TECHNICAL MANUAL

WESTERBEKE 40
Marine Diesel Engine

WESTERBEKE WPDS
Marine Diesel Generators

Publication #20502

Edition 8

July 1980

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WESTERBEKE CORPORATION
MYLES STANDISH INDUSTRIAL PARK
150 JOHN HANCOCK ROAD, TAUNTON, MA 02780-7319

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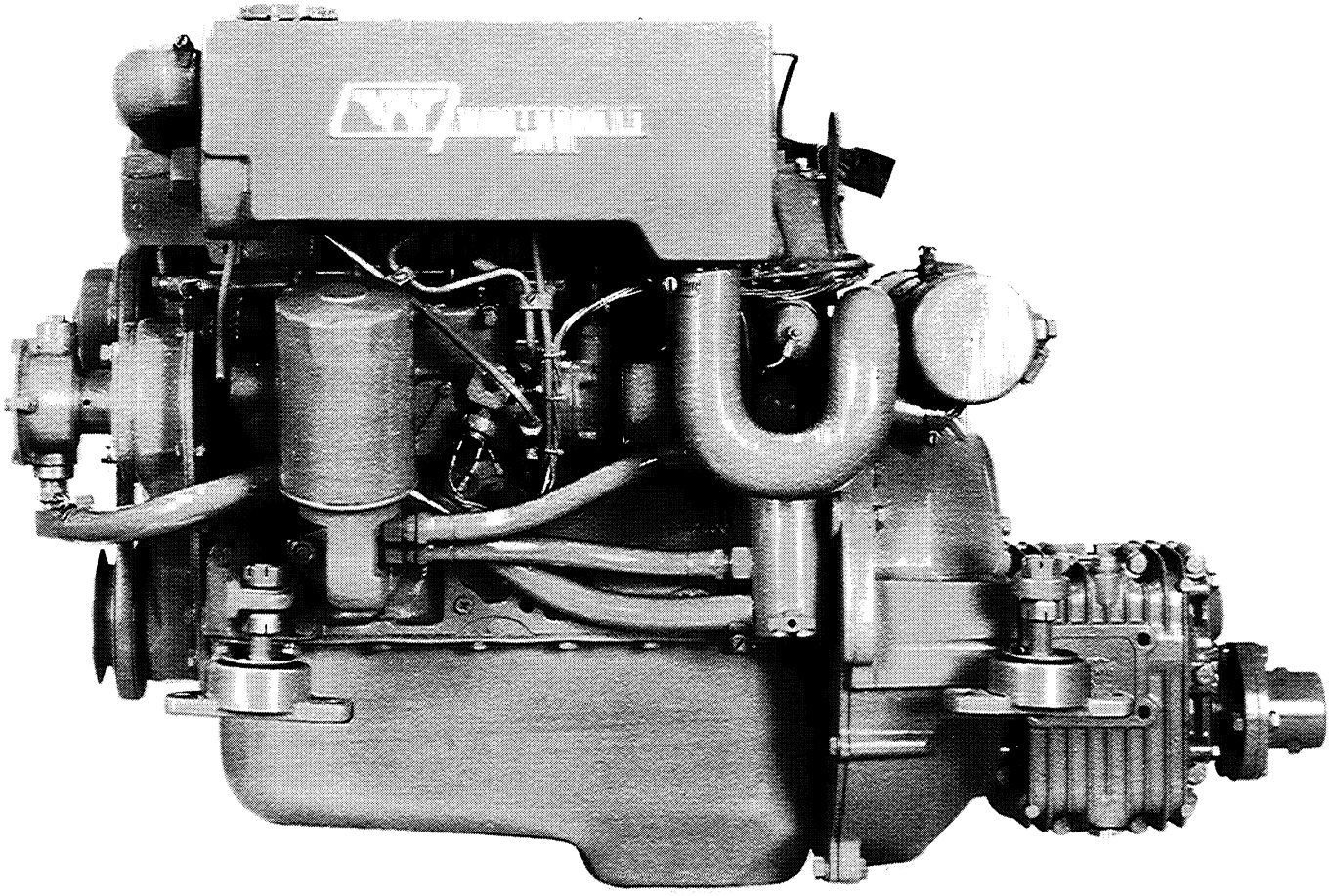
WESTERBEKE 40

This marine diesel engine, previously designated WESTERBEKE Four-107, incorporates a basic engine model known variously as 4-99, 4-107, and 4-108. You will notice continual references to the latter three engine model numbers througout the workshop portion of this manual. They are used to distinguish among the three major engineering changes already made to the engine.



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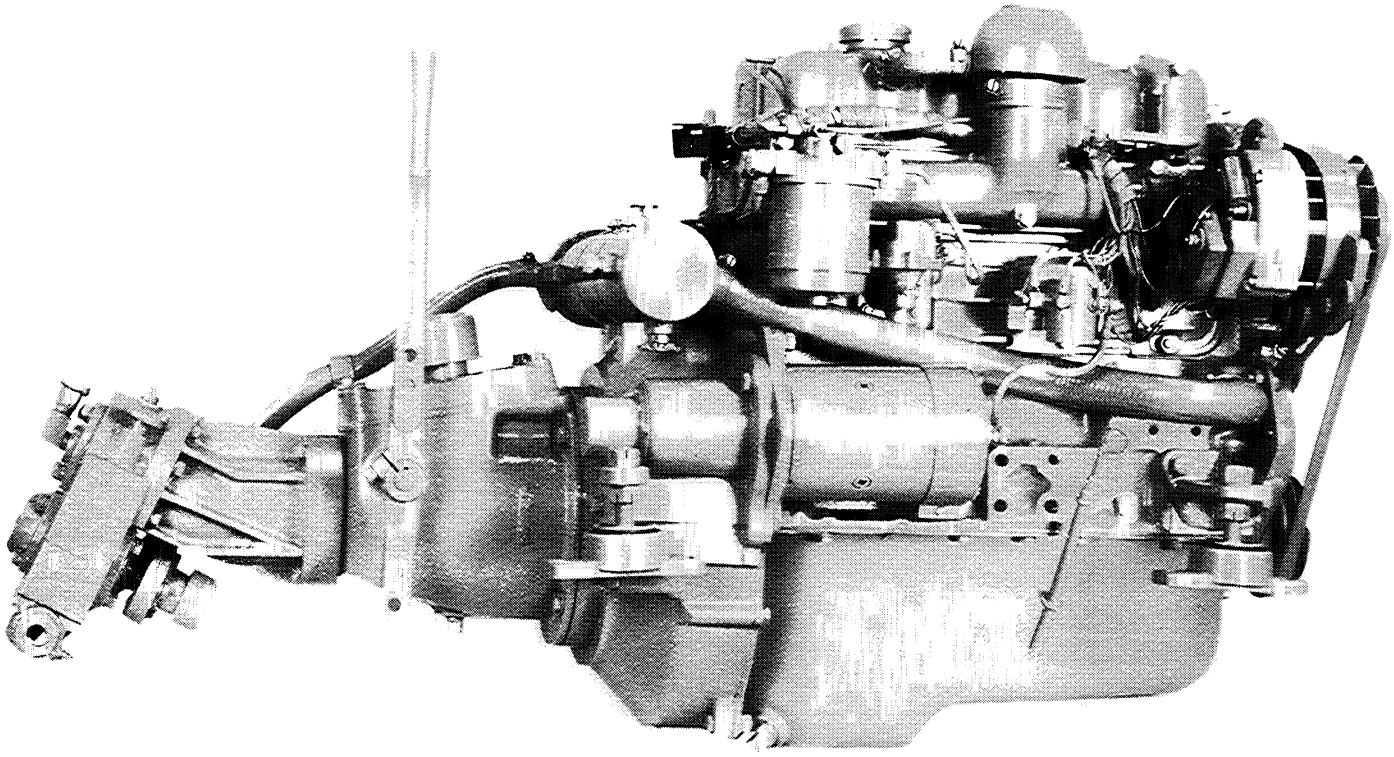

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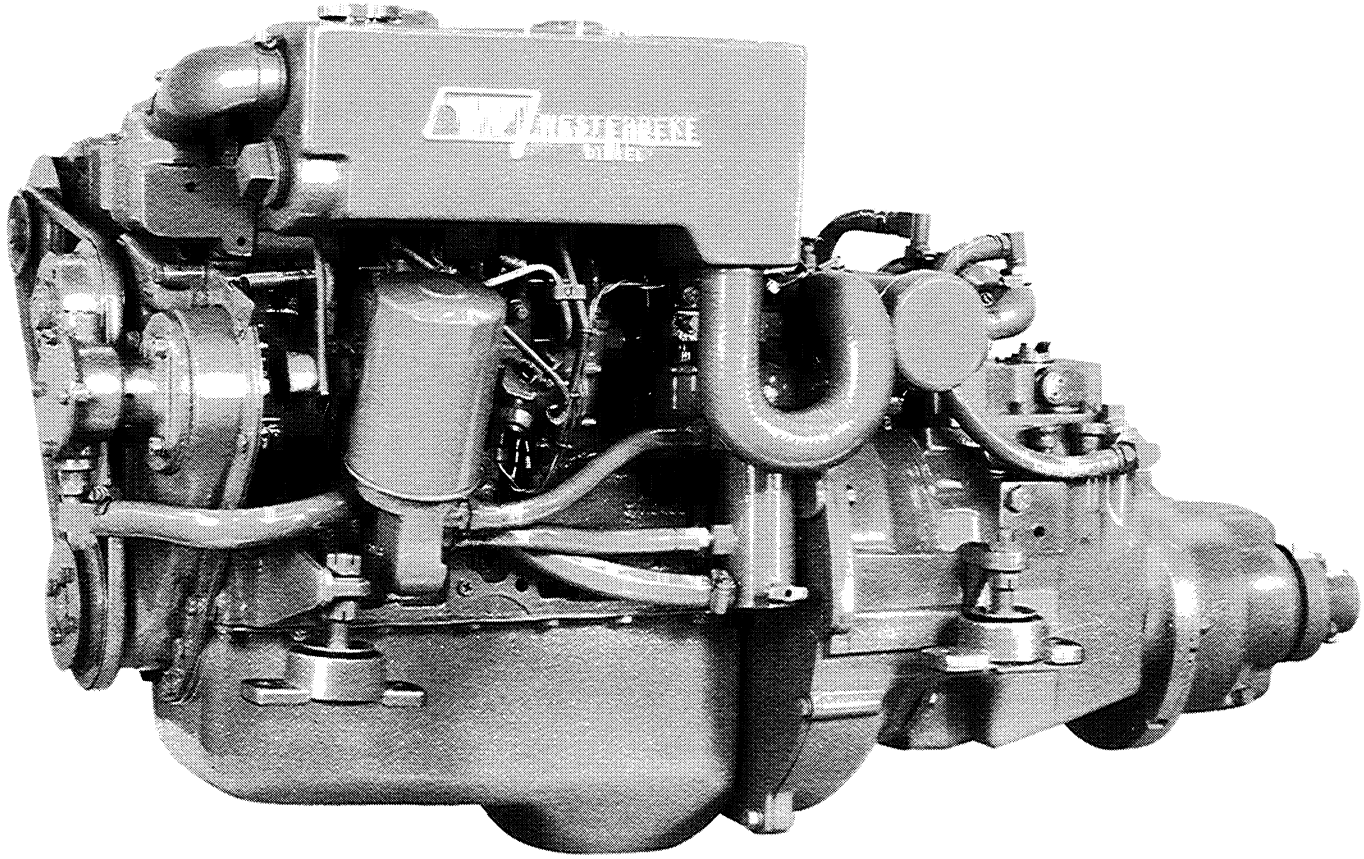

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INTRODUCTION

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 IT !
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.

YOUR NOTES

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 carrier, 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^{o} 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

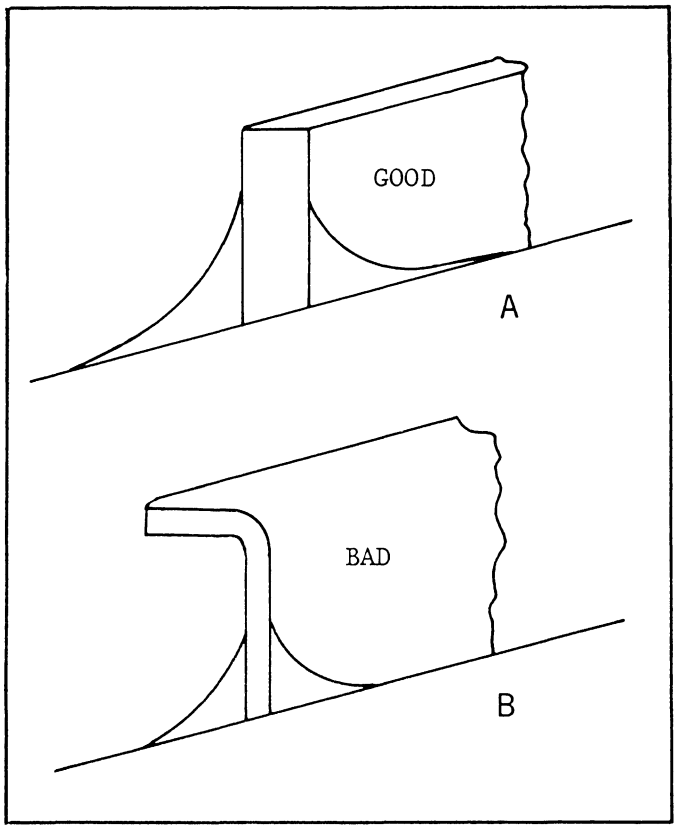
It is recommended that bronze hanger bolts of appropriate size be used through the engine flexible mounts. Lag screws are less preferred because their hold on the wood is weakened every time they are moved, whereas the lag bolt stays in position and the nut on top is used to tighten the engine down or 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 fiberglas 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 fiberglas "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 for 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 shaft 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 shape 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 align-

ment 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.

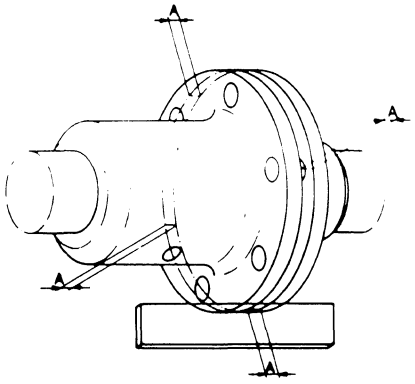
One particularly annoying result of misalignment may be leakage of transmission oil through the rear oil seal. Check to make sure that alignment is within the limits prescribed.

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 tank 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 can be slipped backwards 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° 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° 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 in 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 realign at a further period.

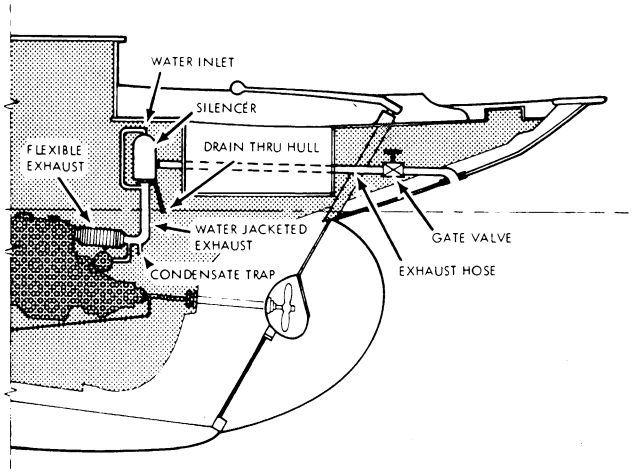
The coupling should always be opened up and the bolts removed whenever the boat is hauled out or moved from the land to the water, and during storage in a cradle. The flexibility of the boat often puts a very severe strain on the shaft or the coupling or both when it is being moved. In some cases the 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

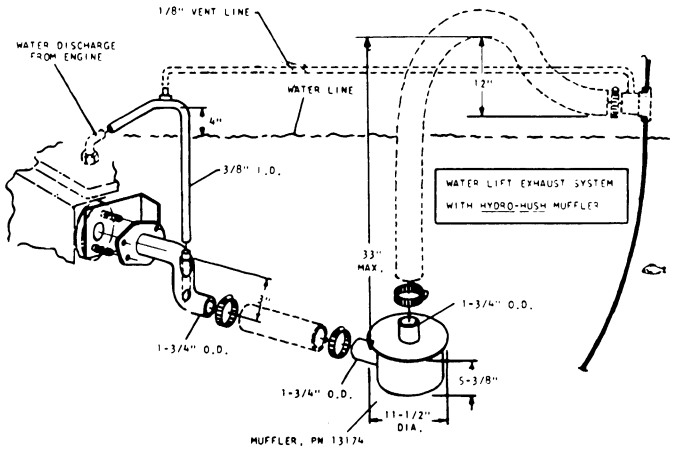
cause rapid deterioration. Galvanized iron fittings and galvanized iron pipe is recommended for the exhaust line. The exhaust line must be at least as large as the engine exhaust manifold flange and be increased in size if there is an especially long run and/or many elbows. It should be increased by 1/2" in I.D. for every 10 feet beyond the first 10 feet.



EXHAUST SYSTEM WITH WATER JACKETED STANDPIPE

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.

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 (4kg).



WATER LIFT EXHAUST SYSTEM WITH "HYDRO-HUSH" MUFFLER

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 the manifold outlet and the exhaust system.

The exhaust system must be supported or suspended independently of the engine manifold, 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

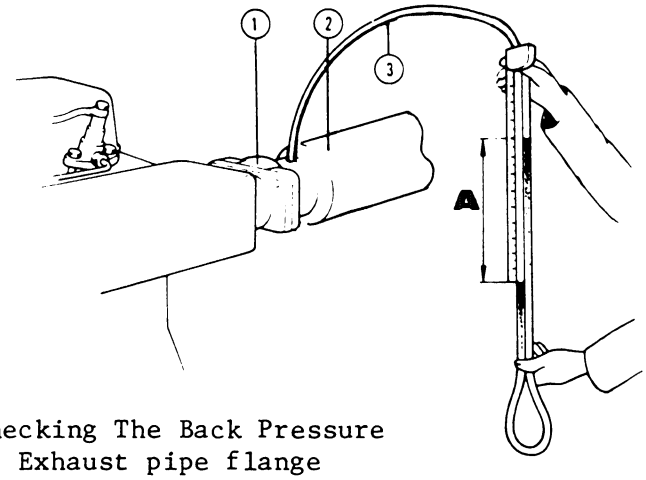
Back pressure must be measured on a straight section of the exhaust line and as near as possible to the engine exhaust manifold. The engine should be run at maximum load during the measurement period. Set-up should be as shown below.

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 any 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's being realigned. 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 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 recommended 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/cicuit 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 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 travel, 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 W52.

OPERATION

PREPARATION FOR FIRST START

The engine is shipped "dry"...with lubricating oil drained from the crankcase and 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. Oil level for the Short Profile Sailing Gear is measured before threading the dipstick into the housing.

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 on the V drive housing.

3. Fill fresh water cooling system with a 50-50 anti-freeze 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 en-

gine 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 R.P.M.) (Figure 1)

1. With the use of a 5/16 box wrench or common screw driver, open the bleed screw one to 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 & WPO 10, 12½, 15, (Figure 3)
W50 & WBO 15, (Figure 4)
W80 & BR 30, (Figure 5)
W120 & BR45, (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 to 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 W-30 injection pump.)

4. W50 injection pump only Open the 5/16 bleed screw (Bleed Point D) on the injector line banjo bolt one to 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.

5. 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 (Figure 6)
W21 & 7.7KW (" ")
W27 & 11KW (" ")
W33 (" ")

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 10mm 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 keeps 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.

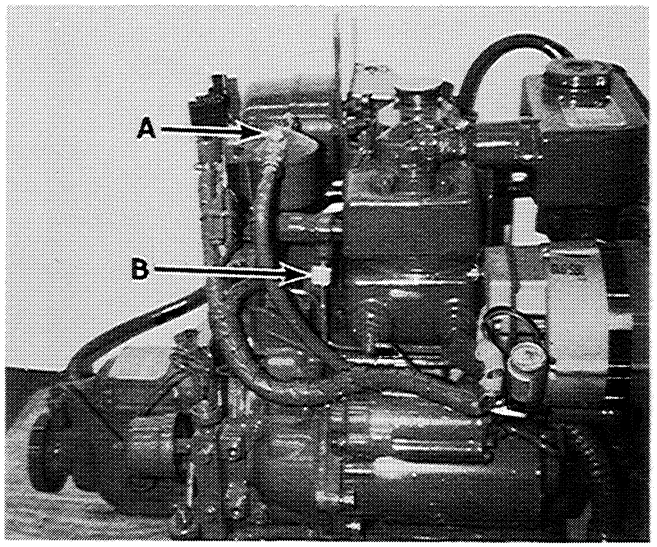


Figure 1

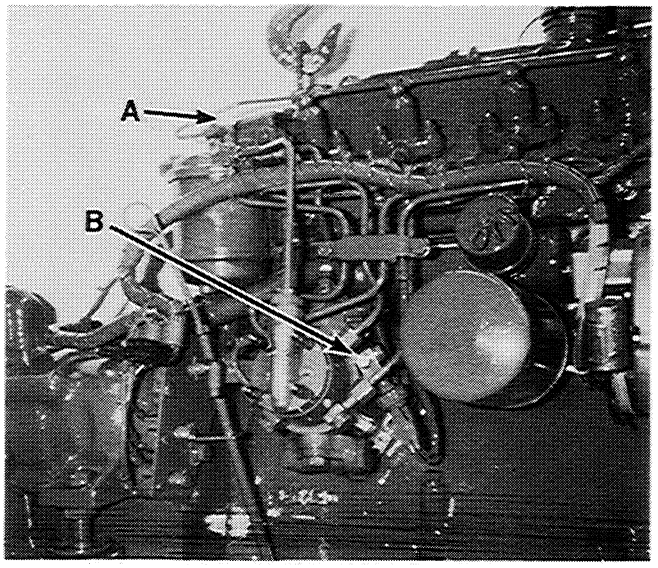


Figure 2

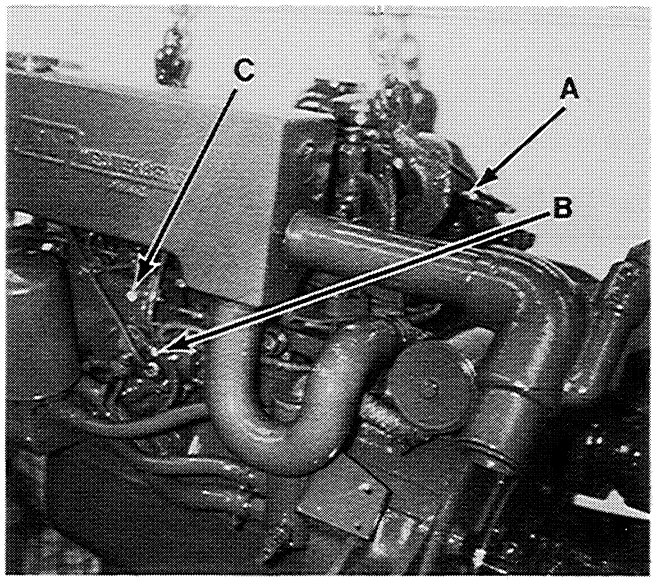


Figure 3

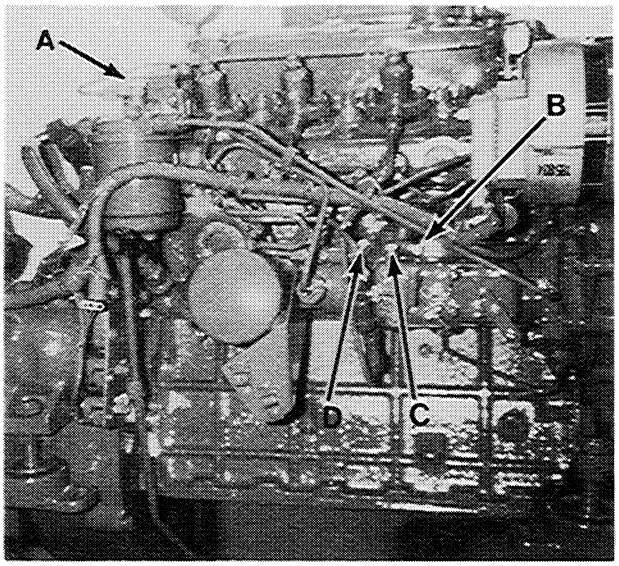


Figure 4

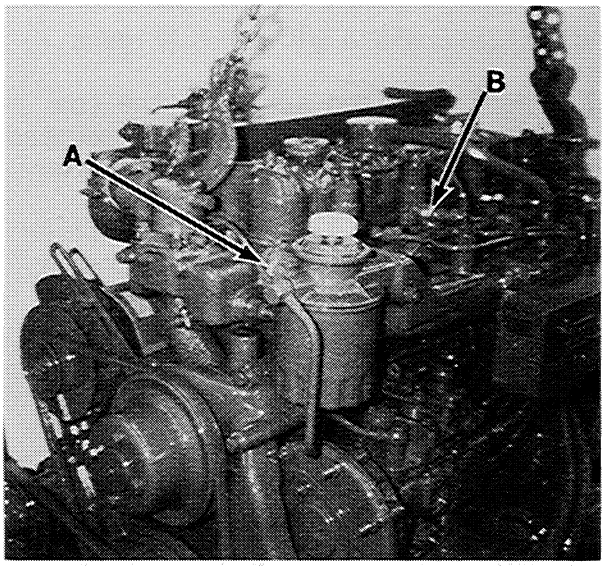


Figure 7

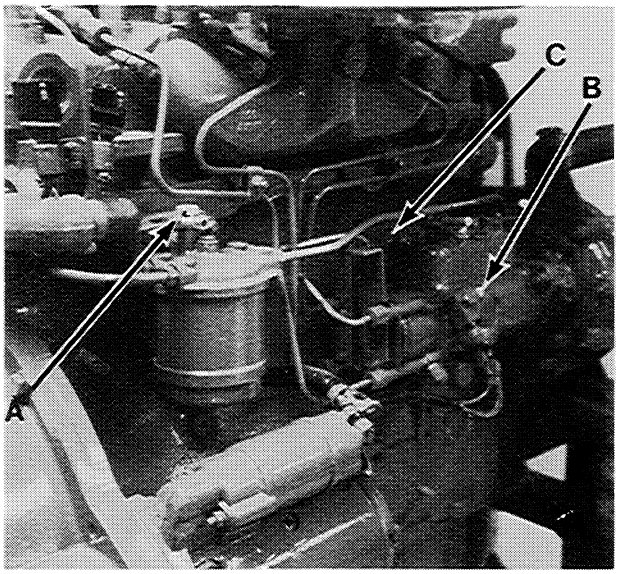
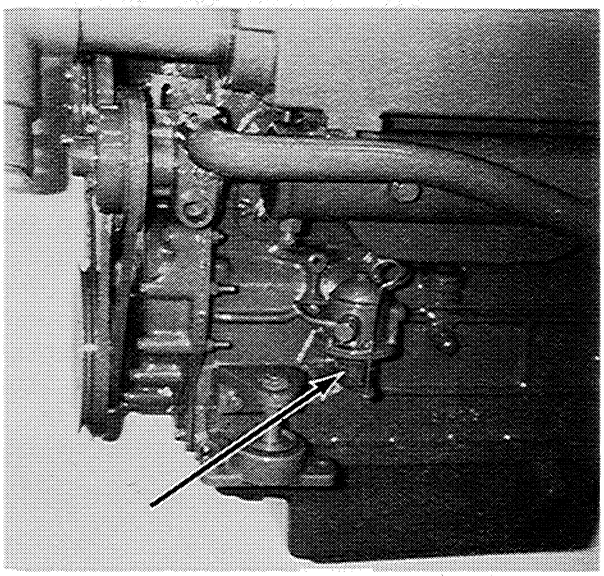


Figure 5



Typical Mechanical Fuel Lift Pump

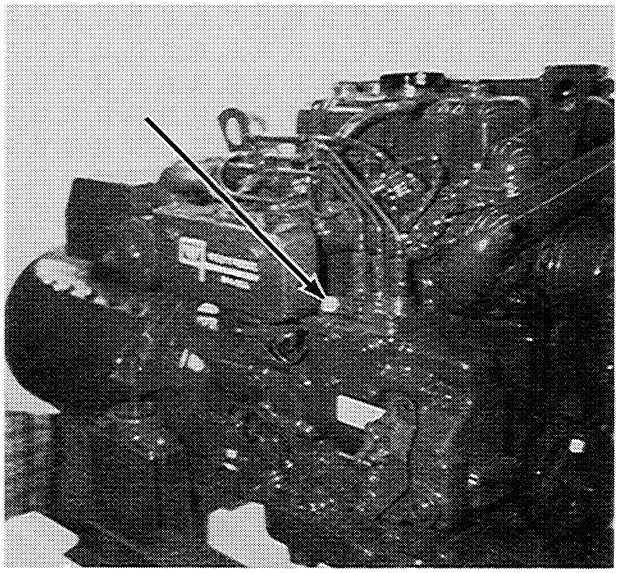


Figure 6

PREPARATION FOR STARTING

1. Check water level in expansion tank. It should be 1½ to 2 in. below the top of the tank when cold.

2. Check the engine sump oil level.

3. Check the transmission oil 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 keyswitch 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 keyswitch to the "Start" position and hold for no more than 20 seconds. Some units may be equipped with a pushbutton to start rather than the keyswitch and in these cases the electrical system is activated by fuel pressure.

5. If the engine fails to start in 20 seconds, release start switch and preheat for an additional 15-20 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 any one 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 for 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 to fill the engine's internal oil passages and oil filter. Add oil as necessary. Check oil level each day of operation.

4. Recheck Transmission Oil Level. (This applies only subsequent to an oil 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 oil as necessary. Check oil 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 temp. gauge indicates 130-150°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.

7. Reverse Operation. Always reduce engine to idle speed when shifting gears. However, when the transmission is engaged, it will carry full engine load.

NOTE: The SAO transmission requires that when backing down, the shift lever must be held in the reverse position, since it has no positive overcenter locking mechanism.

STOPPING THE ENGINE

1. Position shift lever in neutral.

2. Idle the engine for 2 to 4 minutes to avoid boiling and to dissipate some of the heat.

3. If equipped with a stop lever, pull the knob and hold in this position until the engine stops. This stops the flow of fuel at the injection pump. After the engine stops, return the control to the run position to avoid difficulty when restarting the engine.

4. Turn off the keyswitch. Some models do not use the stop lever as they are equipped with a fuel solenoid or electric fuel pump which shuts off the fuel supply when the keyswitch is turned to the off position.

5. Close the seacock.

6. Disconnect power to system with battery switch.

OPERATING PRECAUTIONS

1. Never run engine for extended periods when excessive overheating occurs, as extensive internal damage can be caused.

2. DO NOT put cold water in an overheated engine. It can crack the cylinder head, block, or manifold.

3. Keep intake silencer free from lint, etc.

4. Do not run engine at high RPM without clutch engaged.

5. Never Race a Cold Engine as internal damage can occur due to inadequate oil circulation.

6. Keep the engine and accessories clean.

7. Keep the fuel clean. Handle it with extreme care because water and dirt in fuel cause more trouble and service life of the injection system is reduced.

8. Do not allow fuel to run low, because fuel intake may be uncovered long enough to allow air to enter the injection system, resulting in engine stoppage requiring system bleeding.

9. 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 IMPORTANT IMPORTANT

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

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° 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:

FIFTY HOUR CHECKOUT (INITIAL)
Do the following:

1. Retorque the cylinder head bolts.
2. Retorque 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 SA0 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 mount fittings. These could cause mis-alignment.

DAILY CHECKOUT
Do the following:

1. Check 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 lubricating oil level in transmission. Fill to highest mark on dipstick.

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

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

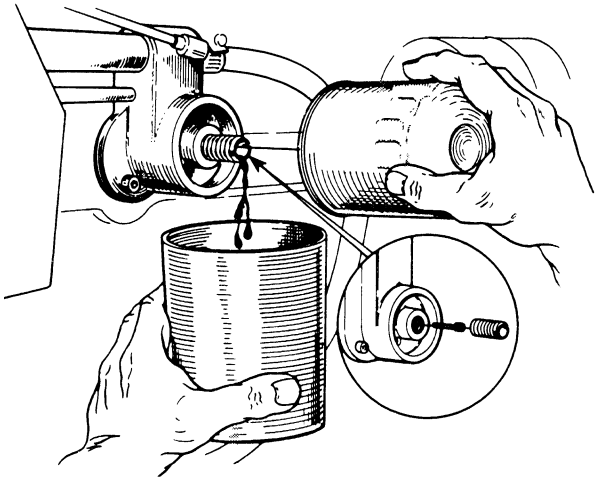


FIGURE 2

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. Change oil in transmission. Use SAE 30, High Detergent Lubricating Oil, Service DG, DM, or DS. Do not overfill. See note below.

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. Clean Air Filter if supplied. (Most models have an air silencer that does not require filtering material and therefore 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 to be cleaned more frequently.
11. Replace secondary fuel filter element.
12. Replace air filter.

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. Remove air filter. 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 oil in transmission.
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 Specification 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.

COMPANY	BRAND	S.A.E. DESIGNATION		
		0°/45°F	45°/80°F	OVER 80°F
American Oil Co.	American Supermil Motor Oil	10W	20W/20	30
BP Canada Limited	BP Vanellus	10W	20W/20	30
	BP Vanellus	10W/30	10W/30	10W/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
Mobile 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

YOUR NOTES

ENGINE OVERHAUL

The following sections contain detailed information relating to the proper operation characteristics of the major components and systems in 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.

CONTENTS SECTION

ENGINE DESCRIPTION..... A
TECHNICAL DATA..... B
FAULT DIAGNOSIS..... D
CYLINDER HEAD..... E
PISTON AND CONNECTING RODS..... F
CYLINDER BLOCK LINERS..... G
CRANKSHAFT & MAIN BEARINGS..... H
FLYWHEEL AND HOUSING..... J
TIMING CASE AND DRIVE..... K
TIMING..... L
LUBRICATION SYSTEM..... M
COOLING SYSTEM (INTERNAL)..... N
FUEL SYSTEM..... P

SECTION A
Engine Description

The 4.108, 4.107 and 4.99 Series Diesel Engines with which this manual is concerned is an indirect injection, four cylinder, four stroke power unit.
The 4.108 and 4.107 has a bore of 3.125 in (79,4 mm) and a stroke of 3.5 in (88,9 mm), and the 4.99 has a bore of 3.0 in (76,2 mm) and a stroke of 3.5 in (88,9 mm).

Throughout this manual, whenever the "left" or "right" hand side of the engine is referred to, it is that side as viewed from the flywheel end of the engine.

Cylinder Block and Crankcase

The cylinder block is of monoblock construction, cast integrally with the crankcase, it is manufactured from high duty cast iron alloy.

The 4.108 engine is fitted with "dry" type, unshouldered thinwall liners, and the 4.107 and 4.99 engines are fitted with "wet" liners, flanged at the top and sealed at the bottom by two synthetic rubber rings located in the cylinder block.
Both liner types are centrifugally cast from high duty alloy iron.

Cylinder Head and Valves

The cylinder head is a specially toughened high duty allow casting and is secured to the cylinder block by studs and nuts, both are phosphated for increased torque characteristics. The joint between the cylinder head and block is made from a black composite material and is known as a 'Klinger' type gasket.

Two overhead valves are fitted to each cylinder, push rod operated via the valve mechanism mounted on the head and enclosed by a pressed steel cover. Each inlet valve has a synthetic rubber oil deflecting seal, both inlet and exhaust valves are retained by two springs located between a hardened steel seat and a hardened spring cap secured by split conical collets. All valves operate in unshouldered cast iron guides pressed into the head.

Combustion System

The 'H' system of combustion is known as the pre-combustion type, being formed completely in the cylinder head, thus giving a flat topped piston with uniform heat distribution. Intimate mixing of the fuel and air over a wide speed range is ensured, which increases the engines performance, efficiency and flexibility. The upper part of the combustion chamber is machined in the cylinder head and is hemispherical in shape: the lower part being formed by an insert in the form of an accurately machined plug located in the cylinder head, this contains the throat connecting the combustion chamber to the cylinder. Fuel is introduced into this chamber by means of pintle type atomiser nozzles.

Valve Mechanism

The valves are operated by cast iron, mushroom type tappets, located in guides machined in the cylinder block, through pushrods to forged steel rocker levers with lead bronze lined, steel backed wrapped bushes. Valve clearances are adjusted by means of a hardened ball ended screw and locknut at the pushrod end of the rocker lever.

Crankshaft

The crankshaft is forged from chrome-molybdenum steel with four integral balance weights. The 4.108 crankshaft is treated by "Tufftride" process. The rear of the crankshaft is machined to accommodate the thrust washers which are replaceable, copper lead lined, steel backed, which control the crankshaft end float and are positioned either side of the rear main bearing. An oil thrower and flywheel location flange are also machined at the rear end, while the front end is keyed for a power take off.

Main Bearings

Three main bearings are provided for the crankshaft and are of the replaceable pre-finished, thin wall, steel backed, aluminium tin lined type. The high duty cast iron bearing caps are dowel located and each is secured by two high tensile steel setscrews locked by tab washers.

Camshaft

The special cast iron alloy camshaft which has chill hardened cams, is mounted in a low position on the right hand side of the cylinder block and supported by three bearings machined directly into the cylinder block. These bearings are pressure lubricated by means of internal drillings and the cams and tappets are splash lubricated.

Connecting Rods and Bearings

The connecting rods are molybdenum alloy steel stampings with 'H' section shank, the big end parting face is inclined at 45° to the axis of the rod and serrated for cap location. The caps are each secured by two high tensile steel setscrews. The big end bearing bores are fitted with replaceable pre-finished thin wall, aluminium-tin lined, steel backed bearings. The small end bores being fitted with bronze lined steel backed bushings.

Timing Gear Arrangement

The camshaft and fuel injection pump are driven by the crankshaft gear via an idler gear. This helical gear train which makes provision for fuel pump timing adjustments is located on the front face of the cylinder block and enclosed by a pressed steel cover bolted to a steel backplate.

The camshaft and fuel injection pump drive gears are manufactured from spheroidal graphite cast iron, the crankshaft and idler gears being of steel treated by the Sulfinuz or Tufftride process.

Pistons and Piston Pins

The pistons are manufactured from special high silicon aluminium alloy, fitted with three compression rings and one oil control ring above the piston pin and one oil control ring below. The upper oil control ring comprises four laminated segments. The piston pins are of the fully floating type, located axially in the piston by circlips. The piston has a steel insert rolled into the top groove.

Lubrication System

The lubrication of the engine is by full pressure feed from a rotor type oil pump, driven by spiral gears from the camshaft. An oil strainer is fitted on the end of the pump inlet pipe, the pump then delivers the oil via a full flow filter, bolted on the fuel pump side of the cylinder block to the main oil gallery. This gallery is drilled lengthwise through the crankcase, drillings from the main oil gallery to the main bearings and drillings in the main crankshaft journals to the crankpin journals provide the lubrication for the crankshaft. Oil feeds are also taken to the idler gear spigot which maintains an intermittent feed by drillings in the spigot and idler gear to lubricate the timing gear arrangement, and to the centre camshaft bearing where due to special machining on the centre camshaft journal an adequate reduced pressure feed is maintained at the rocker assembly. The oil pump incorporates a pressure relief valve which limits the maximum oil pressure, while the oil filter incorporates a by-pass valve which prevents the engine being starved of oil should the filter element become blocked.

Fuel Injection Equipment

A distributor type fuel injection pump is flange mounted on to a drive housing cast on the left hand side of the cylinder block. It is mounted horizontally at the front of the engine and gear driven via a splined drive shaft The majority of pumps incorporate a mechanical governor and an automatic advance and retard mechanism.

The fuel lift pump is of the diaphragm type mechanically operated by an eccentric on the engine camshaft, via a small pushrod. It is located on the tappet inspection cover on the right hand side of the engine and is equipped for hand priming.

Cooling System Fresh Water Circuit

A centrifugal type circulating water pump is fitted to the front face of the cylinder block, to assist the water circulation through the cylinder block and head. The water outlet is via a thermostat housing which is cast integral with the cylinder head, the thermostat restricts the flow of water when the engine is cold and brings about a faster warm up. When the water temperature reaches a pre-determined point the thermostat opens and allows normal coolant circulation. The water pump is belt driven from the crankshaft pulley

The injectors are located in an accessible position on the left hand side of the cylinder head.
The nozzles are of the pintle type.
Provision is made for mounting a fuel filter on either side of the cylinder head. The filter should be of the paper element type and of approved design.

Starting Aid

To aid starting under cold conditions a "Thermostart" heater is fitted into the induction manifold.

Tachometer Drive

Provision is made, on the right hand side of the engine, for a drive at half engine speed to be taken from the oil pump spiral gear to a mechanical tachometer.

SECTION B
Technical data

Engine Data

Westerbeke	4.108 and 4.107	4.99
Bore (nominal — See Page B.3)	3.125 in (79,37 mm)	3.00 in (76,2 mm)
Stroke	3.5 in (88,9 mm)	3.5 in (88,9 mm)
No. of Cylinders	Four	Four
Cubic Capacity	107.4 in³ (1,760 litre)	99 in³ (1,621 litre)
Compression Ratio	22 : 1	20 : 1
Firing Order	1, 3, 4, 2.	1, 3, 4, 2.
Cycle	Four-Stroke	Four-Stroke
Combustion System	Indirect Injection	Indirect Injection

Rating Details

	4.99	4.107	4.108
Maximum Rated Output	34 bhp at 3000 rev/min.	37 bhp at 3000 rev/min	37 bhp at 3000 rev/min
Maximum Torque Output	73 lbf ft (10,1 kgf m)	79 lbf (10,92 kgf m)	79 lbf ft (10,92 kgf m)

Recommended Torque Tensions

The following torque figures will apply with the components lightly oiled before assembly:—

	4.107 and 4.99	4.108
Cylinder Head Nuts	42 lbf ft (5,81 kgf m)	60 lbf ft (8.3 kgf m)
Connecting Rod Setscrews	42 lbf ft (5,81 kgf m)	42 lbf ft (5,81 kgf m)
*Main Bearing Setscrews	85 lbf ft (11,5 kgf m)	85 lbf ft (11,5 kgf m)
Flywheel Setscrews	60 lbf ft (8,3 kgf m)	60 lbf ft (8,3 kgf m)
Idler Gear Hub Setscrews	36 lbf ft (4,98 kgf m)	32 lbf ft (4,4 kgf m)
Crankshaft Pulley Setscrews	150 lbf ft (20,5 kgf m)	150 lbf ft (20.5 kgf m)
Injector Securing Nuts	12 lbf ft (1,7 kgf m)	12 lbf ft (1,7 kgf m)

*The tab and shim washers may be discarded where used on earlier engines, but the setscrews must be tightened to the torque loading indicated.

Service Wear Limits

The following "wear limits" indicate the condition when it is recommended that the respective items should be serviced or replaced.

Cylinder Head Warping	Longitudinal	0.006 in (0,15 mm)
Cylinder Head Warping	Transverse	0.003 in (0,08 mm) concave 0.005 in (0,13 mm) convex
Maximum Bore Wear (when new liners are necessary)		0.006 in (0,15 mm)
Crankshaft Main and Big End Journal	Wear	0.001 in (0,03 mm)
Crankshaft Main and Big End Journal	Ovality	0.0005 in (0,01 mm)
Maximum Crankshaft End Float		0.020 in (0,51 mm)
Valve Stem to Guide Clearance	inlet	0.005 in (0,13 mm)
Valve Stem to Guide Clearance	exhaust	0.006 in (0,15 mm)
Valve Head Thickness at outer edge		0.025 in (0,64 mm)
Rocker Clearance on Shaft		0.005 in (0,13 mm)
Camshaft Journals — Ovality and Wear		0.002 in (0,05 mm)
Camshaft End Float		0.020 in (0,51 mm)
Idler Gear End Float		0.010 in (0,25 mm)
Valve Head Depth below Head Face	inlet and exhaust	0.048 in (1,220 mm)

MANUFACTURING DATA AND DIMENSIONS

The data regarding clearances and tolerances is given for personnel engaged upon major overhauls.

CYLINDER BLOCK

Total Height of Cylinder Block between Top & Bottom Faces	4.108, 4.107, 4.99	9.936/9.939 in (252,374/252,451 mm)
Parent Bore Dia. for Cylinder Liner	4.108	3.249/3.250 in (82,525/82,550 mm)
Parent Bore Dia. for Cylinder Liner	4.107, 4.99	Wet Liners
Main Bearing Parent Bore	4.108, 4.107, 4.99	2.3950/2.3955 in (60,833/60,846 mm)
Camshaft Bore Dia. No. 1	4.108, 4.107, 4.99	1.794/1.7955 in (45,568/45,606 mm)
Camshaft Bore Dia. No. 2	4.108, 4.107, 4.99	1.784/1.787 in (45,314/45,390 mm)
Camshaft Bore Dia. No. 3	4.108, 4.107, 4.99	1.776/1.778 in (45,110/45,161 mm)
Tappet Bore Dia.	4.108, 4.107, 4.99	0.562/0.56325 in (14,275/14,307 mm)
Fuel Pump Drive Hub Bearing Bore Dia.	4.108, 4.107, 4.99	1.8125/1.8141 in (46,037/46,078 mm)

Cylinder Liner 4.108

Type	Cast Iron
Interference Fit of Liners	Dry — Interference Fit
Inside Dia. of Liner after Finish Boring and Honing	0.003/0.005 in (0,076/0,127 mm)
Height of Liner in relation to Cylinder Block Top Face	3.125/3.126 in (79,375/79,40 mm)
Overall Length of Liner	0.023/0.027 in (0,584/0,686 mm) above
	6.495/6.505 in (164,973/165,227 mm)

Cylinder Liner 4.107 and 4.99

Type		Cast Iron
Inside Dia. of Liner Pre-Finished	4.99	Wet — Push Fit
Inside Dia. of Liner Pre-Finished	4.107	3.00/3.001 in (76,20/76,225 mm)
Thickness of Top Flange	4.99	3.125/3.126 in (79,374/79,4 mm)
Depth of Recess in Block for Liner Flange	4.99	0.3125/0.3145 in (7,937/7,988 mm)
Thickness of Top Flange	4.107	0.3115/0.3135 in (7,912/7,963 mm)
Depth of Recess in Block for Liner Flange	4.107	0.250/0.252 in (6,35/6,4 mm)
Height of Liner in relation to Cylinder Block Top Face	4.107 and 4.99	0.249/0.251 in (6,325/6,375 mm)
Liner Flange Outside Dia.	4.99	0.003 in (0,076 mm) Above, 0.001 in (0.025 mm) below
Cylinder Block Top Bore for Liner Flange	4.99	3.618/3.621 in (91,898/91,973 mm)
Clearance Fit of Liner Flange to Block Bore	4.107 and 4.99	3.625/3.627 in (92,075/91,125 mm)
		0.004/0.009 in (0,102/0,229 mm)

Pistons 4.108

Type	Flat Topped
Overall Height (Skirt to Crown)	3.147/3.150 in (79,934/80,010 mm)
Center Line of Piston Pin to Piston Skirt	1.157 in (29,388 mm)
Piston Height in relation to Cylinder Block Top Face	0.002/0.006 in (0,051/0,152 mm) Above
Bore Dia. for Piston Pin	1.06255/1.06275 in (26,989/26,994 mm)
Compression Ring Groove Width—Top	0.0805/0.0815 in (2,045/2,070 mm)
Compression Ring Groove Width—2nd	0.0645/0.0655 in (1,638/1,664 mm)
Compression Ring Groove Width—3rd	0.0645/0.0655 in (1,638/1,664 mm)
Oil Control Ring Groove Width—4th	0.126/0.127 in (3,200/3,225 mm)
Oil Control Ring Groove Width—5th	0.190/0.191 in (4,826/4,851 mm)

Note: There is a Steel Insert fitted above the Top Groove.

Pistons 4.107 and 4.99

Type	Flat Topped
Overall Height (Skirt to Crown)	3.146 in (79,91 mm)
Center Line of Piston Pin to Piston Skirt	1.344 in (34,14 mm)
Piston Height in relation to Cylinder Block Top Face	0.0085/0.012 in (0,22/0,30 mm) Above
Bore Dia. for Piston Pin later 4.99 and all 4.107 engines	0.93755/0.93775 in (23,81/23,82 mm)
Early 4.99 engines	0.87505/0.87525 in (22,22/22,23 mm)
Compression Ring Groove Width—Top	0.0801/0.0811 in (2,034/2,06 mm)
Compression Ring Grooves Width 2nd and 3rd	0.0645/0.0655 in (1,638/1,664 mm)
Oil Control Ring Grooves Width 4th and 5th	0.190/0.191 in (4,826/4,851 mm)

Piston Rings 4.108

Top—Compression	Parallel Faced
Second and Third Compression	Internally Stepped
Fourth—Oil Control	Laminated Segment
Fifth—Oil Control	Slotted Scraper
Top Compression Ring Width	0.0771/0.0781 in (1,958/1,984 mm)
Ring Clearance in Groove	0.0024/0.0044 in (0,061/0,112 mm)
Second and Third Compression Ring Width	0.0615/0.0625 in (1,562/1,587 mm)
Ring Clearance in Groove	0.002/0.004 in (0,051/0,102 mm)
Fifth Scraper Ring Width	0.1865/0.1875 in (4,737/4,762 mm)
Ring Clearance in Groove	0.0025/0.0045 in (0,063/0,114 mm)
Ring Gap—Top Compression	0.009/0.014 in (0,229/0,356 mm)
Ring Gap—Second and Third Compression	0.009/0.014 in (0,229/0,356 mm)
Ring Gap—Fifth Scraper	0.009/0.014 in (0,229/0,356 mm)

Piston Ring Gaps quoted are measured in a ring gauge of 3.125 in (79,38 mm) bore. In practice for every 0.001 in (0,254 mm) difference in cylinder bore diameter from gauge size, 0.003 in (0,762 mm) should be allowed.

Piston Rings 4.107 and 4.99 Agricultural and Industrial Engines

Top Compression	Parallel Cast Iron
*Second and Third Compression	Internally Stepped
Fourth—Oil Control	Chrome Plated Spring Loaded Scraper
Fifth—Oil Control	Slotted Scraper

*4.99 Agricultural engines have taper faced cast iron compression rings fitted in the second and third ring grooves.

Top Compression Ring Width	0.0771/0.0781 in (1,96/1,984 mm)
Ring Clearance in Groove	0.002/0.004 in (0,051/0,102 mm)
Second and Third Compression Ring Width	0.0615/0.0625 in (1,562/1,587 mm)
Ring Clearance in Groove	0.002/0.004 in (0,051/0,102 mm)
Fourth and Fifth Scraper Ring Width	0.1865/0.1875 in (4,737/4,762 mm)
Ring Clearance in Groove	0.0025/0.0045 in (0,064/0,114 mm)
Ring Gap—Compression Rings Chrome Vehicle	0.012/0.017 in (0,30/0,43 mm)
Ring Gap—Oil Control Rings Cast Iron Vehicle	0.009/0.014 in (0,229/0,356 mm)
Ring Gap—Compression Rings Cast Iron Agricultural and Industrial	0.009/0.014 in (0,229/0,356 mm)

Piston Ring Gaps quoted are measured in a ring gauge of 3.000 in (76,20 mm) bore for 4.99 engines and 3.125 in (79,38 mm) bore for 4.107 engines. In practice, for every 0.001 in (0,254 mm) difference in cylinder bore diameter from gauge size, 0.003 in (0,762 mm) should be allowed.

Piston Pin 4.108

Type	Fully Floating
Outside Dia. of Piston Pin	1.0625/1.0627 in (26,987/26,993 mm)
Length of Piston Pin	2.673/2.687 in (67,894/68,250 mm)
Fit in Piston Boss	Transition

Piston Pin 4.107 and 4.99

Type	Fully Floating
Outside Dia. of Piston Pin	0.9375 in/0.9377 in (23,812/23,817 mm)
Earlier Engines	0.875/0.8752 in (22,225/22,23 mm)
Fit in Piston Boss	Transition

Small End Bushing 4.108

Type	Steel Backed, Lead Bronze Lined
Length of Small End Bushing	0.935/0.955 in (23,749/24,257 mm)
Outside Dia. of Small End Bushing	1.221/1.222 in (31,013/31,039 mm)
Inside Dia. before Reaming	1.0495/1.0545 in (26,657/26,784 mm)
Inside Dia. after Reaming	1.06315/1.0632 in (27,004/27,005 mm)
Clearance between Small End Bushing and Piston Pin	0.00045/0.0007 in (0,0114/0,0178 mm)

Small End Bushing 4.107 and 4.99

Type	Steel Backed, Lead Bronze Lined
Length of Small End Bushing	0.865/0.885 in (22,00/22,48 mm)
Outside Dia. of Small End Bushing on later 4.99 and all 4.107 engines	1.065/1.066 in (27,05/27,08 mm)
Early 4.99 engines	1.0025/1.0035 in (25,46/25,49 mm)
Inside Dia. after Reaming on later 4.99 and all 4.107 engines	0.9382/0.93875 in (23,83/23,84 mm)
Early 4.99 engines	0.8757/0.87625 in (22,24/22,26 mm)
Clearance between Small End Bushing and Piston Pin	0.0005/0.00125 in (0,01/0,03 mm)

Note. Bushings to be reamed to suit respective Piston Pins, and are provided with a reaming allowance.

Connecting Rod 4.108

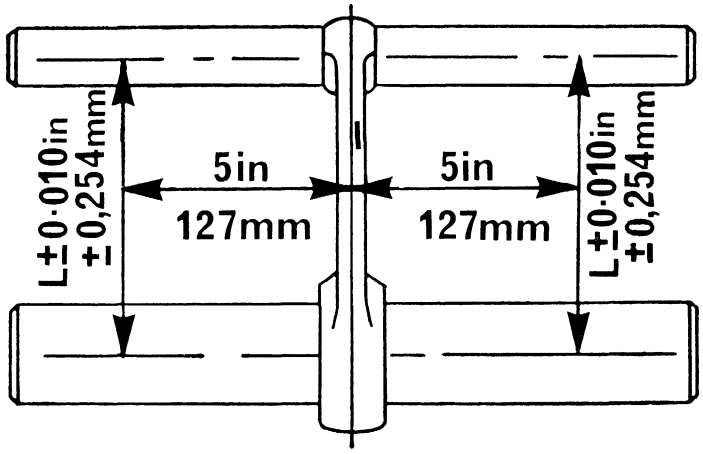
Type	'H' Section
Cap Location to Connecting Rod	Serrations, Offset 45° to the Horizontal
Big End Parent Bore Dia.	2.146/2.1465 in (54,508/54,521 mm)
Small End Parent Bore Dia.	1.21875/1.21975 in (30,956/30,981 mm)
Length from Centre Line of Big End to Centre Line of Small End	6.217/6.219 in (157,912/157,963 mm)
Big End Setscrew	0.375 in ($\frac{3}{8}$ in) U.N.F.
Connecting Rod End Float	0.0065/0.0105 in (0,165/0,267 mm)

Connecting Rod 4.107 and 4.99

Type	'H' Section
Cap Location to Connecting Rod	Serrations, Offset 45° to the horizontal
Big End Parent Bore Dia.	2.146/1.1465 in (54,508/54,521 mm)
Small End Parent Bore Dia. on later 4.99 and all 4.107 engines	1.0625/1.0635 in (26,99/27,01 mm)
Early 4.99 engines	1.00/1.001 in (25,4/25,43 mm)
Length from Centre Line of Big End to Centre Line of Small End	6.405/6.407 in (162,69/162,74 mm)
Big End Setscrew	0.375 in ($\frac{3}{8}$ in) U.N.F.
Connecting Rod End Float on later 4.99 and all 4.107 engines	0.0065/0.0105 in (0,16/0,27 mm)
Early 4.99 engines	0.0075/0.0105 in (0,19/0,27 mm)

Connecting Rod Alignment 4.108, 4.107, 4.99

Large and small end bores must be square and parallel with each other within the limits of ±0.010 in (0,25 mm) measured 5 in (127 mm) each side of the axis of the rod on test mandrel as shown in Fig. B.1. With the small end bush fitted, the limit of ±0.010 in (0,025 mm) is reduced to ±0.0025 in (0,06 mm).



Crankshaft 4.108, 4.107, 4.99

Overall Length	21.125 in (536,575 mm)
Main Journal Dia. Nos. 1 and 2	2.248/2.2485 in (57,099/57,112 mm)
Main Journal Dia. No. 3	2.2475/2.248 in (57,086/57,099 mm)
Main Journal Length No. 1	1.40625 in (35,719 mm)
Main Journal Length No. 2	1.496/1.504 in (37,998/38,202 mm)
Main Journal Length No. 3	1.499/1.502 in (38,075/38,151 mm)
Main Journal Fillet Radii	0.125/0.141 in (3,175/3,581 mm)
Crankpin Dia.	1.9995/2.000 in (50,787/50,800 mm)
Crankpin Length	1.1875/1.1895 in (30,162/30,213 mm)
Crankpin Fillet Radii	0.15625/0.17187 in (5/32/11/64 in) (3,969/4,366 mm)
Surface Finish—All Journals	8-16 micro-in (0,2 - 0,4 micron)
Main Journal and Crankpin Regrind Undersizes	0.010, 0.020, 0.030 in (0,25, 0,51, 0,76 mm)
Oil Seal Helix Dia.	2.21075/2.21175 in (56,153/56,178 mm)
Oil Seal Helix Width	0.050/0.080 in (1,270/2,032 mm)
Oil Seal Helix Depth	0.004/0.008 in (0,102/0,203 mm)
Flange Dia.	3.9985/3.9995 in (101,562/101,587 mm)
Flange Width	0.500 in (12,700 mm)
Spigot Bearing Recess Depth	0.875 in (22,225 mm)
Spigot Bearing Recess Bore	1.250 in (31,750 mm)
Crankshaft End Float	0.002/0.015 in (0,0508/0,381 mm)

Special Note:

The crankshaft fitted to the 4.108 engine is hardened by the "Tufftride" process.
Special precautions are therefore necessary when regrinding. Only very light cuts should be taken, especially in the region of the fillet radii and adequate cooling should be ensured during grinding operations.

After regrinding the crankshaft it should be crack-detected and de-magnetised, then retreated by the "Tufftride" process after which the crankshaft should again be crack-detected and de-magnetised. Where facilities are not available to re-harden the crankshaft by this process, a factory replacement crankshaft should be obtained.

Fillet radii and surface finish must be maintained during all crankshaft regrinding. Length of No. 3 main journal not to exceed 1.516 in (38,506 mm) after regrinding. Where necessary use oversize thrust washers to bring crankshaft end float within the correct limits.

Crankshaft Thrust Washers 4.108, 4.107, 4.99

Type	Steel Backed—Lead Bronze Faced
Position in Engine	Rear Main Bearing
Thrust Washer Thickness (STD)	0.089/0.091 in (2,261/2,311 mm)
Thrust Washer Thickness (O/S)	0.0965/0.1005 in (2,451/2,553 mm)
Thrust Washer Outside Dia.	3.245/3.255 in (82,423/82,677 mm)
Thrust Washer Inside Dia.	2.590/2.600 in (65,786/66,040 mm)

Main Bearings 4.108, 4.107, 4.99

Type	Pre-finished, Steel Backed, Aluminium Tin Lined
Shell Width	1.245/1.255 in (31,623/31,877 mm)
Outside Dia. of Main Bearing	2.3955 in (60,846 mm)
Inside Dia. of Main Bearing	2.2505/2.2515 in (57,163/57,188 mm)
Running Clearance—Nos. 1 and 2	0.002/0.0035 in (0,051/0,089 mm)
Running Clearance—No. 3	0.0025/0.004 in (0,063/0,102 mm)
Steel Thickness	0.060 in (1,524 mm) Max.
Aluminium Thickness	0.012/0.01225 in (0,305/0,311 mm)

Connecting Rod Bearings 4.108, 4.107, 4.99

Type	Pre-finished, Steel Backed, Aluminium Tin Lined
Shell Width	0.870/0.880 in (22,098/22,325 mm)
Outside Dia. of Con. Rod Bearing	2.1465 in (54,521 mm)
Inside Dia. of Con. Rod Bearing	2.0015/2.0025 in (50,838/50,863 mm)
Running Clearance	0.0015/0.003 in (0,038/0,076 mm)
Steel Thickness	0.060 in (1,524 mm) Max.
Aluminium Thickness	0.012/0.01225 in (0,305/0,311 mm)

Camshaft 4.108, 4.107, 4.99

No. 1 Journal Length	1.347/1.351 in (34,214/34,315 mm)
No. 1 Journal Dia.	1.791/1.792 in (45,491/45,517 mm)
No. 1 Cylinder Block Camshaft Bore Dia.	1.794/1.7955 in (45,568/45,606 mm)
No. 1 Journal Running Clearance	0.002/0.0045 in (0,051/0,114 mm)
No. 2 Journal Length	1.250 in (31,750 mm)
No. 2 Journal Dia.	1.781/1.782 in (45,237/45,263 mm)
No. 2 Cylinder Block Camshaft Bore Dia.	1.784/1.787 in (45,314/45,390 mm)
No. 2 Journal Running Clearance	0.002/0.006 in (0,051/0,152 mm)
No. 3 Journal Length	1.000 in (25,400 mm)
No. 3 Journal Dia.	1.773/1.774 in (45,034/45,060 mm)
No. 3 Cylinder Block Camshaft Bore Dia.	1.776/1.778 in (45,110/45,161 mm)
No. 3 Journal Running Clearance	0.002/0.005 in (0,051/0,127 mm)
Cam Lift	0.266 in (6,766 mm)
Oilways for Rocker Shaft Lubrication	No. 2 Journal

Camshaft Thrust Plates 4.108, 4.107, 4.99

Type	180° Oil Impregnated Sintered Iron
Thrust Plate Outside Dia.	2.555/2.557 in (64,897/64,948 mm)
Cylinder Block Recess Dia. for Thrust Plate	2.5585/2.5685 in (64,986/65,240 mm)
Clearance Fit of Thrust Plate in Recess	0.0015/0.013 in (0,038/0,330 mm)
Thrust Plate Inside Dia.	1.500 in (38,100 mm)
Thrust Plate Thickness	0.160/0.162 in (4,060/4,115 mm)
Cylinder Block Recess Depth for Thrust Plate	0.158/0.164 in (4,009/4,166 mm)
Thrust Plate Height in relation to Cylinder Block Face	0.004 in (0,102 mm) above or below
Camshaft End Float	0.003/0.013 in (0,076/0,330 mm)

Valve and Fuel Pump Timing

Refer to later section on timing (page L.1).

CYLINDER HEAD 4.108, 4.107, 4.99

Overall Length of Cylinder Head	20.000 in (508,000 mm)
Overall Depth of Cylinder Head	2.617/2.633 in (66,472/66,878 mm)
Resurfacing Allowance on Cylinder Head Face	NIL—On no account can the cylinder head face be resurfaced.
Pressure for Water Leakage Test	20 lbf/in² (1,4 kgf/cm²)
Valve Seat Angle	45°
Bore in Cylinder Head for Guide	0.4995/0.5005 in (12,687/12,713 mm)
Bore in Cylinder Head for Combustion Chamber Inserts	1.250/1.252 in (31,750/31,801 mm)
Depth of Bore in Cylinder Head for Combustion Chamber Inserts	0.373/0.376 in (9,474/9,550 mm)

Combustion Chamber Inserts 4.108, 4.107, 4.99

Outside Dia. of Insert	1.248/1.249 in (31,699/31,724 mm)
Depth of Insert	0.374/0.375 in (9,499/9,525 mm)
Height of Insert in relation to Cylinder Head Face	0.002 in (0,051 mm) above or below
Clearance Fit of Insert in Cylinder Head Bore	0.001/0.004 in (0,025/0,102 mm)
Method of Location in Cylinder Head	By Cylinder Block Face and Expansion Washer

Valve Guides (Inlet) 4.108, 4.107, 4.99

Inside Dia.	0.3145/0.3155 in (7,988/8,014 mm)
Outside Dia.	0.50125/0.50175 in (12,744/12,757 mm)
Interference fit of Guide in Cylinder Head Bore	0.00075/0.00225 in (0,019/0,057 mm)
Overall length of Guide	2.130 in (54,102 mm)
Guide Protrusion Above Top Face of Cylinder Head	0.800/0.815 in (20,320/20,701 mm)

Valve Guides (Exhaust) 4.108, 4.107, 4.99

Inside Dia.	0.3145/0.3155 in (7,988/8,014 mm)
Outside Dia.	0.50125/0.50175 in (12,744/12,757 mm)
Interference fit of Guide in Cylinder Head Bore	0.00075/0.00225 in (0,019/0,057 mm)
Depth of Counterbore	0.380 in (9,650 mm)
Overall Length of Guide	2.440 in (61,980 mm)
Guide Protrusion above Top Face of Cylinder Head	0.800/0.815 in (20,320/20,701 mm)

Valves (Inlet) 4.108, 4.107, 4.99

Valve Stem Dia.	0.312/0.313 in (7,925/7,950 mm)
Clearance fit of Valve Stem in Guide	0.0015/0.0035 in (0,038/0,089 mm)
Valve Head Dia.	1.410/1.414 in (35,814/35,916 mm)
Valve Face Angle	45°
Valve Head Depth Below Cylinder Head Face	0.028 in (0,711 mm)/0.039 in (0,991 mm)
Overall Length of Valve	4.592/4.608 in (116,637/117,043 mm)
Sealing Arrangement	Rubber Oil Seal

Valves (Exhaust) 4.108, 4.107, 4.99

Valve Stem Dia.	0.3115/0.3125 in (7,912/7,937 mm)
Clearance Fit of Valve Stem in Guide	0.002/0.004 in (0,051/0,102 mm)
Valve Head Dia.	1.191/1.195 in (30,251/30,353 mm)
Valve Face Angle	45°
Valve Head Depth Below Cylinder Head Face	0.021 in (0.53 mm)/0.032 in (0,813 mm)
Overall Length of Valve	4.600/4.616 in (116,840/117,246 mm)
Sealing Arrangement	No Seal fitted to Exhaust Valve

Inner Valve Springs (where fitted)

Fitted Length	1.530 in (38,862 mm)
Load at Fitted Length	28.6 lbf ± 2 lbf (13.0 kgf ± 0,91 kgf)
Fitted Position	Damper Coil to Cylinder Head

Outer Valve Springs 4.108, 4.107, 4.99

Fitted Length	1.780 in (45,212 mm)
Load at Fitted Length	56.0 lbf ± 2.8 lbf (25,4 kgf ± 1,27 kgf)
Fitted Position	Damper Coil to Cylinder Head

Rocker Levers 4.108, 4.107, 4.99

Length between Center Line of Adjusting Screw and Center Line of Rocker Shaft	1.042/1.058 in (26,467/26,873 mm)
Length between Center Line of Rocker Lever Pad and Center Line of Rocker Shaft	1.567/1.583 in (39,802/40,208 mm)
Inside Dia. of Rocker Lever Bore	0.71825/0.71950 in (18,243/18,275 mm)
Outside Dia. of Rocker Lever Bushing	0.7205/0.7215 in (18,301/18,326 mm)
Interference Fit of Bushing in Rocker Lever	0.001/0.00325 in (0,025/0,082 mm)
Finished Inside Dia. of Rocker Lever Bushing	0.6245/0.62575 in (15,862/15,894 mm)
Clearance of Rocker Lever Bushing on Rocker Shaft	0.00075/0.0035 in (0,019/0,089 mm)

Valve Clearances 4.108, 4.107, 4.99

Clearance between Valve Stem Tip and Rocker Lever	0.012 in (0,30 mm) Cold

Rocker Shaft 4.108, 4.107, 4.99

Overall Length of Shaft	14.5625 in (369,887 mm)
Outside Dia. of Shaft	0.62225/0.62375 in (15,805/15,843 mm)
Lubrication	Oil Feed from Cylinder Head through Central Passage to Individual Rocker Levers

Push Rods 4.108, 4.107, 4.99

Overall Length	8.527/8.560 in (216,58/217,42 mm)
Outside Dia.	0.250 in (6,350 mm)

Tappets 4.108, 4.107, 4.99

Overall Length	2.250 in (57,150 mm)
Outside Dia. of Tappet Shank	0.560/0.561 in (14,224/14,249 mm)
Cylinder Block Tappet Bore Dia.	0.562/0.56325 in (14,275/14,307 mm)
Tappet Running Clearance in Cylinder Block Bore	0.001/0.00325 in (0,025/0,082 mm)
Outside Dia. of Tappet Foot	1.245/1.255 in (31,623/31,877 mm)

TIMING GEARS 4.108, 4.107, 4.99

Camshaft Gear

Number of Teeth	48
Inside Dia. of Gear Boss	1.750/1.7514 in (44,450/44,486 mm)
Outside Dia. of Camshaft Hub	1.7496/1.7509 in (44,430/44,473 mm)
Transition Fit of Gear and Hub	0.0009/0.0018 in (0,023/0,046 mm)

Fuel Pump Gear

Number of Teeth	48
Inside Dia. of Cylinder Block Bore for Fuel Pump Drive Hub Bearing	1.8125/1.8141 in (46,037/46,078 mm)
Outside Dia. of Fuel Pump Drive Hub Bearing	1.8145/1.8152 in (46,088/46,106 mm)
Interference Fit of Drive Hub Bearing in Cylinder Block Bore	0.0004/0.0027 in (0,010/0,069 mm)
Inside Dia. of Fuel Pump Drive Hub Bearing	1.3125/1.3135 in (33,34/33,78 mm)
Outside Dia. of Fuel Pump Gear Drive Hub	1.3105/1.3115 in (33,287/33,312 mm)
Running Clearance of Drive Hub in Bearing	0.0031/0.0051 in (0,079/0,129 mm)
Drive Hub End Float	0.002/0.010 in (0,051/0,254 mm)

Idler Gear and Hub

Number of Teeth	57
Inside Dia. of Gear Boss	1.7187/1.7197 in (43,655/43,680 mm)
Inside Dia. of Gear Boss with Bushing Fitted	1.5625/1.5641 in (39,687/39,728 mm)
Outside Dia. of Gear Hub	1.5612/1.5619 in (39,654/39,668 mm)
Running Clearance of Gear on Hub	0.0003/0.0016 in (0,008/0,041 mm)
Idler Gear Width	1.3105/1.3135 in (33,287/33,363 mm)
Hub Width	1.3165/1.3185 in (33,439/33,490 mm)
Idler Gear End Float	0.002/0.007 in (0,051/0,178 mm)

Crankshaft Gear

Number of Teeth	24
Inside Dia. of Gear	1.250/1.2512 in (31,750/31,780 mm)
Crankshaft Dia. for Gear	1.250/1.2506 in (31,750/31,756 mm)
Transition Fit of Gear on Crankshaft	0.0006/0.0012 in (0,015/0,030 mm)

Timing Gear Backlash

Clearance between Crankshaft/Idler and Camshaft/Idler Gear	0.0015/0.003 in (0,038/0,076 mm)

LUBRICATING SYSTEM 4.108, 4.107, 4.99

Lubricating Oil Pressure	30/60 p.s.i. (2,1/4,2 kgf/cm²) at maximum engine speed and normal working temperature.

Sump

Dipstick Position	Camshaft side of engine opposite No. 2 cylinder
Strainer Location	End of suction pipe to lubricating oil pump.

Typical Sump Capacities

Refill Capacities—Engine Level	Imp. pt	U.S. pt	Litre
Standard Sump	7.0	8.4	4.0

Note: The above sump capacities are intended to be used as a guide and actual capacities should be governed by the level indicated on the dipstick.

Lubricating Oil Pump

Type	Rotor Type
Number of Lobes—Inner Rotor	Three or Four
Number of Lobes—Outer Rotor	Four or Five
Method of Drive	By Spiral Gears from the Camshaft

Pump Clearances

Inner Rotor to Outer Rotor	0.0005/0.0025 in (0,013/0,063 mm)
Outer Rotor to Pump Body	0.011/0.013 in (0,28/0,33 mm)
Inner Rotor End Clearance	0.0015/0.0003 in (0,0380,076 mm)
Outer Rotor End Clearance	0.0005/0.0025 in (0,013/0,063 mm)
Inside Dia. of Bore for Pump Shaft	0.500/0.501 in (12,700/12,725 mm)
Outside Dia. of Pump Shaft	0.4983/0.4986 in (12,655/12,664 mm)
Running Clearance. Shaft in Bore	0.0014/0.0027 in (0,036/0,069 mm)

Lubricating Oil Pump Drive Gear

Number of Teeth	12
Inside Dia. of Gear Bore	0.4965/0.4970 in (12,611/12,624 mm)
Outside Dia. of Oil Pump Drive Shaft	0.4983/0.4986 in (12,655/12,664 mm)
Interference Fit of Gear on Shaft	0.0013/0.0021 in (0,033/0,053 mm)
Lubricating Oil Pump Drive Gear Backlash	0.0155/0.019 in (0,394/0,483 mm)

Relief Valve

Type	Spring Loaded Plunger
Pressure Setting	50/65 lbf/in² (3,5/4,6 kgf/cm²)
Length of Plunger	0.9375 in (23,813 mm)
Outside Dia. of Plunger	0.5585/0.5595 in (14,19/14,21 mm)
Inside Dia. of Valve Housing Bore	0.5605/0.5625 in (14,24/14,29 mm)
Clearance of Plunger in Bore	0.001/0.004 in (0,025/0,102 mm)
Outside Dia. of Spring	0.368/0.377 in (9,347/9,576 mm)
Spring—Free Length	1.5 in (38,10 mm)
Spring—Solid Length	0.754 in (19,15 mm)

Lubricating Oil Filter

Type	Full Flow
Element Type	Paper
By-Pass Valve Setting	Opens between 13-17 lbf/in² (0,91-1,2 kgf/cm²) pressure differential
Type of Valve	Spring Loaded Ball

COOLING SYSTEM 4.108, 4.107, 4.99

Type	Water Cooled
Cylinder Block and Head	Thermo-Syhpon Impeller Assisted
Engine Water Capacity	Approx. 10 U.S. quarts

Thermostat

Type	Wax Capsule
Opening Temperature	175-182°F (79,5-83,5°C)
Fully open at	200-205°F (93,5-96°C)
Minimum Travel at Fully Open Temp.	0.3125 in (7,94 mm)

Water Pump

Type	Centrifugal—Belt driven from Crankshaft
Outside Dia. of Shaft for Pulley	0.5905/0.5908 in (14,999/15,006 mm)
Inside Dia. of Pulley Bore	0.588/0.589 in (14,935/14,961 mm)
Interference Fit of Pulley on Shaft	0.0015/0.0028 in (0,038/0,071 mm)
Outside Dia. of Shaft for Impeller	0.498/0.499 in (12,649/12,675 mm)
Inside Dia. of Impeller Bore	0.497/0.4975 in (12,624/12,636 mm
Interference Fit of Impeller on Shaft	0.0005/0.002 in (0,013/0,051 mm)

Outside Dia. of Impeller	3.094/3.125 in (78.588/79.375 mm)
Impeller to Body Clearance	0.005/0.025 in (0.127/0.635 mm)
Water Pump Seal Type	Synthetic Rubber—Carbon Faced
Inside Dia. of Seal for Impeller Shaft	0.472 in (11.989 mm)
Outside Dia. of Seal	1.102 in (27.991 mm)
*Water Pump Insert Type	Phosphor Bronze—Surface Finish of Sealing Face to be 12-20 micro-in (0.3-0.5 micron)
Outside Dia. of Insert	1.6241.6245 in (41.250/41.263 mm)
Inside Dia. of Insert Bore in Water Pump Housing	1.625/1.626 in (41.275/41.300 mm)

*Later water pumps are fitted with ceramic faced inserts.

Fuel Lift Pump

Type	AC Delco Diaphragm 'YJ' Series
Spring Colour Code	Green
Method of Drive	From Eccentric on Camshaft via Push rod
Total Stroke of Operating Lever	0.192 in (4.877 mm)
Static Pressure—No Delivery	4-7 lbf/in² (0.28-0.49 kgf/cm²)
Pump to Distance Piece Gasket Thickness	0.018/0.022 in (0.457/0.559 mm)
Distance Piece—Lift Pump to Tappet Inspection Cover	0.256 in (6.502 mm)

Fuel Injection Pump

Make	C.A.V.
Type	D.P.A.
Rotation	Clockwise (Viewed from Drive End)
Plunger Dia.	6 mm

Hydraulically Governed	4.108	4.107	4.99
Timing Letter	A		A
No. 1 Cylinder Outlet	W		W

Mechanically Governed			
Timing Letter	C	C	C
No. 1 Cylinder Outlet	W	W	W

Static Timing Position

The static timing position varies according to application, but can be obtained by referring to the first group of letters and digits of the fuel pump setting code (stamped on the fuel pump identification plate), i.e..

First Group of Fuel Pump Code	Static Timing B.T.D.C.	Piston Displacement B.T.D.C.	Remarks
EH39, MH26, MH27, PH28, PH30	18°	0.108 in (2,75 mm)	
CH35	19°	0.120 in (3,05 mm)	
PH34	20°	0.134 in (3,40 mm)	
LH23, LH29	20°	0.134 in (3,40 mm)	4.107 engines rated up to and including 2,500 rev/min
LH31	22°	0.160 in (4,06 mm)	4.107 engines rated above 2,500 rev/min
DH19, AH28, BH26	26°	0.226 in (5,74 mm)	

Note: For 4.107 and 4.99 mechanically governed engines rated above 3,000 and 2,500 rev/min respectively, the static timing is altered to 22° B.T.D.C. - piston displacement 0.160 in (4,06 mm). For 4.108 engines prior to engine numbers 108U15973 and 108UD20214, the static timing was 19° B.T.D.C. - piston displacement 0.120 in (3,05 mm). When re-setting these pumps, it is advisable to set at the figures quoted in above table.

For 4.107 industrial engines having a fuel pump coding of PH30 and an idling speed of 1,000 rev/min, the static timing is 21° B.T.D.C. and a piston displacement of 0.147 in (3,73 mm).

Injectors
4.108 Marine & Industrial
4.107 Marine & Industrial

Make	C.A.V.
Holder Type	BKB40SD5224
Nozzle Type	BDN12SD6236
Code Letter	BG
Min. Working Pressure	135 atm (2000 lbf/in² or 140 kgf/cm²)
Setting Pressure	150 atm (2200 lbf/in² or 155 kgf/cm²)

Note: Earlier atomisers bearing the identification code letter 'J' had a setting pressure of 140 atm. When servicing of these atomisers is carried out, they should be reset in accordance with the settings quoted above.

Starting Aid

Make	C.A.V.
Type	Thermostart
Voltage	12 Volt
Maximum Current Consumption	12.9 Amperes at 11.5 Volts
Fuel Flow Rate through Unit	4.3-4.9 cm³ min at 70°F (21°C)
Height of Reservoir above Centre of Thermostart	4.5-10 in (11,4-25,4 cm)

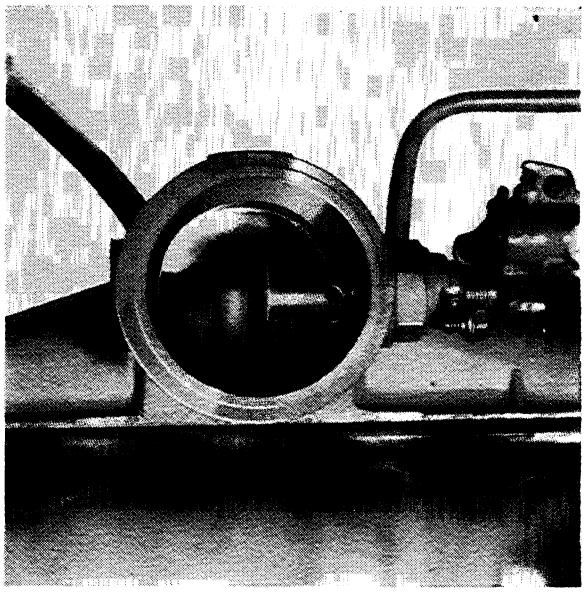
SECTION D
Fault Diagnosis

Fault	Possible Cause
Low cranking speed	1, 2, 3, 4.
Will not start	5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 31, 32, 33.
Difficult starting	5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 24, 29, 31, 32, 33.
Lack of power	8, 9, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33.
Misfiring	8, 9, 10, 12, 13, 14, 16, 18, 19, 20, 25, 26, 28, 29, 30, 32.
Excessive fuel consumption	11, 13, 14, 16, 18, 19, 20, 22, 23, 24, 25, 27, 28, 29, 31, 32, 33.
Black exhaust	11, 13, 14, 16, 18, 19, 20, 22, 24, 25, 27, 28, 29, 31, 32, 33.
Blue/white exhaust	4, 16, 18, 19, 20, 25, 27, 31, 33, 34, 35, 45, 56.
Low oil pressure	4, 36, 37, 38, 39, 40, 42, 43, 44, 58.
Knocking	9, 14, 16, 18, 19, 22, 26, 28, 29, 31, 33, 35, 36, 45, 46, 59.
Erratic running	7, 8, 9, 10, 11, 12, 13, 14, 16, 20, 21, 23, 26, 28, 29, 30, 33, 35, 45, 59.
Vibration	13, 14, 20, 23, 25, 26, 29, 30, 33, 45, 47, 48, 49.
High oil pressure	4, 38, 41.
Overheating	11, 13, 14, 16, 18, 19, 24, 25, 45, 50, 51, 52, 53, 54, 57.
Excessive crankcase pressure	25, 31, 33, 34, 45, 55.
Poor compression	11, 19, 25, 28, 29, 31, 32, 33, 34, 46, 59.
Starts and stops	10, 11, 12.

Key to Fault Finding Chart

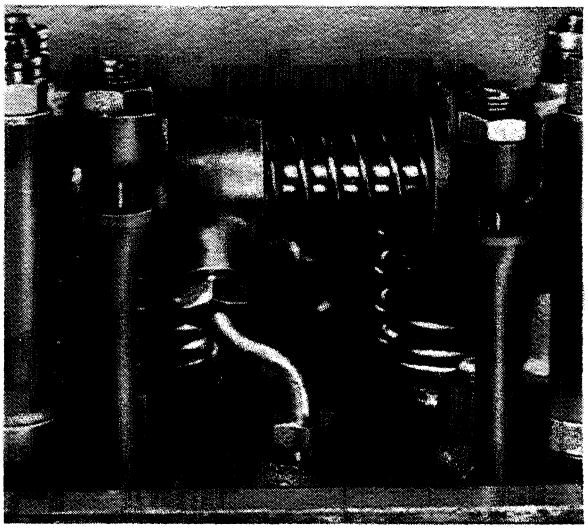
1. Battery capacity low.
2. Bad electrical connections.
3. Faulty starter motor.
4. Incorrect grade of lubricating oil.
5. Low cranking speed.
6. Fuel tank empty.
7. Faulty stop control operation.
8. Blocked fuel feed pipe.
9. Faulty fuel lift pump.
10. Choked fuel filter.
11. Restriction in air cleaner.
12. Air in fuel system.
13. Faulty fuei injection pump.
14. Faulty injectors or incorrect type.
15. Incorrect use of cold start equipment.
16. Faulty cold starting equipment.
17. Broken fuel injection pump drive.
18. Incorrect fuel pump timing.
19. Incorrect valve timing.
20. Poor compression.
21. Blocked fuel tank vent.
22. Incorrect type or grade of fuel.
23. Sticking throttle or restricted movement.
24. Exhaust pipe restriction.
25. Cylinder head gasket leaking.
26. Overheating.
27. Cold running.
28. Incorrect tappet adjustment.
29. Sticking valves.
30. Incorrect high pressure pipes.
31. Worn cylinder bores.
32. Pitted valves and seats.
33. Broken, worn or sticking piston ring/s.
34. Worn valve stems and guides.
35. Overfull air cleaner or use of incorrect grade of oil.
36. Worn or damaged bearings.
37. Insufficient oil in sump.
38. Inaccurate gauge.
39. Oil pump worn.
40. Pressure relief valve sticking open.
41. Pressure relief valve sticking closed.
42. Broken relief valve spring.
43. Faulty suction pipe.
44. Choked oil filter.
45. Piston seizure/pick up.
46. Incorrect piston height.
47. Damaged fan.
48. Faulty engine mounting (Housing).
49. Incorrect aligned flywheel housing, or flywheel.
50. Faulty thermostat.
51. Restriction in water jacket.
52. Loose fan belt.
53. Choked radiator.
54. Faulty water pump.
55. Choked breather pipe.
56. Damaged valve stem oil deflectors (if fitted).
57. Coolant level too low.
58. Blocked sump strainer.
59. Broken valve spring.

SECTION E
Cylinder Head



E1

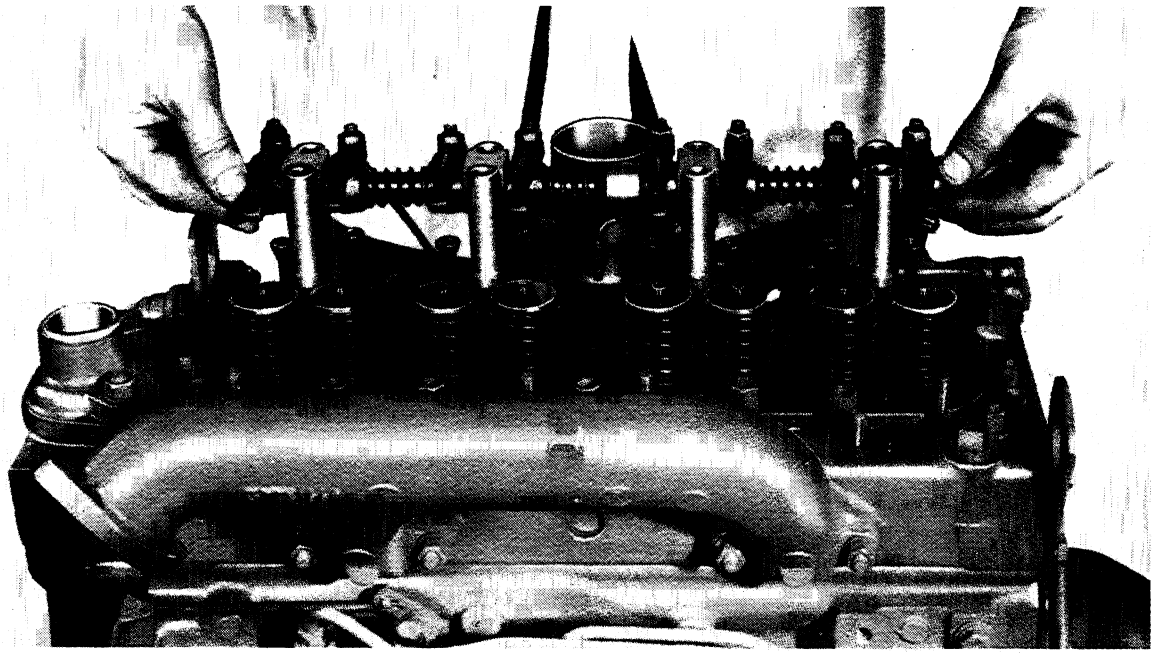
Before commencing to overhaul the cylinder head ensure that all joints, gaskets and any other parts expected to be required are available.
Remove any external components from the vicinity of the cylinder head cover, atomisers and fuel pump.



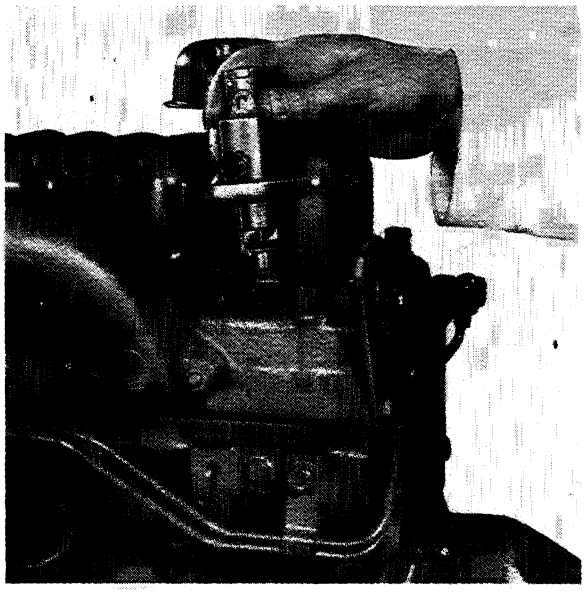
E2

To Remove the Cylinder Head

1. Completely drain the cooling system.
2. Disconnect the battery terminals.
3. Remove the securing nuts and detach the exhaust pipe from the exhaust manifold. Blank off the end of the exhaust pipe to prevent entry of any foreign matter.

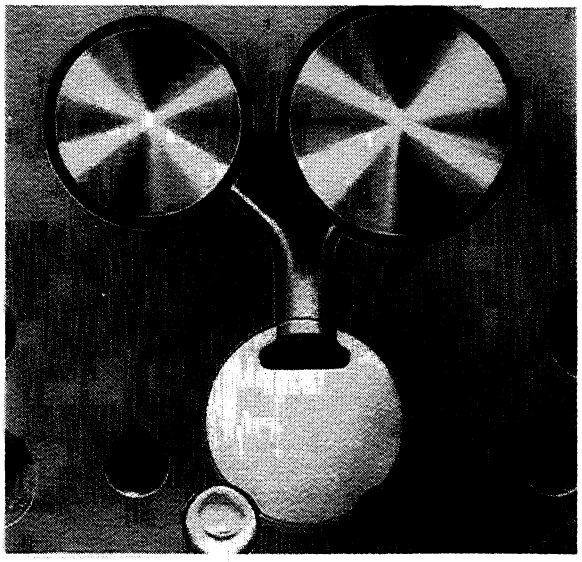


E3



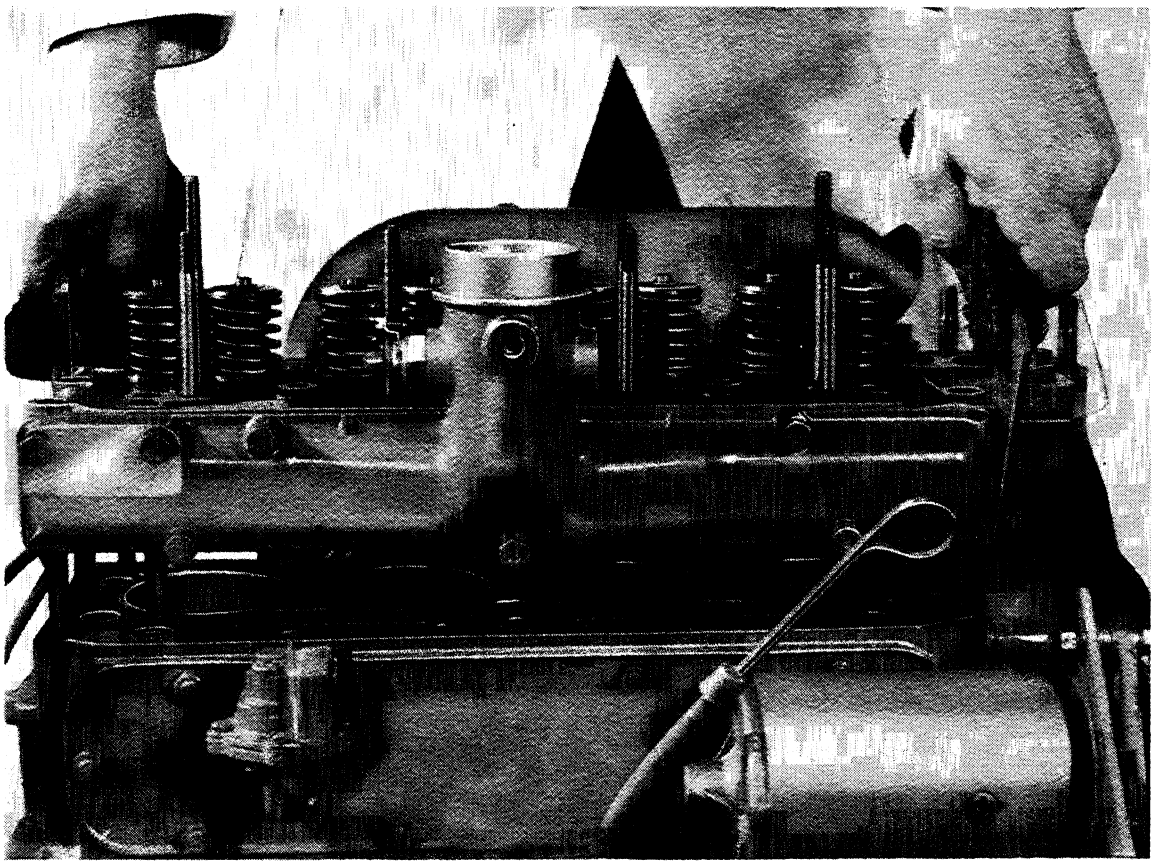
E4

4. Uncouple the water outlet connection on the front of the cylinder head.
5. Remove the air cleaner and place somewhere level ready for servicing.
6. Disconnect the fuel pipe and electrical connection to the starting aid located in the induction manifold. (Refer to Fig. E.1).

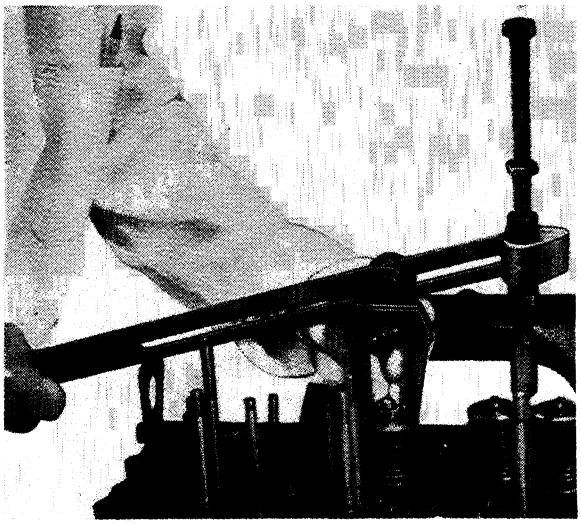


E6

7. Remove the cylinder head cover together with the breather pipe.
8. Unscrew the oil feed pipe to the rocker shaft at the cylinder head end. (Refer to Fig. E.2 for its location).
9. Remove the eight rocker shaft bracket securing nuts **evenly** and remove the rocker shaft complete with the oil feed pipe. (Refer to Fig. E.3).

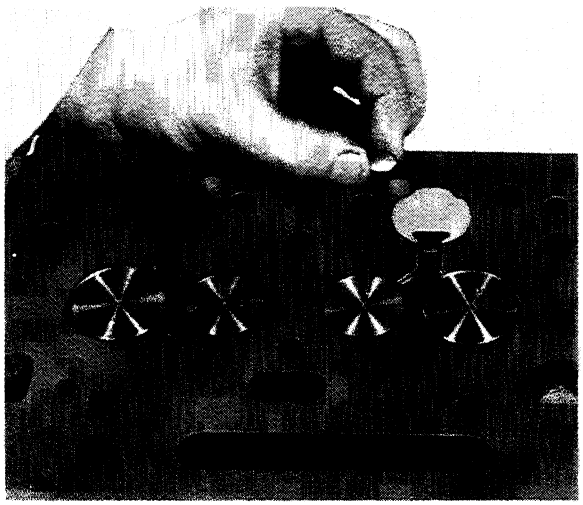


E5

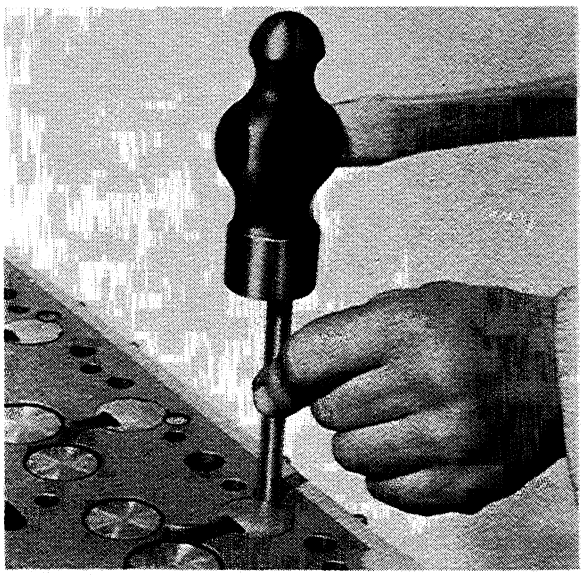


E7

10. Remove the eight push rods and place somewhere safe (possibly in the cylinder head cover) to avoid the possibility of any being accidentally bent.
11. Unscrew the small banjo bolts on the tops of the atomisers and remove the leak-off pipe by unscrewing the union on top of the fuel filter.
12. Remove the low pressure fuel pipes between the fuel filter and the fuel pump, remove the fuel filter after disconnecting the feed pipe from the lift pump, blank off all pipes and ports to prevent ingress of foreign particles.
13. Remove the four high pressure fuel pipes from the fuel pump to the injectors. Blank off fuel pump outlet ports.
14. Remove the injector securing nuts and carefully remove the injector. (Refer to Fig. E.4).
    Blank off the exposed ports on the injectors.
15. Uncouple the alternator adjusting link.



