

# **TECHNICAL MANUAL**

## **WESTERBEKE 30**

### **Marine Diesel Engine**

**(Formerly Four-91)**

PUBLICATION #11874

Edition Five

September 1980



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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° from the vertical. A spacer bar must be placed between the two lifting eyes, if supported by valve cover studs.

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

pry against this with crowbar, as you may distort the coupling.

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

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

## ENGINE BOLTS

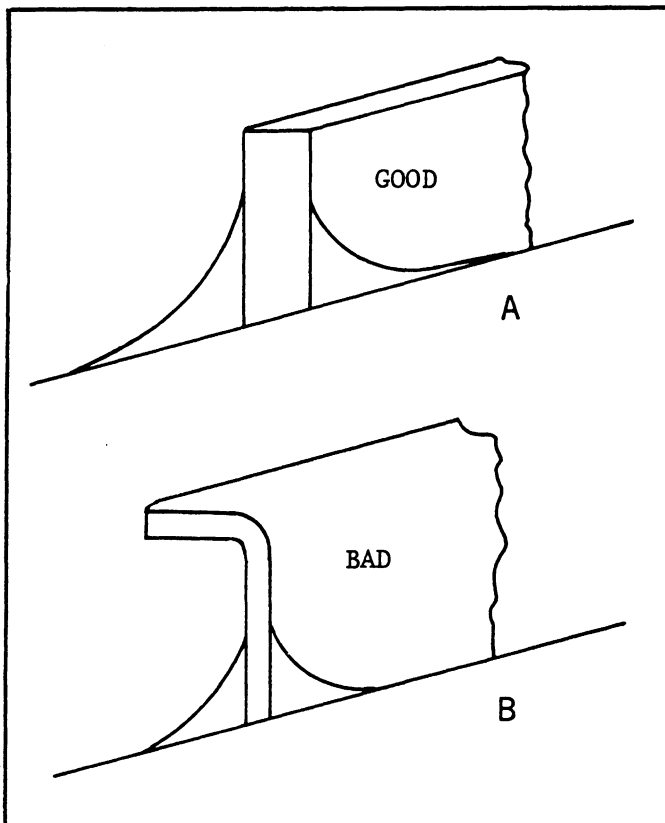
It is recommended that bronze hanger bolts of appropriate size be used through the engine flexible mounts. Lag screws are less preferred because their hold on the wood is weakened every time they are moved, whereas the lag bolt stays in position and the nut on top is used to tighten the engine down or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

## FOUNDATION FOR ENGINE

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

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

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



## PROPELLER COUPLING

Each Westerbeke Diesel engine is regularly fitted with a suitable coupling 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.

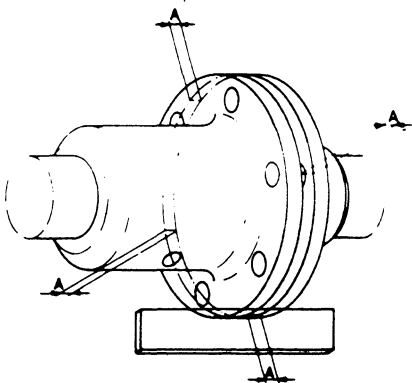
One particularly annoying result of misalignment may be leakage of transmission oil through the rear oil seal. Check to make sure that alignment is within the limits prescribed.

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 is not because the work was improperly done at first, but because the boat has taken some time to take its final shape and the engine bed and engine stringers have probably absorbed some moisture. It may even be necessary to re-align at a further period.

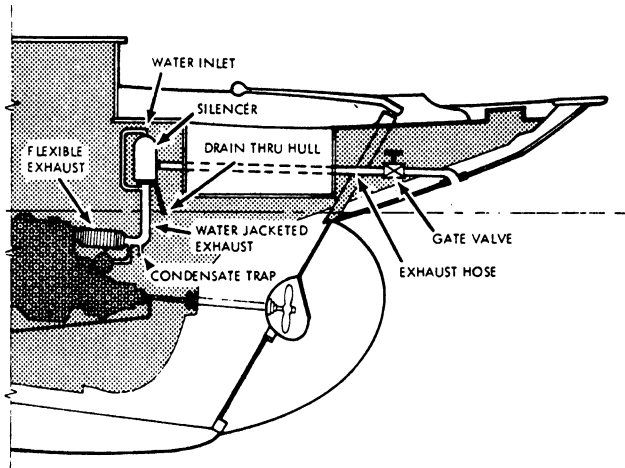
The coupling should always be opened up and the bolts removed whenever the boat is hauled out or moved from the land to the water, and during storage in a cradle. The flexibility of the boat often puts a very severe strain on the shaft or the coupling or both when it is being moved. In some cases the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

#### EXHAUST SYSTEM

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

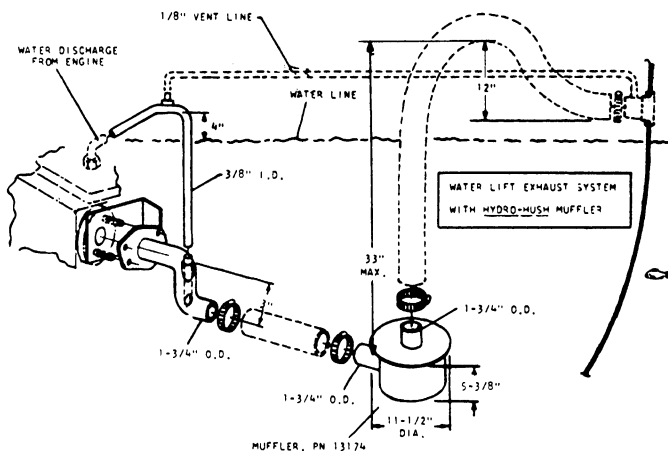
Brass or copper is not acceptable for wet exhaust systems, as the combination of salt water and diesel exhaust gas will

cause rapid deterioration. Galvanized iron fittings and galvanized iron pipe 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**

To insure vibration doesn't transmit to hull, use a flexible section preferably of stainless steel, no less than 12" overall, threaded at each end and installed as close to the engine as possible. This flexible section should be installed with no bends and covered with insulating material. The exhaust pipe should be properly supported by brackets to eliminate any strain on the manifold flange studs. 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



**WATER LIFT EXHAUST SYSTEM WITH "HYDRO-HUSH" MUFFLER**

support for the rubber hose to prevent sagging, bending, and formation of water pockets.

Always arrange that water discharge into the rubber hose section is behind a riser or sufficiently below the exhaust flange 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**

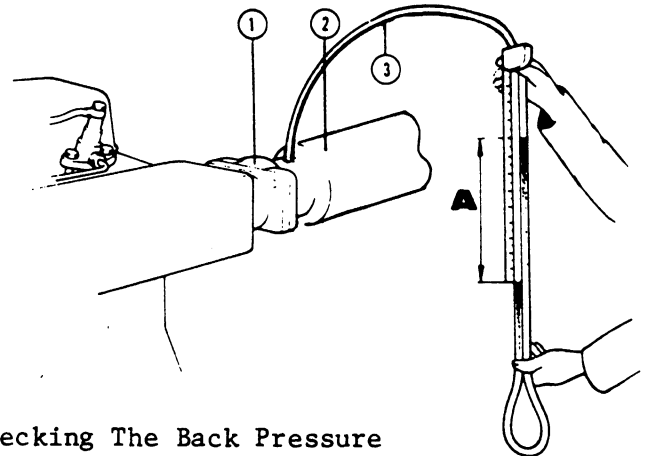
Back pressure must be measured on a straight section of the exhaust line and as near as possible to the engine exhaust manifold. The engine should be run at maximum load during the measurement period. Set-up should be as shown below.

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 re-aligned. Do not use street elbows in suction piping. All pipe and fittings should be of bronze. Use sealing compound at all connections to prevent air leaks. The neoprene impeller in the sea (raw) water pump should never be run dry.

#### FUEL TANK AND FILTERS

Fuel tanks may be of fiberglass, monel, aluminum, plain steel or terne plate. If made of fiberglass, be certain that the interior is gel coated to prevent fibers from contaminating the fuel system. Copper or galvanized fuel tanks should not be used. It is not necessary to mount the tank above the engine level as the fuel lift pump provided will raise the fuel from the tank. The amount of lift should be kept minimum (6 feet being maximum). If a tank is already installed above 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 airlocks 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/circuit breaker requirements.

Starter batteries should be located as close to the engine as possible to avoid voltage drop through long leads. It is bad practice to use the starter batteries for other services unless they require low amperage or are intermittent. In cases where there are substantial loads (from lights, refrigerators, radios, depth sounders, etc.) it is essential to have a complete, separate system and to provide charging current for this by means of a second alternator or "alternator output splitter".

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



Carefully follow the recommended wire sizes shown in the wiring diagrams. Plan installation so the battery is close to 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, W13, W27 and W33.

# 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.

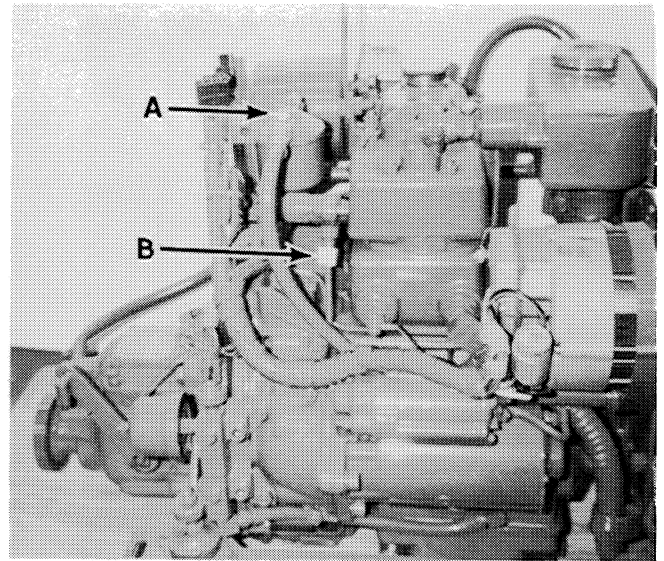


Figure 1

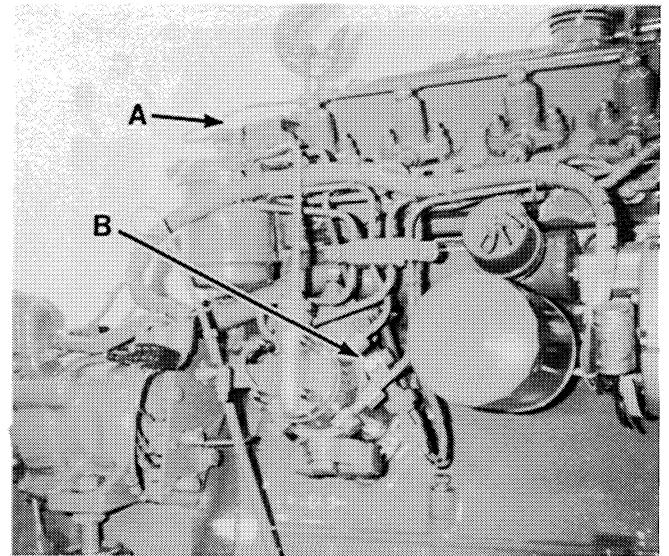


Figure 2

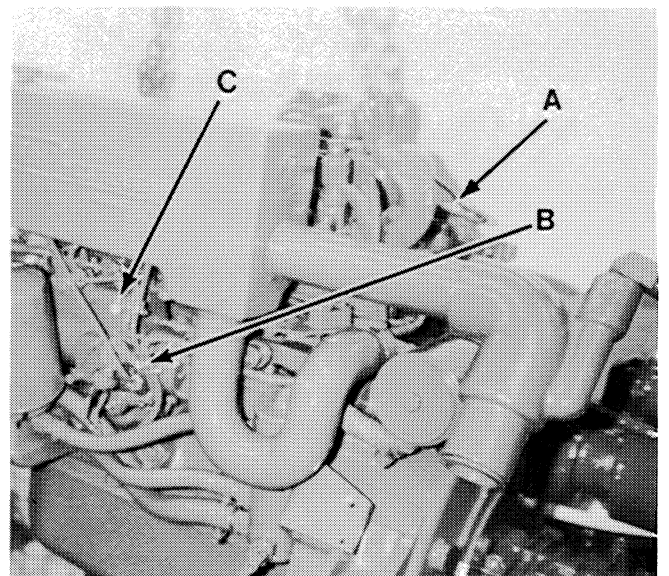


Figure 3

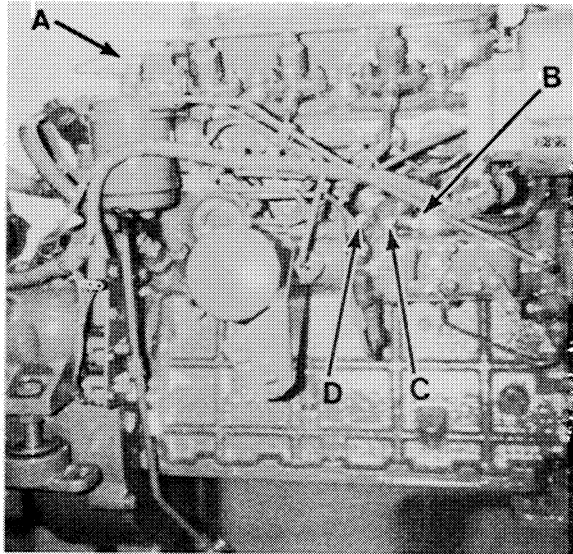


Figure 4

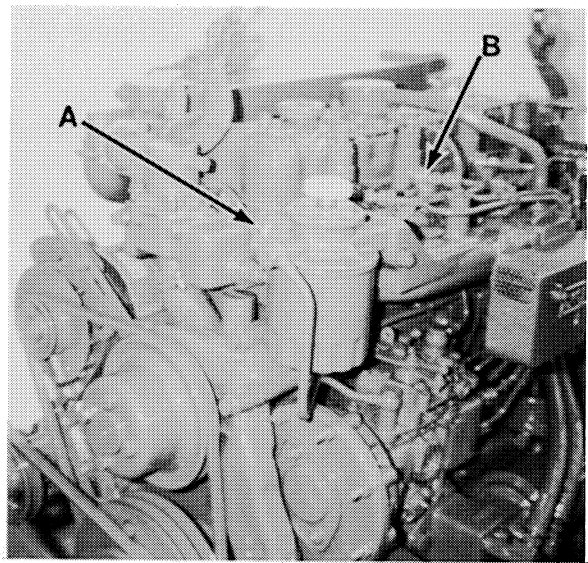


Figure 7

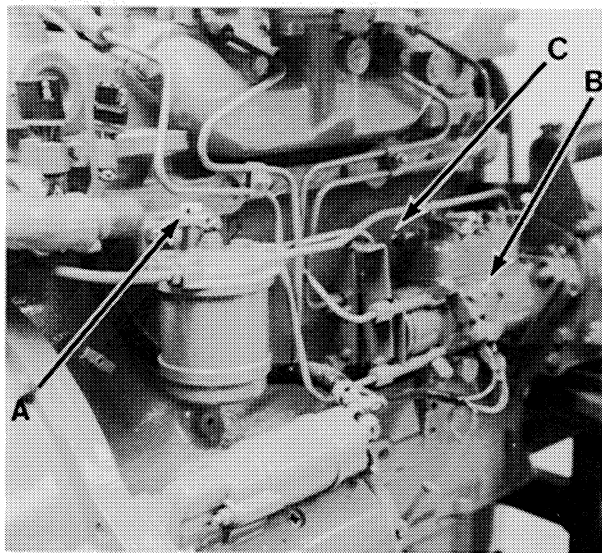
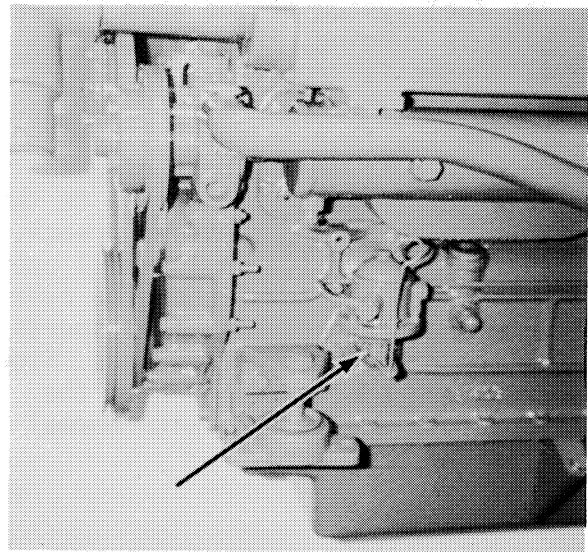


