pump, through the engine, through the engine oil cooler, and back to the oil pump. The oil cooler may be cooled either by engine fresh water or by sea water.

10. **TRANSMISSION OIL COOLER**

Certain transmissions require oil cooling. In these cases, the transmission oil cooler is usually cooled by sea water.

Normally, sea water enters this cooler after exiting the heat exchanger, but not always.

11. **EXHAUST MANIFOLD - EXTRUDED TYPE**

REMOVAL

Removal of the exhaust manifold from the engine should be done as a complete assembly in the following manner.

a. Drain the engine and cooling system of all coolant.
b. Remove the exhaust connection.
c. Loosen and remove all hose connections to the manifold.
d. Loosen and remove the nuts or bolts attaching the manifold assembly to the cylinder head.
e. Remove the manifold from the cylinder head as a complete unit.

SERVICING

a. Remove the exhaust elbows from the lower surface of the manifold. Clean and inspect for cracks and defects. Replace as needed.
b. Remove exhaust nipples, elbows and plugs from the manifold.

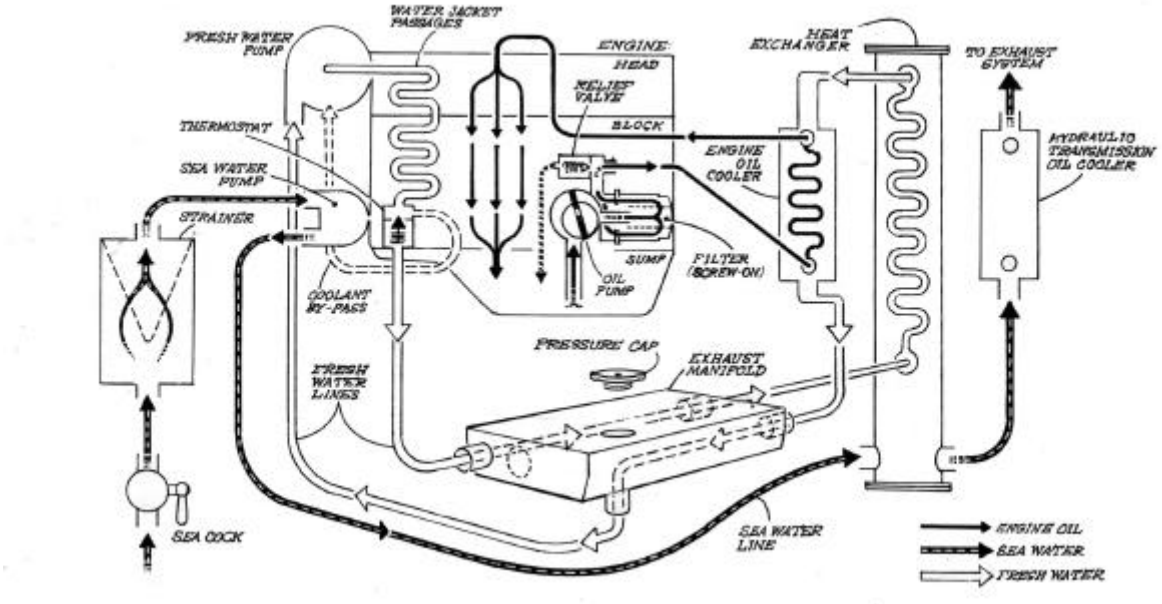
c. Remove water connectors from the ends of the manifold and the end plates. Be sure to note the proper location and arrangement of each for proper replacement.

d. Examine all parts lor defects, corrosion and wear and replace as a needed..

REASSEMBLY

a. If the manifold was removed as an assembly and left intact, it can be replaced on the cylinder head in the reverse order of removal. Do not reuse the gaskets; install new ones and torque the bolts or nuts to the proper specification (10-12 lb-ft).
   If the manifold has been disassembled, follow the steps below.
   1. Loosely attach the elbows to the cylinder head and the manifold using new gaskets. Do not use any gasket sealant.
   2. Gradually tighten each fitting to make sure of proper alignment of all the parts. Torque to 10-12 lb-ft. This should be done in three steps.
   3. Reassemble the end plates, connectors on the manifold. Be sure to use new gaskets and coat the gasket surfaces with a suitable gasket cement such as "High Tack". Torque the nuts to 8-10 lb-f t .
   4. Reinstall the exhaust connections and plug into the manifold using "Locktite-Anti-Seize" on the threads.
   5. Reconnect all hoses, replacing them as needed.
   6. Refill the system with coolant as detailed above.
   7. Pressure test system and check for leaks.