E8



E9

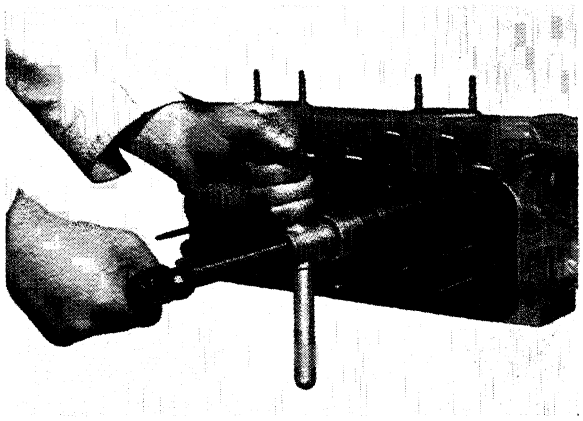
16. Remove the cylinder head securing nuts and lift off the cylinder head complete with inlet and exhaust manifolds. (Refer to Fig. E.5).

NOTE: On 4.99 and 4.107 engines, to prevent liner movement should the engine be turned with the cylinder head removed, it is suggested that the liners are held in position by suitable tubing placed over two of the cylinder head studs and locked with nuts and washers.

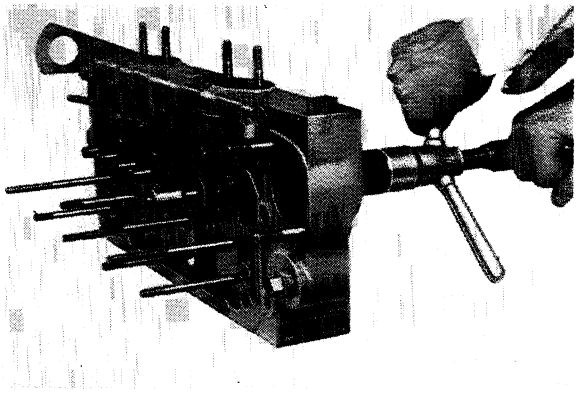
To Remove the Valves

All valves are numbered. The cylinder head is marked with corresponding numbers. (Refer to Fig. E.6).

1. Remove collets by compressing the valve springs as shown in Fig. E.7.
2. Remove the spring caps, springs, seals (where fitted) and spring seats. Remove valves.



E10



E11

COMBUSTION CHAMBER INSERTS

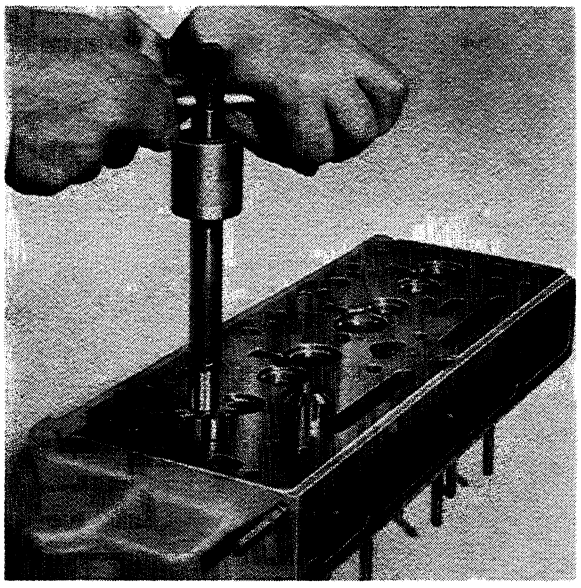
These can be gently tapped out of their locations by means of a short length of curved bar through the injector bore. When refitting they must be located by means of expansion washers in the recesses provided, as shown in Figs. E.8 and E.9.

Cleaning

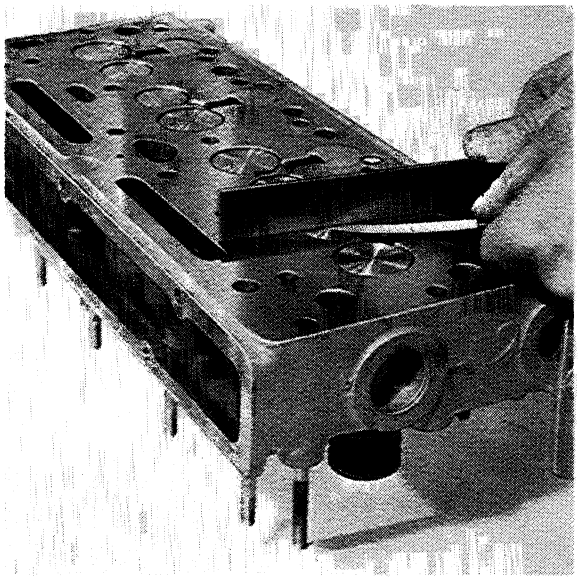
Remove any carbon from the cylinder head.
If the water jacket within the cylinder head shows signs of excessive scale, then a proprietary brand of descaling solution may be used, if possible the cylinder head should be tested for water leakage after such treatment at the pressure given on Page B.7.

VALVE SPRINGS

It is advisable to fit new valve springs whenever the engine undergoes a major overhaul. Where a top overhaul only is being carried out the springs should be examined, paying particular attention to squareness of ends and pressures developed at specific lengths, the details of which can be found on Page B.8.



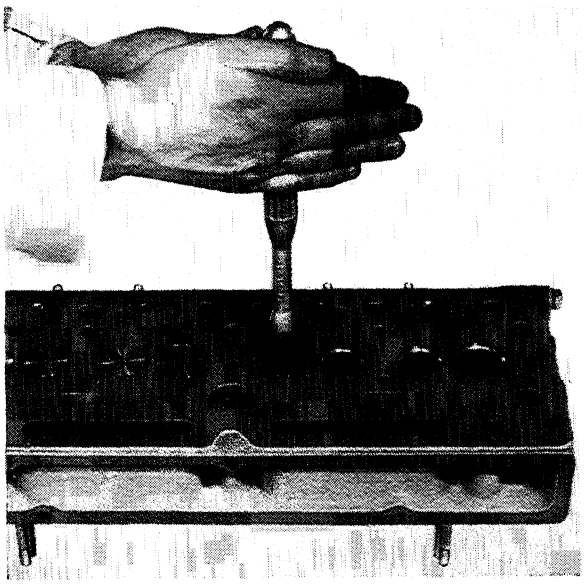
E12



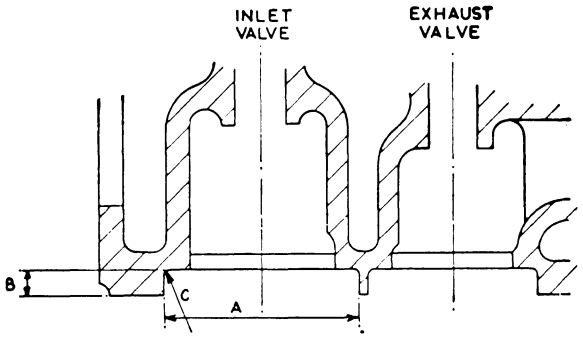
E13

VALVE GUIDES

The worn guides should be removed either by means of a press and a suitable "dolly" or the valve guide removal tool shown in Fig. E.10.
Before fitting the new guides remove any burrs from the cylinder head parent bores, then smear the bores with clean oil and either press in the new guides or pull them in by means of the tool shown in Fig. E.11, until the guide protrusion above the head top face is that quoted on Page B.7.
NOTE: Special care should be exercised during this operation as the guides, being made of cast iron, are therefore comparatively brittle.



E14



E15

Inlet
A—1.530 in to 1.531 in
B—0.3125 in to 0.3175 in
C—0.015 in chamfer at 45° (Max.)

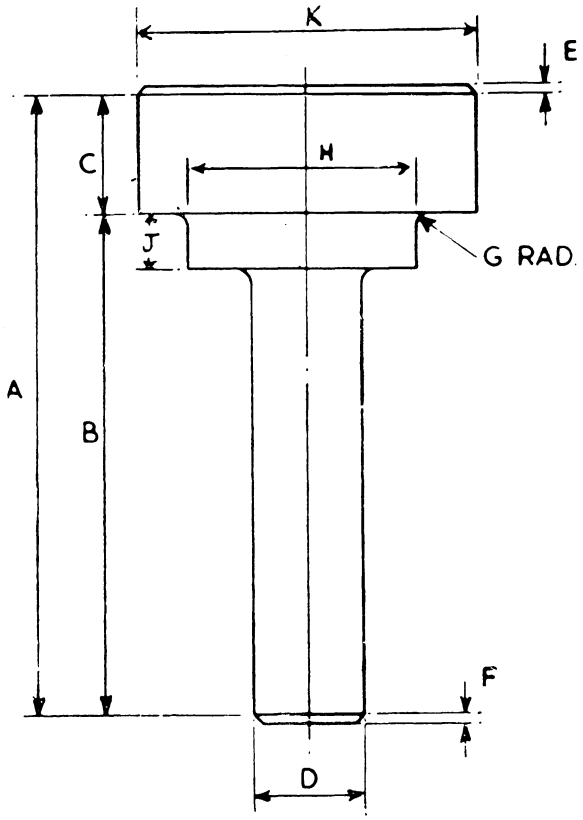
Exhaust
A—1.296 in to 1.297 in
B—0.3125 in to 0.3175 in
C—0.015 in chamfer at 45 (Max.)

VALVES AND VALVE SEATS

The valves should be checked in their respective guides for wear and replaced if wear has taken place. (ensure that the wear is in fact on the valve stem and not in the guide bore before replacing the valve).
The valve and valve seat faces should be reconditioned in the normal way using specialised equipment or with grinding compound, according to their condition. A valve seat (hand operated) cutting tool is shown in Fig. E.12. Valves should always be refitted to their original seats and any new valve fitted should be suitably marked to identify its position if removed at a later date. (Refer to Fig. E.6 for illustration of valve numbering).
Before refitting the valves it should be ascertained whether the valve head depth relative to the cylinder head face is within the limits given on Page B.8. This depth can be checked, as shown in Fig. E.13, by placing a straight edge across the face of the cylinder head, then by careful selection of feeler gauges measuring the distance between the straight edge and the head of the valve.
Where this depth exceeds the maximum limit and even the fitting of a new valve does not reduce this depth below the maximum limit, then the remedy is to fit a valve seat insert, the procedure for this is given in detail commencing on this page.
When refacing valves or valve seats care should be taken to see that only the minimum amount of metal necessary to obtain a satisfactory seat is removed, and that as narrow a valve seat as possible is maintained.

Hand Grinding

When grinding or lapping-in valves make certain that all signs of pitting are removed from the seats.



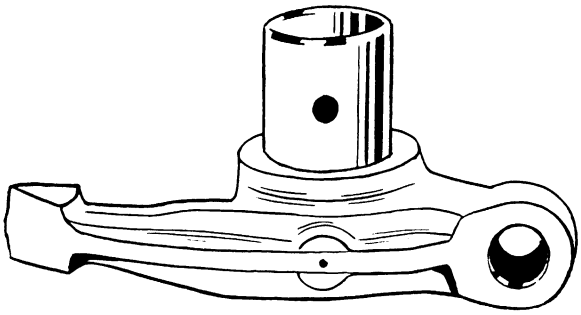
E16

Material EN32A Case Hardened and Ground

Inlet Dimensions
A—2.75 in
B—2 in
C—0.75 in
D—0.309 in to 0.310 in
E—1/16 in at 45
F—1/16 in at 45
G—1/32 in Radius
H—1.238 in to 1.239 in
J—0.222 in to 0.225 in
K—1.523 in to 1.533 in

Exhaust Dimensions
A—2.75 in
B—2 in
C—0.75 in
D—0.309 in to 0.310 in
E—1/16 in at 45
F—1/16 in at 45
G—1/32 in Radius
H—1.018 in to 1.019 in
J—0.222 in to 0.225 in
K—1.287 in to 1.297 in

After all the valves have been lapped in the valve head depths relative to the cylinder head face should be checked to ensure that they are within the limits given on Page B.8.



E17

VALVE SEAT INSERTS

Valve seat inserts are not fitted to production engines, but may be fitted in service.
When fitting inserts ensure that only genuine Westerbeke parts are used.
In order to fit these inserts proceed as follows:

1. Fit new valve guides as described on Page E.4.
2. Using the new valve guide bore as a pilot, machine the insert recess in the cylinder head face to the dimensions shown in Fig. E.15.
3. Remove all machining swarf and thoroughly clean the insert recess (removing any burrs which may be present).
4. Using the valve guide bore as a pilot once again press the insert home with the inserting tool, this tool is shown fully dimensioned in Fig. E.16.
   NOTE: The insert must not under any circumstances be hammered in, neither should any lubrication be used.
5. Visually inspect to ensure that the insert has been pressed fully home, i.e. is flush with the bottom of the recess.
6. Recut the valve seat at an included angle of 90° (which will give the normal 45° seat) until the valve head depth reaches the minimum limit which is given on Page B.8. Lightly lap the valve to its new seat.

To Dismantle the Rocker Shaft Assembly

1. Remove the retaining circlips from each end of the rocker shaft.
2. Withdraw the rocker levers, springs and support brackets from the rocker shaft.
3. Unscrew the oil feed pipe from the banjo and remove the banjo. (When refitting this feed pipe it should be noted that the end of the pipe locates the banjo position on the shaft).

Examine the rocker bushings and shaft for wear. The rocker levers should be an easy fit on the rocker shaft without excessive side play.
New rocker levers are supplied complete with bushing fitted and reamed to size.
NOTE: When fitting new bushes ensure that the oil feed holes are in alignment before pressing home, and when pressed fully home that the holes coincide. (Refer to Fig. E.17).

To Re-Assemble the Rocker Shaft Assembly

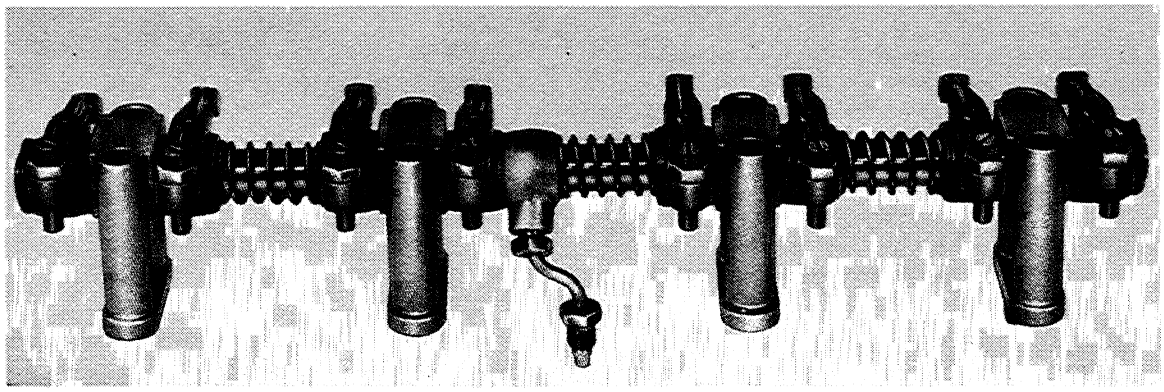
1. Refit the oil feed banjo and locate with the feed pipe.
2. Refit the rocker levers, springs and support brackets in the opposite order to which they were removed. Lightly oil the components during reassembly and ensure that each rocker lever does not bind on the shaft. The assembly should now be as shown in Fig. E.18.

PUSH RODS

Check the push rods for straightness, if any are bent then fit new replacements.

To Refit the Valves

Lightly oil the valve stems to provide the initial lubrication.
Replace valves, springs, spring plates, washers, collars and collets, taking care that the numbers on the valves correspond to the numbers stamped adjacent to the valve seat (see Fig. E.6).



E18

NOTE: Valve springs incorporate a damper coil and care should be taken to ensure that this damper coil is to the bottom of the spring, i.e., nearest the cylinder head when fitted.
Inner valve springs are not required for engines rated at 3,000 rev/min and below.
4.108 and 4.99 marine diesel engines are fitted with rubber sealing rings on inlet valves only.
All latest 4.107 and 4.99 marine diesel engines incorporate oil deflectors on both inlet and exhaust valves.
In the case of earlier 4.107 and 4.99 marine diesel engines which incorporate rubber sealing rings on the inlet valves only, oil deflectors should be fitted to both inlet and exhaust valves after the valve assembly has been dismantled. With this arrangement, a different valve spring seating washer is required for exhaust valves.
a different valve spring seating washer is required for exhaust valves.
Where a groove is cut on the inlet valve stem, a rubber sealing washer should be fitted in addition to the deflector to stop the latter from becoming canted on the stem.
Oil deflectors should not be fitted to 4.99 vehicle and 4.108 engines.

CYLINDER HEAD GASKET

Always use a new cylinder head gasket. Ensure that the correct type is used.

4.108 Engines

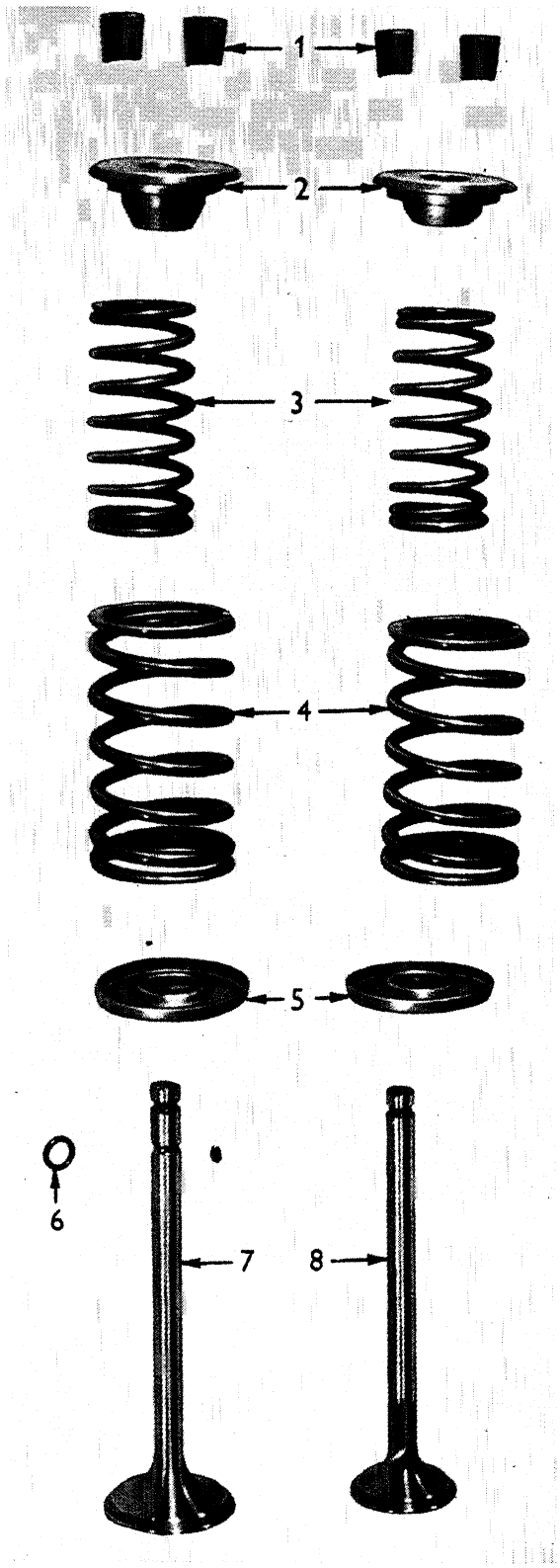
With this engine, the gasket is made of a black composite material and is known as the Klinger type. It MUST be fitted DRY and on no account should sealing compound be used.
It is very important that the gasket is placed correctly, otherwise the steel beading may be nipped between the cylinder head face and the top of the liner.

4.107 and 4.99 Engines

These engines use a copper and asbestos or alternatively, a steel laminated gasket. The copper and asbestos type should be fitted with a good quality sealing compound but the laminated steel type should be fitted DRY.

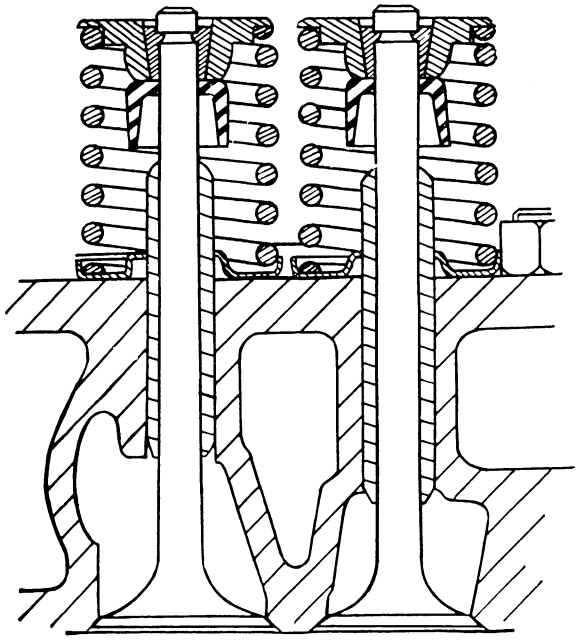
To Refit the Cylinder Head

1. Place the cylinder head gasket carefully in position on the cylinder block top face (the gasket is marked "TOP FRONT" to indicate how it should be fitted). (Refer to Fig. E.22).
2. Lower the cylinder head into position on top of the gasket ensuring that it lays perfectly level.
3. Lightly lubricate both cylinder head studs and nuts with engine oil, then tighten the nuts progressively in three stages in the sequence shown in Fig. E.23 to the torque given on page B.2. This final torque tightening stage should be repeated to ensure that no loss of tension has taken place on any studs earlier in the sequence.

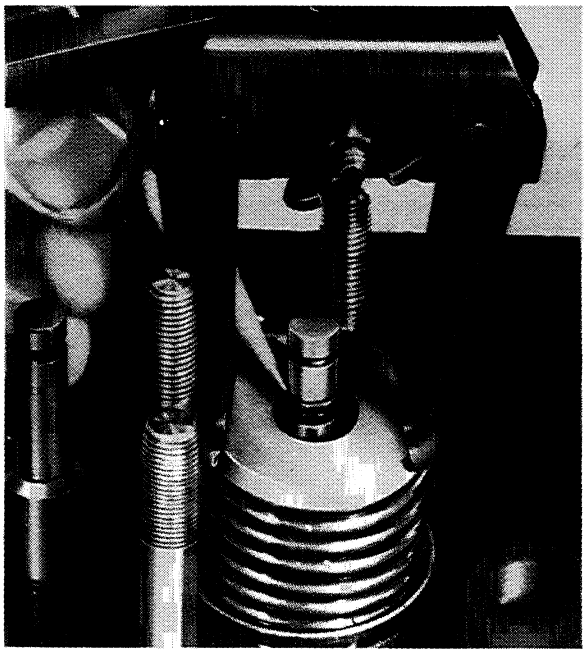


E19

1. Retaining Collets
2. Spring Caps
3. Inner Valve Springs
4. Outer Valve Springs
5. Spring Seating Washers
6. 'O' Sealing Ring (Inlet Valves only)
7. Inlet Valve
8. Exhaust Valve

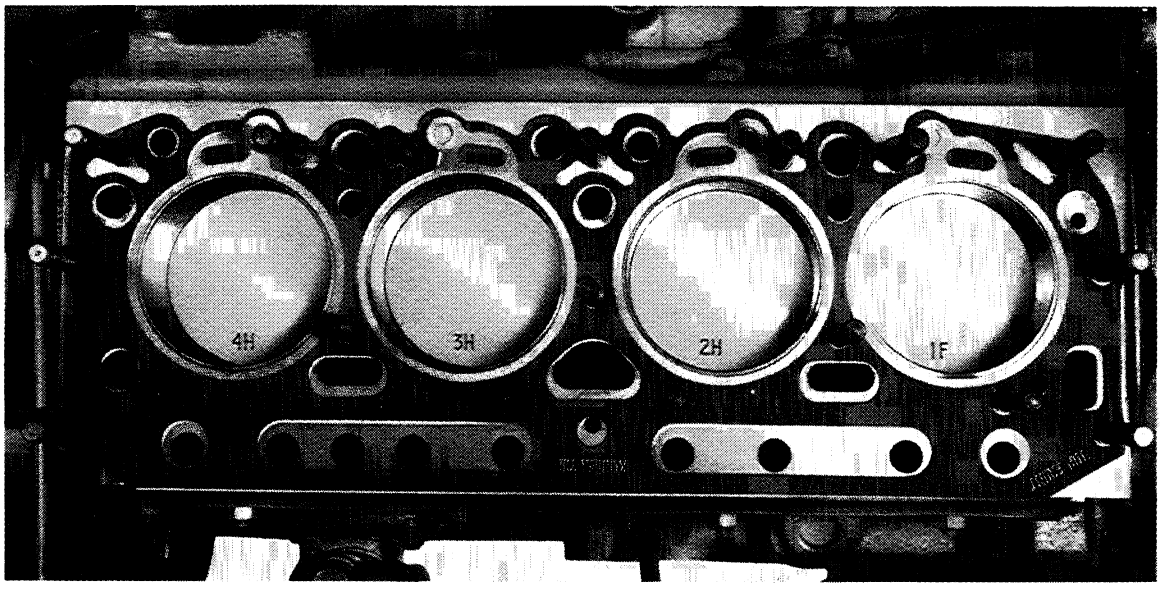


E20

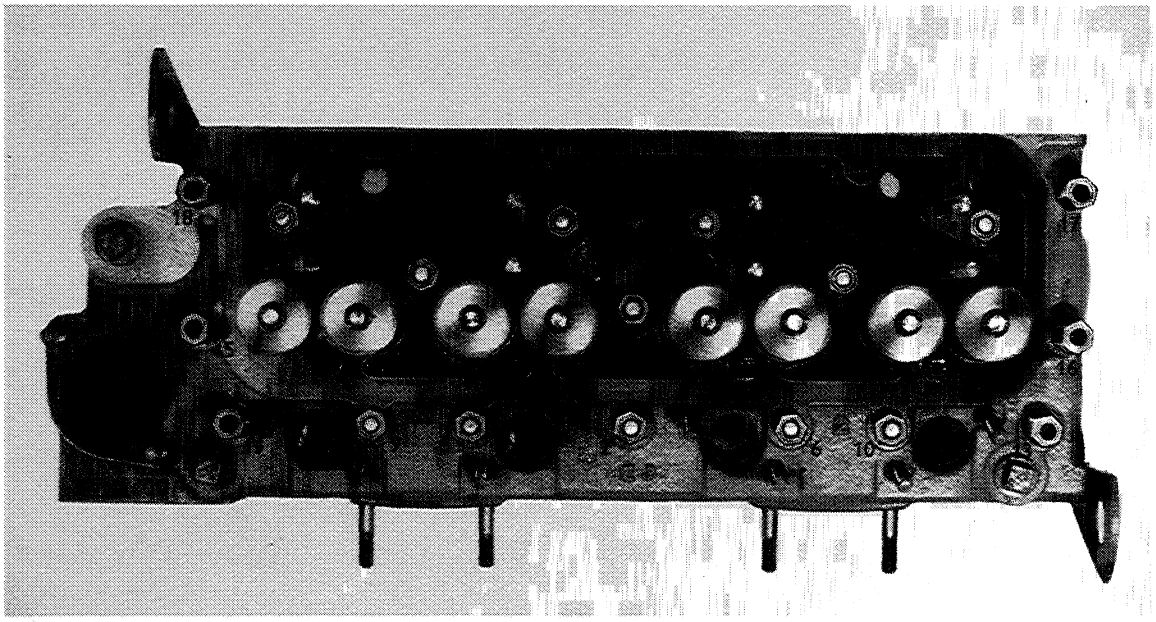


E21

4. Fit the push rods in their locations then carefully fit the rocker shaft assembly, noting that the valve adjusting screw ends locate in their respective push rod cups and the oil feed to the rocker shaft is located correctly.
5. Locate the oil feed pipe nut just finger tight at this stage, then evenly tighten the rocker shaft bracket securing nuts to a torque of 12 - 15 lbf ft (1,7 - 2 kgf m) now tighten the oil feed pipe nut.
   When correctly located the oil feed pipe will be as shown in Fig. E.2.
   NOTE: If the oil feed pipe nut is tightened before the rocker shaft bracket securing nuts, the pipe will either be strained or the olive pulled off the feed pipe.
6. Adjust the valve clearances to 0.012 in (0,3 mm) as follows:—
   Turn the engine so that the valves of No. 1 cylinder are in the position of 'valve overlap', i.e., the period between the opening of the inlet valve and the closing of the exhaust valve. In this position, adjust the clearances of No. 4 cylinder valves: similarly, with the valves of No. 3 cylinder in the overlap position, adjust the valves of No. 2 cylinder. With valves of No. 4 in the overlap position, adjust the valves of No. 1 cylinder and finally with valves of No. 2 cylinder in overlap position, adjust valves on No. 3 cylinder.
7. Replace the alternator adjusting link and tension the "V" belt (Refer to Page N.1).



E22



E23

8. Replace the injectors (Refer to Page P.7) but do not tighten the securing nuts.
9. Replace the leak off pipe assembly and four high pressure fuel pipes to the injectors. Tighten the injector securing nuts.
10. Replace the fuel oil filter and the low pressure fuel pipes between filter and lift pump and filter and fuel pump.
11. Reconnect the electrical and fuel supplies to the starting aid.
12. Reconnect the exhaust pipe to the manifold.
13. Reconnect the water outlet connection at the front of the cylinder head.
14. Fill the cooling system with clean water ensuring the drains are closed. Check for water leaks.
15. Bleed the air from the fuel system as described on Page P.8).
16. Reconnect the battery.

Starting the Engine

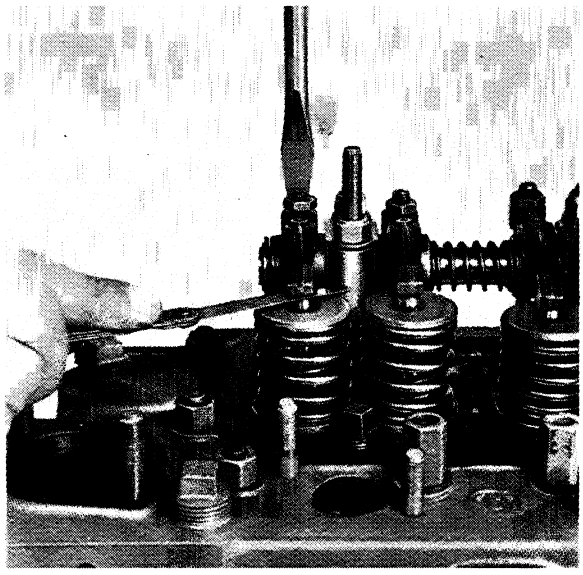
Proceed as instructed on Page P.11, with the engine running at a fast idle check that the oil pressure is satisfactory and that the oil reaches the rocker assembly and oozes gently from the rocker levers at this speed.

After the engine has been thoroughly warmed up it should be shut down, the rocker shaft removed and the cylinder head nuts checked, so that any loss of torque tension can be corrected by tightening the nuts to the torque given on Page B.2 and in the order shown in Fig. E.23.

Replace the rocker shaft as previously described and set the valve clearances to 0.012 in (0,30 mm) COLD. Start engine and check oil flow to rocker levers, if satisfactory refit cylinder head cover and air cleaner. Finally check for oil leaks and rectify immediately if any are visible.

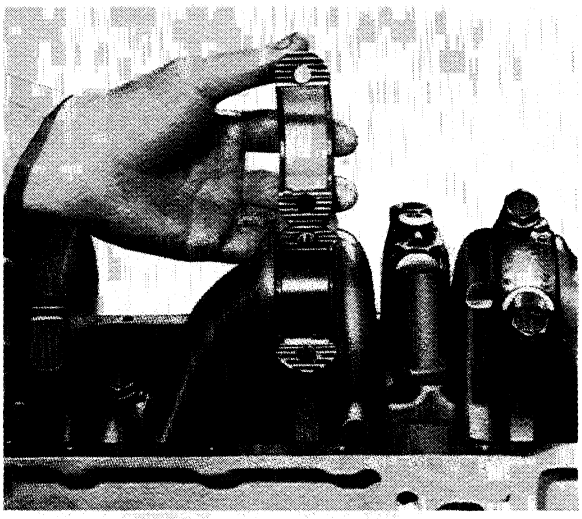
NOTE for 4.108 Engines Only

It is essential that the cylinder head nuts are re-torqued to 60 lbf ft (8,3 kgf m) after the first 6 to 12 hours with the engine hot and in the sequence shown in Fig. E.23.

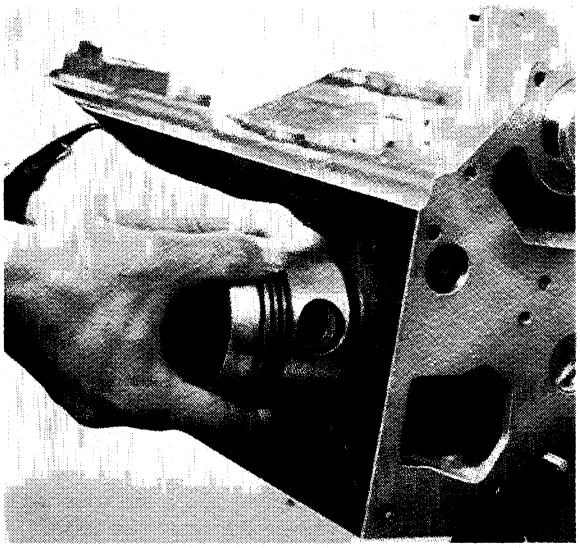


E24

SECTION F
Pistons and Connecting Rods



F1



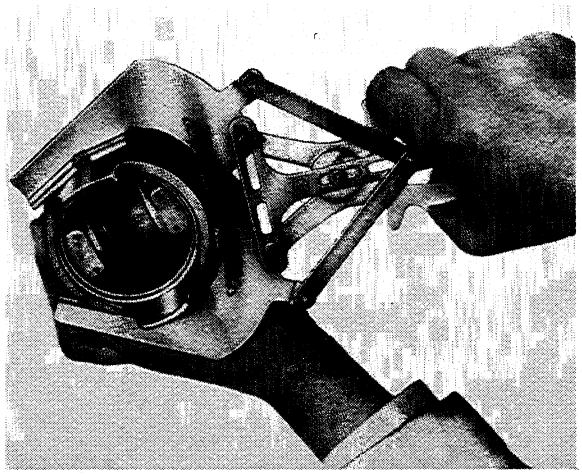
F2

To Remove Pistons and Connecting Rods

1. Remove the cylinder head assembly. (Refer to Page E.1).
2. Remove the oil sump. (Refer to Page M.1).
   NOTE: Any ridges or carbon deposits around the top of the cylinder bores should be removed with a suitable scraper before piston removal is attempted.
3. Rotate the crankshaft until one pair of big ends are at bottom dead centre, then remove their respective connecting rod cap securing bolts.
4. Remove the connecting rod caps and bearing shells. (Refer to Fig. F.1).
   NOTE: If the bearing shells are serviceable, they should be suitably marked to identify them to their original locations.
5. Push the pistons and connecting rods carefully out through the top of the block and remove as shown in Fig. F.2.
6. Rotate the crankshaft through 180° to bring the remaining pair of big ends to bottom dead centre and repeat removal operations.
   When piston removal has been carried out keep each piston and rod assembly separate, each to each as marked. Mark the pistons on the crown (before removing the piston pin) to indicate the 'FRONT' in relation to the 'FRONT' marking cast on the connecting rods.

To Remove Pistons and Rings from the Connecting Rods

1. Remove the piston rings from each piston, using a suitable piston ring tool, such a tool is shown in Fig. F.3.
   NOTE: The laminated segments or spring loaded rings fitted in the fourth ring groove should be removed by hand.
   With 4.108 pistons there is a steel insert rolled into the top ring groove during piston manufacture. It should be regarded as an integral part of the piston and no attempt should be made to remove



F3

it from its location.

2. Remove the circlip retaining the piston pin and push out the piston pin to release the connecting rod.

NOTE: Should difficulty be experienced in removing the piston pin, warm the piston in a suitable clean liquid (usually water) to a temperature of 100—120°F. (40—50°C), this will then enable the pin to be pushed out quite easily.

Inspection

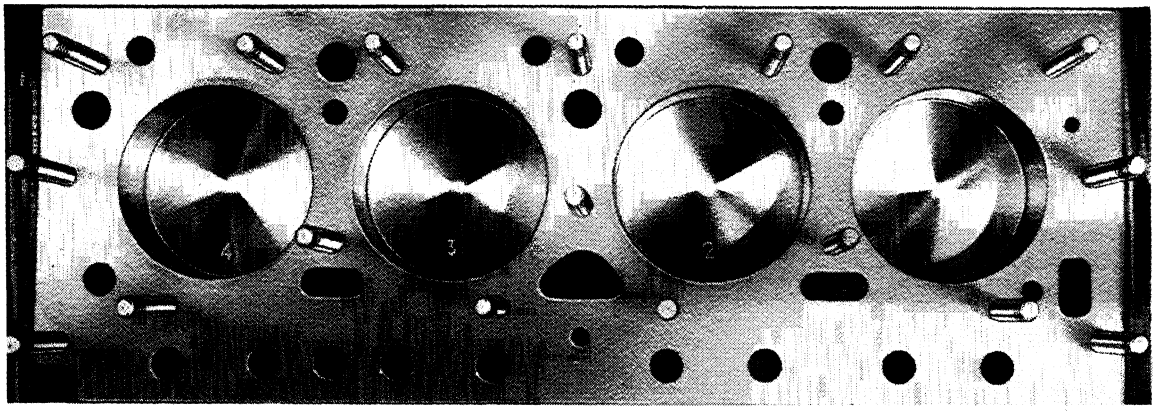
1. Examine the pistons for scoring and any signs of groove damage.
2. Check the clearance of the piston rings in their respective grooves by placing the ring outer face into the groove and a suitable sized feeler between the ring and groove face.
   NOTE: All ring gaps, ring groove clearances etc., are given in the Technical Data Section on Pages A.5 and A.6.
3. Check the fitted gaps of the piston rings, bearing in mind that in worn cylinder bores these gaps should be checked at the **bottom** of the bore.
4. Check the fit of the piston pin in the small end bushing, if excessive, replace the small end bushing.
5. To renew the small end bushing remove the old one by means of a suitable press and 'dolly'. Press in the new bushing, ensuring that the oil holes coincide when fitted. Ream out the new bushing to suit the piston pin, then check the rod for parallelism and twist. (Refer to Page A.7).
6. Examine the big end bearing shells for any signs of wear or pitting.

F4

To Refit the Pistons to the Connecting Rods

If the original pistons are to be refitted they must be re-assembled to the same connecting rods, i.e. No. 1 piston to No. 1 connecting rod assembly. Refer to Figs. F.4 and F.5 for location of piston and rod numbering. Any new components fitted should be numbered the same as those which they replace.

1. Warm the piston in a suitable clean liquid to a temperature of 100 — 120°F (40 — 50°C) which will enable the piston pin to be easily pushed into the piston bore when the piston and rod have been correctly aligned.
2. Place No. 1 piston onto its head, noting the position of the mark previously made to indicate the "FRONT".



F5

3. Hold No. 1 connecting rod with the small end between the piston pin bores so that the word "FRONT" cast on the rod is towards the same side.
4. Push the piston pin into the piston thus locating the connecting rod in position.
5. Fit the two retaining circlips ensuring that they locate correctly in their recesses. (Refer to Fig. F.6).
   NOTE: If the engine has been in service for some considerable time it is advisable to fit new circlips. even if the old ones do not appear to be strained or damaged.
6. Repeat this procedure for the three remaining pistons and connecting rods.

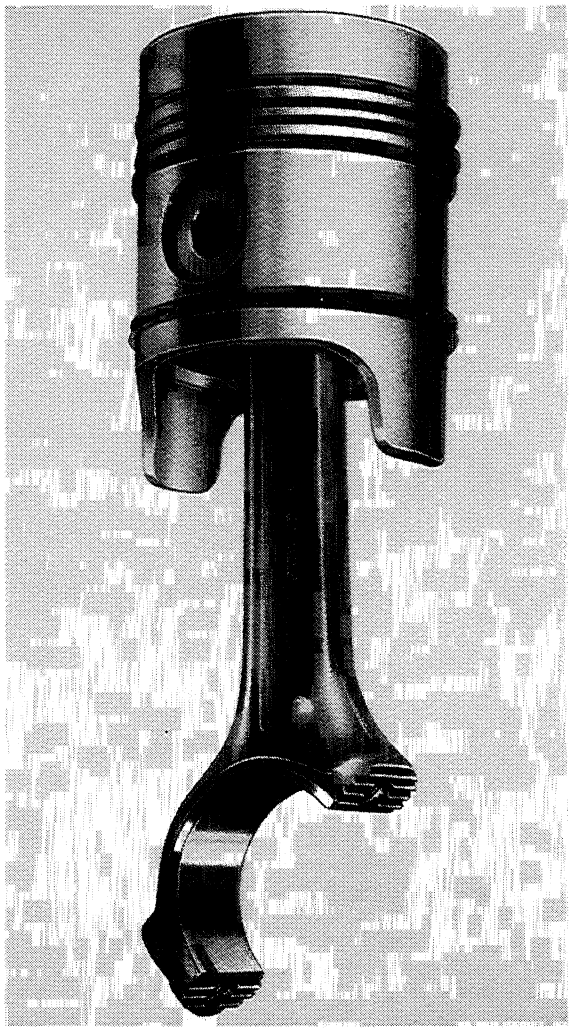
Fitting the Piston Rings

Fit piston rings to the piston. Rings vary according to engine type and application as follows: reading from the top of the piston.

4.108 Engines

1. Plain parallel faced compression.
2. Internally stepped compression.
3. Internally stepped compression.
4. Laminated segment oil control.
5. Slotted scraper.

F6



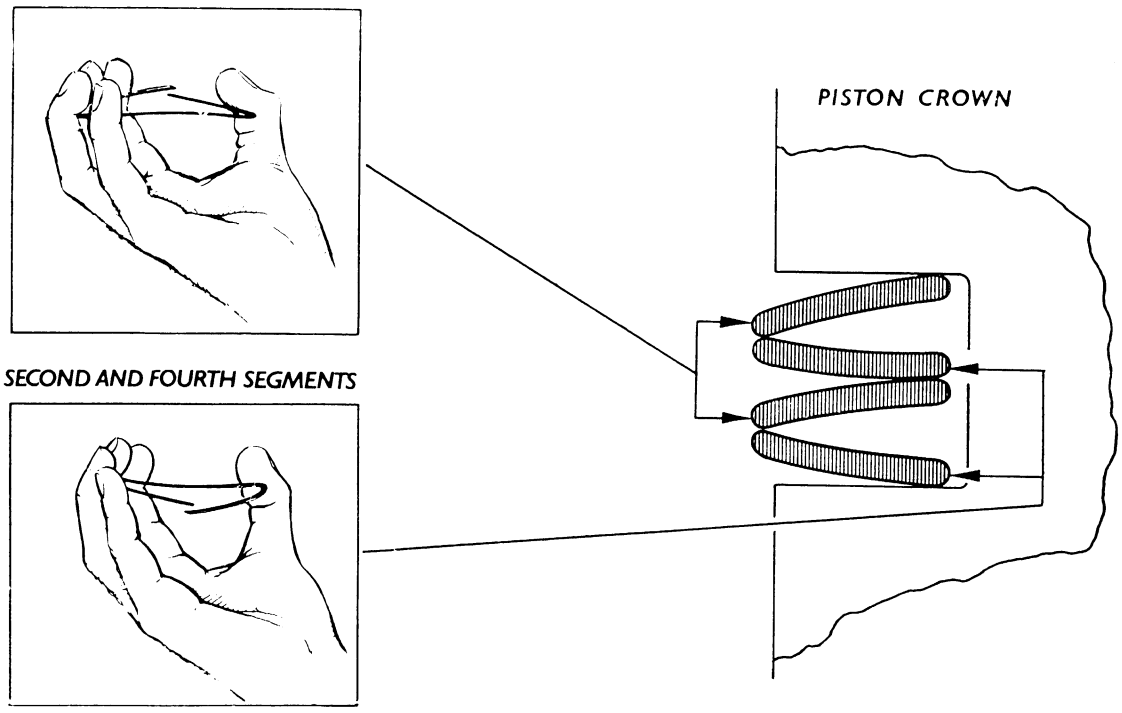
F7

4.107 and 4.99 Marine and Industrial Engines rated at 3000 r.p.m. or below.

1. Plain parallel faced compression.
2. Internally stepped compression.
3. Internally stepped compression.
4. Laminated segment oil control.
5. Slotted scraper.

After an appropriate period of service, when indications of piston ring and/or cylinder bore wear may become apparent, a replacement ring pack has been made available for fitting exclusively to 4.99 service engines and includes a taper faced ring for fitting in

NOTE: All the rings quoted above except the laminated and spring loaded type may be fitted by means of an expanding tool of the type shown in Fig. F.3. These rings, being made of cast iron are therefore comparatively brittle, so when fitting care should be taken not to expand any ring more than is necessary to just clear the piston.

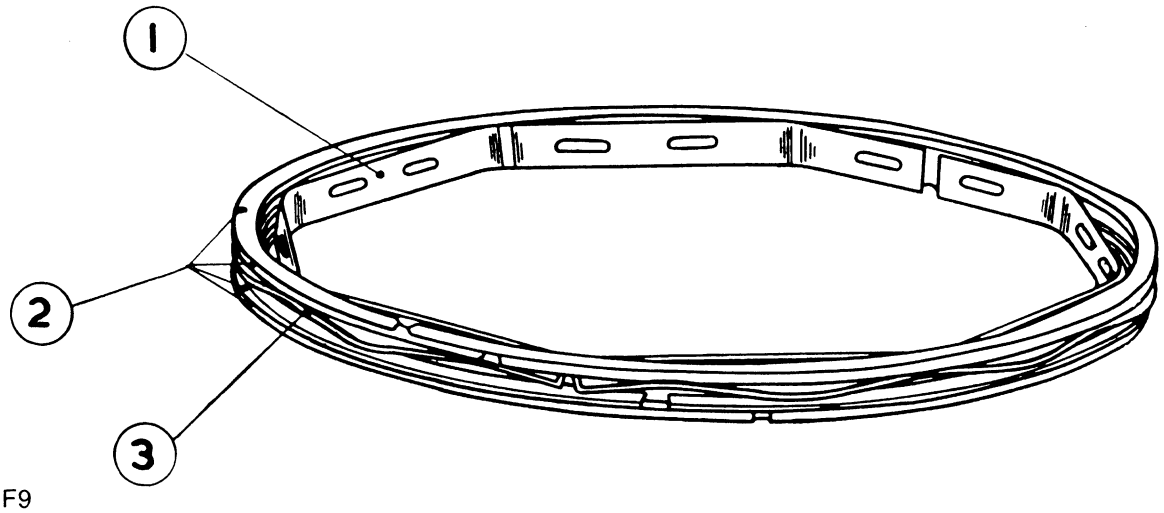


F8

Laminated Segment Rings

The procedure for fitting the laminated type is different, in as much as the ring comprises four separate segments, these may be fitted by hand in the following sequence with the piston crown uppermost:—

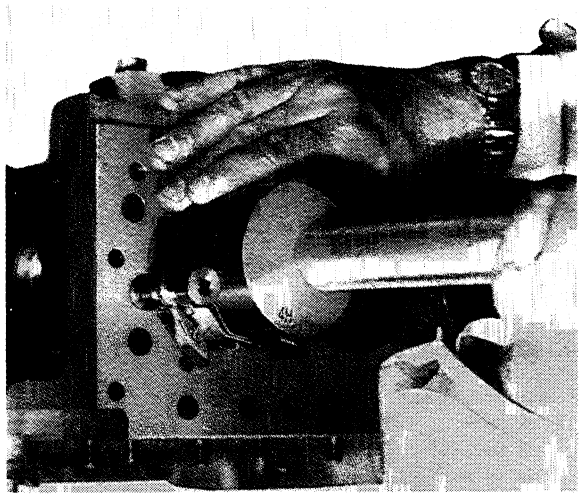
1. Fit the first segment to the piston so that when held horizontally between the thumb and fingers and radially compressed the ring ends point downwards (see Fig. F.8).
   Place this ring on the bottom face of the fourth ring groove with the gap over the piston pin bore.
2. Fit the second segment on top of the first, so that when compressed as described above the ends point upwards. Position the gap at 180° to that of the first segment.
3. Fit the third segment as in (1) above with the gap immediately above the gap of the first segment.
4. Fit the fourth segment as in (2) above with the gap immediately above the gap of the second segment. If all the segments have been fitted correctly then they will be positioned as shown above.



F9

The gaps of the remaining rings should be staggered alternately along the piston pin axis.
Liberally lubricate the rings in their grooves and see that they can move freely in their locations. this does not apply to the laminated type in the fourth groove, which if correctly fitted should **not** move freely due to the outward pressure of the top and bottom segments on the ring groove walls.
When all the rings have been fitted, they should be as shown in Fig. F.8.

Always ensure that internally stepped or taper faced rings are correctly fitted. They are marked TOP or BTM (bottom) to ensure correct replacement.
The top compression and slotted oil control rings may be fitted either way up.



F10

Spring Loaded Scraper Ring

When fitting the chrome plated spring loaded scraper ring, (see Fig. F.9), the following procedure should be adopted:—

1. Fit internal expander (1).
2. Fit two rail rings (2) at the bottom of the groove.
3. Fit spiral ring (3).
4. Fit two top rail rings (2).

When fitting rail rings, the gaps should be staggered.

To Fit Piston and Connecting Rod Assemblies

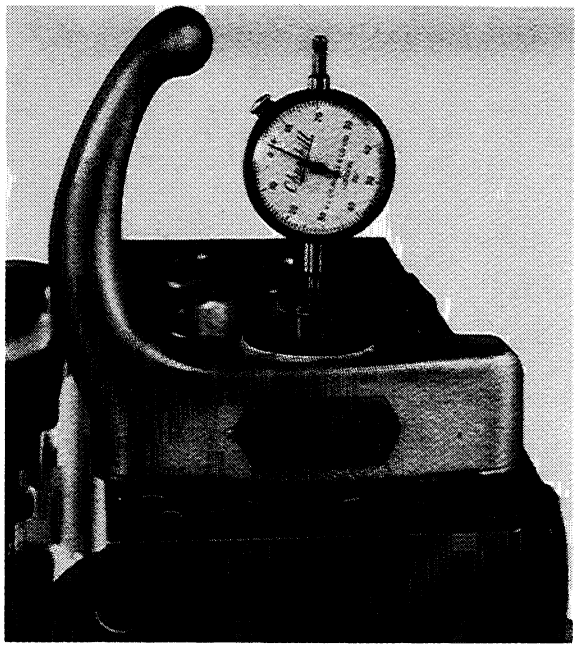
Before fitting the piston and connecting rod assemblies to their respective cylinder bores, thoroughly clean and liberally coat each bore with clean engine oil.

1. Turn the engine until the crankpins of say numbers 1 and 4 cylinders are at bottom dead centre.
2. Using a suitable ring clamp of the type shown in Fig. F.10, carefully compress the rings of No. 1 piston and hold in this position.
3. With the word 'FRONT' on the connecting rod facing the front of the engine, insert the rod carefully into No. 1 cylinder bore.
   NOTE: The cylinders are numbered 1, 2, 3, 4 starting from the front (water pump) end of the engine. It is extremely important that these components (marked as shown in Figs. F.4 and F.5), are returned to their original locations.
4. The piston head may be gently tapped with the shaft of a hammer as shown in Fig. F.10 until all the rings have entered the cylinder bore.
5. Draw the rod towards the crankpin, place the top half bearing shell in position locating the tag in the machined slot and liberally oil, draw the rod onto the crankpin.
6. Fit the lower half bearing shell to the connecting rod cap, locating the tag in the machined slot, liberally oil and fit the cap to the crankpin, ensuring that the numbers on the rod and cap coincide as shown in Fig. F.4.
7. Fit the two connecting rod securing bolts and tighten evenly to the torque quoted on Page B.2.
   NOTE : Locking tabs are not fitted to these bolts.
8. Repeat this procedure for No. 4 piston and connecting rod assembly.
9. Rotate the crankshaft to bring numbers 2 and 3 crankpins to bottom dead centre.
10. Repeat procedures 2 — 7 to fit the two remaining assemblies.
11. Refit the lubricating oil sump. (Refer Page M.4).
12. Refit the cylinder head assembly. (Refer Page E.7).

Fitting New Pistons

With new 4.108 and 4.107 pistons a machining allowance is provided on the crown of the piston to enable the necessary material to be removed by means of a lathe so that when fitted the piston height above the cylinder block top face will be within the limits quoted on Page B.3.
To determine the exact amount to be removed from the piston crown, the piston, connecting rod and bearing assembly will have to be fitted to its respective cylinder bore as previously described, and the piston height above the cylinder block top face measured with the particular piston at top dead centre. This piston height can be measured by means of a piston height gauge of the type shown in Fig. F.11. Repeat for each new piston to be fitted and mark each piston with the number of the cylinder bore it will belong to, (not on the top as any marking here will be removed by the machining). When each piston has been skimmed it should be checked again when finally refitted to ensure that any new piston fitted is now within the limits quoted. Once the piston height is correct mark any such piston on the crown with the number of its respective bore. (Refer to Fig. F.5).

It will of course be appreciated that grade F pistons are suitable for topping to give other grades where these are not to hand.
After fitting pre-topped pistons, the distance between the cylinder block face and piston crowns should be checked to ensure the limit is as already quoted (See Fig. F.11).

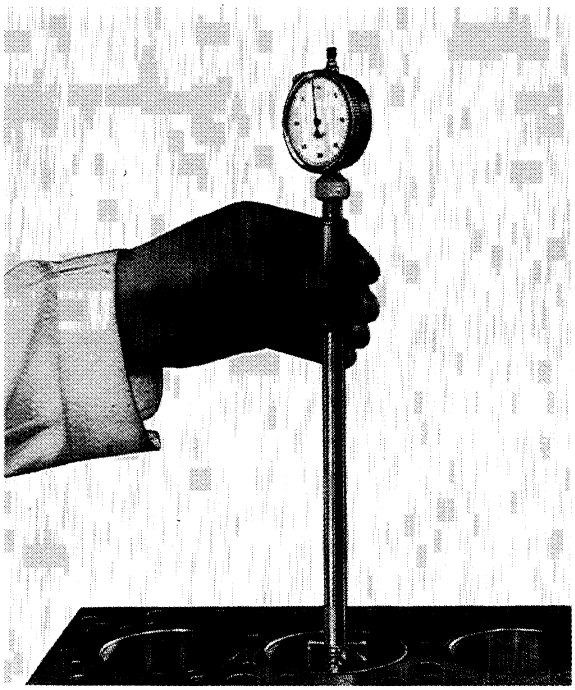


F11

SECTION G
Cylinder Block and Liners

CYLINDER LINERS (4.108 ENGINES)

The cylinder liners fitted to the 4.108 series engines are centrifugally cast alloy iron, they are an interference fit in the cylinder block parent bore and of the thinwall dry type.
Reboring of these liners is not possible and new liners should be fitted when a rebore would normally be considered necessary.
Dimensional checks of the cylinder bore are carried out by means of the gauge tool shown in Fig. G.1. When checking liners each one should be measured in three positions — top, centre and bottom; the readings being taken parallel and at right angles to the centre line of the cylinder block giving six readings for each cylinder bore.
When checking the fitted internal bore of a new thinwall liner it is advisable to allow a period of time to elapse for the liner to settle.



G1

To Renew Cylinder Liners

1. Remove all the various comopents from the cylinder block. (Refer to the appropriate sections for details of their removal).
2. Using a shouldered metal disc slightly smaller on the outside diameter than the parent bore diameter and a suitable press, press the liners carefully out through the top of the cylinder block.

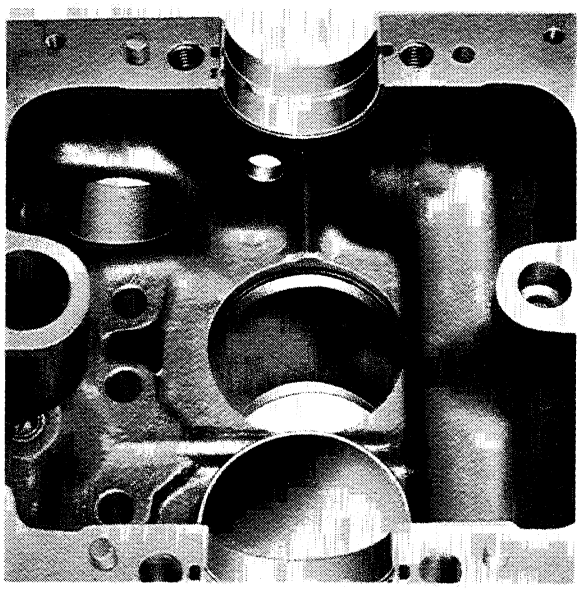
   NOTE: Support the block locally in the area of the top of the liner.

3. Lightly lubricate the outside of the liner with clean engine oil ready for fitting.
4. As the liner must protrude above the cylinder block top face and not be pressed fully home when fitted correctly, a solid stop washer should be available designed to give the correct liner protrusion.
   NOTE: The limits for liner protrusion are given on page B.3 and may be checked as shown in Fig. G.2.
5. Press the liner into the bore progressively until it reaches the solid stop washer.
6. Bore and finish hone the liners to the dimension quoted on Page B.3.
   NOTE: Where boring equipment is mounted on the top face of the cylinder block fit a parallel plate between the boring bar and cylinder block face. Such a plate should be thicker than 0.027 in (0,686 mm).
7. Re-assemble the engine components to the cylinder block. (Refer to the appropriate sections for assembly of these).

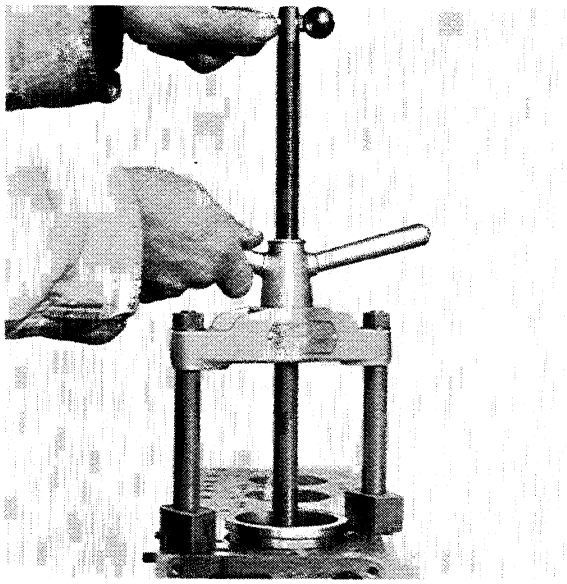
CYLINDER LINERS (4.107 and 4.99)

Cylinder liners fitted to 4.107 and 4.99 engines are of the centrifugal cast iron wet type. They have flanges at the top and are sealed at the bottom by means of two rubber sealing rings which fit in machined recesses in the cylinder block.

G2



G3



G4

Earlier 4.99 engines had only one sealing ring at the bottom of the liner.
4.107 and 4.99 cylinder liners have pre-finished bores. Under normal circumstances, the liner would only need to be renewed during major overhaul, but should it be necessary to remove the liner for any other reason, this can be carried out without removal of the crankshaft.
If at any time, the cylinder liners are removed and these same liners are to be refitted, then before they are removed from the cylinder block, they should be suitably marked so that they may be refitted to their original parent bore and in the same position in that bore, that is, thrust side of the liner to the thrust side of the cylinder block.

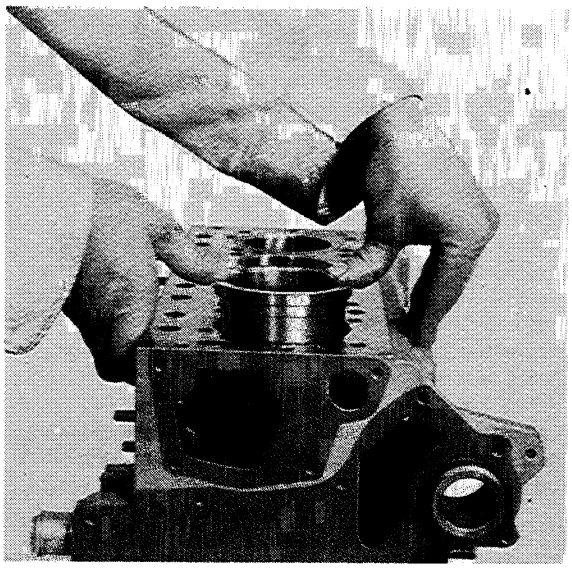
To Renew Cylinder Liners

Remove all components from cylinder block.
Remove liners using a suitable liner removing tool (see Fig. G.4).
Once the liner has cleared the rubber sealing rings in the cylinder block, the liner can be removed by hand.
Remove any corrosion and burrs which may be present at the inner ends of the landings.
Renew the rubber sealing rings in the grooves at the bottom lands.
To ease fitting of the liners when the rings have been placed in position, smear the liners with soft soap or soapy water.
Place liner in position and press home by hand, ensuring that the rubber sealing rings remain in their grooves (see Fig. G.5).
The liners are a push fit and no force is required.
After fitting the liners, the cylinder block should be water tested at a pressure of 20 lbf/in² (1,4 kgf/cm²).
Re-assemble engine as required and to instructions given for the various components.

Note: If engine is overheated, it could have an adverse affect on the liner sealing rings.

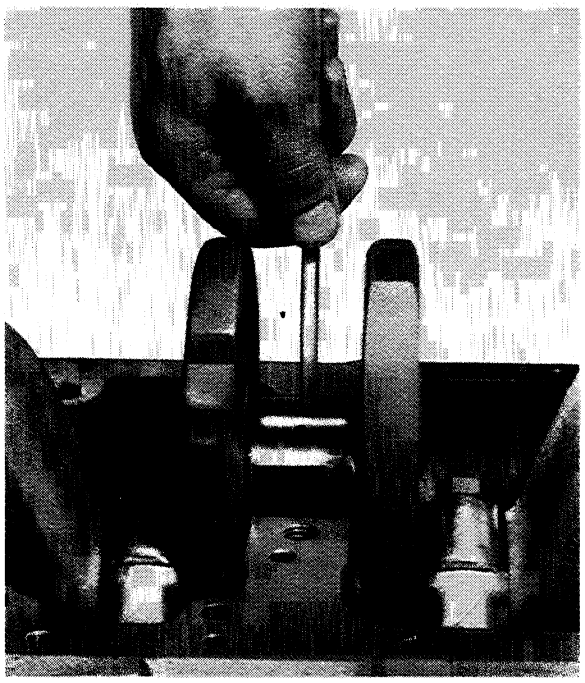
All 4.107 and later 4.99 engines have four small holes drilled along the fuel pump side of the cylinder block, each one breaking through into the area between the two sealing rings at the bottom of each cylinder liner. These holes permit any coolant which may have leaked past the upper sealing ring to escape thus relieving the bottom sealing ring of any pressure above it and preventing coolant from entering the engine sump.

In the case of a new engine, or where cylinder liners and/or sealing rings have been fitted, it is possible that a slight leakage of coolant could occur from these holes. This should ease as the liners and sealing rings settle down after the initial period of running, but where difficulty is experienced, then the use of BARSEAL in the cooling system (in accordance with the manufacturers instructions) is approved.



G5

SECTION H
Crankshaft and Main Bearings



H1

Description

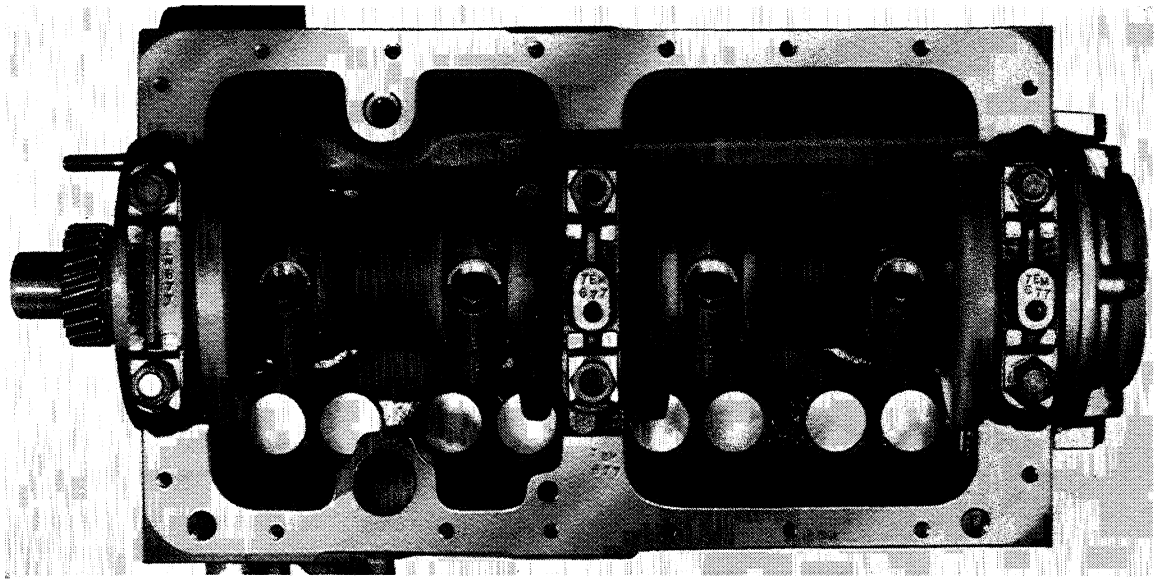
The crankshaft runs in three pre-finished replaceable thinwall, steel backed, aluminium tin-lined bearings. Crankshaft end float is controlled by thrust washers located either side of the rear main bearing. 0.0075 in (0,19 mm oversize) thrust washers are available which if used on one side of the rear main bearing only will reduce crankshaft end float by 0.0075 in (0,19 mm) and by 0.015 in (0,38 mm) if used on both sides The limits for the crankshaft end float are given on Page B.6.

The main bearing caps are numbered and are not interchangeable. The main bearing shells are located by means of tabs which locate in slots in the bearing housings.

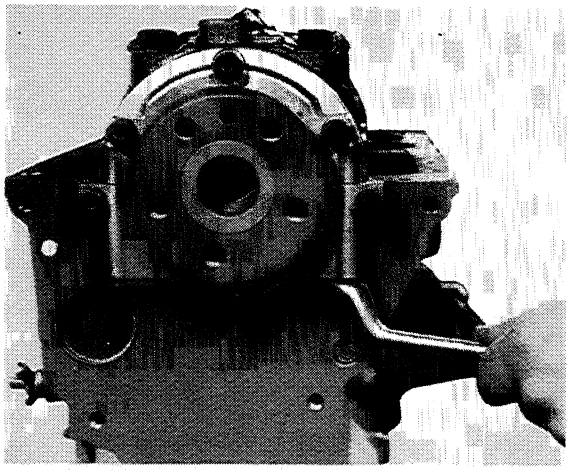
NOTE: Before renewal of the main bearings is attempted make absolutely certain that the correct replacements are available, reference to the relevant parts list will ensure this, but for identification purposes the new bearings should have an annular groove machined in the inner (bearing) face along the centre line of the feed holes, when the bearings are correctly located these feed holes will correspond exactly with those machined in the cylinder block.

On later 4.107 and 4.99 engines, the annular oil groove in the main bearing parent bore (cylinder block and bearing cap) has been deleted. Adequate lubrication is maintained by repositioning the oil feed holes radially in the shell bearings and continuing to machine the annular groove in the bearing on the centre line of these feed holes.

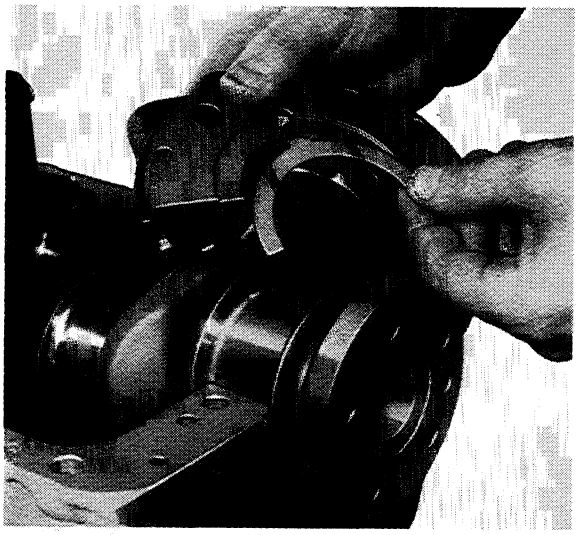
These later type shell bearings may be used on both early and later type engines, whereas the early type of shell bearings must NOT on any account, be fitted to later engines where the annular groove in the main bearing parent bore has been deleted.



H2



H3

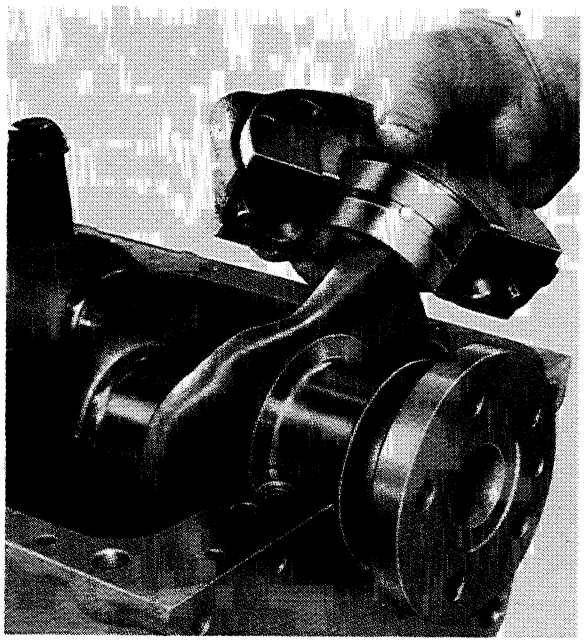


H4

To Renew Main Bearings and Thrust Washers

Removal of the main bearings and thrust washers can be carried out without removing the crankshaft by the following procedure:—

1. Remove the engine from its application.
2. Remove the sump and suction pipe assembly.
3. Slacken the setscrews which secure the main bearing caps.
4. Remove completely one of the main bearing caps and remove the bearing shell from the cap.
5. Remove the top half of the bearing shell by pushing it, on the opposite side to the one having the locating tag, with a suitable strip of wood and rotating it on the crankshaft as shown in Fig. H.1.
6. Inspect the bearing shells and if replacements are necessary continue by lightly lubricating and inserting the new top half bearing shell, plain end first, into the side having the tag location.
7. Rotate the bearing shell on the crankshaft until it locates correctly with the tag in the machined slot.
8. Locate the lower half bearing shell in the main bearing cap, liberally lubricate and refit.
9. Tighten the two securing setscrews to positively locate the bearing shells then slacken a turn or two.
10. Repeat items 3—8 for the remaining two bearings. NOTE: To enable the **rear** main bearing cap to be removed, first remove the two oil seal housing setscrews as shown in Fig. H.3.
11. Finally tighten the main bearings to the torque given on Page B.2.



H5

Renewal of the thrust washers is accomplished by carrying out the following procedure:—

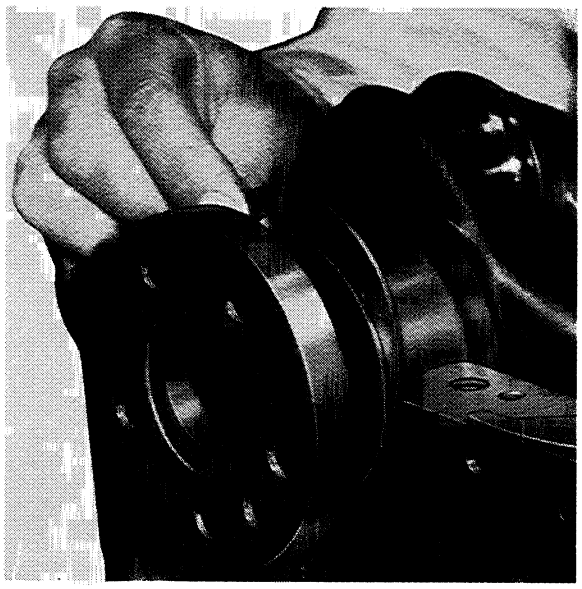
1. Remove the two setscrews securing the two rear main bearing oil seal half housing as shown in Fig. H.3.
2. Remove the rear main bearing cap securing setscrews.
3. Remove the rear main bearing cap and from it the two lower half thrust washers. (Refer Fig. H.4).
4. The single upper half thrust washer is removed by rotating it with a thin piece of wood until it can be lifted out of its recess.
   NOTE: The new thrust washers should be lightly lubricated before fitting. The steel faces of the lower thrust washers should face inwards towards the bearing cap, (Refer Fig. H.5), the steel face of the upper thrust washer should also face inwards.
5. Locate the upper thrust washer half as shown in Fig. H.6, place the lower halves either side of the rear main bearing cap as described and refit the cap.
6. Tighten the setscrews evenly and finally to the torque given on Page B.2.

7. Check that the crankshaft end float is within the limits given on Page B.6 by means of feeler gauges as shown in Fig. H.7. If incorrect, oversize thrust washers are available to give an overall reduction of 0.015 in (0,38 mm). (Refer to Page H.2).
8. Refit the two setscrews securing the rear main oil seal half housing.
   NOTE: If any leakage of oil is apparent from this seal then new seals should be fitted to the half housings as described under the heading "Crank-shaft Rear End Oil Seal" or fit a new assembly.
9. Refit the suction pipe assembly and sump.

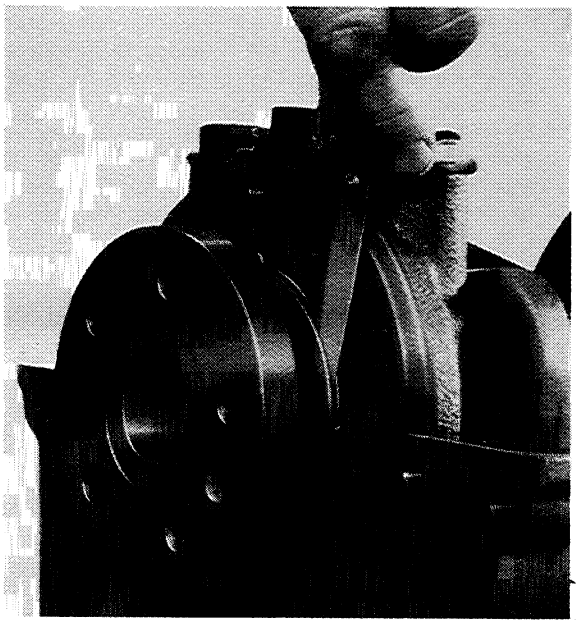
To Remove the Crankshaft

To remove the crankshaft it will be necessary to remove the engine.

1. Remove the starter motor, flywheel and flywheel housing.
2. Remove the crankshaft front pulley, timing case cover, timing gears and fuel pump drive hub. (Refer to Page K.1 for details of their removal).
3. Remove the securing setscrews (also any studs fitted) and remove the timing case back plate.
4. Remove the sump and lubricating oil pump complete with suction and delivery pipes. (Refer to Page M.1 for removal of these).
5. Remove all the connecting rod setscrews, connecting rod caps and bearing shells. (Refer to Page F.1).
   NOTE : All the bearing shells should be marked to indicate "top" or "bottom" and number of the rod assembly.
6. Unscrew the main bearing caps.



H6



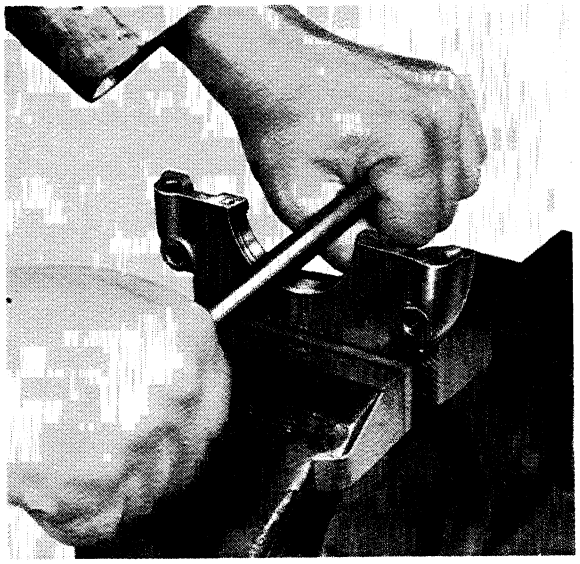
H7

   NOTE: The rear seal half housing securing setscrews will require removal to enable the rear main bearing cap to be removed. (Refer to Fig. H.3).
7. Lift out the crankshaft and place where it is not likely to be damaged ready for inspection.
8. Remove the top half main bearing shells.
9. Finally, remove the top half oil seal housing.

To Refit the Crankshaft

1. First ensure that crankshaft oilways are clear.
2. Place the three top bearing shells in position then oil liberally with clean engine oil.
   NOTE: Unless a new set of main bearings is being fitted, those removed must be returned to their original locations.
3. Place the crankshaft in position.
4. Locate the upper thrust washer in position as shown in Fig. H.6.
5. Fit the three lower bearing shells, oil, and fit the three main bearing caps in their respective locations.
   NOTE: Ensure at this stage that the two lower thrust washer halves are positioned correctly either side of the rear main bearing cap when it is fitted.
6. Check the main bearing setscrews prior to fitting for signs of stretch or thread damage. Where damage or any doubt exists fit new replacements.
7. Fit the setscrews then tighten evenly to the torque tension given on Page B.2.
8. Check that the crankshaft can be rotated freely, if satisfactory check the crankshaft end float by means of feeler gauges as shown in Fig. H.7. Should it not be within the limits quoted on Page B.6, then oversize thrust washers are available to give the necessary adjustment. (Refer to Page H.2).

9. Fit new sealing strips to the rear main bearing oil seal housings and refit the housings as described under the heading "Crankshaft Rear End Oil Seal" on Page H.4.
10. Liberally oil the crankpins, locate the connecting rod bearing shells, again ensuring their correct relative positions, then fit the connecting rod caps as described on Page F.5. The crankcase should now be as shown in Fig. H.2.
11. Refit the lubricating oil pump complete with suction and delivery pipes. (Refer to Page M.4).
12. Refit the sump using new seals and gaskets. (Refer to Page M.1).
13. Refit the timing case back plate, fuel pump drive hub, timing gears, timing cover and crankshaft front pulley. (Refer to later text commencing on Page K.1 for their reassembly.
14. Refit and correctly align the flywheel housing as described in Section J.
15. Refit the flywheel and starter motor.



H8

CRANKSHAFT REAR END OIL SEAL

This sealing arrangement consists of two half housings bolted around the rear of the crankshaft. The bore of these housings is machined to accommodate a rubber cored asbestos strip which, in conjunction with a right hand helix machined between the thrust collar and the flywheel mounting flange to the dimensions given on Page B.6, acts to return the surplus oil reaching the seal. The two half housings fit over this helix and the contact of the sealing strips with the crankshaft prevents leakage beyond this point.

NOTE: When traces of oil become apparent from behind the flywheel and a faulty rear oil seal is suspected, first ensure that the crankcase is breathing normally. Any build up in crankcase pressure could cause oil to be forced past the rear sealing arrangement. If crankcase pressure is normal and new seals require to be fitted the following procedure should be adopted with the crankshaft in position.

1. Set up a half housing in the vice with the seal recess uppermost.
2. Settle approximately 1 in (25 mm) of the strip, at each end, into the ends of the groove ensuring that each end of the strip projects 0.010/0.020 in (0,25/0,50 mm) beyond the half housing joint face.
3. With the thumb or finger press the remainder of the strip into the groove, working from the centre, then use any convenient round bar to further bed in the strip by rolling and pressing its inner diameter as shown in Fig. H.8. This procedure takes advantage of the friction between the strip and the groove at the ends to compact the rope, while ensuring that the projections of the end faces of the rope remain as set.
4. Fit the sealing strip to the other half housing in a similar manner.
5. Remove all traces of the old gasket from the cylinder block rear face and fit a new gasket treated with a suitable sealing compund.
6. Lightly coat the faces of the housing with a suitable sealing compound.
7. Spread a film of graphite grease over the exposed inside diameter surface of the strip.
8. Assemble the half housings around the crankshaft rear journal and fasten together by the two setscrews (See Fig. H.3).
9. Swivel the complete seal housing on the shaft to bed in the strips, and to establish that the assembly turns on the crankshaft.
10. Bolt the seal housing in position on the block and the rear main bearing cap then finally tighten the securing setscrews.

SECTION J
Flywheel and Housing

Alignment of the Adaptor Plate, Flywheel Housing and Flywheel.

It is most important that the adaptor plate, flywheel housing and flywheel be correctly aligned with the crankshaft. If the plate and housing have been removed as is necessary for a complete overhaul, the greatest care must be taken on replacement to insure accuracy of alignment. The appropriate procedure is as follows:

See that the faces of both the rear of the cylinder block and the adaptor plate are perfectly clean and free from burrs.

Secure the adaptor plate to the cylinder block with set-screws and spring washers.

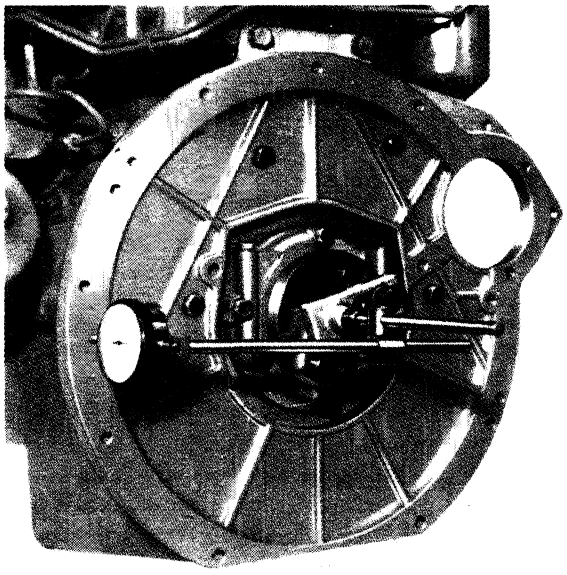
Alignment of the Adaptor Plate Face.

Secure the base of an indicator gauge to the flange of the crankshaft.

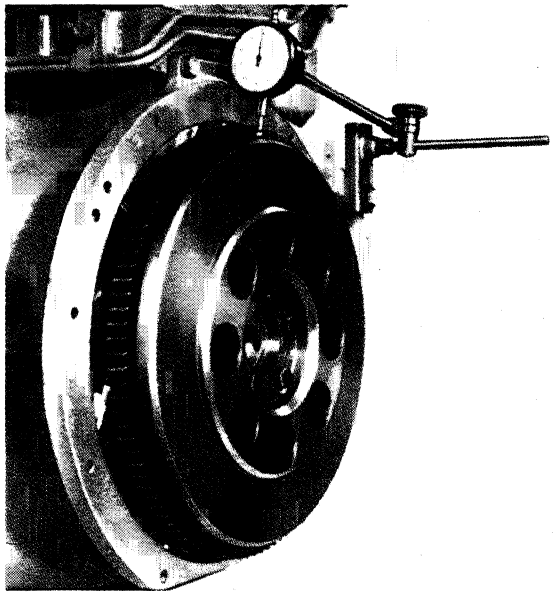
Set the needle of the gauge against the vertical face of the adaptor plate (See Fig. J1).

Turn the crankshaft and check that this face is perpendicular to the crankshaft axis.

Flywheel housing face should be within a limit of .006 total indicator reading of being truly at right angles to the crankshaft axis.



J1



J2

All adjustments to bring the adaptor plate within the limits must be on the adaptor plate and under NO CONDITIONS must the rear of the cylinder block be interfered with.

When the adaptor plate is properly aligned to the above limits, tighten the setscrews evenly.

Ream the dowel holes and fit the correct length and size of dowels.

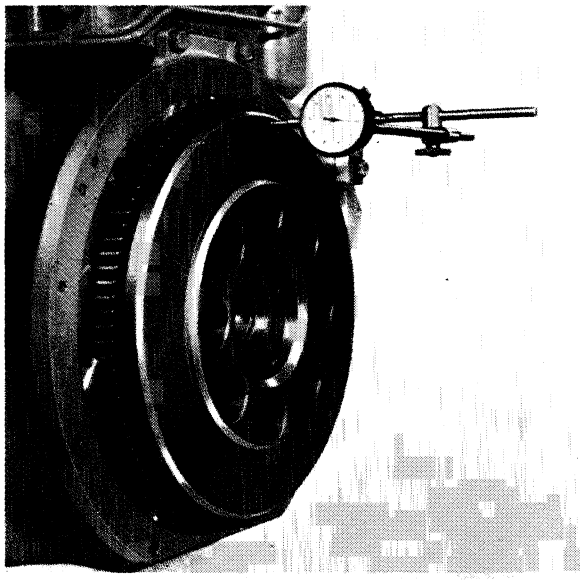
Fitting Flywheel and Checking Alignment.

With the flywheel and crankshaft flange perfectly clean and free from burrs, place the flywheel on the crank-shaft flange.

Insert the setscrews complete with tab washers into the flywheel holes and tighten evenly.

Secure the base of the indicator gauge to the adaptor plate. With the flywheel at top center, set the needle of the gauge on the periphery at T.D.C. See Fig. J2.

Turn the crankshaft and check the indicator, the flywheel should run true within .012 in. total indicator reading.

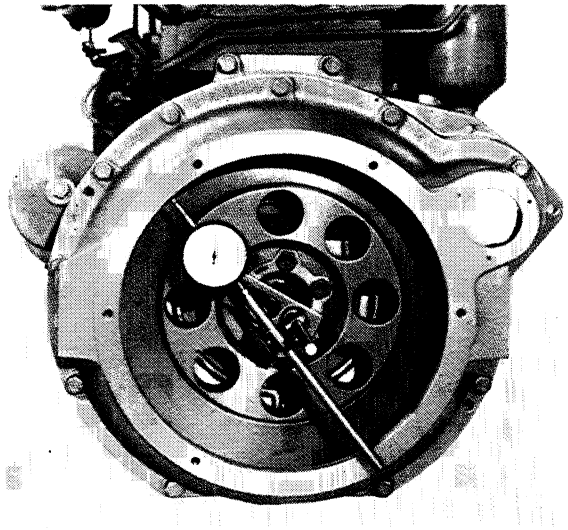


J3

With the base of the indicator gauge still bolted to the adaptor plate adjust the indicator so as to set the needle against the vertical machined face of the flywheel. See Fig. J3.

Again turn the crankshaft and check the indicator, the flywheel should be within .0005″ per inch of flywheel diameter (total indicator reading) of being truly at right angles to the crankshaft axis.

When the flywheel is correctly aligned, lock the securing setscrews by means of the tab washers.



J4

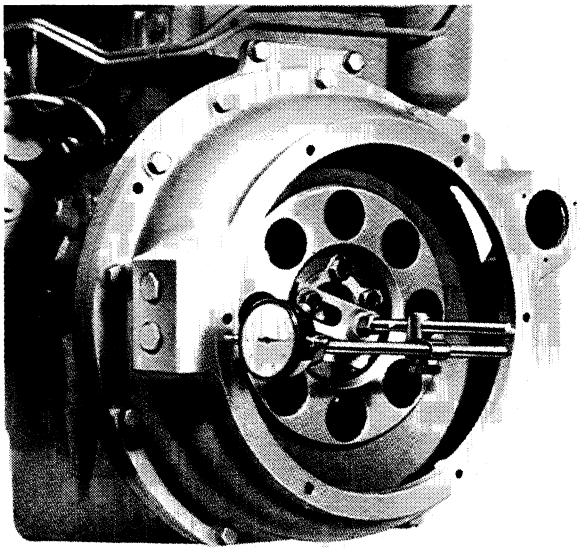
See that the face of the housing is perfectly clean and free from burrs.

Secure the housing to the adaptor plate with setscrews and spring washers, but not overtight so as to allow adjustment.

Attach the indicator gauge to the flywheel centre and set the needle of the gauge to the interior of the bored hole in the flywheel housing (See Fig. J4).

Turn the crankshaft and check that this hole is truly central. The housing is adjusted until the bored hole is central.

The hole in the housing should be truly central with the crankshaft within a limit of .006 (total indicator reading).



J5

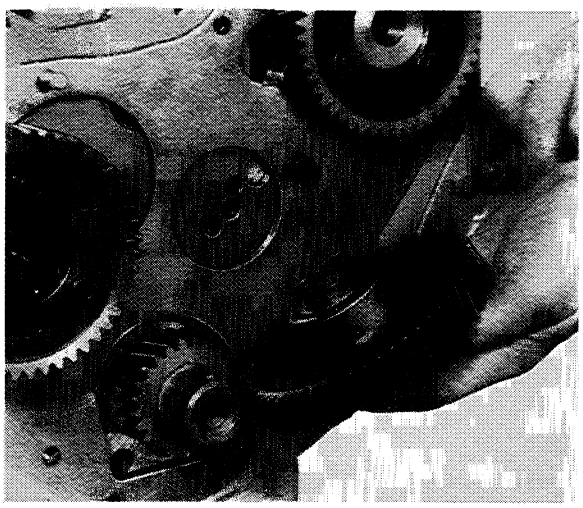
Alignment of the Flywheel Housing Face.

With the base of the indicator gauge still bolted to the flywheel centre, adjust the indicator so as to set the needle against the vertical machined face of the flywheel housing, and again turning the crankshaft, check that this face is perpendicular to the crankshaft axis (See Fig. J5).

The limits for this facing are the same as those given for the adaptor plate facing. When the housing is properly aligned to the above limits, tighten the securing setscrews evenly.

Ream the dowel holes and fit the correct length and size dowels.

SECTION K
Timing Case and Drive



K1

To carry out the following procedure it is assumed that either working space exists with the engine 'in place' or it is removed from the application.

To Remove the Timing Case Cover

1. Slacken alternator mounting bolts, release the adjusting arm setscrew and remove the alternator drive belt.
2. Remove the crankshaft pulley retaining setscrew or dognut and withdraw the pulley which is a keyed fit on the crankshaft.
3. Remove the securing setscrews and nuts from the timing case and carefully remove the cover, taking care not to catch the rubber lip of the oil seal on the crankshaft pulley locating key.

To Renew the Crankshaft Front Oil Seal

1. Using a suitable dolly and press, remove the oil seal from the timing case cover by pushing out through the front.
2. Locate the new seal in position so that the lip faces inwards.
3. Press in the new seal from the front until it just butts against the seal retaining lip, giving local support to the cover as the seal is pressed home.

To Refit the Timing Case Cover

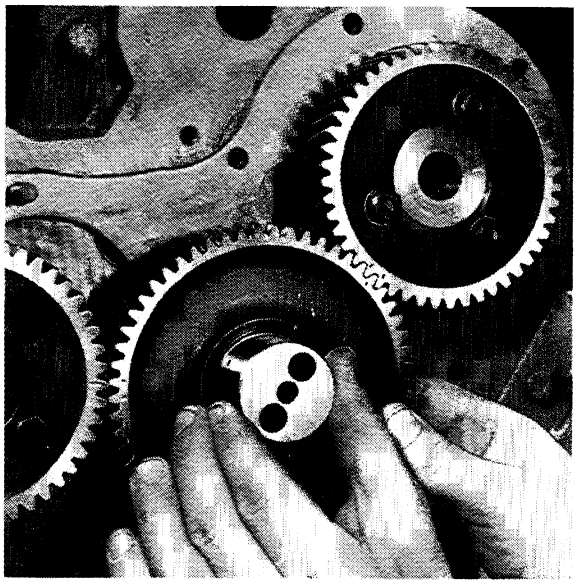
1. Using a new gasket, lightly coated with a suitable sealing compound, place the front cover in position taking care not to damage the rubber lip of the oil seal on the crankshaft pulley key.
2. Loosely fit the front cover securing setscrews and nuts.
3. Fit the crankshaft pulley to centralise the seal, then tighten the securing setscrews and nuts.
4. Fit the crankshaft pulley retaining setscrew or dognut and tighten to the torque given on Page B.2.
5. Refit the "V" belt and tension as described on Page N.1.

To Remove the Idler Gear and Hub

1. Remove the timing case front cover as previously described in this section.
2. Tap back the locking tabs and unscrew the two idler hub securing setscrews.
3. The setscrews, idler gear and hub may now be removed together as shown in Fig. K.1.
4. Clean and thoroughly examine the gear and hub for signs of excessive wear, cracks, pitting, etc.

To Refit the Idler Gear and Hub

1. After ensuring that the oilways in the hub and gear are clear, hold the gear in position with the timing marks correctly aligned.



K2

NOTE: If the cylinder head assembly has not been disturbed, then the cylinder head cover and rocker shaft should be removed in order to allow the camshaft to be turned to facilitate the aligning of the timing marks.

2. Insert the hub as shown in Fig. K.2 so that the holes in the hub and the cylinder block are in alignment and secure with the two setscrews.

   NOTE: Clearance is provided in the setscrew holes of the idler gear hub, to provide the necessary backlash adjustment for the timing gears.

3. Using the adjustable idler gear, backlash between both crankshaft gear/idler gear and camshaft gear/idler gear should be set within the range given on Page B.9 with the gears held together in order to take up the effect of bearing clearance. Backlash may be checked by the use of feeler gauges as shown in Fig. K.3.
4. When the backlash has been correctly set, finally tighten the idler gear hub securing setscrews to the torque given on Page B.2.
5. Check the idler gear end float as shown in Fig. K.4 the limits are given on Page B.9.
6. Lock the idler gear hub securing setscrews with the tabwashers.

   NOTE : The timing gears when correctly set should appear as shown in Fig. L.1.

7. Refit the timing case front cover, etc., as previously detailed in this section.

K3

To Remove the Fuel Pump Gear

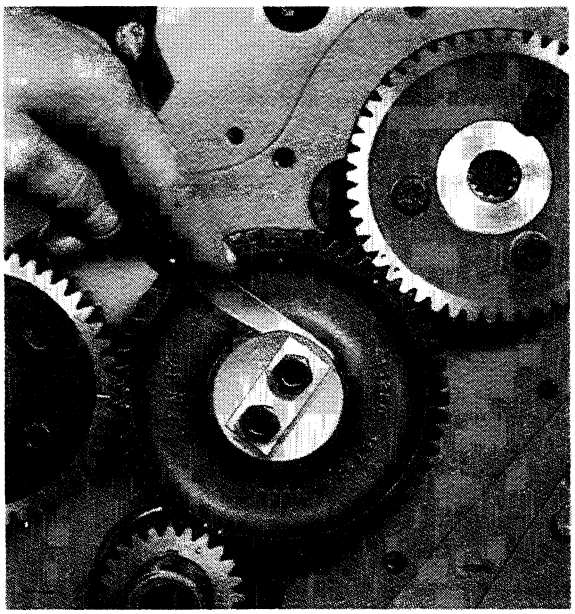
1. Remove the timing case front cover.
2. Remove the idler gear and hub.
3. Remove the three securing setscrews and ease the gear from its location on the fuel pump driving hub.
4. Examine the gear for signs of excessive wear, cracks, pitting, etc.