Figure 5



Typical Mechanical Fuel Lift Pump

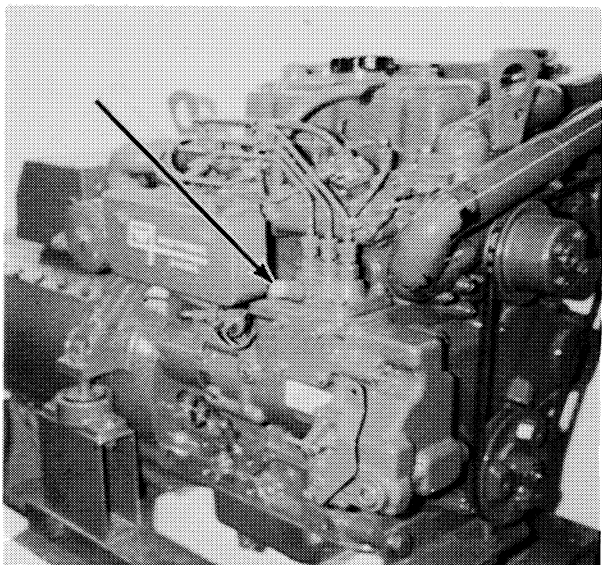


Figure 6

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. Oil may be sucked out of sump by attaching a suction hose (3/8" ID) over the outside of the oil sump pipe, located aft of the dipstick. Figure 1. See Note, next page.
4. Replace lubricating oil filter. Fig. 2. See Note, next page.
5. Fill sump with approximately 4.5 US quarts of diesel lubricating oil to high mark on dipstick. Do not over fill. See Note next page.

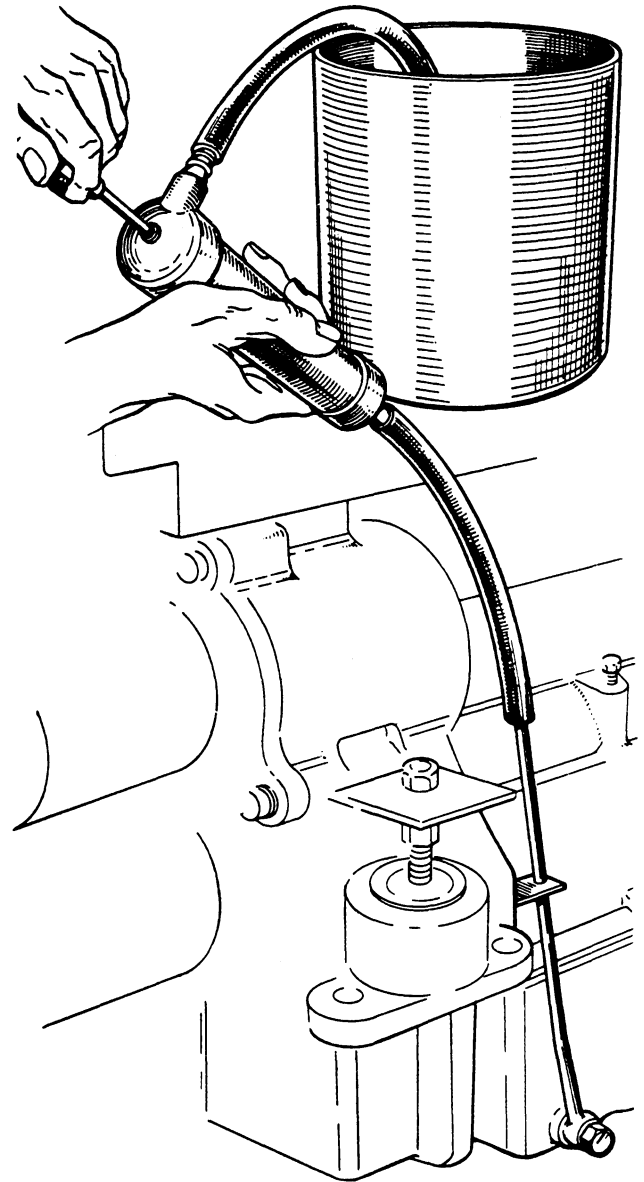


FIGURE 1

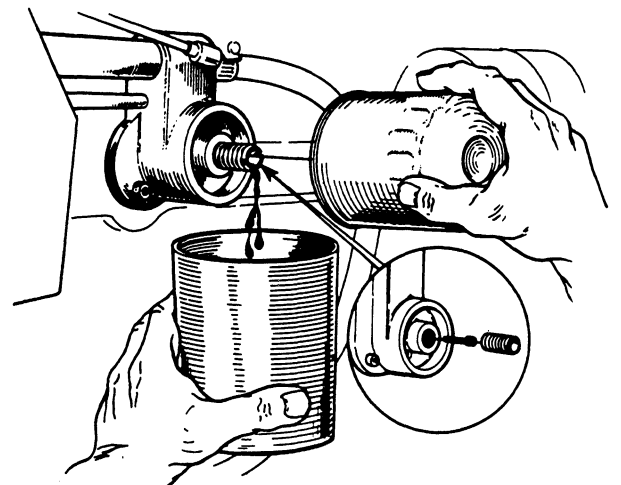


FIGURE 2

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. 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.
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.

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.

## 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





SPECIFICATIONS — *continued***Camshaft**

Journal diameter: Front	..	..	..	..	..	1-78875 to 1-78925 in. (45-434 to 45-447 mm.).
Centre	..	..	..	..	..	1-72875 to 1-72925 in. (43-910 to 43-922 mm.).
Rear	..	..	..	..	..	1-62275 to 1-62325 in. (41-218 to 41-231 mm.).
End-float (taken on thrust plate at front end)	..	..	..	..	..	.003 to .007 in. (.08 to .18 mm.).

**Camshaft bearings**

Number	..	..	..	..	..	3.
Type	..	..	..	..	..	Steel-backed white metal.
Inner diameter (reamed in position): Front	..	..	..	..	..	1-79025 to 1-79075 in. (45-472 to 45-485 mm.).
Centre	..	..	..	..	..	1-73025 to 1-73075 in. (43-948 to 43-961 mm.).
Rear	..	..	..	..	..	1-62425 to 1-62475 in. (41-256 to 41-269 mm.).
Running clearance	..	..	..	..	..	.001 to .002 in. (.025 to .051 mm.).

**Valve timing**

Chain pitch	..	..	..	..	..	.375 in. (9-525 mm.).
Number of pitches	..	..	..	..	..	54.
Chain type	..	..	..	..	..	Duplex roller.
Valve to rocker clearance: Running	..	..	..	..	..	.015 in. (.38 mm.).
Timing check	..	..	..	..	..	.021 in. (.53 mm.).
Inlet valve: Opens	..	..	..	..	..	5° B.T.D.C.
Closes	..	..	..	..	..	45° A.B.D.C.
Exhaust valve: Opens	..	..	..	..	..	45° B.B.D.C.
Closes	..	..	..	..	..	5° A.T.D.C.
Timing markings	..	..	..	..	..	Dimples on timing wheels, timing disc on crankshaft pulley, and pointer on crankcase front cover.
Tensioner type	..	..	..	..	..	Renold spring-loaded slipper type with oil feed.

**Flywheel**

Diameter	..	..	..	..	..	11-375 in. (289 mm.).
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**Lubrication**

System	..	..	..	..	..	Pressure.
Pump type	..	..	..	..	..	Eccentric rotor.
External filter	..	..	..	..	..	Tecalemit, full-flow.
Oil pressure: Idling	..	..	..	..	..	15 lb./sq. in. (1-05 kg./cm. <sup>2</sup> )
Normal running	..	..	..	..	..	50 lb./sq. in. (3-52 kg./cm. <sup>2</sup> )
Release valve spring: Free length	..	..	..	..	..	2-859 in. (72-64 mm.).
Fitted length	..	..	..	..	..	2-156 in. (54-77 mm.) at 13½ lb. (6-12 kg.) load.
Recommended lubrication oil	..	..	..	..	..	See Page B. 1

**TRANSMISSIONS**

SAO Westerbeke/Paragon	..	..	..	..	..	Direct Drive 2:1 RG
SAOV (Vee drive)	..	..	..	..	..	Direct Drive 1.67:1 and 2:1 RG
RB Freewheeling sailing gear	..	..	..	..	..	1.9 :1 RG
Hydraulic-Paragon or Warner Gear	..	..	..	..	..	All ratios
Propeller rotation — All left hand except Warner	1.91:1	..	..	..	..	

**ENGINE MOUNTS**

All Models	..	..	..	..	..	Flexible Adjustable
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**COOLING SYSTEM**

Type	..	..	..	..	..	Centrifugal Pump, Thermostat
Thermostat Setting	..	..	..	..	..	176F to 183F
Water Capacity (Fresh)	..	..	..	..	..	7 Quarts



SPECIFICATIONS — *continued***FUEL SYSTEM**

Lift pump .. .. .	A.C. mechanical.
Type .. .. .	U.
Static pressure (no delivery) .. .. .	5 lb./sq. in. (.35 kg./cm. <sup>2</sup> ).
Injection pump .. .. .	C.A.V.
1st type .. .. .	DPA.3246496.
2nd type.. .. .	DPA.3246776 or DPA.3246776B.
3rd type.. .. .	DPA.3246847.
Injectors .. .. .	C.A.V. Pintaux
Nozzle type: Early engines .. .. .	BDN.0.SPC.6209.
Later engines .. .. .	BDN.0.SPC.6389.
Nozzle holder type: Early engines .. .. .	BKB.35.SD.5091.
Later engines .. .. .	BKB.35.SD.5188.
Opening pressure .. .. .	135 atmospheres.*
Main filter .. .. .	C.A.V. bowl-less.
Type .. .. .	FS5836020.
Static injection timing .. .. .	22° B.T.D.C. (fully retarded).

**CAPACITIES**

Sump (including filter) .. .. .	4.5 Quarts
---------------------------------	------------

**TORQUE WRENCH SETTINGS**

<b>Engine</b>	
Cylinder head nuts .. .. .	71 lb. ft. (9.8 kg. m.).
Main bearing nuts .. .. .	75 lb. ft. (10.37 kg. m.).
Big-end bolts .. .. .	35 lb. ft. (4.85 kg. m.).
Flywheel nuts .. .. .	37 lb. ft. (5.07 kg. m.).
Injector securing nuts .. .. .	12 lb. ft. (1.7 kg. m.).
Injector nozzle nut .. .. .	50 lb. ft. (7.0 kg. m.).
Rocker bracket nuts .. .. .	25 lb. ft. (3.4 kg. m.).
Manifold nuts .. .. .	15 lb. ft. (2.1 kg. m.).
Engine rear distance piece bolts: $\frac{1}{4}$ in. .. .. .	20 lb. ft. (2.8 kg. m.).
$\frac{1}{2}$ in. .. .. .	30 lb. ft. (4.1 kg. m.).
Water pump bolts .. .. .	17 lb. ft. (2.3 kg. m.).
<b>Fuel injection pump:</b>	
Governor housing securing screws .. .. .	40 lb. in. (.46 kg. m.).
Distributor rotor screw .. .. .	28 lb. in. (.32 kg. m.).
Cam advance screw .. .. .	400 lb. in. (4.6 kg. m.).
Drive plate screw:	
Direct .. .. .	160 lb. in. (1.85 kg. m.).
Indirect:	
Ring spanner and torque adaptor centres at 2.6 in. (66 mm.) .. .. .	140 lb. in. (1.61 kg. m.).
Ring spanner and torque adaptor centres at 5 in. (127 mm.) .. .. .	115 lb. in. (1.32 kg. m.).
Transfer pump rotor .. .. .	65 lb. in. (.75 kg. m.).
End plate set bolt .. .. .	45 lb. in. (.52 kg. m.).
Hydraulic head locating fitting .. .. .	350 lb. in. (4.05 kg. m.).
Advance unit housing cap nut .. .. .	110 lb. in. (1.25 kg. m.).
Advance unit housing stud .. .. .	60 lb. in. (.69 kg. m.).
Advance unit housing spring cap and end plug .. .. .	250 lb. in. (2.9 kg. m.).
Hydraulic head locking screw .. .. .	170 lb. in. (1.96 kg. m.).
High-pressure outlet unions and banjo pipe bolts .. .. .	270 lb. in. (3.1 kg. m.).
Control and 'shut-off' lever bolt or nut .. .. .	30 lb. in. (.34 kg. m.).
Fuel inlet connection .. .. .	360 lb. in. (4.15 kg. m.).