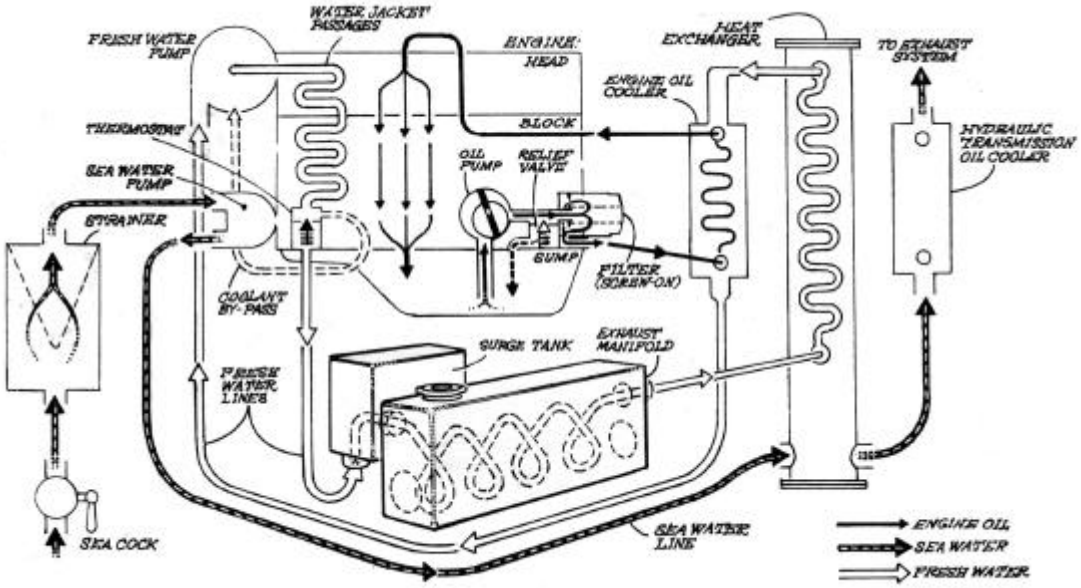
TWO PASS MANIFOLD



Note: Drawing is indicative only. Specific models may vary in detail.

SINGLE PASS MANIFOLD

Note: Drawing is indicative only. Specific models may vary in detail.



SECTION S

TRANSMISSIONS

HBW SHORT PROFILE SAILING GEAR

DESCRIPTION

1. BRIEF DESCRIPTION

The Type HBW Short Profile Sailing Gears are equipped with a positively driven, mechanically operated helical gearing system. The servo-operated multiple-disc clutch requires only minimum effort for gear changing, making the transmission suitable for single-lever remote control via a rod linkage, Morse or Bowden cable.

The torque transmission capacity of the clutch is exactly rated, preventing shock loads from exceeding a predetermined value and thus ensuring maximum protection of the engine.

The transmission units are characterized by low weight and small overall dimensions. The gearbox castings are made of a high-strength, corrosion-resistant aluminum alloy, chromized for improved sea water resistance and optimum adhesion of paint.

The transmissions are immersion-lubricated. Maintenance is restricted to oil level checks (see "Maintenance").

2. GEAR CASING

The rotating parts of the HBW transmission are accommodated in an oil-tight casing divided into two halves in the plane of the vertically axis. Amply dimensioned cooling ribs ensure good heat dissipation and mechanical rigidity.

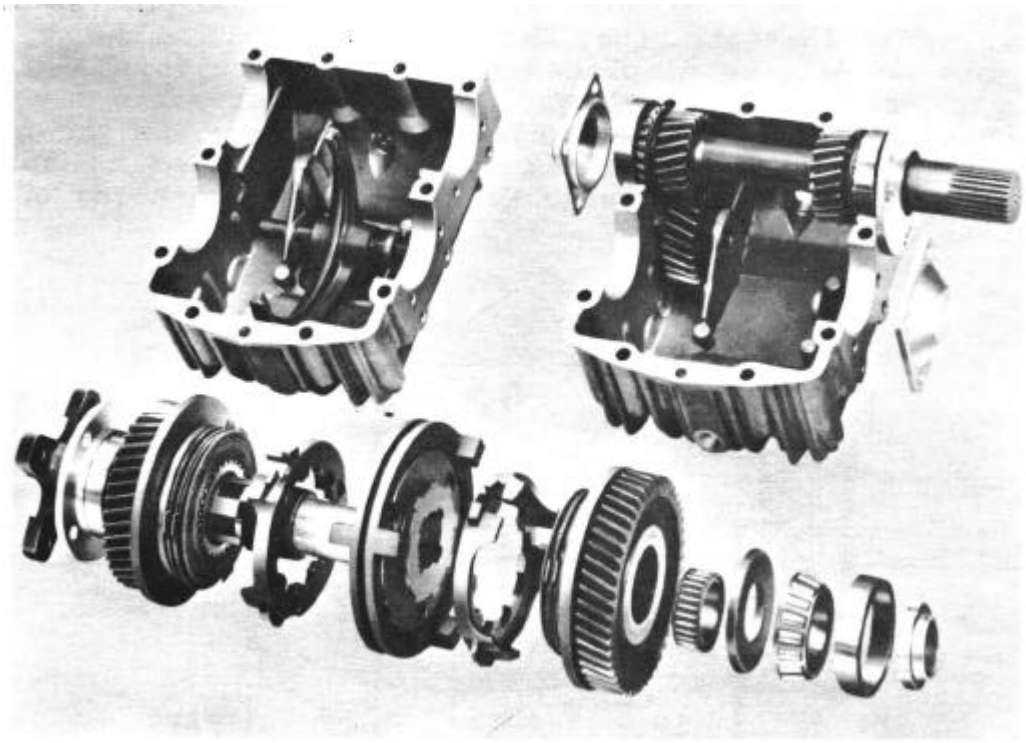
An oil filler screw with dipstick and an oil drain plug are screwed into the gear casing. The filler screw is provided with a breather hole.

The shaft for actuating the multiple-disc clutch extends through a cover on the side of the gear casing.