To Remove the Camshaft Gear

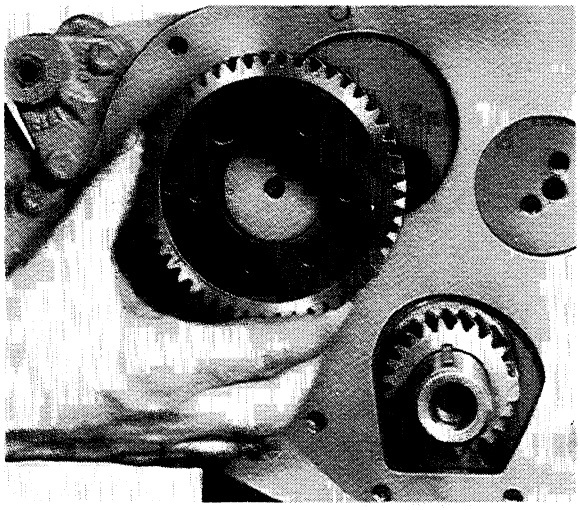
1. Remove the timing case front cover.
2. Remove the three securing setscrews and ease the gear away from its location.
3. Examine the gear for signs of excessive wear, cracks, pitting, etc.

To Refit the Camshaft Gear

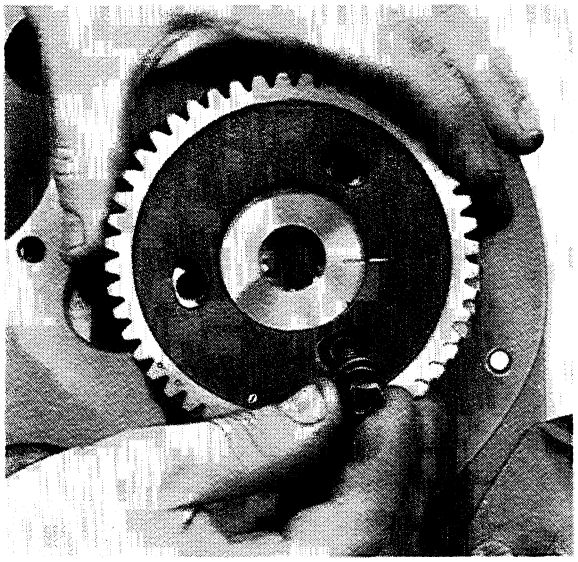
1. Remove the idler gear and hub, cylinder head cover and rocker shaft (if not previously removed).
2. Refit the gear to the camshaft ensuring that the 'D' marks on the gear and camshaft hub respectively align as shown in Fig. K.5.
3. Refit the three securing setscrews and tighten to a torque of 19—21 lbf ft (2,6—2,9 kgf m).
   NOTE: Only the plain (non-slotted) holes in the camshaft gear are to be used and these will align with the tapped holes on the camshaft hub when the 'D' marks are in alignment.
4. Refit the idler hub and gear, timing case front cover, etc., as previously detailed in this section.



K4



K5



K6

To Refit the Fuel Pump Gear

1. Refit the fuel pump gear so that the timing marks on the gear and hub respectively are in alignment as shown in Fig. K.6.
2. Refit the three securing setscrews and tighten to a torque of 19—21 lbf ft (2,6—2,9 kgf m).
3. Refit the idler gear and hub, timing case front cover, etc.

To Remove the Fuel Pump Drive Hub

1. Remove the timing case front cover and fuel pump gear.
2. Remove the low and high pressure fuel pipes from the fuel (injection) pump.
3. Remove the fuel pump securing setscrews and withdraw the pump.
4. Remove the drive hub locating circlip and withdraw the drive hub from its bearing (Refer Fig. K.7).
5. Examine the drive hub also the bearing in which it runs for signs of excessive wear, surface cracks, pitting etc.

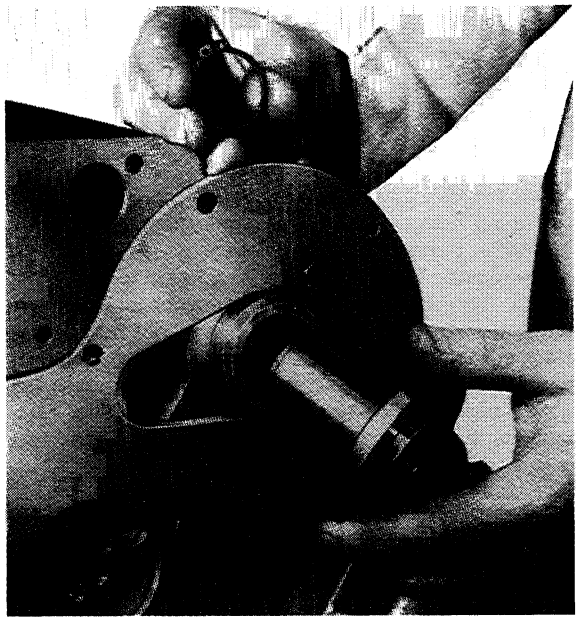
   NOTE: The bearing is an interference fit in the cylinder block and replacement is carried out by means of a suitable dolly and puller or press if the block is completely stripped, the new one being fitted in the reverse manner.

To Refit the Fuel Pump Drive Hub

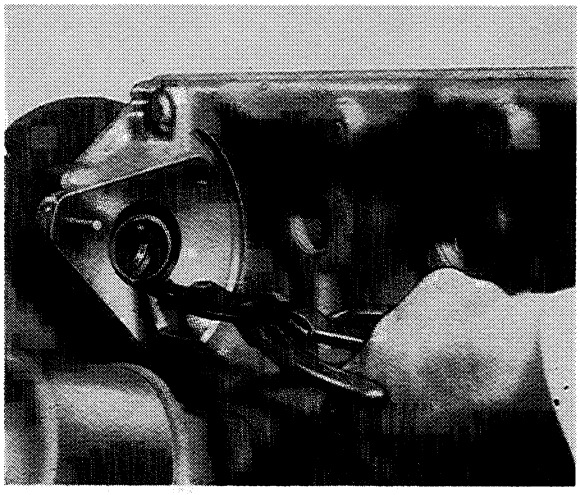
1. Replace the drive hub in the bearing and locate with the circlip as shown in Fig. K.8.
2. Check the drive hub end float by means of feeler gauges placed between the front face of the bearing and the rear face of the drive hub. The end float limits are given on Page B.9.
3. Refit the fuel pump as detailed on Page P.4.
4. Refit the low and high pressure fuel pipes to the fuel pump.
5. Refit the fuel pump drive gear, idler gear and hub, timing case front cover etc.

To Remove the Timing Case Back Plate

1. Remove the timing case front cover and timing gears.
2. Remove the fuel pump and drive hub.
3. Remove the securing setscrews and studs (where fitted).



K7



K8

4. Lift the timing case back plate clear from the camshaft hub and crankshaft gear.
   NOTE: The crankshaft gear is an interference fit on the crankshaft. Should its removal become necessary, then this can be accomplished by the use of a suitable puller.

To Refit the Timing Case Back Plate

1. Fit the timing case back plate to the cylinder block using a new gasket and suitable sealing compound.
2. Refit any studs removed and secure with the setscrews.
3. Refit the fuel pump drive hub and fuel pump.
4. Refit the timing gears, timing case front cover etc.

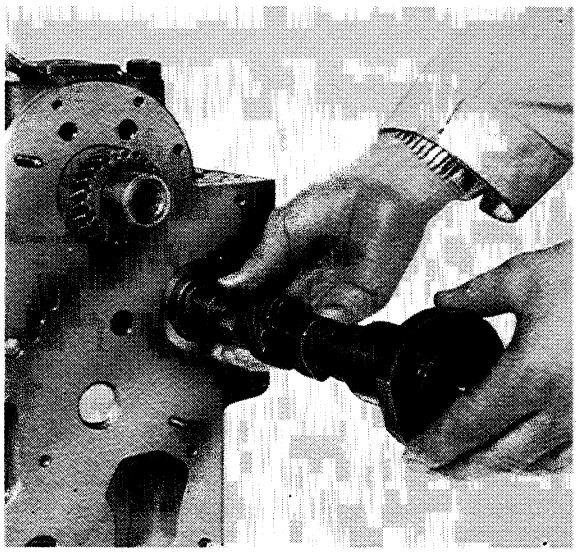
To Remove the Camshaft and Tappets

To remove the camshaft it may be necessary to remove the engine from the application and place in a suitable dismantling stand where it can be turned upside down. The purpose of this is to prevent the tappets from falling out of their locations when the camshaft is removed. If, however, it is not possible to turn the engine over in this manner, then this problem may be overcome by attaching suitable clips (when the tappet inspection cover has been removed) to each tappet to hold them in their locations when the camshaft is withdrawn from the block.

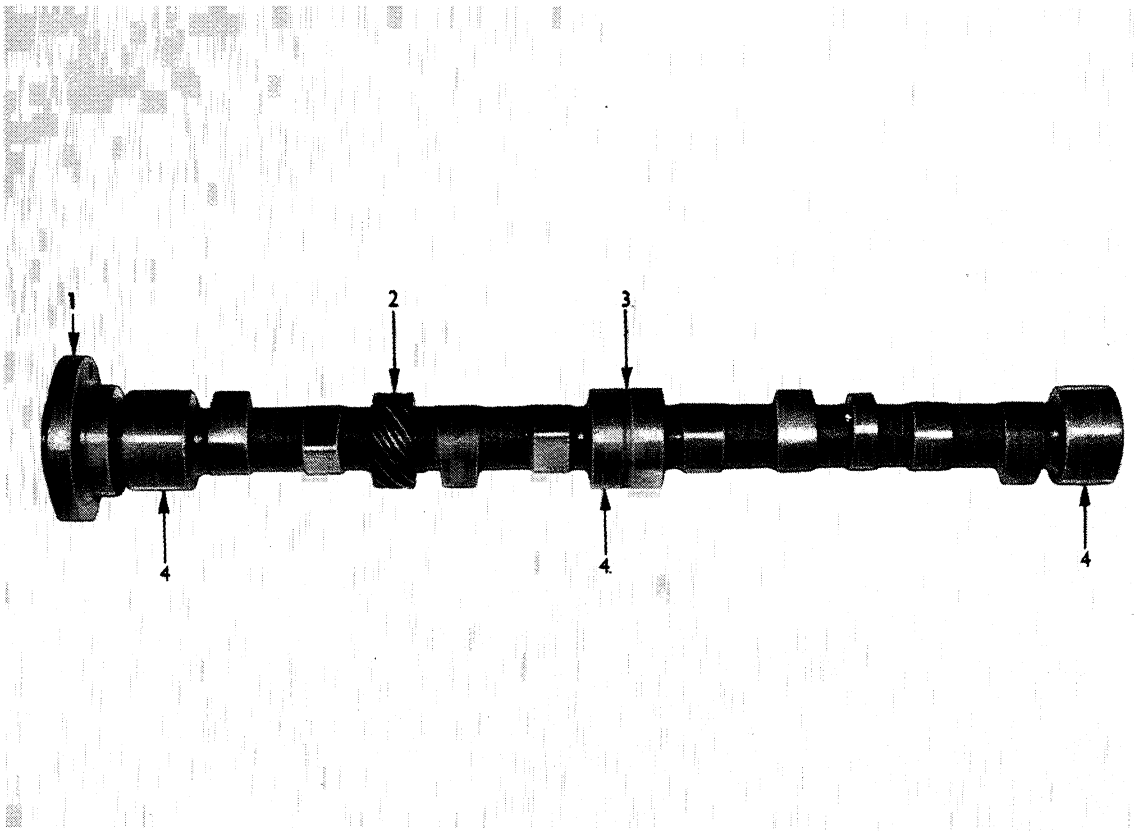
1. Remove the engine from the application and mount in a suitable dismantling stand (where available) correct way up.
2. Remove the cylinder head cover, rocker shaft and push rods.
3. Remove the timing case front cover and timing gears.
4. Remove the fuel lift pump, tappet inspection cover and fuel lift pump operating push rod.
5. Turn the engine over so that the sump is now uppermost.
   NOTE : At this stage if it is not possible to turn the engine over then the tappets should be lifted to the top of their locations and secured with suitable clips.
6. Remove the sump and lubricating oil pump assembly. (Refer to Page M.1 for details of their removal).
7. Remove the timing cover back plate as previously detailed, this will show the camshaft and thrust plates as illustrated in Fig. K.13.
8. Ease the camshaft out from the block and catch the two thrust plates as they come out of their recess in the cylinder block.
9. Withdraw the camshaft as shown in Fig. K.9 taking care to ensure that the cams and journals are not damaged during this operation.
10. The tappets may now be removed by lifting them out of their locations (Refer to Fig. K.11) or by removal of the retaining clips if the engine is still the normal way up.
11. Examine camshaft and tappets for signs of excessive wear, surface cracks, pitting etc.

To Refit the Tappets and Camshaft

1. If the tappets have been removed liberally lubricate them with clean engine oil and return to their respective locations. Secure with clips (if applicable).
2. Carefully refit the camshaft into the cylinder block exercising the same care as used during its removal.

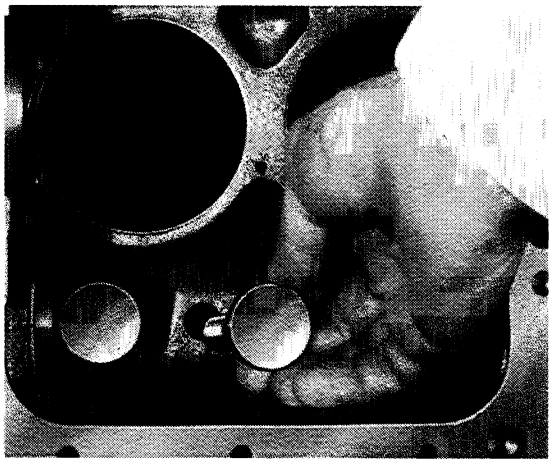


K9



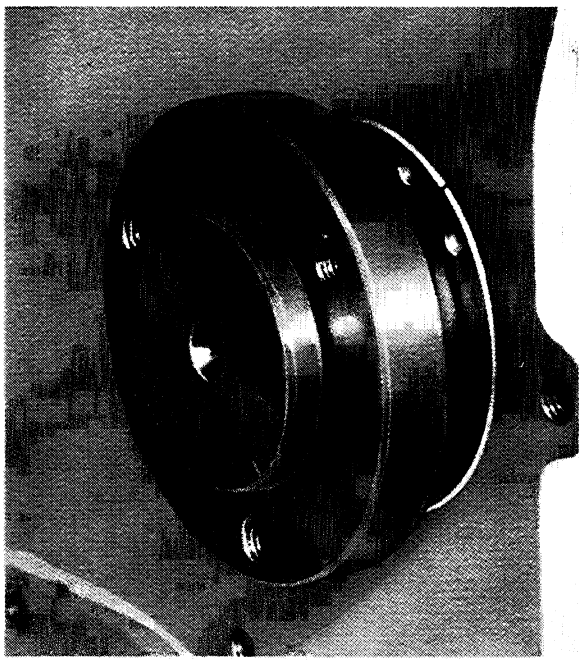
K10

1. Drive Hub
2. Lubricating Oil Pump Drive Gear
3. Groove for reduced oil pressure feed to Rocker Shaft
4. Bearing Journals

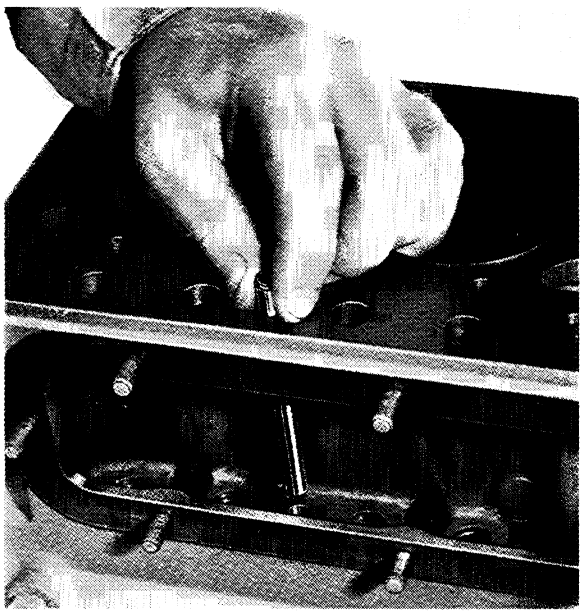


K11

K12



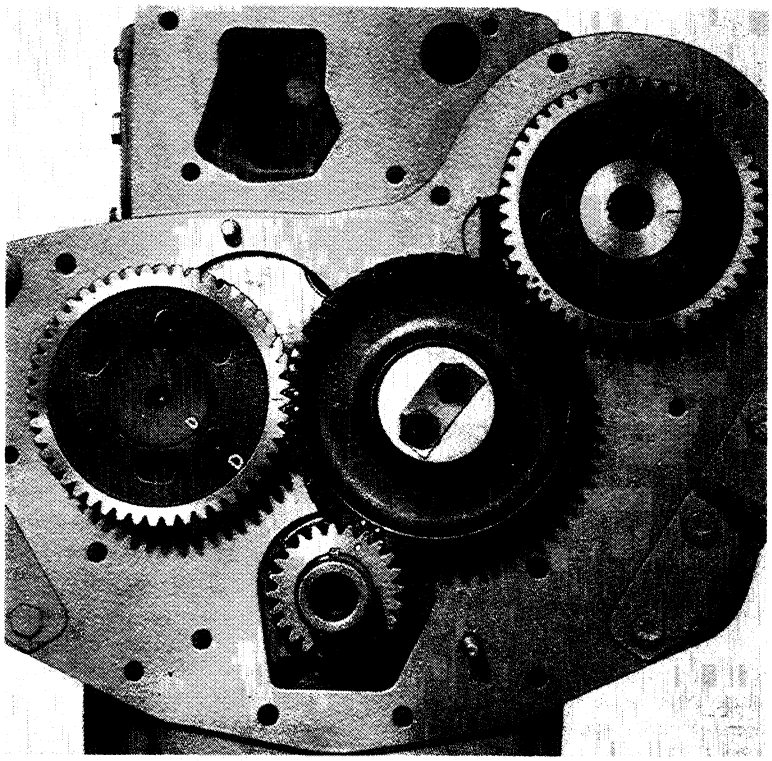
K13



K14

3. Before the camshaft is pushed fully home locate the two thrust plates (Refer to Fig. K.12) (one of which locates on the dowel in the recess) in position, either side of the camshaft hub, when correctly located the camshaft can be pushed fully home and will appear as in Fig. K.13.
4. Refit the timing case back plate as previously described.
5. Refit the lubricating oil pump assembly and sump as described on Pages M.1 and M.4.
6. Turn the engine over so that the cylinder block top face or cylinder head (if fitted) is uppermost.
7. Refit the timing gears, timing case front cover etc., as previously detailed.
8. Refit the fuel lift pump operating push rod (Refer to Fig. K.14), tappet inspection cover, (after removing any retaining clips) and fuel lift pump. Refer to Fig. P.9.
9. Re-assemble the remainder of the engine components in accordance with the instructions given for each in the relevant part of this section.

SECTION L
Timing



L1

General

As timing gears are employed, the factory setting remains constant. It is also worth remembering that the removal of the cylinder head in no way effects either the fuel pump or the valve timing.

TIMING MARKS

When the engine is originally timed at the factory, certain marks are stamped on the gears, so that if for any reason the engine timing has to be disturbed, then to reset to the original timing is quite straight forward.

To Reset the Engine to the Original Timing

Before commencing the retiming procedure it is assumed that (a) the camshaft, fuel pump and idler gears have all been removed, and (b) the camshaft is free to turn by hand. (If the cylinder head assembly is still in position, it is advisable to remove the injectors and rocker shaft to facilitate the retiming operations).

1. Turn the engine until the keyway in the front of the crankshaft is uppermost as shown in Fig. L.1. (This will bring Nos. 1 and 4 pistons to T.D.C.)

2. Fit the camshaft gear to its hub ensuring that the 'D' marks are correctly aligned. (Refer to Fig. K.5). Secure with the three setscrews.

3. Similarly, fit the fuel pump gear to the fuel pump drive hub ensuring that the stamped timing marks align as shown in Fig. K.6. Secure with the three setscrews.

4. Replace the idler gear so that the double dots on the idler gear are matched to the single dot on the crankshaft gear and single line (or dot) on the camshaft gear, while the single dot on the idler gear matches with the double dots on the fuel pump gear. These timing marks when correctly positioned will appear as shown in Fig. L.1.

5. Locate the idler gear with the hub and the two securing setscrews using a new tabwasher.

6. Backlash adjustment should be carried out as described under the heading 'To Refit the Idler Gear and Hub .

Checking Fuel Pump Timing—See Page P.5

Checking Valve Timing

To check the valve timing proceed as follows :

1. Turn the crankshaft until the valves of No. 4 cylinder are on overlap .
2. In this position set the valve clearance of No. 1 inlet valve to 0.039 in (1 mm).
3. Turn the engine slowly in the normal direction of rotation until the clearance of No. 1 inlet valve is just taken up. (In this condition it will just be possible to rotate No. 1 inlet valve push rod between the thumb and the forefinger).
4. Nos. 1 and 4 pistons will now be at T.D.C. if the timing has been correctly set.

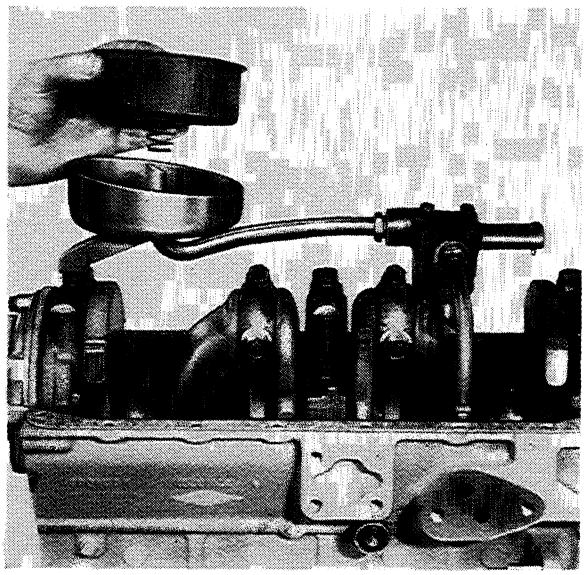
NOTE : No adjustment is provided for valve timing, should the timing be incorrect and the camshaft gear has been correctly fitted to the camshaft hub, the error will probably be due to incorrect alignment of the original timing marks on the drive gears. Recheck as detailed on Page L.1.

When valve timing is originally set and checked during production a timing tolerance of plus or minus $2\frac{1}{2}$ (flywheel) degrees is allowed for item (4) above. When the timing has been correctly set, do not forget to reset No. 1 inlet valve clearance to the correct figure.

check T.D.C.

NOTE : When the timing has been reset, great care should be exercised when first turning the engine, for should the timing be incorrectly set, even by only one tooth, there is the possibility that a valve head will strike the piston crown.

SECTION M
Lubrication System



M1

The importance of correct and clean lubrication cannot be stressed too highly and all references to engine oil should be taken to mean lubricating oil which falls within the specification given in the appendix. Care should be taken to ensure that the oil chosen is that specified for the climatic conditions under which the engine is operated.

THE LUBRICATING OIL PUMP

The oil pump fits into a machined bore in the clyinder block and is located by means of a screw locked by a tab washer. (Refer to "Engine Photographs" for its location).

The oil pump is driven through spiral gears from the camshaft, on the other end of the drive shaft is pressed and pinned a four lobed rotor. This rotor meshes with and drives a five lobed rotor which is free to rotate within the cast iron pump body.

NOTE: Length of oil pump set screw is critical. If replaced by a longer unit, oil pump shaft will lock and gear failure will result.

To Remove the Sump

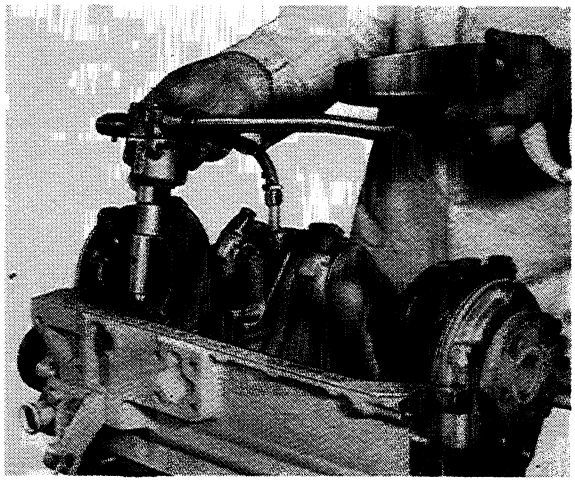
1. Remove the sump drain plug and drain the oil.
2. Remove the dipstick, sump securing setscrews and remove the sump.

To Refit the Sump

1. Lightly apply a coating of a suitable sealing compound to the crankcase and sump faces, position the gaskets so that all the holes align.
   NOTE: When the gaskets are being placed in position it is important that the mitred ends go right up into the recesses in the front and rear main bearing caps.
2. Lightly apply a coating of sealing compound to the cork strips, then press these strips into the grooves provided in the main bearing caps.
3. Place the sump in position and fit all the retaining setscrews, tighten evenly.
4. Replace the dipstick and sump drain plug, then refill with clean new oil of an approved grade to the correct level. Do not overfill.

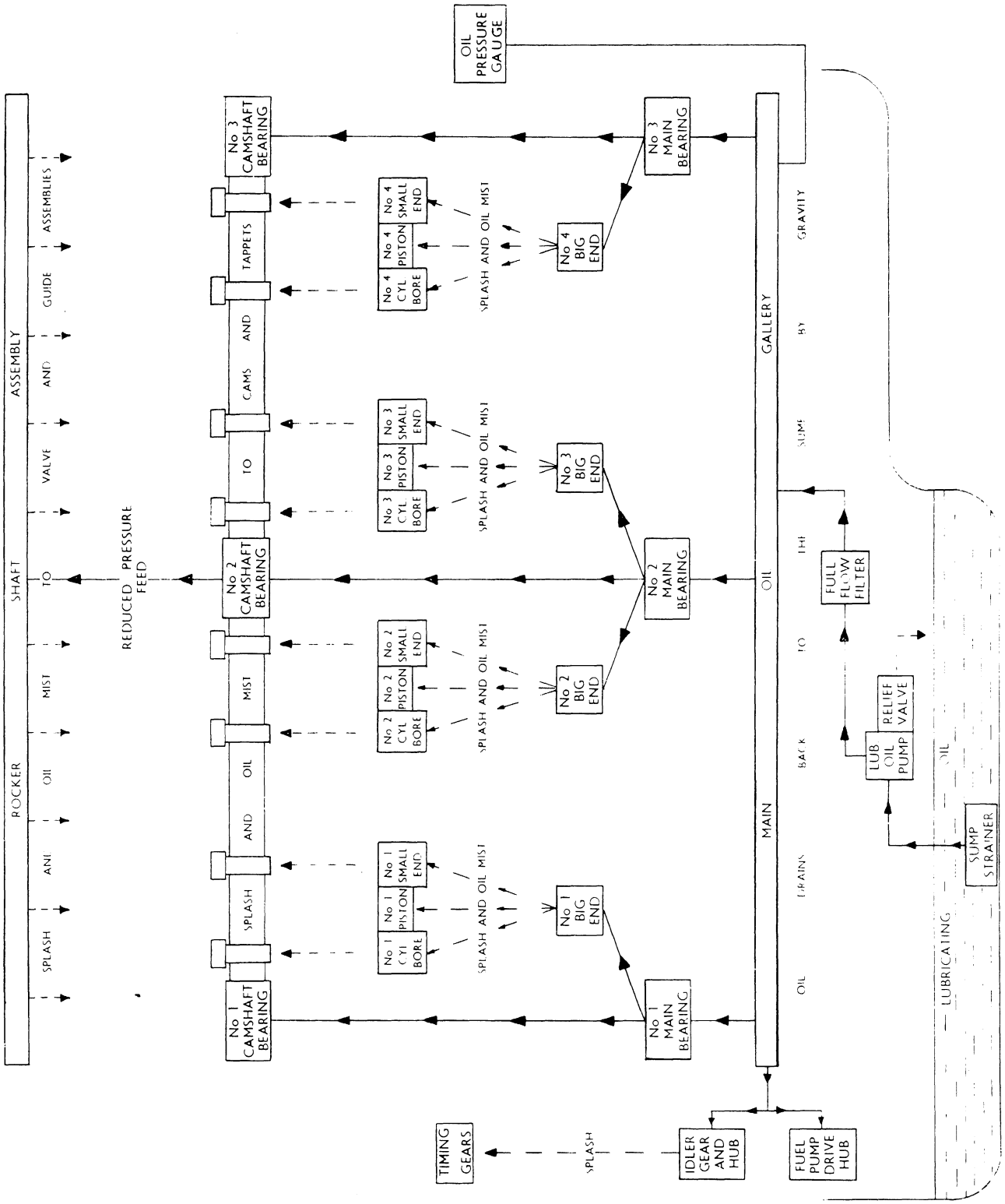
To Remove the Oil Pump

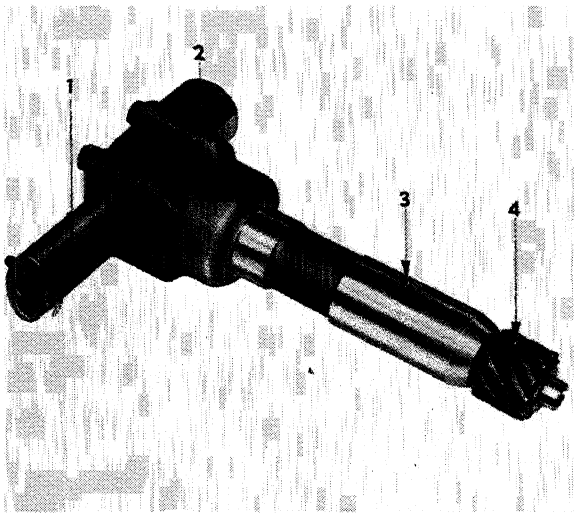
1. Drain the engine oil and remove sump.
2. Remove the strainer from the end of the lubricating oil suction pipe. (Refer to Fig. M.1).
3. Unscrew the delivery pipe securing nut to the cylinder block and the setscrew securing the suction pipe assembly to the rear main bearing cap.



M2

LUBRICATION SYSTEM—M.2





M4

1. Relief Valve Housing
2. Rotor Housing
3. Hole for Locating Screw
4. Pump Drive Gear

4. Tap back the tab washer locking the location screw and support the lubricating oil pump assembly (if the engine is the normal way up), while the locating screw is removed.
5. Remove the lubricating oil pump assembly from the cylinder block as shown in Fig. M.2.

To Dismantle the Oil Pump

1. Remove the delivery and suction pipes. The pump will now be as shown in Fig. M.4.
2. Withdraw the drive gear by means of a suitable puller.
3. With the pump suitably held in a vice, (using protective clamps) remove the four securing set-screws and remove the end cover assembly.
   N.B. This end cover assembly also incorporates the pressure relief valve housing.
4. Withdraw the drive shaft complete with inner rotor.
   N.B. It is advisable not to remove this inner rotor from the shaft as this item is not available as a separate part (See later note).
5. Withdraw the outer rotor.

Inspection

1. Inspect for signs of wear, cracks, pitting, etc.

M5

2. Install the drive shaft complete with inner rotor, then the outer (driven) rotor ensuring that the face which carries the chamfered edge enters the pump body first (Refer Fig. M.5), now carry out the three following dimensional checks.

   (a) Check the clearance between the inner and outer rotors. (Refer Fig. M.6).

   (b) Check the clearance between the outer rotor and the pump body (Refer Fig. M.7).

   (c) Check the clearance between the rotors and the end cover assembly using a straight edge and feeler gauges (Refer Fig. M.8).

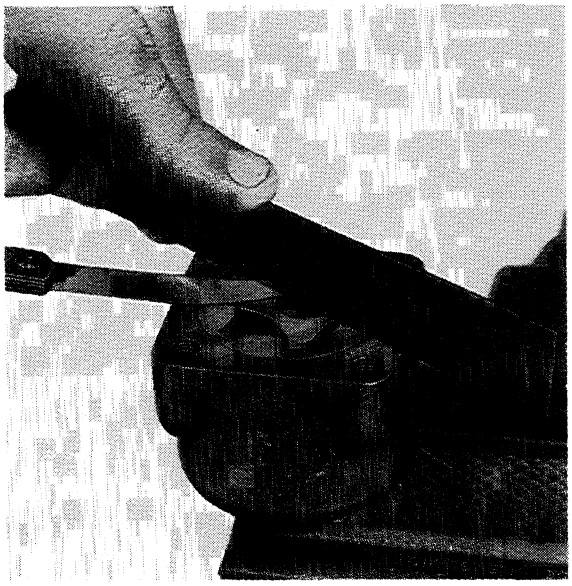
M6

M7

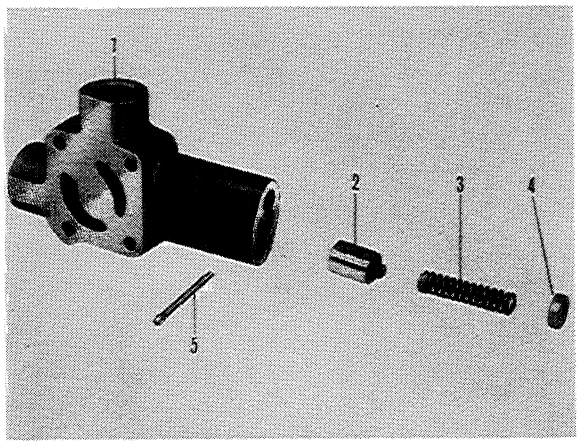
NOTE: The relevant clearances for these dimensional checks are given on Page B.10, they are the clearances applicable to a new pump and are intended to be used as a guide. Should a lubricating oil pump be worn to such an extent that it adversely effects the working oil pressure, then a replacement pump should be obtained.

To Re-Assemble the Oil Pump

1. Insert the outer rotor ensuring that the face which carries the chamfered edge enters the pump body first. (Refer Fig. M.5).



M8



M9

1. Outlet to Main Oil Filter
2. Relief Valve Plunger
3. Plunger Spring
4. Spring Cap
5. Retaining Cotter Pin.

2. Insert the drive shaft complete with inner rotor into the pump body.
3. Replace the end cover assembly and fit the four securing setscrews. Ensure correct positioning so that the suction and delivery pipes will locate correctly.
4. Press the oil pump drive gear onto the shaft.
5. Finally rotate the pump by hand to ensure that it turns quite freely.

To Refit the Oil Pump

1. Refit the suction and delivery pipes, do not tighten the pipes at this stage.
2. Place the lubricating oil pump assembly in position, locate with the securing screw and lock it with the tab washer.
3. Tighten the delivery pipe at both ends, refit the setscrew securing the suction pipe assembly.
4. Tighten the suction pipe at the pump end then refit the strainer on the end of the suction pipe.
   NOTE : The strainer which fits on the end of the suction pipe should be thoroughly cleaned in suitable cleaning fluid before being refitted. It is good practise to remove this strainer and clean it thoroughly on every occasion when the sump is removed.
5. Replace the sump as previously detailed and secure with the setscrews.
6. Fill the sump to the correct level with clean oil of an approved grade.

NOTE : Caution should be exercised when restarting the engine, as it will take a moment or two for the oil pump and pipes to prime, therefore the engine speed should be kept to a minimum until either the gauge shows satisfactory pressure (where fitted) or the oil pressure warning light is extinguished.

The most satisfactory way to prime the lubricating oil pump is to motor the engine for approximately 10/20 seconds before any attempt is made to start the engine.

OIL PRESSURE RELIEF VALVE

The oil pressure relief valve is contained in a housing integral with the oil pump end cover, which is secured to the rotor housing by four setscrews. This relief valve controls the maximum oil pressure by allowing a spring loaded plunger to move and by-pass excess oil back to the sump when the pre-determined spring pressure given on page B.10 is exceeded.

To Dismantle the Oil Pressure Relief Valve

1. Drain the engine oil from the sump.
2. Remove the sump securing setscrews and carefully remove the sump.
3. Continue as for removing the oil pump as previously detailed.
4. Remove suction and delivery pipes.
5. Remove the four securing setscrews and remove the end cover assembly.
6. Remove the cotter pin from the end of the housing and withdraw the spring cap, spring and plunger. An exploded view of the assembly is shown in Fig. M.9.
7. Thoroughly clean the parts, inspect for wear or damage and renew if necessary.

To Re-Assemble the Oil Pressure Relief Valve

1. Replace the plunger, spring and spring cap then secure with the cotter pin.
2. Secure to the lubricating oil pump body by means of the four setscrews.
3. Continue as detailed for refitting the lubricating oil pump.

OIL PRESSURE

Always ensure that with the engine running, oil pressure is registering on the gauge or the oil pressure warning light is extinguished.
Pressures do vary according to climatic conditions and even between individual engines, but the oil pressure range at normal working speed and temperature is given on Page B.9. The pressure will drop whilst the engine is idling and also a slight drop will be experienced when the oil is hot, this is quite normal. If, however, the oil pressure is suspected of being too high or too low then reference to the possible faults listed under these headings given on Page D.1, may prove helpful.
NOTE: Whenever the oil pressure reading is questionable, use a direct reading, mechanical oil pressure gauge attached directly to engine oil gallery on block.

LUBRICATING OIL FILTERS

To ensure cleanliness of the lubricating oil a sump strainer and a main full flow type of oil filter are fitted. The sump strainer consists of a gauze wire container which is fitted over the end of the lubricating oil pump suction pipe. All oil must pass through this strainer before it reaches the oil pump.

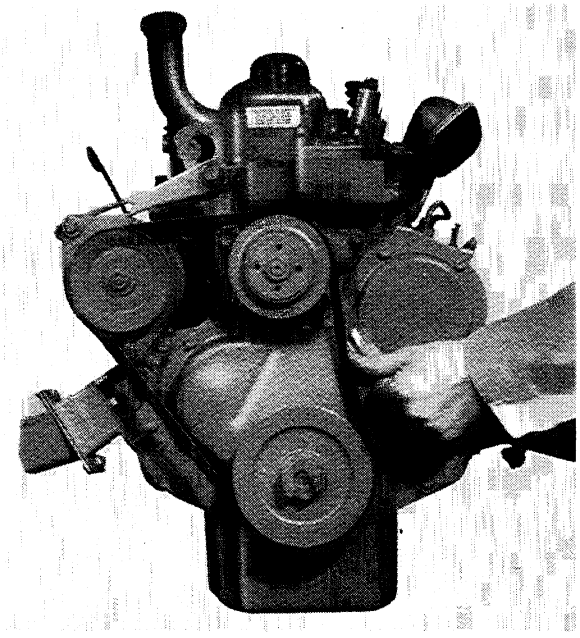
SECTION N
Internal Cooling System

ALTERNATOR BELT

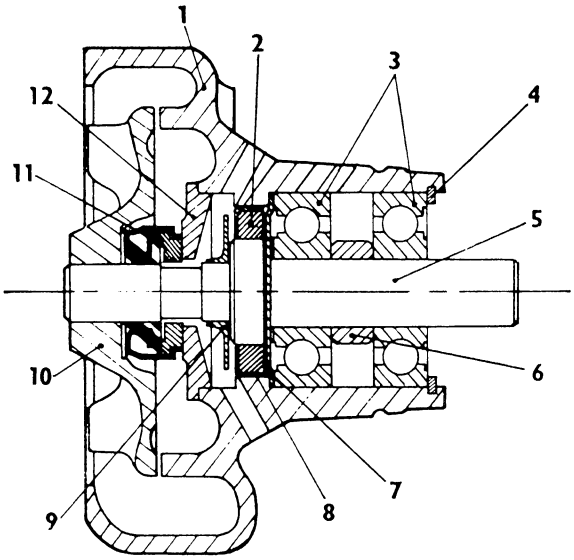
To Adjust the Alternator Belt

Alternator belt adjustment is achieved by altering the position of the alternator as detailed below.

1. Slacken the alternator adjusting lever setscrew.
2. Slacken the two alternator-to-bracket mounting bolts.
3. Move the alternator either towards or away from the engine to either slacken or tighten the belt.
4. Lock in the desired position by tightening the alternator adjusting lever setscrew.
5. Check the tension, if correct, the tension is such that without undue pressure, the thumb applied midway between the water pump and crankshaft pulleys can depress the belt approximately $\frac{3}{8}$ in (10 mm) as shown in Fig. N.1.



N1



N2

1. Pump Body
2. Seal
3. Shaft Bearings
4. Retaining Circlip
5. Pump Shaft
6. Spacer
7. Flange — Oil Seal Retaining
8. Retainer — Oil Seal
9. Flange — Water Pump Thrower
10. Impeller
11. Seal
12. Insert

6. If the tension is correct tighten the two alternator-to-bracket mounting bolts.

NOTE : When a new belt is fitted, it is advisable to recheck the adjustment after only a comparatively short running period. This is to allow for the initial stretch which is common to new belts, once this initial stretch has taken place the belt may be checked in accordance with Operator Instructions.

To Remove the Alternator Belt

1. Slacken the alternator adjusting lever setscrew.
2. Slacken the alternator-to-bracket mounting bolts.

3. Pivot the alternator towards the cylinder block.
4. Turn the engine slowly by hand and work the alternator belt off the water pump pulley.
5. The belt can now be lifted from the alternator and crankshaft pulleys and removed from the engine.
6. Examine the belt for signs or fraying or cracks in the rubber and renew if necessary.

To Refit the Alternator Belt

Refitting the belt is just a reversal of the removal operations. Adjust the belt tension as previously detailed under the heading "To Adjust the Alternator Belt".
If a new belt has been fitted refer to the note given after the details on fan belt adjustment.

To Remove the Water Pump

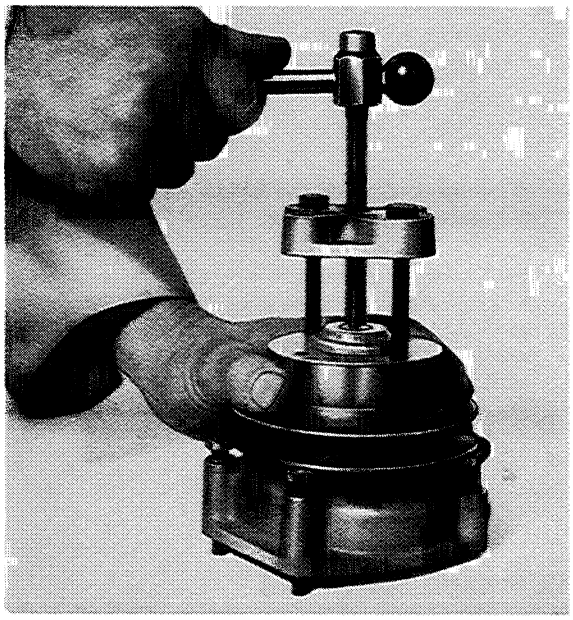
Slacken generator securing setscrews and remove driving belt.

Unscrew the four setscrews securing the water pump and backplate to cylinder block.

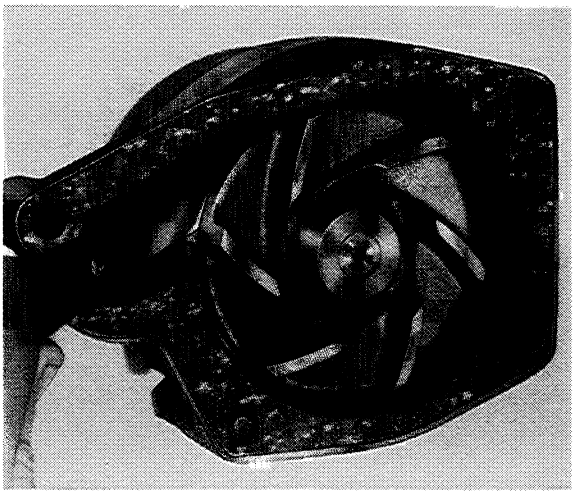
Remove water pump and back plate.

To Dismantle the Water Pump

1. Remove the pulley securing nut or circlip (where fitted).



N3



N4

2. Remove the water pump pulley by means of a suitable puller, the holes in the pulley face may be utilised for this purpose (Refer to Fig. N.3).
3. Press the shaft out of the pump body from the pulley end complete with water pump thrower, insert, seal and impeller.
4. Remove the impeller from the pump drive shaft by means of a suitable puller or press.
5. Remove the bearing retaining circlip then using a suitable mandrel press the two shaft bearings complete with spacer out through the front of the pump body.
6. Remove the felt seal and retaining flanges.

Inspection

1. Examine the pump body for cracks, corrosion or any other damage. Renew where necessary.
2. Examine the shaft and bearing assembly for wear or corrosion. Renew where necessary.
3. Examine the water thrower flange for damage or corrosion. Renew where necessary.
4. Examine the water pump seal and insert for excessive wear, scoring or cracks on the sealing faces. Renew where necessary.
5. Remove rust and scale from the impeller and examine for excessive corrosion or other damage. Renew where necessary.
6. Examine the pump pulley for signs of cracks, corrosion or any other damage. Renew where necessary.

To Re-Assemble the Water Pump

(Refer to Fig. N.2).

1. Insert the oil seal retainer (8) and oil seal (2) followed by the oil seal retaining flange (7).

2. Fit the two bearings (3) and spacer (6) onto the shaft (5) and pack the space between the two bearings approximately ¾ full of high melting point grease.
3. Press the bearings and shaft assembly into the pump body, impeller end first and locate with the circlip (4).
4. Press the water thrower flange (9) into position on the drive shaft.
5. Thoroughly clean the insert recess and drain hole in the pump body.
6. Lightly coat the inner diameter of the insert recess and outside diameter of the insert with grade "AVV' Loctite.
7. After removing any traces of oil or grease from the insert, press it fully home. Remove all traces of surplus Loctite.
   NOTE :—Special care must be taken during this operation not to mark the face upon which the seal registers.
8. Place the carbon-faced seal (11) on the drive shaft so that this face registers with the insert face.
9. Press the impeller onto the shaft over this seal until the clearance given on Page A.13 exists between the back face of the impeller and the pump body. This clearance can be checked as shown in Fig. N.4.
10. Press the pulley fully onto the shaft and fit the securing nut or circlip (where applicable).

    NOTE :— 4.108 Engines Only. When the pulley is originally pressed onto the shaft during production a pressure of $2\frac{1}{2}$—3 ton/in^2 is required. Therefore it is recommended that if the pulley interference on the shaft is such that a substantially reduced pressure will press the pulley back onto the shaft, then a replacement pulley and/or shaft should be fitted.

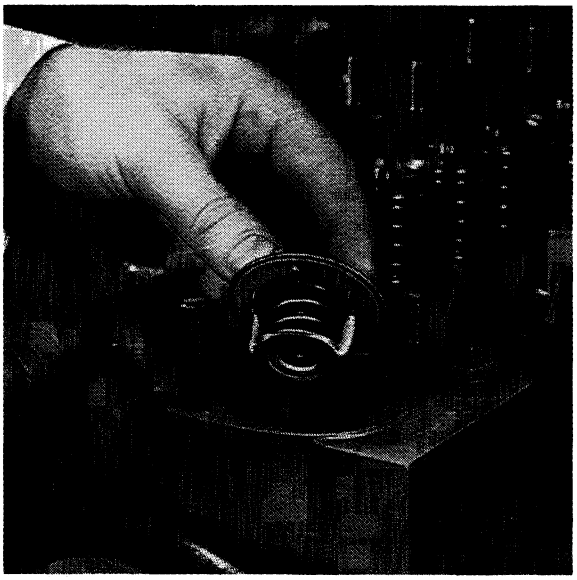
To Refit the Water Pump

1. Fit the backplate followed by the water pump to the cylinder block using new gaskets lightly coated with suitable sealing compound.
2. Secure the water pump assembly to the cylinder block with the four setscrews.
3. Refit the alternator belt and adjust to the correct tension.

THERMOSTAT

To Remove the Thermostat

1. Drain the coolant from the engine block.



N5

2. Remove expansion tank or thermostat housing (whichever is applicable).
3. Lift out thermostat, as in Figure N5.

To Test the Thermostat

1. Immerse the thermostat in a suitable container of water and slowly heat. An accurate thermometer should be available to check the temperature of the water as it rises.
2. Note the temperature at which the valve in the unit commences to open. This temperature should be as stamped on the unit by the manufacturers.
3. If the unit does not function properly then a replacement thermostat will be required, as no adjustment of these units is possible.

To Replace the Thermostat

Replacing the thermostat is a reversal of the removal procedure. A new gasket should be fitted between the thermostat housing and the water outlet connection.

SECTION P
Fuel System

FUEL OIL FILTERS

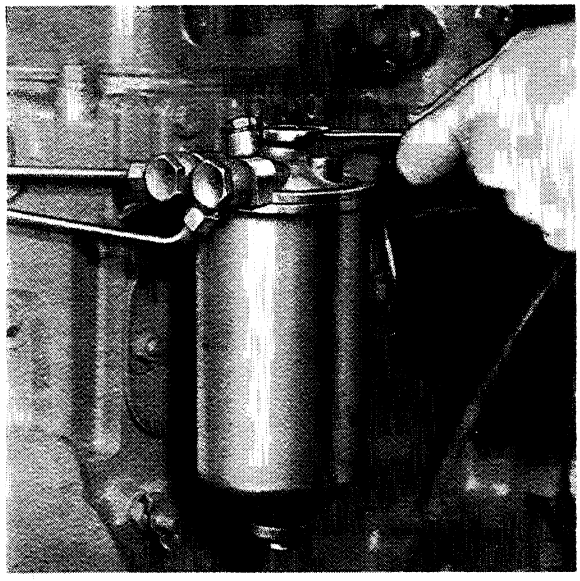
The element in this filter is of the paper type and therefore no attempt should be made to clean it. Its life will be governed by the quality and condition of the fuel passing through it, but under average conditions the element should be renewed in accordance with the recommendations in Operator Section. This period would naturally be reduced if it was apparent from the condition of the element if removed and inspected, that conditions warranted it.

To Renew the Filter Element

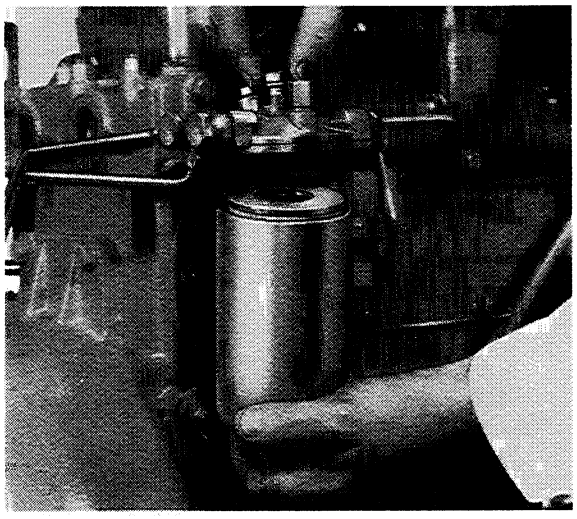
1. Unscrew the filter bowl securing bolt in the centre of the headcasting. Refer to Fig. P.5.
2. Lower the filter bowl clear as shown in Fig. P.6 then discard the fuel therein together with the old element.
3. Inspect the sealing rings and replace if damaged in any way.
4. Place the new element in position inside the filter bowl and offer up the bowl firmly and squarely so that the top rim of the filter bowl locates centrally against the sealing ring in the filter head casting.
5. Hold in this position while the securing bolt is located and screwed home.

   NOTE : If the sealing rings are in good order and the bowl is located correctly, no excessive tightening will be required to obtain a leak proof seal.
6. Prime the fuel system as detailed on Page P.8.

   NOTE : Some filter bowls have a drain plug fitted, in this case the relevant manufacturers service literature should be consulted.



P5

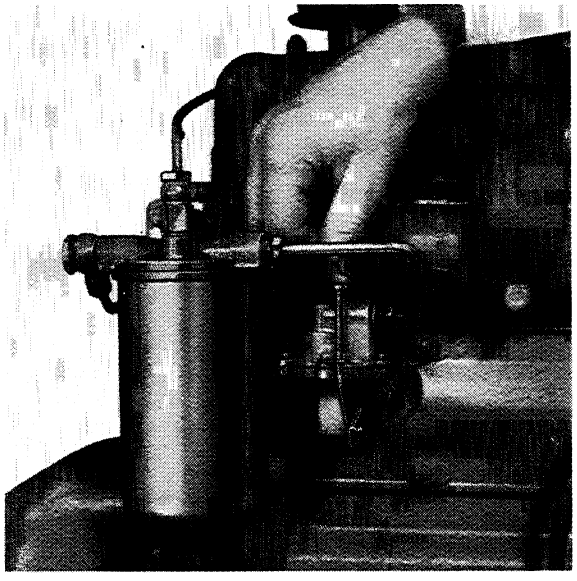


P6

FUEL LIFT PUMP
Testing the Pump in Position

1. Disconnect the outlet pipe (lift pump to filter) leaving a free outlet from the pump.
2. Rotate the engine and note if there is a well defined spurt of fuel from the outlet port once every two engine revolutions.

   NOTE : As an alternative the pump may be operated by means of the hand primer as shown in Fig. P.7, which should give the same result every time the priming lever is operated. However should the engine happen to have stopped in such a position that the eccentric operating the lift pump is in the maximum lift position, then it will not be possible to operate the hand primer properly. If such a condition arises the remedy is to rotate the engine one complete revolution.



P7

To Remove the Lift Pump

1. Disconnect the pipes from the inlet and outlet ports. Seal the ends of the pipes to prevent the entry of foreign matter.
2. Remove the two nuts and washers holding the pump to the tappet inspection cover. Withdraw the pump, spacer and gaskets.

To Dismantle the Lift Pump

1. Before dismantling, make a file mark across the two flanges for location purposes when the pump is being re-assembled.
2. Remove the five cover screws and separate the two main castings, then remove the diaphragm assembly from the lower half by turning the diaphragm through 90° in either direction.

   NOTE : The diaphragm and pull rod assembly is a permanent assembly and no attempt should be made to separate the parts.
3. Remove the retaining clip from one side of the pump body and push out the rocker arm retaining pin. Withdraw the rocker arm, etc., from the body.
4. Prise out the valves with a screwdriver or other suitable tool.

Inspection

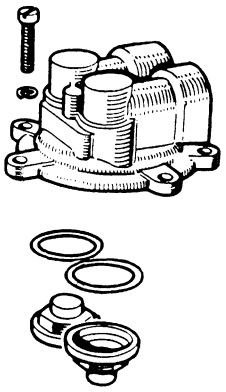
1. Check the diaphragm assembly and renew if the material is split or checked, or if serious wear is apparent in the link engagement slot.
2. The diaphragm spring should be replaced if faulty or corroded. A new spring should have the same color identification (Refer to Page B.11).
3. Replace the valves unless they appear to be in perfect condition.
4. Examine the rocker arm, operating lever, rocker arm retaining pin and rocker arm return spring for wear. Replace any parts where necessary.
5. Replace all joints, seals and washers as routine procedure.
6. Examine upper and lower castings for wear or distortion. Slight distortion of flanges can be remedied by grinding the flange face to restore flatness.

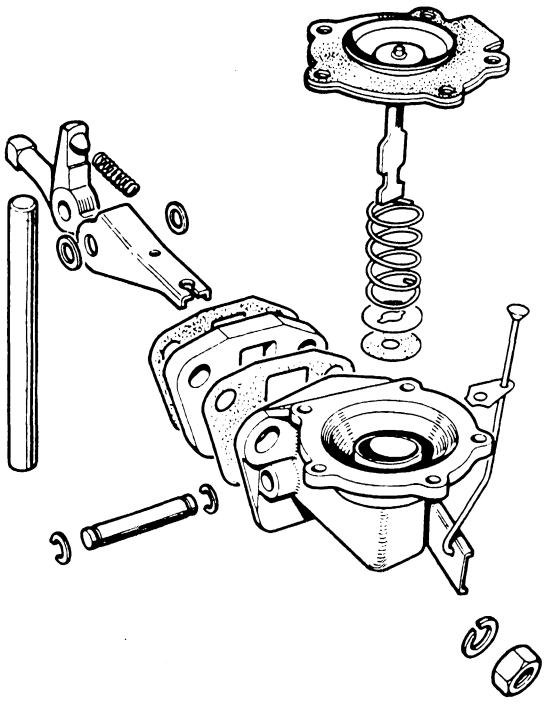
To Re-Assemble the Lift Pump

Examine the casting and ensure that there is sufficient material to provide a sound staking when new valves are fitted.

Clean the valve recesses to allow the new valves to be correctly fitted.

1. Insert a new valve gasket in each valve recess.
2. Place the new valves in the recesses. The valve in the inlet port should be fitted with the spring outwards (i.e., towards the diaphragm flange) and the valve in the outlet port fitted in the reverse position.
3. Press the valves home with a suitable piece of tubing, approximately 9/16 in (14,29 mm) inside diameter and $\frac{3}{4}$ in (19,05 mm) outside diameter.





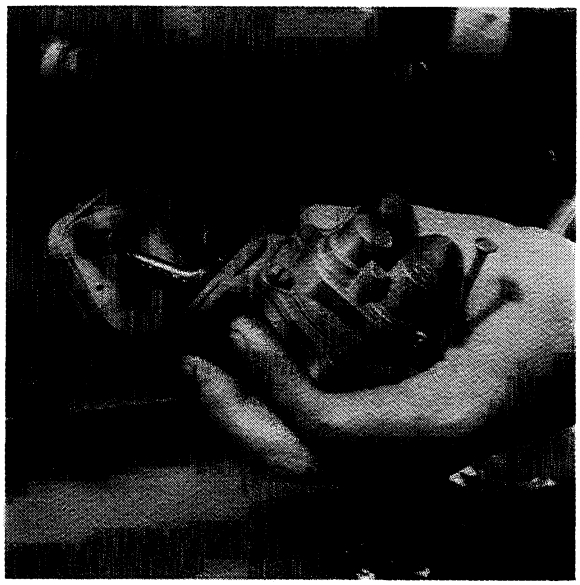
4. Stake the casting in six places (between the original stakings) round each valve, with a suitable punch.

   NOTE: Valves fitted to earlier lift pumps were held in position with a retaining plate and two screws. On no account should attempts be made to stake the valves of this earlier type pump.

5. Place the rocker arm retaining pin in the appropriate hole in the lower casting and push through until it protrudes slightly inside.
6. Fit one packing washer and link into the casting moving the pin in slightly to retain them.
7. Fit the rocker arm and return spring and retain by moving the pin in further, ensuring that the spring seats correctly.
8. Fit the remaining packing washer, then push the rocker arm retaining pin through the link, washer and casting until the ends protrude equally beyond the outside of the casting.
9. Retain by securing with the two clips.
10. Insert the new rubber sealing washer followed by the steel seating washer and diaphragm return spring.
11. Place the diaphragm assembly over the spring with the pull rod downwards, locating the top of the spring in the diaphragm protector washer.
12. Now position the pull rod so that the flat notched blade has one of its thin edges facing the rocker arm. Press downwards on the diaphragm assembly and twist it through 90° in either direction, this action will engage and retain the pull rod in the fork of the link.
13. Operate the rocker arm against the diaphragm spring pressure until the diaphragm is level with the body flange.
14. Place the cover assembly in position and line up the file marks made on the flanges prior to dismantling.
15. Still holding the diaphragm level with the body flanges, fit the five flange securing screws, tighten evenly and securely.

To Refit the Fuel Pump

1. Fit the spacer using a gasket on either side.
2. Enter the pump operating lever into the recess in the tappet inspection cover as shown on Fig. P.9 and secure with the two nuts and washers.
3. Reconnect the low pressure fuel pipes to the inlet and outlet ports.



P9

FUEL INJECTION PUMP

Description

The fuel injection pump is of the D.P.A. distributor type. It is a precision built unit incorporating a simple hydraulic governor or alternatively one of the mechanical flyweight type depending upon the application to which the engine is fitted.

To Remove the Fuel Injection Pump

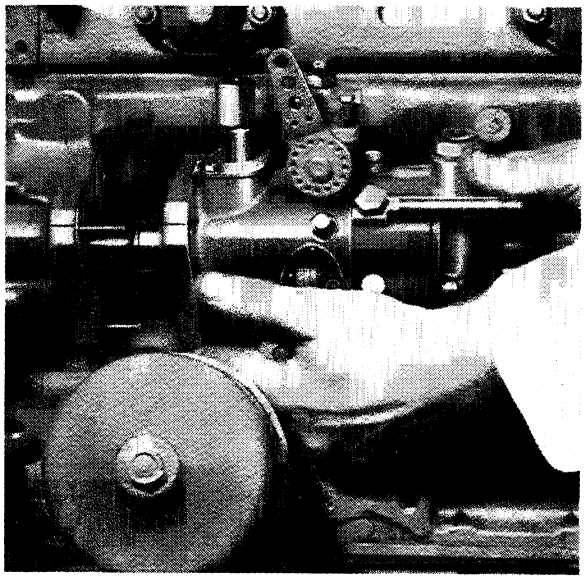
1. Remove the four high pressure pipes between the pump and the injectors and blank off all ports to prevent the ingress of foreign particles.
2. Remove the low pressure fuel pipes from the inlet and outlet connections and blank off all ports.
3. Disconnect the stop and throttle controls and their return springs.
4. Remove the two nuts and the socket headed setscrew which secure the fuel pump to the mounting flange together with their spring and plain washers.
5. Carefully withdraw the fuel pump from its mounting.

To Refit the Fuel Injection Pump

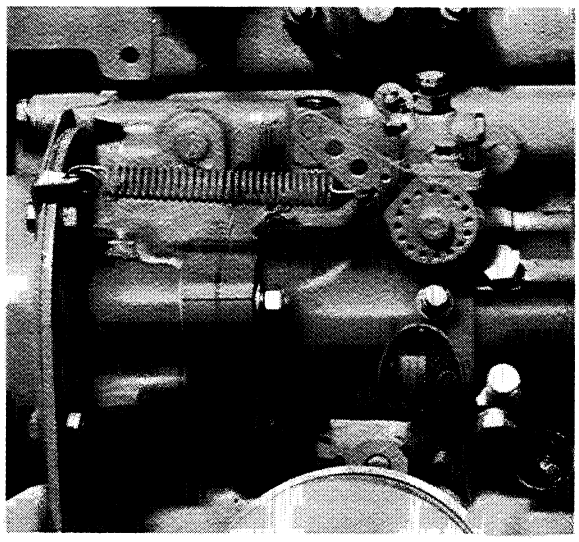
1. Replace the fuel pump mounting flange gasket (where necessary).
2. Fit pump as shown in Fig. P.8 ensuring that the master spline on its quill shaft is correctly positioned to engage with the female splines within the fuel pump drive hub.

   NOTE : This master spline ensures that the pump will only locate in the drive hub in one position for timing purposes. Further, when fitting the mechanically governed injection pump which uses a separate quill shaft, the noticeably shorter, splined end is fitted in the injection pump.

3. When the splines are in correct alignment the pump can be pushed in until the mounting flanges meet and the securing nuts and setscrew with their washers can be fitted.
4. Before tightening, align the timing marks scribed on the fuel pump mounting flanges as shown in Fig. P.11. Tighten the setscrew and nuts.
5. Refit the low pressure pipes to the inlet and outlet connections.
6. Refit the high pressure fuel pipes.
7. Reconnect the throttle and stop controls together with their return springs.
8. Prime the fuel system with fuel oil as detailed on Page P.8
9. Fuel pump timing can be checked as detailed in the following text.



P10



P11

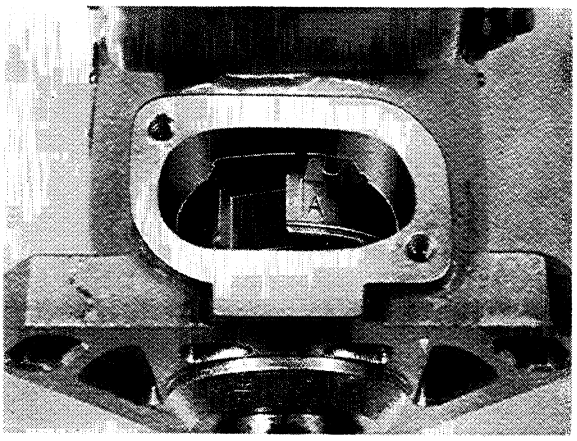
FUEL INJECTION PUMP TIMING

Reference should be made to the details given on Page L.1 covering engine timing. If this timing sequence has been followed regarding the timing gears and the timing marks on the mounting flanges are correctly aligned as shown in Fig. P.11, then the fuel pump timing should be correct.

A further check is possible and utilises the internal timing marks within the pump body. To be able to see these marks necessitates the removal of the inspection cover.

On the fuel pump rotor inside the fuel pump, are a number of scribed lines, each one bearing an individual letter. A timing circlip, one end of which has a straight edge is positioned inside the pump body and is preset so that when the appropriate scribed line on the fuel pump rotor aligns with the straight end of the circlip, it denotes commencement of injection (static timing) see Fig. P.12.

NOTE : On earlier pumps, the timing circlip had a scribed line on one end and on these pumps, the scribed line on the fuel pump rotor should be aligned with the scribed line on the circlip.



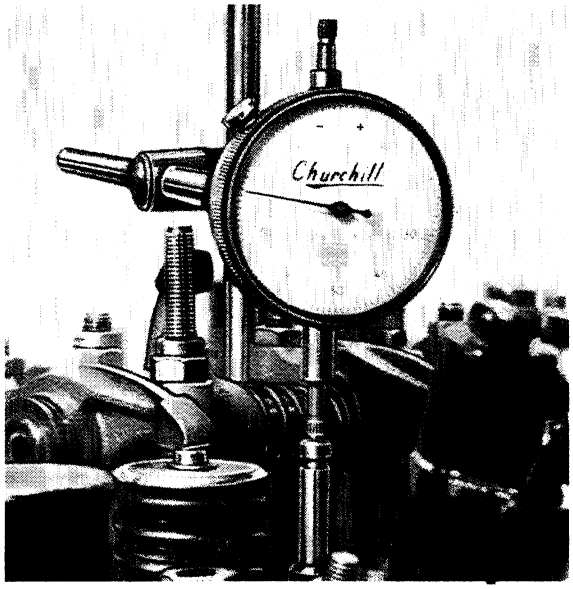
P12

CHECKING FUEL PUMP TIMING

1. Ensure that the fuel pump is correctly fitted with the scribed line on the mounting flange aligning with the adjacent mounting flange on the cylinder block (see Fig. P.11).
2. Position the crankshaft so that No. 1 piston is at T.D.C. on its compression stroke.
3. Remove the cylinder head cover.
4. Slacken the valve adjusting screw on No. 1 exhaust valve sufficiently to allow the rocker lever to be moved to one side and the push rod removed, rotate the rocker lever on the shaft, so that the valve spring cap is accessible for using the valve spring compressor.
5. Remove the collets, spring cap and springs from No. 1 exhaust valve and allow the valve to rest on the top of the piston.
6. With the aid of a dial indicator in contact with the end of the valve now resting on No. 1 piston, it will be necessary to position the crankshaft so that the piston will be 0.120 in (3,05 mm) B.T.D.C. this being the equivalent of 19° on the engine flywheel. Refer Fig. P.13.

   To do this, turn the crankshaft in the opposite direction to normal rotation, approximately an eighth of a turn and then forward until the required position is registered on the indicator. This enables the backlash in the timing gears to be taken up.

   NOTE: The above setting is for 4.108 marine engines. For other applications and engines see Page B.12.
7. Remove the inspection plate on the fuel pump enabling the rotor to be seen (Fig. P.12).
8. With No. 1 piston at the static timing point on its compression stroke, the scribed line on the rotor marked 'A' (for hydraulically governed engines) or 'C' (for mechanically governed engines) should align with the straight edge or scribed line on the timing circlip.
9. If the timing is incorrect proceed by either :—
   (a) making any necessary adjustments by means of the holes in the fuel pump gear, they are slotted enabling the drive shaft to be turned relative to the gear when the securing setscrews are slackened. (Refer to Fig. K.6) or
   (b) by slackening the two nuts end socket headed setscrew which secure the fuel pump to the mounting flange and turning the pump body in the direction required.
10. When the fuel pump timing has been set, turn the engine against the normal direction of rotation once again to the appropriate piston displacement to check that the squared end of the circlip is now aligned with the line on the rotor.
11. When the fuel pump timing has been correctly set, slowly turn the engine to T.D.C. in the normal direction of rotation, remove the indicator and refit the valve springs.
12. Refit the push rod and reset the valve clearance.



P13

NOTE!

For mechanically driven Westerbeke fuel injection pumps see Operations pages 13-14 and Service Bulletin pages V.3, V.7, V.9 and V.31 for information and disregard the following hydraulic injection pump material.

Maximum Speed Setting (Refer to Figs. P.14 and P.15)

The maximum speed screw (5) is set and sealed by the manufacturers and must not be altered or tampered with in any way, unless factory authority is first obtained and any adjustments necessary are carried out by experienced personnel. As with all seals on the pump unauthorised removal may render the guarantee void.

The maximum no load speed may vary according to the application to which it is fitted, reference may be made to the code number stamped on the fuel pump data plate. The last four numbers in the code indicate the maximum no load engine speed, therefore in the case of the following example it would be 4480 rev/min. Code Example EH39/1200/0/4480.

NOTE : If the fuel pump data plate is damaged or defaced so as to make it impossible to read accurately, or if there is no code stamped on the plate you are advised to contact your nearest C.A.V. Distributor, or Westerbeke.

NOTE : The engine must not be allowed to operate at a speed in excess of that specified or severe damage may occur.

IDLING SPEED ADJUSTMENT

This adjustment is carried out by means of the idling adjustment screw (4), it is carried out in conjunction with the setting of the anti-stall device with the engine warmed through as detailed in the following text.

Anti-Stall Device (Refer to Figs. P.14 and P.15)

(a) Slacken the locknut (2) sufficiently to enable the anti-stall device body (1) to be unscrewed two complete turns.

(b) Adjust idling speed to 625 rev/min* with the idling adjustment screw (4).

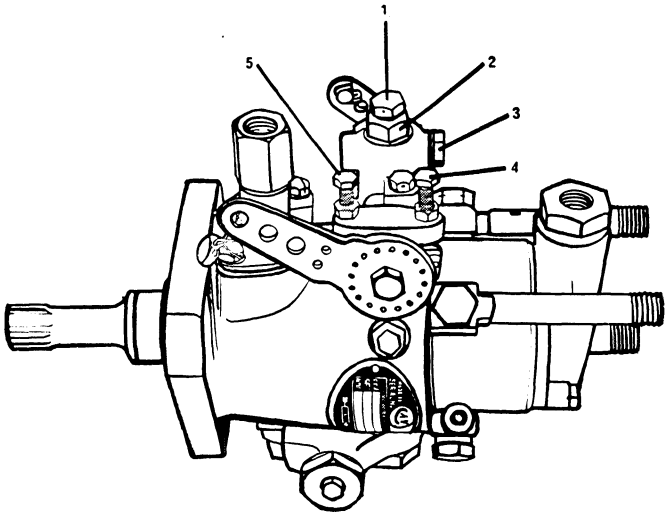
(c) Now screw down the anti-stall device body (1) until there is a very slight increase in engine speed, bring back half a turn and lock with the lock nut (2).

(d) Accelerate the engine to maximum no load rev/min and immediately return to idling.

Should the period of return from maximum rev/min to idling exceed three seconds the device has been screwed in too far.

However should stalling occur, then the device has not been screwed in far enough. Therefore the necessary adjustment should be made to suit whichever is the case.

*This idling speed may vary according to application. refer to relevant manufacturers service literature.



P14
Earlier Fuel Pump

1. Anti-stall device body
2. Anti-stall device body locknut
3. Air vent screw
4. Idling adjustment screw
5. Maximum Speed Screw

INJECTORS

General

When replacing injectors in the cylinder head, it is essential that a new, correct type copper washer is fitted between the nozzle body and cylinder head.
The first symptoms of atomiser trouble usually come under one or more of the following headings :—

1. Misfiring.
2. Knocking in one (or more) cylinders.
3. Engine overheating.
4. Loss of power.
5. Smoky exhaust (black).
6. Increased fuel consumption.

Testing for Faulty Injector

If an injector is suspected of being faulty, try this method to isolate it.

Loosen the union nut at the injector end of the high pressure fuel pipe. If each injector is isolated in turn in this way, (with the engine running at approximately 1,000 rev/min) tightening each union nut firmly before proceeding to the next, then the faulty injector, when isolated in this manner, will have little or no effect on the running.

Warning

Great care should be taken to prevent the hands or face from getting into contact with the spray, as the working pressure will cause the oil to penetrate the skin with ease.

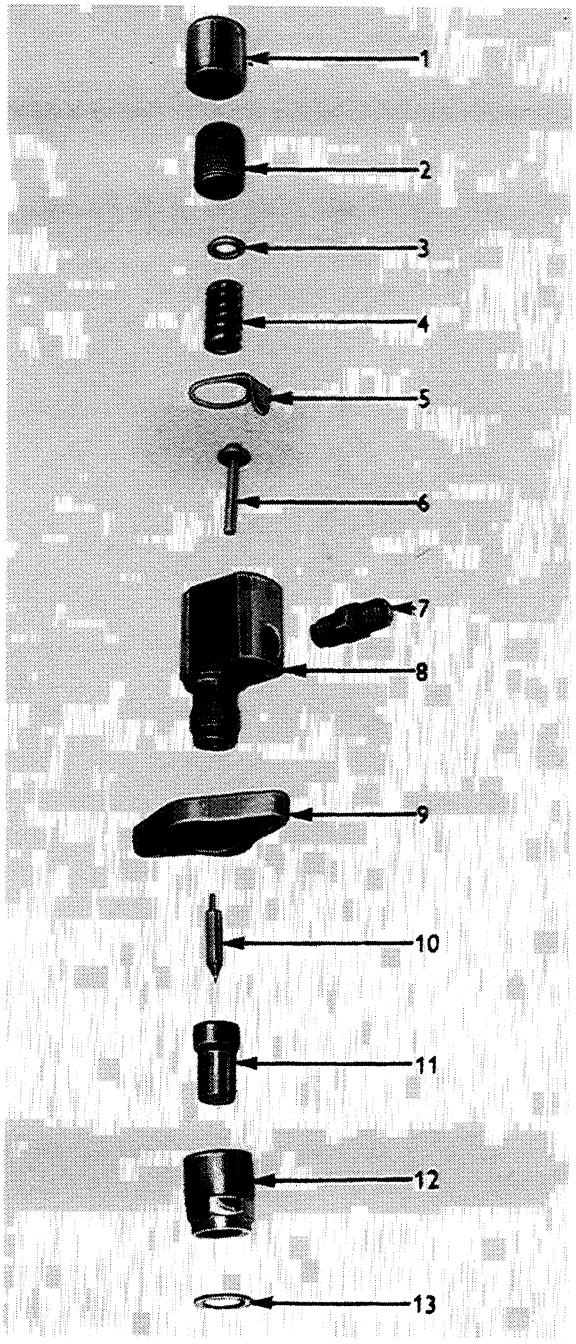
Injector Pressures

Details of holders and nozzle types together with pressure settings are given on Page B.12.

NO ATTEMPT SHOULD BE MADE TO ADJUST THE INJECTION PRESSURE WITHOUT AN INJECTOR TESTING PUMP OF THE TYPE ILLUSTRATED. IT IS QUITE IMPOSSIBLE TO ADJUST THE SETTING OF INJECTORS WITH ANY DEGREE OF ACCURACY WITHOUT PROPER EQUIPMENT.

Injector Identification

Injectors can be identified by code letters stamped on a tab washer fitted under the spring cap nut (see Fig. P.16) or alternatively, the code is stamped on the injector body. Details of codings can be found on Page B.12.



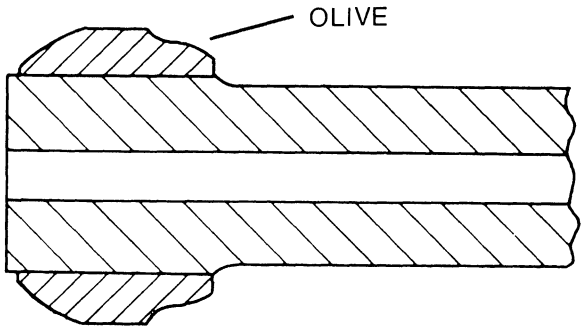
P16

1. Capnut
2. Spring cap
3. Shim washer
4. Nozzle spring
5. Identification tab washer
6. Spindle
7. Fuel inlet union
8. Nozzle holder body
9. Securing flange
10. Nozzle needle
11. Nozzle body
12. Nozzle capnut
13. Copper sealing washer

Fuel Pipes (High Pressure)

When replacing the fuel pipes it should be noted that no two pipes are the same, each is formed to suit an individual injector position. This is important when ordering a replacement pipe, as each one has a different part number.

For standardization purposes, high pressure fuel pipes assemblies are now supplied with olives fitted as shown in Fig. P.17. The earlier type pipe assemblies with olives fitted in the reversed position are still satisfactory.



P17

The pipes should be clean, (wash in clean fuel oil and blow through the fine bore with compressed air if there is any doubt), the olives at each end should not be split or unduly compressed, otherwise leakage will result and a new pipe will be needed.

Ensure when fitting, that the pipe fits squarely at both ends and that the union nuts are tightened firmly but not over-tightened.

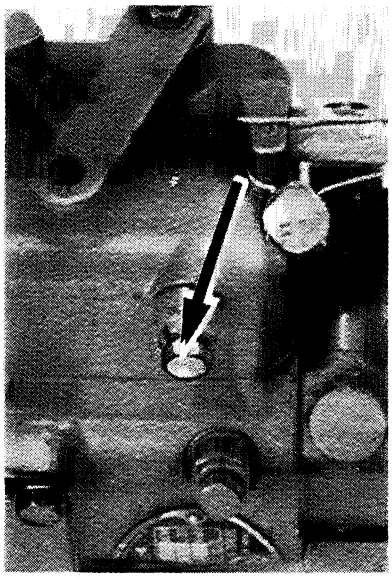
Priming the Fuel System

The air must be vented from the fuel system whenever any part of the system between the fuel tank and injection pump has been disconnected for any reason, or when the system has been emptied of fuel.

No attempt must be made to start the engine until the injection pump has been filled and primed as serious damage can be caused to the pump due to lack of lubrication.

The method of priming detailed below, ensures that only fuel which has passed through the paper filter element can reach the interior of the pump.

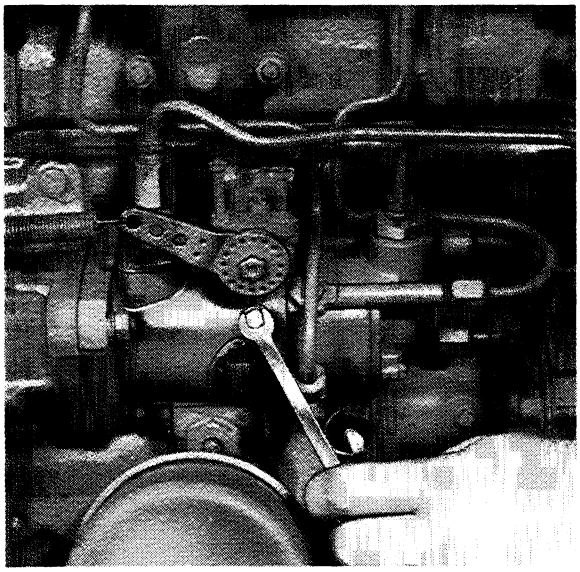
1. Slacken the air vent valve on the top of the control gear housing on hydraulically governed pumps (refer Fig. P.15) or on the front of the governor housing on mechanically governed pumps (refer Fig. P.18).
2. Slacken the vent valve fitted on one of the two hydraulic head locking screws (Refer to Fig. P.19).
3. Slacken the vent screw on the top of the fuel filter (Refer to Fig. P.20).
4. Operate the priming lever on the fuel feed pump (Refer to Fig. P.7) and when fuel, free from air bubbles, issues from each venting point, tighten the screws in the following order :—
   1. Filter cover vent screw.
   2. Head locking screw vent valve.
   3. Governor cover vent valve.
5. Slacken the pipe union nut at the pump inlet, operate the priming lever and retighten when fuel oil, free from air bubbles issues from around the threads.
6. Slacken the unions at the injector ends of two of the high pressure pipes.
7. Set the throttle at the fully open position and ensure that the "stop" control is in the "run" position.
8. Turn the engine until fuel oil, free from air bubbles, issues from both fuel pipes.
9. Tighten the unions on both fuel pipes, and the engine is ready for starting.



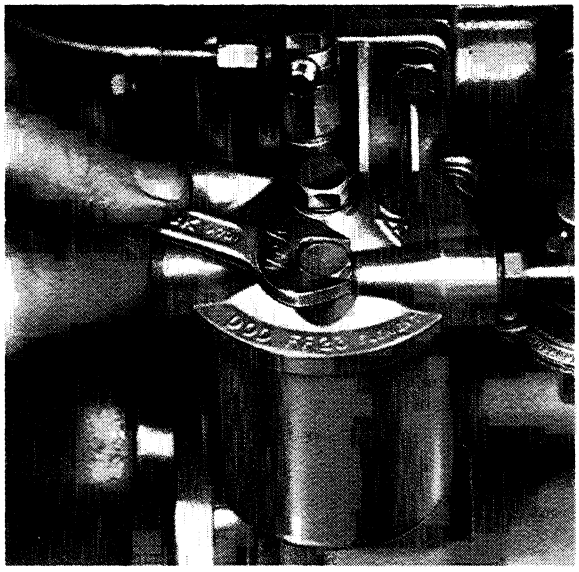
P.18

Priming Procedure after Changing a Filter Element

1. With the vent screw on the filter cover removed, and the union at the filter end of the return pipe (filter to tank) slackened, operate the feed pump priming lever until oil, free from air bubbles, issues from the filter cover vent.
2. Replace the vent plug, and continue to operate the priming lever until oil, free from air bubbles, issues from around the threads of the return pipe union.
3. Tighten the return pipe union.
4. Slacken the union at the filter end of the filter to injection pump feed pipe, and operate the priming lever until oil, free from air bubbles, issues from around the union threads.
5. Tighten the feed pipe union. The pump and filter are now filled and primed and ready for further service.



P19



P20

OTHER OVERHAUL

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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 key switch. No oil pressure switch is required. The engine is preheated by depressing the preheat push button. The engine is cranked by turning the key switch 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 ignition position of the key switch.

Models which have a fuel solenoid or electric fuel pump may be turned off via the key switch. Models with mechanical fuel lift pumps or no fuel solenoid are stopped by pulling a stop cable.

The circuit is protected by a circuit breaker located near the starter. Any time excessive current flows, the circuit breaker will trip. This is a manually resettable breaker, and must be reset before the engine will operate electrically again.

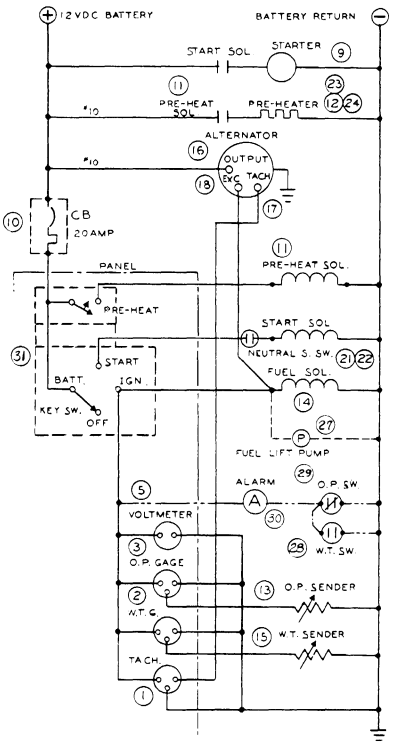
CAUTION - the builder/owner must ensure that the instrument panel, wiring and engine are installed so that electrical devices cannot come in contact with seawater.

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 the notes thereon.

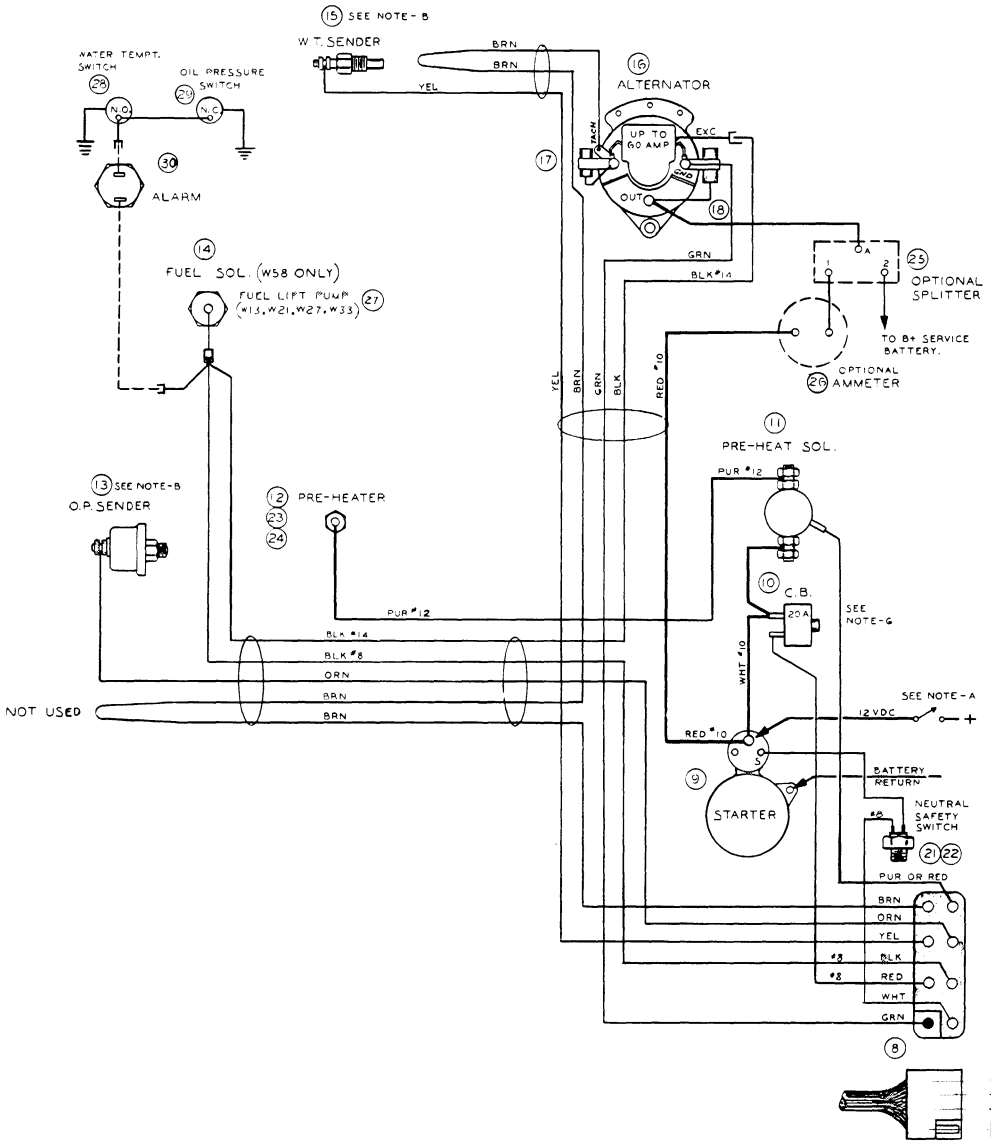
ACTIVATION BY KEYSWITCH

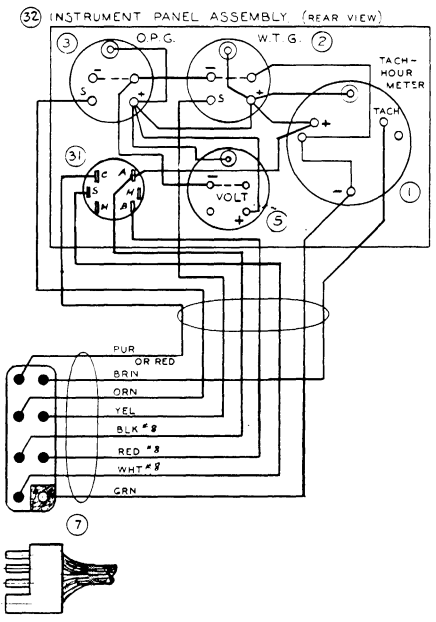
SECTION Q

SCHEMATIC DIAGRAM.



WIRING DIAGRAM.





MARINE ENGINE ELECTRICAL SYSTEM

ACTIVATION BY FUEL PRESSURE
(Push Button Start)

This system is supplied on all four and six cylinder Westerbeke engines beginning January 1975. Basically, the system is very simple and eliminates the need for a separate switch position to activate the engine alarm system, when supplied.

Starting is accomplished by operation of the start push button which causes the starting motor to crank.

Once the engine is running, fuel pressure developed in the low pressure side of the fuel injection pump operates a fuel pressure switch. Voltage is then applied to the alarm system (if supplied) and to the alternator for excitation and for all instruments.

When the engine is stopped, fuel pressure drops and the fuel pressure switch removes voltage from these devices.

When an engine is supplied with a preheating device, the device is energized by a separate push button.

NOTE: It is important that your engine installation includes fuses or circuit breakers, as described under "Ownership Responsibility" on the wiring diagram supplied with your engine.

ACTIVATION BY FUEL PRESSURE
(PUSH BUTTON START)

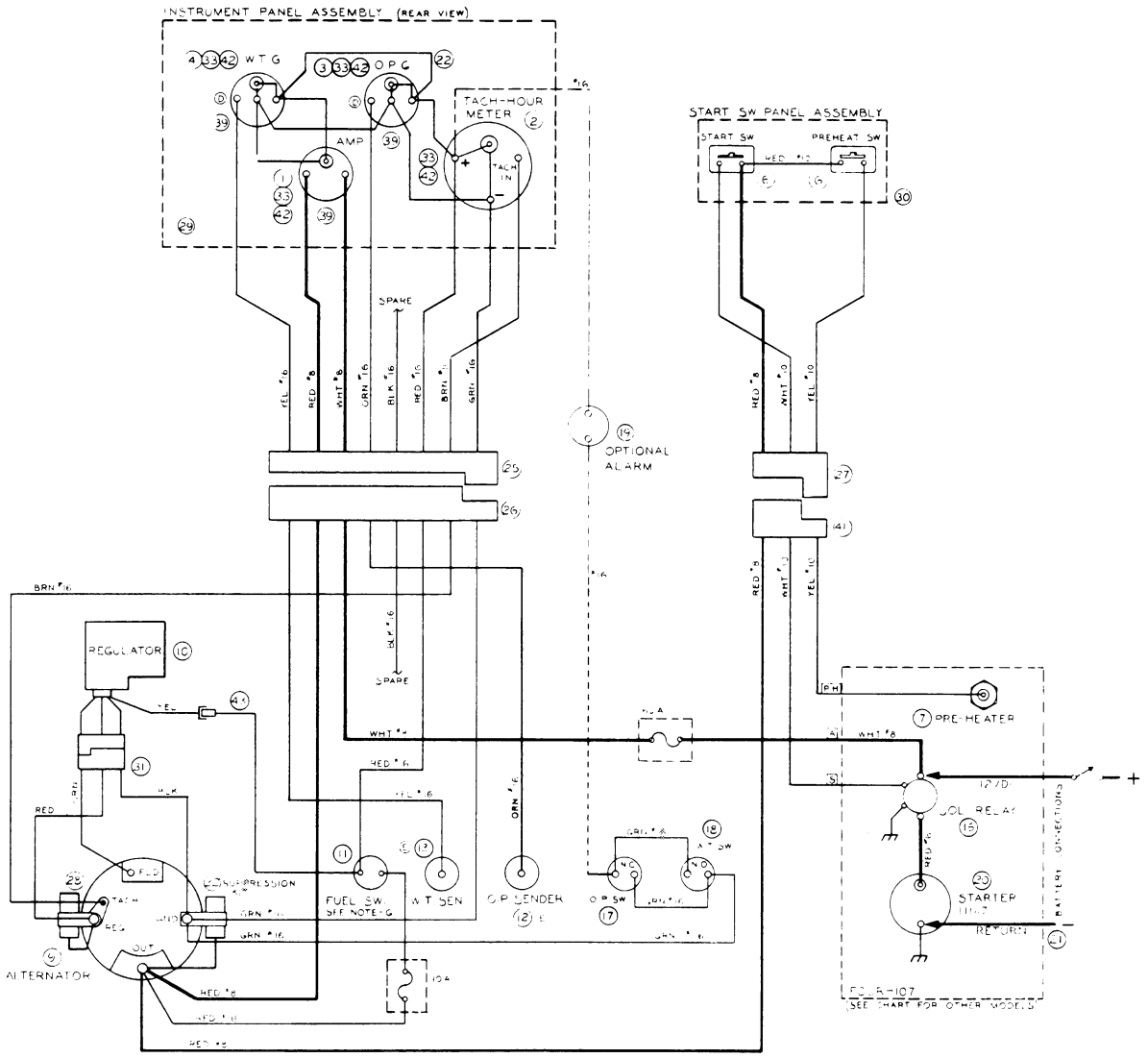
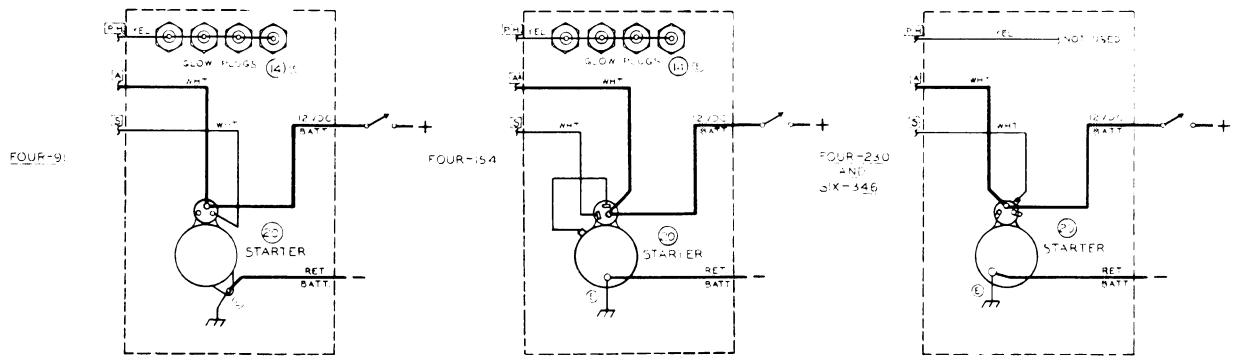


CHART FOR STARTER MOTORS AND HEATERS



Drawing No. 19201

Marine Engine Electrical System

ACTIVATION BY LUBE OIL PRESSURE
(Keyswitch Start)

This system is supplied on all 4 and 6 cylinder Westerbeke diesels produced prior to January 1975. Operation is very simple. Putting the start switch in the Run position energizes an alarm system (when supplied). Returning the start switch to Off position de-energizes the alarm.

Turning the start switch to Crank position operates the starting motor and starts the engine. Upon starting, the start switch is released to the Run position.