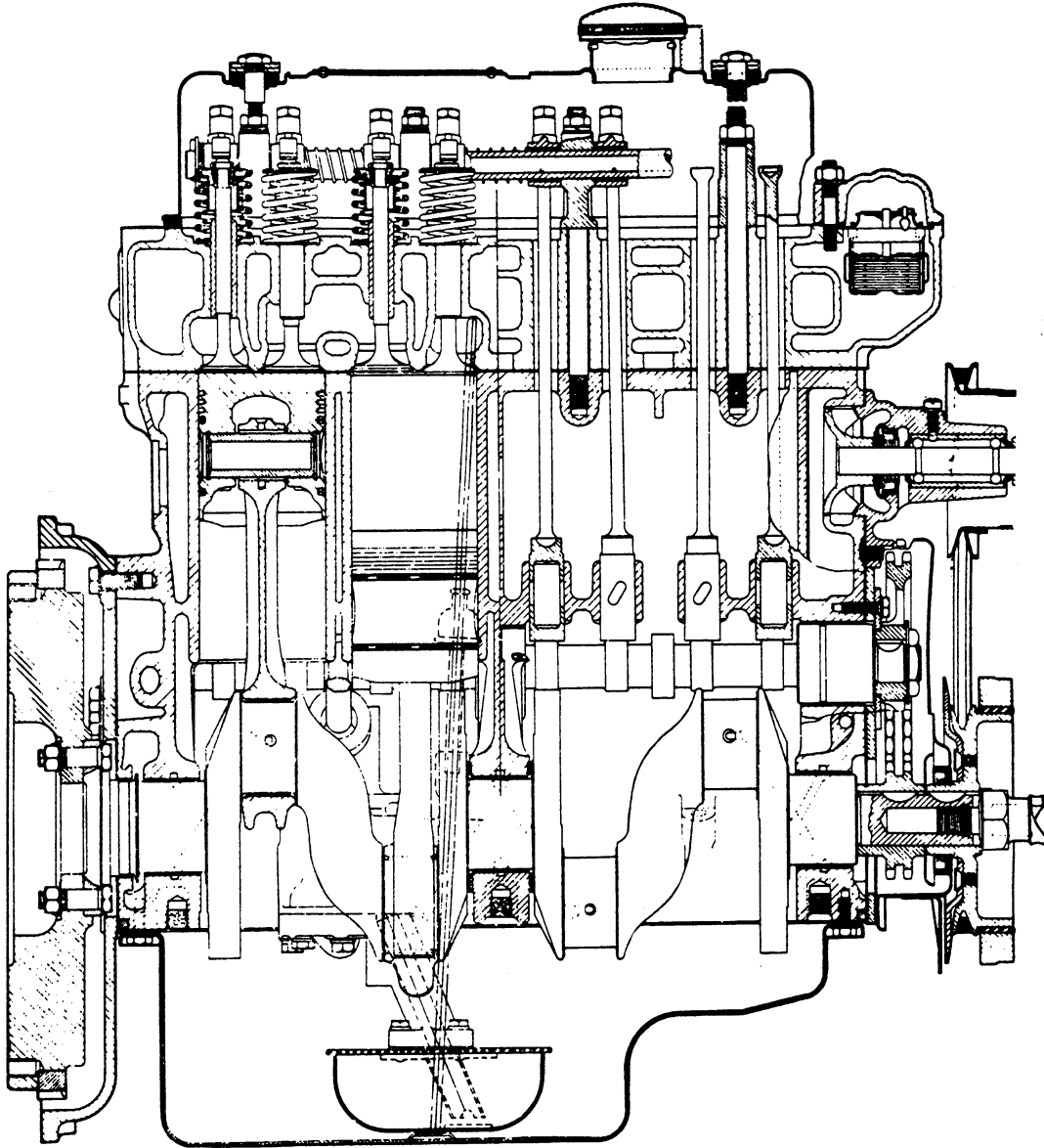
\* Add 5 atmospheres to the opening pressure when setting new injectors or after fitting new springs to allow for settling of the injector components

## SECTION A

## THE ENGINE

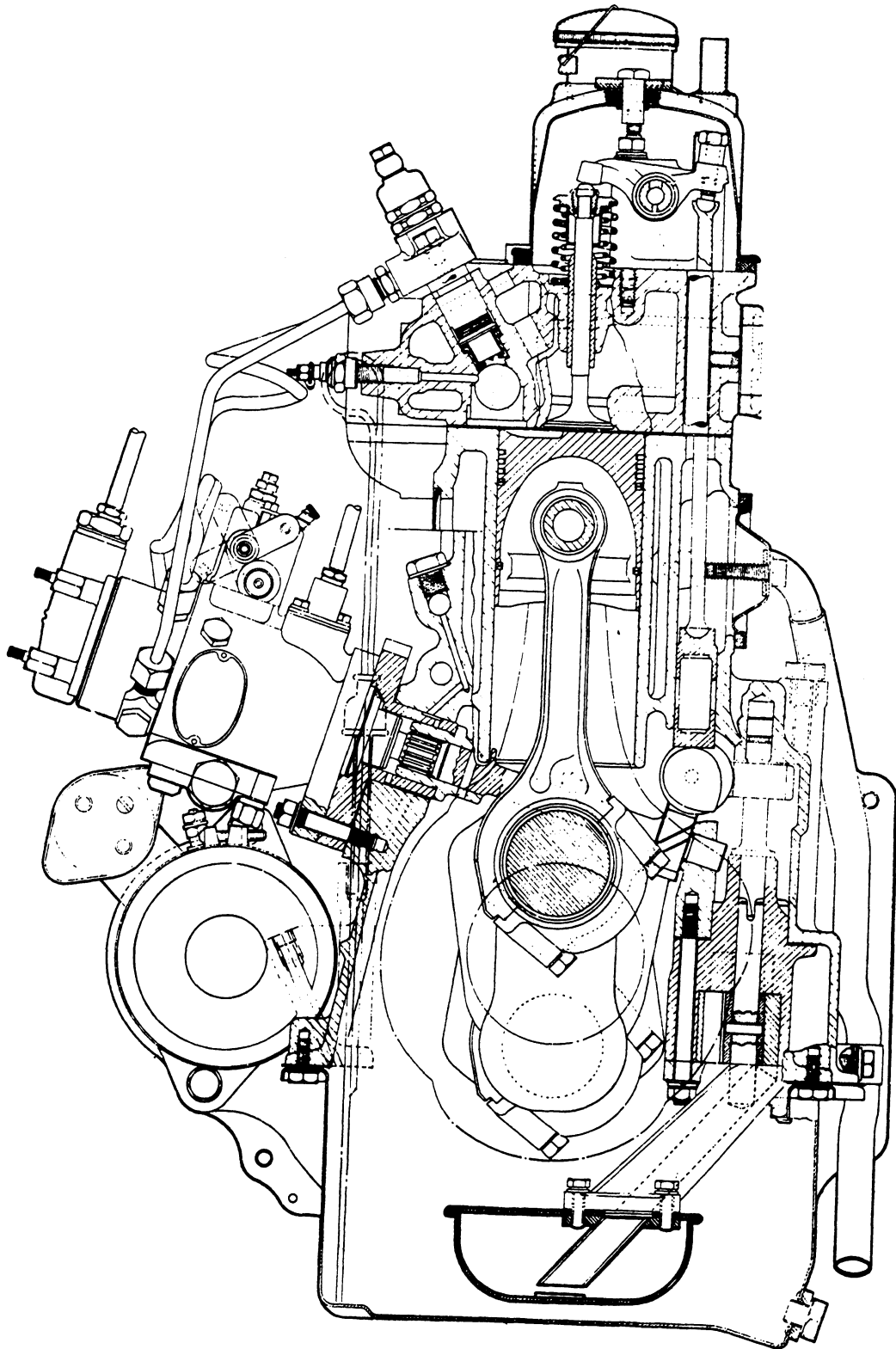
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Camshaft	
Liners—removing and replacing .. .. .	A.35
Removing and replacing .. .. .	A.34
Crankcase front cover—removing and replacing .. .. .	A.30
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Cylinder head—removing and replacing .. .. .	A.18
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Removing and replacing .. .. .	A.14
Valve seat inserts—fitting .. .. .	A.12

**THE ENGINE**  
**(Longitudinal Section)**



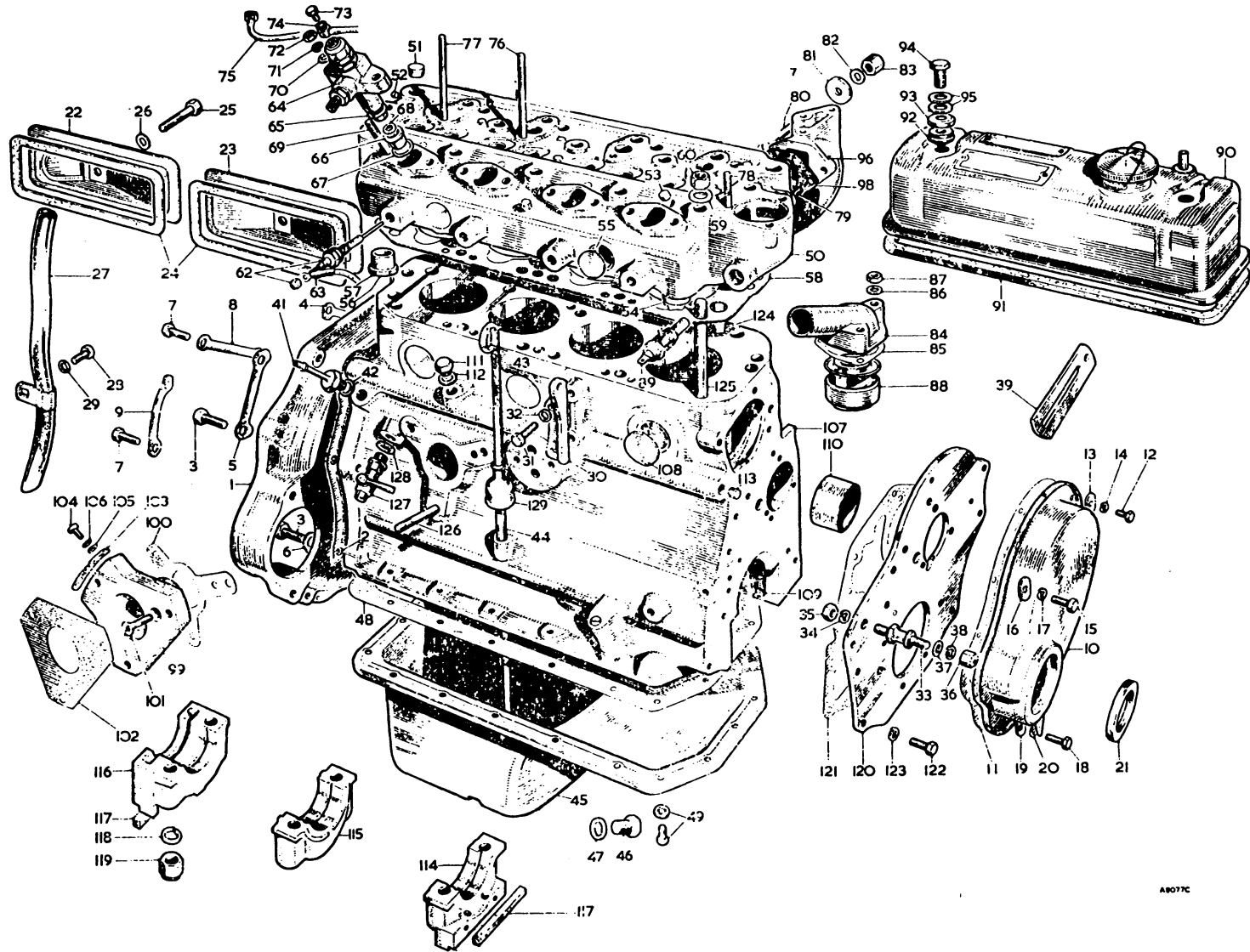
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# THE ENGINE (Transverse Section)



A80911

# THE ENGINE EXTERNAL COMPONENTS

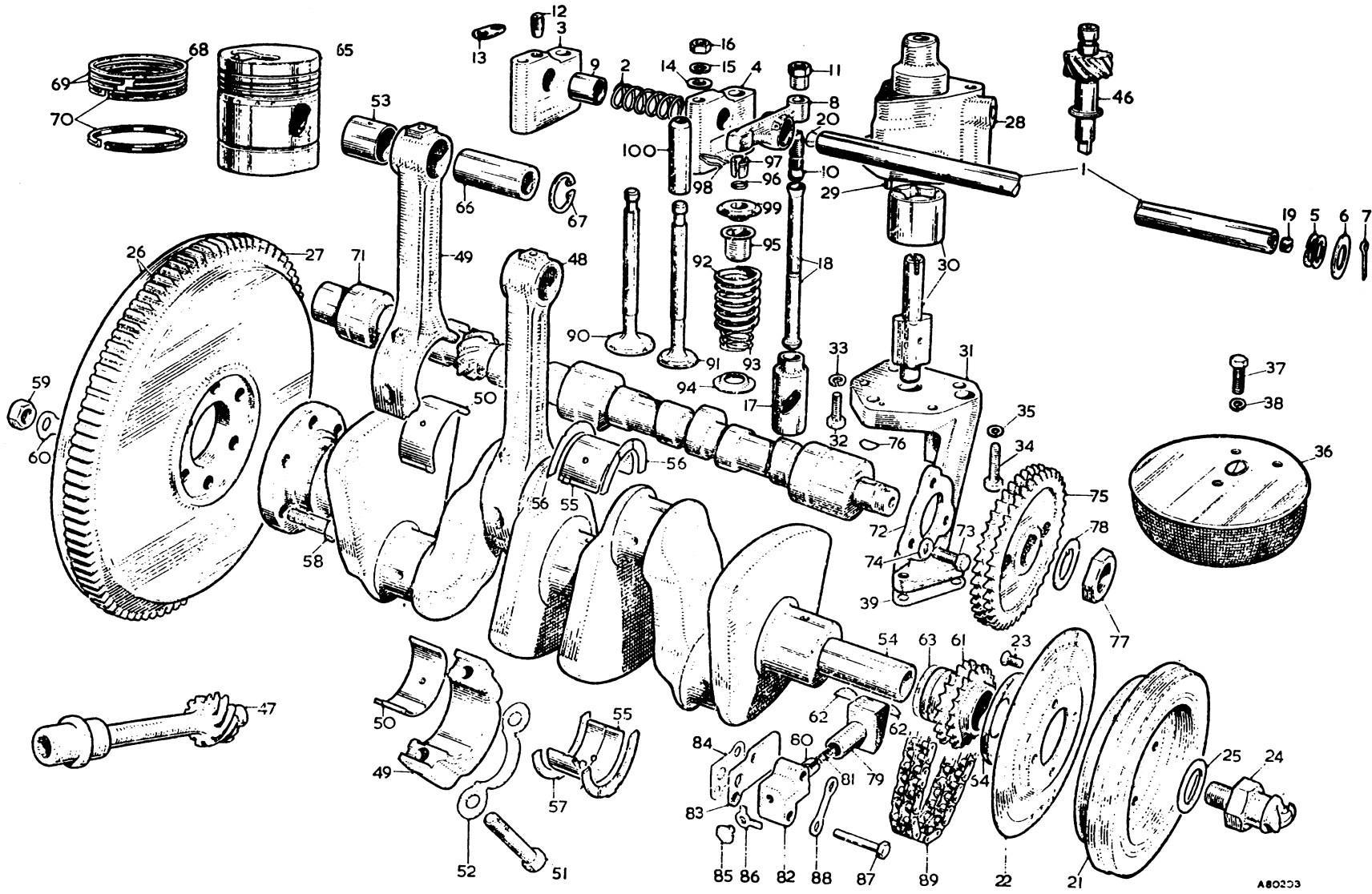


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## KEY TO THE ENGINE EXTERNAL COMPONENTS