3. GEAR SETS

The transmission is equipped with shaved, casehardened helical gears made of forged low-carbon alloy steel. The multi-spline driving shaft connecting the transmission with the engine is hardened as well.

The driven shaft (propeller side) of the transmission is fitted with a forged coupling flange, except on the V-drive model.



4. MULTIPLE-DISC CLUTCH INCLUDING OPERATION - POWER TRAIN

The engine torque is applied to the input shaft (36) in the specified direction of rotation and, IN SHIFTING POSITION A (forward), via gear (44), the frictionally engaged clutch discs (51 and 52) to the external disc carrier (57) and from there via the guide sleeve (59) to the output shaft (66).

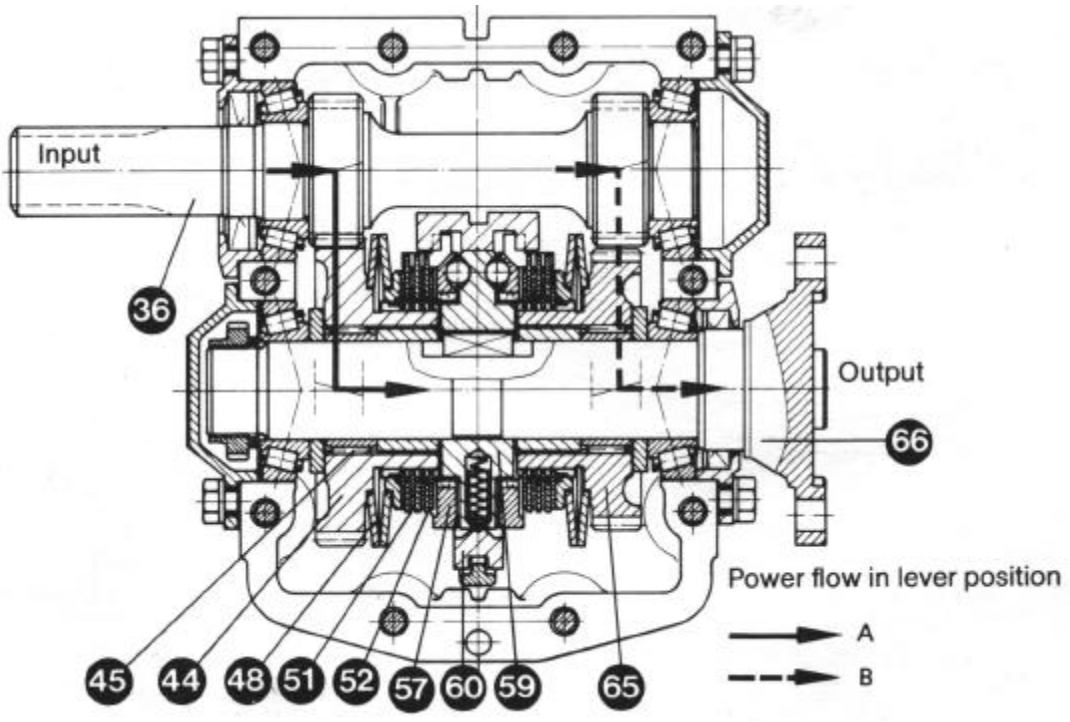
IN SHIFTING POSITION B (reverse), the torque is transmitted from the input shaft (36) via intermediate gear (26), gear (65), clutch discs (51 and 52) to the external disc carrier (57), the guide sleeve (59) and the output shaft (66).

- FUNCTION

The transmission uses a positively driven, mechanically operated multiple-disc clutch system mounted on the output shaft.

The thrust force required for obtaining positive frictional engagement between the clutch discs is provided by a servo system. This essentially comprises a number of balls which, by the rotary movement of the external disc carrier, are urged against inclined surfaces provided in pockets between the guide sleeve and the external disc carrier and in this manner exert axial pressure. The thrust force and, as a result, the transmittable friction torque are thus proportional to the input torque applied. Due to the cup springs (48) supporting the clutch disc stack and a limitation of the range of axial travel of the external disc carrier (57), the thrust force cannot exceed a predetermined value.