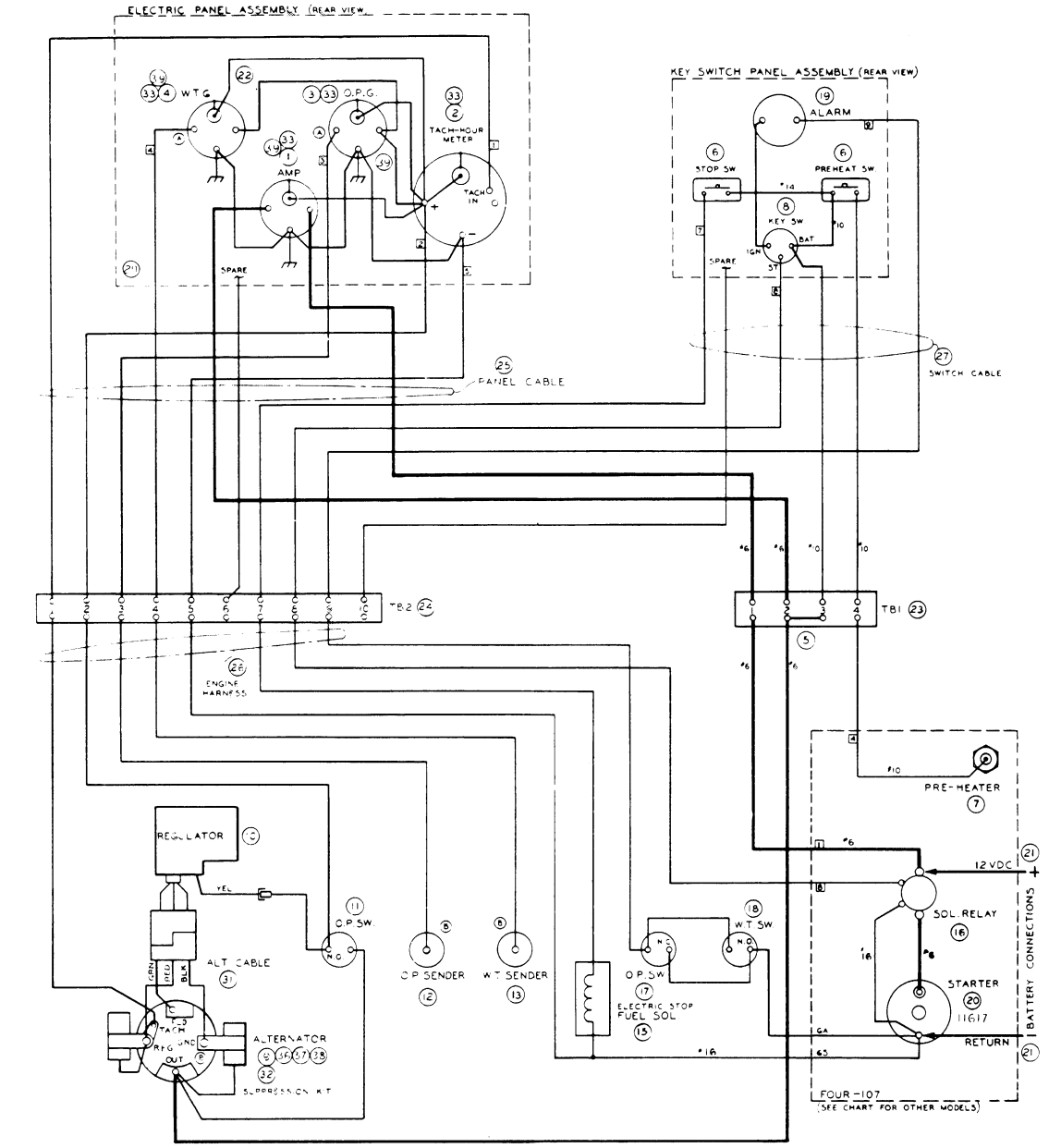
When the engine develops oil pressure, voltage is supplied to the alternator for excitation and to all instruments. Whenever the engine stops, loss of oil pressure removes voltage from these devices.

When an engine is furnished with a preheating device, it is energized by a separate push button at the key switch panel.

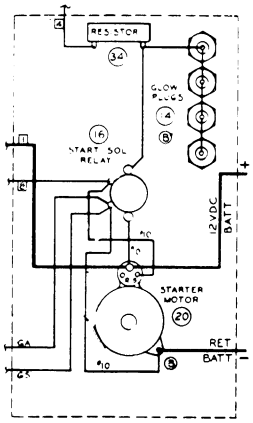
When an engine is furnished with an electric stop solenoid, it is energized by a separate push button at the key switch panel.

NOTE: It is important that your engine installation includes fuses or circuit breakers, as described under "Owner's Responsibility" on the wiring diagram supplied with your engine.

ACTIVATION BY LUBE OIL PRESSURE
(KEYSWITCH START)



FOUR-60



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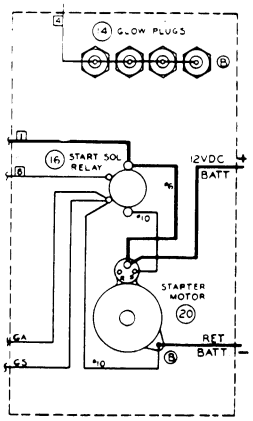
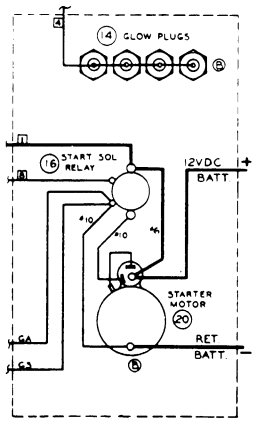
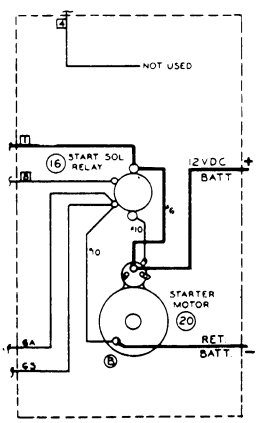


FOUR-154



FOUR-230 & SIX-346



Drawing No. 15245

YOUR NOTES

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 in 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 thru 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 pehaps 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 dumped directly overboard and a portion is used to cool the exhaust system. Full sea water flow entering the exhaust system 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 nonferrous 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 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 ultimately be 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 two 3/16" diameter holes 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. These two holes total approximately 0.06 square inches of area and 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.

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.

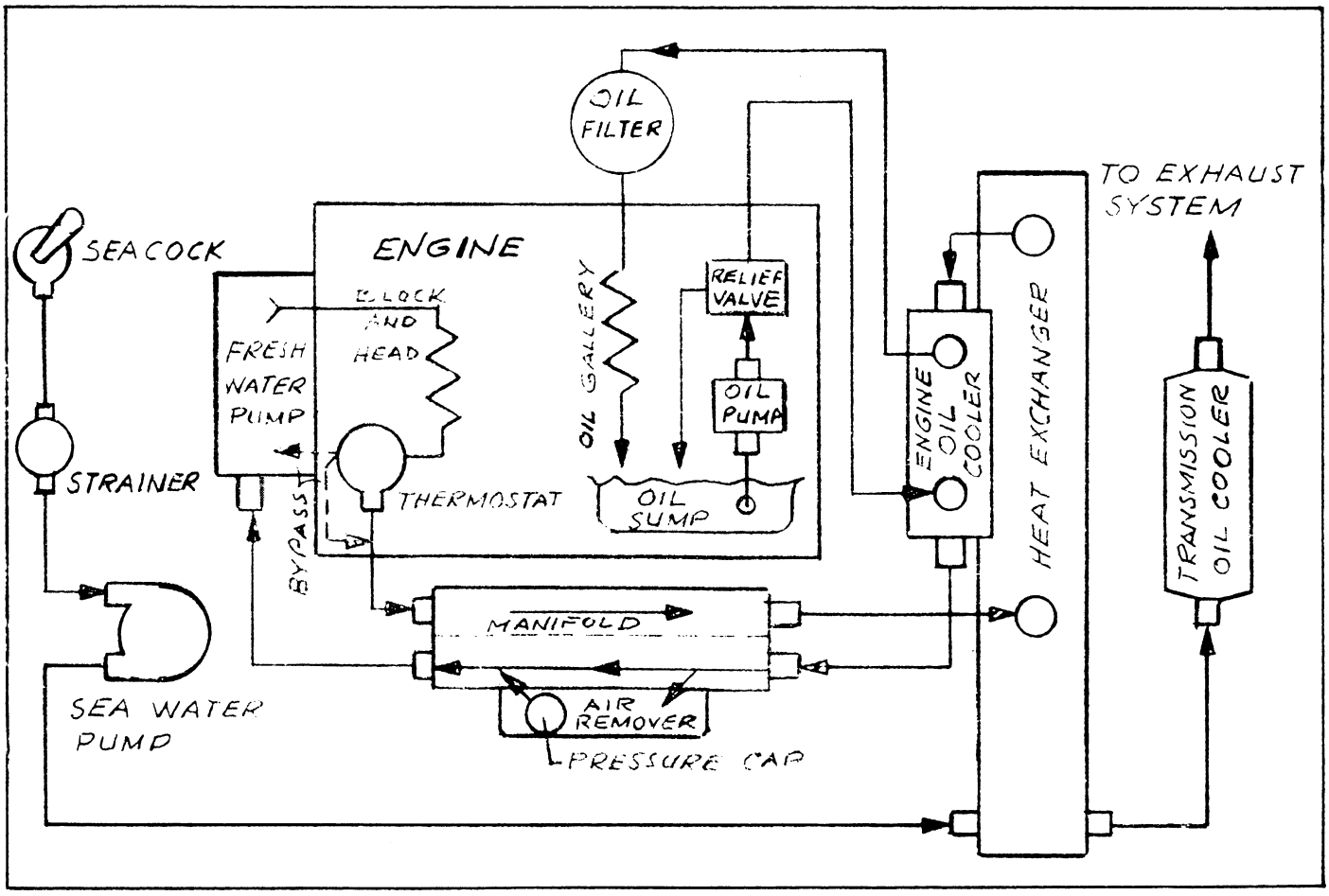
10. TRANSMISSION OIL COOLER:

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.

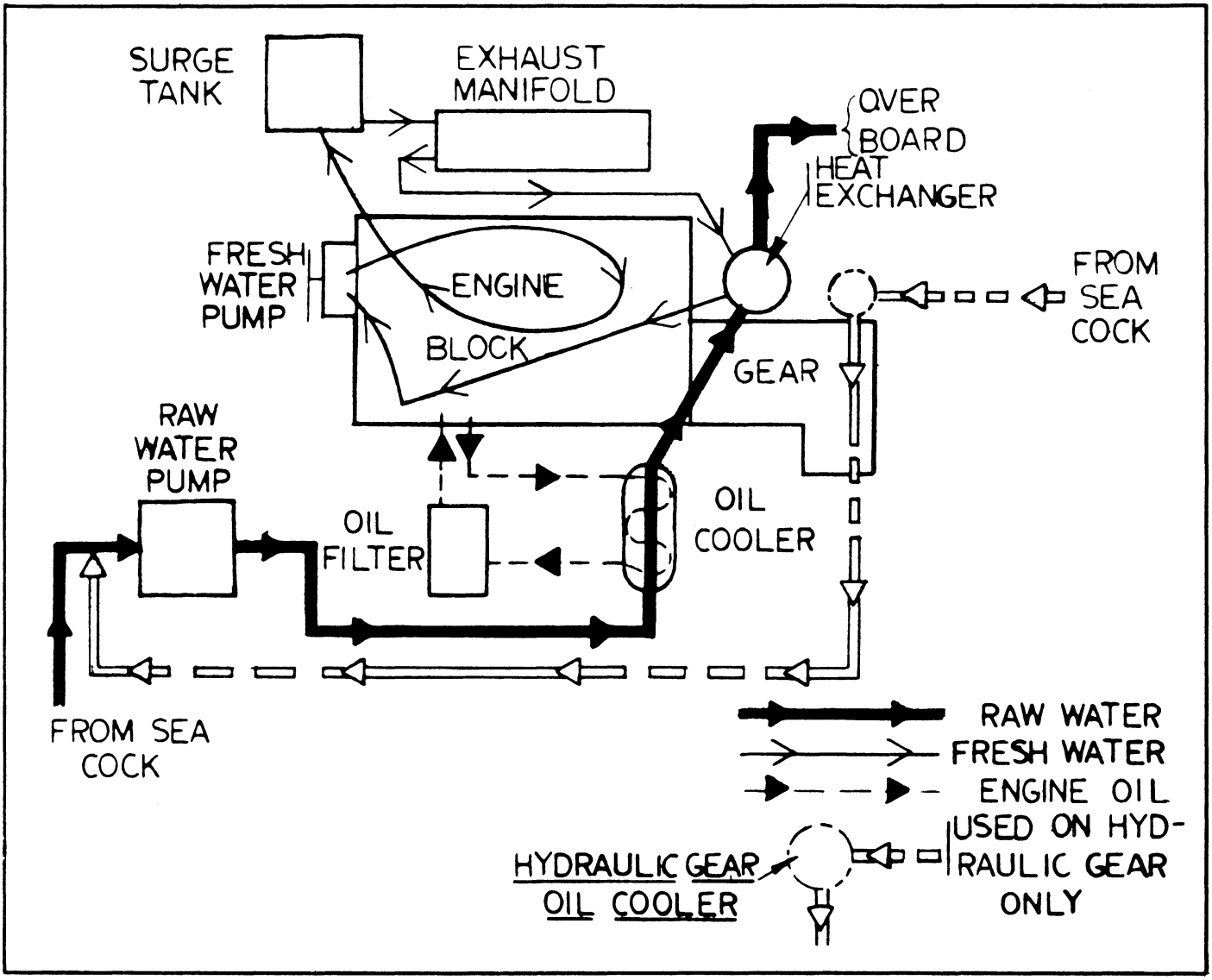
TWO PASS MANIFOLD

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.



TRANSMISSIONS

TYPE SA1 MANUAL

Description

The Westerbeke-Paragon manually operated reverse gear units consist of a multiple disc clutch and a planetary reverse gear train. These units are self contained and are independent of the engine lubrication system.

Operation

On the forward drive, the reverse gear case and multiple disc clutch are locked together as a solid coupling. The multiple disc clutch is locked or clamped by the pressure produced when the shift lever is moved to the forward position. Thus the propeller shaft turns in the same direction as the engine.

The reverse drive is obtained by clamping the reverse band around the reverse gear case which contains the planetary reverse gear train. The reverse band is clamped when the shift lever is moved to the reverse position. The reverse motion is then obtained by driving through the gears thus turning the propeller shaft opposite to the engine rotation.

With the shift lever in the neutral position the multiple disc clutch and the reverse band are unclamped and the planet gears run idle and the propeller shaft remains stationary.

It is desirable to start the engine with the transmission in neutral, thus avoiding moving the boat in either direction. It is recommended that the shifting be done at speeds below 1000 RPM and preferably in the 800 RPM range or lower to prolong the life of the engine, transmission and of the boat.

Lubrication

It is recommended that SAE 30 oil be used for lubrication. The quantity of oil depends upon the angle of installation as well as the reduction model. The level should be maintained at the high mark on the dipstick. The level should be checked periodically to ensure proper operation.

The number of hours that can be run between oil changes varies with the operating conditions. Under normal conditions, the oil should be changed every 100 hours or each season, whichever is shorter.

Model and Serial Numbers and Part Numbers

The model numbers and serial numbers are on the name plate on the cover of the transmission. The parts lists accompanying the exploded views are intended only to identify the parts in regards to disassembly and assembly and are not intended to be used to identify parts by number. To order parts, refer to the part numbers and names as given in the above mentioned parts lists.

TROUBLE-SHOOTING

The accompanying 'trouble-shooting' charts should be studied and the suggestions carried out prior to any disassembly to determine as best as possible what the trouble may be. Also, the exploded views and the accompanying discussions should be carefully read and understood so that any or all of the service work as indicated from the trouble-shooting charts may be carried out properly.

DISASSEMBLY OF TRANSMISSION

As in any servicing operation, cleanliness is a must and all rules for good workmanship apply. Some of these rules are as follows:

1. Use only clean fluid in any cleaning or washing of parts.
2. Use only clean oil for lubrication when pressing parts together
3. Never use a hammer to drive ball bearings in place.

4. Never press a ball bearing so that the force is carried through the balls.

5. Use only properly sized wrenches in removing or securing nuts and capscrews.

6. Replace gaskets and "O" rings with new material.

7. Work on a clean bench and protect gear teeth and oil seal surfaces from nicks and scratches.

REMOVAL OF REDUCTION GEAR ASSEMBLY FROM REVERSE GEAR HOUSING

NOTE: To facilitate removal of the transmission from the engine, it is simpler to remove the reduction gear assembly first. Make certain that all of the oil is removed from the reverse and reduction unit before removal is attempted.

1. Remove capscrews and lockwashers around flange of reduction gear housing.

2. Strike gear half coupling flange with soft mallet to break reduction gear unit from reduction adapter plate. Slide entire reduction unit straight back approximately 3 inches until reduction unit clears reduction drive gear and lift reduction unit clear of reverse gear housing assembly.

NOTE: Refer to reduction gear service manual for disassembly and assembly of reduction unit.

REMOVAL OF REVERSE GEAR HOUSING ASSEMBLY FROM ENGINE

1. Remove capscrews and lockwashers from flange of cover (4) and remove cover.

2. Remove capscrews and lockwashers that secure reverse gear housing (60) to front end plate (58) or timing gear cover.

3. Slide entire reverse gear housing straight back approximately 3 inches until housing is clear of engine gear (92) and lift reverse gear housing assembly clear of engine.

4. Remove pilot roller bearing (95) from engine gear (92) if it remains on engine gear.

5. Remove front end plate (93) from transsion.

6. Remove engine gear (92) from engine, following engine manufacturer's recommendation, only if necessary to replace.

7. If necessary to replace, remove oil seal (94) from front end plate

REMOVAL OF GEAR CASE ASSEMBLY FROM REVERSE GEAR HOUSING

REDUCTION MODEL

1. Remove screw (81) from arm of yoke (79) and remove ball joint (80) and lockwasher (82) from eye of link on reverse band assembly.

2. Loosen capscrews in yoke and remove crossshafts (78) from sides of housing being careful not to damage oil seals (68) in housing.

3. Remove yoke (2) from operating sleeve assembly (40) through cover opening in housing.

4. Remove reverse band assembly from gear case assembly from front of housing.

NOTE: On older reverse bands using the drag link, it will be necessary to remove the pins that anchor the reverse band to the housing before removing reverse band from housing.

5. Remove cotter pin from reverse gear tailshaft and remove reverse gear tailshaft nut (69).

6. Support reverse gear housing face down so that gear case may drop free approximately 2 inches.

7. Press on reverse gear tailshaft until tailshaft is free of reduction drive gear (76).

8. Lift reverse gear housing straight up until housing clears tailshaft.

10. Remove capscrews that secure reduction adapter plate (79) to reverse gear housing and remove reduction adapter plate, ball bearing (72) and reduction drive gear (76) from reverse gear housing.

11. Press ball bearing (72) and reduction drive gear (76) from reduction adapter plate (79) and press ball bearing from reduction drive gear.

NOTE: When disassembling direct drive units, use the following procedure.

12. Bend tang of lockwasher (66) away from locknut (96) and remove from reverse gear tailshaft by holding gear half coupling (68) with spanner wrench.

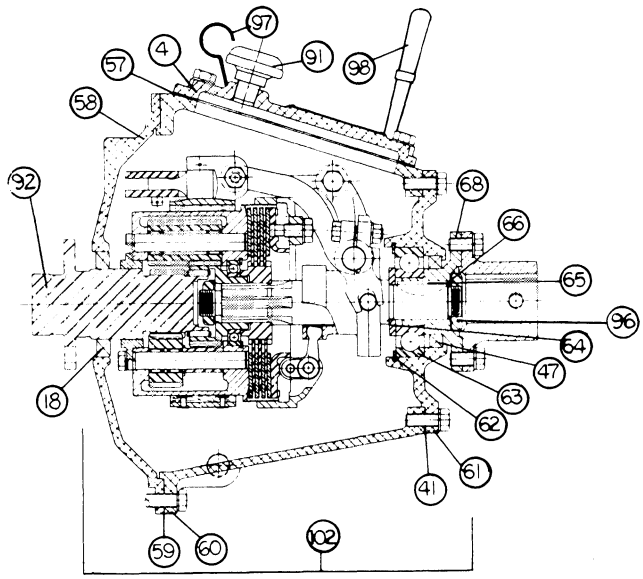
13. Support reverse gear housing face down so that gear case may drop free approximately 2 inches.

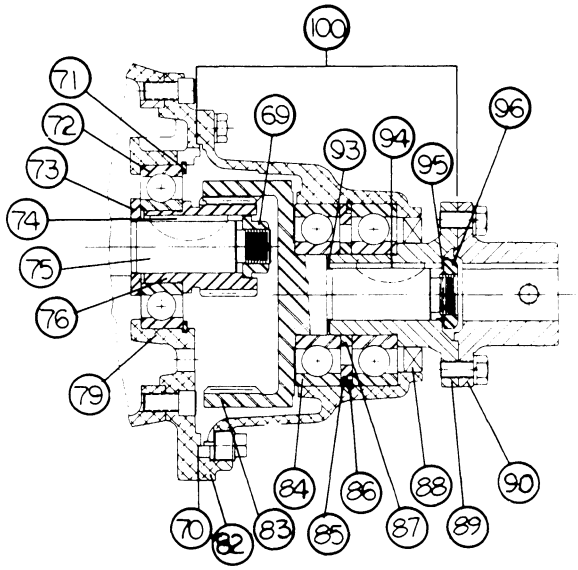
14. Press on reverse gear tailshaft until tailshaft is free of gear half coupling. Lift reverse gear housing straight up from gear case assembly until housing clears tailshaft.

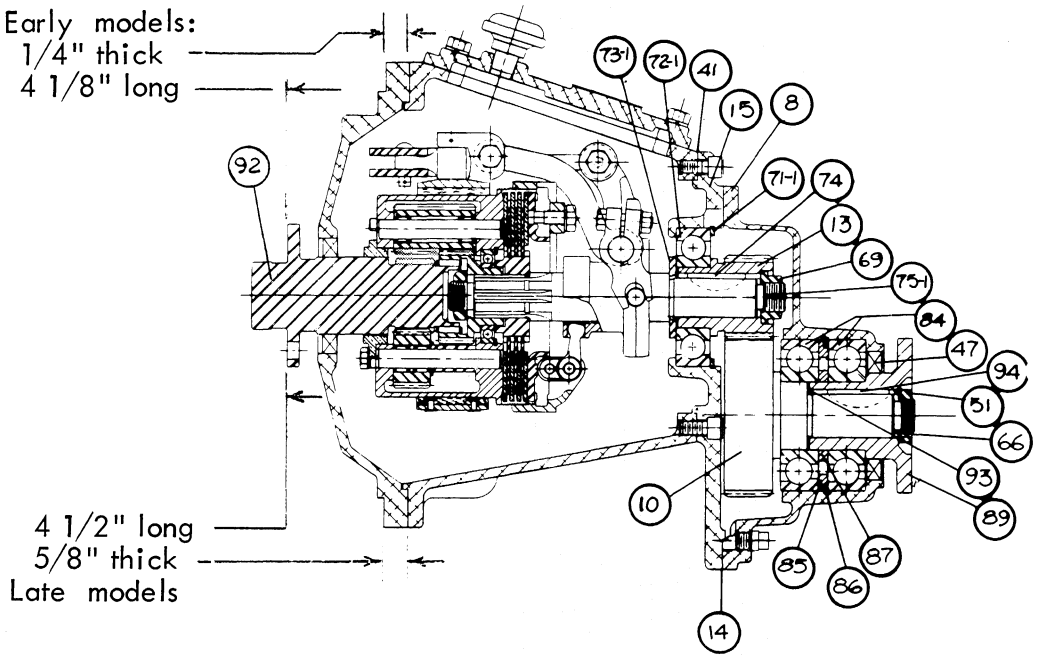
15. Remove capscrews and lockwashers that secure direct drive plate (61) to reverse gear housing (60) and remove direct drive plate (61) ball bearing (63) and gear half coupling (68) from reverse gear housing (60).

16. Press gear half coupling (68) from ball bearing (63) and press ball bearing from direct drive plate (61).

17. If necessary to replace, remove oil seal (47) from direct drive plate (61).







DISASSEMBLY OF THE REVERSE BAND-TOGGLE OPERATED TYPE

1. Remove screw (55), nut (58) and lockwasher (57) that secures brace (56) to ear of reverse band (51) .

2. Remove cotter pin (54) from ear of reverse band and remove pin (53) that holds short lever (52) in forked ear of reverse band. Remove short lever.

3. Remove locknut (50) from adjusting screw (44) and remove adjusting screw and assembled levers from reverse band.

4. Remove adjusting nut (50) from adjusting screw.

5. Remove cotter pins (47) from ends of pins in assembled levers and disassemble link (48), adjusting bolt (44) and pins (46) .

CAUTION: Do not disassemble link (48) or (61) or disturb setting of jam nut.

6. If necessary to re-line reverse band, remove rivets holding reverse band lining to reverse band.

DISASSEMBLY OF GEAR CASE

1. Remove thrust washer (73) from end of reverse gear tailshaft on reduction units and Woodruff key (74) seal washer and thrust washer (64) from end of tailshaft on direct drive units.

2. Remove lockscrew (42) and lockwasher (41) from screw collar (37) and remove screw collar from gear case by unscrewing. Lift operating sleeve assembly (40) from tailshaft when removing screw collar.

3. If finger assembly (36) seems loose or worn, remove from screw collar (37) by removing cotter pins (39) and finger pins (38) .

4. Lift pressure plate (35) and clutch plates (34) and (33) from end of gear case.

5. Bend tang of lockwasher (30) away from sides of locknut (31) inside propeller gear (24) and remove locknut and lockwasher while clamping reverse gear tailshaft.

6. Properly support gear case on clutch plate carrier (27) and press tailshaft (29) or (28) from propeller gear (24) and clutch plate carrier (27). Lift clutch plate carrier from gear case.

7. Remove case ball bearing retaining ring (26) from groove in gear case.

8. Remove capscrews (14) and lockwashers (13) from case roller bearing race (12)

9. Remove case roller bearing retaining rings (15) from case roller bearing race (12) and remove case roller bearing (16) from race.

10. Before removal of the short or long pinions is attempted, first inspect the gear teeth for indication of wear. Also, rotate each pinion to check for rough spots during rotation. If further inspection or replacement is necessary, proceed with the disassembly. However, do not disassemble unless required.

11. Drive pinion shaft (6) of one of the short pinions (11) from threaded end of gear case approximately 1/2 inch. Push pinion shaft on through with dummy shaft. Push dummy shaft until centered in short pinion (11) and short pinion spacer (7). Remove short pinion and dummy shaft from inside of gear case.

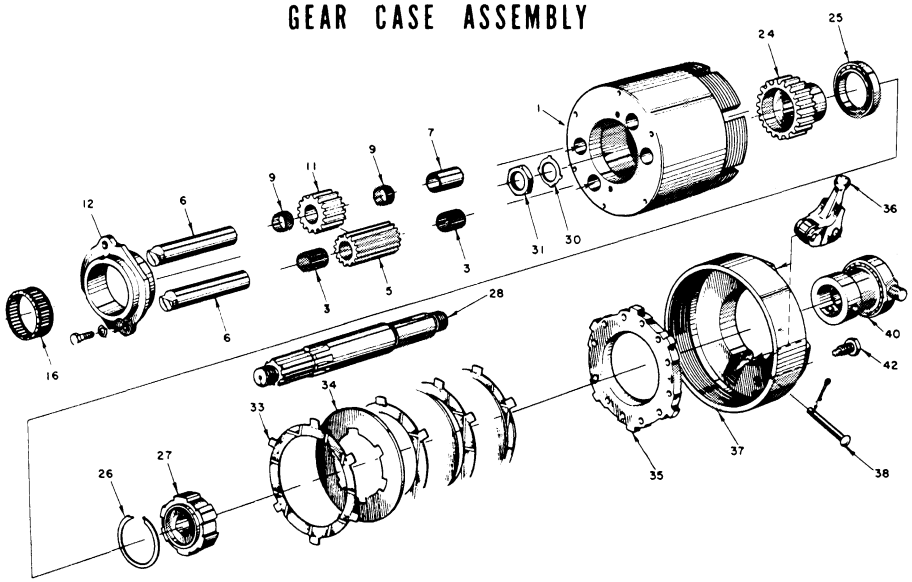
12. Remove remaining short pinions from gear case.

    The propeller gear (24) can be pressed from the case ball bearing (25) at this time.

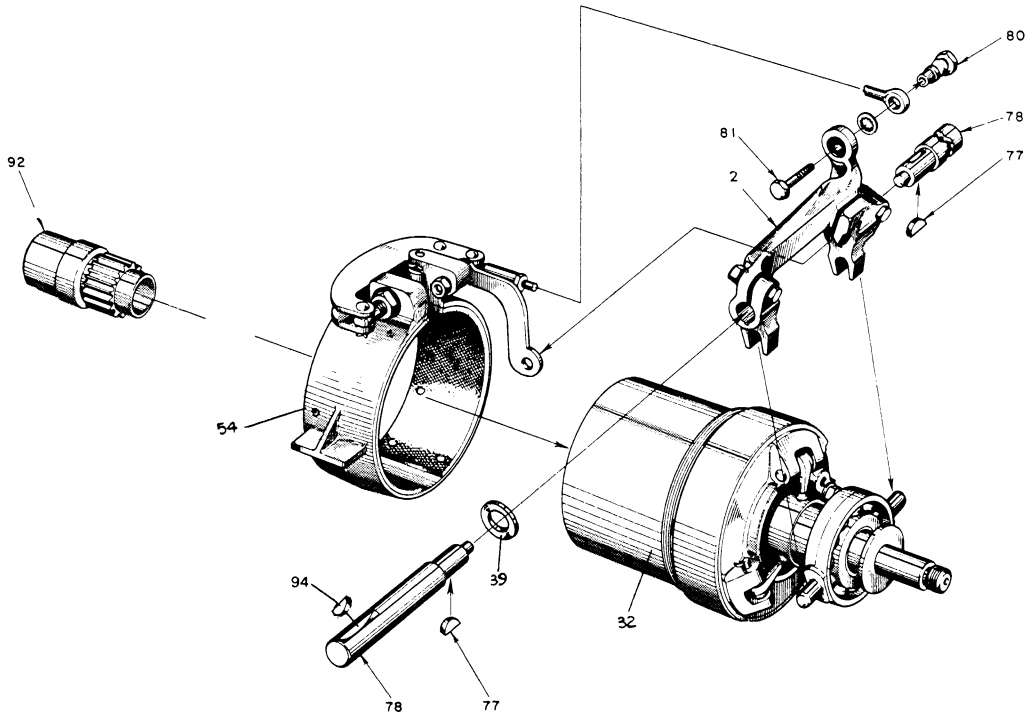
13. Remove long pinions (5) using dummy shaft as in removing short pinions.

14. Remove thrust pads (2) from inside gear case (1).

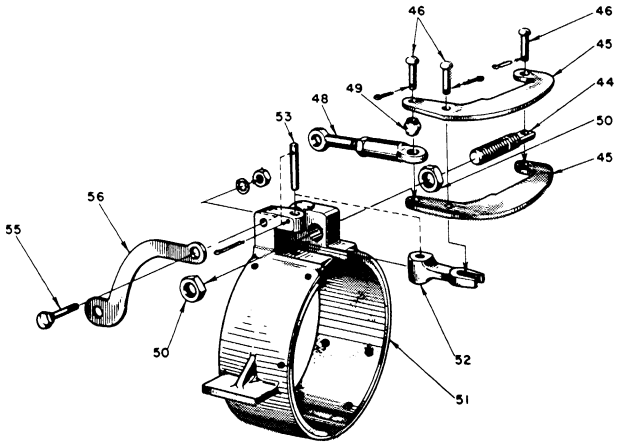
GEAR CASE ASSEMBLY



ASSEMBLY OF REVERSE BAND AND YOKE TO GEAR CASE ASSEMBLY



TOGGLE OPERATED REVERSE BAND ASSEMBLY STANDARD



YOUR NOTES

TYPE SAO MANUAL

DESCRIPTION

The Westerbeke Paragon manually operated reverse gear units consist of a multiple disc clutch and a planetary reverse gear train. The units are self contained and are independent of the engine lubrication system.

OPERATION

On the forward drive, the reverse gear case and multiple disc clutch are locked together as a solid coupling. The multiple disc clutch is locked or clamped by the pressure produced when the shift lever is moved to the forward position. Thus the propeller shaft turns in the same direction as the engine.

The reverse drive is obtained by clamping the reverse band around the reverse gear case which contains the planetary reverse gear train. The reverse band is clamped when the shift lever is moved and held in the reverse position. The reverse motion is then obtained by driving through the gears thus turning the propeller shaft opposite to the engine rotation.

With the shift lever in the neutral position the multiple disc clutch and the reverse band are unclamped and the planet gears run idle and the propeller shaft remains stationary.

It is desirable to start the engine with the transmission in neutral, thus avoiding moving the boat in either direction.

It is recommended that the shifting be done at speeds below 1000 RPM and preferably in the 800 RPM range or lower to prolong the life of the engine, transmission and of the boat.

TROUBLE SHOOTING

The trouble shooting charts below and on the next page should be studied and the suggestions carried out prior to any disassembly to determine as well as possible what the trouble may be. Also, the exploded views and the accompanying discussions should be carefully read and understood so that any or all of the service work as indicated from the trouble shooting charts may be carried out properly.

DISASSEMBLY

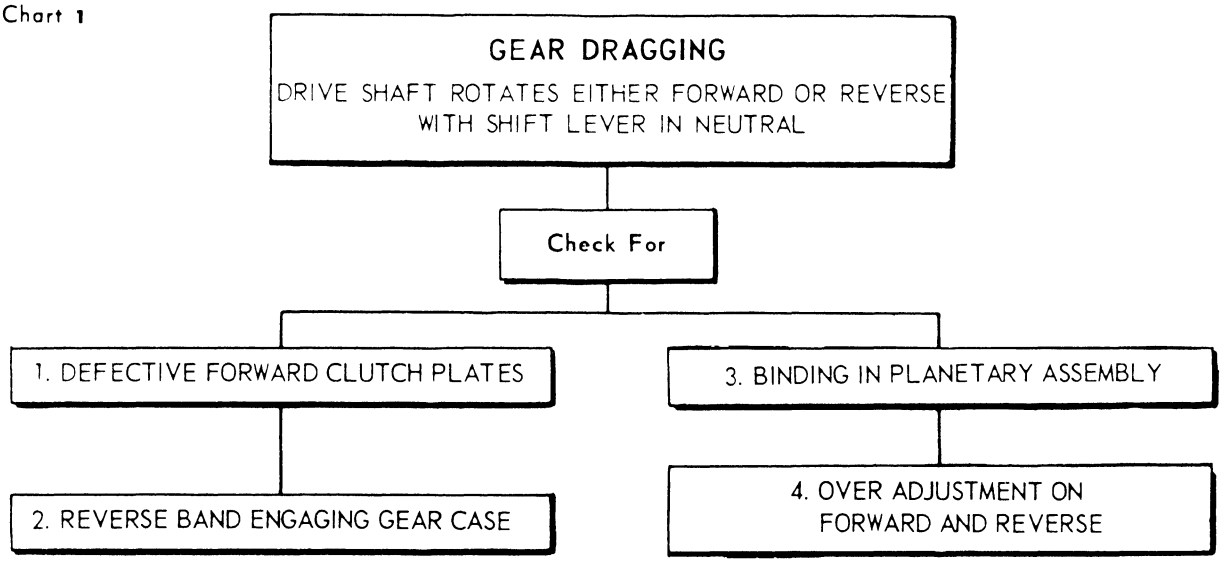
As in any servicing operation, cleanliness is a must and all rules for good workmanship apply. Some of these rules are as follows:

1. Use only clean fluid in any cleaning or washing of parts.
2. Use only clean oil for lubrication when pressing parts together.
3. Never use a hammer to drive ball bearings in place.
4. Never press a ball bearing so that the force is carried through the balls.
5. Use only properly sized wrenches in removing or securing nuts and capscrews.
6. Replace gaskets and "O" rings with new material.
7. Work on a clean bench and protect gear teeth and oil seal surfaces from nicks and scratches.

NOTE: Remove the reverse and reduction gear as a complete unit before removing the oil to avoid fouling the bilges.

TROUBLE SHOOTING CHARTS

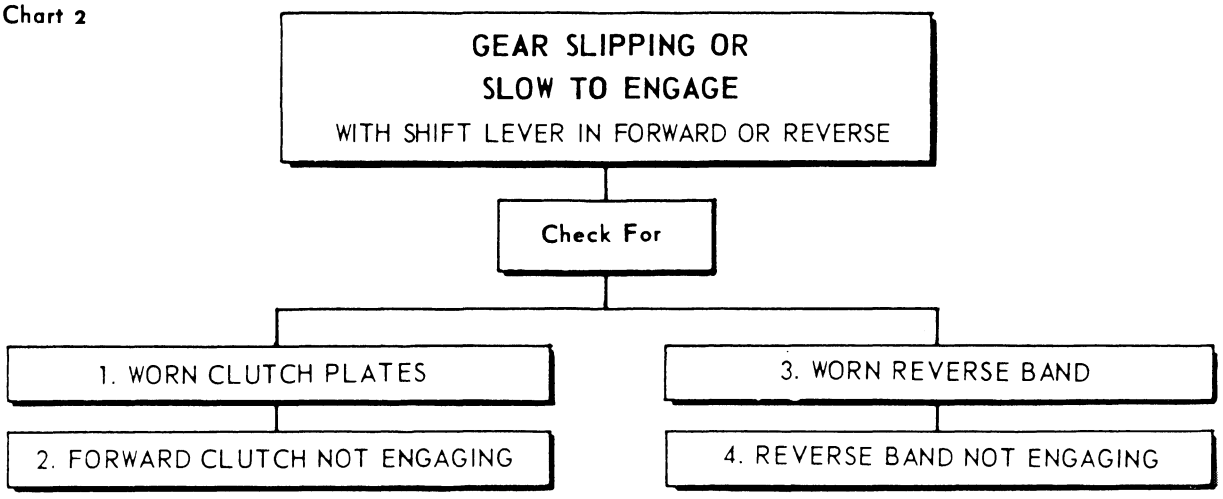
Chart 1



REMEDY

1. Forward clutch plate warped and sticking. Remove and replace clutch plates.
2. Improper reverse band adjustment. Adjust reverse band as outlined under adjustment.
3. Check the following items:
   a. Bearings and gears worn excessively in gear case. Replace necessary parts.
   b. Engine gear bearings worn excessively, causing misalignment of engine shaft. Replace necessary parts. Check misalignment of engine gear.
4. Over-adjustment of either forward and reverse or both will result in loss of neutral. Check and readjust as outlined under adjustment.

Chart 2



REMEDY

1. Remove forward clutch plates and check for wear. Replace if worn excessively.
2. Improper forward clutch adjustment. Adjust as outlined under adjustment.
3. Remove reverse band and check for wear. Replace lining if worn below rivets.
4. Improper reverse band adjustment. Adjust as outlined under adjustment.

TROUBLE SHOOTING CHART

Chart 3

GEAR INOPERATIVE

DRIVE SHAFT DOES NOT ROTATE WITH SHIFT LEVER IN FORWARD OR REVERSE

Check For

1. FAILURE OF PLANETARY ASSEMBLY
2. FAILURE OF REDUCTION GEAR
3. FORWARD CLUTCH NOT ENGAGING
4. REVERSE BAND NOT ENGAGING GEAR CASE
5. BROKEN OUTPUT SHAFT

REMEDY

1. Remove gear case assembly and check for defective or damaged parts. Replace defective or damaged parts.
2. Remove reduction gear assembly and check for defective or damaged parts. Replace defective or damaged parts. Refer to reduction gear service manual.
3. Check the following items:
   a. Improper forward clutch adjustment. Adjust forward clutch as outlined under adjustment.
   b. Forward clutch plates worn. Replace clutch plate.
4. Check the following items:
   a. Improper reverse band adjustments. Adjust reverse band as outlined under adjustment.
   b. Reverse band lining worn. Replace lining.
   c. Cracked ears or bent or damaged linkage parts. Replace defective material.
5. Check for broken output shaft. Replace defective shaft.

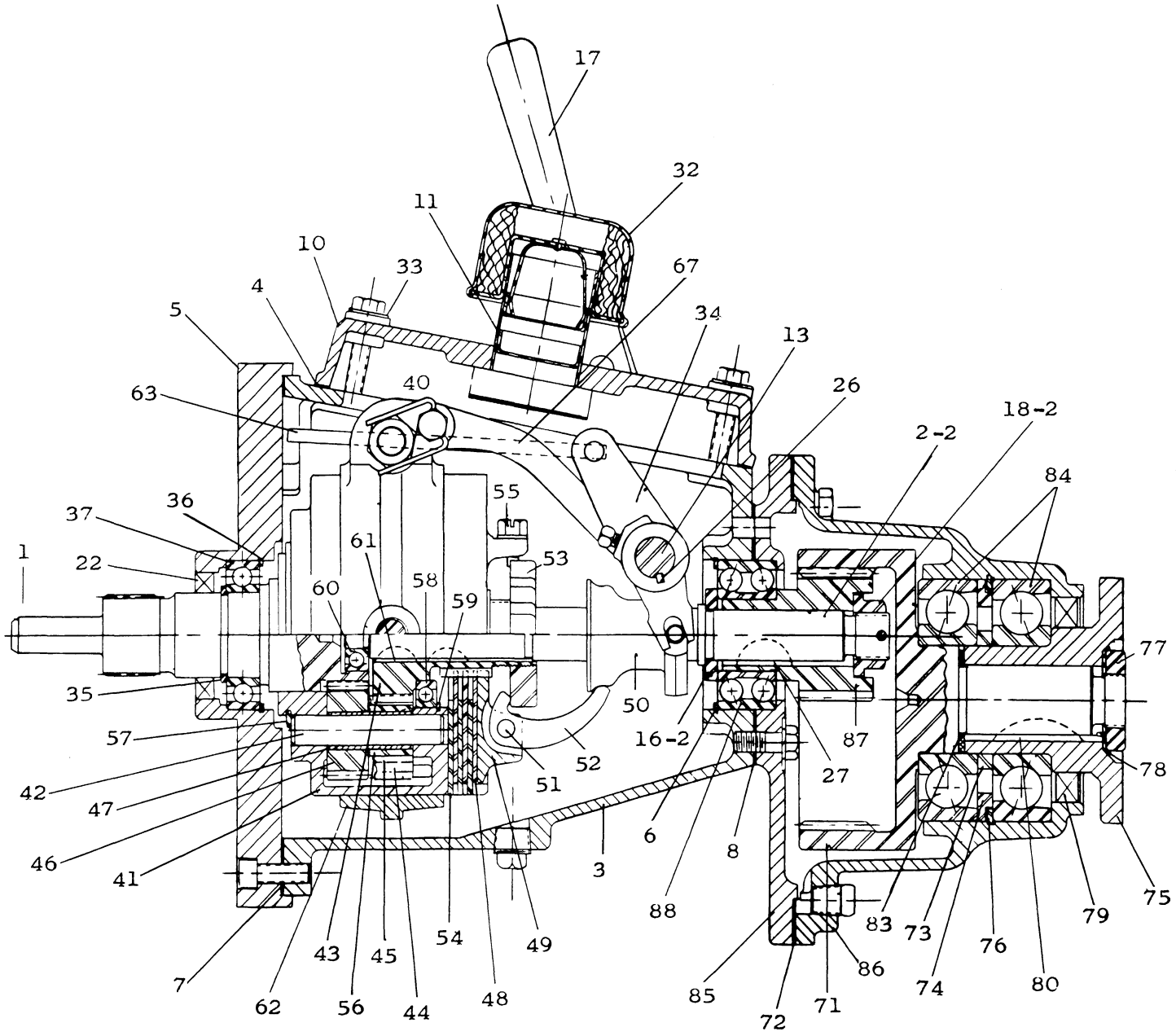
NOTE: Disassembly need be carried out only as far as is necessary to correct those difficulties which interfere with proper marine gear operation.

REMOVAL OF REDUCTION GEAR ASSEMBLY FROM REVERSE GEAR HOUSING IF INSTALLED

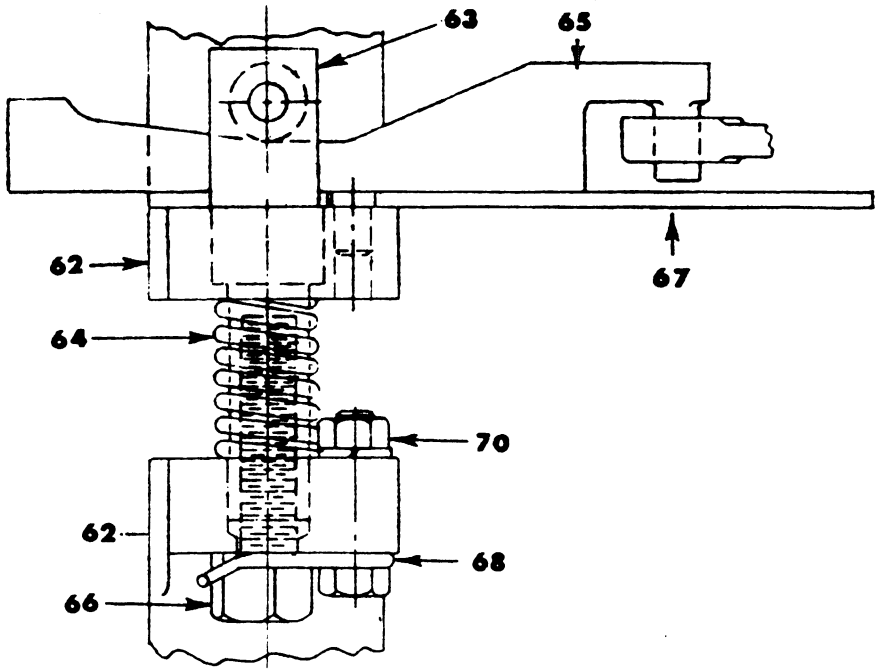
NOTE: Remove the reverse gear with reduction gear attached as a complete unit before draining oil, to avoid fouling the bilges.

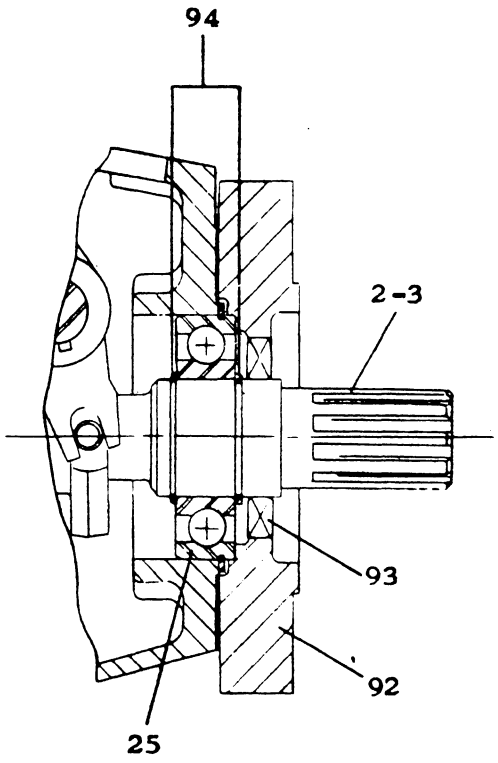
1. Remove starter motor
2. Disconnect propeller half coupling and slide back approximately 4 inches.
3. Remove capscrews securing reverse gear to bellhousing.
4. Strike gear half coupling flange with soft mallet to break reverse gear from bellhousing. Slide entire reverse and reduction gear streight back approximately 3 inches until reverse gear clears bellhousing and lift units clear of engine.

   (Refer to "Reduction Gear" section of manual for disassembly and assembly of reduction unit.)



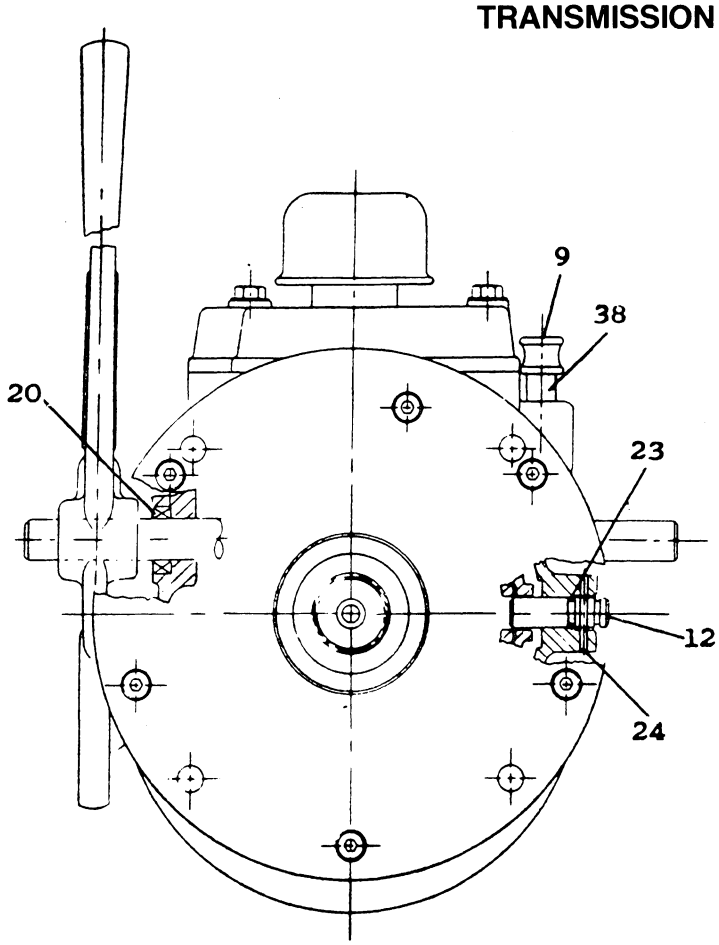
SA0 MANUAL
TRANSMISSION

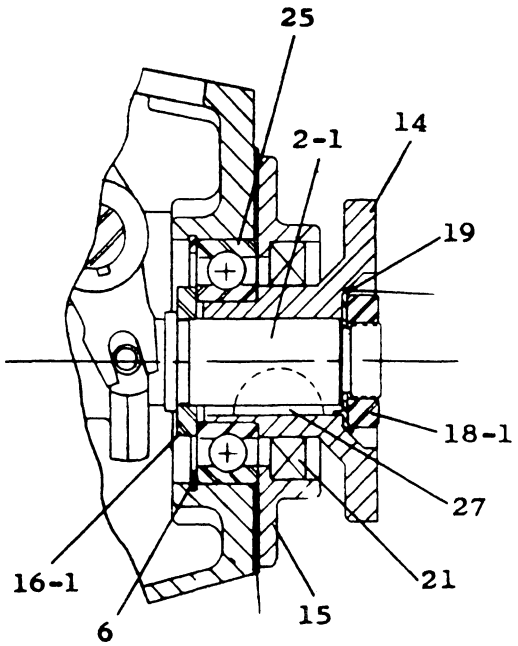




DIRECT DRIVE FOR WALTER'S "V" DRIVE

SA0 MANUAL TRANSMISSION





DIRECT DRIVE SAOD

REMOVAL OF REVERSE GEAR HOUSING ASSEMBLY FROM ENGINE

1. Remove capscrews and lockwashers that secure reverse gear housing (3) to front end plate (5).
2. Slide entire reverse gear housing (3) straight back approximately 3 inches until housing is clear of front plate engine gear (1) and lift reverse gear housing assembly clear of front plate (5).
3. Remove pilot roller bearing (60) from front plate engine gear (1) if it remains on gear.
4. If necessary to replace front end plate (5), oil seal (22), or bearing (37) proceed as follows:
   a. Remove capscrews and lockwashers securing front end plate (5) to engine flywheel housing.
   b. Slide front end plate (5) straight back approximately two inches until front plate engine gear (1) is clear of flywheel housing, and lift clear of engine.
   c. Remove retaining ring (36), bearing (37), retaining ring (35) and oil seal (22).
   d. Replace new oil seal and bearing if required.

REMOVAL OF GEAR CASE ASSEMBLY FROM REVERSE GEAR HOUSING

REDUCTION MODEL

1. Remove four capscrews, cover seals (33), cover (10), and gasket (4) from reverse gear housing (3).
2. Through cover opening in reverse gear housing (3), remove nut (70), lockwasher and screw, securing adjustment nut lockspring (68) to ear of brake band assembly (62). Remove lock spring.
3. Remove adjustment nut (66) from reverse cam (65). Remove reverse cam (65) from eye in yoke (34) and slide out reverse cam (65) from reverse cam slide assembly (63).
4. Remove cross shaft (13) from reverse gear housing (3) as follows:
   a. Loosen the two capscrews securing the yoke (34) to the cross shaft (13).
   b. With small end of housing toward mechanic, slide cross shaft (13) from left to right being careful cross shaft doesn't come in contact with operating sleeve bearing (50), or Woodruff key (26) in cross shaft under yoke arm (34) isn't forced against cross shaft oil seal (20) in right side of housing. Remove the two Woodruff keys from cross shaft.
   c. Slide cross shaft out of housing and remove brace (67) and lift yoke (34) from operating sleeve (50).
5. On dipstick side of housing remove roll pin (24) securing brake band locking pin (12) that secures brake band to housing. Remove locking pin and inspect "O" ring (23) and replace if damaged.
6. Slide brake band (62) from gear case assembly (41) and remove band from front of housing.
7. Remove cotter pin and nut (18-2) from reverse gear tailshaft (2-2).
8. Support reverse gear housing (3) with front end down so that gear case (41) may drop free approximately two inches.
9. Press on reverse gear tailshaft (2-2) until tailshaft is free of reduction drive gear (87).
10. Lift reverse gear housing (3) straight up until housing clears tailshaft (2-2).

11. Remove capscrews and lockwashers that secure reduction adapter plate (85) to reverse gear housing (3).

    a. Remove reduction adapter plate with attached bearing (88) and reduction drive gear (87).
    b. Press bearing with drive gear from adapter plate.
    c. Press bearing from drive gear.

DIRECT DRIVE UNIT (perform procedures 1 through 6 above)

12. Bend tang of lockwasher (19) away from locknut (18-1) and remove nut from reverse gear tailshaft (2-1), by holding gear half coupling (14) with spanner wrench. Remove lockwasher.
13. Support reverse gear housing (3) face down so that gear case may drop free approximately 2 inches.
14. Press on reverse gear tailshaft (2-1) until tailshaft is free of gear half coupling (14). Lift reverse gear housing (3) straight up from gear case assembly (41) until housing clears tailshaft (2-1).
15. Remove capscrews and lockwashers that secure direct drive plate (15) to reverse gear housing (3).

    a. Remove direct drive plate (15) with attached bearing (25) and gear half coupling (14) from reverse gear housing (3).
    b. Press gear half coupling from bearing.
    c. Press bearing from drive plate.
    d. If necessary to replace, remove oil seal (21) from direct drive plate.

DISASSEMBLY OF GEAR CASE

1. Remove thrust washer (16-2) and retainer ring (6) from end of reverse gear tailshaft on reduction units, and Woodruff key (27), seal washer (6) and thrust washer (16-1) from end of tailshaft on direct drive units.
2. Remove lockscrew (55) and lockwasher from screw collar (53) and remove screw collar from gear case by unscrewing. Lift operating sleeve assembly (50) from tailshaft when removing screw collar.
3. Lift pressure plate (49) and clutch plates (48) and (54) from end of gear case.
4. Properly support gear case on clutch plate carrier and press tailshaft (2-1) or (2-2) from propeller gear (43) and clutch plate carrier. Lift clutch plate carrier from gear case.
5. Remove case ball bearing retaining ring (59) from groove in gear case.
6. Remove capscrews (14) and lockwashers (13) and case bushing (23) from gear case.
7. Before removal of the short or long pinions is attempted, first inspect the gear teeth for indication of wear. Also, rotate each pinion to check for rough spots during rotation. If further inspection or replacement is necessary, proceed with the disassembly. However, do not disassemble unless required.
8. Drive pinion shaft (20) of one of the short pinions (22) from threaded end of gear case approximately 1/2 inch. Push pinion shaft on through with a dummy shaft.
9. Push dummy shaft until centerec in short pinion (46) and short pinion spacer (56). Remove pinion shaft (42) from front end of gear case.
10. Remove remaining short pinions (46) from gear case.
11. Press propeller gear (43) from the case ball bearing (58).
12. Remove long pinions (44) using dummy shaft as in removing short pinions.

NOTE: Bushings are pressed into the long and short pinions.

INSPECTION

All parts should be thoroughly cleaned before inspection. Parts showing excessive wear should be replaced.

1. Ball and roller bearings should be examined for indication of corrosion and pitting on balls or rollers and races.
2. Long and short pinion bushings should be examined for wear.
3. Pinion shafts should be examined for wear or "brinelling".
4. Long and short pinion spacers should be examined for wear.
5. Long and short pinion bore diameters should be examined for wear.
6. All gear teeth should be examined for "pitch line pitting", unever wear pattern or excessive wear.
7. All shafts should be examined for wear on splines and shoulders.
8. Clutch plates should be examined for flatness, roughness, indicating of excessive heating and wear or peening of driving lugs.
9. Clutch plate carrier should be examined for wear and peening of lugs and splines.
10. Examine all oil seals for rough or charred lips.
11. Reverse band links, pins, etc. should be examined for wear or bending.
12. Reverse band lining should be examined for wear.

NOTE: Lining should be replaced before rivets come in contact with gear case.

13. Gear case should be examined for wear from reverse band linking, short or long pinions wearing into inside faces or wear in clutch plate slots on threaded end.
14. Screw collar and finger assembly should be examined for wear.
15. Pressure plate should be examined for wear.
16. All old gaskets should be replaced.
17. Operating sleeve assembly should be examined for wear.
18. Engine gear should be examined for wear on oil seal surfaces, case roller bearing race, pilot bearing race and gear teeth for "pitch line pitting", uneven wear or excessive wear.

NOTE: When uneven gear teeth wear has been noticed, check engine gear for eccentricity. Maximum eccentricity at pilot bearing race is .005 inches.

19. Where special vibration dampers are used as flexible couplings, check springs and splines for wear.

ASSEMBLY OF GEAR CASE

1. If pinion gears (45) and (46) bushings (21), and pinion shafts (42) were removed from gear case (41), assembled as follows:

   a. Insert dummy shaft into long pinion (44).

NOTE: Use same dummy shaft as used in disassembly.

   b. Insert four bushings (21) equally spaced around dummy shaft to center shaft in gear; then assemble remaining bushings.

NOTE: Smear dummy shaft with cup grease to prevent bushings from dropping out. Install bushing spacer (56) in gear next to first row of bushings.

   c. Lay gear case (41) on side and insert long pinion (44) in case to align with hole in outer row.

d. Insert pinion shaft (42) plain end first, into unthreaded end of gear case and push through pinion as far as rear wall of gear case, forcing out the dummy shaft.
e. Remove dummy shaft, and start pinion shaft into rear wall of case. Do not drive pinion shaft all the way into gear case until all shafts are inserted.
f. Assemble remaining long pinions in gear case.
g. Using dummy shaft, insert short bushings (47) into short pinion (46) in same manner covered in paragraphs a and b above. With short pinion, use pinion spacer (56).
h. Insert short pinion (46) into gear case, pinion toward front of case, to line up with hole in inner row and insert pinion shaft (20) as described in d above.
i. Assemble remaining short pinions in gear case.

2. Assemble case bushing (23) to gear case with edges of race in line with flats on pinion shafts. Replace lockwashers (13) and capscrews (14).
3. Insert propeller gear (24) through rear of gear case in mesh with long pinions.
4. Press case ball bearing (58) into gear case and onto propeller gear by supporting entire assembly on propeller gear inside front end of gear case. Make certain that case ball bearing is seated properly on propeller gear and into gear case. Install case ball bearing retaining ring (59) in groove in gear case next to case ball bearing.
5. Press clutch plate carrier (27) onto reverse gear tailshaft (2-1) or (2-2).
6. Align splines on reverse gear tailshaft and press tailshaft through propeller gear until propeller gear is seated against the clutch plate carrier already on tailshaft. Support the entire assembly on propeller gear inside front end of gear case during pressing operation.
7. Place Woodruff key (61) on end of tailshaft inside propeller gear.
8. Install clutch plates in clutch plate cavity in rear of gear case starting first with bronze clutch plate (54) and alternating steel plate (34) and bronze clutch plate.
9. Install pressure plate (49) on top of last bronze clutch plate in clutch plate cavity.

NOTE: Make certain that all plates ride freely and that no binding is apparent during assembly.

10. Assemble finger assembly (52) to screw collar (53) using finger pins (51) and securing with cotter pins.
11. Thread screw collar (53) onto gear case assembly (41) approximately half of the thread length.
12. Place operating sleeve assembly (50) onto tailshaft. Position ball ends of finger assembly over sleeve assembly.
13. Continue screwing screw collar onto gear case (41) until finger assembly will snap over center and lock into position against the shoulder of the pressure plate (49).
14. Push operating sleeve assembly (50) forward until finger assemblies are free.
15. Place lockwasher over end of lockscrew (55) and thread lockscrew into one hole near edge of screw collar (53). Rotate screw collar until dog on end of lockscrew lines up with closest hole in pressure plate.
16. On reduction tailshafts, install retaining ring on reverse gear tailshaft making certain that retaining ring is seated properly in groove in reverse gear tailshaft.

CAUTION: The forward clutch is not properly adjusted at the end of this assembly. Proper adjustment is made after installation in boat is complete. Follow instructions as outlined under section on adjustments.

ASSEMBLY OF REVERSE GEAR CASE IN REVERSE GEAR HOUSING

REDUCTION MODEL

1. Place new gaskets (8), (7), and (4) on front, rear, and top of reverse gear housing (3).
2. If removed for replacement, install new oil seals (20) in cross shaft holes in housing.
3. Support gear case assembly (41) on propeller gear (43) inside front end of gear case so that reverse gear housing (3) will not rest on face when lowered over gear case assembly.
4. Lower reverse gear housing (3) over gear case assembly with reverse gear tailshaft (2-2) protruding through bore in rear of housing.
5. Place thrust washer (16-2) with counter-bored side down over reverse gear tailshaft (2-2). (Make certain that thrust washer seats properly on shoulder of retaining ring (6) on tailshaft (2-2.)
6. Press reduction drive gear (87) into ball bearing (88).
7. Place new gasket (8) on reverse gear housing (3) and press reduction drive gear (87) and ball bearing (88) on reverse gear tailshaft (2-2) until ball bearing is seated against thrust washer (16-2). Thread on reverse gear tailshaft nut (18-2).
8. Press reduction gear adapter plate (85) over ball bearing and secure with necessary bolts.
9. Install reduction gear crescent (74).
10. Tighten all capscrews. Tighten reverse gear tailshaft nut (18-2) until cotter pin can be installed through castellation in nut and hole in reverse gear tailshaft.
11. Install cotter pin and bedn ends over nut.
12. Place new gasket (72) on reduction adapter plate (85).
13. Install brake band assembly (62) onto gear case assembly (41) in reverse gear housing.
14. With reduction adapter plate (85) facing mechanic, insert yoke (34) through cover opening in housing placing forked arms of yoke over pins of operating sleeve assembly (50). Ensure part number of yoke is facing mechanic.
15. Align and hold hole in brace (67) on inside right hole in yoke and push cross shaft through yoke and brace to left side of housing.
16. Pull cross shaft out from right side of housing approximately one inch and insert Woodruff key in cross shaft to the right of each yoke hole to position yoke to cross shaft.
17. Secure yoke to cross shaft by tightening the two cap screws in yoke.
18. Slide reverse cam (65) through reverse cam slide assembly (63) and in hole in arm of yoke (34).
19. Position pin in brake band (62) in hole in brace (67).
20. Replace and tighten adjustment nut (66) to reverse cam slide assembly (63).
21. Secure lock spring (68) over adjustment nut (66) with screw, lockwasher and nut (70).

DIRECT DRIVE UNIT

22. After paragraph 4 above place thrust washer (16-1) over reverse gear tailshaft. Place seal washer (6) over reverse gear tailshaft against thrust

washer and install Woodruff key (27) in keyway in tailshaft.

23. If removed for replacement, press new oil seal (21) into direct drive plate (15). Press ball bearing (25) into direct drive plate.
24. Place direct drive plate, oil seal and ball bearing assembly on suitable support and press gear half coupling (14) into oil seal (21) and ball bearing (25) until gear half coupling is seated against ball bearing. Care must be taken not to damage oil seal during assembly.
25. Align direct drive plate and gear half coupling up with key in reverse gear tailshaft and press together until ball bearing is seated against thrust washer (16-1).
26. Place lockwasher (19) over reverse gear tailshaft with tang in keyway in gear half coupling and thread locknut (18-1) on reverse gear tailshaft.
27. Install lockwashers and capscrews in holes in direct drive plate and bolt to reverse gear housing.
28. Tighten all capscrews. Tighten locknut (18-1) and bend up one tang on lockwasher (19) over locknut.
29. Continue with paragraphs 13 through 20.

ASSEMBLE TRANSMISSION TO ENGINE

1. If front end plate (5) was removed from reverse gear housing (3) or engine flywheel housing proceed as follows:
   a. Replace oil seal (22) or bearing (37) if necessary.
   b. Slide engine gear (1) into flywheel housing damper spline.
   c. Align mounting holes in front end plate (5) with holes in flywheel housing and secure with lockwashers and capscrews.
   d. After installing on engine, check engine gear for runout. Maximum eccentricity is .005 inches at pilot roller bearing.
2. Insert two studs three inches long in two opposite bolt holes in front end plate (5).
3. Check to be certain that pilot roller bearing (60) is properly installed in propeller gear inside gear case.
4. Start reverse gear housing (3) over the two studs and slide housing over engine gear (1) right up against flywheel housing. It may be necessary to rotate gear case slightly to properly mesh teeth on engine gear and short pinions in gear case.
5. Install lockwashers and capscrews in holes around flange of housing.
6. Remove the two studs and install remaining lockwashers and capscrews. Tighten all capscrews.

ASSEMBLY OF REDUCTION GEAR ASSEMBLY TO REVERSE GEAR HOUSING ASSEMBLY

NOTE: Refer to reduction gear assembly and disassembly procedures.

1. Install two studs 3 1/2 inches long in two opposite holes in reduction adapter plate.
2. Position reduction gear assembly over studs with oil drain plug at bottom and slide onto reduction drive gear. It may be necessary to rotate reduction ring gear slightly to properly mesh gear teeth.
3. Install lockwashers and capscrews around flange of reduction gear housing and tighten uniformly.

YOUR NOTES

SA1 AND SA0 MANUAL CLUTCH ADJUSTMENTS

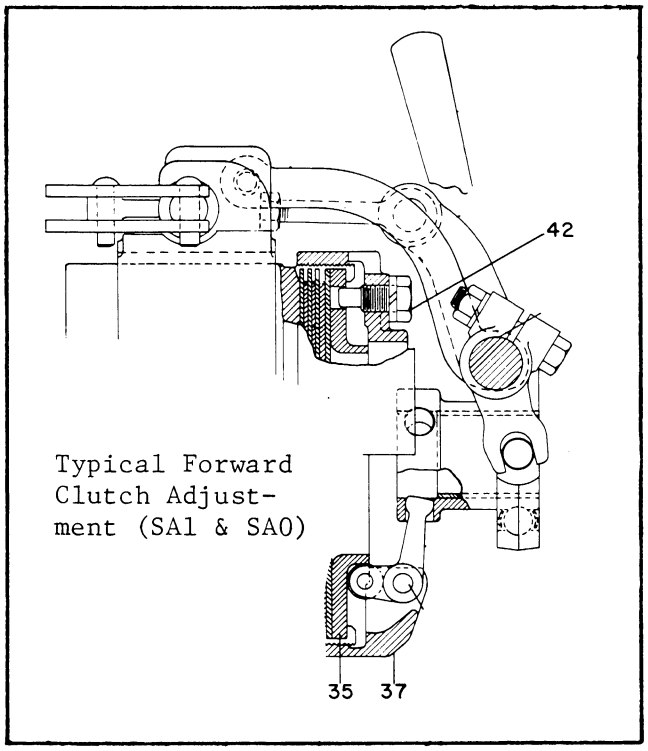
With the transmission secured to the engine, replace all water lines, etc. However, do not connect the shifting linkage until all the adjustments have been made and are satisfactorily tested.

Before securing the propeller half coupling to the gear half coupling, check to make certain that the couplings do not run out more than .002 inches with respect to each other. Study section "Alignment to Engine" on Pages 14 and 15 of Technical Manual.

The transmission should be filled with new oil as specified under lubrication.

The transmission can be partially adjusted before the engine has been run. However, a complete running test is necessary to satisfactorily determine whether the adjustments have been properly made.

The preliminary adjustments for the forward drive are made as follows: remove reverse cover plate, rotate pressure finger assembly and screw collar (37) until lock screw (42) is up and facing you. Then, working carefully to avoid dropping either screw or tools into clutch housing --



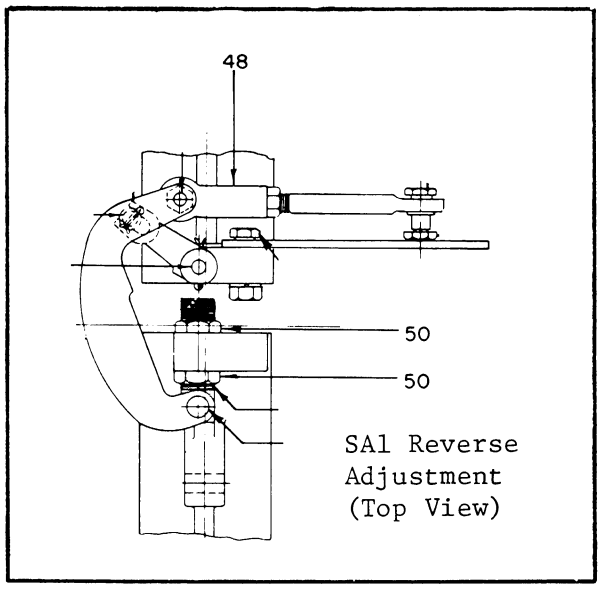
Typical Forward Clutch Adjustment (SA1 & SA0)

1. Back out the lockscrew (42) until the dog on the end of the lockscrew is clear of the hole in the pressure plate (35).

2. Rotate the screw Collar (37) to the right until the lockscrew (42) is opposite the next hole in the pressure plate (35).

3. Tighten the lockscrew making certain that the dog on the end properly enters the hole in the pressure plate.

4. Continue this until a decided effort is required to shift into forward (approximately 26 foot pounds).



SA1 Reverse Adjustment (Top View)

The preliminary adjustments for the reverse drive are made as follows:

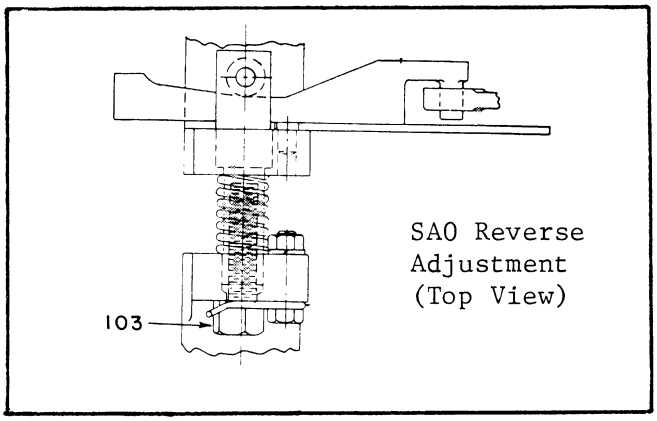
1. Loosen the locknut (50) on the inside of the upright ear at the top of the reverse band.

2. Tighten the adjusting nut (50) on the outside of the ear until both nuts are again tight against the ear of the reverse band.

3. Repeat until a decided snap is required to shift into reverse.

4. Do not tamper with adjustment of link (48).

5. For Four-99s and early Four-107s there was a cam operated reverse adjustment. Simply turn screw head (103) clockwise one flat at a time until satisfactory reverse engagement is obtained (see Figure 3).



SAO Reverse Adjustment (Top View)

Replace the cover on the reverse gear housing. The transmission is ready for a preliminary test which may be done at dockside.

Check all of the mooring lines before continuing the test.

With the engine running at idle speed, shift the transmission into forward and reverse noting how well the transmission responds.

If the transmission does not engage in one or both of the forward or reverse positions further dockside adjustments are necessary. Continue the adjustments as outlined above until the transmission will engage in both forward and reverse drives.

A complete running test is necessary to determine that the transmission is properly adjusted. The transmission should not slip or "break" away under full power conditions in the forward drive and should hold in reverse under all normal reversing conditions.

If further adjustments are necessary, continue the adjustments as outlined above until satisfactory operation is reached. It should be noted however that the adjustments should be carried out only until satisfactory operation is reached since it is possible to over-adjust the transmission. If the transmission is over-adjusted it will be more difficult to shift into forward and reverse and the parts will be heavily stressed and subject to early fatigue failure. Therefore, once the preliminary adjustments have been made, only a very small amount of adjustment will be necessary for either forward or reverse. Usually, an adjustment of a half a step on the forward, or at the most, a full step is required for full adjustment. Only a very small adjustment is required for the reverse drive.

On the forward drive, a full step of adjustment is as outlined above or is made by loosening the lockscrew (42) and rotating the screw collar (37) to the right until the next hole in the pressure plate (35) can be lined up under the lockscrew. A half a step is made by taking the lockscrew out of the hole that it is in and placing it in the hole adjoining it in the screw collar. Then rotate the screw collar to the right until the next hole in the pressure plate is lined up under the dog of the lockscrew. Make certain that the lockscrew enters the hole properly or it will bind up the forward clutch.

When the transmission is properly adjusted, replace the cover and secure all external bolts and fasteners. Before replacing the shifting linkage, check to make certain that it operates freely and does not bind or drag. Replace the linkage on the transmission shift lever and secure properly.

WHEN CLUTCH SLIPPING IS NOTICED, STOP AND ADJUST AT ONCE. PROPER ADJUSTMENT WILL MAINTAIN YOUR CLUTCH FOR YEARS, BUT A SLIPPING CLUTCH MAY DESTROY ITSELF, CAUSING COSTLY REPAIRS.

SA1 AND SA0 REDUCTION UNITS

DESCRIPTION

The Westerbeke/Paragon reduction gears consist of an internal ring gear and a drive gear that offers a variety of reduction ratios.

ADJUSTMENTS

There are no adjustments necessary to maintain the reduction gears in proper running condition.

DISASSEMBLY OF REDUCTION UNIT

NOTE: Disassembly need be carried out only as far as necessary to correct those difficulties which interfere with proper marine gear operation.

Remove reverse and reduction gear as a complete unit before removing the oil to avoid fouling the bilges.

1. Remove oil drain plug from bottom of reduction gear housing (86) and drain oil from unit. Make certain that all lubricating oil is removed from reverse gear unit.
2. Remove capscrews and lockwashers from flange of reduction gear housing and slide entire reduction unit straight back approximately 3 inches until reduction unit clears reduction drive pinion.
3. Bend tang of lockwasher (78) away from locknut (77). Remove locknut using suitable wrench and lift lockwasher from shaft.
4. Remove gear half coupling (75) with gear type puller or by supporting entire assembly under flange of gear half coupling and press against shaft to force coupling from assembly.
5. Support reduction gear housing so that flanged shaft assembly can drop free approximately 2 inches and press flanged shaft assembly from reduction gear housing.
6. Remove retaining ring (76) from groove next to ball bearing (84) inside reduction gear housing and press ball bearing from housing.
7. If necessary to replace, remove oil seal (79).
8. Remove Woodruff key (80) from flanged shaft and remove seal washer (74) and spacer (73).
9. Press ball bearing (84) from flanged shaft using two holes in flange.
10. Remove capscrews and lockwashers from rim of flanged shaft and remove ring gear (71) from flanged shaft.

INSPECTION

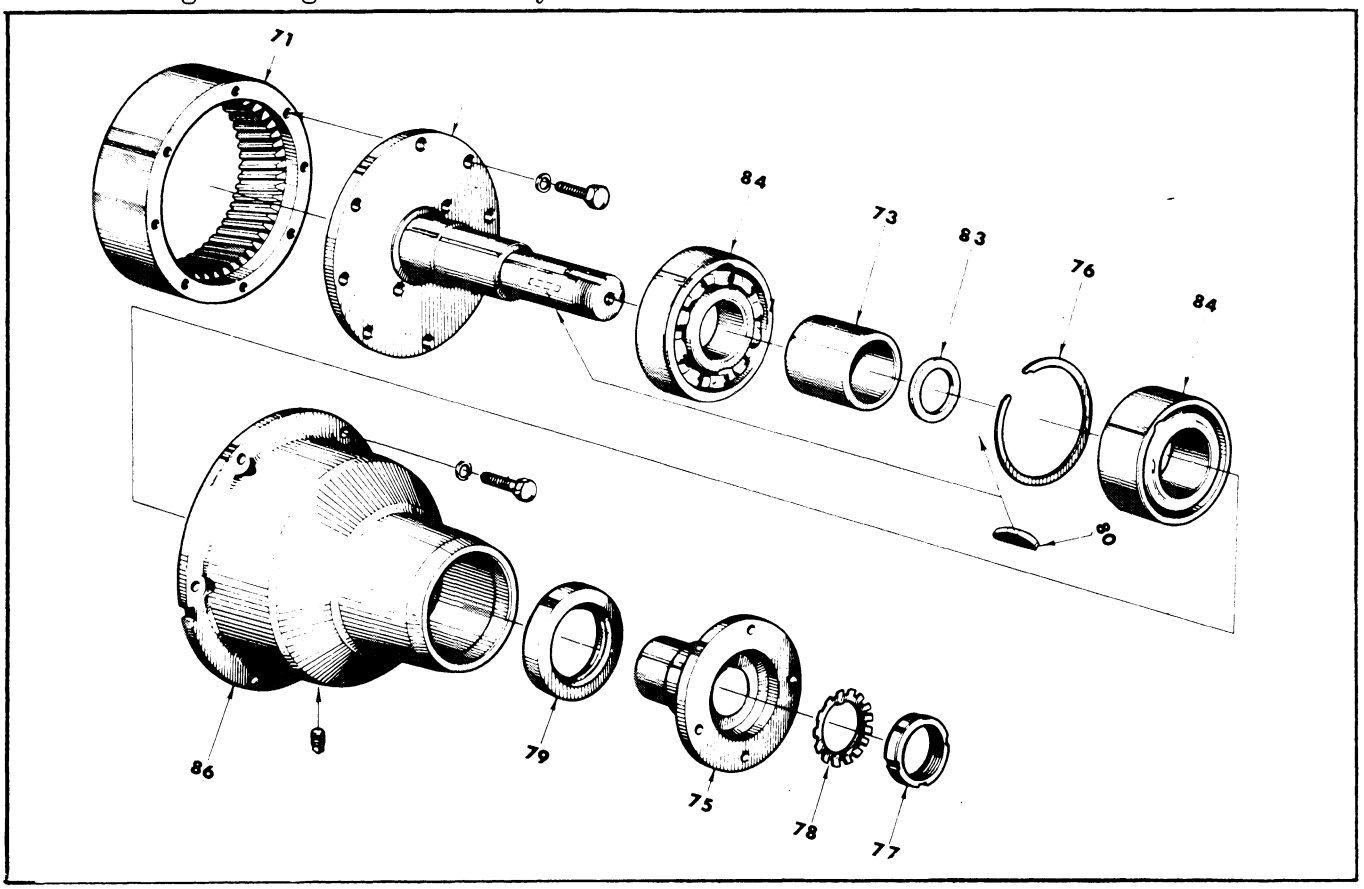
All parts should be thoroughly cleaned before inspection. Parts showing excessive wear should be replaced.

1. Ball bearings should be examined for indications of corrosion and pitting on balls and races.
2. All gear teeth should be examined for "pitch line pitting", uneven wear pattern or excessive wear.
3. Examine oil seal for rough or charred lips.
4. Retaining rings should be checked for burrs or deformities.
5. All gaskets should be replaced.

ASSEMBLY OF REDUCTION UNIT

1. Replace oil drain plug into reduction gear housing (86).
2. Press ball bearing (84) into reduction gear housing (86) and install retaining ring (76) into groove next to ball bearing.

3. If removed for replacement, press new oil seal (79) into reduction gear housing.
4. Place flanged shaft over ring gear (71) and line up holes in flange with those in ring gear.
5. Place lockwasher over capscrew and insert capscrew into hole in flanged shaft and secure flanged shaft to ring gear.
6. Press ball bearing (84) onto flanged shaft. Place spacer (73) over shaft next to ball bearing and place seal washer (74) over shaft next to spacer.
7. Install Woodruff key (80) into keyway in flanged shaft.
8. Place reduction gear housing over small end of flanged shaft and start ball bearing (84) on flanged shaft into bore in housing by tapping housing with a soft mallet.
9. Turn unit over with small end of housing down and press on center of flanged shaft until spacer (73) is seated against ball bearing (84) in reduction housing.
10. Support unit on inside of flanged shaft with large end of unit down and press gear half coupling (75) onto shaft end and into ball bearing until coupling is seated against ball bearing. Care must be taken to line up keyway in coupling and key in shaft before pressing together.
11. Place lockwasher (78) over end of flanged shaft with tang on inside of lockwasher in slot on flanged shaft. Place locknut (77) onto shaft and secure using suitable wrench.
12. Bend one tang of lockwasher into slot on locknut.
13. Install two studs 3 1/2 inches long into two opposite holes in reduction adapter plate.
14. Position reduction gear assembly over studs with oil drain plug at bottom of housing and slide onto reduction drive gear. It may be necessary to rotate reduction gear slightly to properly mesh gear teeth.
15. Install lockwashers and capscrews around flange of reduction gear housing and tighten uniformly.



TYPE RB — FREEWHEELING

The Volvo Penta reduction-reverse gear, type RB, has a built-in reduction gear, with reduction ratio 1.91:1. Engagement "Ahead" or "Astern" takes place by means of self-adjusting cones which are held in the engaged position partly with the help of the propeller thrust.

When engaging "Ahead", the output shaft is moved with its cone so that it meshes with the front cone. When "Astern" is engaged, the output shaft is moved backwards and meshes with the inner cone which operates via an intermediate gear. The direction of rotation of the output shaft will therefore be reversed. In the neutral position the cone is held by the locking plunger in such a potition that there is clearance between the cone and the gear wheel.

Reduction-reverse gear with ratio 1.9 :1 has a separate oil changer and is watercooled.

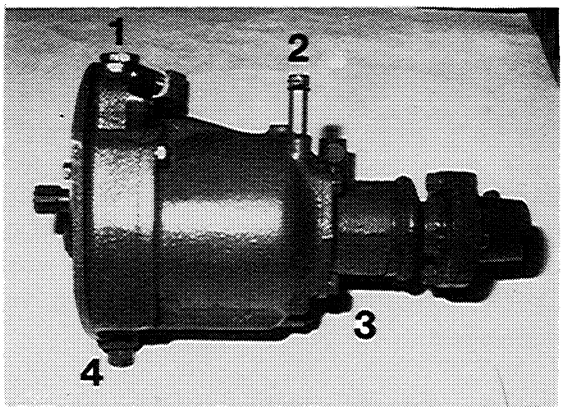


Fig. 1. RB type reduction-reverse gear, ratio 1.9 :1
1. Plug for oil filling
2. Oil dipstick
3. Plug for draining oil
4. Drain plug for cooling water

REPAIR INSTRUCTIONS - REMOVING

The repair instructions refer to Fig. 2 for ratio 1.9 :1.

1. Disconnect the cooling water connections (ratio 1.9 :1). Remove the propeller shaft and push it aft.

2. Remove the bolts holding the reverse gear to the engine and pull the reverse gear carefully aft, without breaking, so that it is released from the engine.

3. Remove the bolt (12) and pull off the coupling flange (10). Also lift off the rubber protector (18). The key (15) need not be removed.

4. Remove the reverse gear lever from the control shaft (1). Then remove the cover (2). Pull out the control shaft (1) and the eccentric stud (9) (note the position of the stud which has marked sides.

5. Remove the bolts which secure the reverse gear housing (32) to the casing (33). Part the casing from the housing by means of light blows with a mallet.

6. Remove the bolts (22) and take out the shaft (17) with the sleeve (20).

8. Remove the bolts (23) and the washer (24). Place one of the bolts (23) in the center hole of the support bearing (27) and pull off the gear wheel (30). If the ball bearing (29) is to be removed from the gear wheel, remove the bolts (25) and the ring (26) after which the ball bearing is pressed out.

9. Lift out the cone (28).

10. Remove the gear wheel (31) with bearing (34) from the housing (33). For the reduction-reverse gear with ratio 1.9 :1, removing is made easier by tapping carefully on the bevelled side of the gear wheel (31),

11. See Fig. 2. Remove the bolts (38). The flange (44) need not be removed from the shaft. Press out the shaft (42) together with the cover (43) and the ball bearing. Pres-

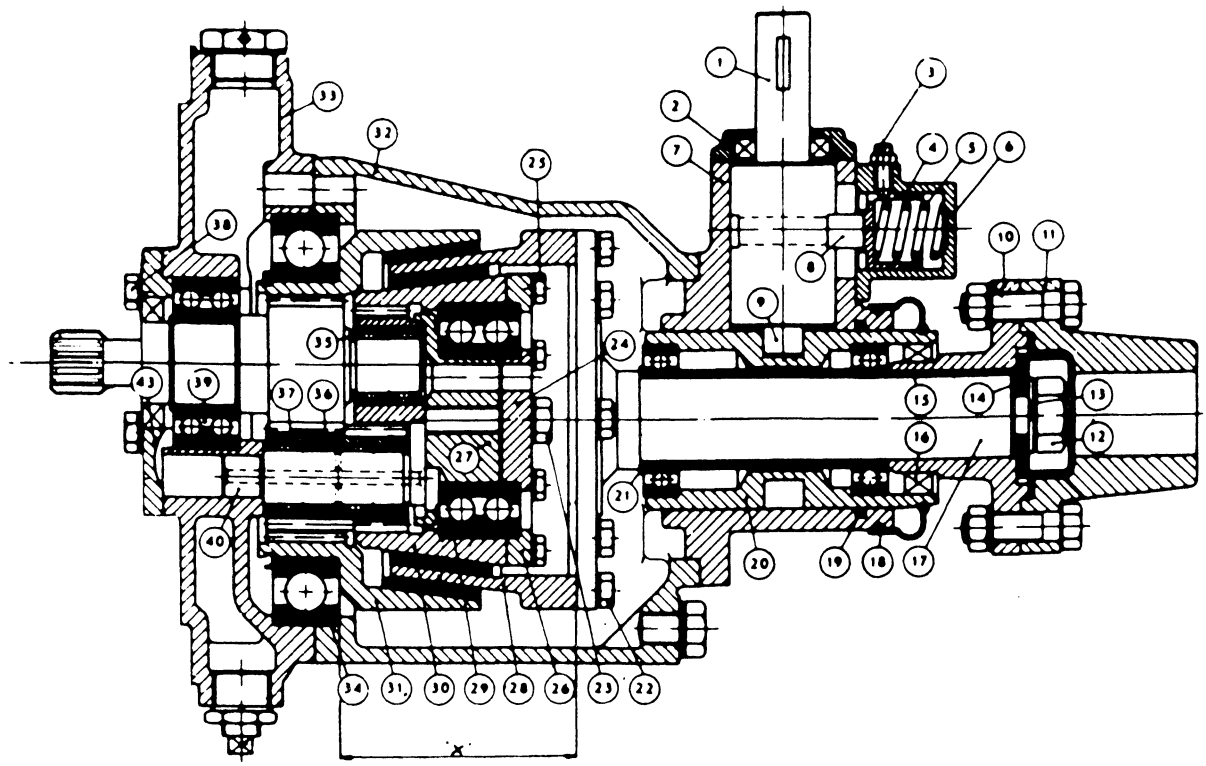


Fig. 2. Cross-section of reduction-reverse gear, ratio 1.9 :1

sure is applied to the shaft journal for the bearing (35). Take care to ensure that the needle bearing (35) is not damaged. Protect the bearing from dirt and place it so that it will take up the same position again when being fitted.

12. Drive out the shaft (40) with the gear wheel (37) and the bearing (36). With regard to taking care of the bearings, see point 11.

13. See Fig. 2. Removal of flange (44) and bearing (3) from the shaft (42) should be done in a press after the locking flange has been removed. Pressure must not be applied to the outer circumference of the flange (44).

INSPECTION

Before the reverse gear is refitted, all its components should be carefully cleaned. At the same time inspect the parts and replace those that are worn. Fit new gaskets, O-ring and spring washers. Check carefully to see that all sealing rings are undamaged.

See Fig. 2. Friction lining wear on the gear wheel (31), which is most subjected to wear, is compensated for by increasing the thickness of the shim (21) as follows: Place the cone (28) in the gear wheel (31) and measure the distance "X" shown in Fig.4 The amount by which the measurement "X" is less than 85mm (3.35") determines how much the thickness of the shim (21) shall be increased. For example, if the distance measures 83mm (3.29"), then a 2mm (0.08") thick shim should be fitted. If the wear is so great that the measurement "X" is less than 81mm (3.19"), then the worn parts must be replaced. The friction linings in the gear wheel and cone are not interchangeable.

1. Fit the bearing (36) and the gear wheel (37), also press the shaft into the housing.

2. Fit the gear wheel (31) with bearing (34) into the housing (33).

3. See Fig. 2. Fit together the shaft (42), bearing (39), cover (43) and the flange (44) into one unit. The ball bearing (39) is fitted so that the recess on one side of the bearing (Fig.7) faces opposite the teeth on the shaft (42). If the sealing ring in the cover (43) shows the least sign of damage or if it has been removed from the cover, it should be replaced by a new one. A protecting sleeve should be used to prevent damage to the sealing ring by the passage of the keyway in the shaft (42).

4. See Fig. 2. Fit the shaft unit into the housing (33). Take care to ensure that the gear wheel on the shaft (42) meshes with both gear wheels (37 and 31).

5. See Fig. 2. Fit the needle bearing (35).

6. Fit the cone (28) in the gear wheel (31).

7. Fit together the bearing support (27), bearing support (27), bearing (29), cover (24) and the gear wheel (30) into one unit and and tighten on the cover (24). The ball bearing is fitted so that the recess one side of the bearing faces away from the teeth on the gear wheel (30). The bearing support (27) and the washer are fitted so that the middle through hole comes upwards.

8. Place the unit in the cone (28).

9. Fit the shaft (17) and the sleeve (20) onto the cone (28).

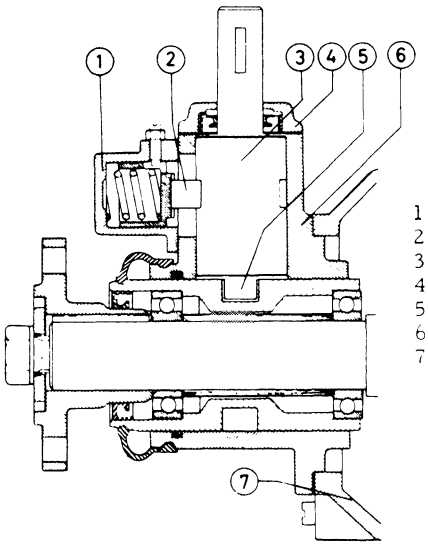
10. Fit the reverse gear housing (32) over the assembled parts and tighten it onto the housing (33).

11. Fit the rubber protector (18) and the coupling flange (10). Before fitting check that the bolt (12) is well tightened and that the key (15) is properly bedded down in its keyway in the shaft (17).

12. Fit the flange (9), shaft (1), locking plunger (8), sleeve (4), spring (5) and the plunger housing (6). Oil the parts liberally before fitting. The flange (9) is fitted so that its sides marked "O" follow the longitudinal direction of the engine. Fit the reverse gear lever and check the movements of the lever from neutral to "Ahead" and "Astern" positions respectively, which should be equi-distant. If the movement in one direction is appreciably more than in the other direction, this is to be adjusted by turning the flange (9). This is shaped such that the center of the rectangular portion is offset in relation to the center of the cylindrical portion (guide). If the flange is fitted so that the projecting side faces forwards, the movement of the reverse gear lever from the "Ahead" position to "Neutral" is decreased. If the flange is turned half a turn so that the projecting side faces aft, the movement of the lever from "Neutral" to the "Astern" position is decreased.

    Then check that the reverse gear engages in both the "Ahead" and "Astern" positions.

13. Fit the reverse gear to the engine. Regarding the reverse gear with ratio 1.9 :1, fitting is facilitated if the rubber bushings on the driving studs (45) as well as the holes for these in the engine flywheel, are carefully coated with talc.



1. Spring housing
2. Interlock pin
3. Control shaft
4. Cover
5. Flange
6. Bearing housing
7. Reverse gear housing

Fig. 3. Rear section of reverse gear

1. Set the reverse gear lever in the neutral position.

2. Remove the bolts which hold the bearing housing (6, Fig. 3) to the housing (7). Pull the bearing housing aft several millimeters (this is facilitated by carefully engaging the lever), insert a knife between the sealing surfaces and loosen the basket carefully so that it remains in contact with only one of the sealing surfaces.

3. Turn the bearing housing to the desired position and tighten down the housing.

   If the keyway on the shaft is in such a position after being moved round that the reverse gear lever cannot be fitted, the shaft and flange are turned as follows: On the shaft there is only one keyway so that both the lever retainer and the shaft must be turned.

   a. Remove the spring housing (1, Fig. 3) and lift out the locking plunger (2).

   b. Remove the cover (4) without pulling it off the shaft.

   c. Lift the shaft (3) with cover (4) from the housing and turn the shaft 180° (half a turn). Turn also the flange (5) half a turn and fit the shaft.

4. Refit the parts.

If the remote control for the RB reduction-reverse gear is fitted, it may not be done in such a way that a constant pressure operates on the reverse gear control components. In both "Ahead" and "Astern" positions the remote control device must be completely unloaded so that the propeller thrust can maintain the cones in the reverse gear in the engaged position.

DATA

Type	Volvo Penta RB 1.9 :1
Ratio "Ahead"	1.9 :1
Ratio "Astern"	1.73:1
Lubricating system	Circulation type
Oil capacity, approx	0.5 liter (1 quart)
Oil grade	Service DS
Oil viscosity	SAE 20
Oil change	Every 100 hours
Propeller type	Left-hand thread
Weight, approx	28 kg (61 lb.)

PARAGON P-21 SERIES HYDRAULIC

I. SPECIFICATIONS

A. Description Chart

MODEL	REDUCTION RATIO	DIRECTION OF ROTATION
P21L	DIRECT	ALL LEFT HAND AS VIEWED FROM THE OUTPUT END OF THE TRANS-MISSION
P22L	1.5:1	
P23L	2:1	
P24L	2.5:1	
P25L	3:1	

B. Model and Serial Numbers

Each reverse gear has a model number and a serial number. These numbers are on the name plate, located on the housing of the transmission.

MODEL AND SERIAL NUMBER CHART

DIRECT DRIVE MODEL AND SERIAL NUMBERS

P21- L 5J-1234

P2 - Gear Size
1 - Direct Drive
L - Left Hand Rotation Unit
5J-1234 - Transmission Serial No.

REDUCTION GEAR MODEL AND SERIAL NUMBERS

P 23 L 5J-5678

P2 - Gear Size
2, 3, 4, 5 — Reduction Gear Size
1.5:1, 2.0:1, 2.5:1, 3.0:1 — Reduction Gear Ratio
L - Left Hand Rotation Unit
5J-5678 - Transmission Serial No.

II. INTRODUCTION

Transmissions have been designed for smooth operation and dependability in marine use. The transmission is self-contained, having an oil pressure system and oil supply completely separated from engine lubricating oil systems.

Transmission oil under pressure is used to engage a forward or reverse drive. The forward drive is through a multiple disc clutch arrangement, while the reverse drive utilizes a reverse clamp band and planetary gear train. The transmission oil is circulated and cooled through a separate external oil cooler core, which is in turn cooled by the engine water. Paragon transmissions are furnished with either direct drive or reduction gears. Gear reduction ratios and corresponding model identification numbers are listed in Section I, under "SPECIFICATIONS".

III. INSTALLATION

A. The installation instructions below are for use when the original transmission has been removed for servicing and must be re-installed, or when the transmission unit is to be adapted as non-original equipment to a marine engine.