<i>No.</i>	<i>Description</i>	<i>No.</i>	<i>Description</i>	<i>No.</i>	<i>Description</i>
1.	Gearbox distance piece.	45.	Sump.	88.	Thermostat.
2.	Joint washer for distance piece.	46.	Drain plug for sump.	89.	Thermal transmitter.
3.	Screw for distance piece.	47.	Washer for drain plug.	90.	Valve rocker cover.
4.	Locking washer for screw.	48.	Joint washer for sump.	91.	Joint washer for valve rocker cover.
5.	Locking washer for screw.	49.	Screw assembly for sump.	92.	Rubber bush for valve rocker cover.
6.	Locking washer for screw.	50.	Cylinder head.	93.	Cup washer for valve rocker cover.
7.	Screw for distance piece.	51.	Plug for water jet boss and air vent.	94.	Cap nut for valve rocker cover.
8.	Locking washer for screw.	52.	Plug for oil hole.	95.	Washer for cap nut.
9.	Locking washer for screw.	53.	Plug for core support hole.	96.	Exhaust manifold.
10.	Crankcase front cover.	54.	Plug for core support hole.	97.	Air inlet manifold.
11.	Joint washer for front cover.	55.	Welch plug.	98.	Joint washer
12.	Screw for front cover to front plate.	56.	Combustion chamber insert.	99.	Hub for fuel injection pump.
13.	Washer plate for screw.	57.	Ball for insert.	100.	Joint washer for injection pump hub.
14.	Spring washer for screw.	58.	Joint washer for cylinder head.	101.	Screw for injection pump hub.
15.	Screw for front cover and plate to crankcase.	59.	Washer for cylinder head stud.	102.	Joint washer for fuel injection pump.
16.	Washer plate for screw.	60.	Nut for cylinder head stud.	103.	Timing indicator.
17.	Spring washer for screw.	62.	Heater plug.	104.	Screw for indicator.
18.	Screw for front cover to bearing cap.	63.	Connection for heater plug.	105.	Plain washer for screw.
19.	Washer plate for screw.	64.	Fuel injector assembly.	106.	Spring washer for screw.
20.	Spring washer for screw.	65.	Joint washer for injector nozzle holder.	107.	Cylinder and crankcase assembly.
21.	Crankshaft oil seal.	66.	Heat shield for injector nozzle.	108.	Welch plug.
22.	Cylinder side cover with elbow—rear.	67.	Washer for heat shield.	109.	Main bearing stud.
23.	Cylinder side cover—front.	68.	Seal washer for injector atomizer.	110.	Camshaft front bearing liner.
24.	Joint washer for side cover.	69.	Stud for injector nozzle holder.	111.	Screw for oil gallery.
25.	Screw for side cover.	70.	Plain washer for stud.	112.	Washer for plug.
26.	Washer for screw.	71.	Spring washer for stud.	113.	Plug for oil gallery.
27.	Crankcase vent pipe.	72.	Nut for stud.	114.	Cap for front main bearing.
28.	Screw for vent pipe clip.	73.	Banjo bolt for injector leak-off pipe.	115.	Cap for centre main bearing.
29.	Plain washer for screw.	74.	Washer for banjo bolt.	116.	Cap for rear main bearing.
30.	Dynamo rear bracket.	75.	Fuel leak-off pipe for injectors.	117.	Joint for front and rear main bearing cap.
31.	Screw for dynamo bracket.	76.	Short stud for rocker bracket.	118.	Spring washer for main bearing cap stud.
32.	Spring washer for screw.	77.	Long stud for rocker bracket.	119.	Nut for main bearing cap stud.
33.	Pillar for dynamo adjusting link.	78.	Stud for water outlet elbow.	120.	Engine front mounting plate.
34.	Spring washer for pillar.	79.	Stud for exhaust manifold.	121.	Joint washer for mounting plate.
35.	Nut for pillar.	80.	Stud for air and exhaust manifold.	122.	Screw for front mounting plate.
36.	Nut for link to pillar.	81.	Clamp washer for air and exhaust manifold.	123.	Spring washer for screw.
37.	Plain washer for nut.	82.	Plain washer for air and exhaust manifold.	124.	Long stud for cylinder head.
38.	Spring washer for nut.	83.	Nut for air and exhaust manifold.	125.	Short stud for cylinder head.
39.	Dynamo adjusting link.	84.	Water outlet elbow.	126.	Stud for fuel injection pump.
41.	Oil gauge union.	85.	Joint washer for water outlet elbow.	127.	Water drain tap.
42.	Washer for union.	86.	Plain washer for stud.	128.	Washer for drain tap.
43.	Oil level indicator.	87.	Nut for stud.	129.	Dust cap for oil level indicator.
44.	Guide tube for oil level indicator.				

# THE ENGINE INTERNAL COMPONENTS



A80253

## KEY TO THE ENGINE INTERNAL COMPONENTS

<i>No.</i>	<i>Description</i>	<i>No.</i>	<i>Description</i>	<i>No.</i>	<i>Description</i>
1.	Valve rocker shaft.	33.	Spring washer.	70.	Piston ring—Nos. 4 and 5—oil control.
2.	Rocker spacing spring.	34.	Set screw—long.	71.	Camshaft.
3.	Rocker bracket—tapped.	35.	Spring washer.	72.	Camshaft locating plate.
4.	Rocker bracket—plain.	36.	Oil strainer.	73.	Screw for locating plate.
5.	Spring washer—double-coil.	37.	Set screw.	74.	Shakeproof washer for screw.
6.	Rocker shaft washer.	38.	Spring washer.	75.	Camshaft gear.
7.	Split cotter pin.	39.	Joint washer for oil strainer.	76.	Key for camshaft gear.
8.	Valve rocker.	46.	Oil pump driving spindle.	77.	Nut for camshaft gear.
9.	Valve rocker bush.	47.	Fuel injection pump driving spindle.	78.	Lock washer for nut.
10.	Tappet adjusting screw.	48.	Connecting rod assembly—Nos. 1 and 3.	79.	Timing chain tensioner slipper head.
11.	Adjusting screw locknut.	49.	Connecting rod and cap—Nos. 2 and 4.	80.	Cylinder for chain tensioner.
12.	Rocker shaft locating screw.	50.	Connecting rod bearing.	81.	Spring for chain tensioner.
13.	Locking plate for locating screw.	51.	Bolt for connecting rod cap.	82.	Body for chain tensioner.
14.	Plain washer for rocker bracket stud.	52.	Lock washer for bolt.	83.	Tensioner back-plate.
15.	Spring washer for rocker bracket stud.	53.	Bush for connecting rod little-end.	84.	Joint washer for tensioner body.
16.	Nut for rocker bracket stud.	54.	Crankshaft.	85.	Plug for tensioner body.
17.	Tappet.	55.	Crankshaft main bearing.	86.	Lock washer for plug.
18.	Push-rod.	56.	Crankshaft thrust washer—upper.	87.	Bolt for tensioner.
19.	Screwed plug for rocker shaft.	57.	Crankshaft thrust washer—lower.	88.	Lock washer for bolt.
20.	Plain plug for rocker shaft.	58.	Bolt for flywheel.	89.	Timing chain.
21.	Crankshaft pulley and vibration damper.	59.	Nut for flywheel bolt.	90.	Inlet valve.
22.	Timing disc.	60.	Lock washer for nut.	91.	Exhaust valve.
23.	Screw for timing disc.	61.	Crankshaft gear.	92.	Outer valve spring.
24.	Starting nut.	62.	Crankshaft gear and pulley key.	93.	Inner valve spring.
25.	Lock washer for starting nut.	63.	Crankshaft gear packing washer.	94.	Valve spring bottom collar.
26.	Flywheel assembly.	64.	Crankshaft oil thrower—front.	95.	Valve guide shroud.
27.	Starter ring.	65.	Piston.	96.	Valve packing ring.
28.	Oil pump body.	66.	Gudgeon pin.	97.	Valve cotter.
29.	Dowel.	67.	Circlip for gudgeon pin.	98.	Circlip for valve cotter.
30.	Oil pump rotor assembly.	68.	Piston ring—No. 1—compression.	99.	Valve spring cap.
31.	Oil pump cover.	69.	Piston ring—Nos. 2 and 3—compression.	100.	Valve guide.
32.	Set screw—short.				



## Section A.1

### DESCRIPTION

The Westerbeke 25 HP diesel engine is of the indirect injection type, with four cylinders, having a nominal bore of 2.875 in. (73 mm.) and a stroke of 3.5 in. (88.9 mm.), with a compression ratio of 23 : 1.

The cylinder block and crankcase is a one-piece casting in high-quality cast iron, ensuring maximum rigidity and strength. Full-length water jackets are provided so that even cylinder temperatures and high wear resistance are assured.

The cylinder head carries the valve operating gear, inlet and exhaust valves, fuel injectors, and heater plugs. Large circulation passages are cast in the head, ensuring adequate cooling. The combustion chambers are the Ricardo Comet V type. The combustion intake, exhaust manifold, and expansion tank is a one piece aluminum casting mounted to the left-hand side of the cylinder head.

A quickly detachable rocker cover, embodying an oil filler, encloses the overhead valve gear, which is push-rod-operated.

The forged-steel camshaft is mounted in the left-hand side of the cylinder block and is supported by three white-metal bearings. The cam profiles are designed to prevent surge and to give quiet operation of the valve gear. The

timing chain is of the double-roller type, and a slipper-type, oil-fed timing chain tensioner is fitted.

The forged-steel, counterbalanced crankshaft is supported by three main bearings of generous dimensions to give adequate bearing surfaces in order to withstand the considerable loads experienced in diesel engines. The bearings are of the steel shell type lined with lead-copper.

Crankshaft thrust washers of steel-backed white metal are fitted on each side of the centre main bearing.

●The connecting rods are of 'H'-section forged steel with renewable big- and small-end bearings. Like the main bearings, the big-end bearings are of the steel shell type lined with lead-copper.

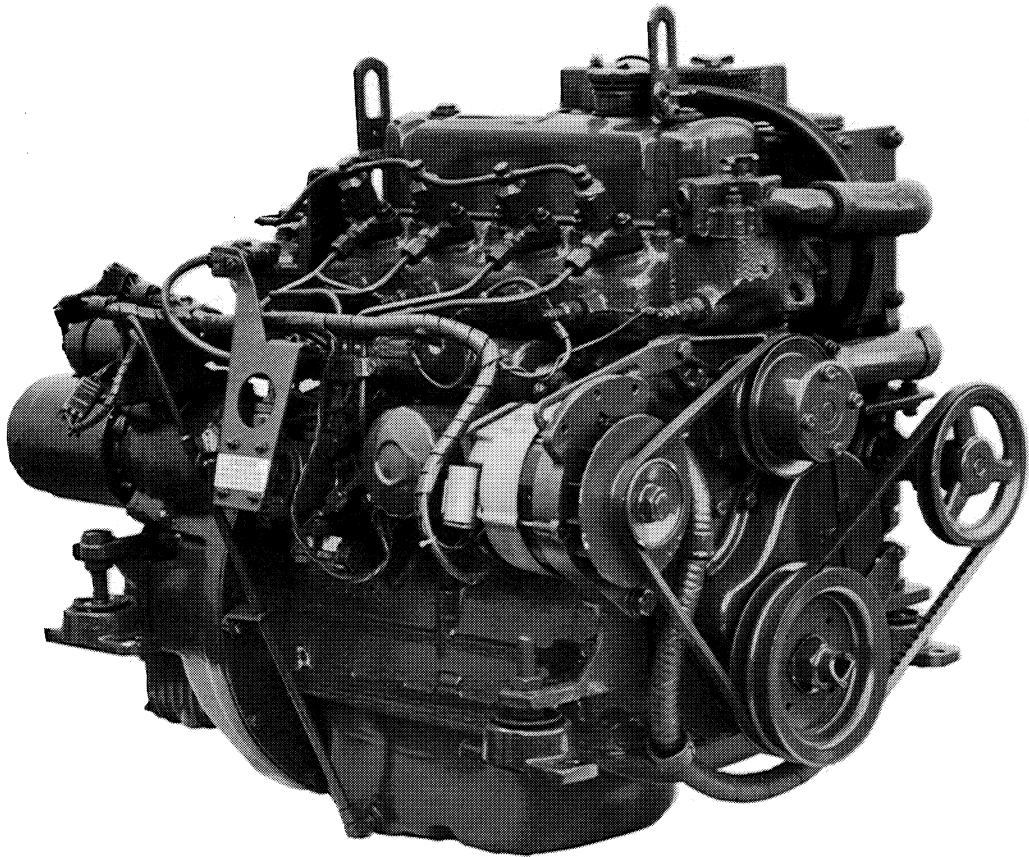
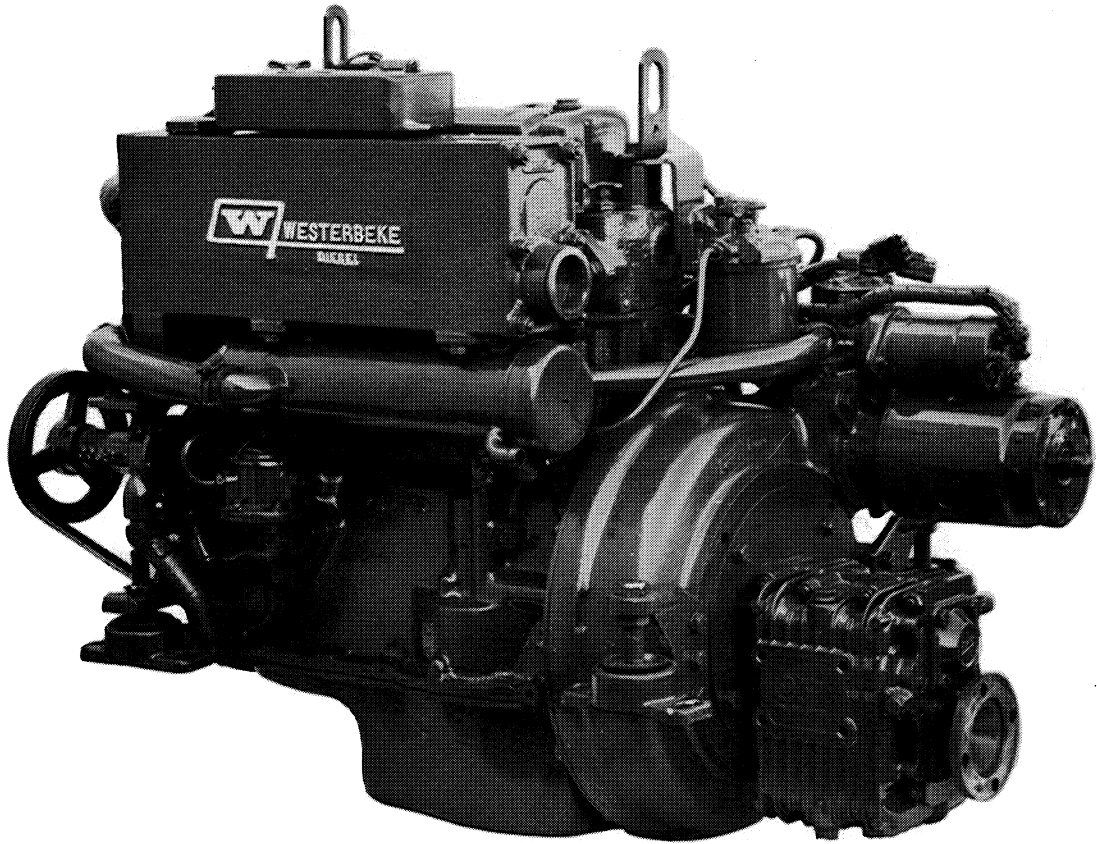
The big-ends are diagonally split to permit the pistons and connecting rods to be withdrawn upwards through the cylinder bores.