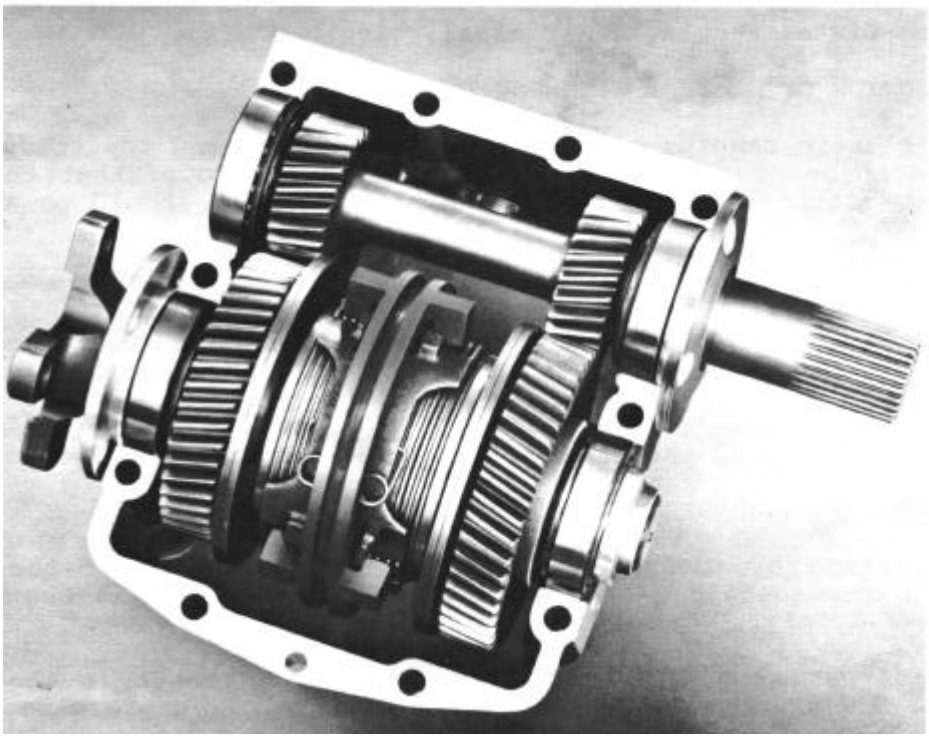
The actuating sleeve (60) is held in the middle position by springloaded pins. To initiate the shifting operation, the actuating sleeve (60) need merely be displaced axially by a shifting fork until the arresting force has been overcome. Then the actuating sleeve (60) is moved automatically by the spring-loaded pins, while the external disc carrier, which follows this movement, is rotated by the frictional forces exerted by the clutch discs, and the shifting operation is completed as described above.



5. SHAFT BEARINGS

Both the input and the output shafts are carried in amply dimensioned taper roll bearings.

The intermediate gear and the movable gears are carried in sturdy needle roller bearings.



6. SHAFT SEALS

External sealing of the input and output shafts is provided by radial sealing rings. The running surface on the shafts is casehardened.

7. LUBRICATION

The transmissions are immersion-lubricated. The bearings are generously supplied with splash oil and oil mist.

INSTALLATION

1. DELIVERY CONDITION

For safety reasons, the gearbox is NOT filled with oil for shipment. The actuating lever is mounted on the actuating shaft.

Before leaving the factory, each transmission is subjected to a test run with the prescribed ATF oil. The residual oil remaining in the transmission after draining acts as a preservative and provides reliable protection against corrosion for at least 1 year if the units are properly stored.

2. PAINTING THE GEARBOX

ALWAYS COVER THE RUNNING SURFACES AND SEALING LIPS OF THE RADIAL SEALING RINGS ON BOTH SHAFTS BEFORE PAINTING. Make certain that the breather hole on the oil filler screw is not closed by the paint. Indicating plates should remain clearly legible.

3. CONNECTION OF GEARBOX WITH ENGINE

A torsio-elastic damping plate between the engine and the transmission is to compensate for minor alignment errors and to protect the input shaft from external forces and loads. Radial play should be at least 0.5 mm.

4. SUSPENSION OF ENGINE-GEARBOX ASSEMBLY IN THE BOAT

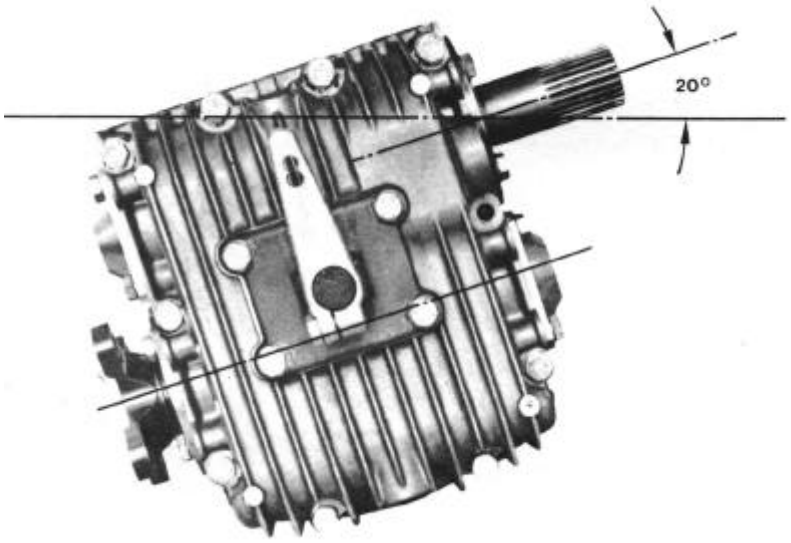
To protect the gearbox from detrimental stresses and loads, provision should be made for elastic suspension of the engine-gearbox assembly in the boat or craft.

The oil drain plug of the gearbox should be conveniently accessible.

5. POSITION OF GEARBOX IN THE BOAT

The inclination of the gearbox unit in the direction of the shafts should not permanently exceed an angle of 20 degrees (15 degrees for the V-drive model). (See illustration.)

The gearbox can also be mounted with the output shaft in the UPWARD position. Interchange the oil dipstick and the oil drain plug in this case.