B. It is important that the engine and transmission rotations are matched. The direction of rotation of an engine is defined in this manual as the direction of rotation of the engine crankshaft as viewed from the output end of the transmission. A clockwise rotation of the engine is a right hand rotation and a counterclockwise rotation of the engine is a left hand rotation.

   A letter "R" or "L" appearing on the transmission serial number plate illustrated in Section I, "SPECIFICATIONS", indicates whether the transmission is for use with a right or left hand rotating engine.

C. The hydraulic transmission is attached to the engine in the following manner:

   1. Insert two 3-1/2" studs in opposite transmission mounting holes in the engine adapter plate.

   2. Place the transmission against the studs so that the studs go through two of the matching holes in the transmission housing flange.

   3. Slide the transmission along the studs toward the engine so that the spline on the shaft at the front of the transmission enters the matching splined hole in the engine vibration dampener.

   4. Install and tighten four bolts with lockwashers through the transmission housing flange into the engine adapter plate. Remove the 3-1/2" studs. Install and tighten the two remaining bolts with lockwashers through the transmission housing flange.

D. The transmission and propeller shaft coupling must be carefully aligned before the propeller shaft is connected to the transmission, in order to avoid vibration and consequent damage to the transmission, engine, and boat hull during operation. To align the coupling, move the propeller shaft, with attached coupling flange, toward the transmission so that the faces of the propeller shaft coupling flange and transmission shaft coupling flange are in contact. The coupling flange faces should be in contact throughout their entire circumference. The total runout or gap between the faces should not exceed .002" at any point. If the runout exceeds .002", reposition the engine and attached transmission by loosening the engine support bolts and adding or removing shims to raise or lower either end of the engine. If necessary, move the engine sideways to adjust the runout or to align the coupling flange faces laterally. Tighten the engine support bolts and recheck the alignment of the coupling before bolting the coupling flanges together. Connect the coupling flanges with bolts, lockwashers, and nuts.

E. Connect the oil cooler lines to the transmission.

F. Connect the shift control cable from the cockpit control station to the transmission control valve lever, shown in Figure on page 5. Place the transmission control valve lever in the neutral position and

adjust the shaft control cable length until the cockpit control station hand lever is in the neutral position. Move the cockpit control hand lever to forward and reverse positions several times while observing the transmission control valve lever motion. The transmission control valve lever should move fully into forward or reverse position when the hand lever is moved into forward or reverse position, and should return exactly to the neutral position when the hand lever is in the neutral position.

G. Remove the oil dipstick, shown in Figure on page 5, and fill the transmission with Type A transmission fluid to the mark on the dipstick. Replace the dipstick in the transmission housing.

IV. OPERATION

Principle of Operation

The transmission forward and reverse drives are operated by transmission oil under pressure. An internal gear type oil pump delivers the transmission oil, under pressure, to the external oil cooler. The transmission oil is returned, still under pressure, to the oil distribution tube and relief valve. The relief valve maintains the oil pressure by remaining closed until the oil pressure reaches 60 PSI. When the control lever is shifted to the forward position, oil under pressure is delivered to the multiple disc clutch piston, which moves to clamp the clutch discs and planetary reverse gear case together. The discs and case then revolve as a solid coupling in the direction of engine rotation. The reverse drive is engaged by shifting the control lever to the reverse position, so that oil under pressure is delivered to the reverse piston. The reverse piston moves to clamp the reverse band around the planetary gear case, preventing the planetary gear case from moving but allowing the planetary gears to revolve to drive the output or propeller shaft in a direction opposite to the rotation of the engine. With the control lever in the neutral position, pressurized oil is prevented from entering the clutch piston or reverse band piston and the propeller shaft remains stationary.

Starting Procedure

1. Always start the engine with the transmission in NEUTRAL to avoid moving the boat suddenly forward or back.

2. When the engine is first started, allow it to idle for a few moments. Stop the engine and check the transmission oil level. Add oil if necessary to bring the oil level up to the mark on the transmission dipstick.

NOTE

ON SUBSEQUENT START-UPS, THE TRANSMISSION OIL LEVEL MAY BE CHECKED BEFORE RUNNING THE ENGINE, WHEN ENGINE OIL IS CHECKED.

3. Start the engine again, with the transmission in NEUTRAL, and allow the engine to warm up to operating temperature.

4. Shift the transmission into FORWARD or REVERSE as desired. If the engine should stall when the transmission is shifted to FORWARD or REVERSE, place the transmission in NEUTRAL before restarting the engine.

   It is recommended that shifting be done at speeds below 1000 RPM, and preferably in the 800 RPM, or idle engine range, to prolong the life of the engine, transmission, and boat. EMERGENCY shifts may be at higher engine speeds, but this is not a recommended practice.

V. MAINTENANCE

A. Lubrication

The Models P200, P300 and P400 transmissions are self-contained units, independent of the engine lubricating systems. The units are lubricated by pressure and by splash from its own oil. The type of oil recommended is "Transmission Fluid, Type A", commonly used for automatic transmissions in automobiles.

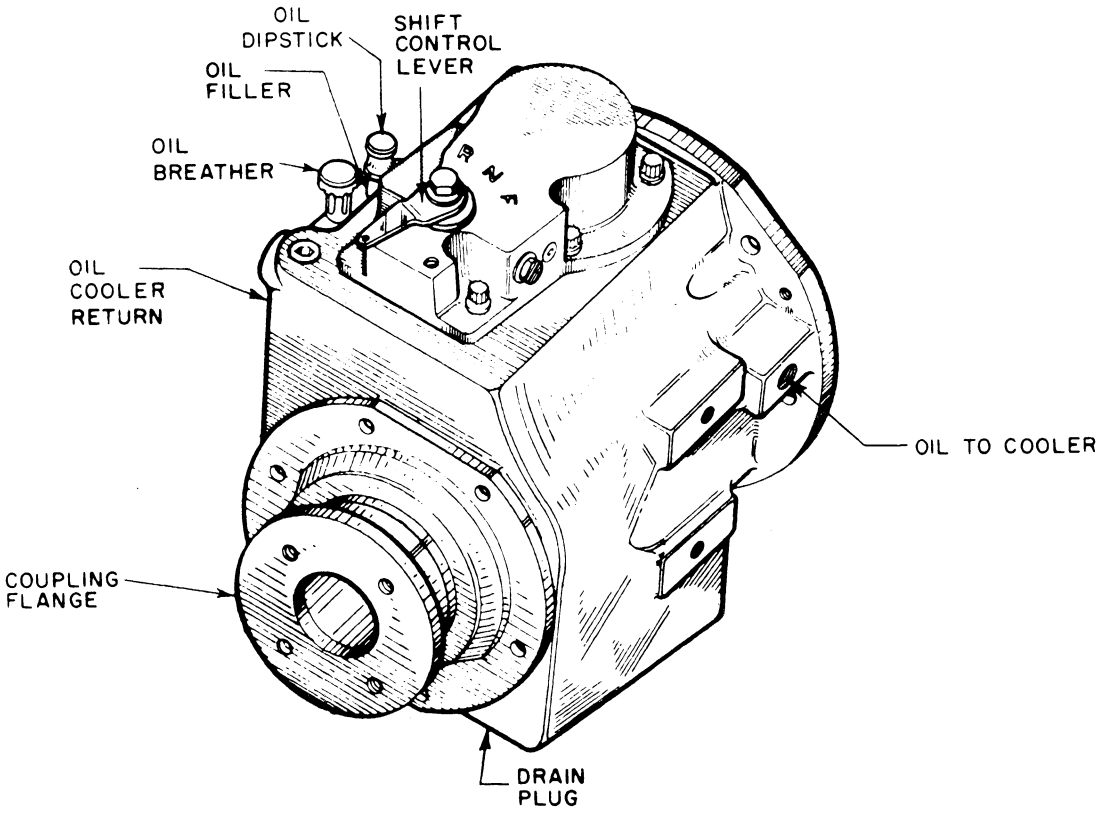
The quantity of oil depends upon the angle of installation, as well as the reduction model. The level must be maintained at the mark on the dipstick and should be checked periodically to ensure satisfactory operation.

When filling for the first time or refilling after an oil change, check the level after running for a few minutes to make certain that the oil cooler and the various passages are full. If necessary, refill to the mark on the dipstick to ensure proper operation of the transmission. The transmission oil level should be checked each time the engine oil level is checked, before running the engine.

The oil in the transmission should be changed every 100 hours, or each season under normal conditions. However, the number of hours that can be run between oil changes varies with the operating conditions. Drain plugs are located at the bottom of the reverse gear housing and the reduction gear housing.

B. Adjustments

No adjustment is necessary for the FORWARD drive multiple disc clutches, and the reverse band is self adjusting to compensate for lining wear, so that no external reverse band adjustment is necessary.



PROBLEM	POSSIBLE CAUSES AND METHODS OF CORRECTION	
GEAR INOPERATIVE		
Drive Shaft does not operate with selector valve in forward or reverse.	1. Low Oil Pressure.	a. Low oil supply. Add oil, refer to lubrication.
		b. Faulty oil gauge. Replace gauge. Oil gauge slow to register, air or obstruction in oil gauge line. Clean and bleed oil gauge line.
		c. Plugged oil lines or passages. Clean lines or passages.
		d. Oil pressure relief valve scored and sticking. Remove relief valve. Clean valve and valve bore in control valve housing with crocus cloth to free valve, or replace.
		e. Defective pistons and oil distributor seal rings. Replace seal rings.
		f. Defective oil pump. Check for wear, and replace if necessary.
	2. High Oil Temperature	a. Low oil supply. Add oil, refer to lubrication.
		b. Low water level in cooling system. Add water, and check for leaks.
		c. Plugged raw water inlet screen. Clean screen.
		d. Collapsed or disintegrated water inlet hose. Replace hose.
		e. Air leak in cooling water suction line. Replace suction line.
		f. Raw water pump impeller worn or damaged. Replace impeller.
		g. Clogged or dirty oil cooler element. Remove and clean
	3. Reverse Band not engaging Planetary Gear Cage.	a. Reverse band lining worn out. Replace lining.
		b. Defective reverse piston "O" ring. Replace "O" ring.
	4. Failure of Planetary Assembly.	Remove gear case assembly, and check for defective or damaged parts. Replace defective or damaged parts.
	5. Failure of Reduction Gear.	Remove reduction gear assembly and check for defective or damaged parts. Replace defective or damaged parts.

PROBLEM	POSSIBLE CAUSES AND METHODS OF CORRECTION
GEAR DRAGGING Drive Shaft rotates either forward or reverse with Selector Valve in neutral position.	1. Defective forward Clutch Plates. — Forward clutch plates warped and sticking. Remove clutch plates and replace. 2. Defective forward Clutch Piston Release Spring. — Forward clutch piston release spring broken or weak. Replace spring. 3. Binding in Planetary Assembly. — a. Bearings and gears worn excessively in gear case. Replace necessary parts. b. Input shaft bearings worn excessively, causing misalignment of input shaft. Replace necessary parts.
GEAR SLIPPING OR SLOW TO ENGAGE With Selector Valve in forward or reverse position.	1. Low Oil Pressure. — See "Gear Inoperative," (1). 2. Worn forward Clutch Plates. — Remove forward clutch plates and check for wear excessively, replace clutch plates. 3. Reverse Band not engaging Gear Case. — See "Gear Inoperative", (3).
INTERNAL AND EXTERNAL LEAKS	1. Water in Lubricating Oil. — a. Hole in oil cooler element permitting water to seep into oil compartment. Replace oil cooler element. b. Oil cooler gaskets. Check gaskets and replace. 2. Excessive Oil in Engine Crankcase or Flywheel Housing. — Defective front end plate oil seal. Replace oil seal. 3. Oil on Exterior of Marine Gear. — a. Oil seeping from breather. Check for too high oil level. b. Defective rear end oil seal. Replace oil seal. 4. Loss of Oil from Transmission. — a. Check for defective gaskets and seal.

WARNER HYDRAULIC

DESCRIPTION

Westerbeke Four-107 Engines are also furnished with Warner hydraulic direct drive and reduction gear assemblies.

The direct drive transmission consists of a planetary gear set, a forward clutch, a reverse clutch, an oil pump, and a pressure regulator and rotary control valve. All of these are contained in a cast iron housing along with necessary shafts and connectors, to provide forward, reverse and neutral operation. A direct drive ratio is used for all forward operation. In reverse, the speed of the output shaft is equal to input shaft speed, but in the opposite direction. Helical gearing is used to provide quieter operation than can be obtained with spur gearing.

Oil pressure is provided by the crescent type pump, the drive gear of which is keyed to the drive shaft and operates at transmission input speed to provide screened oil to the pressure regulator.

From the regulator valve the oil is directed through the proper circuits to the bushings and anti-friction bearings requiring lubrication. A flow of lubricant is present at the required parts whenever the front pump is turning and it should be noted that supply is positive in forward, neutral and reverse conditions.

The unit has seals to prevent escape of oil.

Both the input and output shafts are coaxial, with the input shaft splined for the installation of a drive damper, and the output shaft provided with a flange for connecting to the propeller shaft.

CONTROL LEVER POSITION

The position of the control lever on transmission when in forward should be shifted to the point where it covers the letter "F" on the case casting, and is located in its proper position by the poppet ball. The Warranty is cancelled if the shift lever poppet spring and/or ball is permanently removed, or if the control lever is changed in any manner, or repositioned, or if linkage between remote control and transmission shift lever does not have sufficient travel in both directions. This does not apply to transmissions equipped with Warner Gear electrical shift control.

LUBRICATION

The properties of the oil used in the transmission are extremely important to the proper function of the hydraulic system. Therefore, it is extremely important that the recommended oil, automatic transmission fluid (ATF), Type "A" be used.

PROCEDURE FOR FILLING TRANSMISSION WITH OIL

When filling the transmission, oil should be added until it reaches the full mark on the dipstick. The quantity of oil depends upon the angle of the installation. The unit should be turned over at engine idle speed for a short time in order to fill all circuits, including the cooler and cooler piping.

PROCEDURE FOR CHECKING OIL LEVEL

The oil level should be checked immediately after shutting off engine and sufficient oil added to again bring the transmission oil level to the full mark on the dipstick assembly. The dipstick assembly need not be threaded into the case to determine the oil level. It need only be inserted into the case until the cap or plug rests on the surface surrounding the oil filler hole.

The transmission should be checked periodically to assure proper oil level, and oil should be added if necessary.

CHANGING OIL

It is recommended that the transmission oil be changed once each season. After draining oil from the unit, the removable oil screen should be thoroughly cleaned before refilling the transmission with the recommended oil (ATF) Type "A".

REDUCTION GEAR BOX

The reduction gear box operates in conjunction with the direct drive unit. The reduction gear box consists of a planetary gear set which reduces the input revolutions to a fixed ratio.

It is recommended that all installations using a reduction gear have a suitable locking device or brake to prevent rotation of the propeller shaft when the boat is not under direct propulsion. If the marine gear is not in operation and the forward motion of the boat causes the propeller shaft to rotate, lubricating oil will not be circulated through the gear because the oil pump is not in operation. Overheating and damage to the marine gear may result unless rotation of the propeller shaft is prevented.

Except in an emergency, shift from forward to reverse drive through neutral at engine speeds below 1000 rpm to prevent damage to the engine, or marine gear.

SHORT PROFILE SAILING GEAR

1. Description

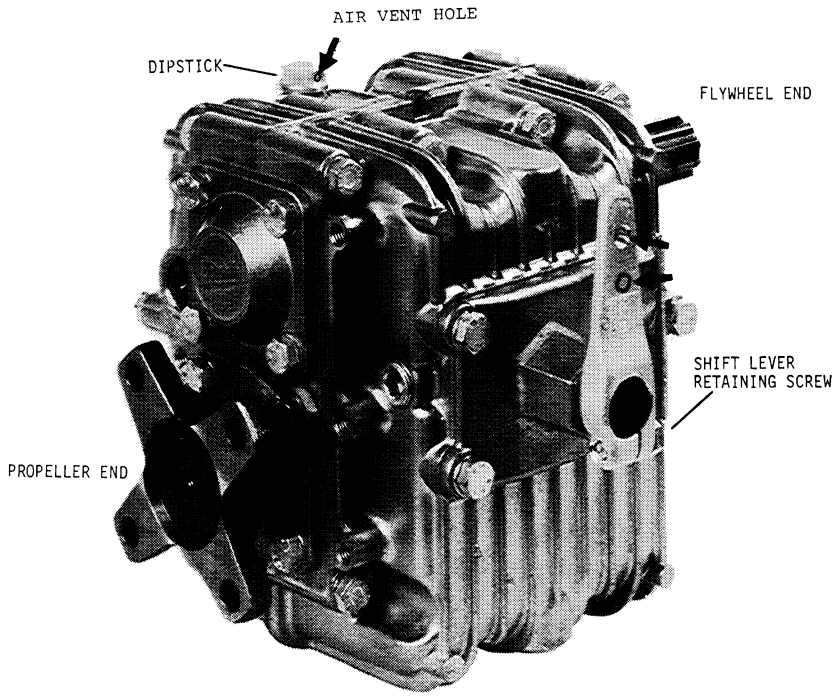
1.1 Brief description

The 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").



1.2 Gear casing

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

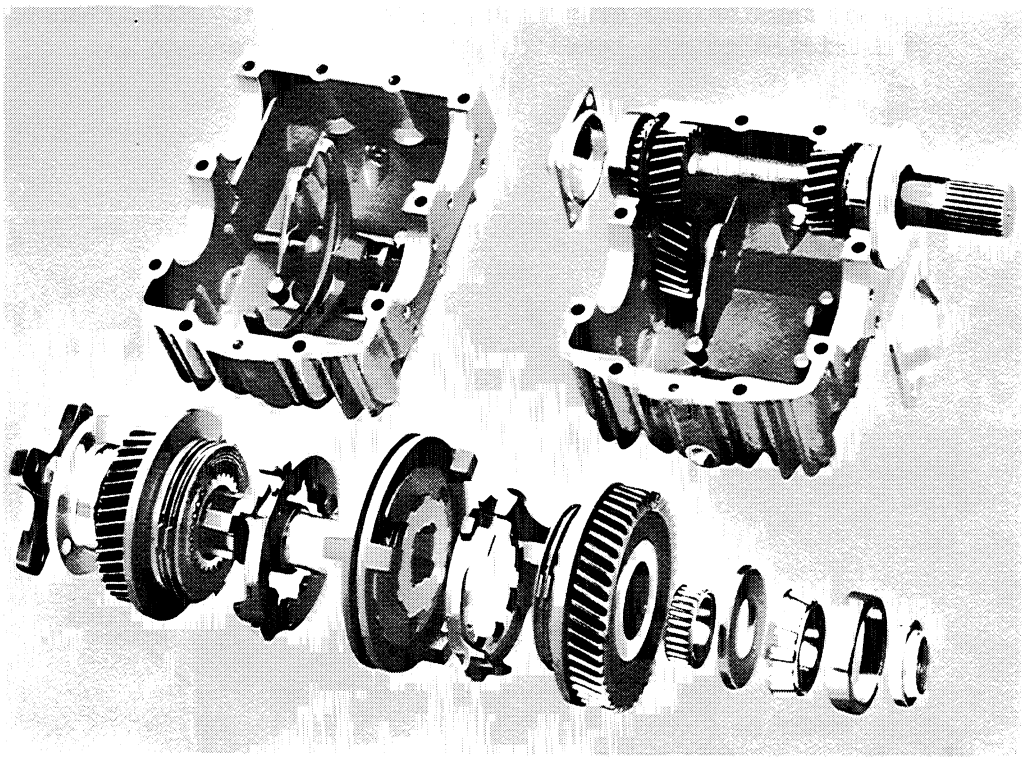
An oil filler screw with dipstick and an oil drain plug are screwed into the gear casing. The filler screw is provided with a breather hole.

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

1.3 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.



1.4 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** (see item 1.2), 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).

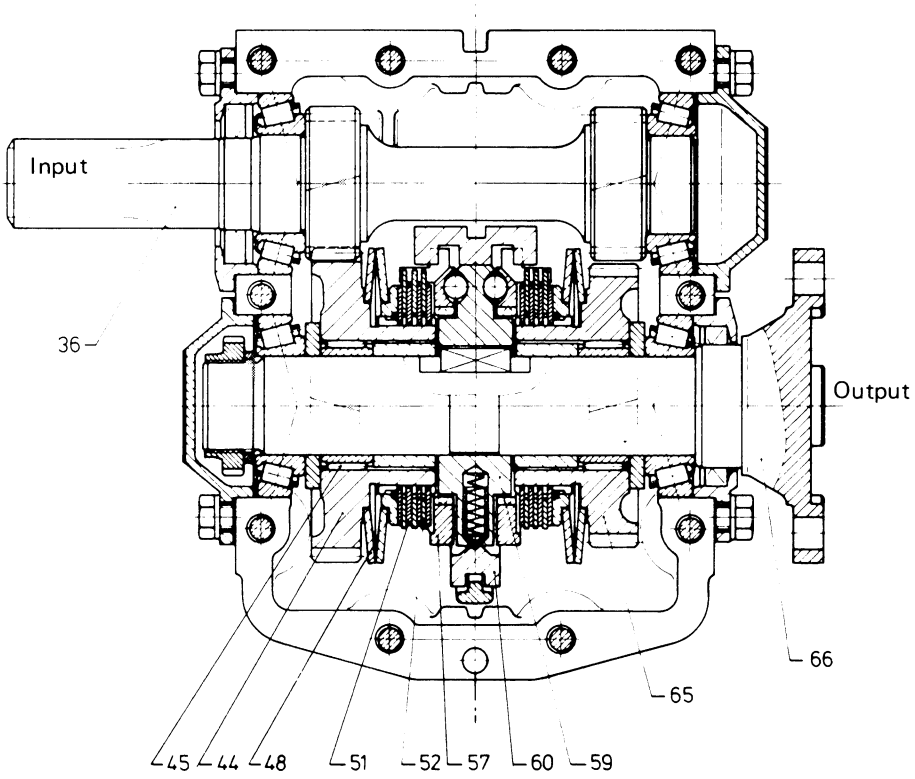
In shifting position B (see item 1.2), the torque is transmitted from the input shaft (36) via intermediate gear (26), gear (65), clutch discs (51 and 52) to the external disc carrier (57), the guide sleeve (59) and the output shaft (66).

– 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, so that the torque transmission capacity of the clutch is limited.

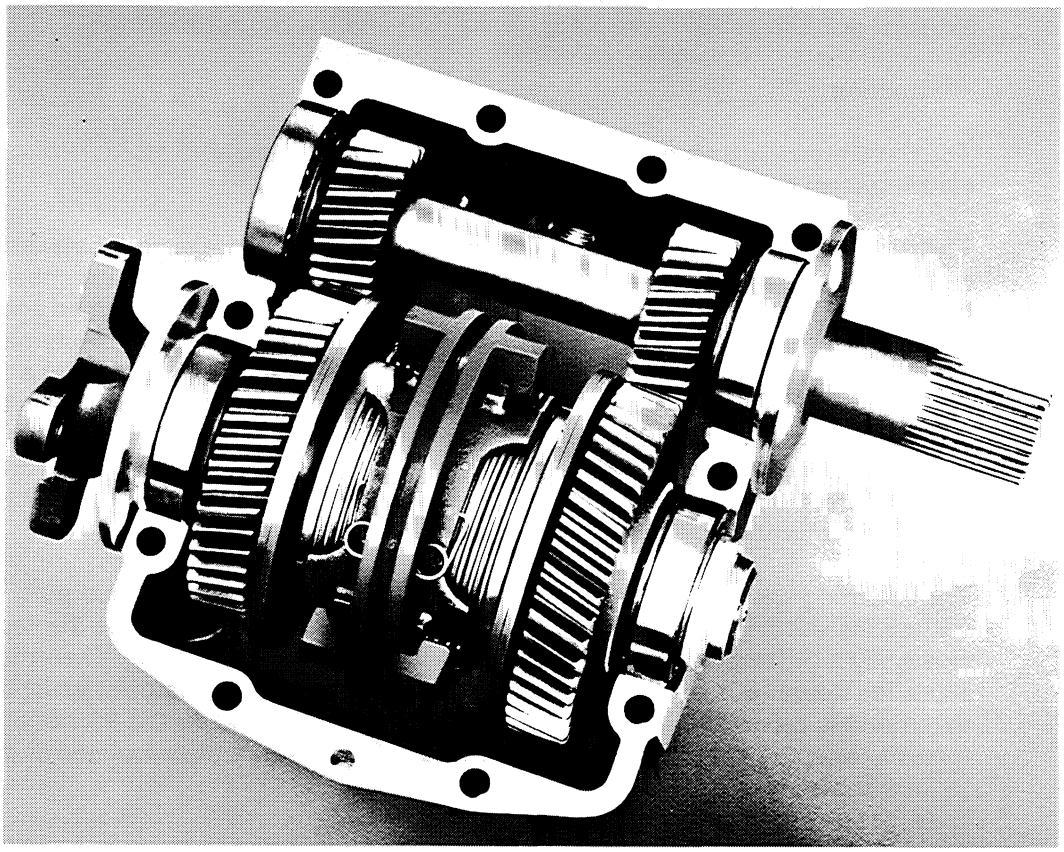
The actuating sleeve (60) is held in the middle position by spring-loaded pins. To initiate the shifting operation, the actuating sleeve (60) need merely be displaced axially by a shifting fork until the arresting force has been overcome. Then the actuating sleeve (60) is moved automatically by the spring-loaded 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.



1.5 Shaft bearings

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

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



1.6 Shaft seals

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

1.7 Lubrication

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

2. Installation

2.1 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.

2.2 Painting the gearbox

Before painting the gearbox, take care to remove any oil films by means of suitable agents (e.g. HST safety cleansing fluid).

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.

2.3 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 0.5mm.

2.4 Suspension of engine-gearbox assembly in the boat

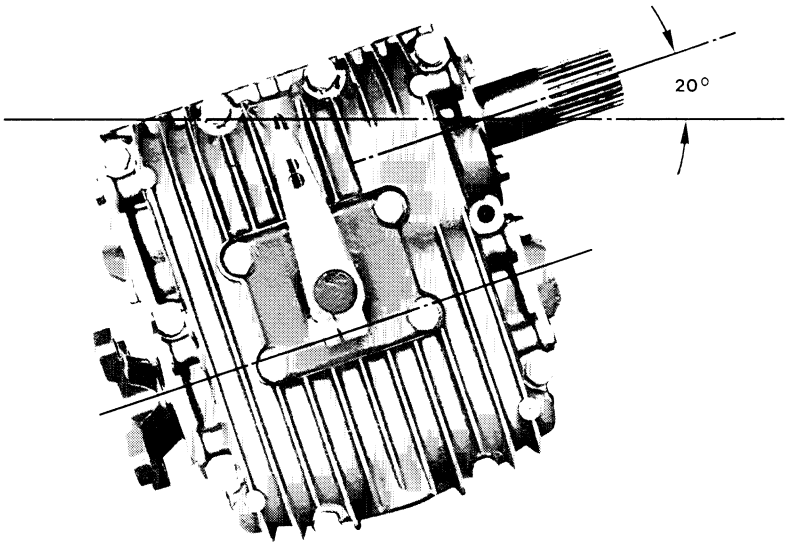
To protect the gearbox from detrimental stresses and loads, provision should be made for elastic suspension of the engine-gearbox assembly in the boat or craft.

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

2.5 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 (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.



2.6 Operation of gearbox

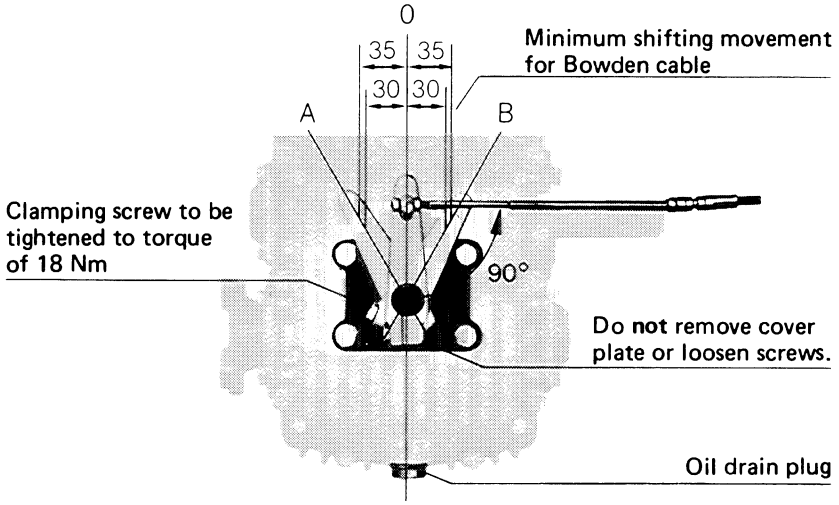
Gear changing requires only minimum effort. The gearbox is suitable for single lever remote control. Upon loosening the retaining screw, the actuating lever (see illustration) can be moved to any position required for the control elements (cable or rod linkage). Make certain that the lever does not contact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

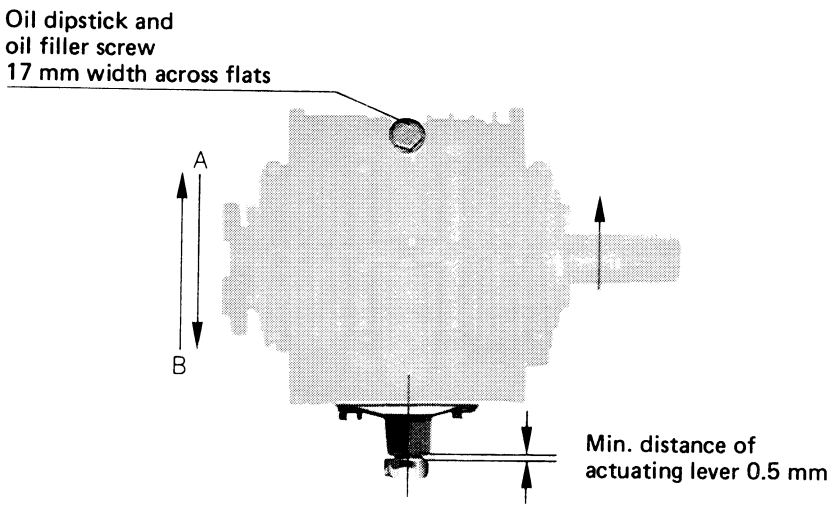
The control cable or rod should be arranged at right angles to the actuating lever in the neutral position of the lever.

The shifting travel, as measured at the pivot point of the actuating lever, between the neutral position and end positions A and B should be at least 35 mm for the outer and 30 mm for the inner pivot point.

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

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.

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

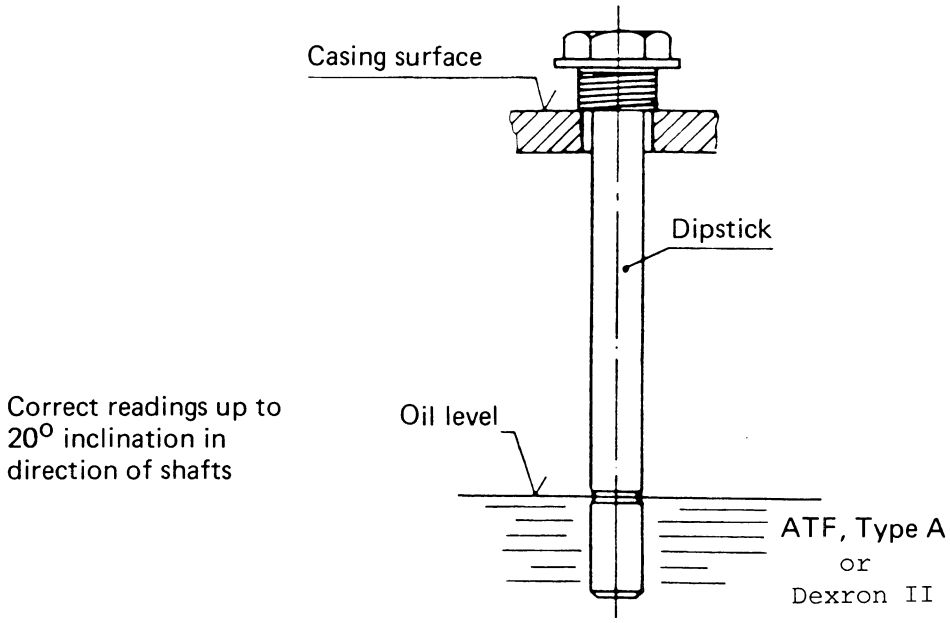
2.7 Engine-gearbox compartment

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

3. Operation

3.1 Initial operation

Fill the gearbox with oil of the recommended grade (see items 4.1 and 4.2). 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.

3.2 Operating temperature

The max. permissible temperature of the transmission oil is 130 °C.

3.3 Operation of gearbox

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 **automatic** and cannot be influenced by external control. The actuating lever is mounted on an actuating shaft and fixed by means of a retaining screw.

Gear changing should be smooth, not too slow, and continuous (without interruption). The multiple-disc clutch permits gear changing at high engine rpm, including sudden reversing at top speeds in the event of danger.

3.4 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.

3.5 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 anticorrosive coating if required.

3.6 Preparation for re-use

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

4. Maintenance

4.1 Transmission oil

To ensure trouble-free operation of the clutch, only use oil of the recommended type.

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.

4.2 Oil quantity

HBW 5 approx 0.4 ltr
HBW 10 approx 0.6 ltr
HBW 20 approx 0.8 ltr
Use the index mark on the dipstick as a reference.

4.3 Oil level checks

Check the oil level in the transmission daily. Correct oil level is the index mark on the dipstick (see item 3.1). Always use the same oil grade when topping up.

4.4 Oil change

Change the oil for the first time after about 25 hours of operation, then at intervals of at least 1 year.

4.5 Checking the Bowden cable or rod linkage

The Bowden cable or rod linkage should be checked at shorter time intervals. The minimum lever travel from the neutral position to 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 2.9).

4.6 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.

GENERATOR SETS

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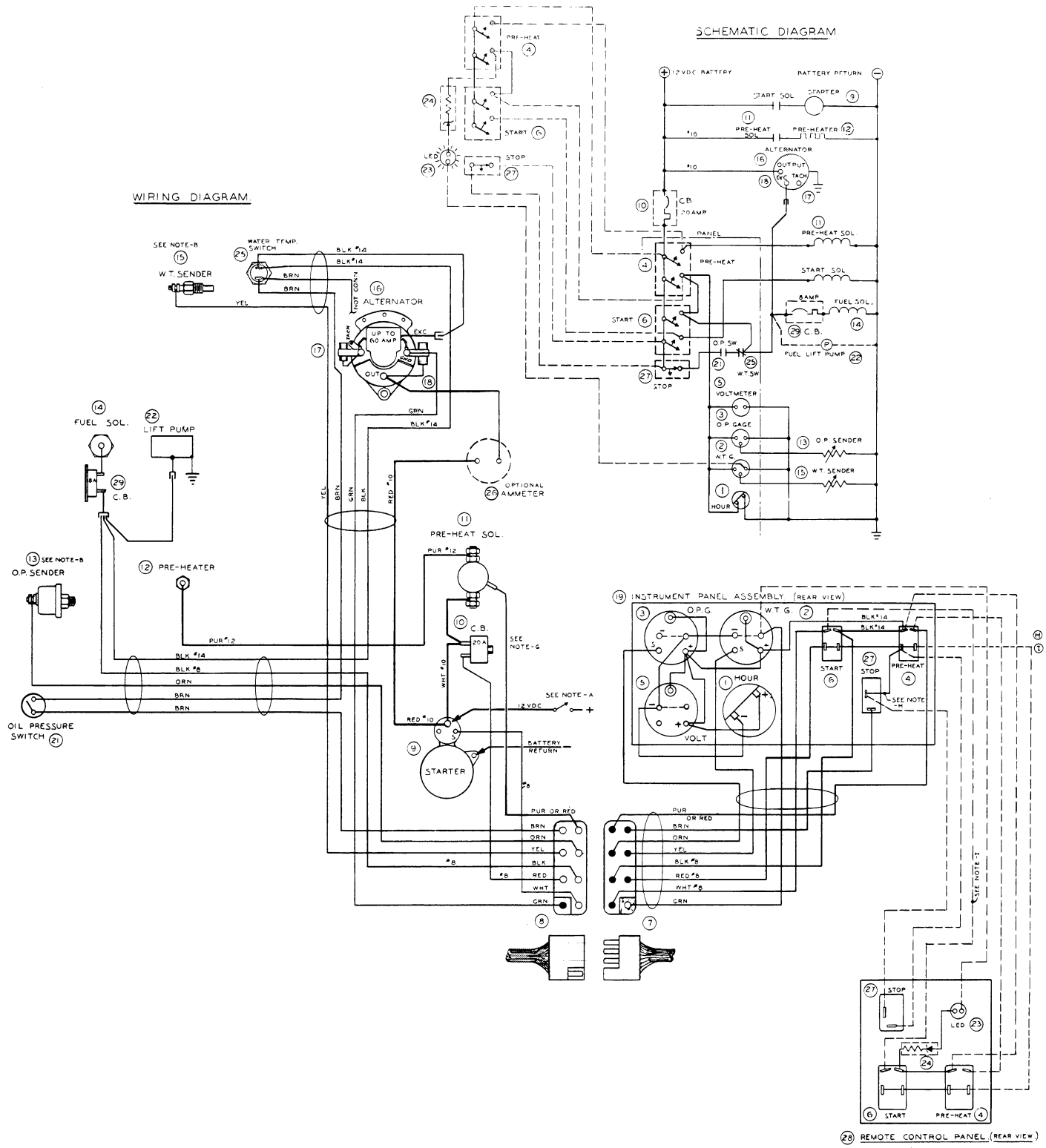
MANUAL STARTER DISCONNECT (TOGGLE SWITCHES)



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: pre-heating the engine for easy starting and defeating or by-passing the engine protective oil pressure switch. The defeat function turns on the fuel solenoid, instrument power, and alternator excitation.

2. Start: The START/DEFEAT toggle switch is a double pole, single throw switch. The switch also serves two purposes: starting the engine and defeating or by-passing 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 thermostarts (installed in intake manifold) and forty to sixty seconds in conjunction with glowplugs.

   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 & START switches are connected in parallel with the local panel switches and serve the same functions as in the 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 WTO as injection pump has solenoid included.)

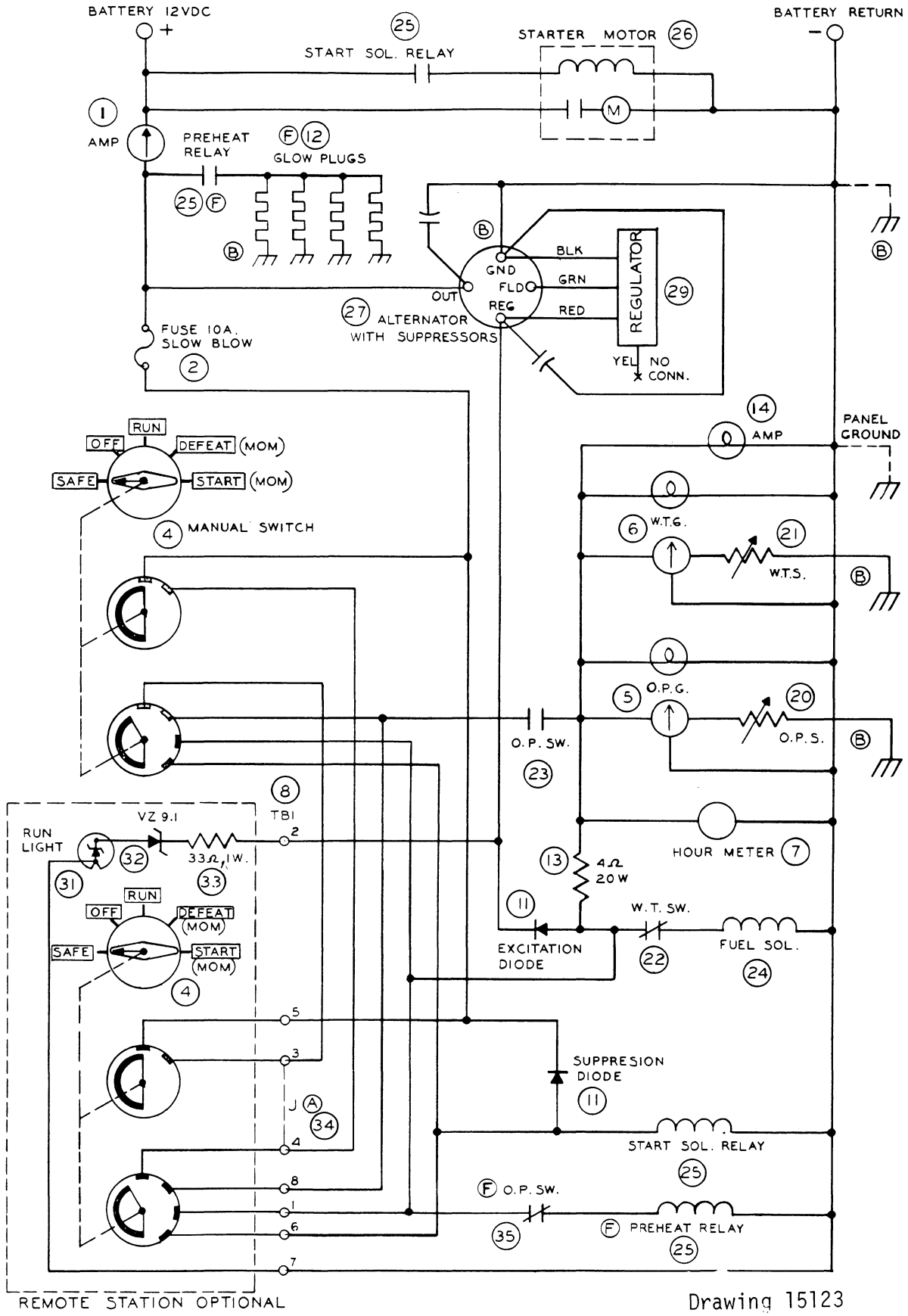
Manual control (toggle switch) troubleshooting.

Nature of Trouble	Probable Cause	Verification
1. Preheat depressed, no panel indications, fuel solenoid not energized.	a. Battery switch or power not on	1. Check switch and/or battery connections.
	b. 20 AMP circuit breaker tripped	1. Reset breaker if opens again, check preheat solenoid circuit and "run" circuit for shorts to ground.
2. Start depressed, no panel indications, fuel solenoid not energized. Start solenoid not engaged.	a. Battery switch or power not on	1. Check switch and/or battery connections
	b. 20 amp circuit breaker tripped	1. Reset breaker. If open again check start solenoid circuit and "run" circuit for shorts to ground.
3. Start depressed,panel indications O.K. Start solenoid O.K. Fuel solenoid not functioning.	a. 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 tripping, check for defective breaker fuel solenoid.
4. No ignition,cranks, doesn't start. Fuel solenoid energized.	a. Faulty fueling system	1. Check for fuel to generator system 2. Check for air in fuel system (bleed system) 3. Fuel lift pump failure
5. Failure to stop	a. Fuel solenoid (P/N 23041) return spring	1. Stop engine by freeing fuel pump lever. That failing, shut off fuel check fuel solenoid linkage and repair for free movement
	b. Stop switch failure	1. Disconnect power leads thru stop switch. Test switch for proper operation by continuity test.
	c. Fuel injection pump failure	1. Stop engine with fuel line shut off

6. Engine stops	a. Low oil pressure or overheated	1. Check oil, fresh water and sea water cooling.
	b. Low oil pressure switch fails to close	1. Check for satisfactory operation with switch bypassed.
	c. High water temperature switch open at too low a temperature	1. Same as above.
	d. Switch and wiring	1. Inspect all wiring for loose connections and short circuits
7. Not charging battery	a. Alternator drive	1. Check drivebelt and its tension. Be sure alternator turns freely. Check for loose connections.
	b. Regular unit and alternator ("MA" series only)	1. With engine running, momentarily connect B+ to field. A good alternator will produce a high charge (50 amps). If no response, replace alternator. Check for shorting of alternator output connections to ground.
8. Battery runs down	a. Oil pressure switch	1. Observe if gauges and panel light are on when engine is not running. Test the normally open oil pressure switch by disconnecting one lead. If lights go out, replace oil pressure switch.
	b. High resistance leak to ground.	1. Check wiring. Insert sensitive (0-.25 amp) meter in battery lines. (Do not start engine). Remove connections and replace until short is located.
	c. Low resistance leak to ground	1. Check all wires for temperature rise to locate fault.
	d. Alternator	1. Disconnect alternator at output, after a good battery charging. If leakage stops, replace alternator protective diode plate. That failing, replace alternator.

Generator Set Controls

MANUAL STARTER DISCONNECT (ROTARY SWITCH)
10-20 KW



Drawing 15123

MANUAL CONTROL OPERATION

GENERAL: The Manual Control series of Westerbeke marine diesel generators is equipped with a bar handle rotary control switch on the engine panel and, optionally, at a remote panel. The following instructions and methods of correcting minor problems apply to the following manual control generators:

DESIGNATION	ENGINE/GENERATOR	REFERENCE DIAGRAMS	
WPDS 10.0	Four-107/JC	15123	15687
WPDS 12.5	Four-107/JC	15123	15687
WPDS 15.0	Four-107/JC	15123	15687
WPDS 20.0	Four-154/JC	15123	15687
WPDS 30.0	Four-230/UR	15227	15555
WPDS 45.0	Six-346/UR	15227	15555

The five rotary switch positions on the panel and on the remote panel are marked to indicate the functional state of the control circuit.

1. SAFETY The 12 volt D.C. power to control circuit is interrupted when either the panel or remote switch is in the SAFETY position. Its purpose is to positively shut down the set from either station. A running engine will stop and cannot be restarted when either switch is in SAFETY. Turn panel switch to SAFETY when servicing engine to prevent an attempted start-up at the remote station.

2. OFF The normal stopping position is OFF. When a remote panel is the usual station from which the generator is operated, the engine panel switch is left in the OFF position, which allows full control by the remote switch.

3. RUN The normal operating position. When the set is running, a red light emitting diode (LED) is illuminated above the RUN position on the remote panel. This is a warning to operators not to engage the starter on a running engine.

4. O.P. CIRCUIT DEFEAT (momemtary spring return). When the set is not running, the low oil pressure shut-down switch is open preventing the fuel solenoid from operating. The DEFEAT position provides direct energization of the fuel solenoid, at full battery voltage, by by-passing the oil pressure switch. In addition, DEFEAT energizes the instrument panel independently of the oil pressure switch (an oil pressure switch provides power to the panel when the engine is running). The temperature gauge may be checked without starting the engine by use of this switch position. At the remote panel the LED is illuminated when either panel or remote switch is positioned to DEFEAT. This checks the RUN light and, more importantly, signifies that there is sufficient charge in the batteries to crank the engine.

5. START (momentary spring return). This position energizes the cranking motor through a solenoid relay. The by-pass and LED connections, activated by the DEFEAT position, are maintained in the START position. When ignition occurs, the starting motor is disengaged by releasing the switch from the START position. At the remote station, the LED is extinguished by the drop in system voltage as the crank motor is engaged. Relighting of the LED signifies that ignition has occurred.

ENGINE OPERATION

1. STARTING AT THE ENGINE PANEL. Installations with remote stations must set the remote switch to OFF.

   A. Turn switch to DEFEAT and pause to allow the fuel solenoid to operate. Check panel lights and instruments for appropriate indications and the hour meter "blinking". The ammeter shows a momentary large discharge and a small sustained discharge depending on the use of preheaters. Preheat twenty seconds in the DEFEAT position on Model WPDS 20.

   B. Turn the switch from DEFEAT to START and hold there while the engine cranks. When engine ignition occurs, allow the switch to return to DEFEAT and hold until the oil pressure indicator rises. Then release to the RUN position.

2. STARTING AT THE REMOTE PANEL. Check that the LED is not illuminated due to the engine already running.

   A. The engine mounted switch must be on OFF.

   B. Turn the switch to DEFEAT and hold. Verify that LED illuminates. Hold briefly for fuel solenoid engagement to occur. On Model WPDS 20, which is preheated, hold DEFEAT twenty seconds.

   C. Turn the switch to START. Observe that LED extinguishes momentarily. When LED again flares up brightly, ignition has occurred. Release to DEFEAT holding there sufficiently long for the oil pressure to rise. Then release the switch to RUN.

3. SHUT OFF. To shut the engine off, simply turn the switch to OFF or SAFETY. When there is a remote panel, shut off requires that both switches be in the OFF position or either switch be placed in the SAFETY position.

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.

SPECIAL CONTROLS ON WPDS 30 AND WPDS 45

The engine panels on these generators have four additional features.

1. OVERSPEED 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 switch to the OFF or SAFETY condition. When the reason for the overspeed shutdown is corrected, the engine is ready to be restarted.

2. FIELD BREAKER The generator automatically monitors its power output. A sustained overload or short circuit in the output lines causes the FIELD BREAKER to open. This removes the generator excitation and the output ceases. The engine will continue to run with no A.C. output. After determining and correcting the cause of overload, the FIELD BREAKER can be reset with the engine still running.

3. A.C. VOLTAGE ADJUSTMENT This rheostat allows the output voltage to be adjusted a few percent in relative value. A second adjustment can be made using a potentiometer mounted on the printed circuit voltage regulator in the cabinet.

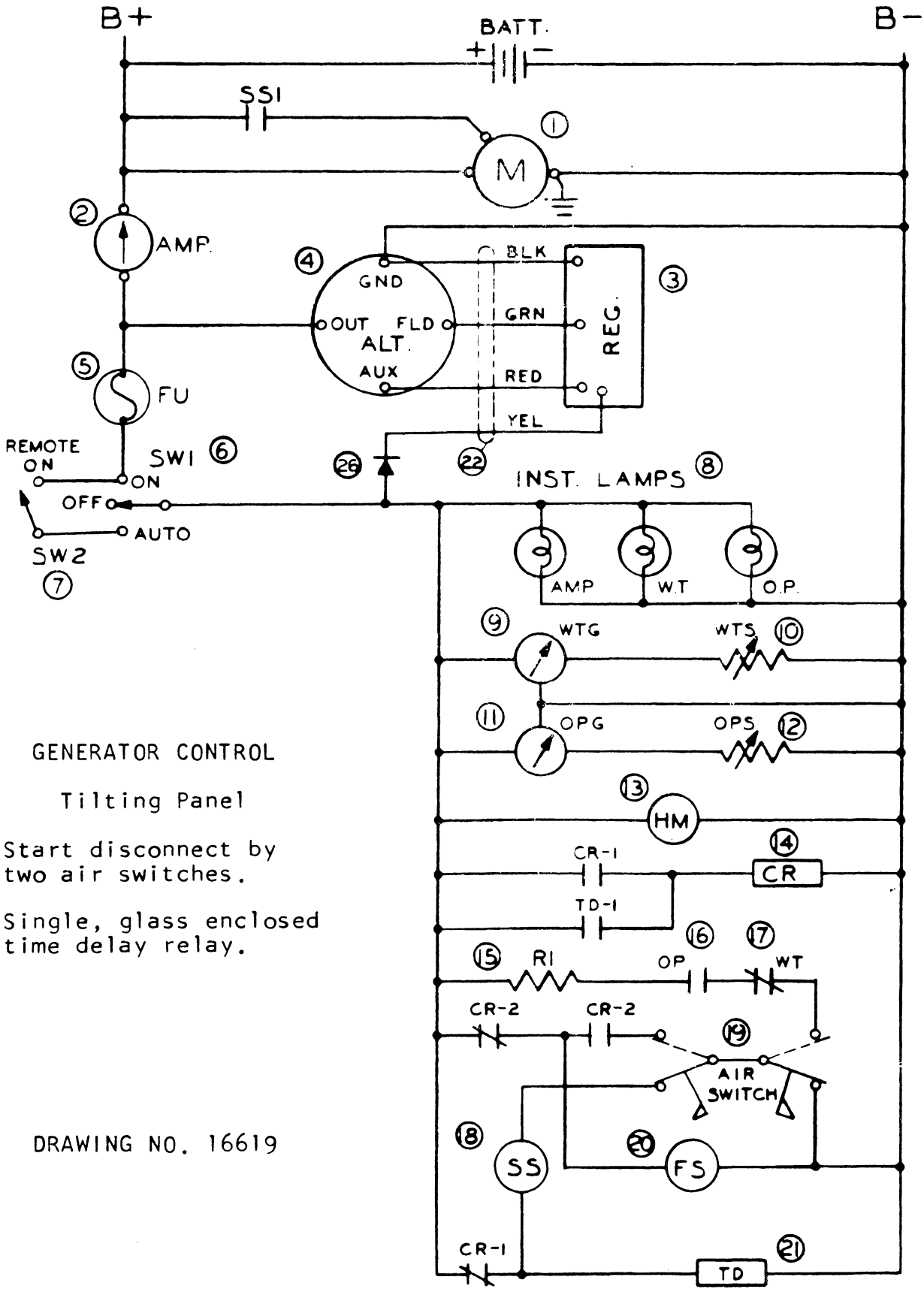
4. 10A SLOW BLOW This fuse's principle function is the protection of the fuel solenoid which rapidly overheats if its ability to complete its stroke and bottom is impeded. A second function is general protection of the 12 volt control wiring against inadvertant overload. The set shuts off and gives no indication of panel power in the DEFEAT and START position when the fuse blows. Replace only with slow blow 5 ampere fuses. The slow blow feature allows the initial solenoid surge currents to pass. Permanent damage to the fuel solenoid can result from overfusing.

MANUAL CONTROL TROUBLE SHOOTING HINTS

Nature of trouble	Probable cause	Verification
1. No panel indications or switch response	A. Remote or engine switch on SAFETY	1. Visual check
	B. Engine panel fuse	1. Check, replace 5 amp slow blow 2. Repeated blowing-check for short circuits and fuel solenoid bottoming.
	C. Battery	1. Check connections and disconnect switch. 2. Jump B+ to start solenoid coil. If cranks, battery is OK.
	D. Continuity, grounding or shorted circuits	1. Check voltage point by point from battery through ammeter. Tighten loose connections and locate any faults.
2. Doesn't crank, panels and voltages are OK	A. Start solenoid	1. Bypass solenoid with heavy wire. If cranks OK, start solenoid or coil input at fault.
	B. Crank by engine switch but not by remote panel	1. Remote cable wire too small for length of run. Open circuit.

	C. Starter jammed	1. Voltage drops and starter motor heats. Remove motor. Check pinion ring gear and engagement mechanism. Replace as required.
	D. Starter engagement - solenoid and switch	1. Apply voltage to (B) and (S) on starter. No response. Check starter motor return lines (R). Both connected to battery.
3. No ignition (cranks - doesn't start, fueled and primed)	A. Fuel solenoid	1. Check +12V on terminals at DEFEAT position. Check for free mechanical action. Adjust spring and linkages. Replace solenoid if weak, overheating or dead. 2. No voltage. Test with bypassed oil pressure switch then bypassed temperature switch. If no voltage, check wiring.
	B. Overspeed relay (30 and 45 KW)	1. Check solenoid return circuit through relay. Check relay movement and contacts. 2. A faulty overspeed circuit will hold relay closed. Reset with switch and isolate cause.
	C. Faulty fueling system	1. See engine maintenance section.
	D. Preheat not working (20 KW)	1. Check preheat solenoid relay and glowplugs. 2. Glowplugs burned out. Replace and check pressure switch shut off operation.
4. Failure to shut down	A. Fuel solenoid return spring	1. Stop engine by freeing fuel pump lever. That failing, shut off fuel. Check fuel solenoid linkage and repair for free movement.
	B. Control circuit or switch failure	1. Stop engine by removing fuse. Locate malfunction by voltage test after removing wire from the start solenoid relay and replacing fuse.
	C. Fuel injection pump failure	1. Stop engine with fuel line shut off. Repair or replace pump.
	D. Major engine fault	1. Stop engine with fuel line cutoff. That failing, plug air inlet with rags. Put maximum load on generator to attempt to stall engine.

Engine stops in RUN	A. Low oil pressure or overheated	1. Check oil, fresh water and sea water cooling.
	B. Low oil pressure switch fails to close	1. Check for satisfactory operation with switch bypassed.
	C. High water temperature switch open at too low a temperature	1. Same as above.
	D. Switch and wiring	1. Inspect all wiring for loose connections and short circuits.
6. Not charging battery	A. Alternator drive	1. Check drivebelt and its tension. Be sure alternator turns freely. Check for loose connections.
	B. Regulator unit and alternator	1. With engine running, momentarily connect B+ to field. A good alternator will produce a high charge (50 amps). If no response, replace alternator. Check for shorting of alternator output connections to ground.
7. Battery runs down	A. Oil pressure switch	1. Observe if gauges and panel light are on when engine is not running. Test the normally open oil pressure switch by disconnecting one lead. If lights go out, replace oil pressure switch.
	B. High resistance leak to ground	1. Check wiring. Insert sensitive (0-.25 amp) meter in battery lines. (Do not start engine). Remove connections and replace until short is located.
	C. Low resistance leak to ground	1. Check all wires for temperature rise to locate fault.
	D. Alternator	1. Disconnect alternator at output, after a good battery charging. If leakage stops, replace alternator protective diode plate. That failing, replace alternator.



GENERATOR CONTROL

Tilting Panel

Start disconnect by two air switches.

Single, glass enclosed time delay relay.

DRAWING NO. 16619

START DISCONNECT BY TWO AIR SWITCHES.
(Single, Glass Enclosed Time Delay Relay). 16619

OPERATION

1. To start generator from the local position throw switch #6 to ON. To start it from the remote position throw switch #7 to ON (Switch #6 must then be in the AUTO position). This applies B (Pos.) to the instruments, the time delay coil TD through CR-1 NC; the start solenoid coil through CR-1 NC and then the two air switches in series, normally closed contacts, to B (Neg.) return; the time delay coil TD through CR-1-NC, and the fuel solenoid through CR-2-NC.

2. To stop, return switch #6 to OFF or open #7 if control is AUTO. Always leave a non-running set with switch in the OFF condition.

ASSUME SET STARTS

1. When the set starts and runs both air switches operate, immediately disconnecting the start solenoid (even if only one operates, the solenoid would disconnect).

2. After approximately 20 seconds after either switch #6 or #7 is closed, TD times out and closes, energizing relay CR which locks itself up through contacts CR-1-NO. When CR operates the fuel solenoid then gets holding current through resistor R-1, the oil pressure and water temperature switches, the normally open contacts of both air switched which are closed while the set is operating, and through contacts CR-2-NO. An oil pressure or water temperature failure will shut down the set and it will not restart since CR-1-NC and CR-2-NC are locked. To restart from an oil pressure or water temperature shut down, throw switch #6 or #7 to the OFF position momentarily which releases relay CR and then back to the ON position.

ASSUME SET DOES NOT START

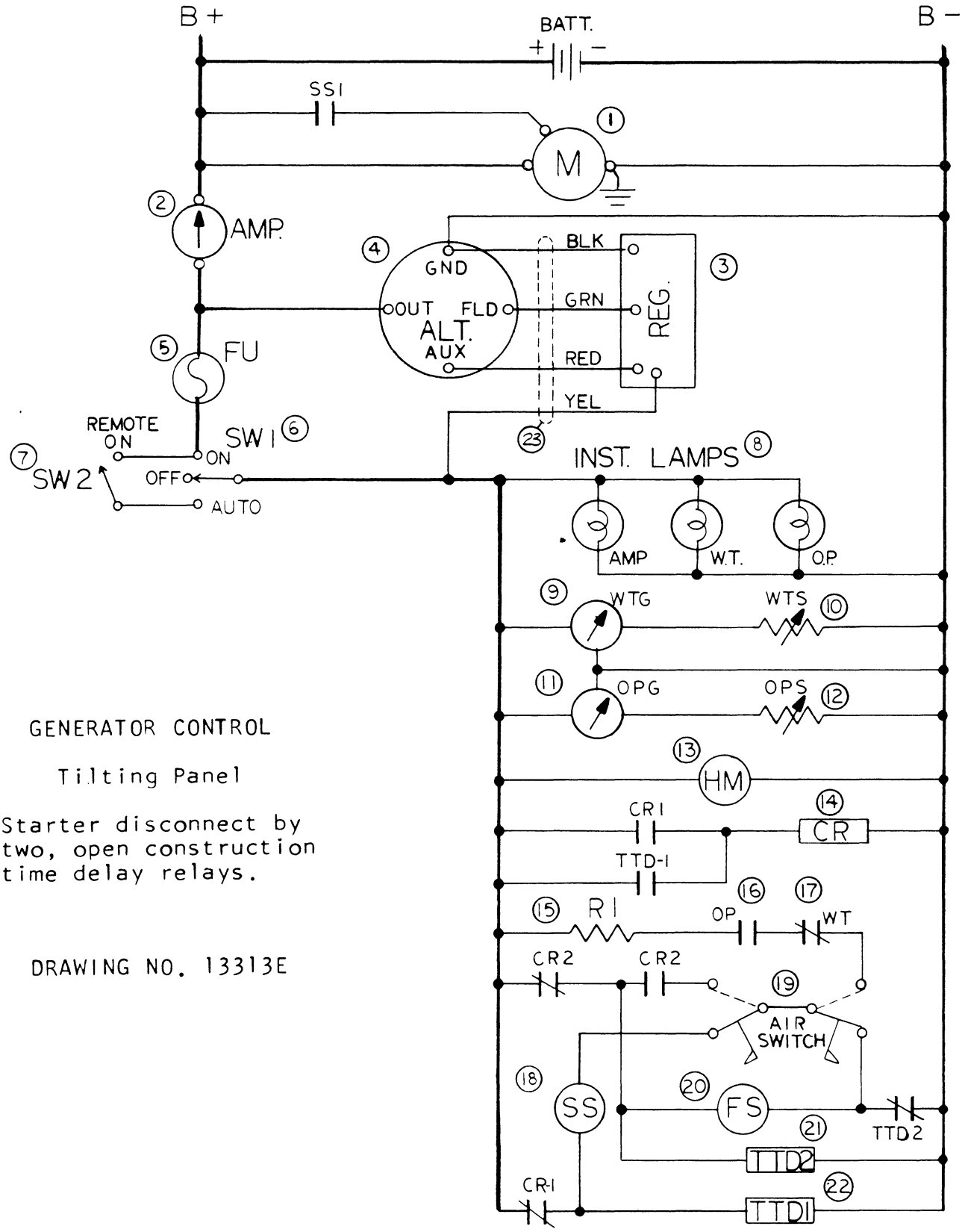
1. After approximately 30 seconds TD times out, as before, and closes, energizing and locking up relay CR as above. CR-1-NC opens, immediately dropping out the start solenoid. Since the air switched have not closed the fuel solenoid is de-energized by the opening of contact CR-2-NC. To restart the generator after it has been shut down by the cranking limited turn switch #6 or #7 momentarily to the OFF position thereby dropping out relay CR. Twenty seconds or less after last cranking has stopped, TD will cool sufficiently to allow a restart attempt by putting switch #6 or #7 in the ON position.

TROUBLE SHOOTING HINTS

16619

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
1. ENGINE WON'T CRANK	DEFECTIVE START SOLENOID	PLACE 12 VOLTS ON COIL OF SOLENOID. IF ENGINE CRANKS, TROUBLE IS IN CONTROL PANEL. IF IT WON'T CRANK, PUT B (POS.) ON CONTACT THAT LEADS INTO STARTER. IF ENGINE CRANKS, TROUBLE IS IN START SOLENOID. IF ENGINE DOES NOT CRANK STARTER IS DEFECTIVE.

	DEFECTIVE CR RELAY	CHECK CR1 NC, CONTACTS FOR OPEN CIRCUIT.
	DEFECTIVE AIR SWITCH	CHECK AIR SWITCHES FOR OPEN IN THE NC POSITION.
2. SET RUNS FOR LESS THAN 30 SECONDS AND SHUTS DOWN	CR2 NO, DOESN'T CLOSE	CHECK TO SEE IF CONTACT CLOSES.
	AIR SWITCHES DEFECTIVE	CHECK BOTH TO SEE IF THEY CLOSE.
	WT SWITCH DEFECTIVE	CHECK FOR OPEN.
	OP SWITCH DEFECTIVE	CHECK FOR OPEN.
	RESISTOR R1 DEFECTIVE	CHECK RESISTANCE 4 OHMS.
3. SET SHUTS DOWN INTERMITTENTLY	SAME AS STEP 2 OR,	CHECK SPRING TENSION.
	FUEL SOLENOID DEFECT	CHECK ALIGNMENT.
		CHECK SOLENOID.
4. ALTERNATOR WON'T CHARGE	DEFECTIVE REGULATOR	WITH GEN. OFF CHECK FOR VOLTAGE.
	DEFECTIVE ALTERNATOR	AT AUXILIARY TERM'L TO GROUND. IF YOU HAVE VOLTAGE THE ISOLATION DIODES ARE SHORTED. REPLACE.
		PLACE JUMPER FROM FIELD TERM'L TO AUX. IF JUMPER PROVIDES CORRECT OUTPUT, REG. IS DEFECTIVE. IF NOT BRUSHES OR ROTOR CIRCUIT DEFECTIVE.
		WITH ENGINE RUNNING AT FAST IDLE, CONNECT VOLTMETER FROM AUX. TO GROUND. WITH READING OF 15.0 TO 15.7 VOLTS. MOVE VOLTMETER POS. LEAD TO OUTPUT. THIS SHOULD BE .8 TO 1.2 VOLTS LOWER THAN VOLTAGE NOTED AT THE AUX. TERM'L.
5. W.T.G. DEFECTIVE	GAUGE AND/OR SENDER	CHECK GAUGE AGAINST A TEST THERMOMETER IN SURGE TANK. GAUGE SHOULD BE SAME TO 10° F HIGHER. CHECK SENDER.
6. O.P.G. DEFECTIVE	SAME	CHECK O.P. WITH TEST GAUGE AT SENDER TAP.
7. FUEL SOLENOID OVERHEATS	TD DEFECTIVE	CHECK FOR SHUT DOWN WITH WIRE REMOVED FROM O.P. OR W.T. SWITCH. IF NO SHUT DOWN, REPLACE TD AND CHECK ITS WIRING FOR BREAKS.
	CR DEFECTIVE	CHECK FOR OPEN COIL AND LOW RESISTANCE OF N.O. CONTACTS WHEN CLOSED.



GENERATOR CONTROL

Tilting Panel

Starter disconnect by two, open construction time delay relays.

DRAWING NO. 13313E

OPERATION

1. To start generator from the local position throw switch #6 to "On". To start it from the remote position throw switch #7 to "On" (Switch #6 must then be in the "Auto" position). This applies B (Pos.) to the instruments, the time delay coil TD through CR-1 (NC), the Start Solenoid coil through CR-1 (NC), the air switches in series, normally closed, and also the Fuel Solenoid through CR-2 (NC).

ASSUME SET STARTS

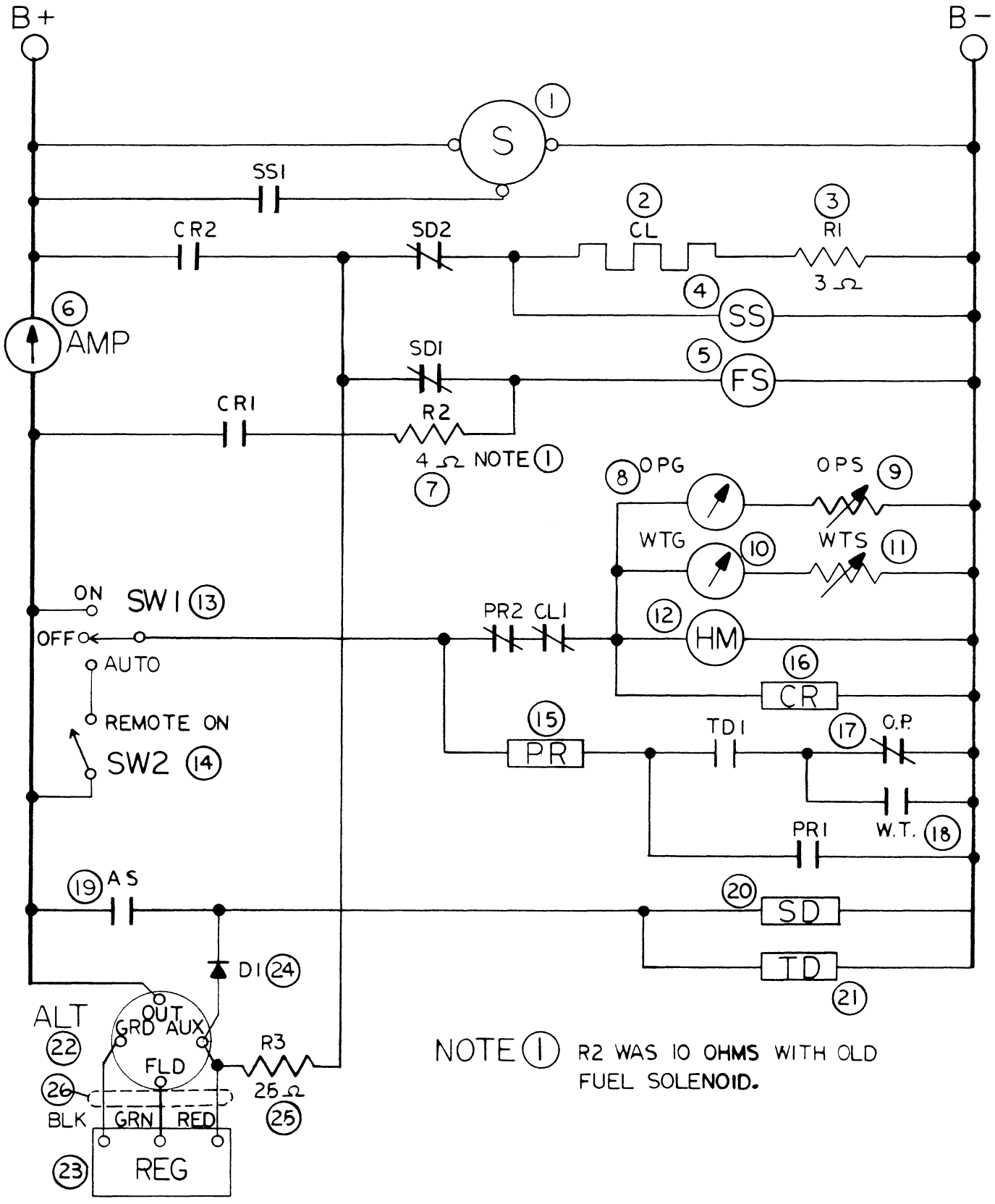
1. When the set starts and runs both air switches operate, immediately disconnecting the start solenoid (even if only one operates, the solenoid would disconnect).
2. After 30 seconds cranking limiter TD times out and closes, energizing relay CR which locks itself up through contacts CR-1 (NO). When CR operates the fuel solenoid then gets holding current through resistor R-1, the oil pressure and water temperature switches, the normally open contacts of both air switches which are closed while the set is operating, and through contacts CR-2 (NO). An oil pressure or water temperature failure will shut the set down and it will not restart since CR is locked up. To restart set, throw switch #6 or #7 to the "Off" position momentarily which releases relay CR and then back to the "On" position.

ASSUME SET DOES NOT START

1. After 30 seconds cranking limiter TD times out and closes, energizing and locking up relay CR as above. CR-1 (NC) opens, immediately dropping out the start solenoid. Since the air switches have not closed, the fuel solenoid is de-energized by the opening of contact CR-2 (NC). To restart the generator after it has been shut down by the cranking limiter turn switch #6 momentarily to the "Off" position thereby dropping out relay CR and then back to the "On" position.

TROUBLE SHOOTING HINTS

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
1. ENGINE WON'T CRANK.	DEFECTIVE START SOLENOID.	PLACE 12 VOLTS ON COIL OR SOLENOID. IF ENGINE CRANKS, TROUBLE IS IN CONTROL PANEL. IF IT WON'T CRANK, PUT B(POS.) ON CONTACT THAT LEADS INTO STARTER. IF ENGINE CRANKS, TROUBLE IS IN START SOLENOID. IF ENGINE DOES NOT CRANK STARTER IS DEFECTIVE.
	DEFECTIVE CR RELAY.	CHECK CR1 NC, CONTACTS FOR OPEN CIRCUIT.
	DEFECTIVE AIR SWITCH.	CHECK AIR SWITCHES FOR OPEN CIRCUITS.
	TTD-2 NC, OPEN CIRCUIT.	CHECK FOR OPEN.
2. SET RUNS FOR TWO MINUTES AND SHUTS DOWN.	CR DEFECTIVE.	CHECK FOR OPEN COIL OR SHORTED CONTACT CR2-NC.
	TTD-1 DEFECTIVE.	CHECK TTD-1.
3. SET RUNS FOR 30 SECS. THEN STOPS.	CR2 NO, DOESN'T CLOSE.	CHECK TO SEE IF CONTACT CLOSES.
	AIR SWITCHES DEFECTIVE.	CHECK BOTH TO SEE IF THEY CLOSE.
	WT. SWITCH DEFECTIVE	CHECK FOR OPEN.
	OP. SWITCH DEFECTIVE	CHECK FOR OPEN.
	RESISTOR R1 DEFECTIVE	CHECK RESISTANCE 4 OHMS.
4. SET SHUTS DOWN INTERMITTENTLY.	SAME AS STEP 3, OR,	CHECK SPRING TENSION.
	FUEL SOLENOID DEFECT.	CHECK ALIGNMENT. CHECK SOLENOID.
5. ALTERNATOR WON'T CHARGE.	DEFECTIVE REGULATOR.	WITH GEN. OFF CHECK FOR VOLTAGE AT AUXILIARY TERMINAL TO GROUND. IF YOU HAVE VOLTAGE THE ISOLATION DIODES ARE SHORTED. REPLACE.
	DEFECTIVE ALTERNATOR.	PLACE JUMPER FROM FIELD TERMINAL TO AUX. IF JUMPER PROVIDES CORRECT OUTPUT, REG. IS DEFECTIVE. IF NOT BRUSHES OR ROTOR CIRCUIT DEFECTIVE. WITH ENGINE RUNNING AT FAST IDLE, CONNECT VOLTMETER FROM AUX. TO GROUND. WITH READING OF 15.0 TO 15.7 VOLTS. MOVE VOLTMETER POS. LEAD TO OUTPUT. THIS SHOULD BE .8 TO 1.2 VOLTS LOWER THAN VOLTAGE NOTED AT THE AUX. TERMINAL.
6. W.T.G. DEFECTIVE.	GAUGE.	CHECK GAUGE.
	SENDER.	CHECK SENDER.
7. O.P.G. DEFECTIVE.	SAME AS STEP (6).	



10-15 KW WPDS GENERATOR WITH STARTER DISCONNECTED BY AIR SWITCH OR ALTERNATOR OUTPUT

DRAWING NO. 12868C

12868

SEQUENCE OF OPERATIONS

1. THROW CONTROL SWITCH TO RUN.

2. CR ENERGIZES.

3. CR-2 N.O. CLOSES - FS AND SS ARE ENERGIZED.

4. STARTER (S) IS ENERGIZED.

5. ENGINE STARTS.

6. AIR SWITCH CLOSES AT APPROXIMATELY 400-rpm.

   A. IF ALTERNATOR VOLTAGE AT AUX. TERMINAL BUILDS UP BEFORE AIR SWITCH CLOSES, SD AND TD ARE ENERGIZED VIA ALT. AUX. OUTPUT.

   B. IF AIR SWITCH CLOSES BEFORE ALT. VOLTAGE BUILDS UP SD AND TD ARE ENERGIZED BY B(POS.) THRU AIR SWITCH.

7. SD-1 N.O. OPENS. NOW FS IS HELD IN AT REDUCED CURRENT VIA RESISTOR R-2. SD-2 N.C. OPENS, DE-ENERGIZING SS AND DISENGAGING STARTER.

8. OIL PRESSURE BUILDS UP AND OP OPENS.

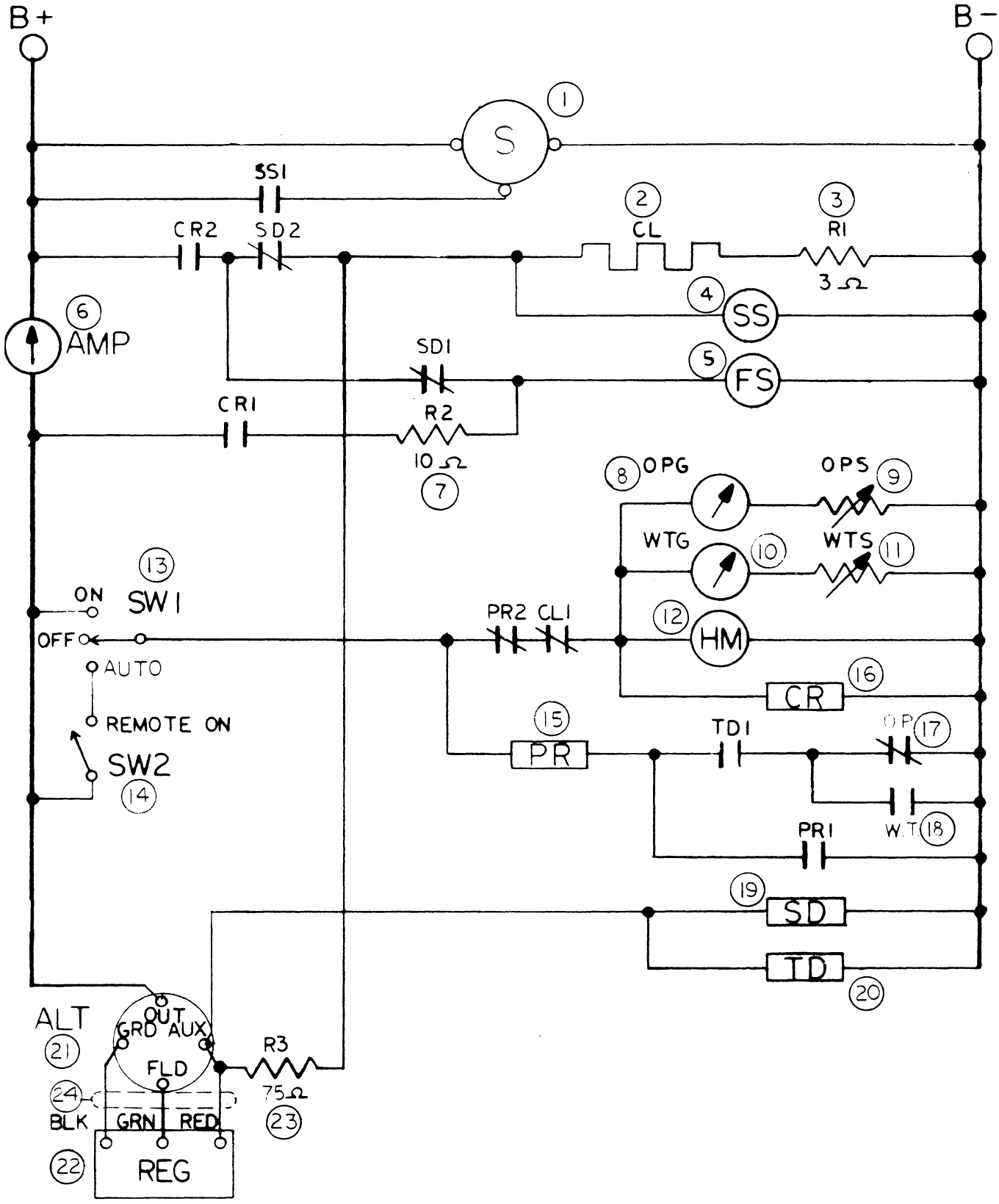
9. TD HEATS AND TD-1 CLOSES. PR CANNOT DE-ENERGIZE CR SO ENGINE CONTINUES TO RUN.

10. IF ENGINE FAILS TO START IN APPROXIMATELY 40 SECONDS CRANKING LIMIT HEATS AND CONTACTS OPEN, THUS DE-ENERGIZING CR. CR-1-N.O. OPENS AND FUEL SOLENOID DROPS OUT, STOPPING ENGINE. (RESET CL AFTER APPROX. ONE MINUTE IF DESIRED)

11. LOW OIL PRESSURE OR HIGH WATER TEMP. AFTER TD ACTUATES (APPROX. 15 SECONDS) ENERGIZES PR, THUS DROPPING OUT CR AND STOPPING ENGINE.

TROUBLE SHOOTING HINTS 12868

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
1. ENGINE WON'T CRANK.	DEFECTIVE START SOLENOID.	PLACE 12-VOLTS ON COIL. IF DEFECTIVE REPLACE.
2. ENGINE WON'T CRANK BUT S.D. RELAY PULLS IN.	AIR SWITCH DEFECTIVE.	DISCONNECT BATTERY AND MAKE CONTINUITY TEST ACROSS SWITCH.
	OUTPUT TERM. AT ALTERNATOR SHORTED TO AUX.	CHECK TWO OUTPUT DIODES FOR SHORT.
	PRIMARY RELAY SHORTED.	CHECK PR-N.O. FOR SHORT.
	CRANKING LIMITER POPPED OPEN.	PUSH RESET.
	CRANKING LIMITER DEFECTIVE.	CHECK FOR OPEN CIRCUIT.
	CRANKING RELAY DEFECTIVE.	CHECK COIL.
3. ENGINE CRANKS BUT WON'T START.	FUEL SOLENOID DEFECTIVE.	CHECK LINKAGE FOR PROPER ALIGNMENT. THROW SWITCH TO ON AND SEE IF PLUNGER PULLS IN; IF NOT CHECK SD-1 FOR OPEN. CHECK FUEL SYSTEM.
	AFTER 30 SECS. C.L. POPS OUT.	RESET AFTER 1 MIN.
4. STARTER KICKS IN AND OUT.	AIR SWITCH NOT PULLING IN.	CHECK VANE.
	START DISCONNECT RELAY IS DEFECTIVE.	CHECK RELAY.
5. ENGINE RUNS FOR 15 SEC. APPROX., THEN SHUTS DOWN.	PROTECTIVE CIRCUIT ENGAGING.	CHECK FOR LOW OIL. ENGINE WATER TEMP.TOO HIGH. DEFECTIVE WATER TEMP.SWITCH. DEFECTIVE OIL SWITCH. PR-1 RELAY CONTACTS SHORTED. CHECK FOR LOW WATER.
6. ENGINE RUNS, STOPS INTERMITTENTLY FOR NO APPARENT REASON, THEN ENGINE RESTARTS ITSELF.	DEFECTIVE FUEL SOLENOID.	MAY CHECK GOOD BUT WON'T BUILD UP ENOUGH MAGNETISM.
	DEFECTIVE 4-OHM RESISTOR.	CHECK RESISTANCE.
	CRANKING RELAY.	CHECK CONTACT CR-1-N.O.
7. AMMETER NOT CHARGING	DEFECTIVE ALT. OR REGULATOR.	CHECK OUTPUT AT AUX.TERM'L. PLACE JUMPER FROM AUX.TERM'L TO FIELD TERMINAL. A) IF THERE IS AN OUTPUT, SHUT SET DOWN.RESTART AND IF STILL CHARGING IT IS ALRIGHT. IF NOT,REGULATOR IS DEFECTIVE. B) IF THERE IS NO OUTPUT ALTERNATOR IS PROBABLY DEFECTIVE.



10-15 KW WPDS GENERATOR WITH STARTER DISCONNECTED
BY ALTERNATOR OUTPUT ONLY
DRAWING NO. 13795B

13795

SEQUENCE OF OPERATIONS

1. Control SW to ON.

2. CR energizes.

3. CR2 NO, closes - FS and SS are energized, cranking limiter is energized. Alternator field is energized thru the 75 OHM resistor.

4. Starter is energized.

5. Engine starts.

6. SD and TD are energized via Alternator auxiliary output.

7. SD-1 NC, opens. Now FS is held in at reduced current via 10 OHM resistor. SD-2 NC, opens, de-energizing SS and disengaging the starter.

8. Oil pressure builds up and OP opens.

9. TD heats and TD-NO, closes. PR cannot de-energize CR so engine continues to run.

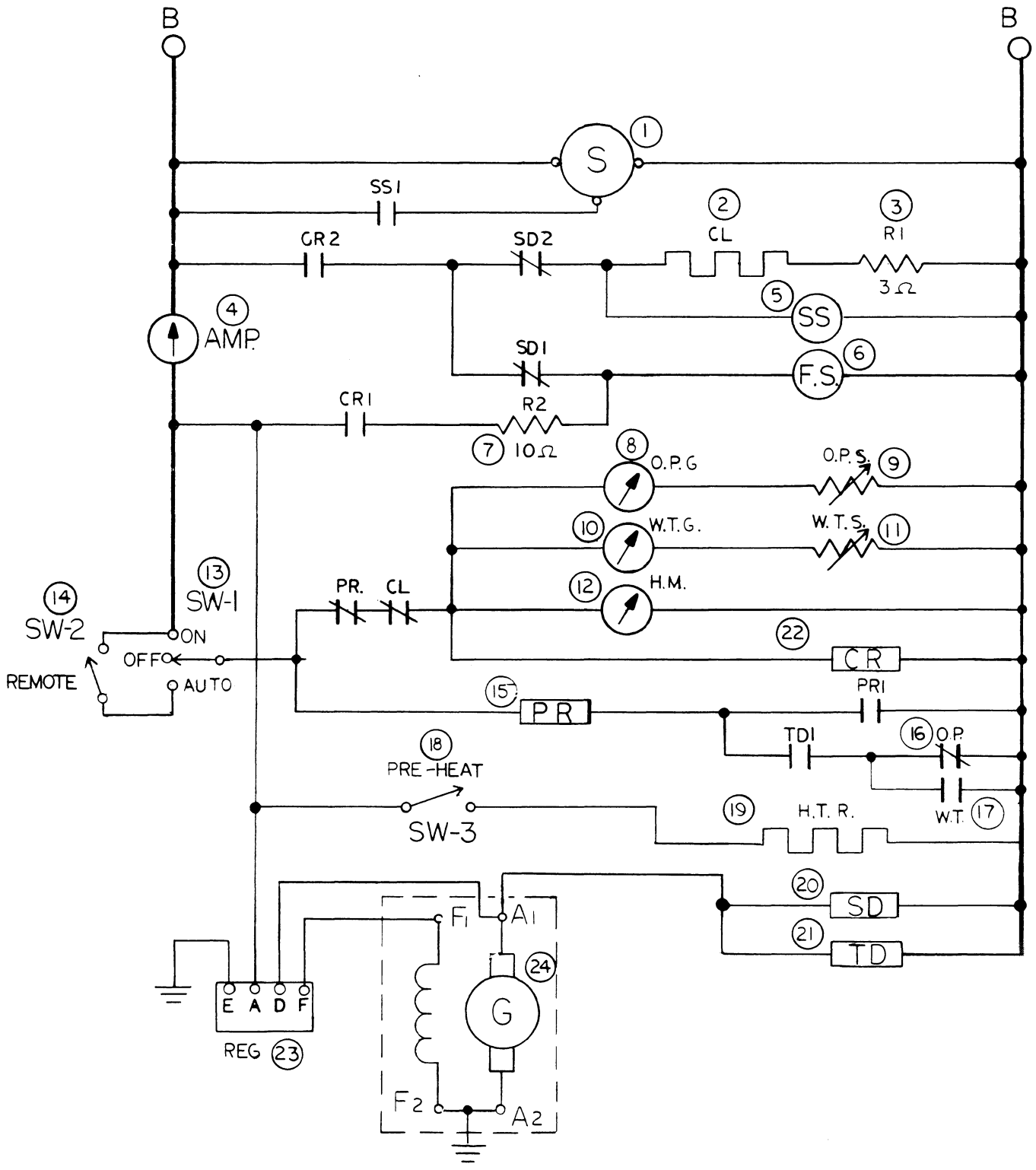
10. If engine fails to start in approx. 40 seconds, cranking limiter heats and contacts open, thus de-energizing CR. CR1-NO, opens and fuel solenoid drops out, stopping engine. (Reset CL after approx. 1 minute if desired).

11. Low oil pressure or high water temp. after TD actuates (approx. 15 secs.) energizes PR, thus dropping out CR and stopping engine.

13795

TROUBLE SHOOTING HINTS

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
1. ENGINE RUNS FOR APPROX 15 SECS. THEN SHUTS DOWN	PROTECTIVE CIRCUIT ENGAGING.	A) CHECK FOR LOW OIL. B) ENGINE WATER TEMP. TOO HIGH. C) DEFECTIVE WATER TEMP. SWITCH. D) DEFECTIVE OIL SWITCH. E) TIME DELAY RELAY SHORTED.
2. ENGINE RUNS, STOPS INTERMITTENTLY FOR NO APPARENT REASON THEN RESTARTS ITSELF.	DEFECTIVE FUEL SOLENOID.	MAY CHECK GOOD BUT WON'T BUILD UP ENOUGH RESIDUAL MAGNETISM.
	DEFECTIVE 10 OHM RESISTOR.	CHECK RESISTANCE.
	CRANKING RELAY.	CHECK CONTACT CR1-NO.
3. AMMETER NOT CHARGING.	DEFECTIVE ALTERNATOR OR REGULATOR.	CHECK OUTPUT AT AUXILIARY. PLACE JUMPER FROM AUXILIARY TERMINAL TO FIELD TERM'L. A) IF THERE IS AN OUTPUT, SHUT SET DOWN. RESTART AND IF STILL CHARGING IT'S ALRIGHT, IF NOT, DEFECTIVE REGULATOR. B) IF THERE IS NO OUTPUT YOU PROBABLY HAVE A DEFECTIVE ALTERNATOR.



10-15 KW WPDS GENERATOR WITH STARTER DISCONNECTED

BY D.C. BATTERY CHARGING GENERATOR

DRAWING NO. 13742

13742

SEQUENCE OF OPERATIONS

1. Control SW to ON.

2. CR energizes.

3. CR2-NO, closes. FS and SS are energized. CL is energized.

4. Starter is energized.

5. Engine starts.

6. SD and TD are energized via D.C. generators output.

7. SD1-NC, opens. Now FS is held in at reduced current via 10 OHM resistor. SD2-NC, opens, de-energizing SS and disengaging the starter.

8. Oil pressure builds up and OP opens.

9. TD heats and TD-NO, closes. PR cannot de-energize CR so engine continues to run.

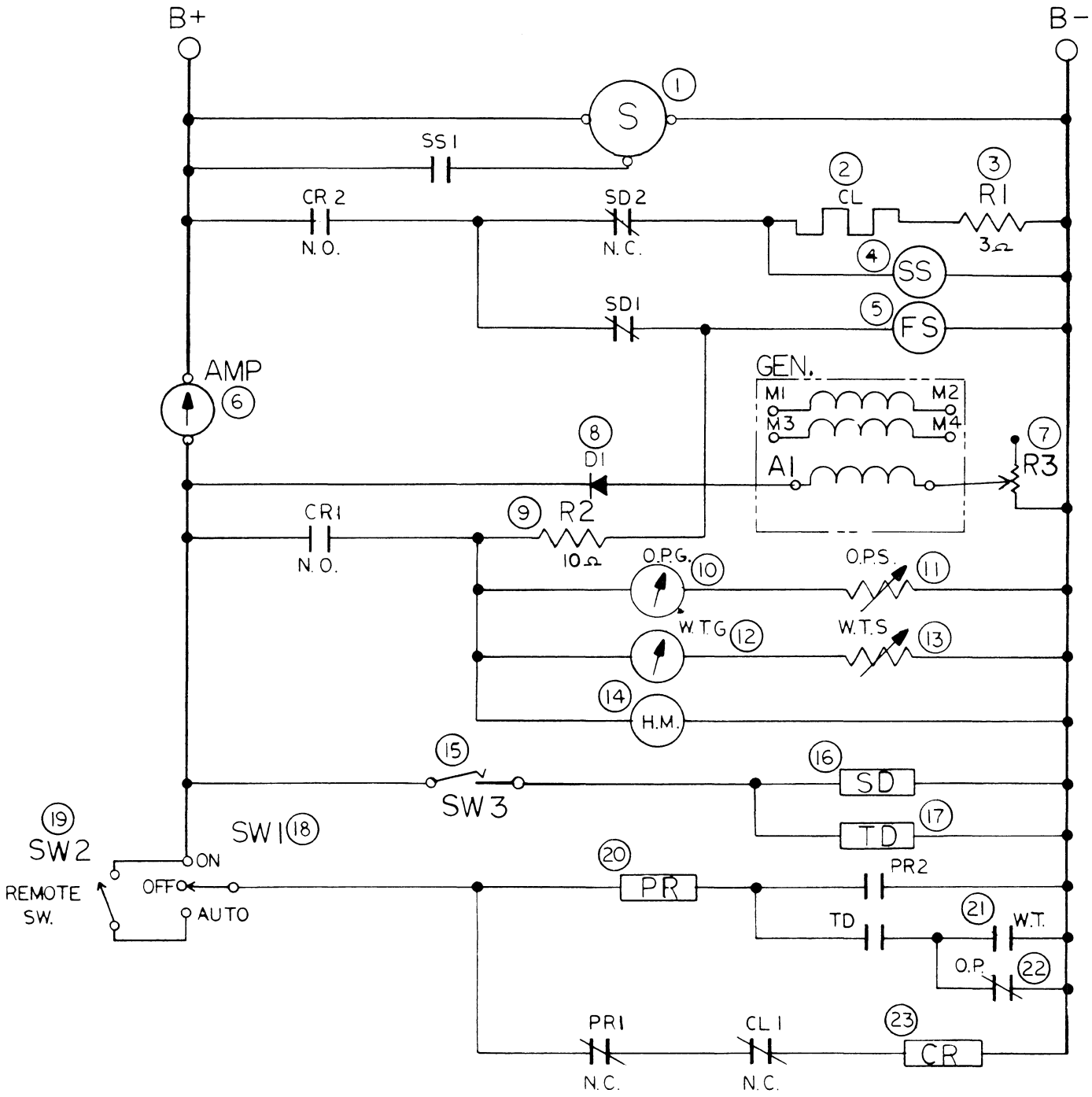
10. If engine fails to start in approx. 40 seconds, cranking limiter heats and contacts open, thus de-energizing CR. CR1-NO, opens and fuel solenoid drops out, stopping engine. (Reset CR after approx. 1 minute if desired).

11. Low oil pressure or high water temp. after TD actuates (approx. 15 secs.) energizes PR, thus dropping out CR and stopping engine.

13742

TROUBLE SHOOTING HINTS

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
1. ENGINE RUNS FOR APPROX. 15 SECS. THEN SHUTS DOWN.	PROTECTIVE CIRCUIT. ENGAGING.	A) CHECK FOR LOW OIL. B) ENGINE WATER TEMP. TOO HIGH. C) DEFECTIVE WATER TEMP. SWITCH. D) DEFECTIVE OIL SWITCH. E) TIME DELAY RELAY SHORTED.
2. ENGINE RUNS, STOPS INTERMITTENTLY FOR NO APPARENT REASON THEN RESTARTS ITSELF.	DEFECTIVE FUEL SOLENOID.	MAY CHECK GOOD BUT WON'T BUILD UP ENOUGH RESIDUAL MAGNETISM.
	DEFECTIVE 10 OHM RESISTOR.	CHECK RESISTANCE.
	CRANKING RELAY.	CHECK CONTACT CR1-NO.
3. AMMETER NOT CHARGING	DEFECTIVE GENERATOR OR REGULATOR.	CHECK OUTPUT AT A1. A) IF THERE IS AN OUTPUT, REGULATOR IS PROBABLY DEFECTIVE. B) IF THERE IS NO OUTPUT YOU PROBABLY HAVE A DEFECTIVE GENERATOR.



10-15 KW WPDS GENERATOR WITH AUXILIARY CHARGING WINDING AND STARTER DISCONNECTED BY CENTRIFUGAL SPEED SWITCH

DRAWING NO. 13743

13743

SEQUENCE OF OPERATION

1. SW-1 switch to on position, CR energizes.

2. SS and FS energize - cranking limiter is energized. Starter is energized. Voltage is fed to meters.

3. Engine starts.

4. At 400 r.p.m. overspeed switch SW-3 closes energizing SD and TD. SD-2 opens removing voltage from cranking limiter and start solenoid. Starter drops out. SD-1 opens putting a 10-ohm resistor in series with the fuel solenoid.