Oil jet holes are drilled in the upper halves of the big-ends and these supply the cylinder walls with adequate lubrication. The small-ends are fitted with Clevite bushes.

Aluminium pistons of the solid skirt type are fitted and a specially shaped crown is incorporated to suit the characteristics of the combustion chamber.

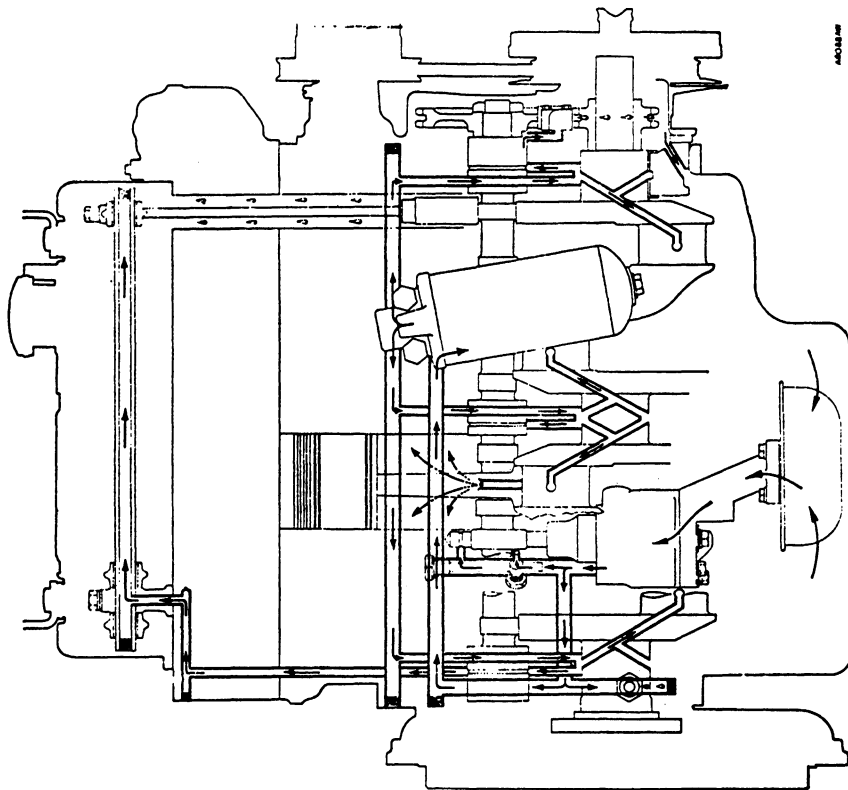
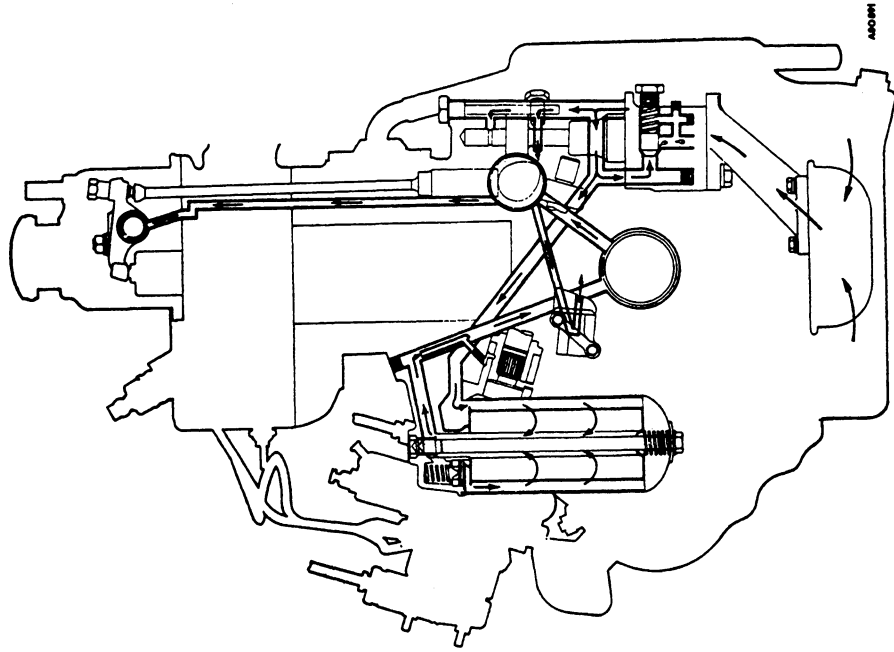
Three compression and two oil control rings are fitted, and the floating-type gudgeon pin is secured in position by means of circlips. The top compression ring is chrome-plated, while the peripheries of the other two are tapered.

Inlet valves of large head diameter are used to promote good charging and oil seals are fitted to the stems of all valves.



STARBOARD AND PORT VIEWS MODEL FOUR-91

**THE ENGINE LUBRICATION SYSTEM**



The oil pump is of the eccentric rotor, non-draining type and is driven from the camshaft.

A full-flow oil filter is mounted on the side of the crankcase

The fuel injection pump is of the C.A.V. distributor type incorporating an automatic advance device and a governor, both of which are hydraulically operated. The pump is flange-mounted on the right-hand side of the engine and is driven by the camshaft through a shaft and gear mounted transversely in the crankcase.

The fuel lift pump is of the A.C. mechanical type and is driven by the engine camshaft. Fuel oil is delivered to the injection pump via an external filter of the C.A.V. bowl-less type, having a renewable paper element.

C.A.V. Pintaux-type fuel injection nozzles are used, and a leak-off pipe returns any back-leakage of fuel from the injector nozzles to the supply side of the fuel system. The leak-off pipe is connected to the main fuel filter to provide continuous air-venting of the filter and to prevent the build-up of excessive pressure inside the filter.

A centrifugal fresh water pump mounted on the front of the cylinder block and the raw water pump mounted below the combination manifolds and expansion tank, along with the alternator are belt driven from the crankshaft pulley. The cooling system is controlled by a thermostat in the cylinder head.

## Section A.3

### LUBRICATION SYSTEM

The oil supply is carried in the sump below the cylinder block and the filler cap is fitted on the valve rocker cover. The oil level indicator rod is on the right-hand side of the engine and is marked to indicate both the maximum and minimum levels.

An eccentric-rotor, non-draining-type oil pump, located in the left-hand side of the crankcase, is driven from the camshaft. Oil is drawn through a gauze strainer mounted inside the sump, and is delivered through drilled passages in the crankcase to the fuel injection pump drive gear lubricator and the oil pump driving spindle via a pencil-type filter gauze, and to a non-adjustable, plunger-type release valve, all of which are located at the rear of the crankcase on the left-hand side. From the release valve oil is fed through a drilling across the rear of the crankcase and a horizontal feed gallery in the right-hand side of the crankcase to the external full-flow-type oil filter. From the clean side of the filter oil passes through the oil cooler into main oil gallery and then through drillings in the crankcase

and crankshaft to the main, big-end, and camshaft bearings and the fuel injection pump drive coupling. From the camshaft rear bearing oil at reduced pressure is fed through drilled passages in the crankcase, cylinder head, rocker shaft rear bracket, and rocker shaft to the valve rockers and adjusting screws. Surplus oil from the valve rockers returns to the sump via the push-rod tunnels to lubricate the tappets. From the front camshaft bearing oil is supplied at reduced pressure to the timing chain tensioner, through a drilled passage in the front of the cylinder block, to lubricate the timing chain. Surplus oil from the timing chain returns to the sump through two holes in the front main bearing cap. Lubrication of the cylinder bores is effected by jet holes drilled in the connecting rod big-end bearings.

## Section A.4

### DRAINING THE SUMP

The sump is pumped out by attaching a 3/8 I.D. hose over the dip stick tube. This operation should be performed immediately after a run while oil is hot. Refill at once with new oil of the same brand and grade.

## Section A.5

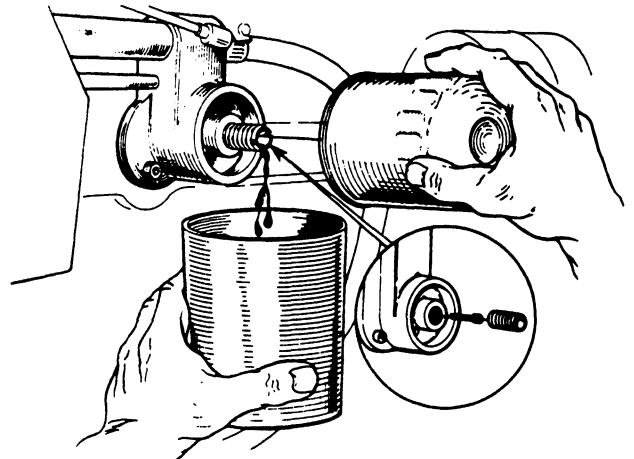
### EXTERNAL OIL FILTER

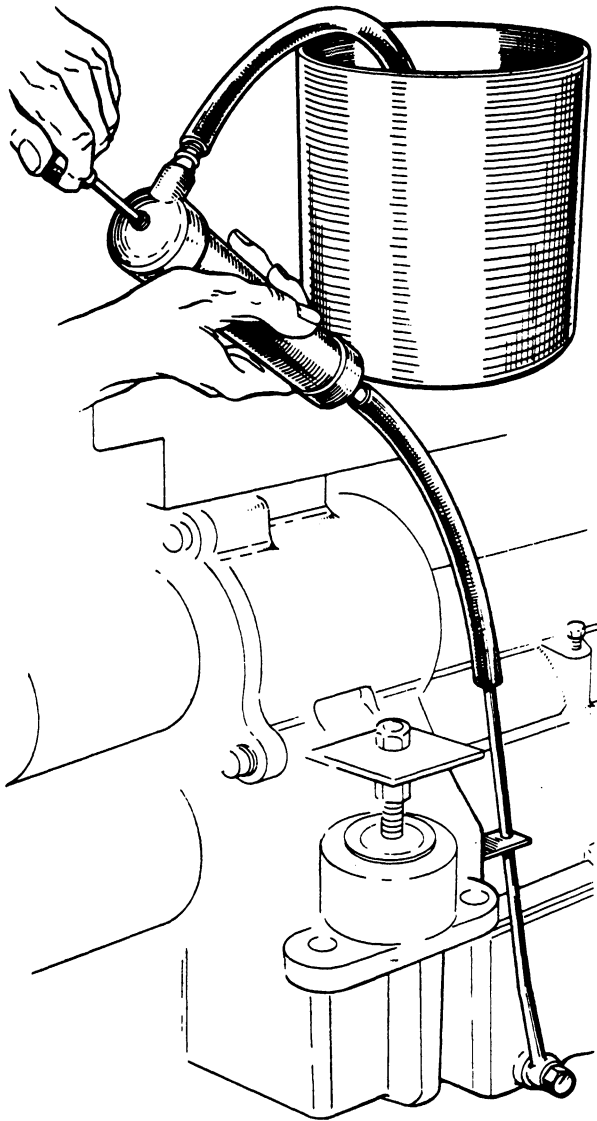
The external filter is of the full-flow type, thus ensuring that all oil in the lubrication circuit passes through the filter before reaching the bearings.

Oil is passed through the filter from the pump at a pressure controlled at 50 lb./sq. in. (3.5 kg./cm.<sup>2</sup>) by the engine oil pressure release valve.

Should the filter become completely choked due to neglect, a balance valve is provided to ensure that oil will still reach the bearings.

The filter element is removed by unscrewing the case from its base. A small amount of spillage will occur when this is done and a small waste container should be held underneath as the element is unscrewed.





## Section A.6

### FUEL INJECTION PUMP DRIVING GEAR LUBRICATOR AND LUBRICATOR FILTER GAUZE

The fuel injection pump driving gear is pressure-lubricated through a lubricator and lubricator filter gauze, both of which are screwed into tappings in the main feed passage from the oil pump on the left-hand side of the engine.

At every alternate engine oil change the lubricator and the filter gauze should be withdrawn and cleaned in petrol. A stiff brush should be used to remove the particles of 'sludge' from the filter gauze, and the lubricator should be blown clean with compressed air.

A.12

When reassembling, ensure that the copper joint washers are in good condition and will make an oil-tight joint.

## Section A.7

### OIL PRESSURE RELEASE VALVE

The non-adjustable oil pressure release valve is situated at the rear, on the left-hand side of the crankcase, and is held in position by a large hexagon nut sealed by a fibre washer. The release valve spring maintains a valve cup against a seating machined in the cylinder block.

During major overhauls or in the event of low oil pressure, when it is known that all other components of the engine are in good condition, the release valve should be removed, using tool 18G69, and examined to ensure that the cup is seating correctly and that the spring has not lost its tension. If the valve cup is scored or shows signs of wear it should be renewed.

The release valve spring should be checked by measuring its free length; it should be renewed if it is below the specification given in the 'GENERAL DATA' section.

The valve seating can be checked by applying engineer's blue to the conical face of the valve and testing for continuous marking. Should the seating be damaged, the valve cup must be lapped in, using valve grinding-in tool 18G69.