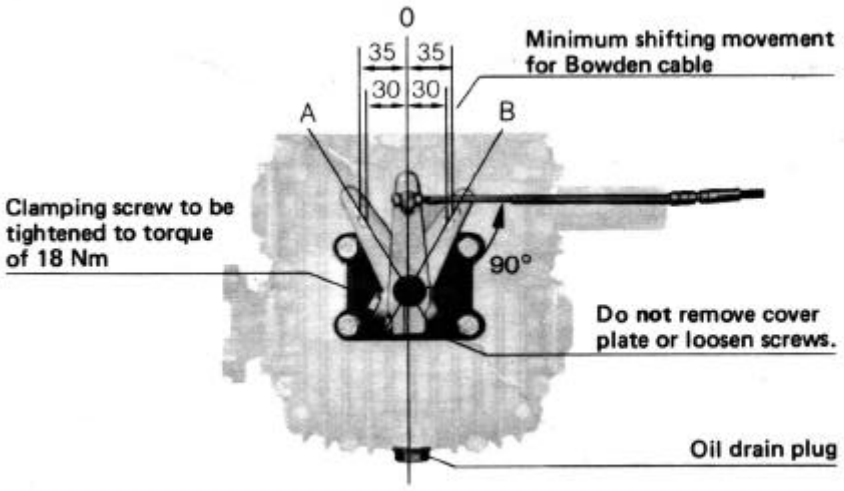
6. OPERATION OF GEARBOX

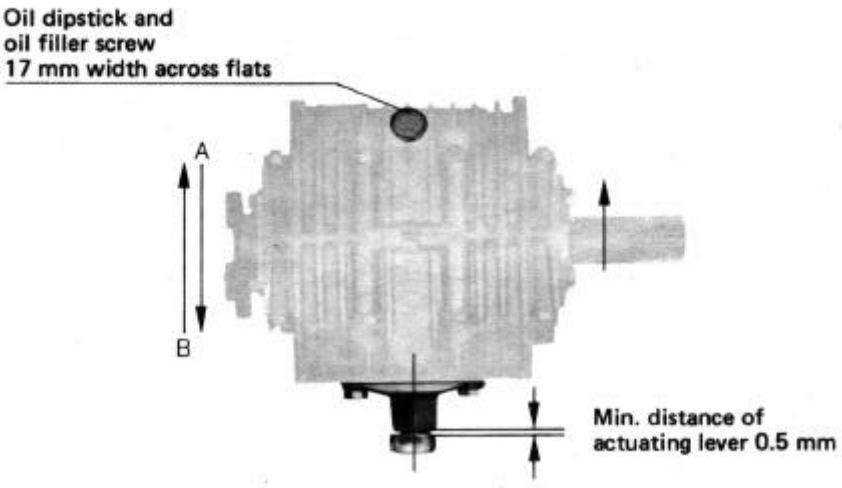
Gear changing requires only minimum effort. The gearbox is suitable for single lever remote control. Upon loosening the retaining screw, the actuating lever (see illustration) can be moved to any position required for the control elements (cable or rod linkage). Make certain that the lever does not contact the actuating lever cover plate (9): the minimum distance between lever and cover should be 0.5 mm.

The control cable or rod should be arranged at right angles to the actuating lever in the neutral position of the lever.

A larger amount of lever travel is in no way detrimental.

However, if the lever travel is shorter, proper gear engagement might be impeded which, in turn, would mean premature wear, excessive heat generation and resulting damage.





The position of the cover plate underneath the actuating lever is factory-adjusted to ensure equal lever travel from neutral position to A and B. Therefore, do not loosen the capscrews mounting this assembly.

When installing the gearbox, make certain that shifting is not impeded e.g. by restricted movability of the cable or rod linkage, by unsuitably positioned guide sheaves, too small bending radius, etc.

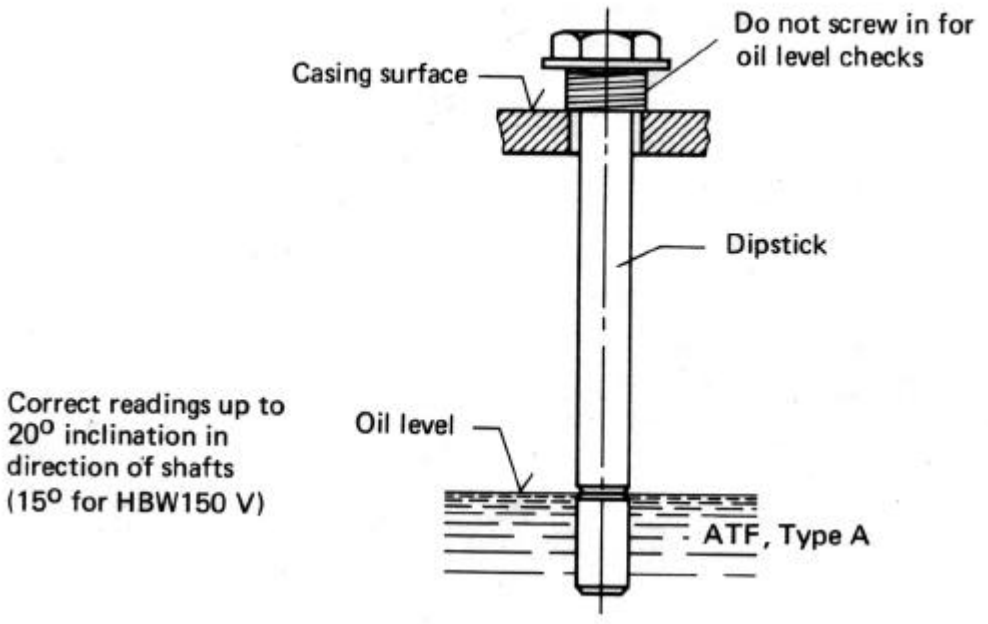
7. ENGINE-GEARBOX COMPARTMENT

Care should be taken that, the engine-gearbox compartment is properly ventilated.