5. Generator builds up voltage and charging current is taken from auxiliary winding A-1, thru diode D-1.

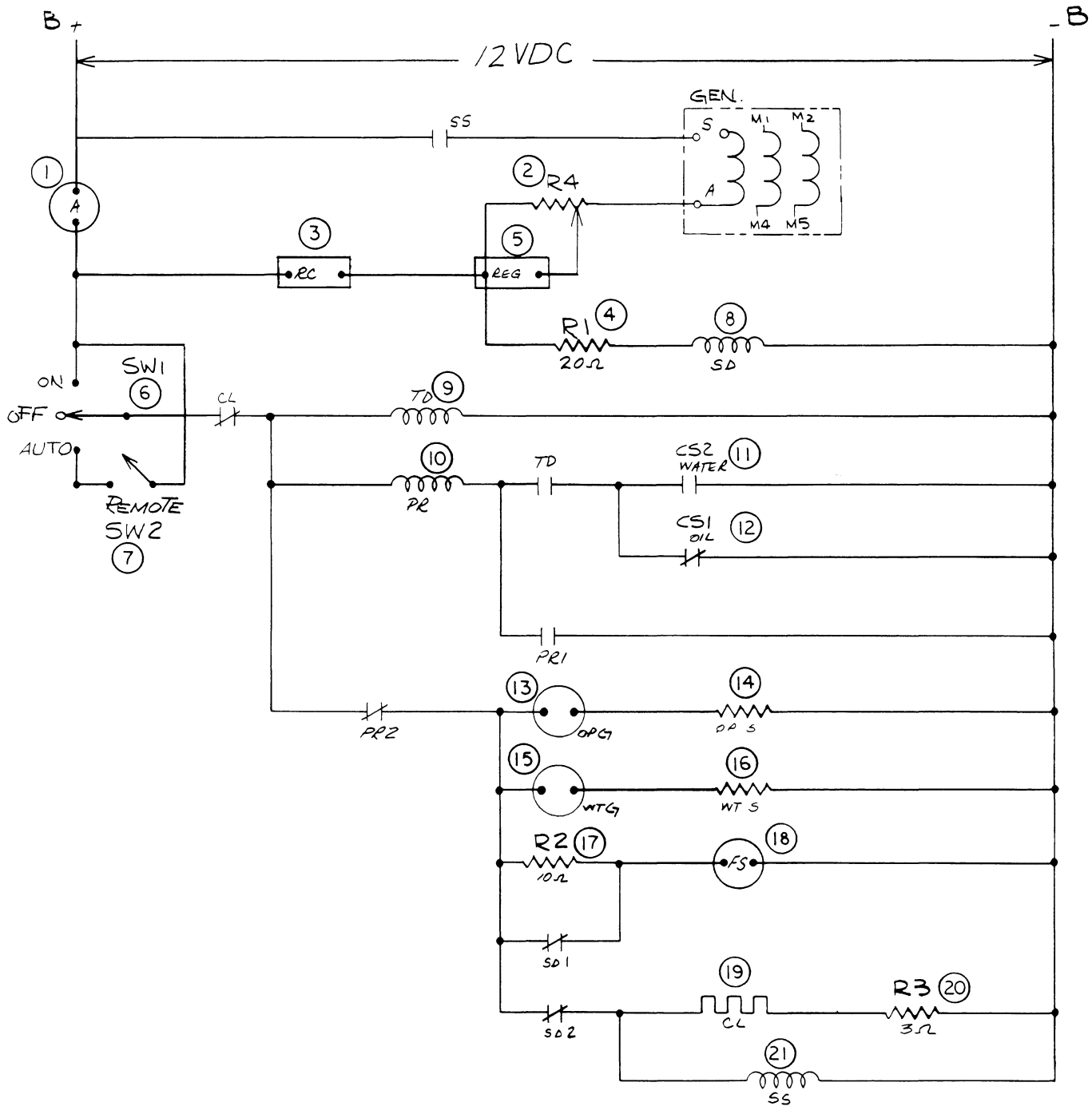
6. The TD relay is energized after 15 seconds by which time the oil pressure has built up, opening the low oil pressure switch. If oil pressure becomes low or the water temp. too high, the respective switches will close, thereby placing a ground on PR which opens PR-1 removing voltage from CR which opens CR-1 & CR-2, removing voltage from FS. PR-2 gives PR a permanent ground for shutdown.

7. To restart turn control switch to off and start engine. If problem has not been corrected, engine will shut off again in 15 seconds.

8. If engine fails to start in approx. 40 seconds, cranking limiter heats up and contacts open, thus de-energizing CR. CR-1, NO, opens and fuel solenoid drops out, stopping engine. (Reset CL after approx. one minute if desired).

TROUBLE SHOOTING HINTS 13743

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
1. ENGINE WON'T CRANK.	DEFECTIVE STARTER OR START SOLENOID.	PLACE 12 VOLTS ON COIL OF SS. IF SOLENOID ENERGIZES, STARTER IS DEFECTIVE. IF SOLENOID DOES NOT ENERGIZE, SOLENOID IS DEFECTIVE.
2. ENGINE WON'T START.	DEFECTIVE FS DEFECTIVE SD RELAY.	CHECK FUEL SOLENOID & LINKAGE. CHECK SD1 NC.
3. ENGINE STARTS BY ITSELF.	CR2 NO, DEFECTIVE.	CHECK CR2 NO, FOR SHORT.
4. ENGINE CRANKS & STARTS BUT STARTER DOES NOT DISENGAGE.	START DISCONNECT RELAY DEFECTIVE. SPEED SWITCH DEFECTIVE.	CHECK COIL OR SD-NC. SEE IF IT CLOSES WHEN ENGINE STARTS.
5. ENGINE CRANKS & STARTS BUT STOPS AND RESTARTS ITSELF.	CR1 NO, DEFECTIVE. 10 OHM RESISTOR DEFECTIVE.	CHECK CONTACT. MEASURE RESISTANCE.
	FUEL SOLENOID TOO WEAK. TO PULL ITSELF IN.	CHECK SPRING TENSION ON SOLENOID ARM.
6. ENGINE RUNS & SHUTS DOWN AFTER 15 SECS.	PROTECTIVE CIRCUIT ENERGIZED.	CHECK FOR LOW OIL OR HIGH WATER TEMP.
	OIL PRESSURE SWITCH SHORTED.	REPLACE.
	WATER TEMP. SWITCH SHORTED.	REPLACE.
	PROTECTION RELAY DEFECTIVE.	CHECK CONTACT PR2 NO.
7. BATTERY RUNS DOWN IN A DAY BUT TAKING GOOD CHARGE.	D1 SHORTED.	REPLACE.



10-15 KW WPD GENERATOR WITH AUXILIARY CHARGING AND CRANKING WINDINGS

DRAWING NO. 12970

12970

SEQUENCE OF OPERATIONS

1. WITH SWITCH IN ON POSITION, THE FUEL SOLENOID AND START SOLENOID ARE ENERGIZED PUTTING BATTERY VOLTAGE TO THE GENERATOR STARTER.

2. ENGINE STARTS.

3. WHEN THE VOLTAGE BUILDS UP, IT'S TAPPED OFF AT TERMINAL "A" AND ENERGIZES THE START-DISCONNECT RELAY.

4. SD1 OPENS, PUTTING A 10 OHM RESISTOR IN SERIES WITH THE FUEL SOLENOID. SD2 OPENS, REMOVING VOLTAGE FROM THE START SOLENOID WHICH DISCONNECTS THE STARTER, AND CRANKING LIMITER.

5. IN THE EVENT THE ENGINE WON'T START FOR SOME MECHANICAL REASON, VOLTAGE IS APPLIED TO THE HEATING ELEMENT OF THE CRANKING LIMITER AND, IF NOT REMOVED BY SD2 WITHIN 30 SECONDS, WILL OPEN CONTACT CL, SHUTTING DOWN THE SET UNTIL THE RESET IS PUSHED.

6. THE TD RELAY IS ENERGIZED AFTER 15 SECONDS BY WHICH TIME THE OIL PRESSURE HAS BUILT UP, OPENING THE LOW OIL SWITCH. IF OIL BECOMES LOW OR THE WATER TEMP. TOO HIGH, THE RESPECTIVE SWITCHES WILL CLOSE, THEREBY PLACING A GROUND ON PR WHICH OPENS CONTACT PR2 REMOVING VOLTAGE FROM THE FUEL SOLENOID AND CLOSING PR1, THUS GIVING PR A PERMANENT GROUND FOR SHUT DOWN.

12970

TROUBLE SHOOTING HINTS

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
1. ENGINE FAILS TO CRANK.	CRANKING LIMITER OPEN.	PRESS RESET.
	SD-2 DEFECTIVE	CHECK FOR AN OPEN.
	PR-2 DEFECTIVE	CHECK FOR AN OPEN.
	START SOLENOID DEFECTIVE.	PLACE 12 VOLTS ON COIL OF START SOLENOID. IF SOLENOID ENERGIZES, STARTER DEFECTIVE. IF IT DOESN'T ENERGIZE, SOLENOID DEFECTIVE.
	STARTER DEFECTIVE.	
	REVERSE CURRENT RELAY DEFECTIVE.	CHECK FOR SHORT.
2. ENGINE CRANKS, WON'T START.	SD-1 NC.	CHECK FOR AN OPEN.
3. ENGINE STARTS BUT STARTER STAYS ENGAGED.	SD RELAY	CHECK COIL. CHECK CONTACTS.
	CHARGING RESISTOR R-4.	CHECK FOR OPEN.
4. ENGINE STARTS, RUNS, THEN STOPS ITSELF, THEN RESTARTS.	FUEL SOLENOID DEFECTIVE.	CHECK LINKAGE, SPRING, POSSIBLY SOLENOID TOO WEAK.
	10 OHM RESISTOR	MEASURE RESISTANCE.
5. ENGINE RUNS AND SHUTS DOWN AFTER 15 SECS.	PROTECTIVE CIRCUIT ENERGIZED.	CHECK LOW OIL & HIGH WATER TEMP. SWITCHES.
	OIL PRESSURE SWITCH SHORTED WHEN YOU HAVE PRESSURE.	REPLACE.
	WATER TEMP. SWITCH SHORTED.	REPLACE.
	PROTECTIVE RELAY.	CHECK CONTACT PR-1 NO.

GENERATOR — TYPE JC (REVOLVING FIELD)

These WPDS generating plants use a 4-pole revolving field generator with static exciter (Magneciter) to excite the field and regulate the plant's ac output.

The generator is mounted to the engine crankcase through the engine-to-generator adapter. The rotor is directly connected by flexible disc to the engine flywheel. A ball bearing housed in the generator endbell, supports the outboard (collector ring) end of the rotor. The endbell is, in turn, supported by studs through the stator assembly to the adapter. Because of its construction, the generator can't be removed from the engine as a complete unit.

The generator's ac output is drawn from the stator windings which also supply 120 volts to the static exciter supply.

To aid servicing and repair, all output leads from the generator and connections to the exciter are marked with metal tags. The lead and terminal markings are noted on the plant wiring diagram. (See this section).

Magneciter is the trade name of ONAN'S static exciter system. As the name implies, it has no moving parts but uses magnetic amplifiers and rectifiers to supply direct current to the alternator's revolving field and regulate the ac output.

Because it is a relatively new development, a brief description of the Magneciter's operation is given here to aid understanding and repair.

The Magneciter functions as a power supply for the revolving field and a voltage regulator. By regulating the amount of current to the field, it controls the ac output of the generator. Here is how it works.

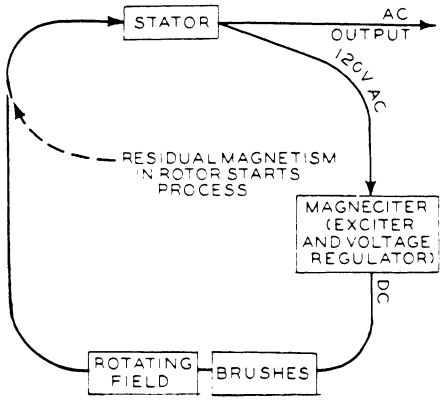


Fig. 4.A — Schematic, Alternator and Exciter

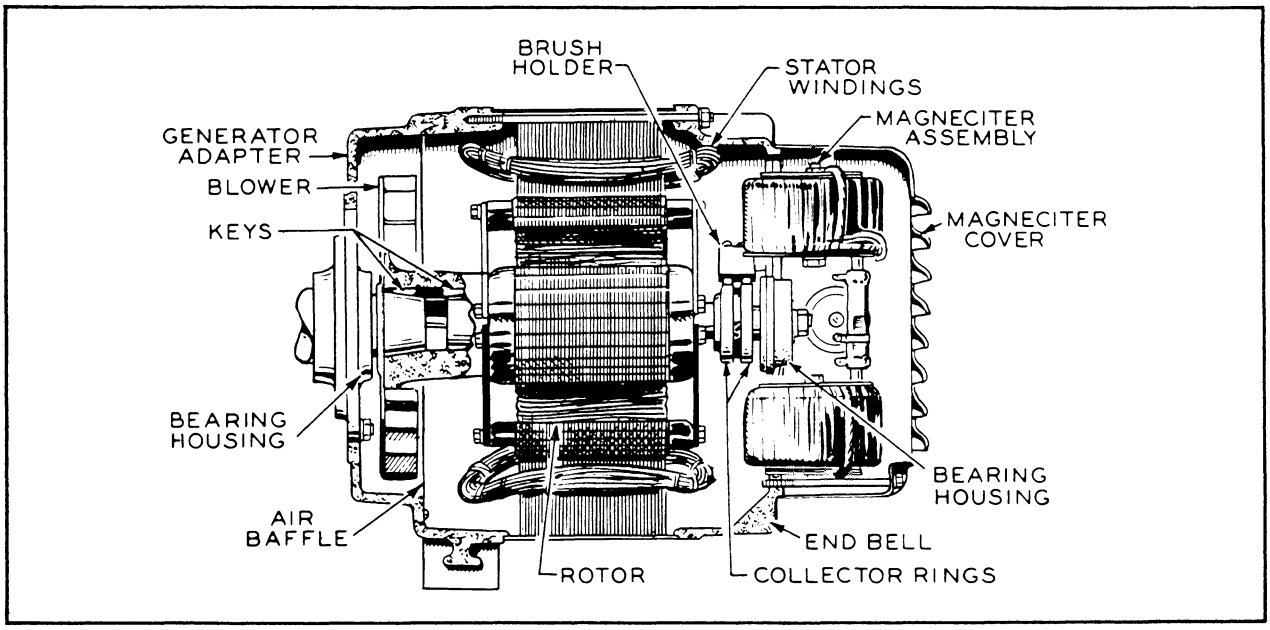


Fig. 4.B — Revolving Field Generator Cross Section

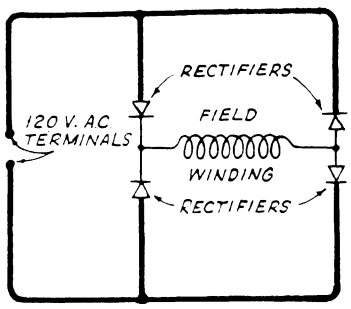


Fig. 4.C — Power Supply

The circuit shown in Fig. 4.C is the power supply. It's a full wave rectifier made up of 2 half wave rectifiers and supplies direct current to the field. In order to regulate the generator output voltage, some form of control over the current flowing in the field is necessary. Two gate reactors provide this control (Fig. 4.D).

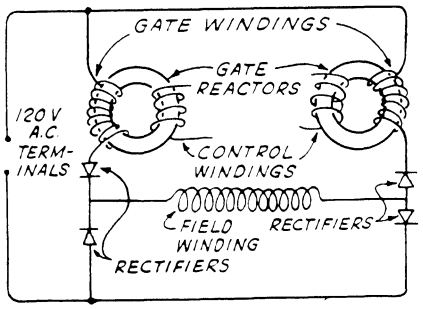


Fig. 4.D — Power Supply with Gate Reactors

Each gate reactor is a metal doughnut shaped core with 2 windings, an output or gate winding and a control winding. The amount of current the reactor allows to flow in the gate winding is dependent on the amount of magnetism in the core. The current flow increases — the gate opens — when there is more magnetism in the core, until finally when the core is saturated, the gate is all the way open, the reactor then does not oppose current flow. Since the rectifiers allow current in the gate winding to flow in only 1 direction, it can act only to magnetize the core. If the magnetism in the core were decreased this would reduce the current flow through the gate winding. That is the purpose of the control windings.

When current flows in the control windings, it decreases the magnetism in the core, reducing the current flow in the gate winding. Therefore, the control regulates the current in the generators' field, which controls the generator's output. More de-magnetizing current in the control winding, less current in the gate winding and generator field and a lower output voltage.

Next, we must introduce a regulator so that the current in the control windings will depend on the voltage output of the generator. The regulator must allow little or no current flow up to a certain output voltage and a large flow above that voltage. That is the purpose of the circuit shown in Fig. 4.E. This circuit uses rectifiers, to allow the current to flow in only one direction, and a control reactor. The control reactor is the voltage sensitive control of the regulator. Its characteristics are shown in Fig. 4.F. Below the proper

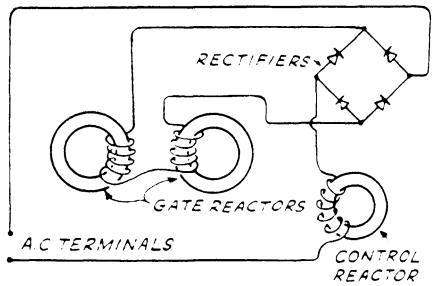


Fig. 4.E -- Control Circuit

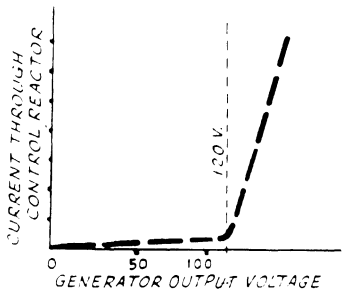


Fig. 4.F — Control Reactor Characteristics

voltage, little current flows through the reactor, so little current flows in the control windings. This allows full current to the field windings. When the reactor saturates magnetically, it suddenly allows a lot of current to flow through the control windings, reducing the current to the field windings. This reduces the generators' output voltage, which, in turn reduces the current through the control reactor and control windings back to the set requirements. The regulator then, holds voltage at a pre-set level determined by the control reactor.

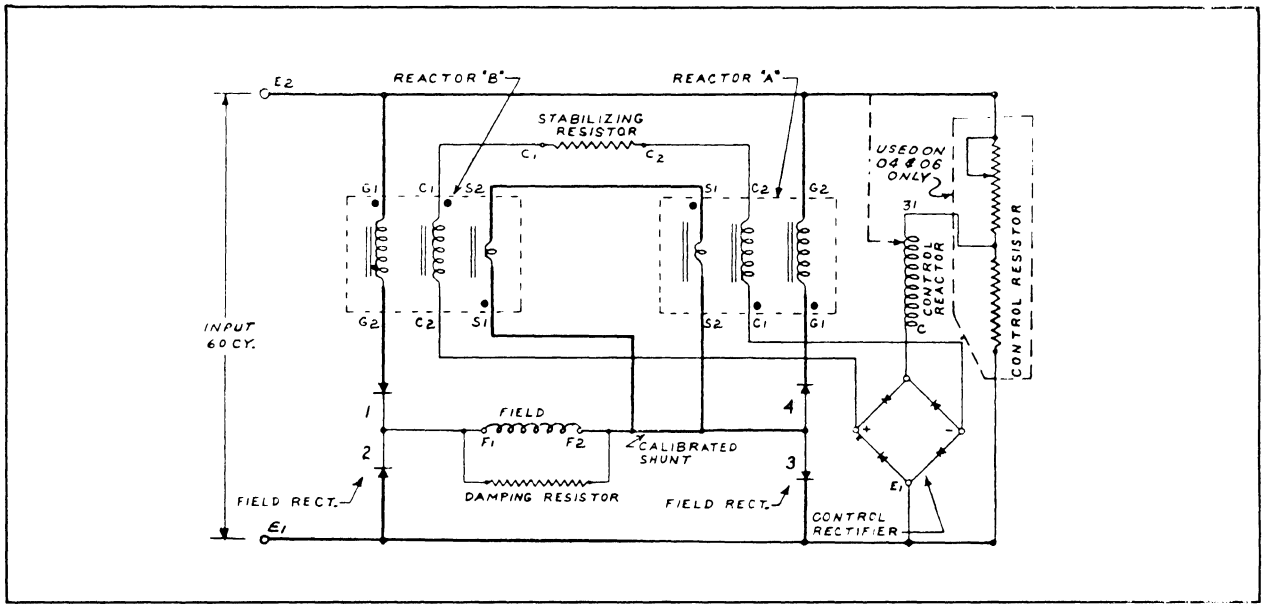


Fig. 4.G — Typical Magneciter Circuit

This is the basic circuit, but some refinements have been added. Compound windings on each large reactor, help to retain voltage control through changes in load and an output voltage control resistor allows adjustment of the output voltage by changing the voltage across the control reactor (Fig. 4.G).

4.1 Adjustments

OUTPUT VOLTAGE. — It's possible, by means of controls in the magneciter, to make small changes in the generator output voltage. DON'T use these controls to increase generator output above the rated voltage (*i.e.* 120 V, 240 V).

On the 06SX Magneciter, an adjustable tapped resistor controls the voltage output. It is adjustable over a range of about 5 percent with the highest voltage when the tap is moved to the top of the resistor.

4.2 Maintenance

The generator normally needs little care other than periodic inspection of the exciter, ballbearing, collector rings and brushes every 1000 hours.

4.2.1 Brushes. — To examine the brushes, brush springs and slip rings, remove the exciter cover at the rear end of the generator. Note that the exciter mounts on a hinged plate. Remove the screws from the right side of the plate and swing the assembly outward. To remove the brush holders, unscrew the 4 machine screws on the endbell near the ballbearing.

Replace the brushes when they wear to about 5/16″ long. Don't use a substitute brush that may look identical. It might have entirely different electrical characteristics.

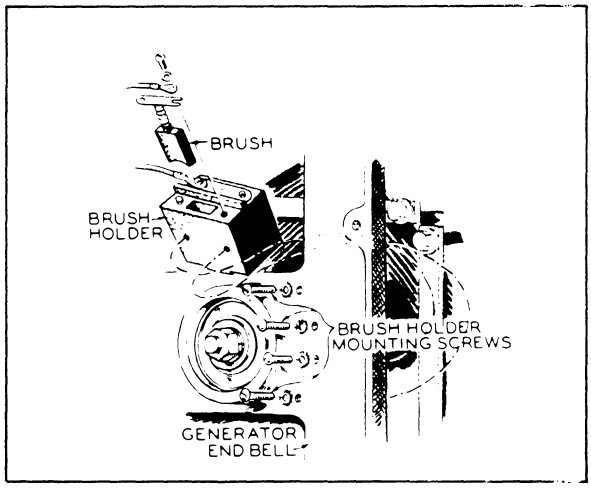


Fig. 4.H — Removing Brushes

4.2.2 Generator Bearing — The generator bearing is pre-lubricated for life and sealed. It requires no servicing.

4.2.3 Exciter. — The exciter contains no moving parts. Periodically blow out any dust and make certain that all components and connections are secure.

4.2.4 Collector Rings. — The collector rings must be clean and free of scratches, burrs and marks. If necessary, use No. 00 sand-

paper to clean the surface. Never use emery cloth or other conducting abrasives.

4.3 Testing and Repair

If repair work is necessary on the generator, it should be performed by a competent electrician who is familiar with operation of electric generating equipment.

4.3.1 Trouble-Shooting. — In the event of abnormal generator output voltage, observe the following procedures.

4.3.1.1 No Voltage Build Up. — First remove the exciter cover and, with the plant running operate the residual reset button on the Magneciter.

If output voltage won't build up after pushing the reset button, flash the field. Connect a voltmeter across the ac output. Then run the plant and touch the leads of a 12 volt battery in series with an 8–10 ohm current limiting resistor to the exciter-to-brush leads . . . positive (+) to F_1 and negative (—) to F_2. If the resistor weren't used, battery current could destroy the Magneciter rectifiers. Watch the voltmeter. If voltage builds up to normal, the trouble was due to lost residual in the field. If the voltmeter indicates a low voltage, the Magneciter is probably defective (see Sect. 4.3.3 and the Magneciter trouble-shooting chart for repair). If there is no voltage output with the battery connected to F_1 and F_2, trouble is in the alternator (see Sect. 4.3.2 for testing and repair).

4.3.1.2 Under-Voltage Condition. — Either the alternator or Magneciter could be defective. But, the defect is probably in the Magneciter so check it first, using Sect. 4.3.3 and the Magneciter trouble-shooting chart.

4.3.1.3 Over-Voltage or Fluctuating Voltage. — If the engine is operating at the correct speed, trouble is most likely in the Magneciter. See Sect. 4.3.3 and the Magnectier trouble-shooting chart.

4.3.2 Alternator Testing. — Most alternator testing can be performed without disassembling the generator.

4.3.2.1 Rotor Continuity Tests. — Remove the brushes so none touches the collector rings.

1. Using an ohmmeter, test for grounding between each slip ring and the rotor shaft.

2. Test for short or open circuit in rotor winding, by measuring resistance of winding. It should measure between 2.5 and 3 ohms (at 70°F). If an accurate ohmmeter isn't available, check the rotor for open circuit or grounding with a dc test lamp (Fig. 4.J).

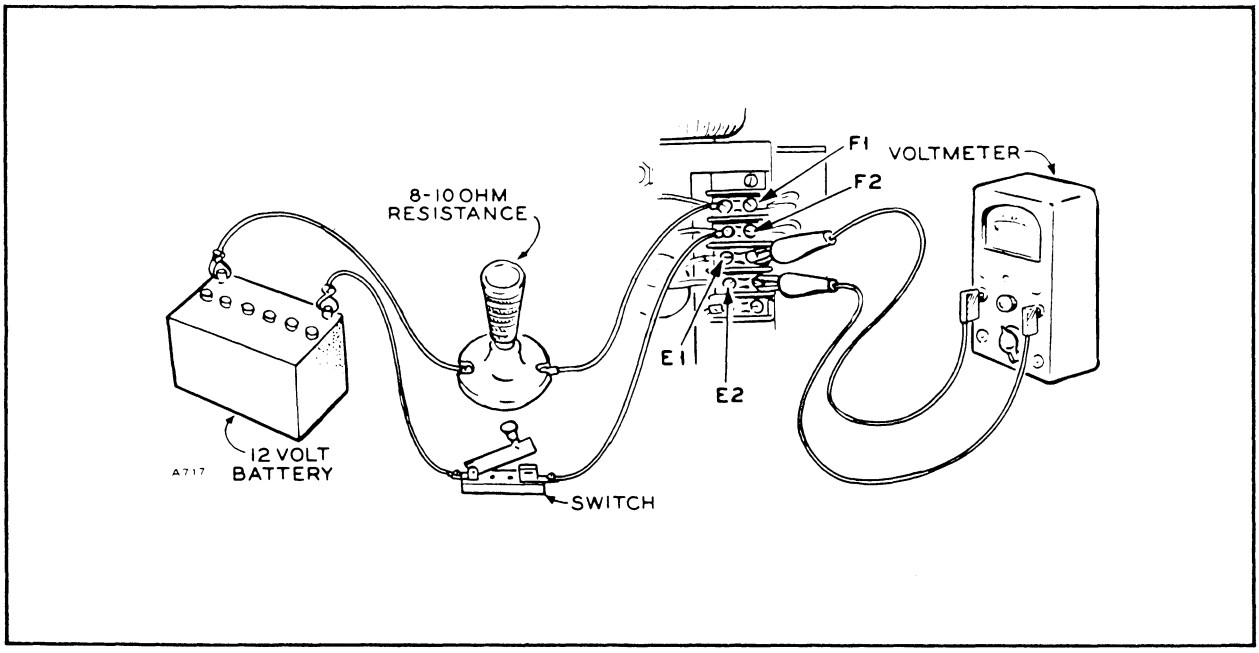


Fig. 4.I — Flashing the Field See Sect. 4.3.1.1.

3. Replace the rotor if it is grounded, or has an open circuit or short.

4.3.2.2 Stator Continuity Tests. — Disconnect the generator output leads in the control box. Use the wiring diagrams in Sect. 10 to determine the output lead coding.

1. Using either the test lamp or an ohmmeter, check each winding of the stator for grounding to the laminations or frame.
   NOTE: Some generators have ground connections to the frame. Check the wiring diagrams.

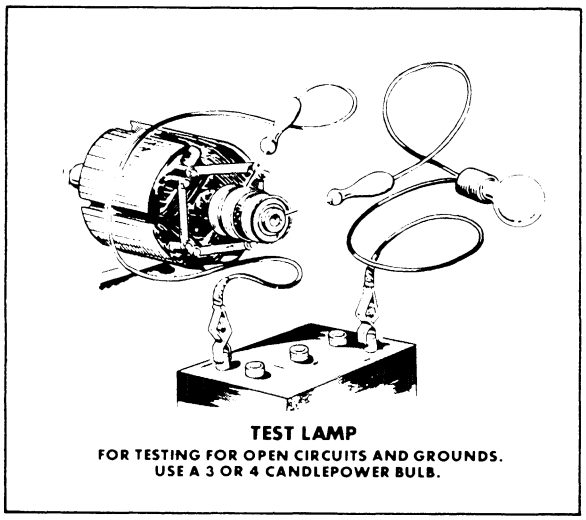


Fig. 4.J — Continuity Test Lamp

2. Using an accurate ohmmeter, test the resistance of each stator winding. Compare the resistances obtained. All windings of equal output voltage should indicate about the same resistance. An unusually low reading indicates a short; a high reading an open circuit.

   If the ohmmeter required for this test isn't available, check for open circuits with the test lamp.

If any windings are shorted, open-circuited or grounded, replace the stator assembly. Before replacing the assembly, check the leads for broken wires or insulation and replace any defective lead. If this does not correct the fault, replace the assembly. It isn't practical to attempt to rewind a defective stator except in a competent rewinding shop.

4.3.2.3 Battery Charging Winding Tests. — Remove the lead from the battery polarity reconnection block to ammeter at the ammeter. Install a dc voltmeter between the lead and ground. At governed engine speed, the average dc output should be 7 to 9 volts. If the output is defective, test for open circuit or grounding in the leads and windings. If leads are defective, replace them. If the winding is defective, replace the stator.

4.3.2.4 Collector Rings. — If the collector rings are grooved, out-of-round, pitted, or rough so that good brush seating can't be maintained, remove the rotor, Sect. 4.4, and refinish the rings in a lathe. Remove or shield the ballbearing during refinishing.

4.3.2.5 Ballbearing. — If the ballbearing becomes noisy, worn or otherwise defective, replace it. Remove the old ballbearing with a gear puller and drive or press a new one into place.

4.3.3. Magneciter Testing and Repair.— If generating failure is traced to the Magneciter see the Magneciter trouble-shooting chart. Perform tests on the components with either an ohmmeter or a 115 volt test lamp (Fig. 4.K).

Always isolate the component being tested by removing its leads. Before testing, make certain that no part of the Magneciter is grounded. Use the tests in the following sections to determine

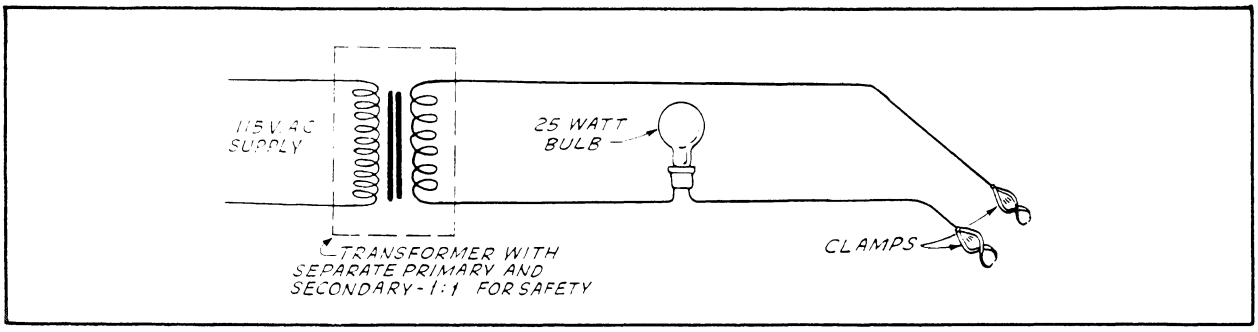


Fig. 4.K — 115V Continuity Test Lamp (Use for testing Magneciter)

whether the components are functioning properly. Replace any components found defective.

4.3.3.1 Reactors. — Test the control reactor with an ohmmeter, using the resistance values in the Table of Resistances (Fig. 4.L). Use the following method to test each gate reactor:

MODEL OF MAGNECITER	CONTROL REACTOR C to 31	C to 1	LARGE REACTOR C_1 to C_2	G_1 to G_2	BUILD-UP RELAY COIL
06SX1N1B	12.5		5.5	.66	None

Fig. 4.L — Table of Resistances, Magneciter

1. Make certain that no part of the Magneciter is grounded.

2. Isolate the gate winding (G_1, G_2) by disconnecting one lead from its point of connection and the control winding by disconnecting both leads (C_1, C_2) from their points of connection.
   CAUTION: The accuracy and reliability of resistance values depends on the accuracy of the ohmmeter used. Reliable readings such as found between G_1 and G_2 can't be accurately read with a multimeter.

3. Connect one test lead to G_1 and the other to G_2 and observe the light bulb.

4. With the test leads still connected to the gate winding leads, short across leads C_1 and C_2 and again observe the bulb.

5. Connect one test lead to the control winding lead and the other test leads to one of the gate winding leads and observe the bulb.

RESULTS

1. Reactor is serviceable if bulb is dark for steps 3 and 5 but bright for step 4.

2. Reactor is defective if bulb lights with low intensity for step 3 indicating presence of a short in either gate winding or control winding. If bulb lights at all during step 5 the control and gate winding are shorted together. If bulb fails to light in step 4 there is very likely an open circuit in either the gate winding or control winding.

If any reactor is defective, replace it.

4.3.3.2 Rectifiers. — Test each rectifier believed to be defective by isolating it and measuring the resistance first in one direction, then in the other. If the rectifier is operating properly, one reading will be much higher than the other. If the 115 volt test lamp is used, first touch the tester probes together and observe the brightness of the bulb. Then touch them across the rectifier. If the bulb lights brightly or not at all,

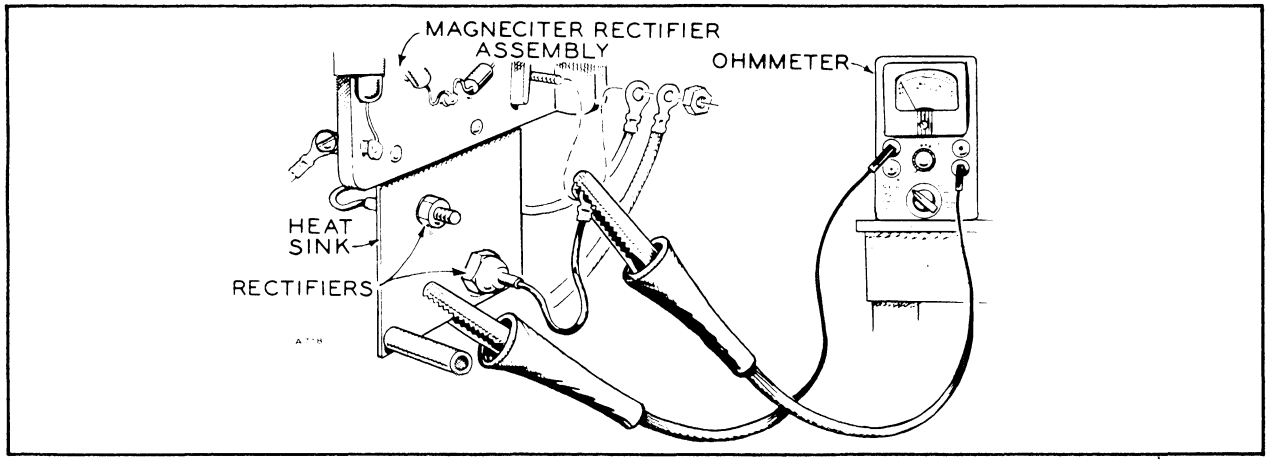


Fig. 4.M — Testing Field Rectifier

the rectifier is defective. If it lights dimly, this indicates that the rectifier is passing current in only one direction and is functioning properly. Replace any rectifier found defective.

4.4 Disassembly, Generator

1. Disconnect the battery so the plant won't accidently start.

2. Remove the exciter cover and open exciter. This reveals the Hex head of the speed governor mechanism and the starter disconnect speed switch.

3. Disconnect leads E1, E2, F1 and F2.

* 4. Remove three 1/4-20 screws that fasten magneciter hinge to end bell and lift magneciter away, being careful not to damage speed switch or governor mechanism.

* 5. Remove micro switch from its bracket and disconnect two leads. These may be unsoldered from their tabs or the tabs may be unscrewed from the switch itself.

* 6. Remove speed switch (Micro-Switch) Mounting Bracket from end bell to avoid possibility of damaging it while performing further disassembly.

* 7. Remove speed governor by unscrewing hex end of its shaft.

8. Remove four machine screws on the end bell near the ball bearing and lift out the brush holders (Fig. 4.H).

* 9. Remove lead from the tapped adjustable resistor in the Flywheel housing blower opening.

10. Remove load wires and generator leads from Terminal block.

11. Remove screws from control box mounting brackets and lay control box forward out of the way.

12. Remove top half of Alternator saddle, lift Alternator end free of lower half saddle and block under Flywheel Housing.

13. Remove Hex nuts from the rim of the end bell.

14. Pull the end bell off the Alternator.

15. Slide the Stator assembly off of its studs being careful not to drag it heavily along the rotor. Keep the weight supported, do not let it rest on rotor which is now unsupported at bearing end.

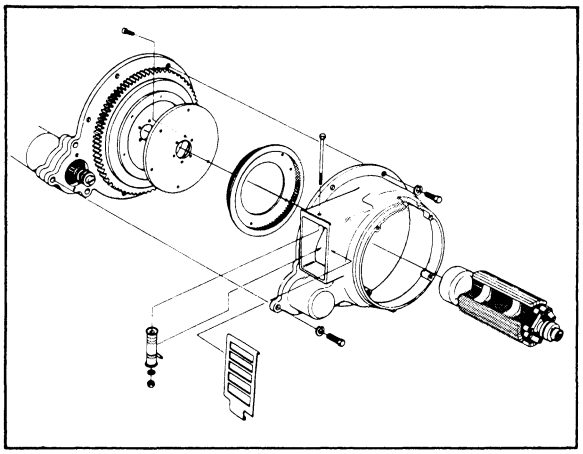


Fig. 4.N — Removing Rotor

16. Remove eight screws that hold Blower Fan, drive disc, and rotor to Flywheel. Lift out rotor.

4.5 Assembly, Generator

1. Reverse procedure for 4.4.

2. CAUTION: When assembling Governor mechanism on armature through stud set up to 25 foot pounds torque and rotate engine. Tap the Hex end of Governor shaft until it runs true. If allowed to run out appreciably, the entire assembly may malfunction causing starter motor overspeed. Starter overspeed may result in destruction of the starter motor.

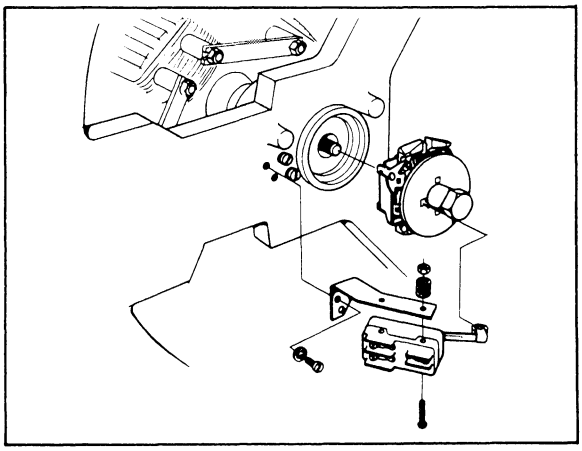


Fig. 4.O — Speed Governor

*Apply to WPDS sets built before serial numbers ending in "A68" or before those WPDS sets built with Battery Charging generators.

When installing or re-connecting after service work, be sure all battery connections are securely tightened. Observe correct Battery Connection Polarity. (See Wiring Diagram) on pages 15 & 16.

Voltage Selection on Reconnectible Single Phase Generators: New plants are supplied as ordered, but all WPDS plants may be reconnected for use as 120/240-volt 3-wire, 120-volt 2-wire, or 240-volt 2-wire power source (Fig. 4.P). Use the connection for two wire service when one load exceeds ½ the rated capacity. Balance the load when connected for three-wire service.

Load Connections: Refer to the figure 4.P which illustrates the load connection for the output shown on your plant's name-plate. See switchboard instructions here when a switchboard is used.

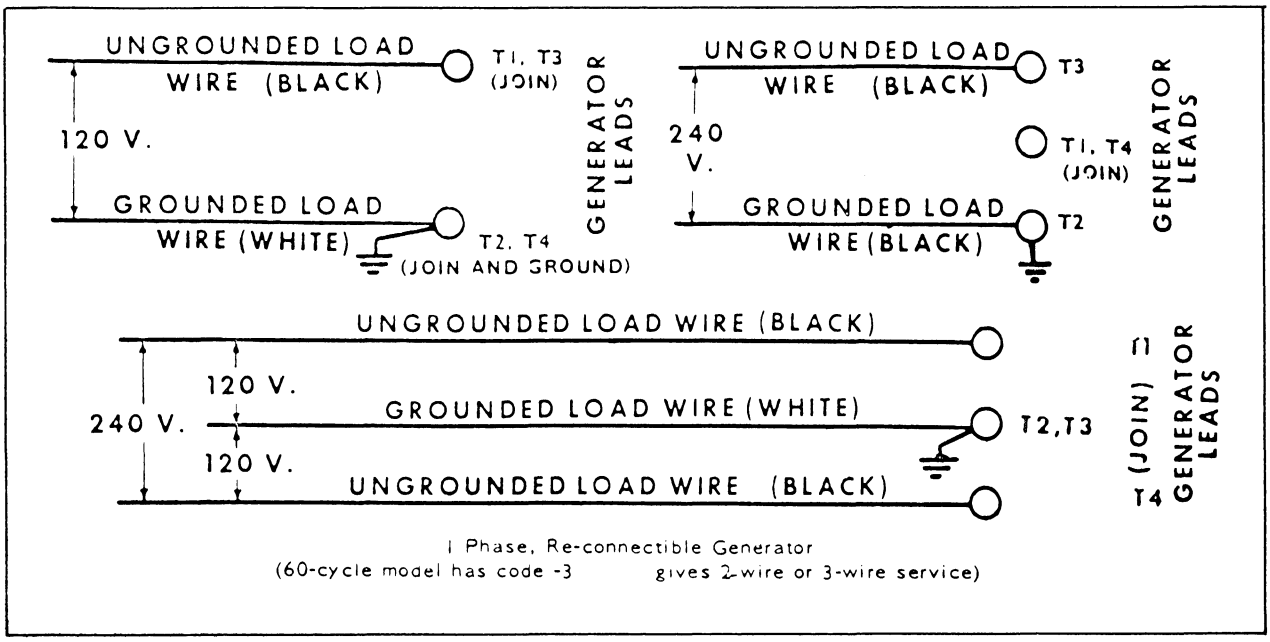


Fig. 4.P

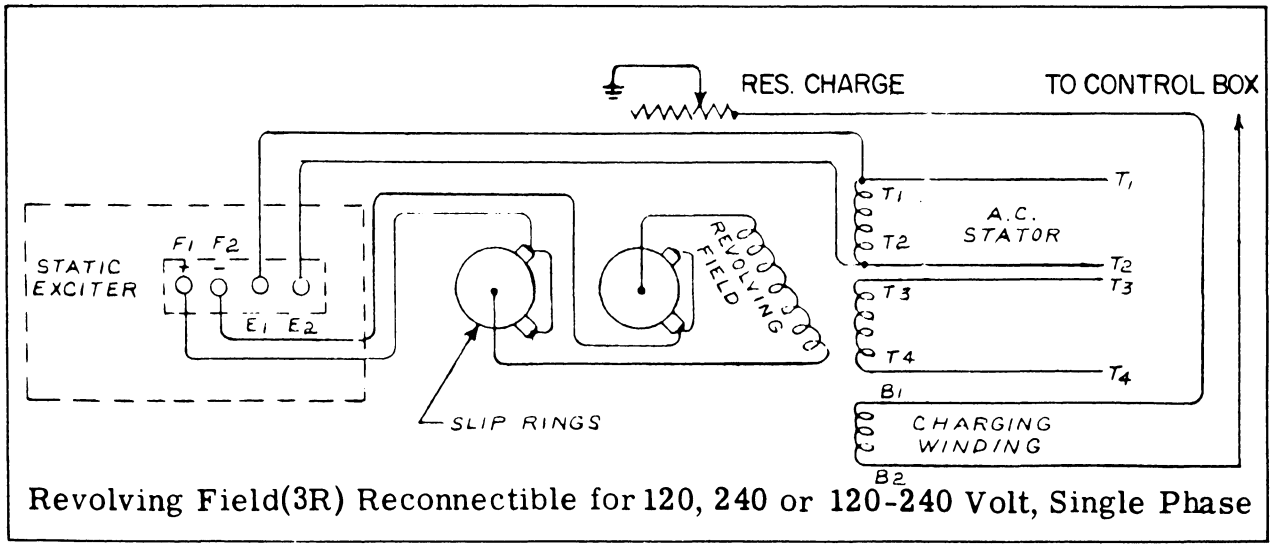


Fig. 4.Q—Internal Generating Diagram.

TROUBLE SHOOTING CHART 8, REVOLVING FIELD GENERATOR

TROUBLE	PROBABLE CAUSE	REMEDY
Engine runs but voltage won't build up.	Residual magnetism gone	See Sect. 4.3.1 for trouble shooting.
	Dead short in load.	Inspect load and correct.
	Magneciter defective.	See Trouble-Shooting-Chart 9 — Magneciter.
	Open circuit, ground or short in revolving field.	Test as per Sect. 4.3.2. Replace if necessary.
	Open circuit, ground or short in stator.	Test as per Sect. 4.3.2. Replace if necessary.
Current unsteady but engine speed not fluctuating.	Loose connection.	Clean and tighten connections.
	Poor brush contact.	Reseat or replace brushes. Clean slip rings.
Frequency drops under heavy load.	Low engine power.	See Trouble-Shooting Chart 1 — Engine.
	Poor governor adjustment.	Adjust engine governor, Sect. 3.4.
Voltage drops under heavy load, little frequency change.	Defective magneciter.	See Trouble-Shooting Chart 9 — Magneciter.
Generator won't deliver rated current.	Unbalanced load on lines.	Adjust load.
	Defective magneciter.	See Trouble-Shooting Chart 9 — Magneciter.
	Defective field windings.	Test and replace if defective.
Generator overheats.	Overloaded.	Reduce load.
	Partial short in load.	Correct short.
	Poor ventilation.	Increase ventilation.
TROUBLE	PROBABLE CAUSE	REMEDY
Incorrect output voltage.	Incorrect adjustment of output control resistor.	See Section 4.1.
	Engine governor set wrong speed.	Check engine speed, adjust governor.
	Defective Magneciter.	See Trouble-Shooting Chart 9 — Magneciter.
Noise in generator.	Defective bearing.	Replace.
	Collector rings out of round.	Turn down in lathe.

TROUBLE SHOOTING CHART 9

Troubles are listed in advancing order, from no output voltage to a rated but fluctuating output voltage. The relationship between trouble and cause is not always consistent from model to model, so the following information must be used as a guide, not an absolute rule.

Before proceeding be sure that connections are in accordance with Figure 4.Q.

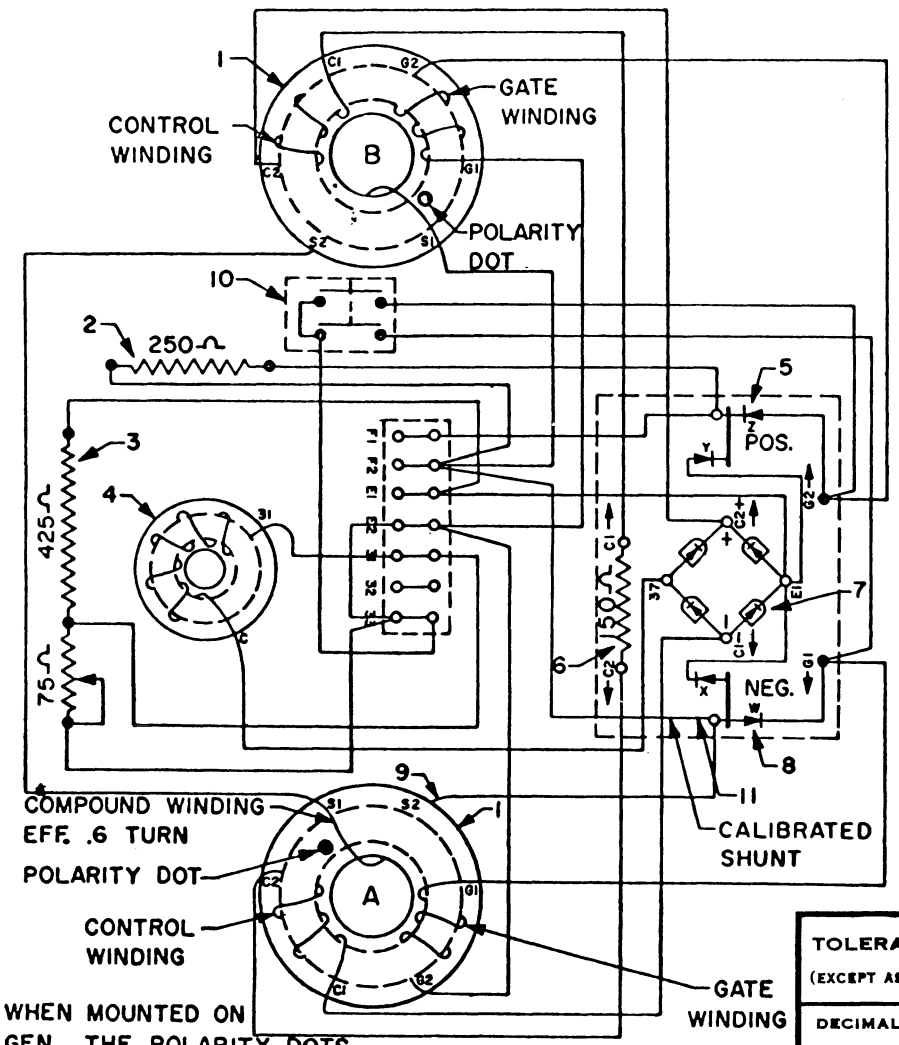
NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
Generator will not build up voltage	Circuit breaker in "off" or "tripped" position.	Reset and close breaker.
	Open in circuit breaker.	Stop plant and check breaker continuity.
	No AC power to Magneciter.	Check AC voltage at E_1-E_2 with the plant operating*. Voltage should be five per cent of the rated voltage. If check continuity from E_1-E_2 back to the generator.
	Partial loss of residual in Rotor.	With plant operating*, place a jumper across G_1-G_2 until voltage begins to build-up. then remove.
	Pair of Field Rectifiers (either 1 & 4 or 2 & 3) open.	Test rectifiers and replace if defective.
	Both Field Rectifiers 2 and 3 shorted.	Test rectifiers and replace if defective.
Output voltage slow to build up. Circuit breaker opens in about five seconds.	Either Field Rectifier 2 or 3 shorted.	Test rectifiers and replace if defective.
Output voltage slow to build up and five per cent below rated voltage after build up. Voltage regulation poor.	Either Field Rectifier 1 or 4 shorted.	Test Rectifier and replace if defective.

*Be cautious when trouble-shooting on an operating plant.

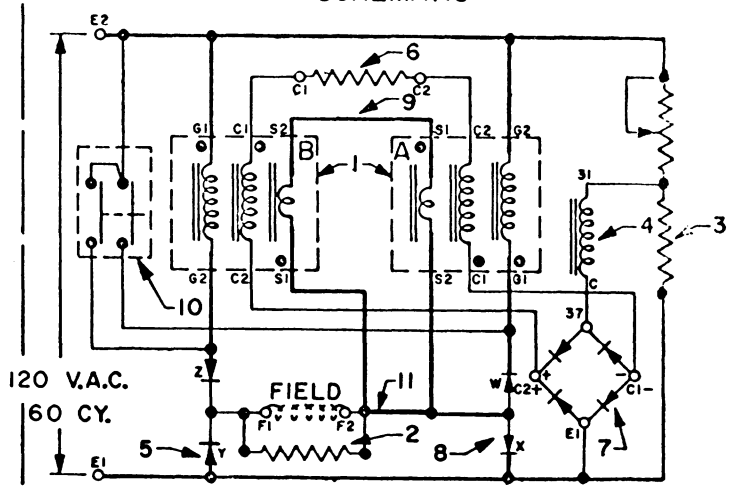
TROUBLE SHOOTING CHART 9 (Continued)

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
Output voltage slow to build up and higher than rated voltage after build up.	Open circuit in one or more Control Rectifier.	Test rectifier and replace if if defective. Check soldered connections to rectifiers.
Output voltage slow to build up and ten to twenty per cent above rated voltage after build up.	Open in one Field Rectifier.	Test rectifiers and replace if if defective.
	Open circuit in Gate winding G_1-G_2 of Recactor A or B.	If Field Rectifiers 1 and 2 check okay, check continuities of Gate windings G_1-G_2.
Output voltage builds up normally but less than rated volttage after build up.	Shorted winding of Control Reactor	Test Control Reactor and if defective.
Output voltage builds up normally with slightly less than rated voltage at no load and low voltage at full load.	Compound winding S_1-S_2 installed backward or has open circuit.	Check wiring diagram for polarity of Compound windings through Reactors A and B and test for continuity.
Output voltage builds up normally but 20 per cent above rated voltage after build up. Voltage regulation poor.	Compound windings S[-S] installed backward through one Reactor (A or B).	Check wiring diagram for polarity of Compound winding through Reactor A or B.
Output voltage builds up normally but is twenty-five per cent above rated voltage after build up.	Open circuit in Control Rectifier bridge.	Check continuity from the junction of Control Rectifiers 1 and 2 to the junction of Control Rectifiers 3 and 4.
Output voltage builds up normally but 125 to 150 per cent above rated voltage after build up.	Shorted turn in gate winding G_1-G_2 of Reactor A or B.	Test Reactors A and B for shorted turns and replace if defective.
Output voltage builds up normally but 100 to 200 per cent above rated voltage after build up. No regulation possible.	Control winding C_1-C_2 of Recactor A or B polarized incorrectly.	Check circuit connections of both Reactors A and B.
	Shorted turn in Control winding C_1-C_2 of Reactor A or B.	Test Reactors A and B for shorted turn and replace if defective.
	Open in Control Circuit.	Check continuity from E_1 to E_2 through Control Circuit.

PICTORIAL



SCHEMATIC



Item	Qty	Part No.	Description
11	1	13775	No. 16 wire
10	1	14270	Switch-residual reset
9	1	15130	No. 14 wire
8	2	14266	Rectifier-field neg.
7	4	14268	Rectifier-control
6	1	14264	Resistor-stabilizing
5	2	14267	Rectifier-field pos.
4	1	14271	Reactor-control
3	1	14265	Resistor-volt. control
2	1	14263	Resistor-damping
1	2	14272	Reactor-gate

TOLERANCES (EXCEPT AS NOTED)
DECIMAL ±
FRACTIONAL ±
ANGULAR ±

J.H. WESTERBEKE CORP.
BOSTON, MASS. 02122

SCALE NONE
DRAWN BY B.J.S.
APPROVED BY F.V.

TITLE STATIC EXCITER WPDS 10 THROUGH WPDS 20. 4-107 & 4-154

DATE 6-26-73
DRAWING NUMBER 15687

DYNAMONITOR

DYNAMONITOR OPERATION

DMS 2-10, 12.5, 15 — 13797 Rev. B

1. With generator control switch to AUTO position and demand control switch to AUTO, apply a load greater than 60 watts across line-1 to neutral. This completes the D.C. circuit by actuating relay K1 through resistor R1 and R2, thereby connecting the load to ground.

2. K1 actuates. K1-2-NO closes, reducing series resistance in K1 coil path, holding K1 closed when cranking reduces B plus voltage. The closing of K1-1-NO puts B plus on remote (R) which starts the generator.

3. The generator builds up voltage and activates K3. K3-3-NC opens the D.C. circuit. K3-1-NO and K3-2-NO close, completing the A.C. circuit. The generator output is through transformer T1 back to the load. K2 energizes. K2-1-NC opens removing B minus from the A.C. circuit and K2-NO closes, completing the control circuit keeping K1 energized and a constant B plus on the remote terminal.

DMS 3-10, 12.5, 15

1. With generator switched to AUTO position, and demand control switch to AUTO, apply a load greater than 60 watts across the output L1 to neutral or L2 to neutral (120 VAC). This completes the D.C. circuit actuating relay K1 through resistors R1 and R2 and the load is thereby connected to ground.

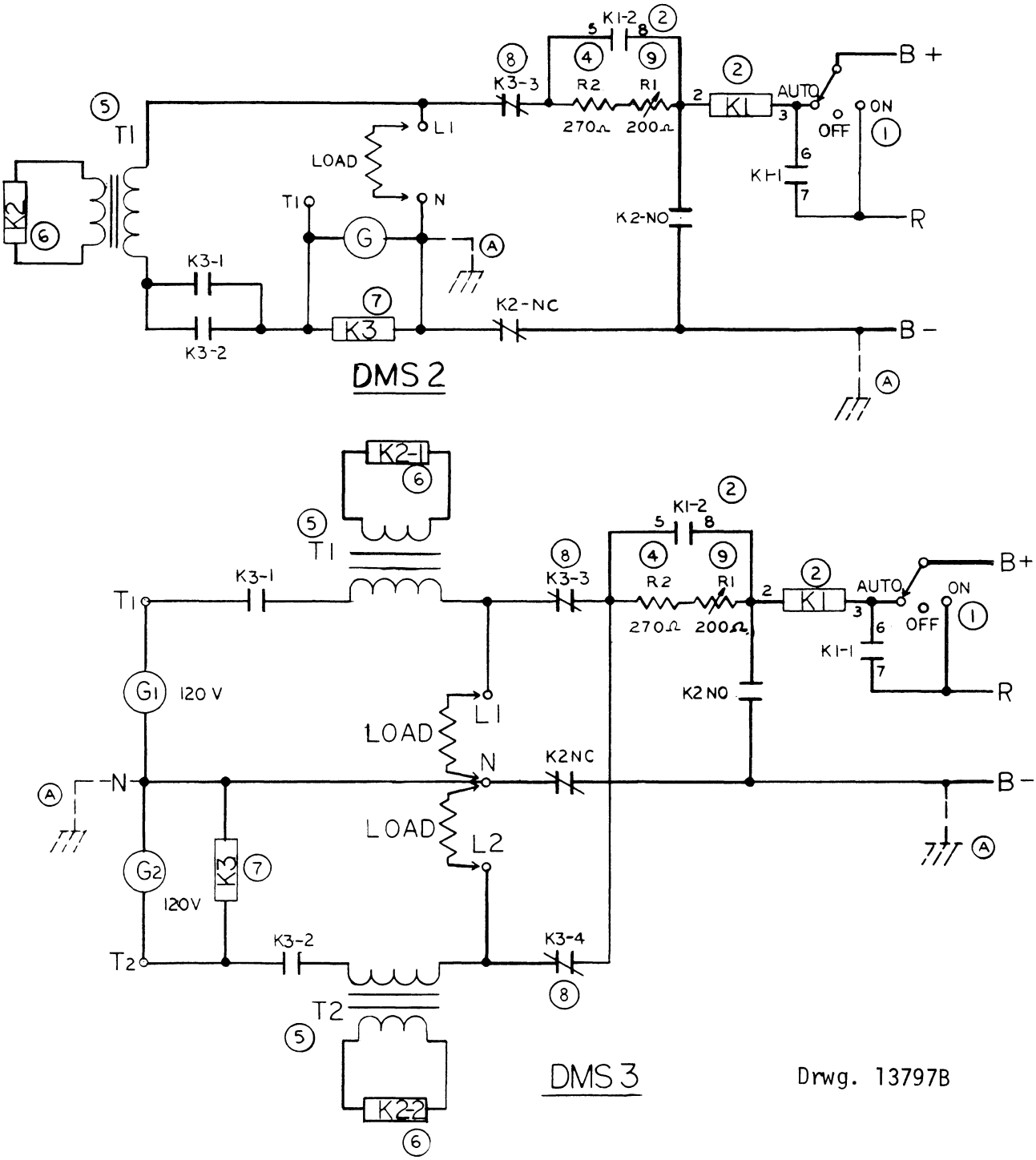
2. K1 actuates. K1-2-NO closes, reducing series resistance in K1 coil path, holding K1 closed when cranking reduces B plus voltage. The closing of K1-1-NO puts B plus on remote (R) which starts the generator.

3. The generator builds up voltage and K3 actuates closing contacts K3-1-NO and K3-2-NO, also K3-3-NC and K3-4-NC open, separating the A.C. and D.C. lines.

   A) If load is across L1 to neutral the path through T1 is complete and K2-1 actuates. K2-NC opens removing B minus from A.C. line. K2-NO closes, putting B minus to K1 which keeps B plus on remote (R).

   B) If load is across L2 to neutral the path through T2 is complete and K2-2 actuates. K2-NC opens removing B minus from A.C. line. K2-NO closes, putting B minus to K1 which keeps B plus on remote (R).

NOTE: R1 is a sensitivity resistor which determines the voltage applied to K1 which starts the generator. If the variable resistor is set low, any insignificant load, including stray leakage due to moisture, may start the set. If the resistor is set too high it may take a larger load than desirable to start the generator. We recommend the setting be to such that a 60 watt lamp will start the generator whereas a 25 watt lamp will not.



Ⓐ IF AC SYSTEM HAS THE NEUTRAL GROUNDED IN COMMON WITH THE B NEGATIVE GROUND, THE GROUNDED AC LINE, N, MUST BE CONNECTED AS SHOWN.

DYNAMONITOR DM-2 AND DM-3, 10-15 KW,
AUTOMATIC DEMAND CONTROL
DRAWING NO. 13797 B

TROUBLE SHOOTING HINTS

12970

NATURE OF TROUBLE	PROBABLE CAUSE	CORRECTIVE ACTION
1. ENGINE FAILS TO CRANK.	CRANKING LIMITER OPEN.	PRESS RESET.
	SD-2 DEFECTIVE	CHECK FOR AN OPEN.
	PR-2 DEFECTIVE	CHECK FOR AN OPEN.
	START SOLENOID DEFECTIVE.	PLACE 12 VOLTS ON COIL OF START SOLENOID. IF SOLENOID ENERGIZES, STARTER DEFECTIVE. IF IT DOESN'T ENERGIZE, SOLENOID DEFECTIVE.
	STARTER DEFECTIVE.	
	REVERSE CURRENT RELAY DEFECTIVE.	CHECK FOR SHORT.
2. ENGINE CRANKS, WON'T START.	SD-1 NC.	CHECK FOR AN OPEN.
3. ENGINE STARTS BUT STARTER STAYS ENGAGED.	SD RELAY	CHECK COIL. CHECK CONTACTS.
	CHARGING RESISTOR R-4.	CHECK FOR OPEN.
4. ENGINE STARTS, RUNS, THEN STOPS ITSELF, THEN RESTARTS.	FUEL SOLENOID DEFECTIVE.	CHECK LINKAGE, SPRING, POSSIBLY SOLENOID TOO WEAK.
	10 OHM RESISTOR	MEASURE RESISTANCE.
5. ENGINE RUNS AND SHUTS DOWN AFTER 15 SECS.	PROTECTIVE CIRCUIT ENERGIZED.	CHECK LOW OIL & HIGH WATER TEMP. SWITCHES.
	OIL PRESSURE SWITCH SHORTED WHEN YOU HAVE PRESSURE.	REPLACE.
	WATER TEMP. SWITCH SHORTED.	REPLACE.
	PROTECTIVE RELAY.	CHECK CONTACT PR-1 NO.

YD GENERATORS

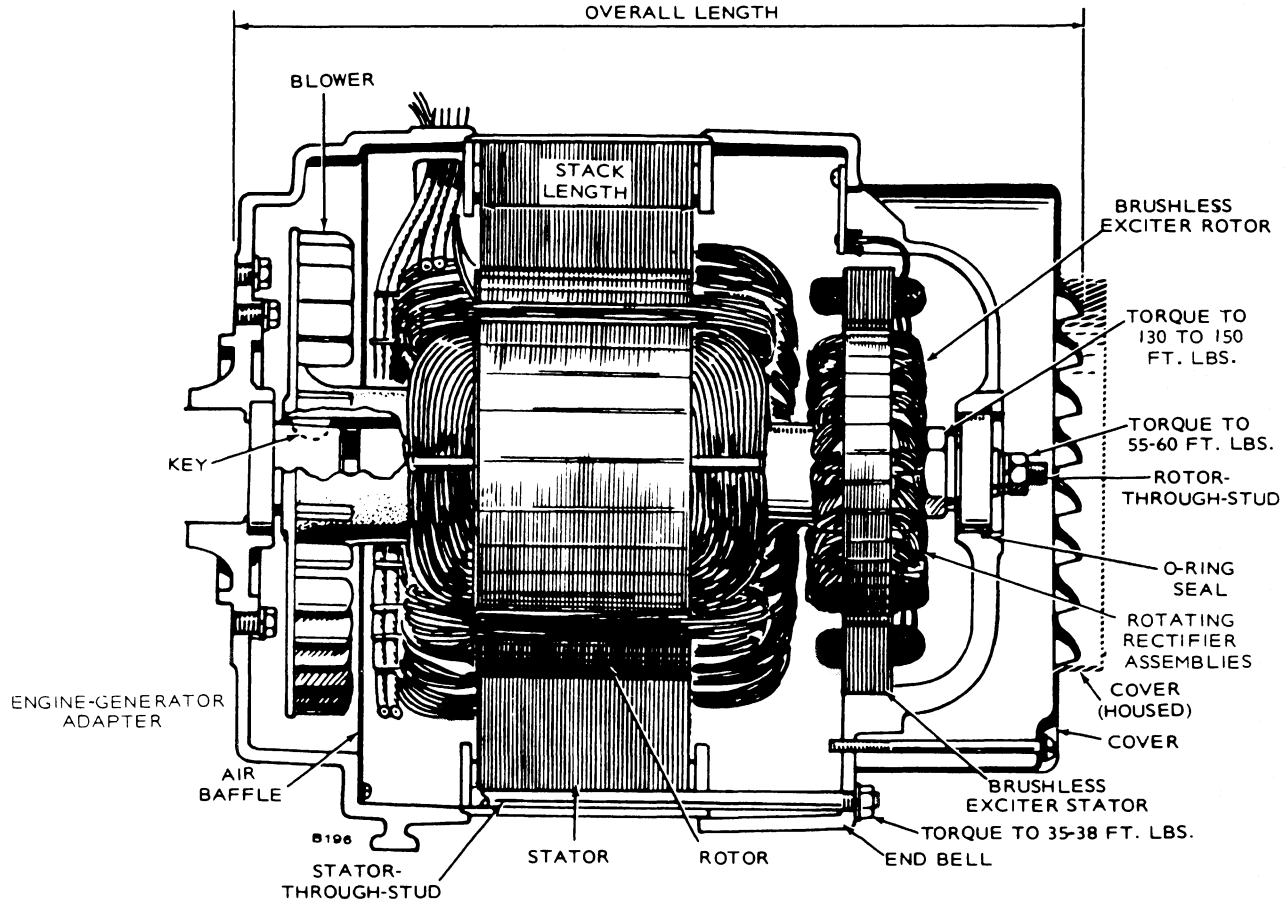


FIGURE 1. GENERATOR (SECTIONAL VIEW)

AC GENERATOR DESCRIPTION

The YD generators beginning with Spec AA (Figure 1) are four-pole, revolving field, brushless exciter, reconnectible models of drip-proof construction. Generator design includes both single and three-phase, 60 and 50 hertz type generators. The generator rotor connects directly to the engine crankshaft with a tapered shaft and key. The generator is fastened to the engine by the rotor-through-stud which passes through the rotor shaft; it has a nut on the outside of the end bell. A centrifugal blower, on the front end of the rotor shaft, circulates the generator cooling air which is drawn in through the end bell cover and discharged through an outlet at the blower end.

A ball bearing in the end bell supports the outer end of the rotor shaft. The end bell and generator stator housing are attached by four-through-studs which pass through the stator assembly to the engine-generator adapter. The brushless exciter stator mounts in the end bell while the exciter rotor and its rotating rectifier assemblies mount on the generator rotor shaft.

F^{1+} and F^{2-} are from the exciter field winding and are

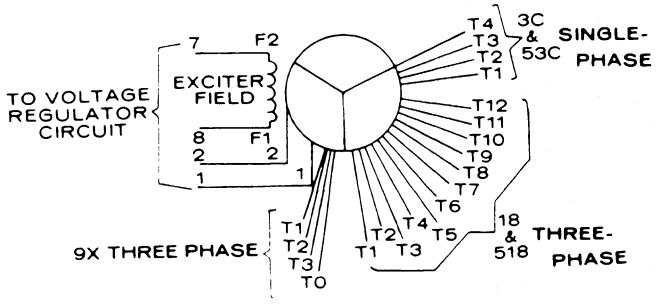


FIGURE 2. SINGLE AND THREE PHASE GENERATOR SCHEMATIC (COMPOSITE)

connected to the output terminals of the voltage regulator. Leads 1 and 2 are connected to the stator windings and provide reference voltage and input power to the voltage regulator. These five leads are connected at the factory.

Figure 2 is a composite illustration showing four output leads for single-phase units, 12 output leads for 3-phase broad range units, and four output leads for code 9X 3-phase 347/600 volt generators.

GENERATOR OPERATION

The basic operation of the generator and voltage regulator involves the stator, voltage regulator, exciter field and armature, a full wave bridge rectifier, and the generator rotor, Figure 3. Residual magnetism in the generator rotor and a permanent magnet embedded in one exciter field pole begin the voltage build-up process as the generator set starts running. Single-phase AC voltage, taken from one of the stator windings, is fed to the voltage regulator as a reference voltage for maintaining the generator output voltage. The AC reference voltage is converted to DC by a silicon controlled rectifier bridge on the voltage regulator printed circuit board and fed into the exciter field windings. The exciter armature produces three-phase AC voltage that is converted to DC by the rotating rectifier assembly. The resultant DC voltage excites the generator rotor winding to produce the stator output voltage for the AC load.

The generator rotor also produces AC voltage in the charging winding of the stator which is converted to direct current for battery charging.

VOLTAGE REGULATOR

The line-voltage regulator (VR22 or VR23) on the Spec AA J-Series generator sets is an all solid state device; that is, no relays or tubes are needed. Basic components of the voltage regulator are:

- Printed circuit board VR21
- Voltage reference transformer T21
- Commutating reactor CMR21
- Field circuit breaker CB21
- Voltage adjust rheostat R22 (Optional)

Figure 4 shows the above components and voltage regulator wiring diagrams for typical control boxes on electric generating sets. The electrical schematic and printed circuit board are shown in Figure 5.

The voltage adjust rheostat (R^{22}) is optional on either VR^{22} or VR^{23} voltage regulator assembly. When R^{22} is used, it is connected between VR^{21-1} and VR^{21-3} (Figure 5) and the jumper between VR^{21-1} and VR^{21-2} (Figure 4) is removed.

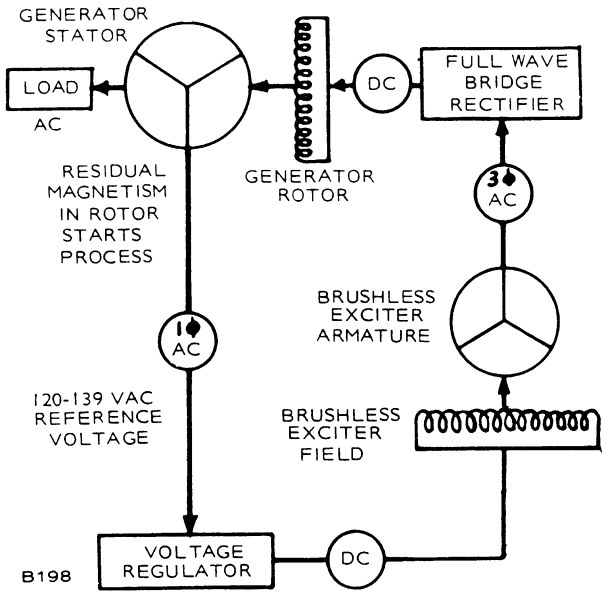


FIGURE 3. EXCITATION BLOCK DIAGRAM

INSTALLATION AND RECONNECTION CAPABILITIES

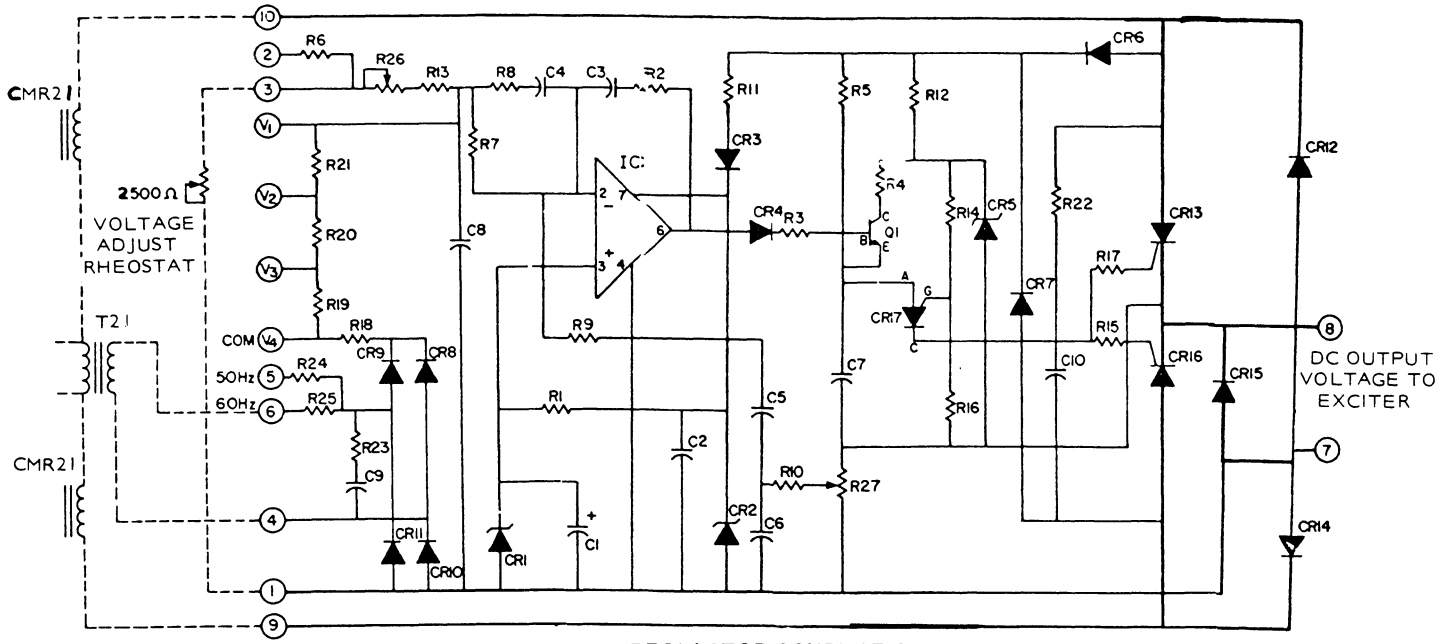
YD generators have the capability of being operated in a number of different voltage connections, and at different voltages in a single connection. The connections and voltages which can be obtained from a given generator are defined by the generator voltage code on the nameplate and listed in Figure 6.

CAUTION **To prevent generator damage, do not attempt to operate a generator with a given voltage code in any connection or at any voltage not listed for that voltage code.**

NOTE 1. When connecting the generator output leads for a new or different connection or when the operating voltage of a single voltage connection is to be changed, be sure that jumper wire W10 on VR^{21} is properly connected from terminal V^4 to V^1, V^2, or V^3 as listed in Figure 6 to provide the correct reference voltage.

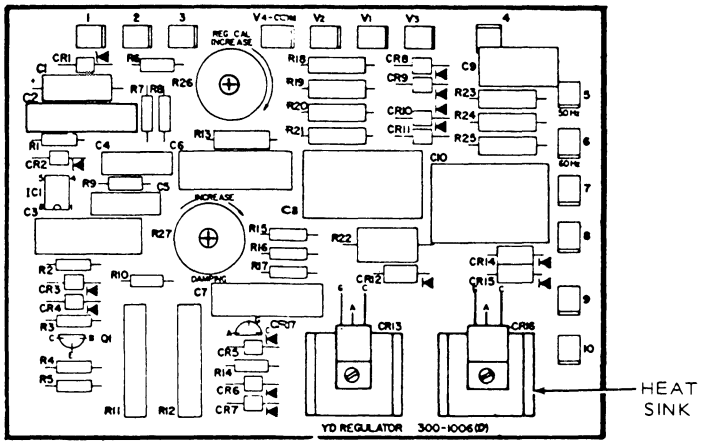
NOTE 2. Connect the wire from transformer T^{21}-X^1 to terminal VR^{21-5} for code -53C and -518 (50 Hertz) generators. Connect T^{21}-X^1 to VR^{21-6} for code -3C, -18, and -9X (60 Hertz) generators. Connect the rest of the wires on the voltage regulator assembly according to the wiring diagram and wiring tabulation chart which applies to your generator set.

Generator sets without a control panel or switchboard containing AC instruments such as voltmeters, ammeters, running time meter, frequency meters, and line circuit breakers are shipped from the factory with the AC output leads separated in the output box. On generator sets with switchboards containing AC instruments, the AC output leads are wired as specified on the customer's purchase order to deliver only the voltage specified.



REGULATOR SCHEMATIC

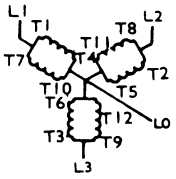
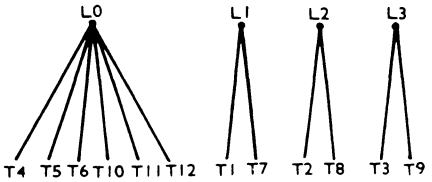
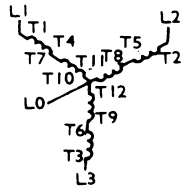
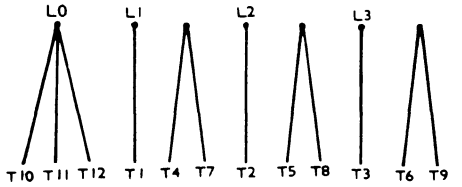
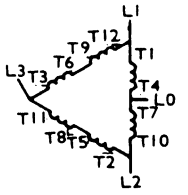
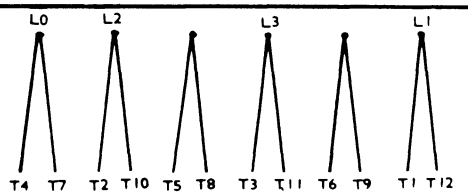
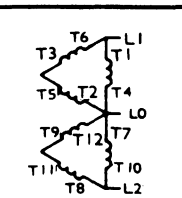
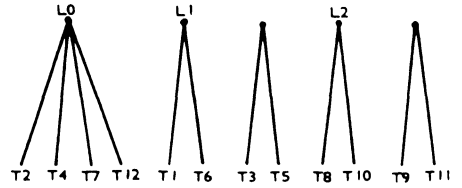
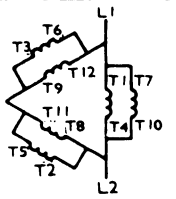
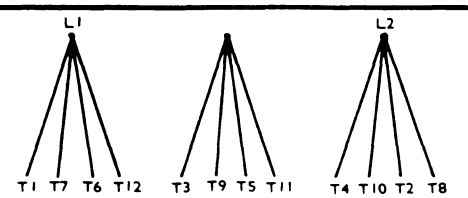
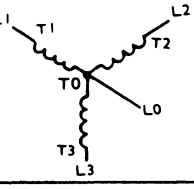
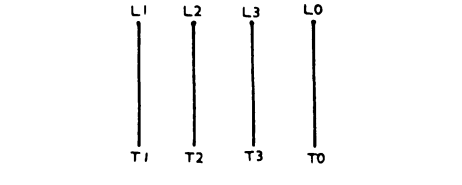
REF. DES.	DESCRIPTION
IC1	Integrated Circuit
Q1	Transistor-NPN
T21	Transformer, Reference Voltage
CMR21	Commutating Reactor
R27	Potentiometer W.W. 8K-Ohm
R26	Potentiometer W.W. 2.5K-Ohm
R25	Resistor-Film 42.2K-Ohm, 1/4W
R24	Resistor-Film 46.4K-Ohm, 1/4W
R23	Resistor 10-Ohm, 1/2W
R22	Resistor 820-Ohm, 2W
R21	Resistor-Film 2.67K, 1/4W
R20	Resistor-Film 1.53K, 1/4W
R19	Resistor-Film 3.09K, 1/4W
R18	Resistor-Film 28.0K, 1/4W
R16	Resistor 8.2K-Ohm, 1/2W
R15,17	Resistor 180K-Ohm, 1/2W
R14	Resistor 2700-Ohm, 1/2W
R13	Resistor-Film 12.1K-Ohm, 1/4W
R11,12	Resistor-Wire Wound 4K, 5W
R9	Resistor 1 MEG Ohm, 1/2W
R8-10	Resistor 100K-Ohm, 1/4W
R7	Resistor 270K-Ohm, 1/2W
R6	Resistor-Film 1.74K-Ohm, 1/4W
R5	Resistor 2 MEG Ohm, 1/2W
R4	Resistor 3K-Ohm, 1/2W
R3	Resistor 330K-Ohm, 1/2W
R2	Resistor 220K-Ohm, 1/2W
R1	Resistor 33K-Ohm, 1/2W
CR17	Transistor-Unijunction
CR13,16	Rectifier-Gate Control
CR12, 14, 15	Rectifier-Diode
CR5	Diode-Zener 18V
CR3,4, 6-11	Rectifier-Diode 400MA 400V
CR2	Diode-Zener 20V
CR1	Diode-Zener 5.6V
C10	Capacitor .47MFD 400V
C9	Capacitor .39MFD 100V
C8	Capacitor 1MFD 100V
C4, C5	Capacitor .1MFD 200V
C3, C7	Capacitor .22MFD 200V
C2, C6	Capacitor .47MFD 100V
C1	Capacitor-Electrolytic 100MFD 10V



PRINTED CIRCUIT BOARD, VR21

NOTE: The 2500 ohm external voltage adjust potentiometer connects between pin 1 and pin 3. See regulator schematic. If your set does not have an external voltage adjust potentiometer, pin 1 is jumpered to pin 2. See Figure 4.

FIGURE 5. VOLTAGE REGULATOR PRINTED CIRCUIT BOARD

NAMEPLATE VOLTAGE CODE	VOLTAGE	PHASE	FREQUENCY	CONNECT W/O JUMPER WIRE FROM V4 TO:	GENERATOR CONNECTION	GENERATOR CONNECTION SCHEMATIC DIAGRAM	LOAD TO GENERATOR CONNECTION WIRING DIAGRAM CONNECT X1 TO VR21-5 FOR 50 HERTZ: CONNECT X1 TO VR21-6 FOR 60 HERTZ GENERATORS.
3C	120/240	1	60	V1		A, B, C	A, B, C
53C	120/240	1	50	V1			
	115/230	1	50	V2			
	110/220	1	50	V3			
18	120/208	3	60	V1	PARALLEL WYE		
	127/220	3	60	V2			
	139/240	3	60	V4			
518	110/190	3	50	V1			
	115/200	3	50	V2			
	120/208	3	50	V3			
	127/220	3	50	V4			
18	240/416	3	60	V1	SERIES WYE		
	254/440	3	60	V2			
	277/480	3	60	V4			
518	220/380	3	50	V1			
	230/400	3	50	V2			
	240/416	3	50	V3			
	254/440	3	50	V4			
18	120/240	3	60	V1	SERIES DELTA		
518	110/220	3	50	V1			
	115/230	3	50	V2			
	120/240	3	50	V3			
18	120/240	1	60	V1	DOUBLE DELTA		
518	110/220	1	50	V1			
	115/230	1	50	V2			
	120/240	1	50	V3			
18	120	1	60	V1	PARALLEL DELTA		
518	110	1	50	V1			
	115	1	50	V2			
	120	1	50	V3			
9X	347/600	3	60	V4	WYE		

B206

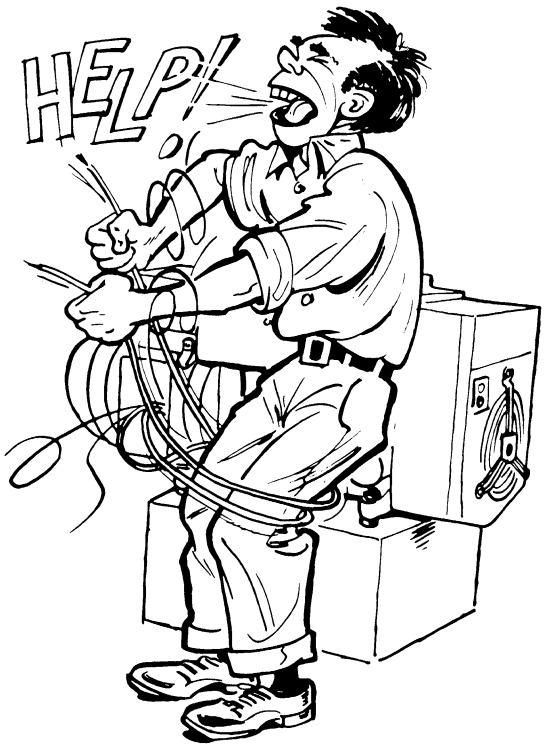
FIGURE 6. GENERATOR WIRING AND RECONNECTION DIAGRAMS

VOLTAGE RECONNECTION WITH OPTIONAL INSTRUMENTS

The optional AC instruments on the control panel (such as voltmeters, ammeters, transformers, and running time meters) are intended for use with specific nameplate voltages. Control components may have to be changed to match new current ratings when field reconnection for other voltage codes or voltages are made.

Under no circumstances shall the generator be connected in any other manner than shown in Figure 6.

Severe damage will result if leads are incorrectly connected or improperly insulated. Use extreme care in checking leads to assure proper connections.



ADJUSTMENTS AND TESTS

GENERAL

The adjustment and test procedures herein are referenced in the generator troubleshooting tables, pages 18-20. The following information is needed by servicemen to effectively service or repair J-series generators beginning with Spec AA.

[A]

VOLTAGE CALIBRATION ADJUSTMENT

The calibration adjustment is made using an accurate AC voltmeter to observe generator output voltage and to set the correct no load voltage. If voltage regulator VR^{21} printed circuit board has been replaced, it may be necessary to make a calibration adjustment. To obtain the correct output voltage, proceed as follows:

1. If set has a voltage adjust potentiometer (R^{22}) on the meter panel, set pointer halfway between minimum and maximum positions.
2. With unit running at no load, turn generator voltage potentiometer R^{26} on VR^{21} (Figure 4) clockwise to increase output voltage; turn R^{26} counterclockwise to decrease output voltage.

[B]

VOLTAGE STABILITY ADJUSTMENT

Voltage stability is set at the factory, but if printed circuit board VR^{21} has been replaced or if damping potentiometer R^{27} has been unnecessarily adjusted it may be necessary to reset stability. Set stability as follows:

1. With generator set running at no load, turn potentiometer R^{27} (Figure 4) to a position where voltage tends to be unstable or hunt.
2. Turn R^{27} clockwise slowly until voltage first stabilizes. This setting will result in stable voltage under all conditions in maximum voltage regulator response time.

[D]

VOLTAGE REGULATOR CHECKOUT

The solid state voltage regulators (VR^{21}) can be checked out on the bench for proper operation or location of faulty components. The following test equipment (one-each) is required for a proper checkout.

REF. DESIGNATION	TEST EQUIPMENT
S	Switch
CMR21	Reactor
F	Fuse, 5 Amps
T1	Transformer, Variable 2 Amp 0-150V
V2	Voltmeter, DC ± 2% of Full Scale 3, Scale 0-50 and 0-150V and 0-10V
V1	Voltmeter, AC ± 2% @ 10VAC, 1% @ 150V
R1	Resistor, 100-Ohm 400 W
T21	Transformer, Input 315-0386

Bench Check:

1. Remove voltage regulator from unit according to procedure given for voltage regulator replacement.
2. Referring to Figure 7 and Table 1, connect test equipment to the printed circuit board VR^{21} terminals as follows:

CONNECT	FROM	TO
Jumper	VR21-V1	VR21-V4
Jumper	VR21-1	VR21-2
Lead	CMR21-1	VR21-10
Lead	CMR21-4	VR21-9
Lead	T21-X1	VR21-6
Lead	T21-X2	VR21-4
AC Voltmeter	Across	T21-H1 & H2
DC Voltmeter	Across	CR21-7 & 8
VARIAC	Across	T21-H1 (fused) and H2

3. Open switch in 120 VAC supply to VARIAC.
4. Plug VARIAC into 120 VAC source.
5. Proceed with checkout according to steps in Table 1.

[E]

FLASHING THE FIELD

The following procedure is used for momentarily flashing the exciter field with a low voltage which restores the residual magnetism in the alternator rotor. Flashing the field is usually necessary when installing a new brushless exciter stator wound assembly, but seldom is necessary under other circumstances. Always check generator residual voltage at terminals 1 and 2 to be certain whether or not flashing the field is necessary. Generator residual voltage should be at least 20 VAC at rated speed. If residual is too low and the output voltage will not build up, flash the field as follows:

1. Locate terminals 7(-) and 8(+) on voltage

TABLE 1. VOLTAGE REGULATOR CHECKOUT

V_1 AC INPUT VOLTAGE
V_2 DC OUTPUT VOLTAGE
(>= LESS THAN) (<= MORE THAN)

STEP NO.	TEST NAME	PROCEDURE	REQUIREMENTS
1	BUILD UP	SET V_1 TO 25 VAC	V_2 SHALL BE > 12 VDC
2	CALIBRATION	SET V_1 TO 120 VAC	SET POT R26 TO HOLD V_2 BETWEEN 50-70 VDC
3	RANGE	A. SET V_1 TO 123 VAC B. SET V_1 TO 125 VAC	V_2 SHALL BE < 30 VDC V_2 SHALL BE < 10 VDC
4	RANGE	A. SET V_1 TO 115 VAC B. SET V_1 TO 117 VAC	V_2 SHALL BE > 85 VDC V_2 SHALL BE > 80 VDC
5	MAX VOLTAGE	SET V_1 TO 150 V	V_2 < 10 VOLTS
6	DAMPING	SET V_1 SO V_2 IS NEAR MAXIMUM RAPIDLY TURN POT R27 FROM FULL COUNTER CLOCKWISE POSITION TO FULL CLOCKWISE POSITION. RETURN R27 TO MIDRANGE POSITION AFTER TEST.	V_2 SHOULD DROP TO < 50 VOLTS THEN RISE TO ORIGINAL VALUE.

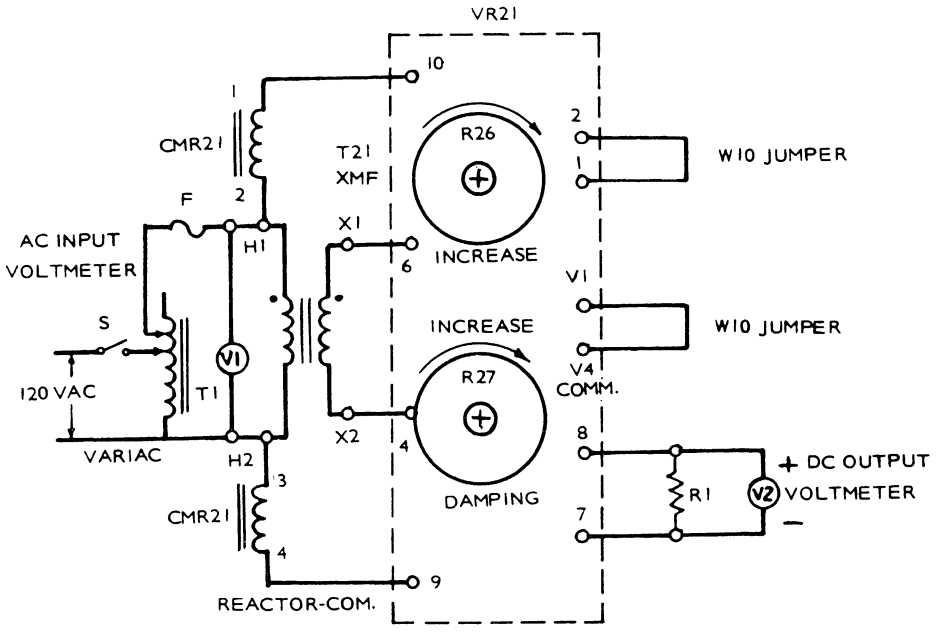


FIGURE 7. VOLTAGE REGULATOR CHECKOUT TEST EQUIPMENT CONNECTIONS

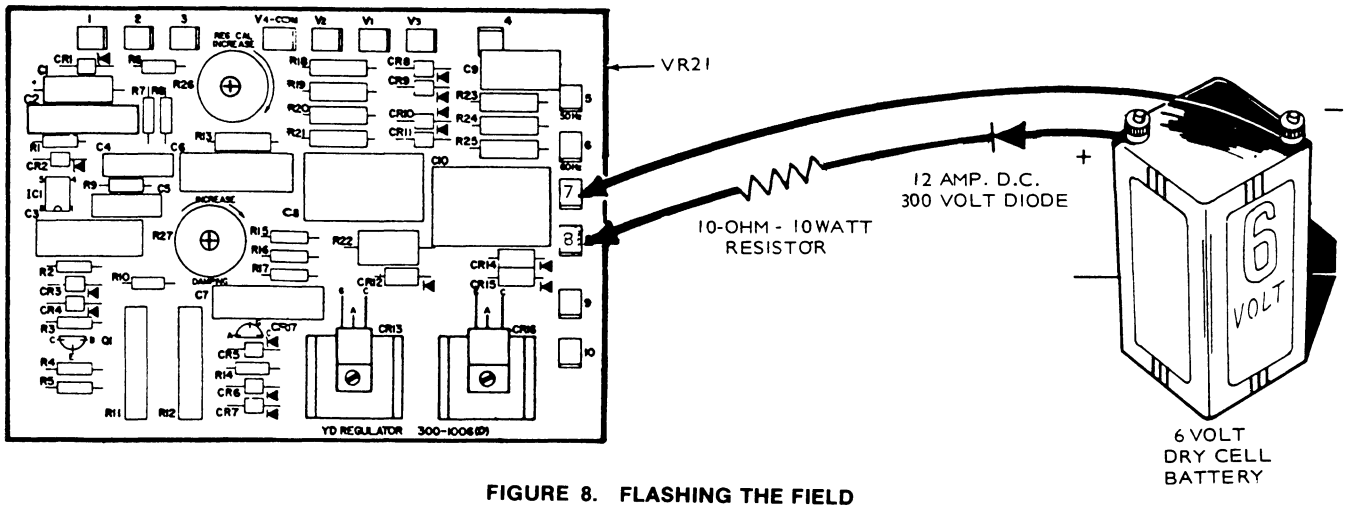


FIGURE 8. FLASHING THE FIELD

regulator printed circuit board (VR^{21}).