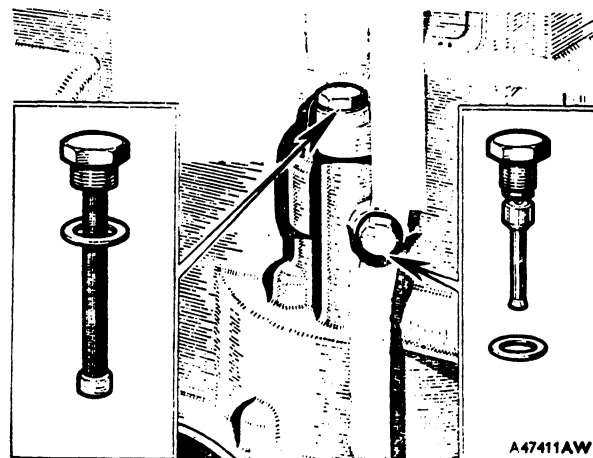


Fig. A.2

*Location of the fuel injection pump driving gear lubricator and the lubricator filter on the left- and side of the crankcase*

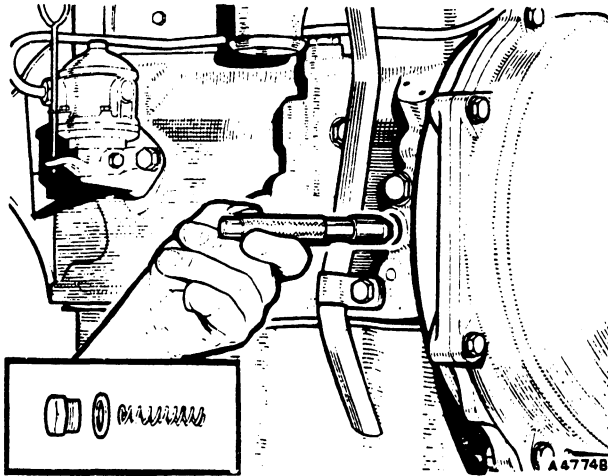


Fig. A.3

Removing the oil pressure release valve cup with tool  
18G69

## Section A.8

### OIL PRESSURE

Provided the oil filter element is clean and in good condition, the oil pressure during normal running and when the engine is idling should be in accordance with the figures given in the 'GENERAL DATA' section. As the filter element becomes choked the pressure will become progressively less, and on an engine known to be in good condition a drop of between 10 to 15 lb./sq. in. (.7 to 1.0 kg./cm.<sup>2</sup>) below the normal pressure is an indication that the filter element has become choked and is being by-passed. This can be remedied by renewing the oil filter element.

Should there be a noticeable drop in oil pressure, when it is known that the oil filter element is in a good and clean condition, the following points should be checked:

- (1) Ensure that there is a good supply of the correct grade of oil in the engine sump.
- (2) Check the oil pressure release valve (Section A.7).
- (3) Check the operation of the oil pressure gauge by substitution.
- (4) Ensure that the oil strainer in the engine sump is clean and not choked with foreign matter.
- (5) Check the oil pump for correct operation and wear (Section A.12), ensuring that there is no air leakage between the pump cover and body.
- (6) Check that the working clearance of all bearings to which oil is supplied under pressure is not excessive (see 'GENERAL DATA').

## Section A.9

### REMOVING AND REPLACING THE SUMP

Remove the drain plug, which is located on the left-hand side of the sump and drain the contents into a suitable container.

Pump out sump. (Refer to Section A.4).

Remove dipstick.

Remove dipstick tube bracket.

Disconnect dipstick tube ferrule nut and remove tube.

Unscrew the 19 securing bolts with washers and detach the sump from the crankcase.

Clean the sump thoroughly with paraffin, allow to dry, and blow out any residue with compressed air.

Before refitting the sump to the crankcase inspect the front and rear main bearing cap cork seals and the sump to crankcase joint washer. If the seals and joint washer are found to be in good condition and have not been damaged during removal of the sump they may be used again, but it is always advisable to renew the sump joint washer.

When fitting a new sump to crankcase joint washer clean the joint faces on the sump and crankcase, ensuring that all traces of the old joint washer are removed. Smear the crankcase joint face with grease and place the new joint washer in position. Lift the sump into position and install the securing screws, tightening them in a diagonal sequence, commencing at the centre and working outwards to the ends of the sump.

## Section A.10

### REMOVING AND REPLACING THE OIL STRAINER

Remove the sump as described in Section A.9.

The oil strainer is mounted direct onto the base of the oil pump and is removed by unscrewing the three set screws and spring washers which secure it to the oil pump cover.

Clean the strainer in kerosene using a stiff brush to dislodge the 'sludge' particles from the strainer gauze.

Replacement is a reversal of the procedure to remove, renewing the strainer to oil pump joint washer.

## Section A.11

### REMOVING AND REPLACING THE OIL PUMP AND DRIVING SPINDLE

Remove the sump and oil strainer as described in Sections A.9 and A.10.

Unscrew and remove the three nuts with plain and spring washers securing the pump to the crankcase and withdraw the pump.

Remove the pump to crankcase joint washer.

Before the oil pump driving spindle can be withdrawn the fuel injection pump and the fuel injection pump

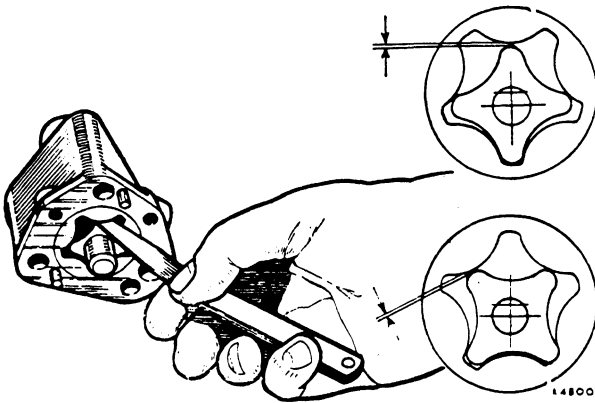


Fig. A.4

The lobe clearance should not exceed .006 in. (.152 mm.) when the oil pump rotors are in the positions illustrated

driving spindle must be removed as described in Sections D.12 and A.33.

Replacement is a reversal of the foregoing procedure, using a new oil pump to crankcase joint washer.

## Section A.12

### DISMANTLING AND REASSEMBLING THE OIL PUMP

Unscrew the two securing screws and carefully withdraw the cover, which is located on the base of the oil pump body by two dowels.

Withdraw the outer rotor, and the inner rotor complete with oil pump shaft, from the pump body.

Thoroughly clean all parts in kerosine and inspect them for wear. The rotor end-float and lobe clearances should be checked as follows:

- (1) Install the rotors in the pump body, place a straight-edge across the joint face of the pump body, and measure the clearance between the top face of the rotors and the under side of the straight-edge. The clearance should not exceed .005 in. (.127 mm.). In cases where the clearance is excessive this may be remedied by removing the two cover locating dowels and carefully lapping the joint face of the pump body.
- (2) Check the diametrical clearance between the outer rotor and the rotor pocket in the pump body. If this exceeds .010 in. (.254 mm.) and cannot be remedied by the renewal of either the pump body or the rotors, then the pump assembly should be renewed.
- (3) With the rotors installed in the pump body measure the clearance between the rotor lobes when they are in the positions shown in Fig. A.4. If the clearance is in excess of .006 in. (.152 mm.) the rotors must be renewed.

Reassembly is a reversal of the dismantling procedure, noting the following points:

A.14

- (1) Lubricate all parts with clean engine oil.
- (2) Ensure that the outer rotor is installed in the pump body with its chamfered end at the driving end of the rotor pocket in the pump body.
- (3) After reassembling check the pump for freedom of action.

## Section A.13

### REMOVING AND REPLACING THE BIG-END BEARINGS

Remove the sump, oil strainer, and oil pump (Sections A.9, A.10, and A.11).

Unlock and remove the big-end bearing cap bolts; withdraw the bearing caps; detach the connecting rods from the crankshaft and extract the bearing liners.

As the bearings are of the shimless type, it is essential that no attempt be made to adjust them. Worn bearings should always be renewed.

The bearing liners are located in their housings by a small tag on one side of each liner engaging a corresponding groove in the connecting rod and bearing cap. It should be noted that the bearings are fitted so that the tags are on the same joint edge of the bearing housing, although on opposite corners.

Connecting rods and bearing caps are mated pairs, and a bearing cap must only be refitted to the connecting rod from which it was originally taken. To assist when reassembling, both the connecting rod and cap are stamped with the cylinder number to which it is fitted, as shown in Fig. A.6. Bearing liners have no such markings, and when used liners are to be refitted they should be suitably marked with the position in the connecting rod—that is, rod half or cap half—and the connecting rod number.

A punch should not be used to mark the liners.

Replacement is a reversal of the foregoing procedure, lubricating the crankpins and bearing liners liberally with clean engine oil and fitting new bearing cap bolt lock washers. Tighten the bearing cap bolts to the torque

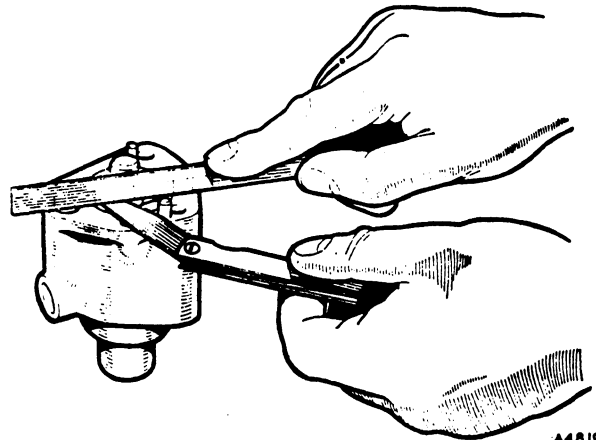


Fig. A.5

Checking the oil pump rotor end-float, which should not exceed .005 in. (.127 mm.)

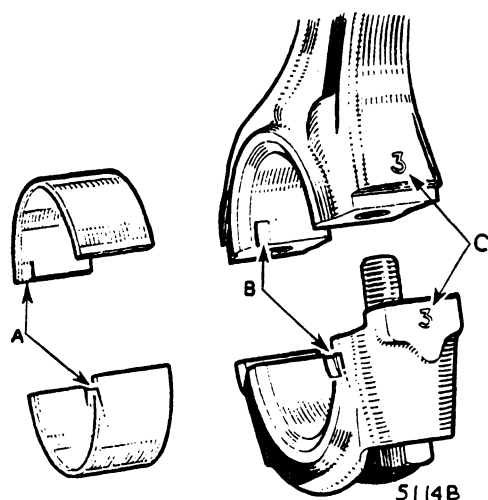


Fig. A.6

The connecting rod big-end bearing locating tags (A) and grooves (B). The figures (C) indicate the cylinder from which the rod and cap were removed

figure given in the 'GENERAL DATA' section, using torque wrench 18G372.

## Section A.14

### REMOVING AND REPLACING THE VALVE ROCKER SHAFT ASSEMBLY

Unscrew the two nuts securing the valve rocker cover, withdraw the plain washers, cup washers, and sealing bushes, and lift off the valve cover, taking care not to damage the cork gasket.

Slacken the 14 cylinder head nuts a turn at a time, in the order shown in Fig. A.9, until the load has been released. Spanner 18G694 should be used to slacken the three nuts located below the valve rocker shaft. This will avoid distortion of the cylinder head, as four of the valve rocker shaft bracket retaining nuts also serve to retain the cylinder head. Completely unscrew these four nuts and remove the remaining four nuts retaining the rocker shaft brackets, noting the rocker shaft locating screw lock plate, positioned under the right-hand nut, securing the rocker shaft rear bracket. Remove the valve rocker shaft complete with rockers and brackets.

Replacement is a reversal of the above procedure, tightening the cylinder head retaining nuts to the torque figure given in the 'GENERAL DATA' section in the order shown in Fig. A.9. The nuts should be tightened half a turn at a time with torque wrench 18G372, using spanner 18G694 to tighten the three nuts located below the rocker shaft.

Before replacing the valve rocker cover check and adjust the valve rocker clearances as described in Section A.28.

## Section A.15

### DISMANTLING AND REASSEMBLING THE VALVE ROCKER SHAFT ASSEMBLY

Unscrew and remove the rocker shaft locating screw from the rocker shaft rear mounting bracket.

Withdraw the split pin and plain and spring washers from each end of the valve rocker shaft and slide off the rockers, brackets, and spacing springs, noting their positions on the rocker shaft. Unscrew the plug from the front end of the rocker shaft; the plug in the rear end of the rocker shaft is a drive fit and should not normally be removed.

Thoroughly clean all components with kerosene dry, and then clear the oilways in the rear rocker bracket, rocker shaft, and valve rockers with compressed air.

When reassembling, commence with the rear bracket and secure the rocker shaft in position, ensuring that the dowel end of the locating screw properly engages the locating hole in the rocker shaft. The valve rockers and remaining rocker brackets are interchangeable, but used parts should be replaced on the rocker shaft in their original positions.

## Section A.16

### REMOVING AND REPLACING ROCKER BUSHES

Remove and dismantle the rocker shaft (Sections A.14 and A.15).

To remove and replace worn rocker bushes the use of Service tool 18G226 is recommended; the bushes and the rockers can be very easily damaged by using improvised drifts. Place the rocker on the anvil and drive out the worn bush (Fig. A.7).

Place a new bush on the driver and position the bush with the butt joint at the top of the rocker bore and the oil groove in the bush at the bottom of the rocker bore, as shown in Fig. A.8.

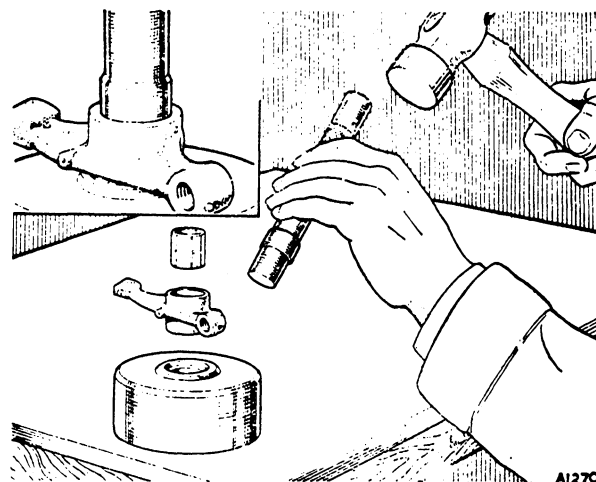


Fig. A.7

Fitting a valve rocker bush, using Service tool 18G226



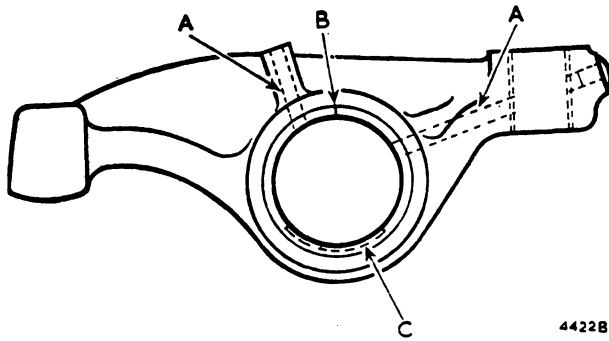


Fig. A.8

Showing the correct position for a valve rocker bush

A. Oilways. B. Joint in rocker bush. C. Oil groove.

It will be necessary to drill the oil holes in the bush to coincide with the oilways in the rocker. The oil hole to the adjuster end can be drilled before the bush is fitted, extra care being taken to keep the holes of the bush and rocker in line during the pressing-in operation.