OPERATION

1. INITIAL OPERATION

Fill the gearbox with automatic transmission fluid. The oil level should be the index mark on the dipstick (see illustration).



To check the oil level, just insert the dipstick; DO NOT SCREW IN. Retighten the hex screw with the dipstick after the oil level check. Do not omit the o-ring seal.

2. OPERATING TEMPERATURE

The maximum permissible temperature of the transmission oil is 130'C. If this temperature is to be exceeded, an optional oil cooler is available.

3. OPERATION OF GEARBOX

The zero position of the operating lever on the control console must coincide with the zero position of the actuating lever on the transmission. Shifting is initiated by a cable or rod linkage via the actuating lever and an actuating cam. The completion of the gear changing operation is servo-automatically controlled.

Gear changing should be smooth, not too slow, and continuous (without interruption). Direct changes from forward to reverse are permissible, since the multiple-disc clutch permits gear changing at high RPM, including sudden reversing at top speeds in the event of danger.

4. OPERATION WITHOUT LOAD

Rotation of the propeller without load, e.g. while the boat is sailing, being towed, or anchored in a river, as well as idling of the engine with the propeller stopped, will have no detrimental effects on the gearbox.

Locking of the propeller shaft by an additional brake is not required, since locking is possible by engaging the reverse gear. Do not sail while engaged in forward.

5. LAY-UP PERIODS

If the transmission is not used for periods of more than 1 year, it should be COMPLETELY filled with oil of the same grade to prevent corrosion. Protect the input shaft and the output flange by means of an anti-corrosive coating if required.

6. PREPARATION FOR RE-USE

Drain the transmission of all oil and refill to the proper level with the prescribed oil.

MAINTENANCE

1. TRANSMISSION OIL

To ensure trouble-free operation of the clutch, use only automatic transmission fluid (ATF).

Under no circumstances should the oil contain any additives such as molybdenum sulphite.

We recommend commercial Automatic Transmission Fluid (ATF), Type A or Dexron II.

2. OIL QUANTITY

HBW 5 approximately 0.4 liter
HBW 10 approximately 0.6 liter
HBW 20 approximately 0.8 liter
HBW 50 approximately 0.3 liter
HBW 100 approximately 0.35 liter
HBW 150 approximately 0.55 liter
HBW 150V approximately 1.0 liter
HBW 220 approximately 0.75 liter
Use the index mark on the dipstick as a reference.

3. OIL LEVEL CHECKS

Check the oil level in the transmission daily. Correct oil level is the index mark on the dipstick (see item 1 under OPERATION). Always use the same oil grade when topping up.

4. OIL CHANGE

Change the oil for the first time after about 25 hours of operation, then at intervals of at least onceaper year.

5. CHECKING THE CABLE OR ROD LINKAGE

The cable or rod linkage should be checked at shorter time intervals. Check the zero position of the operating lever (on the control console) and of the actuating lever (on the gearbox) on this occasion. The minimum lever travel from the neutral position to the operating positions (0-A = 0-B) should be 35 mm for the outer and 30 mm for the inner pivot point. Make certain that these minimum values are safely reached. Check the cable or rod linkage for easy movability (see item 6 under INSTALLATION).

6. OVERHAUL

Disassembly of the transmission in the field is not recommended. If an overhaul or repair is needed, the work should be done by Westerbeke or an authorized Westerbeke service center.

BW TRANSMISSIONS
(BW3, BW&, BW12)

These manual transmissions rotate opposite to the engine when in forward gear. Shifting effort is very low. The input power on the BW3 is transmitted to the output shaft by helical spur gears when in forward. In reverse this task is taken over by a high performance roller chain. The unit also incorporates a servo cone-type clutch. The BW7 and BW12 transmit their power with casehardened helical gears and in reverse there is an intermediate gear. The reversing process on these is carried out by a servo double disc system.

LUBRICATION

1. Fill the transmission with 20 to 40 SAE weight engine oil, the same as is used in the engine.
2. Oil capacity
   BW3 approximately 0.35 liter BW7 approximately 1.0 liter
   BW12 approximately 1.0 liter
3. Check the oil level daily with the engine stopped. The level must be between the upper and lower dipstick marks when the dipstick is completely screwed/inserted into the housing.
4. Change the oil initially after the first 30 hours, thereafter every 250 hours, once per year minimum. The BW7 and BW12 have a drain plug for oil removal. Oil may also be removed by suction through the dipstick tube, where oil is added.
5. Operating oil temperature must not exceed 120'C (250'F).

OPERATION

1. Normal shifting should be done below 1500 RPM.
2. The BW3 may be locked in reverse when sailing or freewheeled in neutral.
3. The BW7 and BW12 may be locked in either forward or reverse when sailing or freewheeled in neutral.