2. Use a six volt dry cell battery with two clip leads, a 12 amp DC, 300 volt avalanche diode, and a 10-ohm resistor as shown in Figure 8. If a six volt battery is not available, a 12 volt automotive battery can be used by increasing the 10-ohm resistance to 20-ohms; or a 24 volt automotive battery can be used by increasing the resistance to 40-ohms.

CAUTION **A series resistor MUST be used to protect the meter. Polarity must be observed.**

3. After starting engine, touch positive (+) battery lead to VR^{21-8} and negative (-) lead to VR^{21-7}, contact terminals just long enough until voltage starts to build up or damage may occur to exciter-regulator system.

WARNING **Be cautious when working on a generator that is running to avoid electrical shocks.**

TEST PROCEDURES

All of the following tests can be performed without disassembly of the generator as shown in the illustrations herein. Use the following test procedures for testing generator components in conjunction with the troubleshooting tables.

[F]

TESTING ROTATING RECTIFIERS

Two different rectifier assemblies make up the rotating rectifier bridge assembly, Figure 9. Using an accurate ohmmeter, test each CR using negative and positive polarities. Test rectifiers as follows:

1. Disconnect all leads from assembly to be tested.
2. Connect one test lead to $F^{1}+$ stud and connect other lead to CR^{1}, CR^{2}, and CR^{3} in turn; record resistance value of each rectifier.
3. Connect one lead to $F^{2}-$ stud and connect other lead to CR^{3}, CR^{4} and CR^{5} in turn; record resistance value of each rectifier.
4. Reverse ohmmeter leads from step 2 and record resistance value of each rectifier $F^{1}+$ to CR^{1}, CR^{2}, and CR^{3} and $F^{2}-$ to CR^{4}, CR^{5}, and CR^{6}.
5. All three resistance readings should be high in one test and low in the other test. If any reading is high or low in both tests, rectifier assembly is defective.
6. Replace defective rectifier assembly with new, identical part.

Use 24 lbs-in. torque when replacing nuts on $F^{1}+$ and $F^{2}-$, CR^{1}, CR^{2}, CR^{3}, CR^{4}, CR^{5}, and CR^{6}.

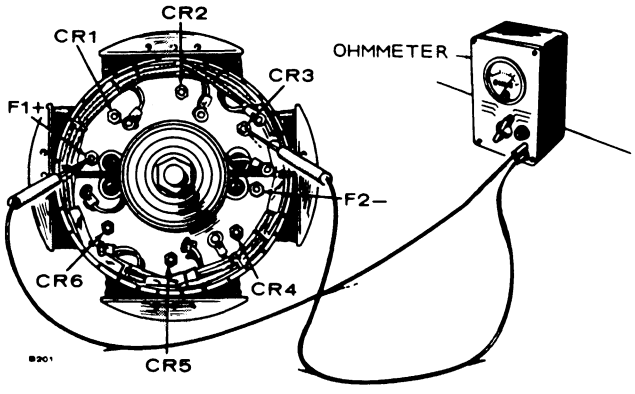


FIGURE 9. TESTING ROTATING RECTIFIERS

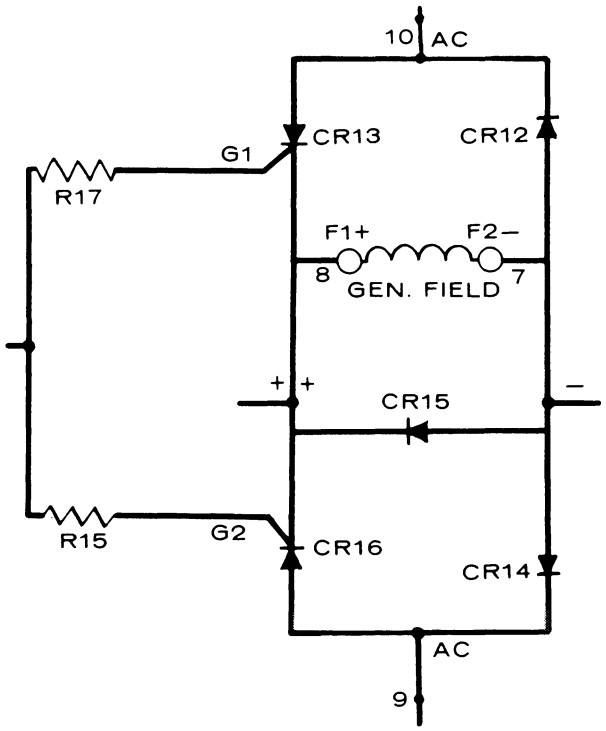


FIGURE 10. SILICON CONTROLLED RECTIFIER BRIDGE

[G]

TESTING OUTPUT BRIDGE DIODES

The output bridge rectifier diodes (Figure 10), CR^{12}, CR^{14}, and CR^{15}, are located on the voltage regulator printed circuit board. Using an accurate ohmmeter, test diodes CR^{12}, CR^{14}, and CR^{15} as follows:

1. Disconnect at least one lead of diode.
2. Connect one lead to each end of diode and observe resistance reading, Figure 11.
3. Reverse ohmmeter leads and again observe resistance readings.

   A good diode has a higher reading in one direction than the other. If both readings are high, or low, diode is defective.

4. Replace defective diodes with new, identical parts.

[H]

TESTING SCR'S

Two identical silicon controlled rectifiers (SCR'S), CR^{13} and CR^{16}, control the DC output voltage to the exciter field. These SCR'S are mounted in heat sinks on the voltage regulator and are tested as follows:

1. Unsolder leads from CR^{13} and CR^{16}.
2. Using high scale on ohmmeter, connect ohmmeter leads to anode and cathode of the SCR as shown in Figure 12. The resistance reading should be one megohm or greater. Reverse ohmmeter leads to anode and cathode; resistance should again be one megohm or greater.

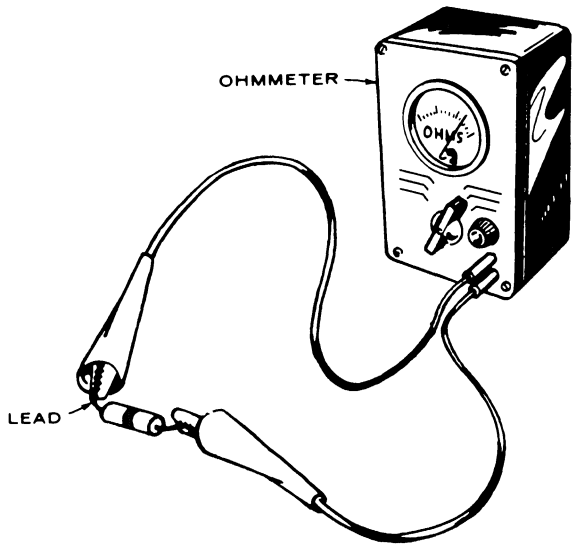


FIGURE 11. TESTING DIODES

3. Using a 6-volt dry cell battery and a 200-ohm series resistor, observe correct polarity and connect battery leads to anode and cathode as shown in Figure 13. Observe polarity and connect a DC voltmeter across the 200 ohm resistor. The voltmeter should now read zero. Jumper anode to gate; voltmeter should now read 6-volts. Remove jumper; voltmeter should still read 6-volts because the SCR remains turned on until voltage is removed from anode to cathode.

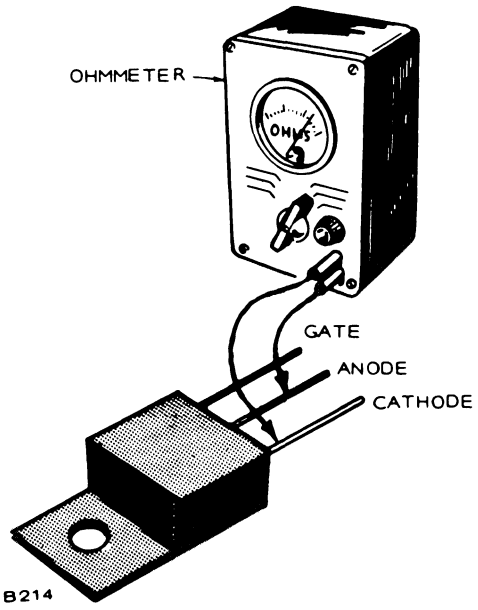


FIGURE 12. SCR RESISTANCE TEST

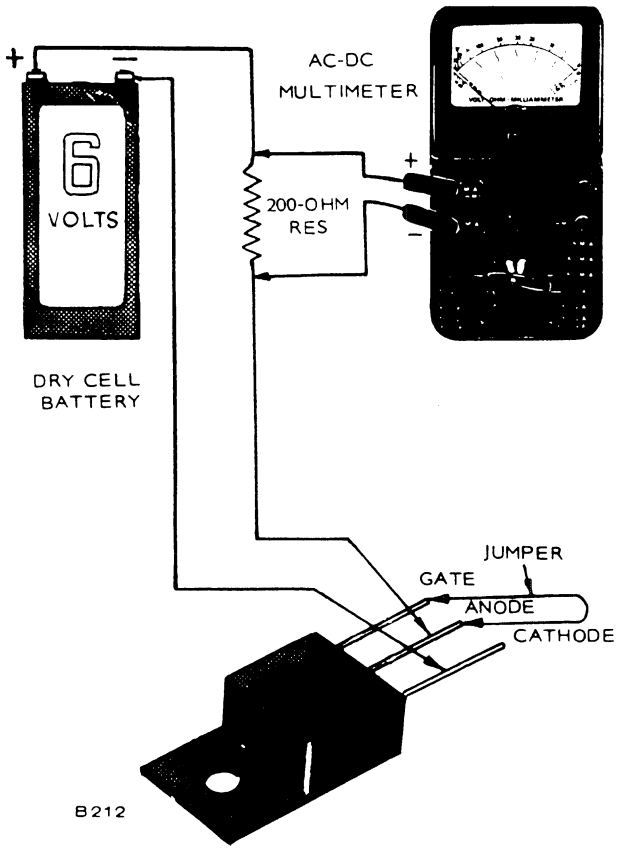


FIGURE 13. SCR VOLTAGE TEST

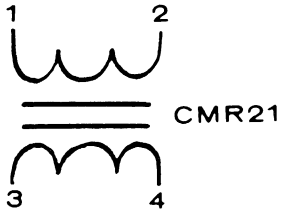
because the SCR remains turned on until voltage is removed from anode to cathode.

4. If the SCR does not pass either test, it is defective. Replace defective SCR with a new, identical part.

[I]

TESTING REACTOR

The reactor assembly CMR^{21} leads are marked 1, 2, 3 and 4. Wires 1-2 and 3-4 are wound on the same iron core.

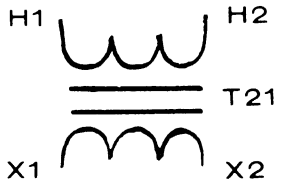


1. Resistance between 1-2 and 3-4 should be about 0.4-ohms.
2. Resistance between 1-3, 2-3, 1-4, or 2-4 should be infinity (∞).
3. Resistance from any terminal to reactor frame should be infinity.
4. If any of the above conditions are not met, install a new reactor.

[J]

TESTING REFERENCE TRANSFORMER

The transformer T^{21} has four leads marked H^1, H^2, X^1, and X^2. H^1-H^2 are the primary leads. X^1-X^2 are the secondary leads.



1. Resistance between H^1-H^2 should be 122 to 150-ohms.
2. Resistance between X^1-X^2 should be 157 to 192-ohms.
3. Resistance between H^1-X^1, H^1-X^2, H^2-X^1 and H^2-X^2 should be infinity.
4. Resistance from any terminal to transformer frame should be infinity.
5. If any of the above conditions are not met, install a new reference transformer.

[K]

TESTING BRUSHLESS EXCITER STATOR

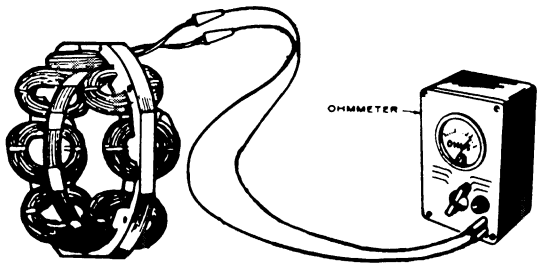
Like the generator, the brushless exciter stator (Figure 14) can be tested for open or shorted windings and grounds.

Testing for Open or Shorted Windings:

Disconnect F^{1+} and F^{2-} exciter field leads from terminal block in generator end bell. The resistance between field leads should be 12.2 ± 10% at 20 C (68 F.).

Testing for Grounds:

Connect ohmmeter between either field lead and exciter stator laminations. Use ohmmeter set at RX 100 scale. An ohmmeter reading of less than infinity (∞) indicates defective ground insulation.



OHMMETER RESISTANCE BETWEEN
F1 AND F2 SHOULD BE
12.2 OHMS (± 10%)

FIGURE 14. TESTING EXCITER FIELD

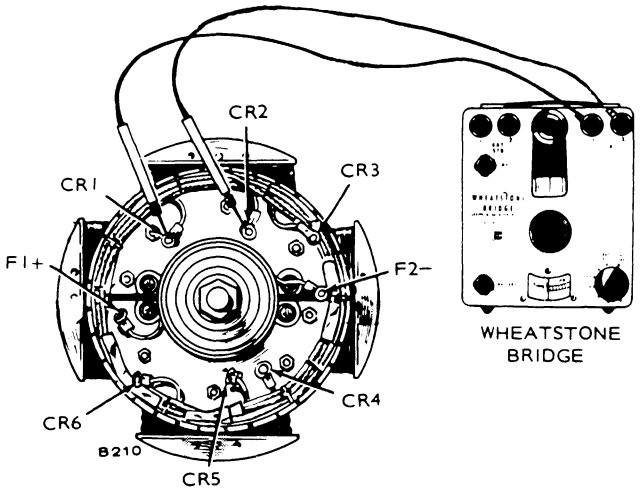


FIGURE 15. TESTING EXCITER ARMATURE

[L]

TESTING BRUSHLESS EXCITER ROTOR (ARMATURE)

The brushless exciter rotor (Figure 15), can be tested for open or shorted windings or grounds.

Testing for Open or Shorted Windings:

Use a Wheatstone Bridge for this test. Disconnect main rotor field leads which connect to rotating rectifier assemblies at F^1+ and F^2-. Disconnect lead wires from diodes CR^1, CR^2, CR^3, CR^4, CR^5 and CR^6. Test between exciter lead pairs T^1-T^2, T^2-T^3 and T^1-T^3. Resistance should be 0.5 to 0.6 ohms at 20 C (68 F.).

Testing for Grounds:

Connect leads of ohmmeter between each CR lead and exciter rotor laminations; use RX 100 scale on ohmmeter. An ohmmeter reading less than infinity (∞) indicates defective ground insulation.

[M]

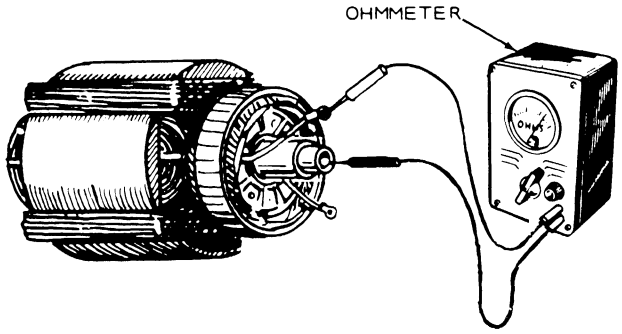
TESTING GENERATOR ROTOR

For these tests, use an ohmmeter on RX 100 scale.

Testing for Grounds:

On brushless type generators, check for grounds between each rotor lead and the rotor shaft, Figure 16 . Perform tests as follows:

1. Remove rotor leads F^1+ and F^2- from rotating rectifier assemblies.
2. Connect ohmmeter leads between F^1+ and rotor shaft and between F^2- and rotor shaft. Meter should not register.
3. If meter registers, rotor is grounded.
4. Replace grounded rotor with new, identical part.



CONTACT ONE PROD TO EACH OF THE FIELD LEADS AND OTHER PROD TO ROTOR SHAFT. IF ROTOR IS GOOD, THERE WILL BE NO READING ON OHMMETER.
B215

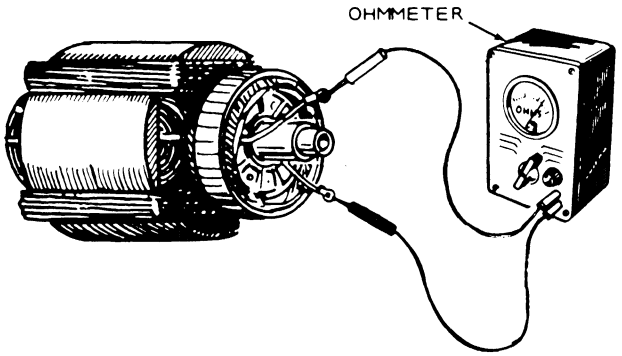
FIGURE 16. TESTING ROTOR FOR GROUNDS

Testing for Open or Shorted Winding:

All resistance values should be within ± 10% of values specified in Table 2 at 20° C. (68° F). Perform tests as follows:

1. Remove rotor leads F^1+ and F^2- from rotating rectifier assemblies.
2. Using ohmmeter, check resistance between F^1 and F^2 leads, Figure 17. See Table 2 for proper resistance values.

   If resistance is low, there are shorted turns. If resistance is high, rotor winding is open. In either case, rotor must be replaced.
3. Replace defective rotor with new, identical part.



CONTACT ONE PROD TO ONE FIELD LEAD AND OTHER PROD TO OTHER FIELD LEAD. RESISTANCE VALUES ARE GIVEN IN TABLE 2.
B213

FIGURE 17. TESTING ROTOR FOR AN OPEN CIRCUIT

TABLE 2. RESISTANCE VALUES FOR ROTORS

Resistance in Ohms at 25C (77F)		
10 KW	60 HZ	2.05-2.09
15 KW	60 HZ	2.50-2.55

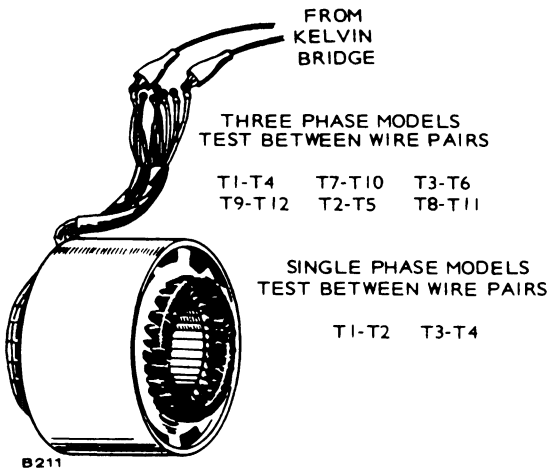


FIGURE 18. TESTING STATOR WINDINGS

[N]

TESTING GENERATOR STATOR

Using proper test equipment, check the stator for grounds, opens, and shorts in the windings.

Testing for Grounds:

Some generators have ground connections to the frame. Check wiring diagram.

Using an ohmmeter set at RX 100, test each stator winding for shorts to laminations. A reading less than one megohm indicates a ground.

Testing for Open or Shorted Windings:

Test for continuity between coil leads shown in Figure 18; all pairs should have equal resistance. Use an accurate instrument for this test such as a Kelvin Bridge. The proper resistance values are given in Table 3 according to KW ratings and voltage codes. All resistances should be ± 10% of value shown at 20° C. (68° F).

If any windings are shorted, open or grounded, replace the stator assembly. Before replacing the assembly, check the leads for broken wires or insulation.

[O]

WIRING HARNESS CHECK

Carefully check wiring harnesses as follows:

1. Inspect all wires for breaks, loose connections, and reversed connections. Refer to applicable wiring diagram.

TABLE 3. RESISTANCE VALUES FOR STATORS

10 KW	60 HZ	1 PH	.172
10 KW	60 HZ	3 PH	.340
15 KW	60 HZ	1 PH	.087
15 KW	60 HZ	3 PH	.220

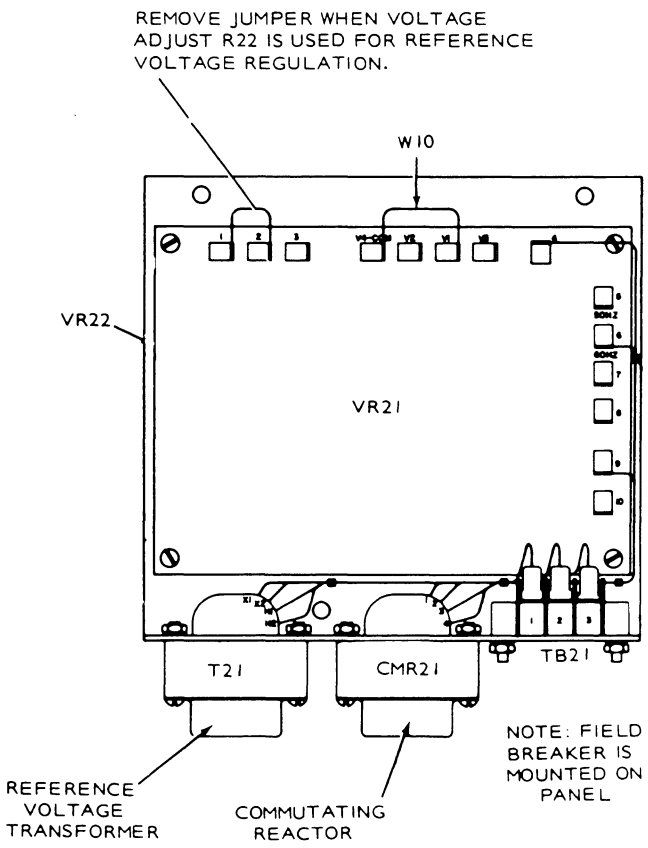
2. Remove wires from terminals at each end and using an ohmmeter, check each wire end to end for continuity or opens.
3. Using an ohmmeter, check each wire against each of the other wires for possible shorts or insulation breaks under areas covered by wrapping material.
4. Reconnect or replace wires according to applicable wiring diagram.

[P]

VR21 REPLACEMENT

Use the following procedure for replacing the voltage regulator PC board.

1. Stop engine.
2. Disconnect and if necessary, label the following wires: 3, 4, 5 or 6, 7, 8, 9, and 10.
3. Remove four screws at corners.
4. Remove used PC board.
5. Install new PC board; secure with four screws.
6. Reconnect wires removed in step 2 at the proper terminals.
7. Place jumper W10 at proper terminals for your particular voltage code and voltage connection. See Figure 6.
8. Perform voltage calibration and stability adjustment procedures to obtain the correct generator output voltage and stability with new PC board in set.



GENERATOR DISASSEMBLY

Disconnect battery to prevent accidental starting of engine.

Remove end bell cover to reveal rotor-through-stud nut.

Remove stator-through-stud nuts, end bell, and stator assembly, Figure 20. Screwdriver slots in adapter provide a means for prying stator loose. Be careful not to let stator touch or drag on rotor.

Remove baffle ring from adapter. Turn rotor-through-stud nut to end of stud. While pulling rotor outward with one hand, strike nut a sharp blow. Support rotor with hoist and sling to avoid bending rotor-through-stud, Figure 21. Use a heavy, soft faced hammer to loosen the rotor from its tapered shaft fit. If rotor does not come loose, strike it a sharp downward blow in center of lamination stack. Rotate rotor and repeat until it comes loose. Be careful not to hit bearing or windings.

After disassembly, all parts should be wiped clean and visually inspected.

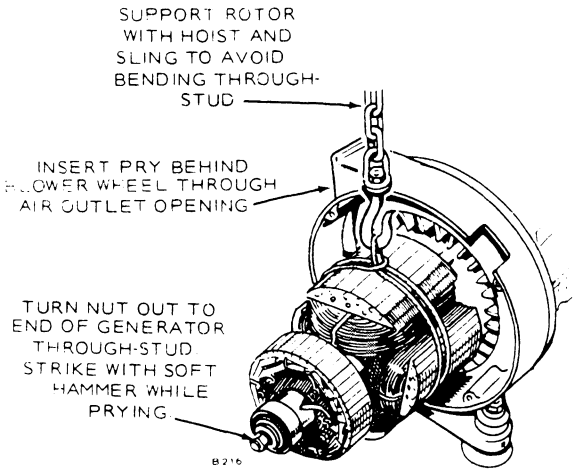


FIGURE 21. ROTOR REMOVAL

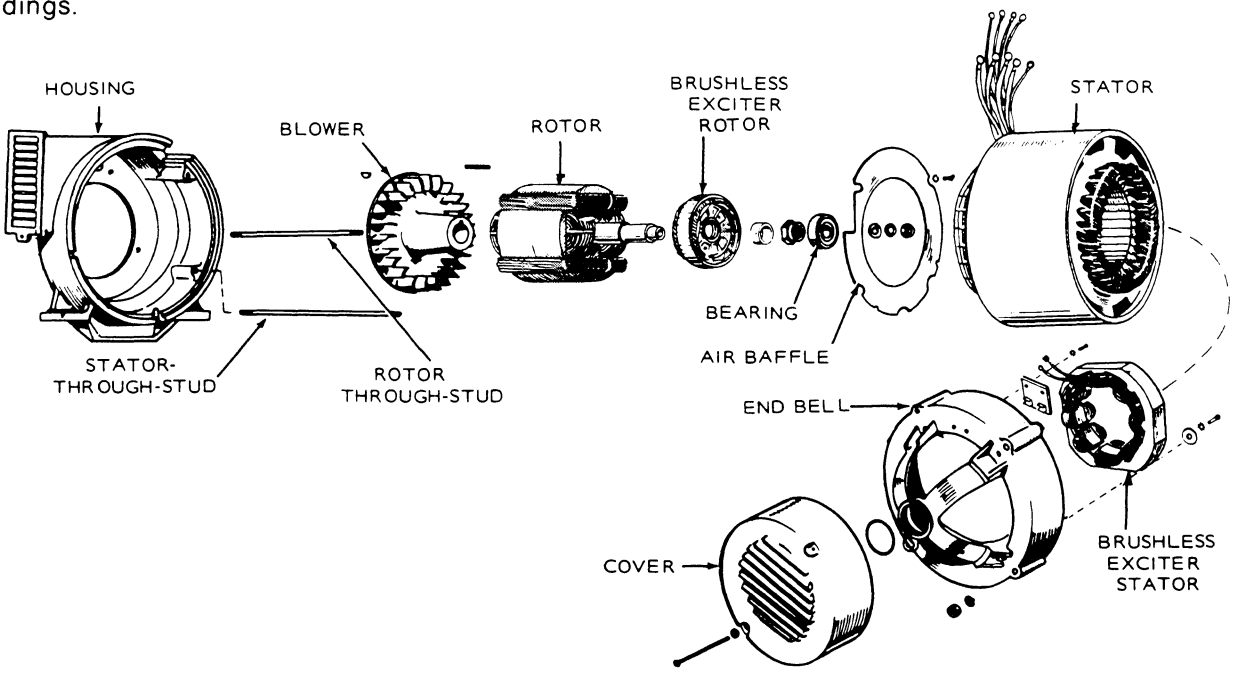


FIGURE 20. GENERATOR DISASSEMBLY

GENERATOR ASSEMBLY

Clean and inspect all mating surfaces.

Coat mating area between generator bearing and end bell bearing hole with a thin film of Molykote or equal.

Install rotor-through-stud in engine crankshaft.

Install key in the crankshaft.

Slide rotor over through-stud and onto crankshaft. Be careful not to let weight of rotor rest on or bend the through-stud.

Install baffle ring.

Install stator through-studs in adapter.

Install stator and end bell. Torque nuts on through-studs to 35 to 38 ft-lbs.

Torque down rotor-through-stud nut (55-60 ft. lb.). The rotor and stator are automatically aligned because stator and bearing support were tightened in step 8.

Tap end bell to align at horizontal and vertic plane; use a lead hammer to relieve stresses components (recheck torque).

Install end cover.

GENERATOR TROUBLESHOOTING

PREPARATION

A few simple checks and a proper troubleshooting procedure can locate the probable source of trouble and cut down troubleshooting time.

1. Check all modifications, repairs, replacements performed since last satisfactory operation of set to be sure that connection of generator leads are correct. A loose wire connection, overlooked when installing a replacement part could cause problems. An incorrect connection, an opened circuit breaker, or a loose plug-in printed circuit board are all potential malfunction areas to be eliminated by a visual check.
2. Unless absolutely sure that panel instruments are accurate, use portable test meters for troubleshooting.
3. Visually inspect components on VR21. Look for dirt, dust, or moisture and cracks in the printed solder conductors. Burned resistors, arcing tracks are all identifiable. Do not mark on printed circuit boards with a pencil. Graphite lines are conductive and can cause short circuits between components.

The question and answer troubleshooting guide which follows, gives a step-by-step procedure for checking the generator components. Refer to Figure 22 for an electrical schematic of the generator and voltage regulator connections.

TROUBLESHOOTING PROCEDURES

This troubleshooting information is divided into tables, A, B, C, and D as follows:

A. No build up of AC output voltage.
B. AC output voltage builds up, but is unstable.
C. AC output voltage builds up, but is high or low.
D. AC output voltage builds up, but field breaker trips.

To correct a problem, answer the question of the step either YES or NO. Then refer to the step number in the answer column and proceed to that step next.

Letters A through P in the Test Procedure column refer to detailed procedures in the Adjustments and Tests section, pages 8-15.

TABLE A. No Build Up of AC Output Voltage	Yes	No	Test Proc.
1. Is Field Breaker CB21 on control panel ON?	2	3	
2. Connect jumper wire across terminals of Field Breaker, CB21. Does AC output voltage build up? If voltage builds up REPLACE FIELD BREAKER.	—	4	
3. Push to reset Field Breaker. Does AC output voltage build up? If voltage builds up but is high, low, unstable, or causes tripping of Field Breaker, refer to Tables B, C, or D.	—	4	
4. Disconnect alternator stator leads 1 & 2 from TB21-1 and TB21-2 on VR22. Is reference voltage across 1 & 2 20 VAC or more?	14	13	

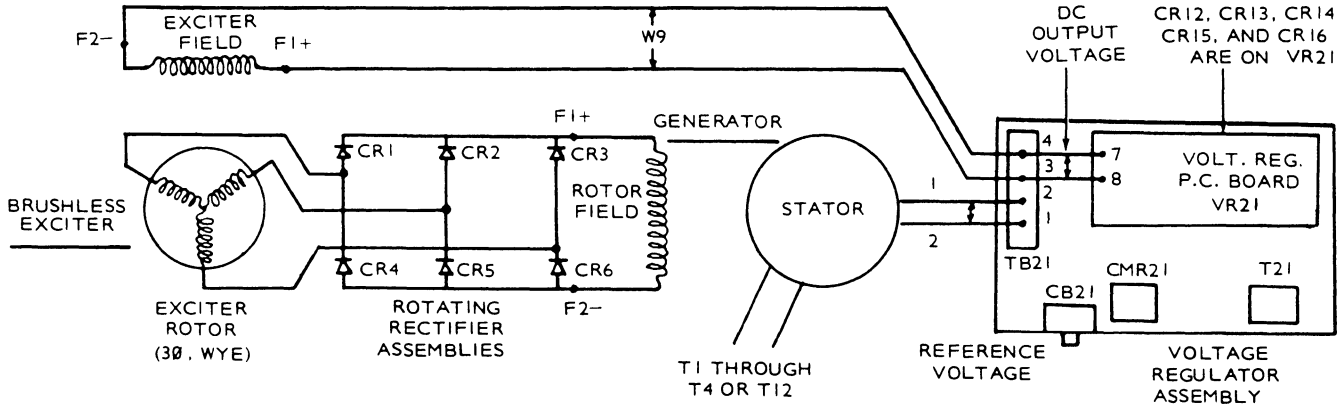


FIGURE 22. GENERATOR-REGULATOR ELECTRICAL SCHEMATIC

TABLE A. (continued)	Yes	No	Test Proc.
5. Is exciter field voltage across F1+ and F2- on endbell terminal block 7.0 VDC or more? If not, check wiring harness W9 from end bell to VR22 terminals 3 and 4.	6	—	
6. Is brushless exciter stator (field) winding OK?	7	—	K
7. Are diodes CR1, CR2, CR3, CR4, CR5, CR6 in rotating rectifier assemblies OK? Check all diodes - more than one may be defective.	8	—	F
8. Are brushless exciter rotor windings OK?	9	—	L
9. Is generator rotor field winding OK?	10	—	M
10. Are generator stator windings OK?	11	—	N
11. Is commutating reactor CMR21 OK?	12	—	I
12. Is reference transformer T21 OK?	18	—	J
13. Flash exciter field. Is reference voltage across 1 and 2 now 20 VAC or more?	14	5	E
14. Reconnect generator leads 1 & 2 to TB21-1 and TB21-2 on VR22. Does reference voltage build up?	—	15	
15. Is regulator DC output voltage across VR21-7 and VR21-8 7 VDC or more? See Figure 22.	5	16	
16. Are SCR's CR13 and CR16 OK?	17	—	H
17. Are diodes CR12, CR14, and CR15 OK?	18	—	G
18. Replace voltage regulator PC board (VR21)	—	—	P

TABLE B. AC Output Voltage Builds Up, But Is Unstable	Yes	No	Test Proc.
1. Are there any loose or broken wires or connections on voltage regulator assembly VR22?	—	2	
2. Is W9 (exciter field) wiring harness from VR22 to End bell OK?	3	—	
3. Does adjustment of Damping Control R27 potentiometer on VR21 result in stable voltage?	—	4	A
4. Replace PC Board VR21.	—	—	P

CAUTION **Do not replace the printed circuit board until the trouble not on the PC board has been located and corrected to avoid damage to new PC board.**

TABLE C. AC Output Voltage Builds Up, But is High or Low	Yes	No	Test Proc.
1. Is set running at correct RPM? (See appropriate engine manual to set RPM)	2	—	
2. Does adjustment of Voltage Adjusting knob for R22 on VR22 result in correct output voltage?	—	3	A
3. Does adjustment of potentiometer R26 on VR21 result in correct output voltage?	—	4	A
4. Is correct voltage reference V4 to V1, V2, or V3 on VR21 being used? Refer to Figure 6.	5	—	
5. Are generator output leads properly connected? Refer to Figure 6.	6	—	
6. Replace voltage regulator, PC board VR21	—	—	P

CAUTION **Do not replace the printed circuit board until the trouble not on the PC board has been located and corrected to avoid damage to new PC board.**

TABLE D. AC Output Voltage Builds Up, But Field Breaker Trips	Yes	No	Test Proc.
1. Does AC output voltage build up to 140% or more of rated voltage before Field Breaker trips?	2	7	—
2. Are there any loose or broken wires or connections on VR22?	—	3	
3. Is diode CR15 on VR21 OK?	4	—	G
4. Are T21 windings and connections OK?	5	—	J
5. Are generator stator leads properly connected? Refer to Figure 6.	6	—	—
6. Replace VR21.	—	—	P
7. Are diodes CR1, CR2, CR3, CR4, CR5, CR6 in rotating rectifier assemblies OK? Check all diodes - more than one may be defective.	8	—	F
8. Is brushless exciter stator winding OK?	9	—	K
9. Is generator rotor field winding OK?	10	—	M
10. Is brushless exciter rotor OK?	11	—	L
11. Are generator stator windings OK?	6	—	N

ADJUSTMENTS AND TESTS — REFERENCE LIST

A. VOLTAGE CALIBRATION ADJUSTMENT
B. VOLTAGE STABILITY ADJUSTMENT
C. BATTERY CHARGE RATE ADJUSTMENT
D. VOLTAGE REGULATOR CHECKOUT
E. FLASHING THE FIELD
F. TESTING ROTATING RECTIFIERS
G. TESTING OUTPUT BRIDGE DIODES
H. TESTING SCR'S
I. TESTING REACTOR
J. TESTING REFERENCE TRANSFORMER
K. TESTING EXCITER STATOR
L. TESTING BRUSHLESS EXCITER ROTOR (ARMATURE)
M. TESTING GENERATOR ROTOR
N. TESTING GENERATOR STATOR
O. WIRING HARNESS CHECK
P. VR21 REPLACEMENT

HYDRAULIC CRANKING SYSTEM

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ILLUSTRATIONS..... U.4

SERVICE INSTRUCTIONS..... U.6

Hydraulic Cranking..... U.6

Hydraulic Hand Pump..... U.8

HYDRAULIC PUMP..... U.10

SERVICE INSTRUCTIONS

ACB SAFETY SEAL ACCUMULATORS..... U.13

ELECTRICAL SYSTEM (LIFE SPHERE)..... U.21

DESCRIPTION

The Hydraulic Cranking System (below) provides positive instant starting for internal combustion engines regardless of temperature extremes, adverse weather or long shut downs. Independent of energy sources such as batteries, this self containing hydraulic cranking system is well adapted to operations requiring extreme precautions against fire or explosions.

The principal components of the hydraulic cranking system are as follows:

A. Reservoir - contains supply of hydraulic fluid for system at atmospheric pressure.

B. Hand Pump - recharges the system in hand pump installations and for emergency recharging in engine pump systems. Also provides slow cranking for timing and engine tune-up.

C. Control Valve - controls flow of hydraulic fluid for system at atmospheric pressure to cranking motor. Integral with Model CM2 and CMC cranking motors.

D. Cranking Motor - a positive displacement high torque, hydraulic motor. Rotor is splined to output shaft which carries drive pinion and an overrunning clutch.

E. Accumulator - a thick wall, piston type cylinder where fluid energy is stored under pressure to actuate the cranking motor. Various capacities are available depending upon application. Pre-loaded with non-combustible nitrogen which it maintains indefinitely.

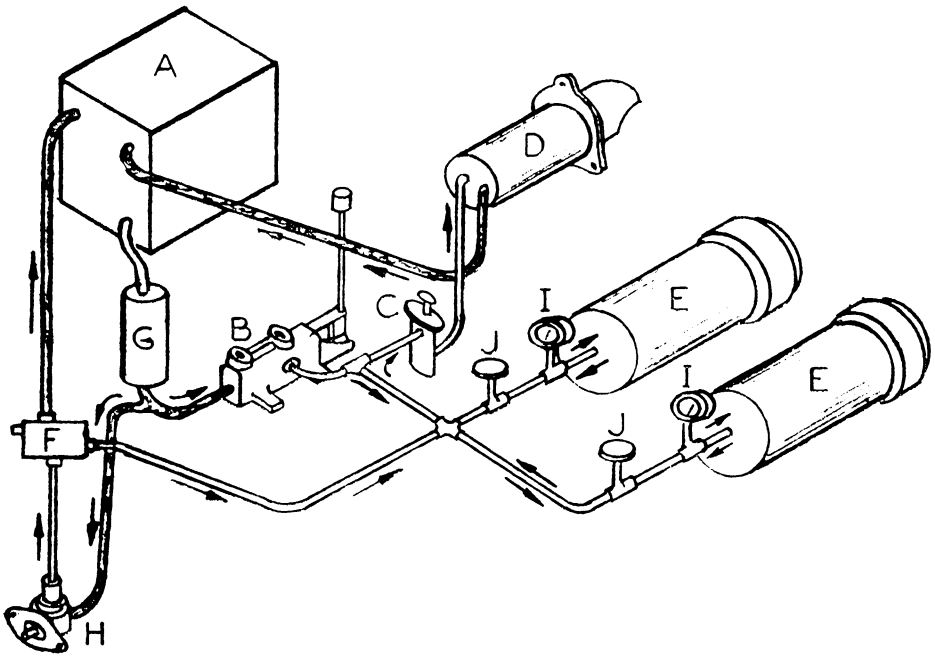
F. Unloading Valve - a ball check valve which by-passes the hydraulic fluid back into the reservoir atfer system reaches required operating pressure.

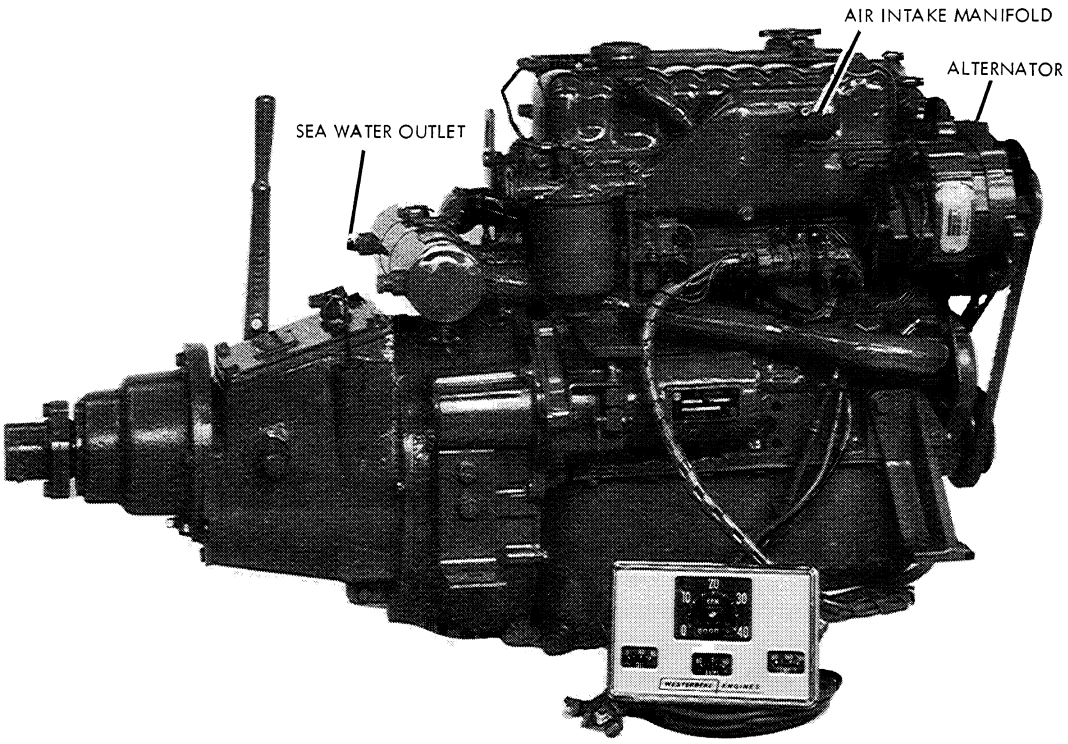
G. Filter - keeps fluid in system free from contaminants.

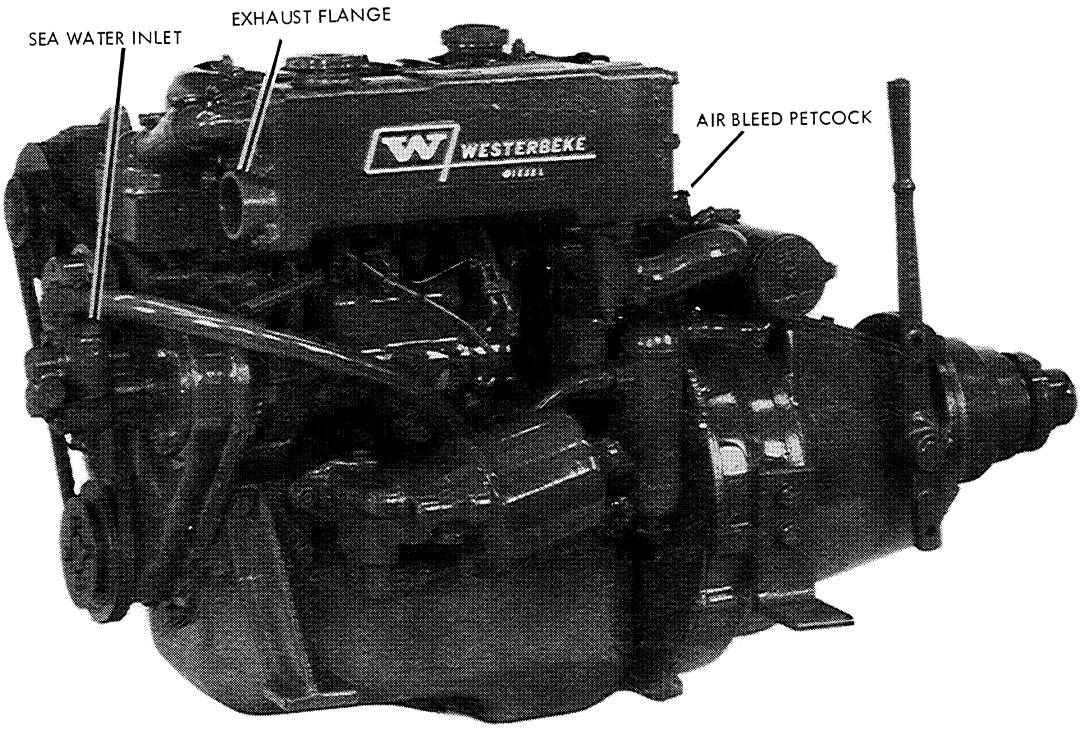
H. Engine Pump (Life Sphere) - a power pump which automatically recharges the system for subsequent starts; thereafter diverts fluid back into reservoir.

I. Pressure Gauge - indicates accumulator pressure.

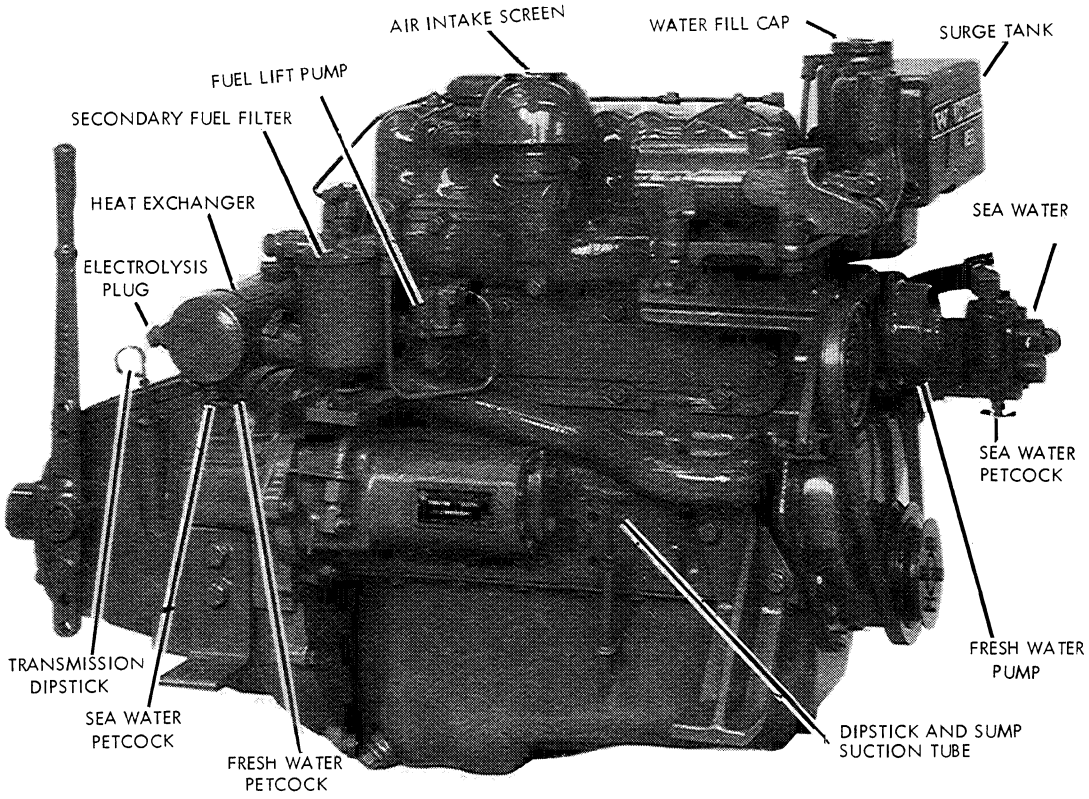
J. Star Valve - prevents hydraulic accumulator from energizing system when in closed position.

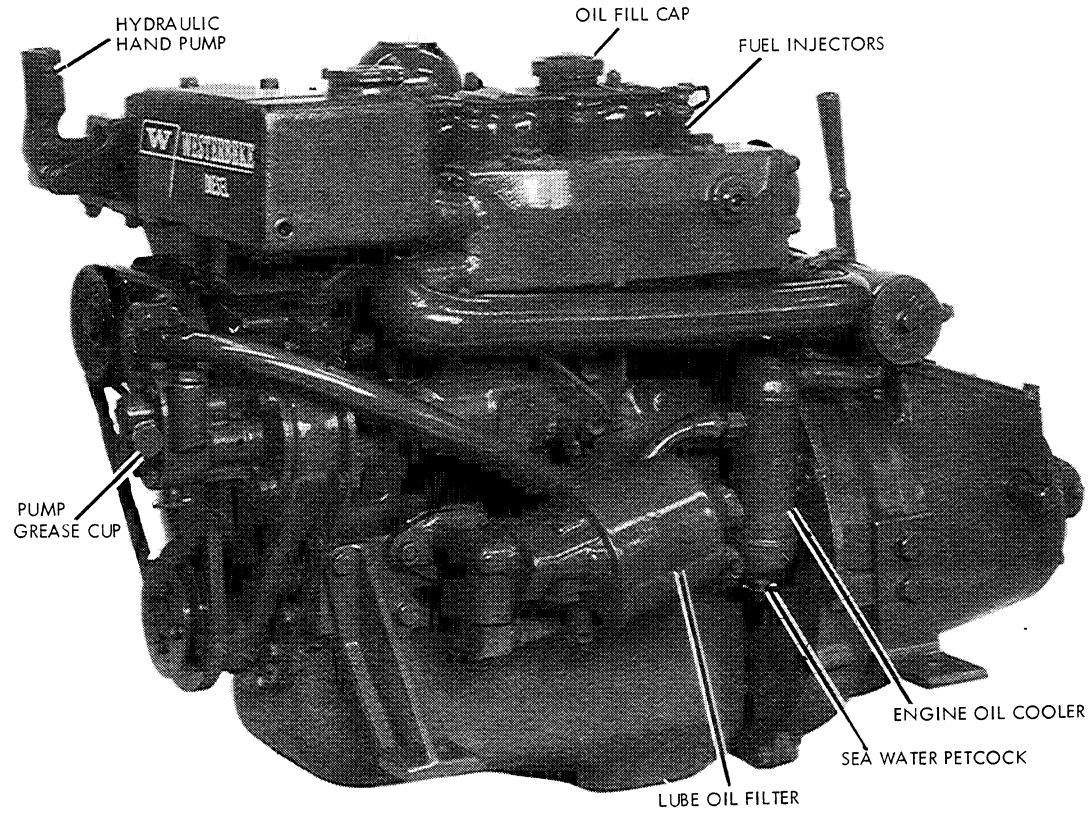






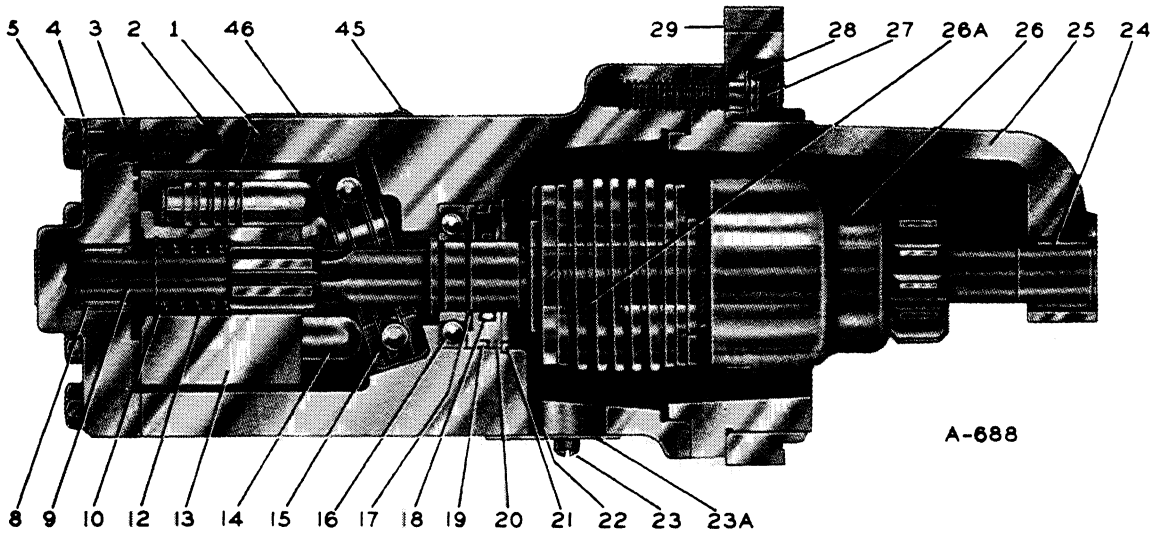
LIFESPHERE - STARBOARD AND PORT VIEWS





LIFEBOAT - STARBOARD AND PORT VIEWS

SERVICE INSTRUCTIONS FOR HYDRAULIC CRANKING MOTOR



DISASSEMBLY

1. Clamp motor housing (2) in a vise. Remove pinion gear housing (25) and mounting flange (29) which are fastened to motor housing (2) by four screws (27).
2. Remove inspection plate (22) and its two fastening screws with lockwashers (23 & 23A). With a screwdriver, move anchor plate of starting drive (26) toward the pinion gear to uncover set screw locking drive assembly (26) on motor shaft (9). Back set screw out of shaft (9) and slide starting drive assembly (26) off shaft. Remove key or keys (26A) from shaft.
3. Before removing port plate (3) put indexing mark between port plate and motor housing (2) to enable proper positioning of port plate at reassembly. Remove eight cap screws (5) that hold port plate (3) to housing (2).
4. Remove barrel assembly (13) from motor shaft (9). Take pistons (14) out of barrel (13).
5. To remove shaft (9) from housing (2) remove seal holder retaining ring (21). Press shaft out of housing from port plate end. Shaft bearing (16) and seal holder (20) will come out on shaft (9).
6. To remove thrust bearing (15) apply even heat to motor housing (2). Bearing will fall out when housing is jarred against wooden block or bench. CAUTION: DO NOT APPLY EXCESSIVE HEAT. Do not remove thrust bearing (15) unless it is to be replaced.

EXAMINATION OF PARTS

Pinion Gear Housing (25): Visually check housing for cracks or other damage. Check needle bearing (24) for damage or wear. Replace if necessary.

Starting Drive Assembly (26): Examine pinion gear to be sure that teeth are not worn excessively or chipped from interference with ring gear. Check anchor plate that holds the starting drive spring to be sure it has not split or spread where spring anchors.

Port Plate (3): The port plate face, where barrel rides, must be smooth and free of scoring. Slight scuff marks can be removed by lapping on surface plate. Check needle bearing (8) for wear or damage. Replace if necessary. To remove bearing (8) apply even heat to port plate (3). CAUTION: DO NOT APPLY EXCES-

SIVE HEAT. Bearing will fall out when port plate (3) is jarred against wooden block or bench. Do not remove bearing (8) unless it is to be replaced. Check threads on inlet and outlet ports.

Motor Barrel (13) and Pistons (14): Examine ported face of barrel for scratching or scoring. Slight scuff marks can be removed by lapping on surface plate. Bores in barrel (13) as well as diameters of pistons (14) should be smooth and free of scoring. Closed ends of pistons may show brinnelling where they contact thrust bearing (15), but no burrs or flat spots on surface.

Motor Shaft (9): Check ends of shaft for wear or scoring.

Check bearing (16): Replace if necessary.

Motor Housing (2): Visually check housing for cracks or other damage. Be sure that thrust bearing (15) rolls free and smooth. Inspect tapped holes for thread damage.

Seal Holder (20) and "O" Rings (18 & 19): Examine holder for cracks or damage. Replace "O" rings with new ones.

REASSEMBLY

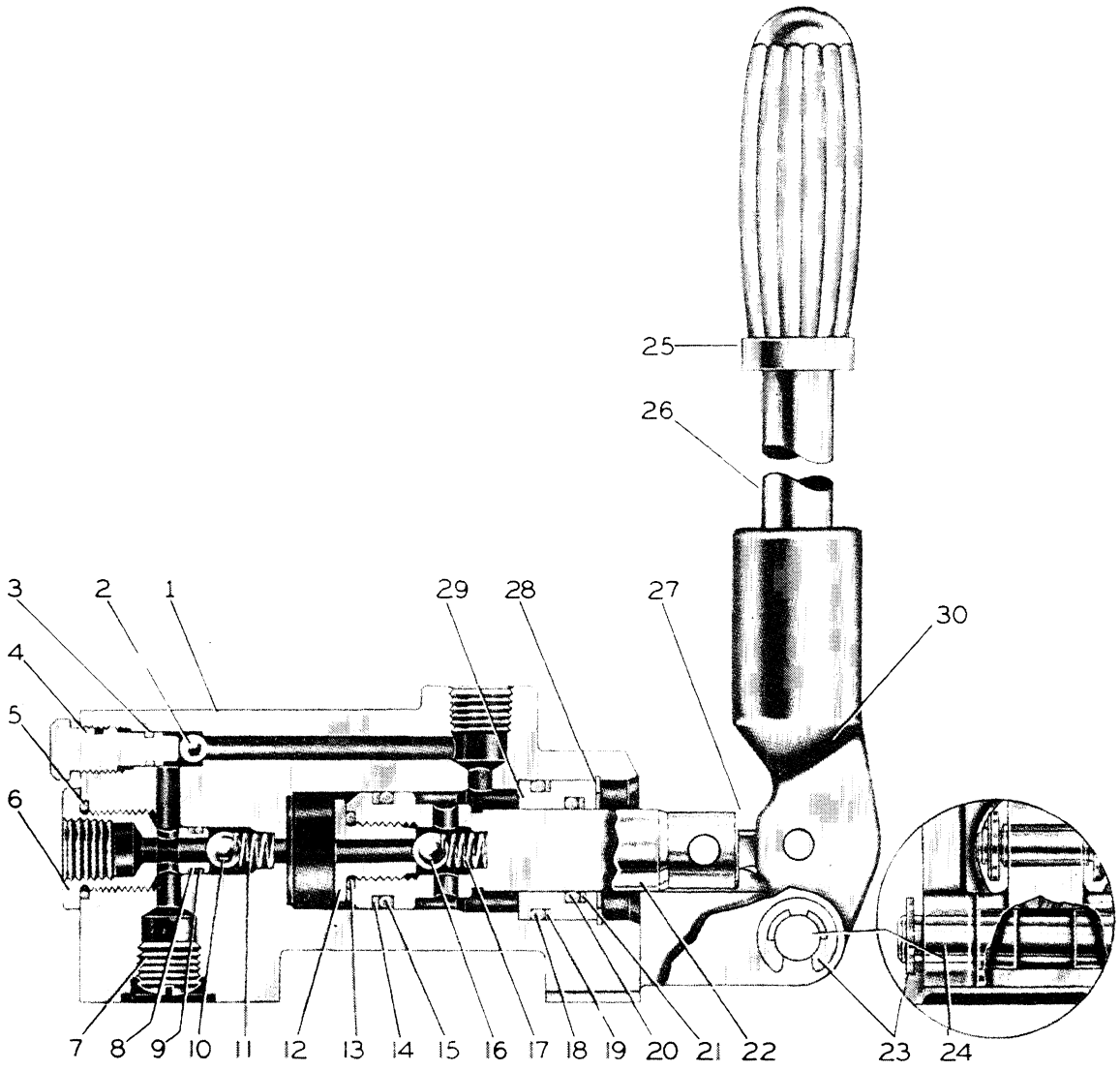
1. Be sure all parts are clean and free of burrs before starting reassembly.
2. Install ball bearing (16) and retaining ring (17) on shaft (9). Press shaft (9) and ball bearing (16) into housing (2). Install seal holder (20) and "O" rings (18 & 19) on shaft (9). The recessed side of seal holder (20) should be next to ball bearing (16). Install retaining ring (21).
3. With pistons (14) in barrel (13), line up splines and install barrel (13) on shaft (9). Using pinion gear housing (25) to help position shaft, put port plate (3) on, being sure to line up indexing marks. There should be slight precompression of spring (12) with port plate (3) against barrel (13). If not replace spring (12). Tighten cap screws (5) alternately and pull port plate (3) down evenly. Torque to 150 in. /lbs.

TEST PROCEDURE

1. Mount hydrotor in suitable holding fixture and connect all hoses to appropriate fittings as illustrated in System Schematic Section.
2. Remove pinion gear housing (25). Open control valve. Start engine pump to circulate oil through complete system with control valve remaining open, thus purging system of air. Examine hydrotor and all fittings for possible leaks before releasing control valve.
3. Allow system pressure to build up to 3000 psi at which pressure the unloading valve by-passes oil back into reservoir. Again examine for leaks in system. Should pressure fail to rise instantly to 1500 psi and then build up gradually to 3000 psi, it would indicate system was not purged completely. Purge again if necessary. **Note:** If at any time leaking occurs externally, the unit must be disassembled to correct leakage before proceeding with test. **CAUTION:** ALWAYS RELEASE ALL HYDRAULIC PRESSURE BEFORE DISCONNECTING ANY LINES.
4. After it has been determined that unit is not leaking, open control valve. Permit unit to operate until accumulator hydraulic charge has been exhausted. Release control valve. The system will now recharge to 3000 psi.
5. Attach TSE 8606 Lock Testing Tool (see Service Tool Section) to motor housing (2) at same location as provided for pinion gear housing, previously removed in step two. Align keyway in TSE 8606 with key (26A) in shaft (9). Fasten TSE 8606 to motor housing (2) by inserting two pinion gear housing fastening screws hand tight 180° apart.
6. Move control valve slowly to full open position. Hold open for approximately 3 to 4 seconds before closing. While control valve is in full open position the pressure drop from 3000 psi to 2500 psi must not occur in less than 3 seconds.
7. Proceed to test each of the pistons inside hydrotor in like manner as described above by rotating lock test tool in increments as provided until all seven pistons have been tested. Should pressure drop faster than specified when testing one particular piston, it will of course indicate internal leakage. This could be a piston which would require replacement. **Note:** Turn lock test tool and shaft one full turn and retest before replacing any one particular piston. A pressure drop at all positions indicate that port plate fastening screws (5) are not properly torqued or that there is insufficient spring tension to keep motor cylinder (13) against port plate (3).

   It may be necessary to lap port plate (3) and motor cylinder (13) on a lapping plate or replace spring (12) to eliminate leakage if they do not seal properly.
8. After preceding test is completed stop engine pump. Remove lock testing tool. Grease motor shaft (9). Install key or keys (26A) and starting drive assembly (26) on shaft (9). Tighten set screw into shaft (9) by holding anchor plate out of the way with screwdriver. Install pinion gear housing (25) and tighten fastening screws (27). Torque to 175 in. /lbs.
9. Move control valve to full open position. Allow system to discharge completely. (Hydraulic pressure gauge should now read 0 psi.) **CAUTION:** DO NOT DISCONNECT ANY LINES UNTIL HYDRAULIC PRESSURE IS COMPLETELY EXHAUSTED.
10. Remove hydrotor from test circuit. Drain remaining quantity of oil from hydrotor and close all openings with a suitable plug to prevent entrance of foreign matter during storage or shipment.

SERVICE INSTRUCTIONS FOR HYDRAULIC HAND PUMP



A-438

DISASSEMBLY

1. Disconnect operating lever (30) from pump housing (1) and plunger (22). Remove retaining ring (23) and clevis pin (24) before removing link assembly (27).

2. Remove plunger gland retaining ring (28) from pump housing (1). Gland (29) will come out on plunger (22) when plunger is pulled from housing (1). Remove gland (29) from plunger.

3. Remove discharge check valve seat (12) from end of plunger (22). Discharge check valve (16) and spring (17) will drop out of plunger.

4. Remove oil inlet fitting (6) from end of pump housing. Inlet check valve (10) and spring (11) will drop out of housing (1).

5. Back out bleeder screw (4) and remove ball (2).

EXAMINATION OF PARTS

Pump Housing (1): Check for cracks and other visible damage. Bore of cylinder must be smooth with no pitting or scoring. All threads should be checked. (It is not necessary to remove plug (7) unless there has been leakage at threads). Bleed ball valve (2) and its seat in housing must be checked. Replace ball valve (2) if damaged. Replace "O" ring (3) on bleed screw with new one.

Inlet Fitting (6): Examine internal and external threads. Inspect inlet check valve seat for nicks or scratches. Replace "O" rings (5 & 9) and back-up ring (8) with new ones. Examine inlet check valve ball (10) and spring (11). Replace if damaged.

Plunger (22): Check plunger for scoring on large diameter and on plunger shank where it rides in plunger gland (29). A wear pattern may be evident but no scores or scratches should be present. Replace seals (13-15) and back-up ring (14) with new ones. Examine discharge check valve (16), spring (17) and check valve seat (12). Replace any damaged parts.

Operating Lever (30): Check roller chain link (27) for wear or damage. Replace if necessary.

Plunger Gland (29): With "O" ring (20) and back-up ring (21) removed, check gland on plunger shank to be sure it does not bind. "O" rings (18 & 20) and back-up rings (19 & 21) should be replaced with new ones.

ASSEMBLY

Note: Make sure that all parts are clean before assembling. To facilitate assembly use light oil or grease on "O" rings and back-up rings.

1. Install inlet check valve spring (11) and ball (10) into housing (1). With "O" rings (5 & 9) and back-up ring (8) on inlet fitting (6), install fitting into housing. Tighten fitting securely being sure that inlet check valve (10) seats properly in end of inlet fitting (6).

2. Install discharge check valve spring (17) and ball (16) into plunger (22). With "O" ring (13) in place, thread valve seat (12) into plunger and tighten securely.

3. Insert plunger (22) into housing, bottoming plunger in pump bore. Install plunger gland (29) being sure that external "O" ring (18) is closest to leading edge. Press gland (29) in until groove for retaining ring is uncovered, then insert ring (28).

4. Drop bleed ball valve (2) into place and with "O" ring (3) in position insert bleed screw (4). Tighten bleed screw securely.

5. Install link assembly (27) to plunger (22) and operating lever (30). Place operating lever (30) in position and insert clevis pin (24) and retaining ring (23). Put other side of link on and secure with clip.

TEST PROCEDURE

1. Mount hand pump in suitable holding fixture and connect all hoses to appropriate fittings as illustrated in Test Circuit Schematic leaving discharge connection loose. Slowly operate hand pump until all air is expelled. Retighten connection. This operation will also assure that plunger is free in housing. With high pressure valve open, operate hand pump long enough to sufficiently purge system.

2. Close high pressure valve, start engine pump and charge system to approximately 2800 psi. While system is being charged inspect for leakage. If a leak is discovered, stop engine pump and correct leak before proceeding with test.

3. Operate hand pump to charge system to 3000 psi. Observe pressure gauge closely to determine that unit is pumping on each stroke. (Pump is double acting).

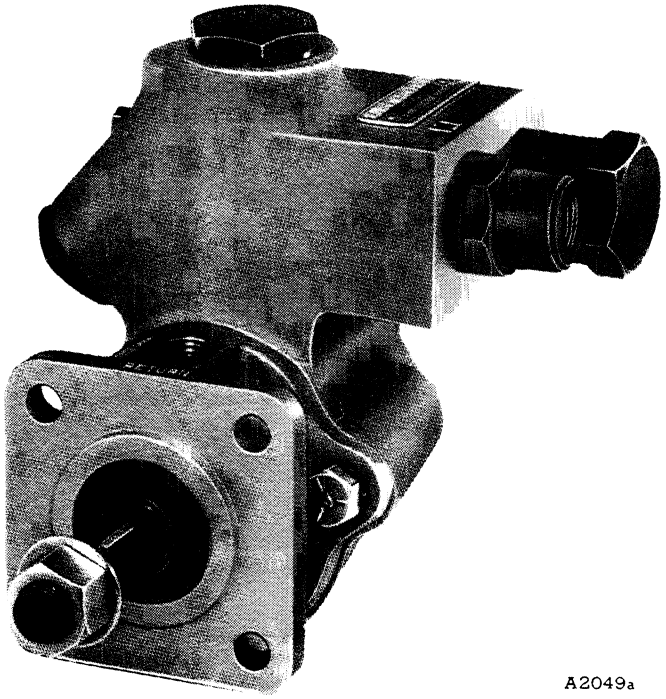
4. Locate pump plunger in mid-position and release operating handle. Any movement of handle indicates leakage past inlet check valve or "O"-rings on inlet fitting. (There should not be any perceptable drop in pressure gauge reading).

5. Move plunger in the full extent of its travel until plunger bottoms in housing. Disconnect inlet line from pump. Holding plunger in this position, pressure in pump chamber at 3000 psi, cautiously trip inlet check valve ball with probe. (Phenol or similar material to be used as probe). A steady pressure reading of 3000 psi indicates that discharge check valve plunger "O" rings and bleed valve are sealing properly. If leakage occurs at this point it will be necessary to correct and retest as required.

6. Open high pressure valve slowly and release pressure to 0 psi. CAUTION: DO NOT DISCONNECT ANY HIGH PRESSURE LINES UNTIL HYDRAULIC PRESSURE IS COMPLETELY EXHAUSTED.

7. Remove hand pump from test circuit. Drain remaining quantity of oil from hand pump and close all openings with a suitable plug to prevent entrance of foreign matter during shipment or storage.

SERVICE INSTRUCTIONS FOR HYDRAULIC PUMP



A2049a

TYPE: - Fixed Displacement Piston Type
ROTATION: - Clockwise or Counter-Clockwise
SPEED: - 600 RPM to 3600 RPM*
UNLOADING VALVE: - Integral and Pressure Adjustable
PRESSURE ADJUSTMENT RANGE: - 1500-3000 PSI
NORMAL PRESSURE CUT-OUT: - 3000 PSI
NORMAL PRESSURE CUT-IN: - 2500 PSI
SELF PRIMING AND SELF BLEEDING
MAXIMUM SUCTION HEAD: - 3 Ft.
HOUSING: - Cast Aluminum
WEIGHT: - 5-1/2 lbs.
DRIVE TORQUE: - 9 in. lbs. @ 0-PSI
28 in. lbs. @ 3000 PSI

*Operation at speeds above 3600 RPM may result in pump damage. Consult the factory on high speed applications.

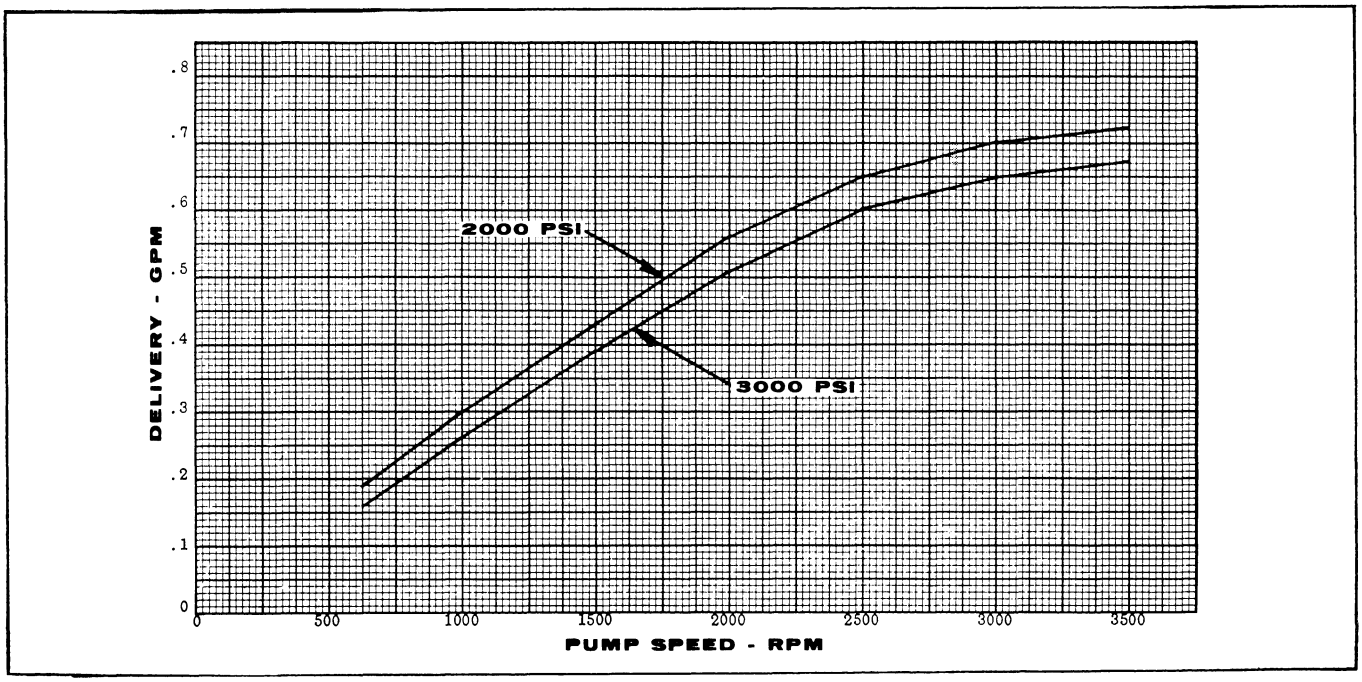
INSTALLATION INFORMATION

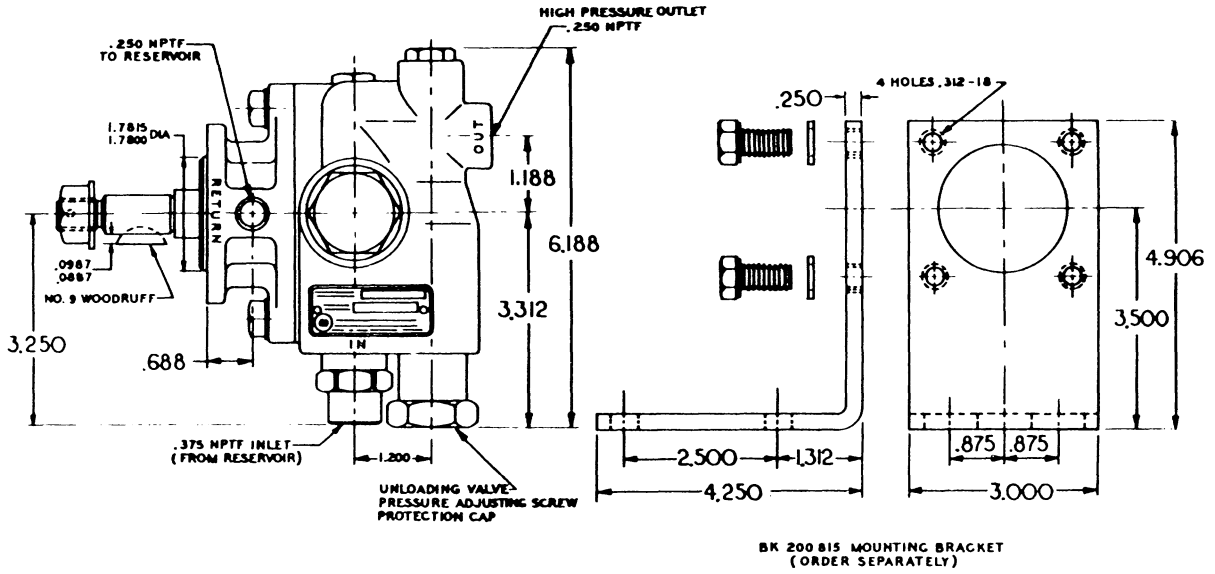
The pump may be mounted radially in any position, however the return port located in the flange portion of the pump must be located above the horizontal centerline to insure adequate internal lubrication. Failure to do so may result in serious damage to the pump.

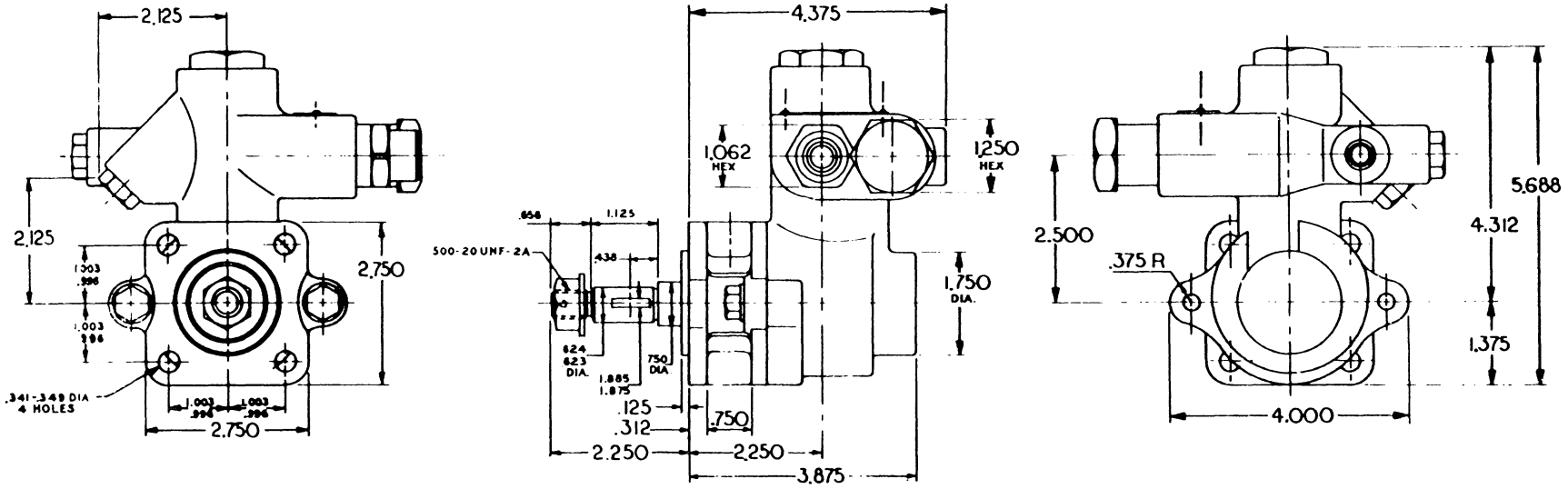
If unusual interference problems are encountered, it is permissable to rotate the flange 180°. Caution is recommended not to separate the two parts more than 1/4". Further separation will cause camshaft seal damage when reassembling.

RECOMMENDED PULLEY

4.000" Diameter for "A" or "B" Size Belt. - .625" Bore







HYDRAULIC PUMP

HYDRAULIC OIL

MIL-H-5606 Hydraulic Oil for Use with Hydraulic Cranking System

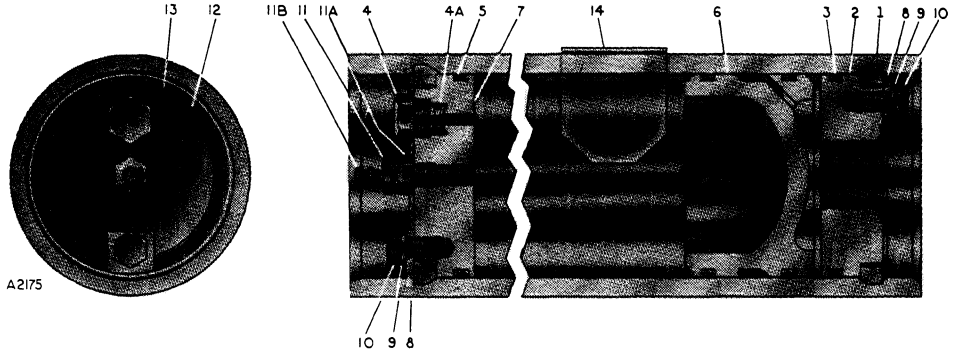
The use of this hydraulic oil will afford optimum performance of the system in the temperature range from 130°F. to -40°F. This oil has good viscosity and temperature characteristics and contains no pour point depressant materials. The pour point is -65°F. and the flash point is 200°F. The weight is 7.25 pounds per gallon at 60°F. It is compatable with Buna N Seals.

The following brand name oils, obtainable in most localities, are also suitable.

Name - - Brand	Supplier
UNIVIS J-43, Code WS 2997	Esso Standard Oil Co.
Mobile Aero-Hydraulic Oil HFA, RL 102A	Socony-Mobile Oil Co.,Inc.
RPM Aviation Hydraulic Oil No. 2	Standard Oil Of California
Aircraft Hydraulic Oil AA or A	Texaco, Inc.
Brayco 756, Code P-190	Bray Oil Co.
Hydraulic Oil, Code 566	Golden Bear Oil Co.
Royco 756	Royal Lubricant Co.
Aero Shell Fluid #4 (ASF 4)	Shell Oil Co.

If temperatures below 10°F. will not be encountered, a reputable brand of quality non-detergent SAE 5W engine oil may be utilized. Texaco Regal Oil A (R and O) is also acceptable.

SERVICE INSTRUCTIONS FOR ACB SAFETY ACCUMULATORS



DISASSEMBLY

1. Prior to any disassembly work, the nitrogen gas must be bled from the accumulator. Remove cap (11B) and loosen lock nut until gas escapes.
2. Remove valve (11). Where accumulator includes a safety fuse holder (4), do not remove it unless the "o" ring (4A) or fuse holder (4) are to be replaced because of leakage.
3. Secure cylinder (1) in a pipe vise and remove screw (10), lockwasher (9), retaining plate (8) Screw 1/2"-20 fitting into air valve port and push end cap (7) away from ring segments (12 and 13). Remove ring segments and pull out end cap (7). Leave fitting in cap for re-assembly.
4. Repeat same procedure for removing the oil end cap (2) as for removing the air end cap (7) being sure to use the proper fitting for the oil port size. Leave fitting in cap for re-assembly.
5. With a wooden dowel, push piston (6) out of cylinder (1).
6. Remove the "o" rings (3) and teflon rings (5) from piston (6) and end caps (2 and 7).

EXAMINATION OF PARTS

Cylinder (1) :	Use a drop light to examine the bore of the cylinder. The bore must be smooth and free of scratches. Check segment ring grooves.
Caps (2 and 7) :	Examine for damage, check fitting threads, valve threads and fuse holder thread if holder has been removed.
Piston (6) :	Examine for scratches or scoring on o. d. The piston must be checked in cylinder to be sure it moves freely throughout the entire length of cylinder.
Air Valve (11) :	Examine threads and replace if damaged. Check for damaged valve seat.
Teflon Rings (5) :	Replace if damaged.
"O" Rings (3) :	Replace all "o" rings with new ones.

REASSEMBLY

Thoroughly clean all parts before assembly, dirt particles larger than 40 microns cannot be tolerated.

1. Use oil or grease to lubricate the "o" rings (3) and install them and teflon rings (5) on piston (6). Install teflon rings before installing "o" rings. Refer to illustration for positioning of teflon rings.
2. Coat I.D. of cylinder with light oil. Use loading sleeve, covering the split ring groove, carefully insert the piston (6) including its "o" ring and teflon rings into the housing bore with the closed end first. Observe that back up rings are correctly installed and "o" rings are coated with BM 1546 grease. "O" rings must not be twisted or otherwise damaged. Once piston has entered cylinder, push it half way down in cylinder.
3. Install "o" rings (3) and teflon rings (5) to cap ends (2 and 7) with "o" ring toward the fluid end. Install teflon rings before installing "o" rings. Apply light grease to "o" rings (3) to insure that it remains in place. Using loading sleeve, slide end cap (2) into the housing beyond the normal position. Be sure oil end cap is on the side with the head of the piston (6).
4. Install retainer ring segments (12 and 13) and hold in place. Push piston (6) against oil end cap to position end cap (2) against the retainer plate (8), lockwasher and screw (9 and 10).
5. Using loading sleeve, slide end cap (7) into the housing beyond the normal position. Install retaining rings (12 & 13) and hold in place. Push end cap (7) into position (same as gas end cap above) by using a wooden dowel from the oil end. Release pressure and remove assembly fittings.
6. Install valve (11) with "o" ring (11A) torque valve (11) to 45-50 ft. lbs. DO NOT tighten the lock nut. Where safety fuse holder (4) with "o" ring (4A) was removed, install with new "o" ring (4A) and torque to 20-25 ft. lbs.
7. The accumulator is now ready to be charged with nitrogen gas. Read instructions pgs. 3 & 4. Continue to charge accumulator until desired pressure is attained. Close valve on nitrogen tank and tighten lock nut on air valve to 140-160 in. lbs. Remove charging hose and install protection cap (11B).

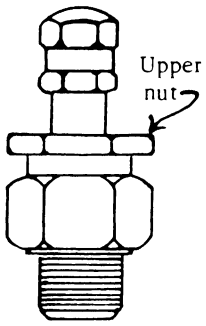
INSTRUCTIONS FOR USE OF CHARGING AND GAGING ASSEMBLY CGA 300389

CHECKING PRECHARGE

1. Before attaching chuck (9) to air valve, VA 200932, be sure valve (5) is in the closed position. Valve is closed when handle is turned 90 degrees from position shown in illustration. (See Note)

2. Hand tighten chuck (9) sufficiently to compress gasket in order to prevent gas leakage.

3. Place a 3/4" wrench on upper nut of air valve and turn in a counter clock-wise direction until precharge pressure on gauge (1) is indicated.



VA 200932

NOTE: Upper nut on air valve will stop turning after approximately 3 to 4 turns.

REDUCING PRECHARGE

1. With charging and gaging assembly connected to air valve per the above instructions, carefully open and close valve (5) until the desired precharge pressure is indicated on gage (1). Lock upper nut and disconnect the "CGA" assembly.

ADDING PRECHARGE

1. Connect nut (8) to nitrogen tank and tighten. WARNING: DO NOT USE OXYGEN NOR SIMILAR COMBUSTIBLE TYPE GASES.

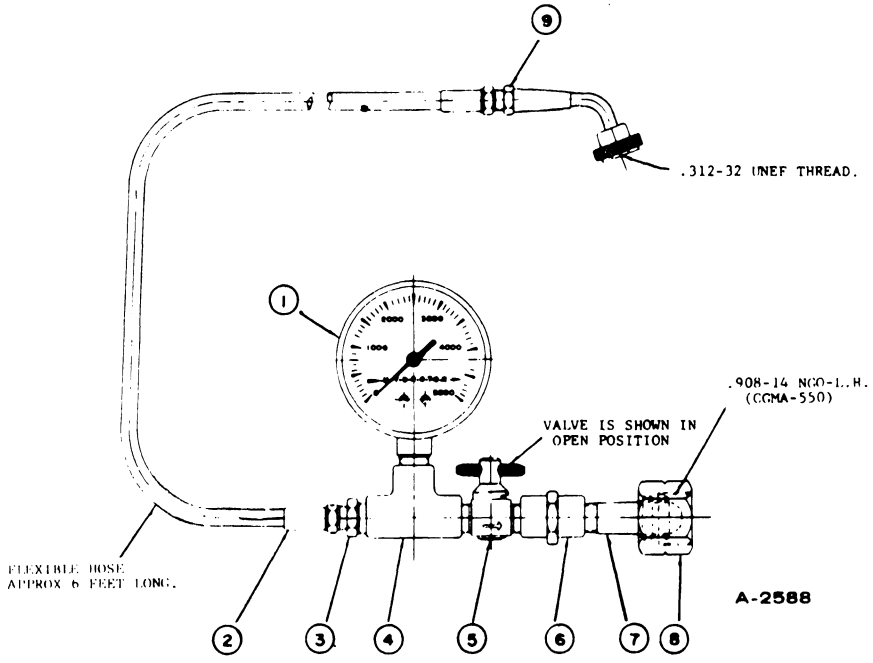
2. IMPORTANT

Valve (5) on the CGA assembly must be in the open position before opening the nitrogen tank valve. Valve (5) is not designed to withstand pressure in the opposite direction of the arrow, stamped on the body, when in the closed position.

3. After completing step (2) above, slowly open the nitrogen tank valve to allow tank pressure into the accumulator, closing it occasionally to allow needle on gage (1) to settle in position. If more pressure than desired is allowed to enter the accumulator, close the air valve on the accumulator and nitrogen tank valve and disconnect the CGA assembly from the nitrogen tank. Repeat the steps for reducing precharge previously described.

CAUTION: NEVER DISCONNECT THE CGA ASSEMBLY FROM THE ACCUMULATOR AIR VALVE AND/OR NITROGEN TANK VALVE UNTIL EACH IS FULLY LOCKED IN THE OFF POSITION.

NOTE: Use this charging and gaging assembly with VA 200932 Valve (MS 28889-1). Do not use with inner tube type needle valves.



TEST PROCEDURE FOR ACCUMULATORS

1. After the accumulator has been charged to the desired pressure, it should be immersed in a tank containing a non-corrosive liquid (Stoddard solvents, Varsol by Esso, etc.) and checked for proper sealing of the "O" rings on accumulator piston. The oil inlet port of the accumulator must be left open during this test. Also check for possible leaks of the Air Valve Assembly (11) (cap 11B removed). Air bubbles in the liquid indicate nitrogen leakage.

2. Drain dry and allow the accumulator to set undisturbed for a minimum period of one hour. With Service Tool CGA 300389 recheck the gas pressure in the accumulator. See Note 1.

3. If the pressure is lower by more than 5%, the accumulator must again be connected to Service Tool CGA 300389 and additional nitrogen added. Repeat steps 1 and 2.

4. A cycling test should be performed to assure that accumulator is functioning properly. The accumulator may be connected to any simple test circuit, consisting of a reservoir, pump, accumulator and a valve.

5. The hydraulic valve should remain in the open position until the pump has run a sufficient period to bleed all air from the line. With the pump still operating, close the valve. Allow pump to charge the accumulator to 3000 PSI. Open the hydraulic valve to allow stored oil in the accumulator to flow back into the reservoir. Repeat this charge and discharge cycle several times to insure the piston is not sticking or binding.

6. During the cycling test, inspect for possible oil leaks at caps and discharge fitting of accumulator.

7. When the test cycle has been completed, remove the accumulator from the test circuit.

   CAUTION: Always release all hydraulic pressure in the system before disconnecting any lines.

   Close the oil port with a suitable plug to prevent entrance of foreign matter during storage and shipping.

NOTE 1: With Service Tool CGA300389 fastened securely to the Air Valve Assembly (11), loosen nut on air valve. The gauge will indicate the amount of nitrogen gas precharge pressure in the accumulator. Before removing gauge, tighten locknut on air valve. When using this tool, the hydraulic pressure in the accumulator should be zero before attaching the gauge device to the accumulator.

TROUBLE SHOOTING THE CRANKING SYSTEM

CAUTION: Before servicing any part of the Hydrotor system, the accumulator pressure must be released to prevent possible injury to personnel.

TROUBLE	REMEDY
A. NO SYSTEM PRESSURE	
1. Air In Engine Driven Pump	All RPA model pumps are self bleeding. Check for dirt in pump piston bleed hole. See that bleed hole is facing the inlet port. To assist pump in expelling air, fill the pump with oil through the return port.
2. Hand Pump Bleed Valve Open	Check to insure hand pump bleed screw (located above the inlet port) is tight. See B. 2
3. Drive Belt Slipping (Belt Driven Pump)	Adjust belt for proper tension.
4. Drive Gear Loose (Direct Driven Pump)	Secure gear to drive shaft.
5. Unloading Valve By-Passing Oil to the Reservoir	Oil will be passing through the return port indicating the unloading valve spindle in the RPA model pumps is stuck in the open position or the pressure adjusting screw is backed off. Check to insure the unloading valve spindle is free. Turn the adjusting screw clockwise to move the spindle into the closed position.
6. Suction Line Plugged	Remove and clean. Make sure the swivel ends are correctly attached.
B. LOW SYSTEM PRESSURE	
1. Unloading Valve set too low	Turn adjusting screw on all RPA model pumps clockwise to increase system pressure to desired level.
2. Hand Pump Bleed Valve Leaking	Remove bleed screw and ball. Use ball to re-coin seat.
3. Engine Pump Valve(s) Leaking	Replace inlet valve or re-coin seats of the three ball checks.
4. Low Oil Level	Add oil to reservoir.
C. CRANKING SPEED TOO LOW	
1. System Fluid Too Heavy	Check fluid in system. USE MIL-H-5606 Hydraulic Oil or equivalent. Oil must be compatible with Buna-N seals.
2. Engine Oil Too Heavy	Replace oil with proper viscosity grade. Refer to the Engine Lubrication Oil Specifications.
3. Control Valve Not Fully Open	Types VCA. Valve body sticking in valve housing. Replace valve cage and valve assembly.
4. Inlet Line Restricted	Check plumbing from Accumulator to Hydrotor to insure hoses are not collapsed and are free of obstructions.
5. Excessive Internal Leakage in Hydrotor	Examine Hydrotor internally for broken thrust bearing plate, scored port plate, frozen piston or broken cylinder spring.

- Continued -

TROUBLE	REMEDY
C. CRANKING SPEED TOO LOW - CONT'D	
6. Line size too long and/or too small	Discharge line from the Hydrotor to the reservoir causing high back pressure. Discharge hose should be at least one size larger than inlet hose. Eliminate elbows and reducers where possible. Insert a tee containing a gage in the Hydrotor discharge port. Attach the discharge hose and measure back pressure which should not exceed 75 psi.
D. LOSS OF FLUID FROM RESERVOIR	
1. External Leaks	With pressure in system, check all hoses and fittings for leaks. Tighten or replace fittings and any defective parts.
2. Hydrotor Shaft Seal Leaking	Remove Hydrotor inspection cover or welsh plug and look for signs of Hydraulic oil on the Bendix drive, the Hydrotor shaft and inside the pinion gear housing. Replace shaft seal assembly.
3. Engine Pump Shaft Seal Leaking	Replace shaft seal using proper tool to prevent seal damage.
4. Hand Pump Seal Leaking	Remove plunger gland and replace inner and outer "O" rings.
E. LOSS OF PRESSURE WHEN ENGINE IS NOT RUNNING	
1. Ambient Temperature Decrease	A small decrease in pressure is normal due to decrease in temperature. Pressure will decrease approximately 3 psi per degree F. temperature change.
2. Engine Pump Check Valve Leaking	Examine unloading valve spool for damaged "O" rings. Re-coin ball check seats in unloading valve portion of the engine driven pump.
3. Hand Pump Leaking	Disconnect inlet line from reservoir. Leakage from inlet fitting means that either the relief valve alone or both the inlet and outlet check valves are defective. Clean ball seats in pump body and replace balls and springs if necessary. See B. 2 and D. 4
4. Control Valve Leaking	To test for leakage, disconnect plumbing at inlet to Hydrotor. If seepage is present replace "O" rings in type VA 202180 valves or replace valve assembly in type VCA valves.
5. External Leakage In System	Visually locate source of oil leakage and tighten applicable connection. Use of teflon tape on pipe threads is permissible if properly applied.
6. Loss of Accumulator Pre-Charge (Nitrogen)	Test for pre-charge after opening bleed screw on hand pump. Install a gage assembly on the accumulator air valve. Open valve and read nitrogen pressure. Correct nitrogen pressure appears on the accumulator name plate, usually one half the system operating pressure.
F. HAND PUMP FAILS TO RAISE SYSTEM PRESSURE	
1. Bleed Valve Open or Leaking	See A. 2 and B. 2.
2. Check Valves Leaking	Hand Pump handle will not stay in neutral position but will move to one end of the stroke. Examine for broken ball check springs or damaged check valve seats. Re-coin seats using the ball checks. Make sure there are no foreign particles in the pump.