If the holes are drilled after fitting, the following procedure should be adopted. Remove the adjuster screw and use a .093 in. (2.36 mm.) drill to drill out the end plug and to continue the oilway through the bush. Replug the end after this operation with a rivet (Part No. 5C2436) and weld the plug into position. The oil hole in the top of the rocker barrel should be continued through the bush with a No. 47 drill, .0785 in. (1.98 mm.).

Finally, burnish-ream the bush to the dimensions given in the 'GENERAL DATA' section.

## Section A.17

### REMOVING AND REPLACING THE INLET AND EXHAUST MANIFOLDS

Close inlet and outlet raw water sea-cocks. Open drain tap on right side of cylinder block. Open drain taps on bottom of heat exchanger. Disconnect hose from integral manifolds. Disconnect hoses from heat exchanger. Loosen alternator adjustment bracket and remove belt.

Remove the two hoses from raw water pump. Disconnect exhaust pipe from integral manifold. Remove air filter. Remove bolt securing each end of manifold to cylinder head, then remove the remaining four nuts. Lift off manifold with heat exchanger and water pump attached.

The exhaust manifold and manifold gasket can be withdrawn after the two remaining nuts with plain washers securing it to the cylinder head have been removed.

When reassembling, which is a reversal of the above procedure, remove all traces of the old gasket from the cylinder head and manifold joint faces and fit a new gasket. Do not forget to fit the foremost manifold clamp washer at the same time as the exhaust manifold is fitted.

Bleed the fuel system (Section D.10).

## Section A.18

### REMOVING AND REPLACING THE CYLINDER HEAD

Drain the water from the cooling system.

Remove the inlet and exhaust manifolds (Section A.17) and the valve rocker shaft assembly (Section A.14). Withdraw the eight push-rods, storing them carefully so that they may be replaced in their original positions. One way of doing this is to punch eight small holes in a piece of cardboard, number the holes, and insert each push-rod into its corresponding hole in the card.

Disconnect the fuel feed pipes from the injectors and the injection pump and remove the pipes complete with clamps and damper bushes. Seal off the fuel injection pump and the injector unions with sealing caps 18G216 to prevent the ingress of foreign matter.

Remove the remaining 10 cylinder head retaining nuts and washers and lift the cylinder head with a direct pull to withdraw it evenly up the studs.

**NOTE.**—The cylinder head joint face is machined with the combustion chamber inserts installed. As the inserts are a loose fit in the cylinder head, they should be removed and suitably labelled with their cylinder number so that they may be replaced in their original positions.

When reassembling, which is a reversal of the above procedure, ensure that the surface of both the cylinder

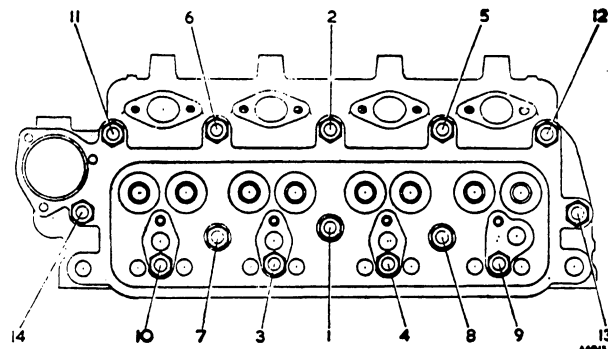


Fig. A.9

Cylinder head nut slackening and tightening sequence

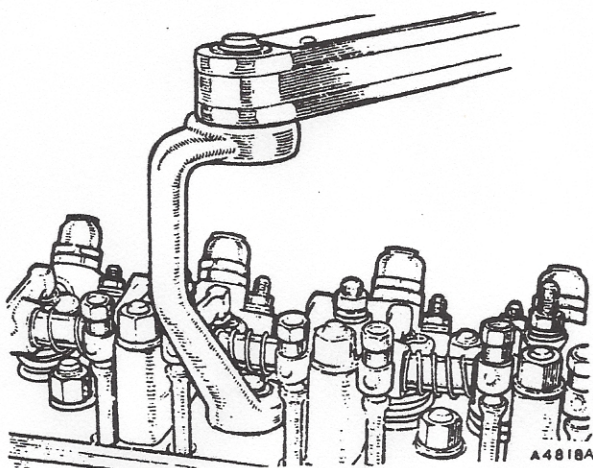


Fig. A.10

Spanner 18G 694 and torque wrench 18G 372 are used to tighten the three cylinder head nuts located below the rocker shaft

head and cylinder block are clean. Coat both sides of the cylinder head gasket with Hylomar SQ32 jointing compound. The later, compound type gasket must be fitted dry. One side of the gasket is marked 'FRONT' and 'TOP' for correct replacement.

Replace the push-rods, ensuring that each one is installed into the position from which it was originally taken, and refit the valve rocker shaft assembly. Tighten the cylinder head nuts a quarter of a turn at a time in the order shown in Fig. A.9 with torque wrench 18G 372 set to break at the torque figure given in the 'GENERAL DATA' section. Spanner 18G 694 should be used to tighten the three nuts located below the rocker shaft.

Check and adjust the valve rocker clearances as described in Section A.28.

Bleed the fuel system of air as described in Section D.10, start the engine, and allow it to run at a fast idling speed until it is thoroughly warm. Stop the engine, remove the valve rocker cover, retighten the cylinder head nuts as described above, and check and adjust the valve rocker clearances if necessary.

## Section A.19

### REMOVING AND REPLACING A PISTON AND CONNECTING ROD

The pistons and connecting rods can be withdrawn only from the top of the cylinder block.

Remove the sump as described in Section A.9, the oil strainer (Section A.10), the inlet and exhaust manifolds (Section A.17), and the cylinder head (Section A.18).

Unlock and remove the big-end bearing cap bolts; withdraw the bearing cap; release the connecting rod from the crankpin journal and push the connecting rod and piston assembly upwards until the piston rings are

clear of the cylinder bore. Withdraw the connecting rod and piston from the top of the cylinder block and refit the bearing cap.

The big-end bearings are offset in the connecting rods; the bearings of Nos. 1 and 3 connecting rods are offset towards the rear and those for Nos. 2 and 4 towards the front.

When used parts are to be refitted it is essential that they are installed in their original positions. To facilitate this, each connecting rod and cap is stamped with the cylinder number (see Fig. A.6) to which it was fitted.

Before fitting, new parts should be marked in a similar manner.

Before replacing the piston and connecting rod, which is a reversal of the above procedure, set the piston ring gaps at 180° to each other.

It is essential that the pistons and connecting rods are installed in their own cylinder bores and the same way round, i.e. the combustion cavity in the piston crown and the oil jet hole in the big-end bearing must be on the side of the engine opposite to the camshaft.

Use piston ring compressor 18G 55 A (see Fig. A.11) to facilitate the installation of the piston in the bore and to avoid the breaking of the piston rings.

Fit new lock washers and tighten the big-end bearing cap bolts to the figure given in the 'GENERAL DATA' section, using torque wrench 18G 372.

## Section A.20

### DISMANTLING AND REASSEMBLING A PISTON AND CONNECTING ROD

Remove the two circlips securing the gudgeon pin in its position, using circlip pliers 18G 1004, and press the gudgeon pin out. Suitably mark the pistons and gudgeon

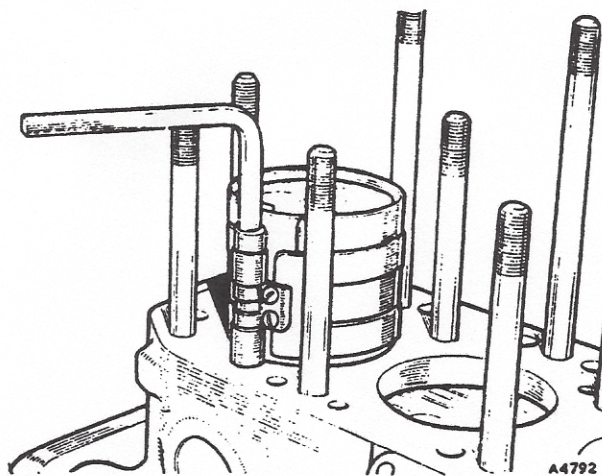


Fig. A.11

Refitting a piston and connecting rod, using Se. vice tool 18G 55 A to compress the piston rings



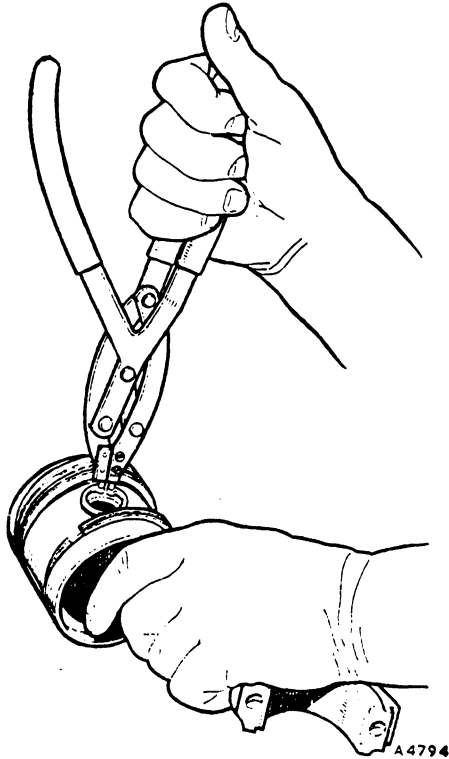


Fig. A.12

Removing a gudgeon pin circlip, using circlip pliers  
18G 1004

pins to facilitate reassembly to their original connecting rods.

Check the gudgeon pin and connecting rod little-end bush for wear against the dimensions given in the 'GENERAL DATA' section. If the little-end bush is worn it should be removed and a new bush installed, using a light press.

When fitting a new little-end bush ensure that the butt joint of the bush is on the camshaft side of the connecting rod, that the oil grooves in the bush are at the top of the little-end bore, and that the oil holes in the bush and connecting rod are aligned with each other.

After installing, new little-end bushes must be finish-reamed to the dimension given in the 'GENERAL DATA' section.

New gudgeon pins should be fitted by selective assembly. The gudgeon pin should be a hard hand-push fit at a room temperature of 20° C. (68° F.).

When reassembling the piston to the connecting rod ensure that the combustion cavity in the piston crown is on the same side of the connecting rod as the oil jet hole in the big-end bearing.

Secure each gudgeon pin in position with the two circlips, ensuring that they fit well into their grooves.

## Section A.21

### REMOVING AND REPLACING PISTON RINGS

In the absence of a special piston ring expander a  
A.18

smoothly ground hacksaw blade or a disused .020 in. (.50 mm.) feeler gauge may be used for this operation.

Raise one end of the ring out of its groove and insert the blade between the ring and the piston. Rotate the blade around the piston, applying slight upward pressure to the raised portion of the ring, until it rests on the land above the ring groove. The ring can then be eased off the piston.

Before refitting the rings clean the grooves in the piston and remove any carbon deposit. Care must be taken not to remove any metal, or excessive side-play between the ring and the groove will result, with consequent increased oil consumption and loss of gas-tightness.

The periphery of No. 1 compression ring is chromium-plated, while the peripheries of Nos. 2 and 3 compression rings are tapered. To assist correct reassembly the upper faces of the tapered rings are stamped with the word 'TOP'.

New rings must be tested in an unworn part of the cylinder bore to ensure that the ends do not butt together. Insert the piston into the cylinder bore, push the new ring onto the top of the piston to ensure that the ring is square with the cylinder bore, and measure the gap with a feeler gauge. The correct ring gaps are given in the 'GENERAL DATA' section.

## Section A.22

### PISTONS SIZES AND CYLINDER BORES

When fitting new pistons selective assembly is necessary, and to facilitate this the pistons are stamped with identification figures on their crowns. Oversize pistons

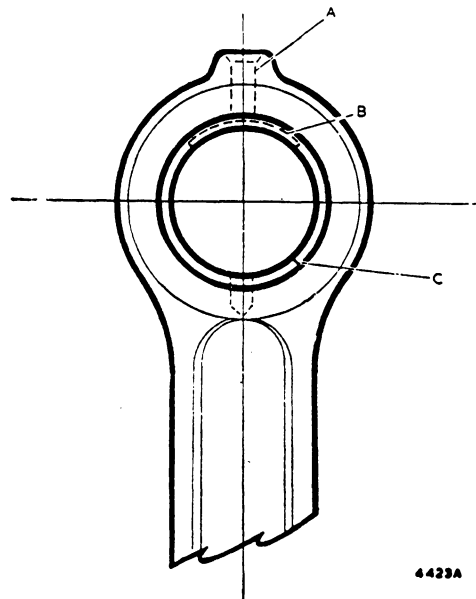


Fig. A.13

Showing the correct position for a connecting rod  
little-end bush

- |                |  |
|----------------|--|
| A. Oilway.     | C. Bush joint on camshaft side<br>of connecting rod. |
| B. Oil groove. |  |

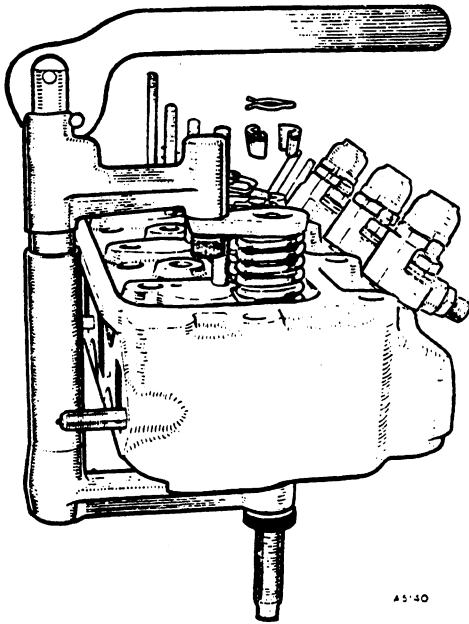


Fig. A.14

Remove the circlip and compress the valve springs with Service tool 18G45

are marked with the actual oversize dimensions. A piston stamped .020 is only suitable for a bore .020 in. (.508 mm.) larger than the standard bore; similarly, pistons with other markings are only suitable for the oversize bore indicated.