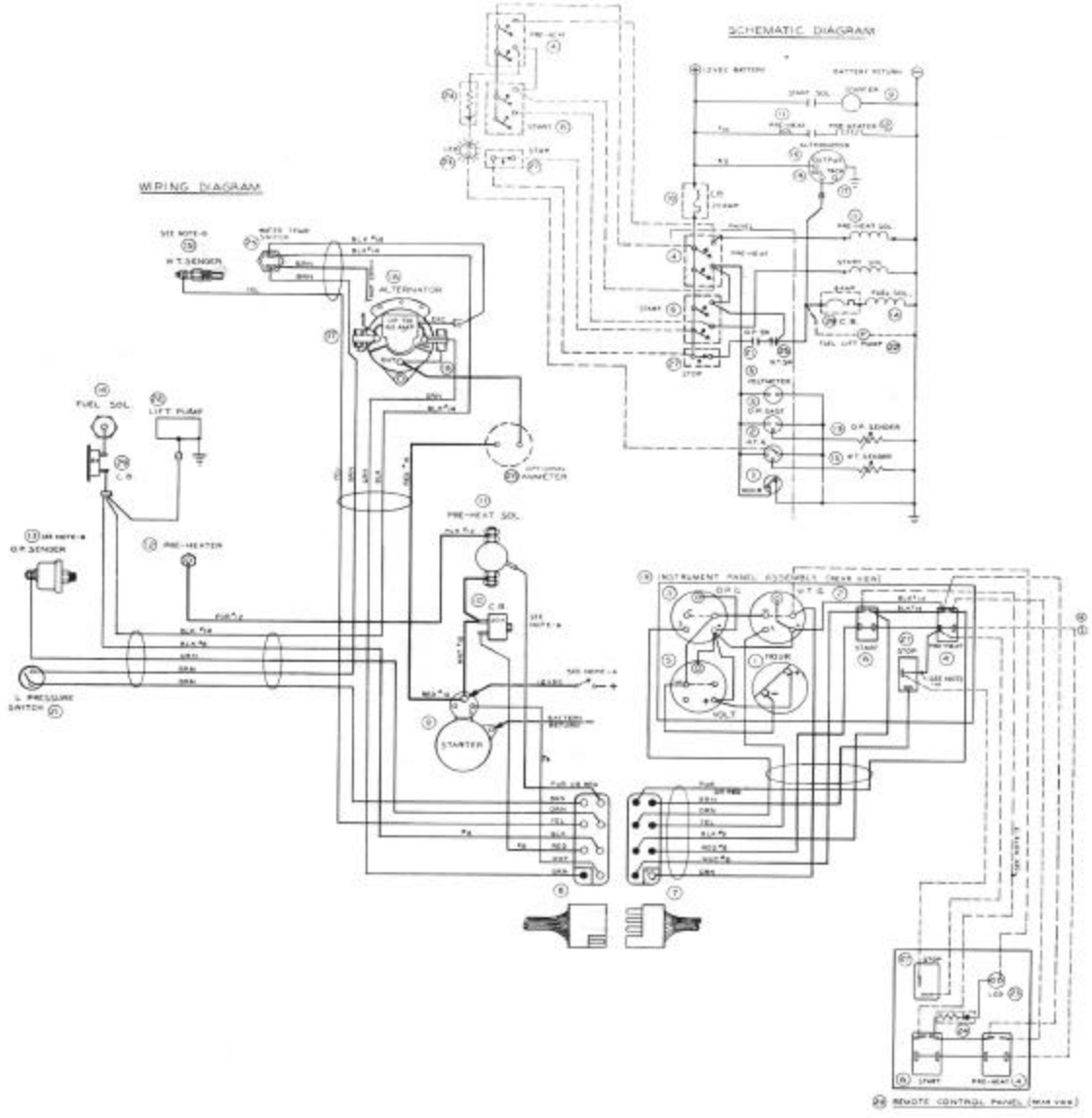
SERVICE

1. Never loosen the shift lever cover screws, except in the course of qualified servicing, as this upsets a critical adjustment.
2. Disassembly of the transmission in the field is not recommended. If an overhaul or repair is needed, the work should be done by Westerbeke or an authorized Westerbeke service center.

SECTION T

GENERATOR SETS

MANUAL STARTER DISCONNECT (TOGGLE SWITCHES)



MANUAL STARTER DISCONNECT (TOGGLE SWITCHES)

GENERAL:

This manually controlled series of Westerbeke marine diesel generators is equipped with toggle switches on the engine control panel and, optionally, at remote panels. The following instructions and methods of correcting minor problems apply only to such toggle switch controls.

All three switches are momentary contact type and serve the following functions:

1. Preheat: The PREHEAT/DEFEAT toggle switch is a double pole, single throw switch. The switch serves two purposes: preheating the engine for easy starting and defeating or bypassing the engine protective oil pressure switch. The defeat function turns on the fuel solenoid, instrument power and alternator excitation.

2. The START/DEFEAT toggle switch is a double pole, single throw switch. The switch also serves two purposes: starting the engine and defeating or bypassing the oil pressure switch. The latter pole serves the same function as in the preheat switch.

3. Stop: The STOP toggle switch is a single pole, single throw, normally closed switch. This switch provides power to the fuel solenoid, instrument cluster and alternator excitation, after the oil pressure switch has closed upon starting. Opening of this switch opens the power circuit to the fuel solenoid, thus stopping the flow of fuel to the engine and stopping the engine.

ENGINE OPERATION:

1. Preheat: Depress the PREHEAT switch. The voltmeter, panel lights, gauges and meters and fuel solenoid will activate. The PREHEAT switch should be depressed for twenty seconds in conjunction with thermostats (installed in intake manifold) and forty to sixty seconds in conjunction with glow-plugs.