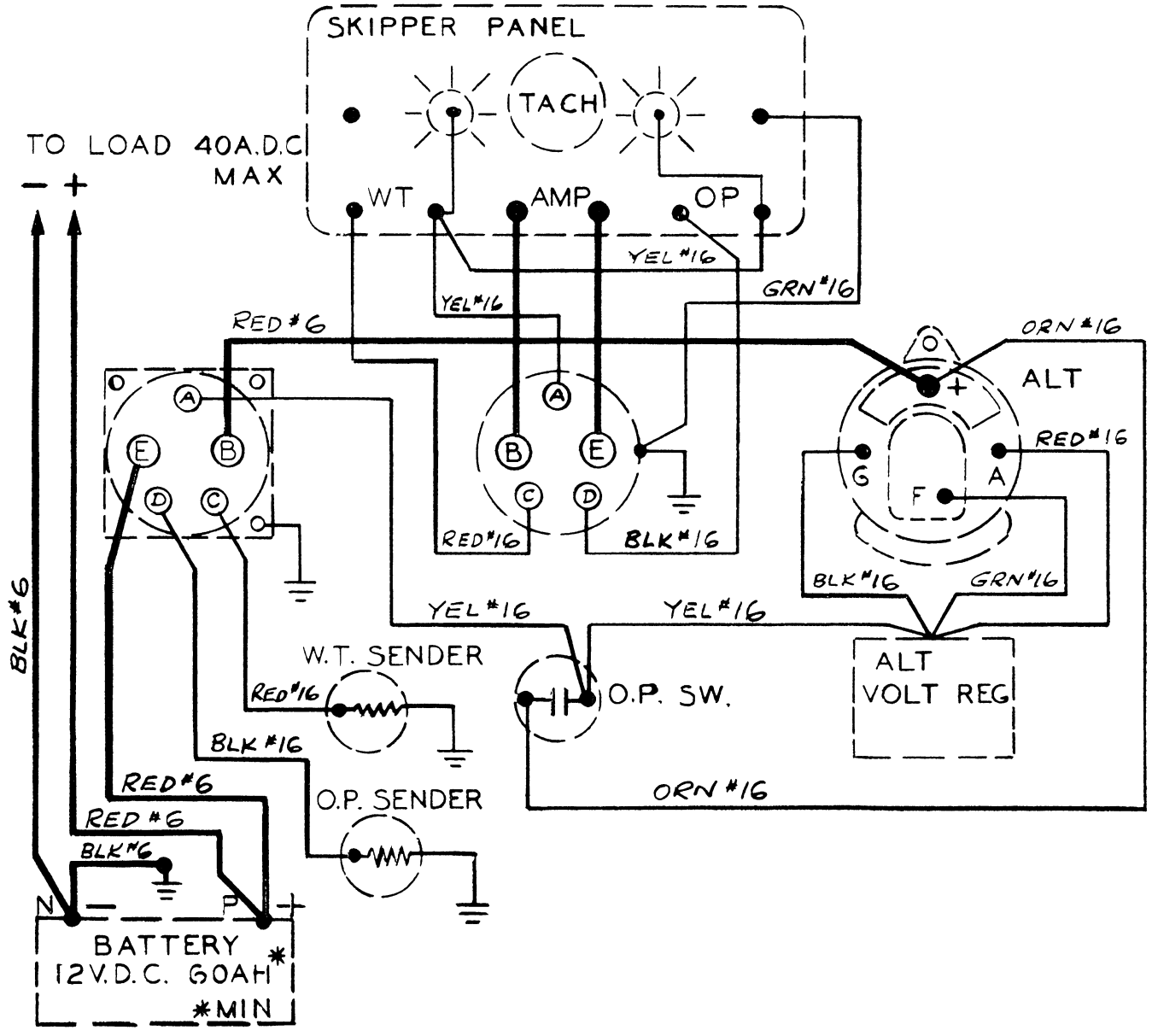
TROUBLE	REMEDY
F. HAND PUMP FAILS TO RAISE SYSTEM PRESSURE - CONT'D	
3. Suction Line Plugged	Remove and clean.
4. Fluid Level Low	Add oil to reservoir.
5. Piston Seal Damaged	See D. 4.
G. HYDROTOR TURNS BUT ENGINE DOES NOT	
1. Pinion Not Engaging Flywheel Ring Gear	Incorrect flange to ring gear dimension. Change pinion gear housing and flange assembly.
2. Bendix Drive Broken	Replace Bendix drive. Operator should disengage Hydrotor as soon as engine starts. Prolonging the period during which clutch over-runs will reduce clutch life.
3. Incorrect Drive	Hydrotor may be assembled for LH rotation but with a RH drive. Change to correct Hydrotor drive.
H. LOSS OF ACCUMULATOR PRECHARGE (NITROGEN)	
1. Damaged Seal on Piston	Overhaul the accumulator. Caution: Release all hydraulic pressure before removing the accumulator from the system and release all nitrogen pressure before disassembling the accumulator.
2. Defective Air Valve	Release pressure in system by opening by-pass valve on hand pump. Then open air valve to release remaining precharge before attempting to remove valve from accumulator. Replace air valve.
3. Damaged Seal On End Cap	Apply liquid soap on accumulator end cap. Bubbling of soap indicates a leak past end cap seal. Release nitrogen precharge before removing cap to replace seals.
4. Defective Safety Fuse	Replace safety fuse assembly after releasing all nitrogen pressure.
I. HIGH PRESSURE IN SYSTEM	
1. Defective Gage	Replace gage.
2. Unloading Valve Not Operating Properly	Clean and adjust to specified operating pressure. Check that the plunger is not binding or sticking. There is a 500 lb. differential between cut-out and cut-in.
J. FLUID EMERGES FROM THE RESERVOIR FILLER CAP WHEN ENGINE IS CRANKED	
1. Filter Element in Filler Cap Loaded with Dirt	Replace filler cap.
2. Excess Fluid in Reservoir	Check fluid level when the accumulator is empty. The fluid level should be approximately 2-1/2" from the top of the tank.
K. FLUID EMERGES AROUND PISTON ON HAND PUMP	
1. Damaged Piston Seal	See D. 4.
L. CRANKING CYCLE TOO SHORT	
1. Insufficient Accumulator Capacity	Add more and/or larger accumulator(s).

- Continued -

TROUBLE	REMEDY
L. CRANKING CYCLE TOO SHORT - CONT'D -	
2. Faulty Pressure Gage	If gage is reading higher than actual system pressure, oil volume in the accumulator will be less. Replace gage.
3. Excessive Internal Leakage in Hydrotor	See C. 5.
4. Hydrotor Too Small	Check engine cubic inch displacement to determine that the hydraulic cranking motor is the correct size.
5. Accumulator Precharge Too High	With the fuel shut off to prevent engine from starting, crank the engine until all oil is used. If the gage then registers zero pressure, install a gaging assembly on the air valve and drop the precharge to 1250 psi. Repeat cranking cycle. If gage will still drop to zero at end of cranking cycle, reduce precharge to 1000 psi.
6. Accumulator Precharge Too Low	Open the by-pass valve on the hand pump to discharge oil from the accumulator. Install a gaging assembly on the accumulator air valve. If precharge is less than 1,500 psi, add nitrogen. Make sure precharge holds by testing for nitrogen leakage per paragraph H.
M. IMPROPER DRIVE ENGAGEMENT	
1. Insufficient Depth of Tooth Engagement	Standard dimension from flange to ring gear is 2.00". Measure with depth gage. If greater than 2.00", depth of engagement will not be adequate.
2. Tooth Engagement Too Deep	Bendix collar behind teeth will be marked by ring gear. Insert spacer between hydrotor flange and ring gear housing.
3. Improper Mesh of Drive and Ring Gear	Use bluing or other marking fluid on Bendix pinion. Install Hydrotor and crank engine one or two turns. Remove Hydrotor and check contact areas for proper mesh.

ELECTRICAL SYSTEM (Life Sphere)

The Life Sphere engine configuration contains an electrical system which is pre-wired at the factory and operates on a negative grounded 12 volt system. Included in the Westerbeke electrical system is a 50-ampere alternator, voltage regulator, instrument panel and battery cables.
The panel contains a built-in tachometer with hour meter, oil pressure gauge, water temperature gauge and an ammeter.
Each instrument is gasketed at the panel and the panel is back-lighted. All electrical wires from the instrument panel are terminated at an amphenol connector, which is mounted to a connector bracket at the rear of the alternator. All other electrical wires from the alternator, voltage regulator, sensors and the number 6 gauge wire from the positive battery terminal are terminated to a mating amphenol connector. The tachometer drive shaft with outer cable housing is supplied with loose equipment shipped with the engine. One end of the tachometer drive cable is installed in the panel tachometer receptacle and secured with its outer cable housing nut. The other end of the drive cable is installed in the engine block drive shaft receptacle located above the engine dipstick and secured with its outer cable housing nut. The engine block tachometer drive shaft receptacle is protected by a threaded cap before cable installation.



YOUR NOTES

SERVICE BULLETINS

The following Bulletins contain supplementary and updated information about various components and service procedures which are important to the proper functioning of your engine and its support systems.

You should familiarize yourself with the subjects and make sure that you consult the appropriate Bulletin(s) whenever your engine requires service or overhaul.

V.2

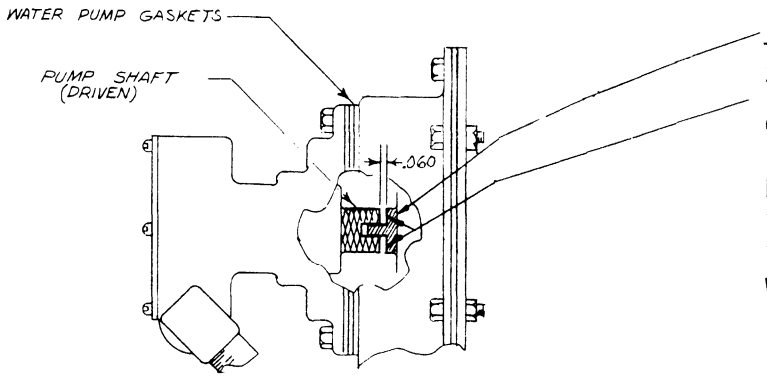
SERVICE BULLETIN

DATE: September 17, 1976 *BULLETIN NUMBER:* 10

MODEL: Westerbeke 40 and WPDS 10-15

SUBJECT: Sea Water Pump Clearance and Alignment

Clearance:
Adequate longitudinal clearance between the sea water pump shaft and the driving shaft is established by the use of multiple pump gaskets. The number of gaskets required can vary from 1 to 4. Enough gaskets must be used so that the shaft ends do not mate. See figure 1.



NOTE:
The application of liquid or paste type Prussian blue (at points indicated by arrows) will give positive indications of pump drive contact which will require the use of additional gaskets.

If the proper clearance is not maintained, the sea water pump shaft will force the fuel pump drive hub against its bushing. The bushing will seize to the drive hub and rotate in its housing. Bushing wear and loss of oil pressure will result.

When replacing the sea water pump be sure that the same number of gaskets is replaced and there is the required clearance.

Alignment:
Alignment is just as critical as clearance. The latest 1/2" pump intentionally has no pilot because the location of the timing cover itself is not precise. To assure that the pump shaft is axial with the driving shaft, install the pump with the four nuts just snugged. WITH THE FUEL STOPLEVER OFF, crank the engine for a few seconds. If the nuts have not been overtightened, the drive tang will cause the pump to align itself. It is best to deliberately offset the pump against its studs so you can visually verify movement of the pump as it centers itself during cranking. The nuts should then be tightened. This procedure must be repeated anytime the pump is loosened.

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P/N: 16742

SERVICE BULLETIN

V.3

DATE: April 23, 1968 *BULLETIN NUMBER:* 11

MODEL: Westerbeke 40 and WPDS 10-15

SUBJECT: Instructions for Replacing Injection Pump Drive Hub Bushing (#0050323)

1. Remove c/s Pulleys
2. Remove water pump
3. Remove timing cover
4. Mark idler gear and fuel pump gears before removing fuel pump gear (This is very important in order to retain proper relation of gears and eliminate re-timing of engine).
5. If fuel pump hub bushing is worn as suspected, gear and bushing will pull right out of block.
6. Remove quill shaft from injection pump (splined pump drive shaft).
7. Remove gear from drive hub
8. Remove hub bushing retaining circlip
9. If bushing is frozen on hub, tighten forward end of bushing in vise and drive hub of bushing with brass drive taking care not to damage female splines in hub
10. Place hub flange on top of vise and with small brass punch knock out drive key from hub
11. Clean hub shaft with crocus cloth or similar material. Pre-oil and fit new bushing. Check that bushing rotates freely. Replace circlip.
12. Clean bushing hole in block
13. With plastic or similar soft headed mallet drive newly assembled bushing in place hitting squarely on center until it has definitely bottomed out against block.

Continued

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WESTERBEKE SERVICE BULLETIN #11 (Continued)

14. After bushing is in place recheck for free rotation of hub making sure no binding is evident

15. Line up master spline of drive hub with master spline of fuel pump drive

16. Replace fuel pump drive shaft by passing it through drive hub until it enters into pump drive. When shaft comes up against fuel pump drive it may be necessary to hold a slight finger pressure against drive shaft and rotate slightly left and right until shaft enters pump drive. (NOTE: On drive shaft longer portion mates in drive hub)

17. After shaft is in place (using a brass or similar hammer) drive the water pump drive key into hub

18. Reinstall pump drive gear making sure gear teeth are matched (same as on removal)

19. Line up corresponding scribe marks on drive hub and drive gear then install and tighten 3 drive gear bolts.
    NOTE: If scribe marks are not properly aligned timing will be off.

20. Reinstall timing cover

21. Reinstall pulleys

22. When installing Sherwood pump refer to attached bulletin. (Service bulletin #10)

4/23/68

SERVICE BULLETIN

V.5

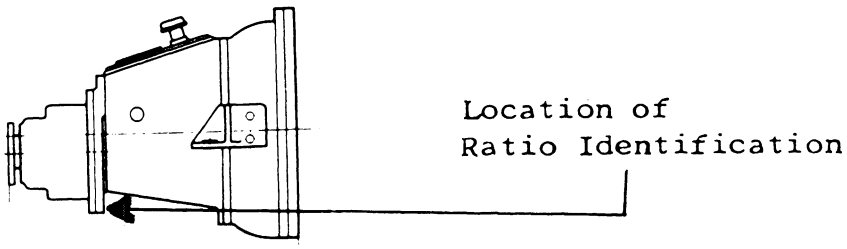
DATE: September 3, 1968 *BULLETIN NUMBER:* 16

MODEL: Westerbeke-Paragon Model SA Transmissions

SUBJECT: Reduction Gear Ratio Identification

To identify the reduction gear ratio on SA transmissions, look for digits marked on the back side of the adapter plate.

See Drawing Below



These digits represent the following ratios:

DIGITS	RATIO
R015	1.5:1
R020	2:1
R025	2.5:1

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V.6

SERVICE BULLETIN

DATE: 6/15/69 *BULLETIN NUMBER:* 20

MODEL: All Engines

SUBJECT: Connecting Pressure Sensing Devices to Oil Galleries

Oil pressure sensing devices, such as senders and switches, must never be connected directly to any oil gallery of an engine. The reason is simply that continued engine vibration causes fatigue of the fittings used to make such a connection. If these fittings fail, the engine loses its oil pressure and very quickly seizes.

Such pressure sensing devices must be bulkhead mounted and connected to the oil gallery using an appropriate grade of lubricating oil hose. Any fittings used to connect the hose to the gallery must be of steel or malleable iron. Brass must not be used for this purpose.

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SERVICE BULLETIN

V.7

DATE: June 15, 1969 *BULLETIN NUMBER:* 21

MODEL: Westerbeke 40

SUBJECT: Replacing Injection Pump Drive Hub Part Number 12632

NOTE: When replacing the drive hub the new hub will have no timing mark scribed on it. For this reason the following procedure must be adhered to step by step. When the procedure is completed and before replacing the timing cover, a new mark is to be punched on the drive hub to coincide with the existing scribe mark on the fuel pump drive gear.

1. Remove the small cover on side of injection pump.

2. Turn engine in direction of rotation (clockwise looking aft). Use a socket and long bar on crankshaft nut and turn by hand.

3. While turning shaft, look into opening in injection pump. It will be noted that pump rotor has a series of letters on it with a scribe mark beneath each letter. It will also be noted that there is a large snap ring visible through the opening.

4. Rotate the shaft until the scribe mark for the letter "C" lines up with the edge of the lower end of the snap ring. (There is also a letter "G" on the rotor -- do not confuse it with "C".)

5. At this point #1 piston is at 22° before top dead center.

6. Remove crank shaft pulleys (when removing the crankshaft nut, if the shaft is moved before removing the pulley, reset the letter "C" with the snap ring in the pump).

7. Remove water pump.

8. Remove timing cover

9. Mark the idler gear and fuel pump gear.(This is very important in order to retain proper relation of gears and eliminate complete engine retiming.)

10. Remove fuel pump gear from drive hub.

11. Obtain three (3) 5/16" fine threaded bolts about 3" long threaded all the way. These are to be threaded into the holes on the drive hub and turned in against the front plate to pull the hub and bronze bushing out of the block as an assembly. (Note: Tighten bolt equally in sequence to prevent galling the bronze bushing in the block.)

Continued

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SERVICE BULLETIN #21 - Continued

REPLACING INJECTION PUMP DRIVE HUB

12. When the hub and bushing are removed pull out the pump splined drive shaft which will now be visible.

13. Remove circlip from old hub and transfer bushing to new hub using new circlip.

14. With plastic or similar soft headed mallet drive assembly back into block hitting squarely on center until it has definitely bottomed out against block.

15. After bushing is in place, recheck for free rotation of hub making sure no binding is evident.

16. Line up master spline of hub with master spline of fuel pump drive.

17. Replace fuel pump drive shaft by passing it through drive hub until it enters into pump drive. When the shaft comes up against fuel pump drive it may be necessary to hold a slight finger pressure against the drive shaft and rotate slightly left or right until shaft enters pump drive.

    NOTE: ON DRIVE SHAFT, LONGER SPLINED END MATES INTO DRIVE HUB.

18. Rotate hub until letter "C" is back on scribe mark.

19. Re-install drive gear making sure letter "C" is lined up before securing bolts.

20. Remark hub to correspond with mark on gear.

21. Using soft headed hammer insert water pump drive key into hub until it bottoms out.

22. Install timing gear cover, pulley, and water pump.

23. Put cover back on injection pump and bleed pump using procedure in manual.

6/15/69

Form A967

SERVICE BULLETIN

V.9

DATE: June 1969 *BULLETIN NUMBER:* 29

MODEL: Westerbeke 40

SUBJECT: Injection Pump History

1. First Pumps:

Marine:	DPA 3243880	Spring 7123-898-J
Code:	P.H.30/500/8/3190	
Generator:	DPA 3248700	Spring 7123-898T
Code:	P.H.30/500/2/1880	

NOTE: ABOVE PUMPS CAN BE USED ON EITHER APPLICATIONS BY CHANGING GOVERNOR SPRING AND CHANGING NAMEPLATE.

2. Second Pumps: Fitted from Engine No. 107U6037. These pumps cannot be changed for previous pumps owing to a timing mark change (3^{o}pump 6^{o}engine)

Marine:	DPA 3248830	
Code:	P.H. 30/500/8/3190	Spring 7123-898J
Generator:	DPA 3249050	
Code:	P.H.30/500/2/1880	Spring 7123-898T

NOTE: THESE PUMPS CAN BE USED ON EITHER APPLICATIONS BY CHANGING GOVERNOR SPRING AND CHANGING NAMEPLATE.

3. Third Pumps; (Note-two marine numbers)

Marine:	DPA 3249030	
Code:	P.H.30/500/5/3190	Spring 7123-94J
Marine:	DPA 3249020	
Code:	P.H.30/500/6/3190	Spring 7123-898H
Generator:	DPA 3248990	
Code:	P.H. 30/500/9/1880	Spring 7123-898Q

NOTE: THESE PUMPS CAN BE USED ON EITHER APPLICATIONS BY CHANGING GOVERNOR SPRING AND CHANGING NAMEPLATE. Pumps listed in #3 can be changed completely for pumps listed in #2 as the timing remains the same.

SUMMARY: #1 pumps for engines earlier than 107U6037

#2 and #3 pumps for engines later than 107U6037

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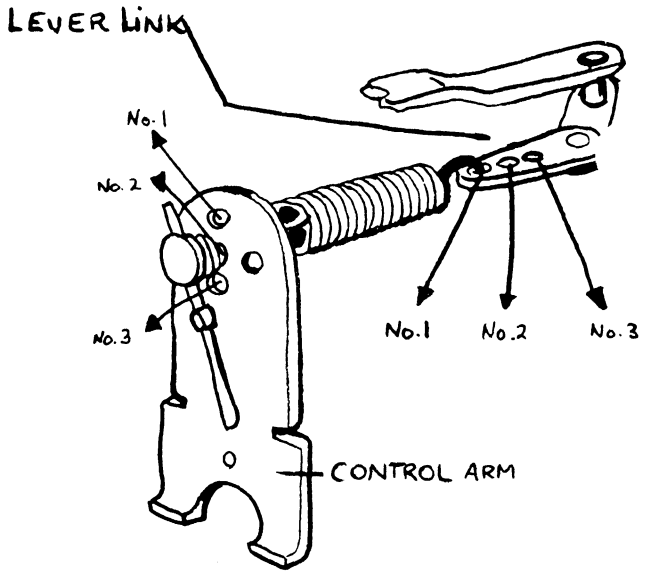
P/N:

Code #	Gov.Arm Hole	Throttle Lever
1	1	1
2	1	2
3	1	3
4	2	1
5	2	2
6	2	3
7	3	1
8	3	2
9	3	3
0	Indicates hydraulically governed	

PH 30/500/8/3190
code for spring position



GOVERNOR MAIN SPRING POSITIONS

GOVERNOR LINK SETTING: This is measured between the inside of the metering valve lever pin and the inside of the governor control cover stud. The measurements should be made with the vernier caliper held with the rule parallel to the axis of the pump. A few applications require the link setting to be set using the Visual Cut-off Tool (7144-601), such information being specified on relevant test data sheets.

The link length is specified to satisfy two main factors for governor performance:

1. Fuel cut-off at maximum speed.
2. Non-interference with fuel delivery at maximum fuel.

Whilst most governors will operate satisfactorily with the nominal link length, some units fail for the above reasons and can be corrected by an alteration to the link length. The following procedure should therefore be adopted:

1. Set to nominal link length before commencing test.
2. If unit fails for "no cut-off at maximum governed speed", reduce link length.
3. If unit fails for maximum fuel interference, increase link length.

Note, however, that incorrectly machined, worn, or wrongly assembled parts can produce the same faults, and alteration to link length, which may be correct, will not necessarily effect a solution. Should adjustment to the link setting fail to correct the fault, then this should be reset to the nominal length and the trouble looked for elsewhere.

Where adjustment to the governor link length has been made, the sequence of the governor setting tests must be repeated and the test requirements satisfied.

Adjustment must NOT be made beyond the specified tolerance.

GOVERNOR CONTROL SPRING: The sketch above indicates clearly the hole numbers in the governor control arm and the throttle shaft link, in which the main governor spring is assembled.

ADVANCE-RETARD DEVICES: A number of variations of this device are now in produc and great care must be taken when testing and adjusting. Details of permissible adjustments are given on the test plans concerned and it is important that:

1. The maximum amount of shimming allowed is not exceeded.
2. Where an unhardened spring cap is used, a 0.5mm shim is fitted over the "pip" inside the cap. The unhardened cap can be identified by the thickness of the hexagon-approximately 5mm against 3mm for the hardened cap formerly used.
3. Tests are carried out strictly in the order specified on the relevant test plan.

VACUUM TEST

It will sometimes be found that, due to the flexible pipe connecting the vacuum gauge to the pump being partially filled with air, an incorrect reading will result. To correct this, slacken the pipe connection at the gauge end with the fuel supply turned on. Wait until fuel flows from this pipe then re-tighten union.

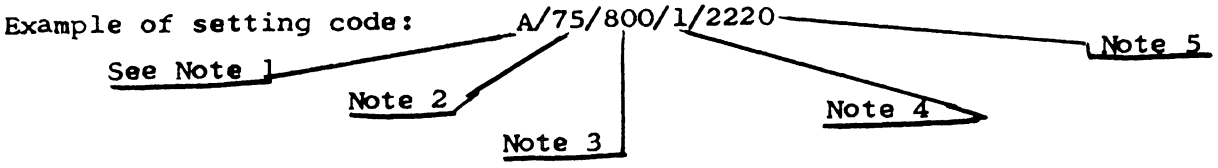
FOR DPA TEST PLANS:

The governor setting speed quoted in the test plan is for test purposes only. The maximum governed speed must be finally set on the engine according to the manufacturer's instruction.

The following test data is not given in the test plan for coded pumps and must be obtained from the setting code on the pump nameplate:

a) Maximum fuel setting
Maximum fuel setting speed

c) Governor checking speeds
d) Governor spring position(mechanically governed pumps)



NOTE 1:(Prefix indicates pump tested with BDN12SD12 nozzles) Not required for test purposes. The letter "A" will normally be used to indicate that the pump is tested with BDN12SD12 nozzles, but in the case of Perkins engines different prefix letters will be used. These will indicate BDN12SD12 nozzles as before but in addition will also indicate the engine type to which the pump is fitted.

NOTE 2:(max fuel setting). The maximum fuel setting code is given in mm^3/stroke and must be divided by 5 to obtain the setting value in c.c/200 strokes.

NOTE 3:(max fuel setting speed). The figure given in the code indicates pump r.p.m which must be used for setting the maximum fuel above.

NOTE 4:(governor spring position) The numbers 1 to 9 will be used to indicate the various spring positions as shown in the guide on page 2. Hydraulically governed pumps will have the figure "0" in this part of the code.

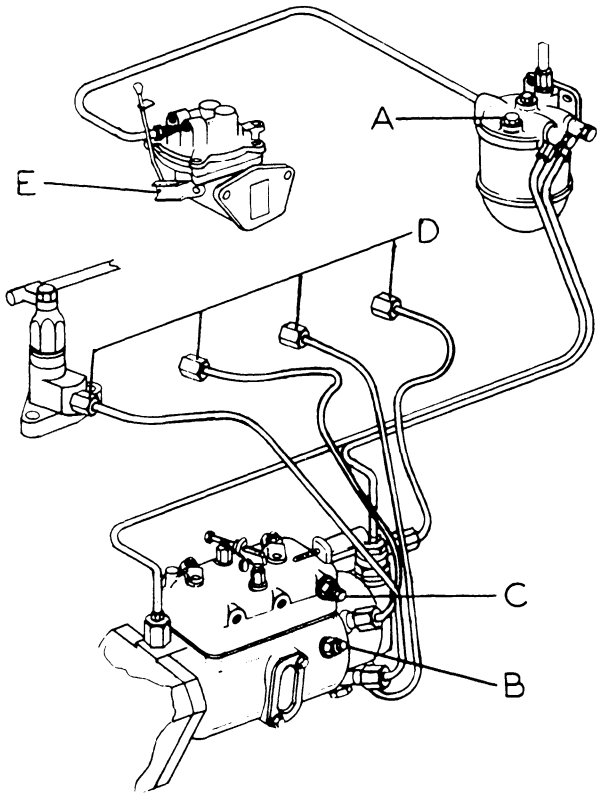
NOTE 5: Maximum no-load speed-engine R.P.M.

SERVICE BULLETIN

DATE: November 27, 1972 *BULLETIN NUMBER:* 49

MODEL: Westerbeke 40

SUBJECT: Bleeding and Priming Fuel System



1. Ensure fuel shut off valve is open.
2. Position shift lever to neutral.
3. Position fuel stop-run and throttel control levers to maximum open positions.
4. Loosen bleed plug (A). Operate priming lever (E). When fuel, free of air bubbles, issues from bleed plug, tighten plug.

   NOTE: If the engine camshaft cam driving the fuel lift pump is on maximum lift, it will not be possible to obtain a full pumping stroke with the priming lever (E), and the engine should be turned with starter motor one complete revolution.
5. Loosen bleed screw (B). Operate priming lever (E) as in step (4) above, then tighten screw.
6. Loosen bleed screw (C). Operate priming lever (E) as in step (4) above, then tighten screw.
7. Loosen the four union nuts (D). Operate the starter motor, when fuel, free of air bubbles, issues from union nuts, tighten nuts.
8. Start engine in full throttle for maximum fuel. Immediately return throttle to idle speed when engine starts.

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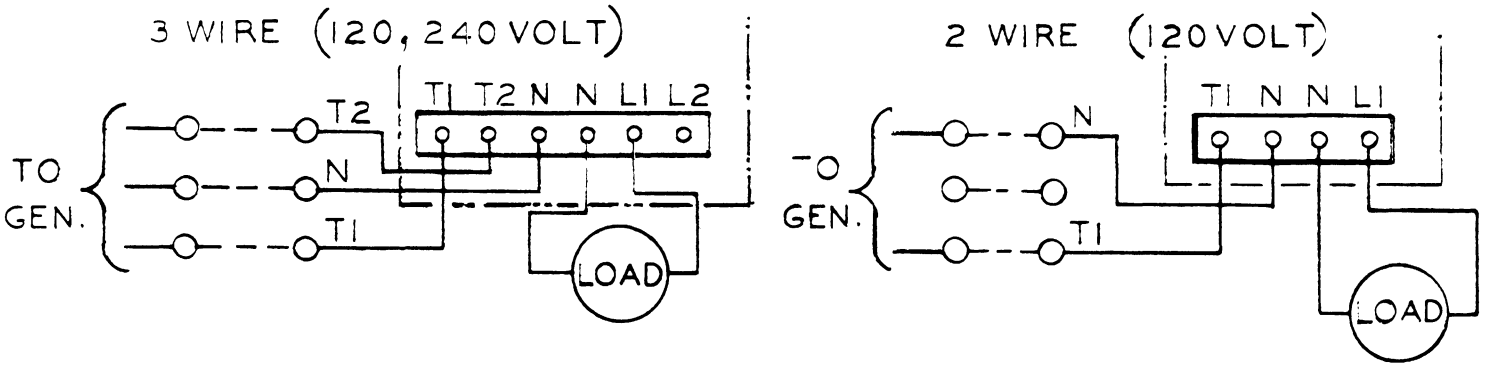
SERVICE BULLETIN

V.13

DATE: April 2, 1973 *BULLETIN NUMBER:* 52

MODEL: WPDS 10-15

SUBJECT: Test Procedure for DMS-2 and DMS-3 Dyna-Monitor



1. Connect DM (Dyna-Monitor) T1, T2, and N to generator junction box as shown above, if not already done.

2. Connect DM to generator as follows, if not already done:

Dyna-Monitor	Generator
1	10
2	11
3	6 (ground)

3. Connect a 60 watt load between L1 and neutral.

4. Turn generator control and DM to remote.

5. Adjust 200 ohm potentiometer slowly until generator just starts.

6. Turn off DM. Generator should shut down.

7. Disconnect the 60 watt load and connect a 25 watt load between L1 and neutral.

8. Switch DM to remote. Generator should not start. If it does, repeat steps 3 through 8.

9. With the 200 ohm potentiometer adjusted correctly, switch DM to "ON". Generator should start. If not, a malfunction is indicated.

10. Remove any extraneous connections which may have been used for this test. Return both DM and generator control to their normal mode of operation. Secure generator.

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V.14

SERVICE BULLETIN

DATE: February 1974 *BULLETIN NUMBER:* 68

MODEL: Four-107

SUBJECT: Service Replacement of Piston Ring Sets

Replacement piston ring sets have been made available for service use on Four-107 engines, should it become apparent after an appropriate period of service, that piston ring and/or cylinder bore wear may have taken place. These ring sets may only be used where the existing liners are not renewed.

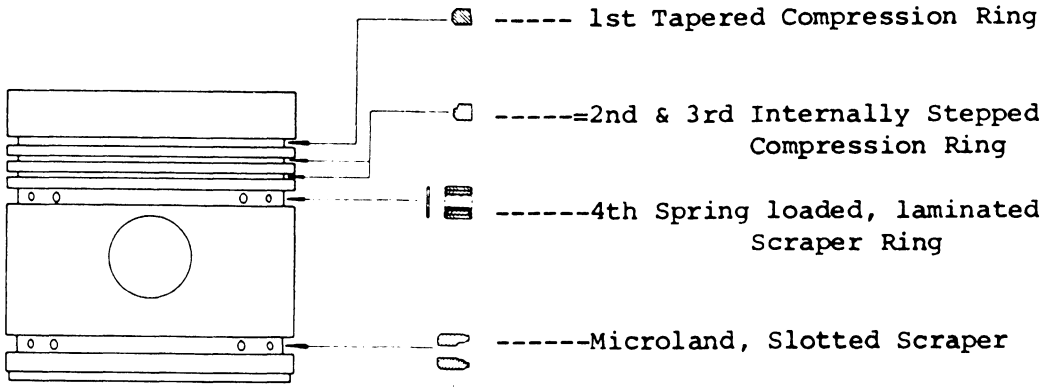
The following instructions are advised for guidance and should be strictly adhered to when undertaking to fit new piston rings to a Four-107 engine:

(a) After removal of the piston, discard the rings.
(b) Thoroughly clean the piston (not forgetting the ring grooves)
(c) Examine the piston for signs of scoring, wear or damage of any kind, paying special attention to the ring grooves.

THE MAXIMUM PERMISSIBLE WORN DIMENSIONS OF THE PISTON RING GROOVE (WIDTH) ARE AS FOLLOWS, THE GROOVES BEING NUMBERED FROM THE CROWN, DOWNWARDS:

PISTON GROOVE	MAXIMUM WORN DIMENSION (WIDTH)
1st	.084 inch
2nd & 3rd	.0695 inch
4th & 5th	.195 inch

(d) If necessary, replace with a new piston.
(e) Fit new piston ring set, part number 12906 to engines rated up to 3000 RPM and #12337 to engines rated in excess of 3,000 RPM. The difference being only in the ring fitted to the 4th piston groove (see below)



Piston Ring Arrangement Shown Four-107 Engines Rated up to 3000 RPM
RING SET, PART NUMBER 12906

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P/N: 19055

NOTE: Ring set, part number 12337, is identical to 12906 with the exception of the ring supplied for the 4th groove. For this groove, the microland slotted scraper ring is supplied as in the 5th groove of both ring sets. Each ring set provides sufficient rings for one piston only. For a complete engine, therefore, four will be required.

FITTING OF PISTON RINGS

With the exception of the laminated ring fitted in the 4th groove of applications rated up to 3,000 RPM, the correct method of fitting will be apparent from the diagram overleaf. Detailed instructions in respect to this type ring are contained below:

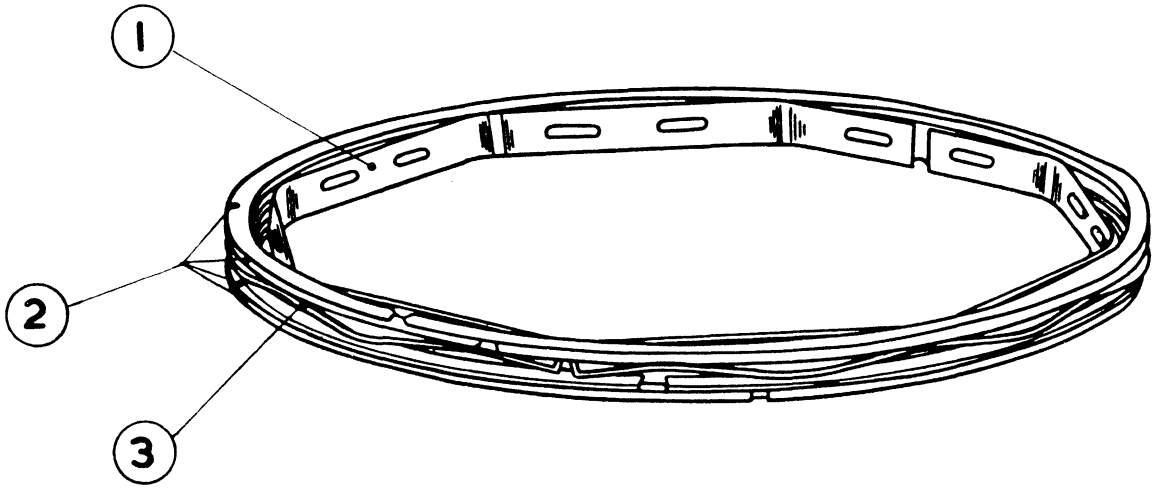
IMPORTANT:

(a) Before re-fitting the pistons, the "glaze" should be removed from the working surface of the liners by means of a medium grade emery cloth, applied in a semi-rotary movement.

(b) Care must be taken, however, to ensure that no abrasive matter is allowed to fall onto the crankshaft journals and bearings. Also, all traces of abrasive matter must be removed from the engine before re-assembly.

Below are part numbers and pertinent information to ensure ordering proper ring sets. As you will note, the rings used vary with engine rated RPM and whether new or original liners are used.

PART NO.	RING SET	REMARKS
12738	Ring Set (1)	New Liner, 3000 RPM -4.99 To Ser. 7034969
12819	Ring Set (1)	New Liner, 3000 RPM-4-107 From Ser.7034969
12958	Ring Set (1)	WORN Liner,3000 RPM- 4.99 From Ser.7007685
12840	Ring Set (1)	New Liner, 3000 RPM- 4.99 From Ser.7007685
12898	Ring Set (1)	WORN Liner,4000 RPM- 4.99 From Ser.7007685
12905	Ring Set (1)	New Liner, 3000 RPM-4-107
12906	Ring Set (1)	WORN Liner,3000 RPM-4-107
12907	Ring Set (1)	New Liner, 4000 RPM-4-107
12337	Ring Set (1)	WORN Liner,4000 RPM-4-107



SERVICE BULLETIN

DATE: 5/6/74 *BULLETIN NUMBER:* 69

MODEL: All marine generators and marine engines

SUBJECT: Exhaust system failures

When engine sea water is fed into an exhaust system so that the full stream strikes a surface, erosion may cause premature failures.

Proper design of either a water jacketed or a water injected ("wet)" exhaust system to prevent this problem requires that the sea water inlet be positioned so that the entering stream of sea water does not strike a surface directly. Also, the velocity of the entering sea water stream should be as low as possible which is achieved by having inlet fittings as big in diameter as possible.

In addition to the above design considerations, it is usually advantageous to divide the sea water flow at the point of entry to the exhaust system so that only a portion of it enters the exhaust system. The remainder is normally piped directly over the side. The proper proportion of the sea water flow to pass through the exhaust system can only be determined by trial and error. The goal is to prevent excessive exhaust temperatures with the least amount of sea water.

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SERVICE BULLETIN

V.17

DATE: May 29, 1974 *BULLETIN NUMBER:* 72

MODEL: All

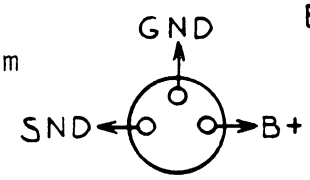
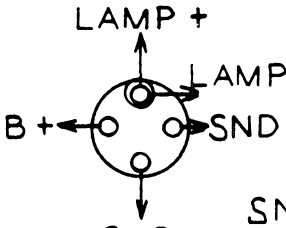
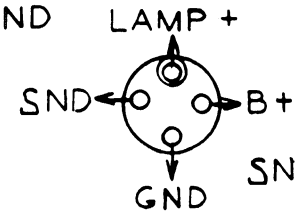
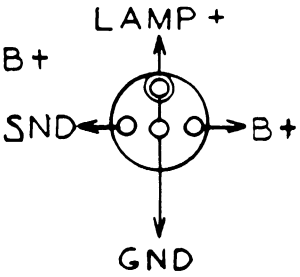
SUBJECT: Non-Interchangeability between Manufacturers of Gauges and Senders

In recent years we have purchased gauges and senders from four different manufacturers.

In no case may the gauge of one manufacturer be used with the sender of another manufacturer. In some cases the wiring of either or both the gauge and the sender varies by manufacturer.

Thus it becomes important, when ordering a replacement gauge or ordering a replacement sender, to order a matched set or to know conclusively who the manufacturer is.

Ammeters are electrically interchangeable.

	STEWART-WARNER 2" DIA CASE	VDO 2 3/8" DIA CASE	FARIA 2" DIA CASE	NOVOX 2" DIA CASE
Ammeter	11581	11931	16550	19165
Oil pressure gauge	11544	11914	16548	19166
Oil pressure sender	11542	11916	16551	19167
Water temp. gauge	11545	11913	16549	19168
Water temp. sender	11543	11915	16552	19169
Adapter ring to install 2" dia gauge in 2 3/8" dia panel cut-out	16023 and SB #44		16023 and SB #44	16023 and SB #44
Wiring diagram		 Also see SB #36		

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P/N: 19190

V.18

SERVICE BULLETIN

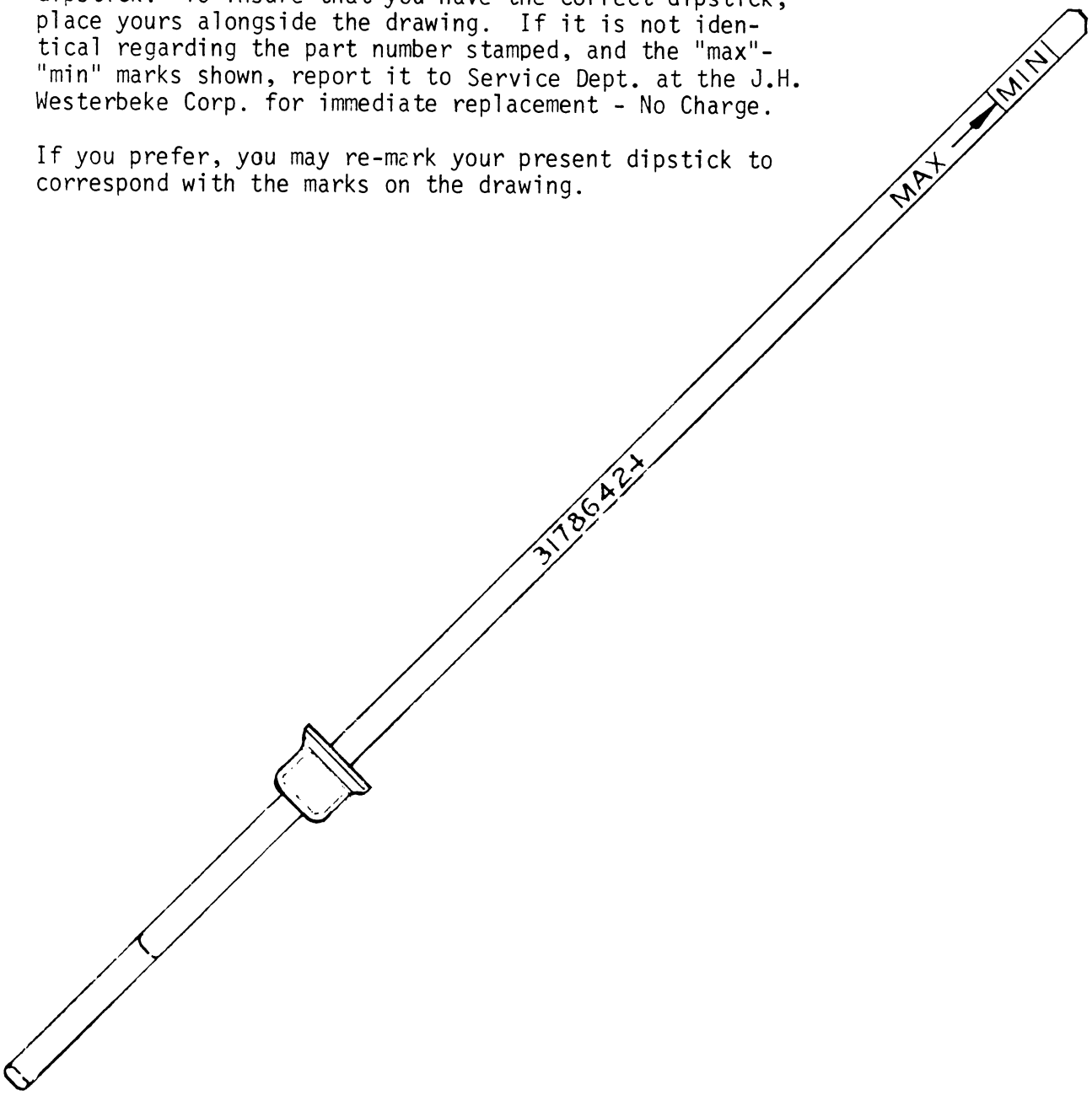
DATE: June 19, 1974 *BULLETIN NUMBER:* 73

MODEL: Four-107

SUBJECT: Lube Oil Sump Dipstick

There have been some reports that a very few Four-107 engines have been shipped with an incorrect oil sump dipstick. To insure that you have the correct dipstick, place yours alongside the drawing. If it is not identical regarding the part number stamped, and the "max"-"min" marks shown, report it to Service Dept. at the J.H. Westerbeke Corp. for immediate replacement - No Charge.

If you prefer, you may re-mark your present dipstick to correspond with the marks on the drawing.



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P/N: 19200

SERVICE BULLETIN

V.19

DATE: March 15, 1975 *BULLETIN NUMBER:* 80

MODEL: Westerbeke 40LB, 40LS, LB-49

SUBJECT: Westerbeke Lue-Cel

DESCRIPTION

The Westerbeke Lub-cel improves diesel engine cold starting and performance, typically allowing starts at 20° F. within 5 seconds in conjunction with hydraulic starting systems. It delivers a pre-determined quantity of lubricating oil, at a pre-determined rate, directly above the engine's intake valves during cranking and, when the engine has started, reloads itself from the engine oil gallery.

Pressure to deliver this oil is taken from the hydraulic starter return line. (Lub-cel is designed for use with American Bosch hydraulic starters.)

OPERATING PRESSURES

Delivery Pressure

Due to the high flow rate in the Bosch hydraulic system the return line builds up between 50 and 100 PSI. Close to the starter, this pressure is used to energise the Lub-cel.

Engine Oil Pressure

The Lub-cel requires 20-30 seconds to reload at 30 PSI lube oil pressure. The engine should never be run for less than a minute or two if the Lub-cel is to be kept fully charged with oil.

SERVICE

1. Engine Oil

The Lub-cel unit is not sensitive to types of oil used. With Westerbeke Four-107, Pilot 20 and LB-49, cold starting in below freezing temperatures it is imperative to use a good brand of S.A.E. 5W20 oil.

2. Hydraulic Fluid

We use 'Esso EP9' hydraulic fluid in our tests but any good grade equivalent hydraulic or telemotor oil may be used. In no case should oils be mixed.

3. Repair and Overhaul

All Lub-cel units should be overhauled every two years. A Factory exchange program is

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Service Bulletin 80 Con't.

available to facilitate this. Spare parts are available thru our parts department.

4. Bleeding air from Lub-cel

With engine running and oil pressure more than 30 PSI. Back off the two top screws in the diaphram housing to expel air. When oil is seen secure the two screws. Bring engine to idle. If the engine shows a short burst of power when idled there is more air in the diaphram housing. Repeat step 9. To flood delivery lines, start and stop engine about 4 or 5 times. Engine should be run at least 30 seconds each time.

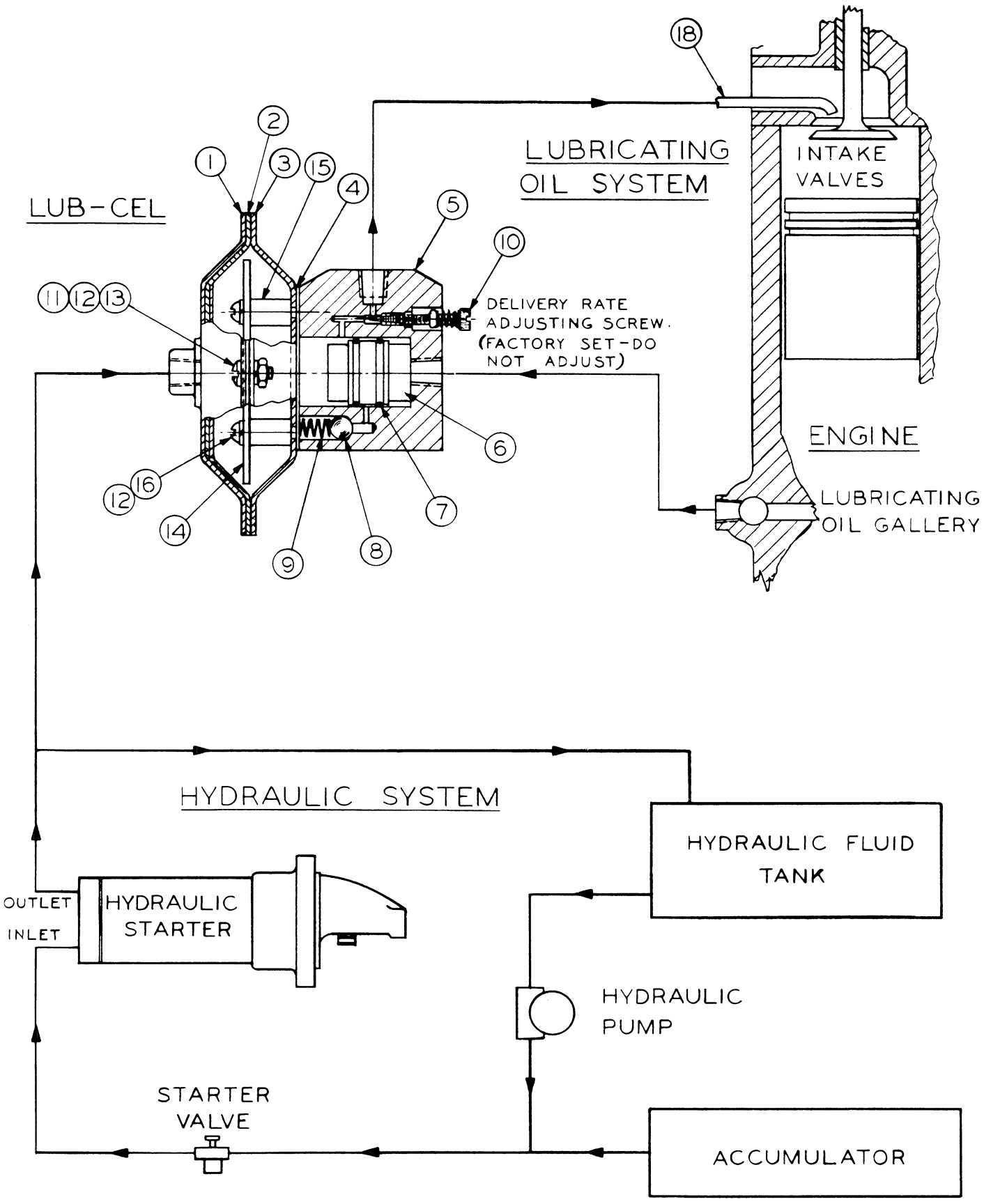
TROUBLE SHOOTING CHART

Fault	Cause	Remedy
No oil delivery	Failure to re-load	Check engine oil pressure, must be over 30 PSI. Check piston action. Should require less than 25 PSI to house.
	Needle valve closed	Open valve (see table below)

Model	Turns counterclockwise from closed position
Pilot 20	2 1/2
4-107LB	2 1/2
4-107LS	2 1/2
LB-49	4

Engine will not shut down	Piston O rings damaged	Close needle valve to stop oil flow. Check for rough or worn bore and replace O rings.
Engine speeds up briefly (1 second) when idled	Air in diaphram	Bleed air from Lub-cel (see SERVICE)
Hydraulic fluid discolored or contaminated by motor oil	Diaphram ruptured	Replace diaphram and change hydraulic and lubricating oil.
Persistant oil leaks	Hydraulic or engine oil pressure too high	Pressures should not be above 100 PSI. Refer to workshop manual for lube oil system and hydraulic starting system details.

WESTERBEKE LUB-CEL



DRWG 19457

WESTERBEKE LUB-CEL

ITEM	PN	NAME	REMARKS	QUAN
1	19371	HOUSING	Diaphragm (Hyd. Side)	1
2	19268	DIAPHRAGM		1
3	19274	HOUSING	Diaphragm (Piston Side)	1
4	19279	GASKET		1
5	19278	MANIFOLD		1
6	19280	PISTON		1
7	19342	O-RING		2
8	15618	BALL		1
9	19352	SPRING		1
10	19313	SCREW	Ass'y.	1
14	19428	PLATE		1
15	19429	PLATE		4
17	19305	NAMEPLATE		1
18-1	19331	LINE	Delivery Ass'y. Pilot-20LB.	1
18-2	19453	LINE	Delivery Ass'y. Four-107LB.	1
18-3	19290	LINE	Delivery Ass'y. LB-49	1
19-1	19470	KIT	Field Installation Four-107LB.	1
19-2	19471	KIT	Field Installation Four-107LS.	1

SERVICE BULLETIN

V.23

DATE: October 3, 1975 *BULLETIN NUMBER:* 81

MODEL: All

SUBJECT: Hydro-Hush Muffler Installation

The diagram on the reverse side shows a proper installation of the Hydro-Hush stainless steel muffler.

Make sure installation is such that water cannot enter engine at any angle of heel or pitch.

Muffler remains approximately twenty-five percent full of water after engine is shut down with maximum thirty-three inch lift used.

Muffler must be installed as close to fore-aft centerline of boat as possible.

There must be an unblocked vent to atmosphere at the high point of the sea water circuit (where it passes above the waterline) to break the vacuum which would encourage siphoning through the sea water circuit upon engine shutdown. Such siphoning would fill the engine with sea water through its exhaust. Pipe the air vent with approximately 3/16 copper tubing to discourage water flow through it when the engine is running. If water flows through the air vent when the engine is running, pipe it over the side or into the transom exhaust outlet. But be sure it will drain upon engine shutdown and function properly as a siphon break by venting the sea water circuit to atmosphere.

Use as few right angle fittings as possible. If there is any question as to back pressure, check your engine manual.

Exhaust line diameters indicated are minimums. Refer to engine manual for specifics regarding run lengths and sizes greater than indicated.

The installation tips given are to be used as a guide only. We cannot be responsible in any way for muffler installation. We presume basic understanding of good marine practice on the part of the installer.

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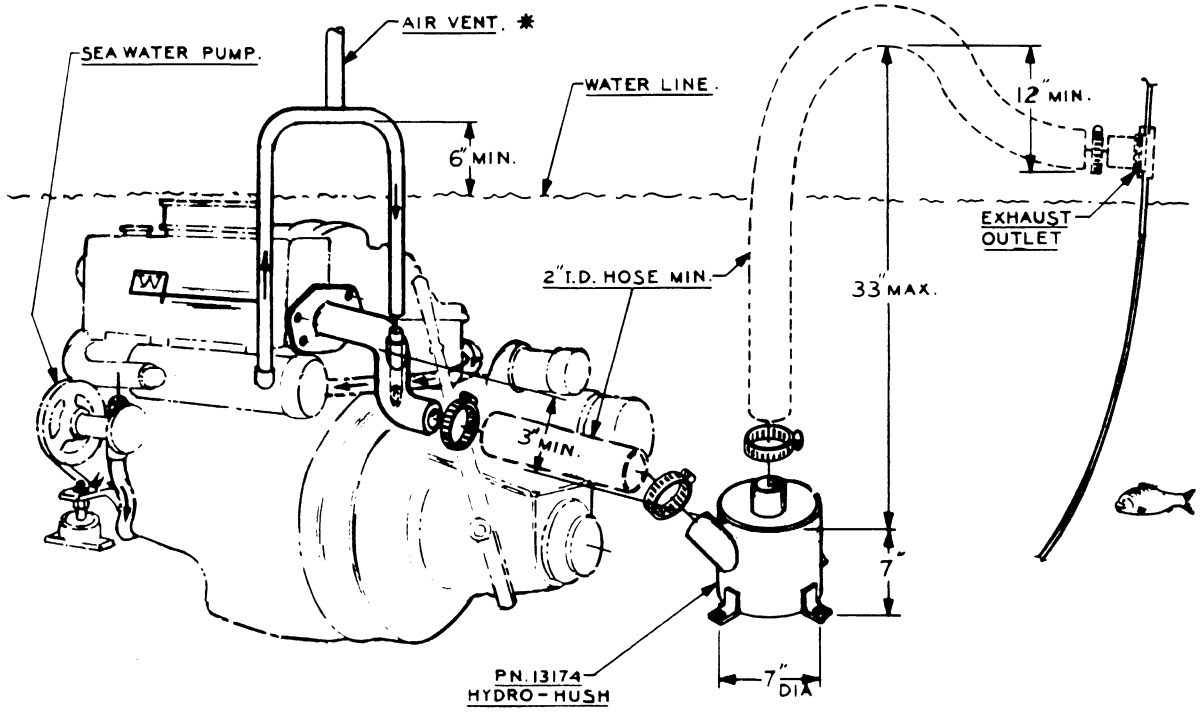
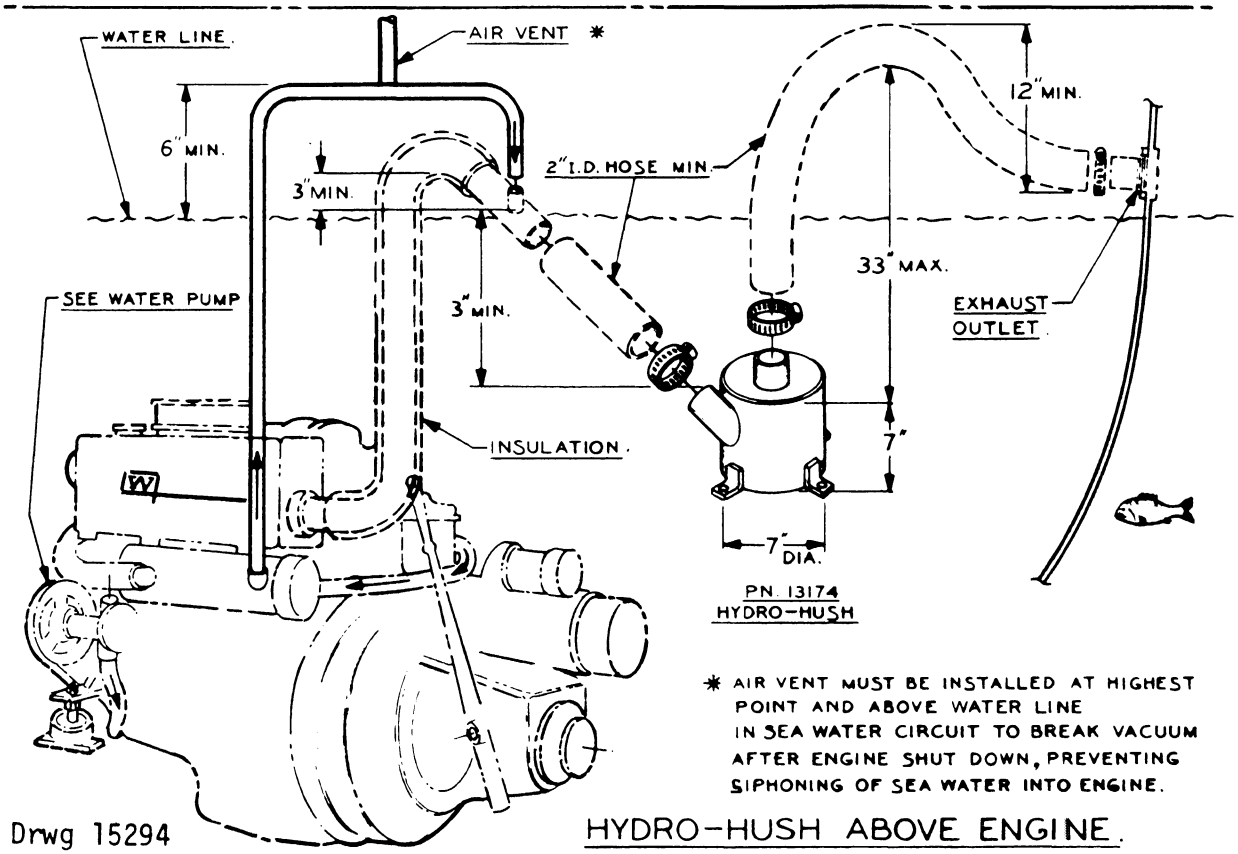
P/N: 19468

HYDRO-HUSH BELOW ENGINE.





* AIR VENT MUST BE INSTALLED AT HIGHEST POINT AND ABOVE WATER LINE IN SEA WATER CIRCUIT TO BREAK VACUUM AFTER ENGINE SHUT DOWN, PREVENTING SIPHONING OF SEA WATER INTO ENGINE.

Drwg 15294

HYDRO-HUSH ABOVE ENGINE.

SERVICE BULLETIN

DATE: May 19, 1980 *BULLETIN NUMBER:* 82

MODEL: All

SUBJECT: Battery Recommendations

BATTERY RECOMMENDATIONS

MODEL	BATTERY AMPERE HOURS	VOLTAGE
W-7, & WPD4	60-90	12 V.D.C.
W-13 & 4.4 KW	90-125	12 V.D.C.
W-21 & 7.7 KW	90-125	12 V.D.C.
W-27 & 11 KW	90-125	12 V.D.C.
W-33	90-125	12 V.D.C.
W-30	125-150	12 V.D.C.
W-40, & WPD-10-15 KW	125-150	12 V.D.C.
W-50	125-150	12 V.D.C.
W-58 & WTO-20 KW	125-150	12 V.D.C.
W-60 & WBO-20 KW	150-170	12 V.D.C.
W-80 & 30KW	170-200	12 V.D.C.
W-120 & 45 KW	200 minimum	12 V.D.C.

The ampere hour range shown is minimum. There is no real maximum.

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V.26

SERVICE BULLETIN

DATE: September 4, 1975 *BULLETIN NUMBER:* 84

MODEL: All

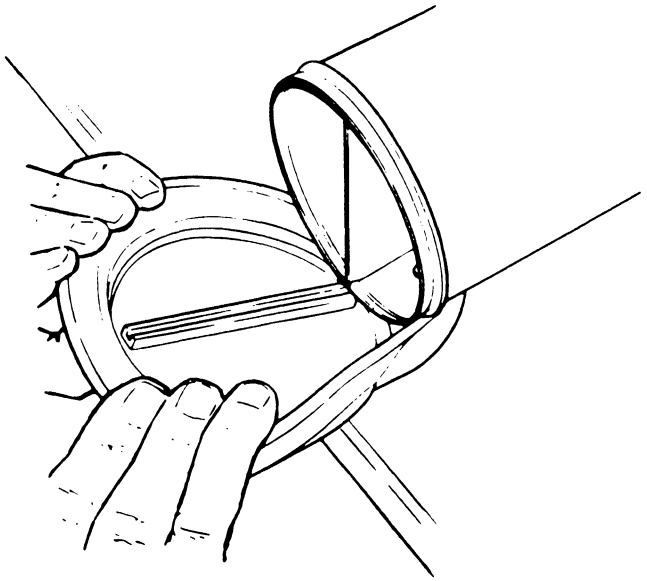
SUBJECT: Heat Exchanger Rubber End Cap

Many heat exchangers supplied on our various products incorporate a molded rubber end cap to facilitate inspection of the tubes.

There have been occasions on which engine overheating has been caused by the improper positioning of this rubber end cap.

It is absolutely essential that the molded channel running across the inside of the cap be positioned over the baffle of the heat exchanger, according to the drawing below.

In any cases of engine overheating where such a rubber end cap is used, it should be checked for proper positioning along with other routine troubleshooting.



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P/N: 20684

SERVICE BULLETIN

V.27

DATE: September 18, 1975 *BULLETIN NUMBER:* 87

MODEL: All Marine Engines

SUBJECT: Alternator Output Splitter

GENERAL DESCRIPTION: The splitter is a solid state device which allows two batteries to be recharged and brought to the same ultimate voltage from a single alternator as large as 120 amp and, at the same time, isolates each battery so that discharging one will have no effect on the other. Charging rates are in proportion to the batteries' voltage (state of discharge). This method precludes the necessity, and even the desirability of a rotary switch for selecting which battery is to be charged. It also assures that ships services cannot drain the engine starting battery.

INSTALLATION:

1. Mount splitter on a metal surface other than the engine, preferably in an air stream if available. Do not install near engine exhaust system. Install with cooling fins aligned vertically.
2. Be sure to use a wire size appropriate to the output of the associated alternator. In full power systems number 4 wire is recommended from the alternator to the splitter and from the splitter to the batteries.
3. Connect the alternator output terminal to the center splitter terminal.
4. Connect one splitter side terminal to one battery (s).
5. Connect the other splitter side terminal to the other battery(s).
6. When the splitter is installed, both batteries will see a charging voltage 8/10 volts less than usual. This voltage drop can be regained, if desired, by connecting the regulator wire directly to the alternator output terminal instead of the regulator terminal.

TEST INFORMATION: When the engine is not running, the side splitter terminals should read the voltage of the respective battery. The center splitter should read zero voltage.

With the engine running and alternator charging, the side splitter terminals should read the same voltage which should be the voltage of the regulator or somewhat less. The center splitter terminal should read .82 volts higher than the readings of the side terminals.

Continued...

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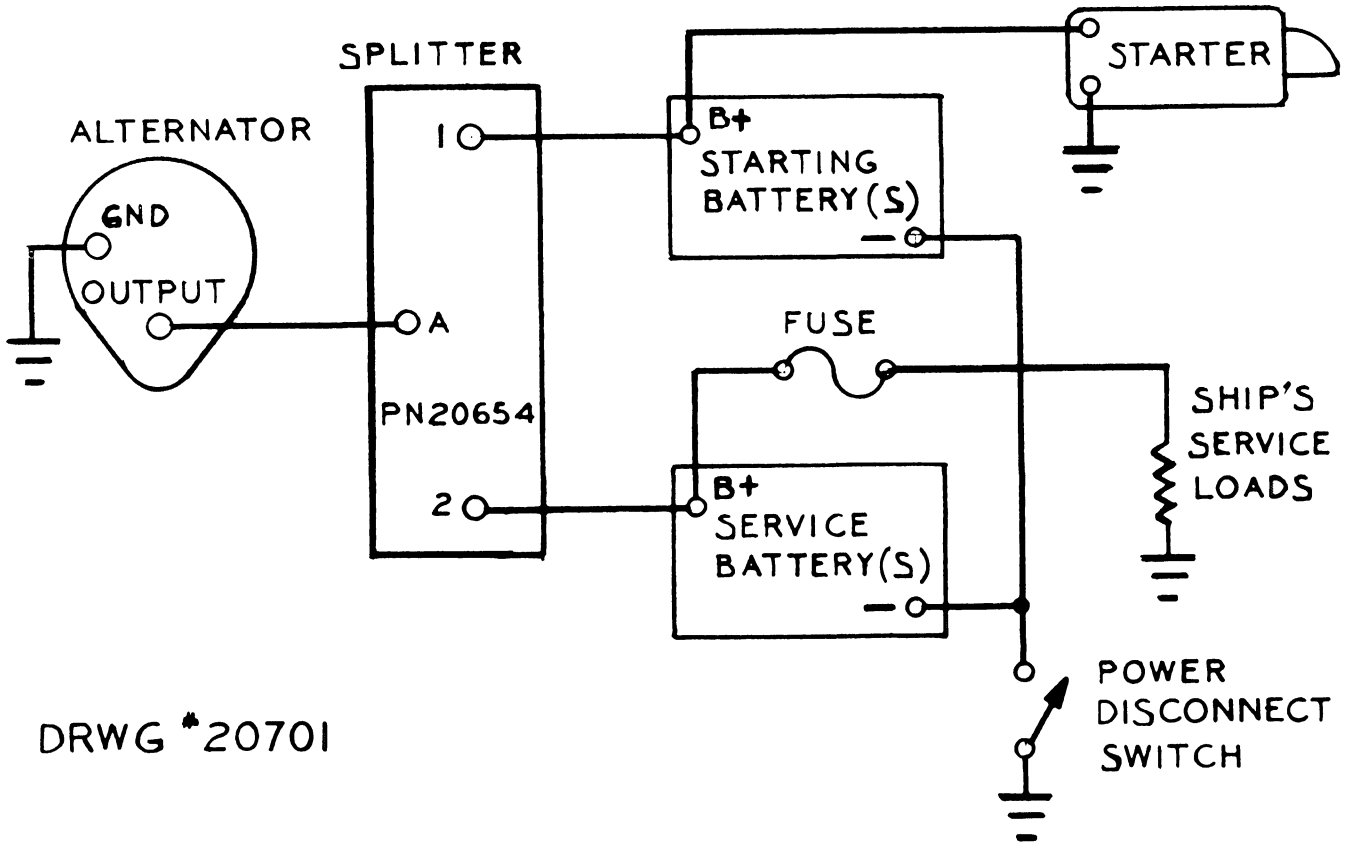
P/N: 20745

SERVICE BULLETIN #87 (Continued)
(Alternator Output Splitter)

BY-PASSING SPLITTER: In the event of failure, batteries may be charged directly from alternator by connecting either splitter terminal #1 or #2 to terminal A, bypassing the splitter itself. This should not be done simultaneously for both batteries unless they are, and will remain at, the same voltage (state of charge).



SERVICE BULLETIN

DATE: April 28, 1976 *BULLETIN NUMBER:* 92

MODEL: All

SUBJECT: Troubleshooting Water Temperature and Oil Pressure Gauges

Given a presumably faulty gauge indication with the instrument panel energized, the first step is to check for 12 VDC between the ign. (B+) and neg. (B-) terminals of the gauge.

Assuming there is 12 volts as required, leave the instrument panel energized and perform the following steps:

1. Disconnect the sender wire at the gauge and see if the gauge reads zero, the normal reading for this situation.

2. Connect the sender terminal at the gauge to ground and see if the gauge reads full scale, the normal reading for this situation.

If both of the above gauge tests are positive, the gauge is undoubtedly O.K. and the problem lies either with the conductor from the sender to the gauge, or with the sender.

If either of the above gauge tests is negative, the gauge is probably defective and should be replaced.

Assuming the gauge is O.K., preoceed as follows. Check the conductor from the sender to the sender terminal at the gauge for continuity.

Check that the engine block is connected to ground. Some starters have isolated ground terminals and if the battery is connected to the starter (both plus and minus) the ground side will not necessarily be connected to the block.

If the sender to gauge conductor is O.K. and the engine block is grounded, the sender is probably defective and should be replaced.

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V.30

SERVICE BULLETIN

DATE: June 22, 1976 *BULLETIN NUMBER:* 93

MODEL: All

SUBJECT: Adjusting Paragon P200 Series Reverse Band

If the boat moves forward when the gear is in neutral at proper idle speed, the reverse band may be out of adjustment. When adjusting, be very careful not to get reverse band too tight or it will burn out. If the boat goes backwards when in neutral, it may be too tight.

The following adjustment procedure should only be carried out when it is not possible to obtain the service of an authorized Paragon transmission service dealer.

To Adjust:

On the outside left side of the gear there is a bolt in the mounting pad. Under its head are 1 to 3 washers. Remove one washer. This should stop forward boat movement. But under NO circumstances use fewer than one washer nor more than three.

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P/N: 21683

SERVICE BULLETIN

V.31

DATE: September 9, 1976 *BULLETIN NUMBER:* 94

MODEL: All

SUBJECT: Fuel Pressure Switch Installation

Overleaf is a parts list and an illustration showing the proper installation of the fuel pressure switch used on most of our engine products.

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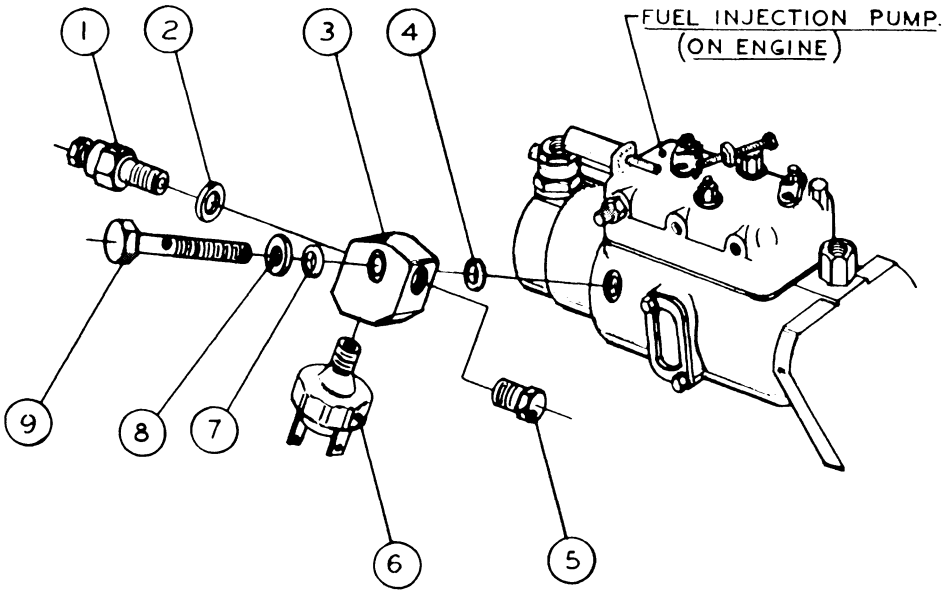
DATE	SYM	REVISION RECORD	AUTH	DR	CK



ITEM	PART NO.	DESCRIPTION	QTY
9	19187	HEX HD. SCREW	1
8	19442	FLAT WASHER	1
7	19320	"O" RING 7/16 O.D.	1
6	11383	FUEL PRESSURE SWITCH	1
5	11615	PLUG	1
4	19321	"O" RING 9/16 O.D.	1
3	19185	ADAPTER	1
2	19261	COPPER WASHER	1
1	19204	SCREW ASS'Y (BLEED)	1

TOLERANCES (EXCEPT AS NOTED)	J. H. WESTERBEKE CORP. AVON, MA. 02322	
DECIMAL ± ~	ALL ENGINES	SCALE NONE; DRAWN BY B.J.S.; APPROVED BY
FRACTIONAL ± ~	TITLE INSTALLATION DWG, FUEL PRESS. SWITCH TO A FUEL INJECTION PUMP.	
ANGULAR ± ~	DATE 9-9-76	DRAWING NUMBER 21743

K·E ALBANENE ® 10 9468 ENGINEERS' STANDARD FORM

MADE IN U.S.A.

SERVICE BULLETIN

V.33

DATE: 7 July 80 Reissued *BULLETIN NUMBER:* 95

MODEL: All

SUBJECT: Domestic Hot Water Heaters

PRINCIPLE

The heater is connected in series with the engine's freshwater circuit. This allows full water flow for maximum heat transfer to the heater. The series installation also avoids several potential pitfalls of installations in which the heater is in parallel with either the engine's by-pass or its internal freshwater circuit.

The only potential disadvantage of a series installation is flow restriction due either to a restrictive heater design, a large engine water flow (such as models W58, W80, W120), or a combination of both.

Installation

The shorter the length of piping to and from the heater, the better. The elevation of the heater should assure that the top of its internal coil is no higher than the engine pressure cap. If the heater must be higher than this at any heel angle, then the optional remote fill tank must be installed to be the highest point of the circuit.

Piping between the engine and heater should rise continuously from the heater to the engine so that trapped air will rise automatically from the heater to the engine. If trapped air can rise to the heater, then a petcock or other convenient method of bleeding that air is a necessity.

Study the attached sketches. A convenient place to interrupt the engine cooling circuit is between the thermostat housing outlet and the exhaust manifold inlet. This is also the hottest water available. CAUTION: While most owners want the hottest water available, it is possible for scalding water or even steam to come from the faucets.

Since the heater is in series with the engine cooling water, any other convenient point of the circuit can also be interrupted for heater installation.

Some engine/heater combinations require that a "by-pass" nipple be installed in parallel with the heater. This is required to maintain an adequate fresh water flow for cooling capability. The table below shows the minimum diameter of "by-pass" nipples in these situations:

	HEATER		
MODEL	SENDURE	ALLCRAFT	RARITAN
W 30			3/8" NPT
W 40			3/8" NPT
W 50			1/2" NPT
W58	1/2" NPT	1/2" NPT	3/4" NPT
W80	1/2" NPT	1/2" NPT	3/4" NPT
W120	1/2" NPT	1/2" NPT	3/4" NPT

Please see sketches on overleaf.

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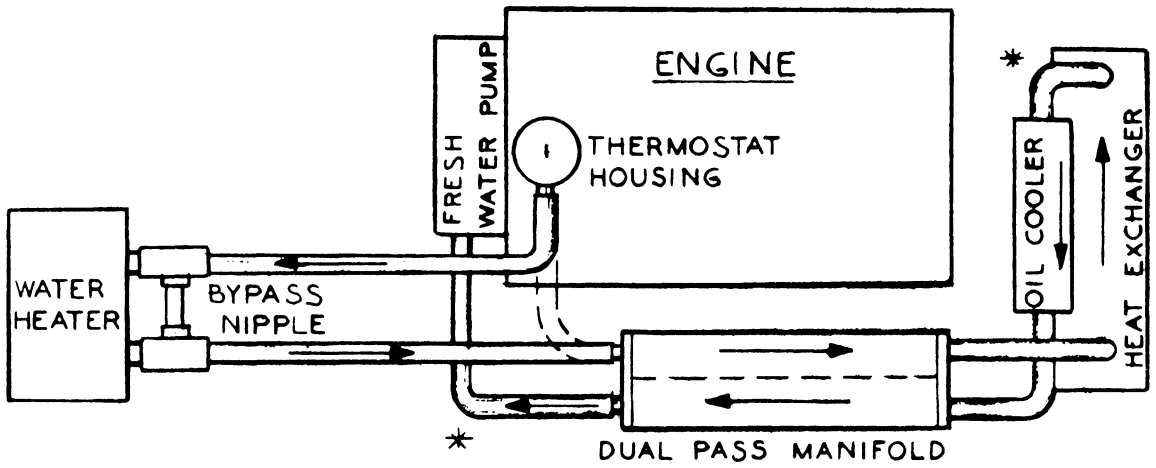
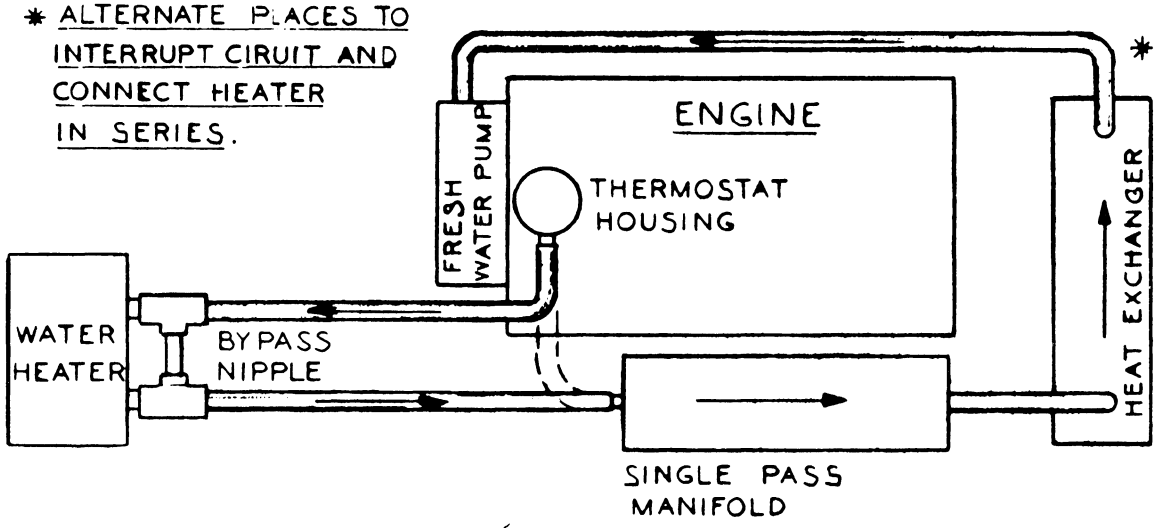
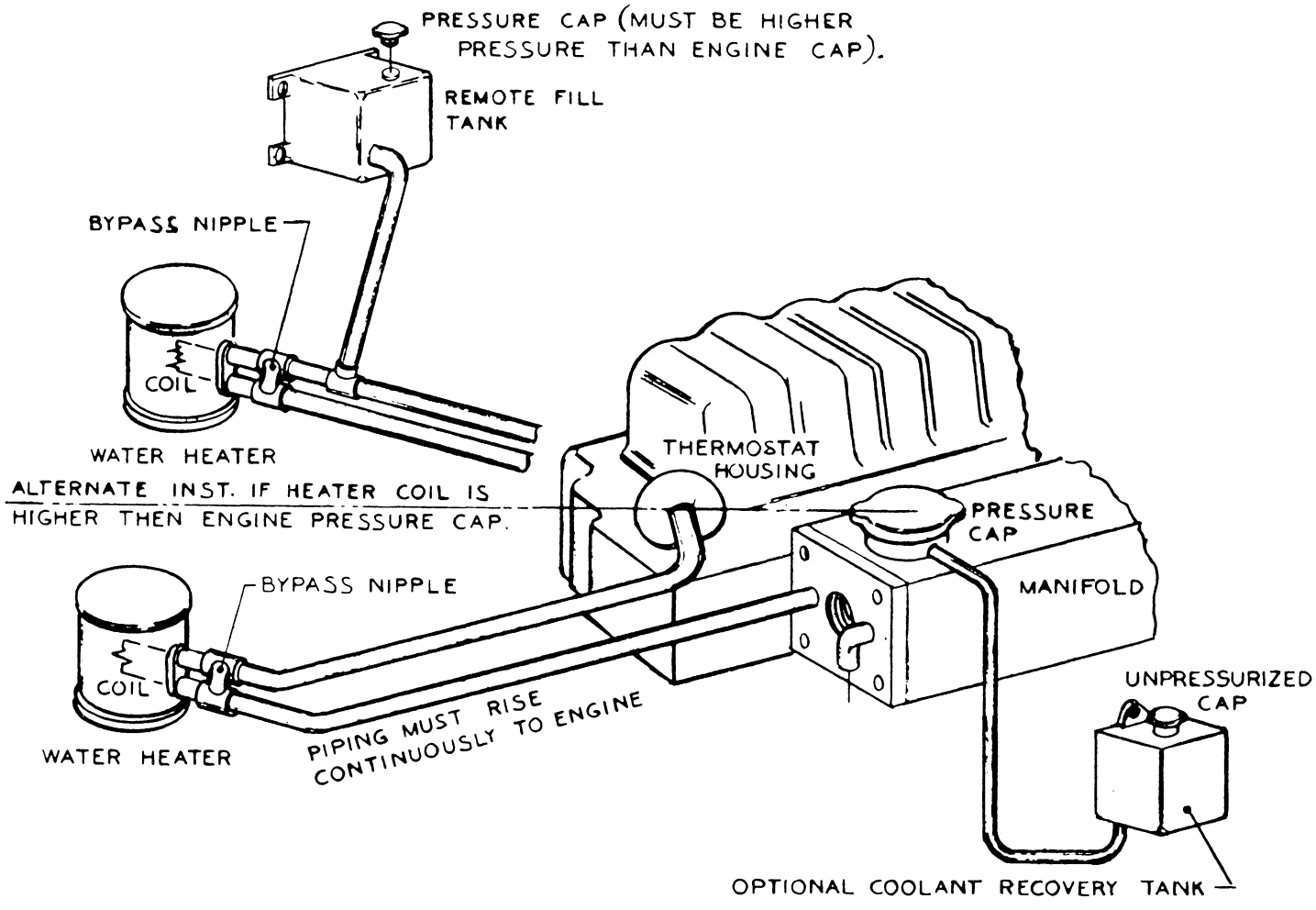


* ALTERNATE PLACES TO INTERRUPT CIRUIT AND CONNECT HEATER IN SERIES.





SERVICE BULLETIN

V.35

DATE: May 1, 1980

BULLETIN NUMBER: 107

MODEL: All Models

SUBJECT: Thermostats

Beginning approximately May, 1980, thermostats supplied by the factory have a by-pass hole sufficient to allow adequate water flow through the exhaust manifold, head, and block, during engine warm-up.

This flow is mandatory, especially in the case of marine engines and generator sets which have significant load applied soon after start-up.

We strongly recommend that only genuine WESTERBEKE thermostats be used in WESTERBEKE products to assure proper design in this regard.

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V.36

SERVICE BULLETIN

DATE: May 5, 1980 *BULLETIN NUMBER:* 108

MODEL: ALL

SUBJECT: Circuitry Change for Marine Propulsion Engines

With the W58 we introduce a new electrical circuit which will eventually be used on most models.

Some features of the new circuit are as follows:

1. A voltmeter is substituted for an ammeter. Naturally an ammeter can still be installed separately.

2. All wires between the engine and the instrument panel need not be heavier than 14 AWG.

3. The panel contains controls for preheating and starting the engine, eliminating the necessity for a separate control panel. Of course the controls can be installed remotely from the panel by the builder if desired.

4. The circuit allows commonization of the instrument panel across the broadest possible range of engine models, simplifying the distribution of spare parts.

5. The circuit allows commonization of engine wiring harnesses across the broadest range of engine models, simplifying the distribution of spare parts.

The same connectors and color coding of the connector poles are used on both new and old harnesses and cables. Functional color codes are not necessarily the same in new and old circuits. The new panel will not operate with an older engine, and new engines will not operate with an older panel. Because the connectors are the same, a physical mating of old and new components is possible, but neither the panel nor the engine will operate and no harm can be done by accidental mismatching.

Please see diagram on overleaf.

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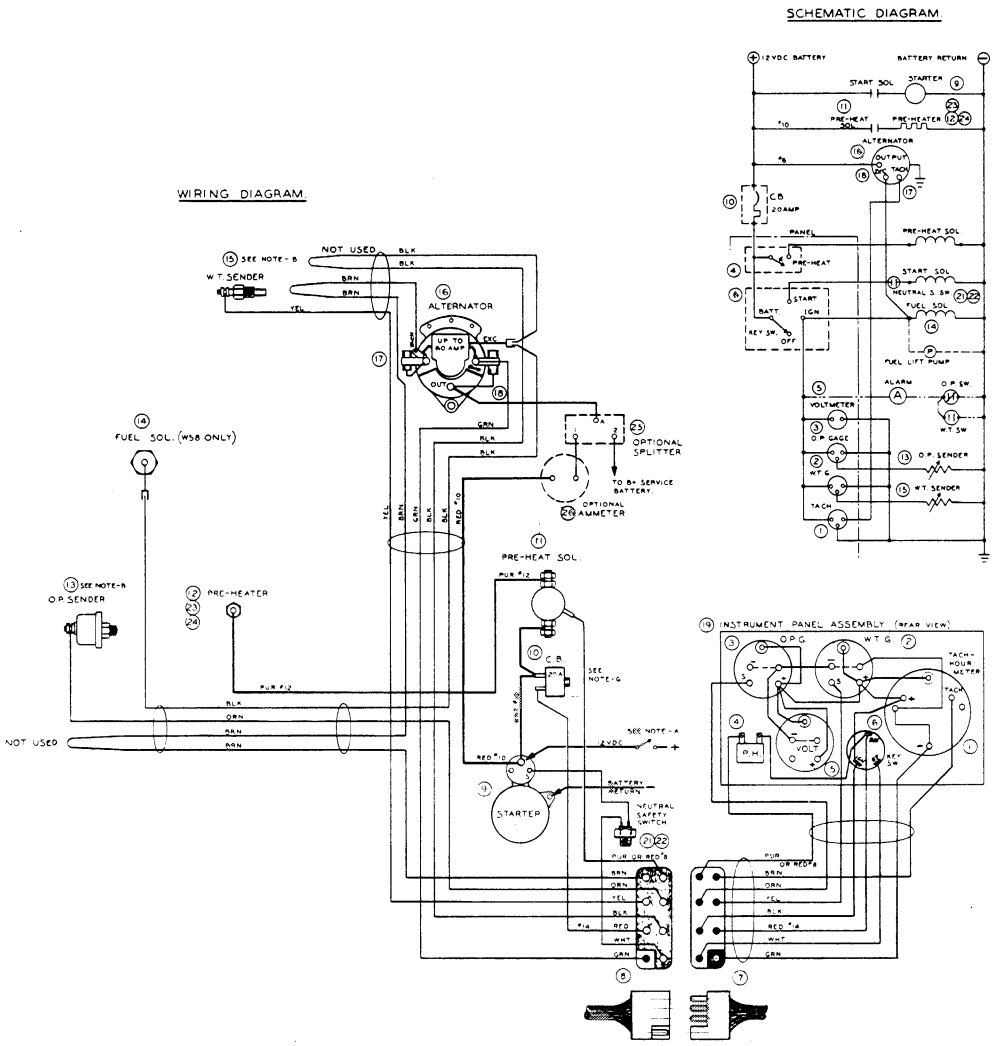
SCHEMATIC DIAGRAM
WIRING DIAGRAM
12 VDC BATTERY
BATTERY RETURN
START SOL
STARTER
PRE-HEAT SOL
PRE-HEATER
ALTERNATOR
CB
20 AMP
PANEL
PRE-HEAT
START
IGN
BATT
KEY SW.
OFF
NEUTRAL S. SW.
FUEL SOL
FUEL LIFT PUMP
ALARM
O.P. SW.
VOLTMETER
O.P. GAGE
W.T. G.
W.T. SW
O.P. SENDER
W.T. SENDER
TACH
NOT USED
W.T. SENDER
SEE NOTE - B
ALTERNATOR
UP TO 40 AMP
FUEL SOL. (WSB ONLY)
OPTIONAL SPLITTER
TO B+ SERVICE BATTERY
OPTIONAL AMMETER
PRE-HEAT SOL.
SEE NOTE-B
O.P. SENDER
PRE-HEATER
C.B.
SEE NOTE-G
SEE NOTE-A
12VDC
STARTER
BATTERY RETURN
NEUTRAL SAFETY SWITCH
INSTRUMENT PANEL ASSEMBLY (REAR VIEW)
O.P.G.
W.T.G.
TACH-HOUR METER
TACH
VOLT
P.H.
KEY SW.

V.38

SERVICE BULLETIN

DATE: May 5, 1980 *BULLETIN NUMBER:* 109

MODEL: W58

SUBJECT: Two Pass Manifold

The W58 employs a two pass manifold. It is a key feature of a new cooling system first appearing on the W58. The system is vented by the pressure cap at the return side of the fresh water circulating pump, the point of the lowest pressure within the system. This has the advantage of increasing cooling capacity by preventing cavitation at the fresh water pump under higher temperature conditions.

This system will ultimately be incorporated on most models.

The schematic on the overleaf shows the water flow. Operation of the circuit is as follows:

1. The thermostat has a permanent by-pass port of .06 square inches to assure water flow through the manifold while the engine is warming up. Replacement thermostats must have this permanent by-pass port.

2. Hot water leaving the engine thermostat housing passes through the inside half of the water jacketed exhaust manifold to the heat exchanger inlet.

3. Water leaving the heat exchanger enters a fresh water cooled oil cooler, if used.

4. Water leaving the oil cooler or heat exchanger enters the outside half of the water jacketed manifold.

5. The outside half of the manifold is comprised of two sections: a cooling path adjacent to the exhaust passage and an air removal path which allows entrained air to rise to the top of the manifold.

6. The pressure cap is located at the top of the air removal path.

7. From the manifold, coolant returns to the suction side of the fresh water pump.

The system is designed to accept an optional coolant recovery tank. This useful accessory offers several advantages, including:

1. A remote fill point for the circuit, in which case it should be located slightly higher than the engine's pressure cap.

Continued.....

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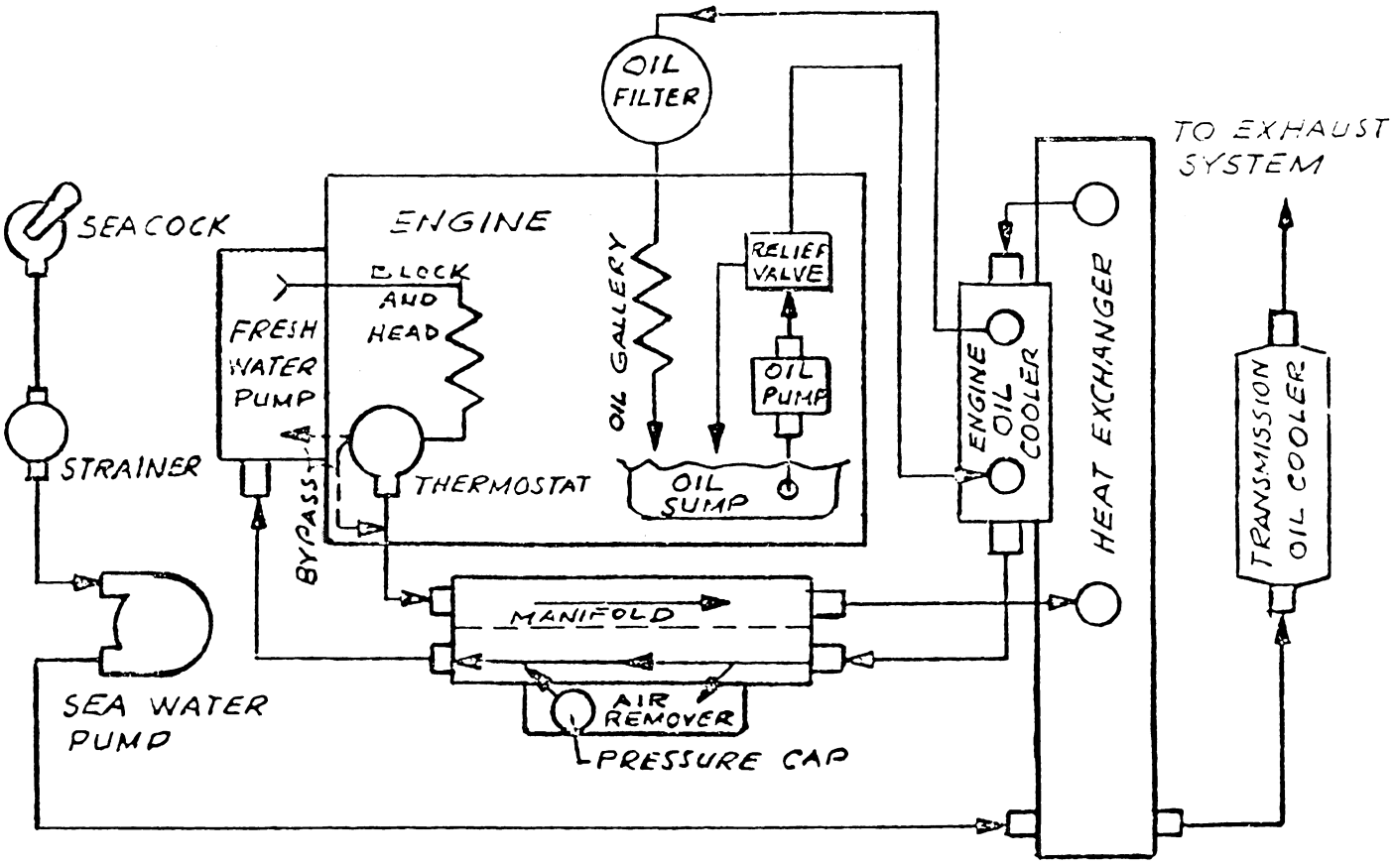
2. A means of conveniently observing the water level in the circuit.

3. A means of assuring that the circuit is always completely full of cooling water.

4. The coolant recovery system operates without diverting engine cooling water. It is a one-way connection to the system which provides a place for expanding water to go while the engine is warming up and, conversely, a source of water to refill the system as the engine cools down.



V.40

SERVICE BULLETIN

DATE: May 20, 1980 *BULLETIN NUMBER:* 110

MODEL: All

SUBJECT: Ammeter Wire Sizes

Ammeters may be installed in conjunction with any Westerbeke marine diesel engine or diesel generator set. The range of the ammeter must be appropriate for the maximum output of the alternator.

Additionally, the wire size for the alternator output circuit, including the ammeter, varies with the total length of that circuit. The table below shows the maximum current that can be carried various total distances by various wire sizes, to and from source to load.

WIRE SIZE TABLE

System Volts	Total Length of wire in feet	MAXIMUM CURRENT(AMPS) 35	40	55	60	70	85	120
12	1 to 5	12	12	12	8	8	8	6
12	5 to 10	10	10	8	6	6	6	4
12	10 to 20	6	6	6	6	3	2	1
12	20 to 30	6	4	4	2	1	1	1
12	30 to 40	4	2	2	1	1	0	0
24	1 to 5	14	14	12	12	10	10	8
24	5 to 10	12	12	10	10	8	8	6
24	10 to 20	10	8	8	6	6	4	4
24	20 to 30	8	6	6	4	4	4	2
24	30 to 40	6	6	4	4	2	2	0
32	1 to 5	14	14	12	12	10	10	8
32	5 to 10	12	12	10	10	8	8	6
32	10 to 20	10	8	8	6	6	4	4
32	20 to 30	8	6	6	4	4	4	2
32	30 to 40	6	6	4	4	2	2	0

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