2. Start: While still depressing the PREHEAT switch, depress the START switch. This will engage the start solenoid. Panel power and the fuel solenoid will be activated. Upon engine firing, release the start switch. Do not release the PREHEAT switch until oil pressure reaches 15 psi. Then as long as the high water temperature and low oil pressure protective circuit does not activate, the set will remain energized and continue to run.

3. Stop: Depress the STOP switch to stop the engine. This opens the power feed to the fuel solenoid, stopping the fuel flow to the engine. It must be depressed until the generator stops rotating..

REMOTE ENGINE OPERATION:

For remote operation of the generator system, the same three switches are used. The PREHEAT and START switches are connected in parallel with the local panel switches and serve the same functions as in the local panel. The STOP switch is in series with the local panel STOP switch, and serves the same functions as in the local panel. The generator may be stopped from local or remote positions.

AC GENERATORS:

Once the diesel generator sets have been placed in operation, there is little or no control adjustment required by the A.C. Generator. When starting the generator, it is always a good plan to switch off all A.C. loads, especially large motors, until the engine has come up to speed and, in cold climates, starts to warm up. These precautions will prevent damage by unanticipated operation of A.C. machinery and prevent a cold engine from being stalled.

OVERSPEED (If equipped with this option):

If the engine governor loses control and the engine speed accelerates, a relay is actuated that de-energizes the fuel solenoid and stops the engine. A red light on the panel illuminates and remains lighted. To extinguish the light, reset the overspeed relay by depressing the engine STOP switch. When the reason for the overspeed shutdown is corrected, the engine is ready to be restarted.

TROUBLESHOOTING

MANUAL STARTER DISCONNECT (TOGGLE SWITCHES)

CIRCUIT PROTECTION:

The engine control system is protected by a 20 amp manual reset circuit breaker located on the engine as close as possible to the power source. An additional circuit breaker is located at the fuel solenoid (P/N 23041) when this solenoid is used. (This solenoid is not used on models which have a solenoid built into the injection pump.)

Manual Control (toggle switch) troubleshooting:

Problem	Probable Cause	Verification
Preheat depressed, no panel indications, fuel solenoid not energized.	Battery switch or power not on	Check switch and/or battery connections
	20 amp circuit breaker tripped	Reset breaker if opens again again, check preheat solenoid circuit and "run" circuit for shorts to ground.
Start depressed, no panel indications, fuel solenoid not energized. Start solenoid not engaged.	Battery switch or power not on	Check switch and/or bat-tery connections.
	20 amp circuit breaker tripped	Reset breaker. If opens again check start sole noid circuit and "run" circuit for shorts to ground.
Start depressed, panel indications O.K. Start solenoid O.K. Fuel solenoid not functioning.	Fuel solenoid (P/N 23041) circuit breaker tripped	1. Check mechanical positioning of fuel solenoid for plunger bottoming. 2. Reset breaker and repeat start cycle. 3. If repeated trip ping, check for defec tive breaker or fuel solenoid.
No ignition, cranks, does not start. Fuel solenoid energized.	Faulty fueling system	1. Check for fuel to generator system. 2.Check for air in fuel system (bleed system). 3. Fuel lift pump failure.

Battery runs down	High resistance leak to ground	Check wiring. Insert sensitive (0-.25 amp) meter in battery lines. (Do not start engine.) Remove connections and replace until short is located.
	Low resistance leak to ground	Check all wires for temperature rise to locate fault.
	Alternator	Disconnect alternator at output, after a good battery charging. If leakage stops, replace alternator protective diode plate. That failing, replace alternator.

4.4 - 7.7 - 11.1 - 12.5 KW GENERATOR SETS

TECHNICAL DATA

4.4KW	115 VAC	34.7 AMP at 115 VAC
7.7 KW	115 or 115/230 VAC	33.5 AMP at 230 VAC
11.1KW	115 or 115/230 VAC	48.2 AMP at 230 VAC
12.5KW	115 or 115/230 VAC	54.3 AMP at 230 VAC

Frequency 60 Hz

RPM 1800

Voltage

Normal	115 VAC	230 VAC
Maximum - No load	132 VAC	264 VAC
Minimum - Full load	108 VAC	216 VAC

Excitation Voltage 115 VAC

Separately Excited 12 VDC to Field (Approximately 50 to 70 VAC)

Field Coil Resistance

4.4KW	32.5ohms +/-1.7 ohms
7.7KW	22.2 ohms +/-1.2 ohms
11.1KW	14.2 ohms +/-0.7 ohms
12.5KW	14.2 ohms +/-0.7 ohms

Armature resistance Less than 1 ohm Ring to Ring (1-3 and 2-4)

TROUBLESHOOTING

No output	Check for loose or open connections Check rectifier Check winding resistance, opens and grounds Separately excite and check output
Low voltage - no load	Check speed (1800 RPM nominal) Check generator load Check for loose connections Check rectifier Check winding resistance
Low voltage - full load	Check speed (1800 RPM nominal) Check generator load Check for loose connections Check winding resistance

FLASHING THE FIELD

The generator is equipped with a silicon rectifier for excitation and to flash the field, connect a 12 volt battery between ground and the cathode (terminal with red dot) of the rectifier. Note: only touch the rectifier terminal for a moment.