After reboring an engine, or whenever fitting pistons differing in size from those removed from the engine, ensure that the size of the piston fitted is stamped clearly on the top face of the cylinder block alongside the appropriate cylinder bore. Pistons are available in the sizes indicated in the following table.

Piston marking	Suitable bore size	Metric equivalent
<b>STANDARD</b>	2.8757 to 2.8760 in.	73.043 to 73.050 mm.
<b>OVERSIZE</b>		
+ .010 in. (.254 mm.)	2.8857 to 2.8860 in.	73.297 to 73.304 mm.
+ .020 in. (.508 mm.)	2.8957 to 2.8960 in.	73.551 to 73.558 mm.
+ .030 in. (.762 mm.)	2.9057 to 2.9060 in.	73.805 to 73.812 mm.
+ .040 in. (1.016 mm.)	2.9157 to 2.9160 in.	74.059 to 74.066 mm.

## Section A.23

### REMOVING AND REPLACING THE VALVES

Remove the inlet and exhaust manifolds (Section A.17) and the cylinder head (Section A.18).

Detach the circlips from the valve spring cap retainers, compress each pair of valve springs, using valve spring compressor 18G45, and detach the two valve cap retainers from the stem of the valve. Release and remove the valve spring compressor, and remove the valve spring cap, valve guide shroud, valve oil seal, inner and outer valve springs, and valve spring lower collar.

Withdraw the valves from their guides, keeping them in their relative positions when removed from the engine to ensure replacement in their original valve guides. The valves are numbered on their heads 1 to 8, commencing from the front of the engine. If new valves are fitted they should be identified in a similar manner.

To replace, fit each valve into its guide and install the lower collar, inner and outer valve springs, valve guide shroud, and valve spring cap.

Compress the valve springs and fit a new oil seal to the valve stem in the bottom of the spring cap retainer groove. **Do not refit the old seals or oil-tightness may be lost, with consequent increased oil consumption. It will be found that the new seals are more easily fitted if they are soaked in engine oil for a short time before use.**

Refit the valve spring retainers, remove the valve spring compressor, and replace the retainer circlip.

Owing to the limited clearance between the crowns of the pistons and the cylinder head joint face when the pistons are in the T.D.C. position it is imperative that the top faces of the valve heads 'stand down' .018 to .038 in. (.46 to .96 mm.) below the joint face of the cylinder head. The dimension is checked by placing a straight-edge across the cylinder head joint face and measuring the clearance between the under side of the straight-edge and the top faces of the valves. Valves having a stand-down clearance greater than the above limit may adversely affect the engine compression and should be renewed.

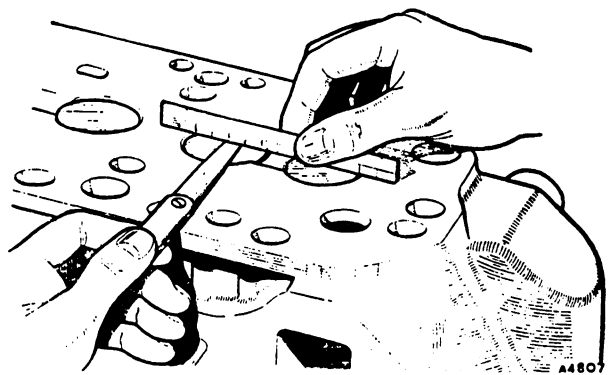


Fig. A.15

Checking the valve 'stand-down' in relation to the cylinder head joint face

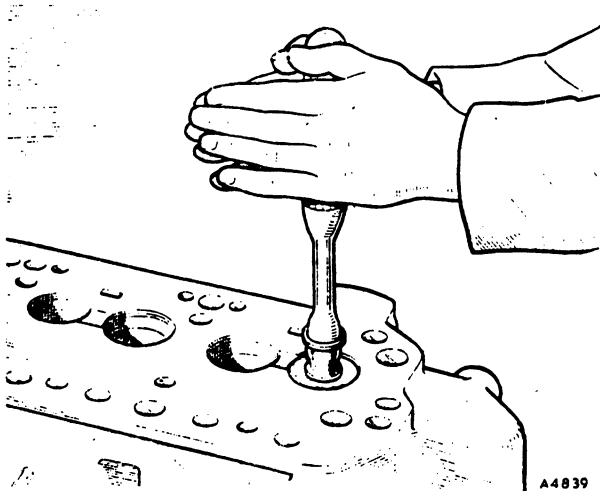


Fig. A.16

Grinding in a valve, using Service tool 18G29. Occasionally lift the valve off its seat to spread the grinding paste evenly over the seat and valve face

If, when fitting new valves, the stand-down is found to be less than the above limit, adjustment should be carried out by refacing or grinding the valves (Section A.24).

## Section A.24

### VALVE-GRINDING

Operational efficiency of the compression-ignition engine depends largely on the maintenance of good compression; therefore contact between the valve faces and their seatings should be perfect.

Remove the valves as described in Section A.23 and clean them thoroughly. Examine the face of each valve for signs of pitting, any badly pitted valves being either renewed or refaced with a suitable grinder. For details of the valve seat angle see the 'GENERAL DATA' section.

If the valve seats in the cylinder head show signs of pitting or unevenness they should be refaced by the use of the valve seat cutting tools illustrated at the end of Section A. When using these tools, which save lengthy and wasteful grinding in, care must be exercised to remove only as little metal as is necessary to ensure a true seat. Worn seats usually have a glass-hard surface and the glaze breaker should be used to prepare the seat surface for any recutting that may be necessary. Narrowing cutters should be used to maintain the valve seats at their correct width as given in the 'GENERAL DATA' section.

When grinding a valve onto its seating the valve face should be smeared lightly with a fine or medium-grade carborundum paste and then lapped to its seat, using grinding-in tool 18G29. Avoid the use of excessive quantities of grinding paste and see that it remains in the region of the valve seating only.

A light coil spring placed under the valve head will assist considerably in the process of grinding. The valve

should be ground to its seat with a semi-rotary motion and occasionally allowed to rise by the pressure of the light coil spring. This assists in spreading the paste evenly over the valve face and seat. It is necessary to carry out the grinding operation until a dull, even, mat surface, free from blemish, is produced on the valve seat and valve face.

On completion, the valve seat and ports should be cleaned thoroughly with a rag soaked in paraffin, dried, and then thoroughly cleaned by compressed air. The valves should be washed in paraffin and all traces of grinding paste removed.

## Section A.25

### DECARBONIZING

Remove the inlet and the exhaust manifold (Section A.17).

Remove the cylinder head and gasket (Section A.18) and withdraw the valves as described in Section A.23 and the fuel injectors as described in Section D.16.

Plug the waterways in the cylinder head and cylinder block with clean rag.

If special equipment for decarbonizing is not available it will be necessary to scrape the carbon deposit from the piston crown and the cylinder head, using a blunt scraper. An odd length of copper tubing with the end flattened and filed up makes an ideal scraping tool which will not scratch.

A ring of carbon should be left round the periphery of the piston crown and the rim of carbon round the top of each cylinder bore should not be removed. An old

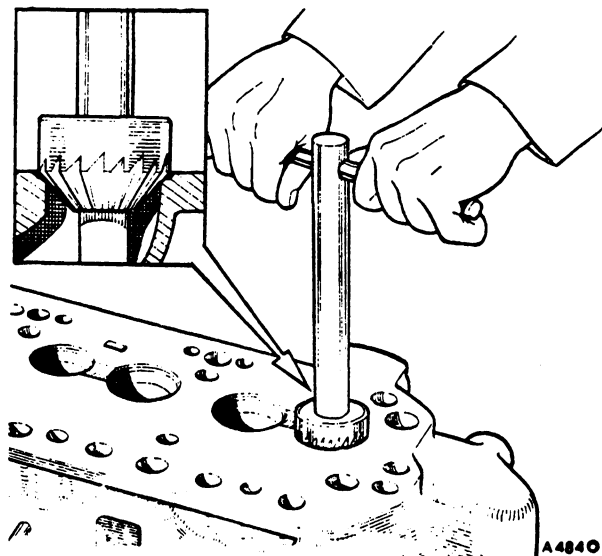


Fig. A.17

Badly pitted valve seats should be refaced, using Service tools 18G25, 18G25A, 18G25B, 18G25C, 18G27, 18G167, 18G167A, 18G167B, 18G167C and 18G174D

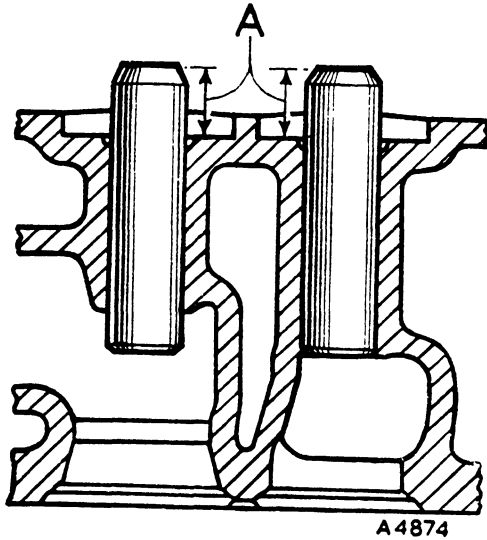


Fig. A.18

Showing the correct location of the valve guides.  
Dimension (A)  $.562 \pm_{-.016}^{+.000}$  in. ( $14.23 \pm_{-.40}^{+.00}$  mm.)

outwards until they protrude  $.562 \pm_{.016}^{+.000}$  in. ( $14.23 \pm_{.40}^{+.00}$  mm.) above the machined face of the valve spring seat (see Fig. A.18).

Valve guides with an outer diameter  $.010$  in. ( $.254$  mm.) oversize are available for fitment where the normal fit has been impaired during the removal of an old guide.

## Section A.27

### REMOVING AND REPLACING THE TAPPETS

Remove the valve rocker shaft assembly (Section A.14) and withdraw the push-rods, taking care to store them as described in Section A.18 so that they may be replaced in their original positions.

Remove the inlet and exhaust manifolds as described in Section A.17.

piston ring sprung into the bore and resting on the top of the piston will facilitate this operation.

The cylinder head is next given attention. Remove the carbon deposit from the valves, valve ports, and cylinder head. Cleaning of the spherical combustion chamber in the cylinder head is not necessary as the heat generated during combustion is such as to prevent the build-up of carbon on the walls of the chamber. Any accumulation of carbon in the valve guides should be removed by dipping the valve stem in kerosene and oscillating the valve in its guide until it is free.

Remove all traces of carbon dust with compressed air, or by the vigorous use of a tire pump, and then clean thoroughly with kerosene and dry off.

Remove the two securing bolts and washers and withdraw the two side covers and joint washers.

Lift out the tappets from their guides in the cylinder block, keeping them in their respective positions so that they may be replaced in their own guides.

New tappets must be fitted by selective assembly so that they just fall into their guides under their own weight when lubricated with engine oil.

Worn tappet bores may be cleaned up by 'fine finish' machining, and tappets  $.010$  in. and  $.020$  in. ( $.254$  mm. and  $.508$  mm.) oversize are available.

Reassembly is a reversal of the foregoing procedure, ensuring that the side cover joint washers will make an oil-tight joint and adjusting the valve to rocker clearances as described in Section A.28.

Bleed the fuel system (Section D.10).

## Section A.26

### REMOVING AND REPLACING THE VALVE GUIDES

Remove the inlet and exhaust manifolds (Section A.17).

Remove the cylinder head (Section A.18) and the appropriate valve and spring as described in Section A.23.

Support the cylinder head with wooden blocks and drive the valve guide outwards from the exhaust or inlet port with a suitable drift. The drift should take the form of a hardened-steel punch  $.5$  in. ( $12.7$  mm.) in diameter and not less than  $5$  in. ( $12.7$  cm.) in length with a locating spigot  $.312$  in. ( $7.9$  mm.) in diameter machined on one end for a length of  $1$  in. ( $2.54$  cm.) to engage the bore of the guide.

New valve guides must be fitted in the same direction—that is, through the inlet or exhaust port—and driven

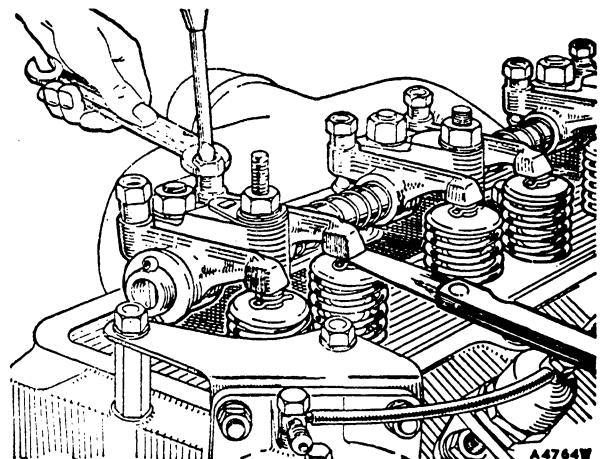


Fig. A.19

Checking and adjusting the valve rocker clearances

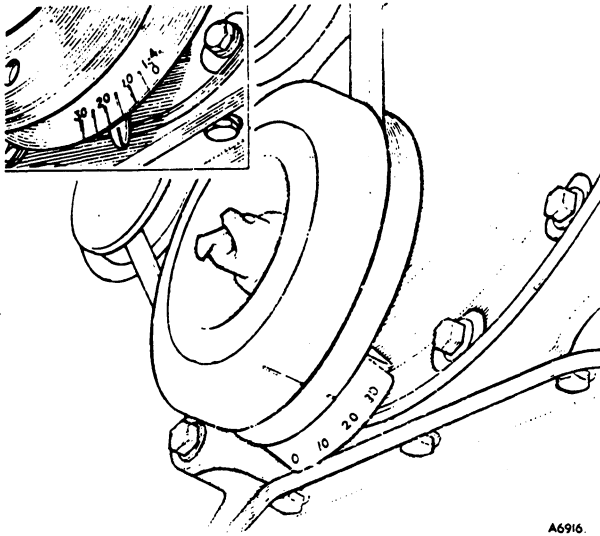


Fig. A.20

The timing mark and timing plate. Shown inset is the timing disc and timing pointer fitted to early engines

### Section A.28

#### ADJUSTING THE VALVE ROCKER CLEARANCES

If the engine is to give its best performance and the valves are to retain their maximum useful life it is essential to maintain the correct valve rocker clearance.

The correct clearance for both inlet and exhaust valves is .015 in. (.381 mm.) when the engine is cold, and as the engine has been designed to operate with this clearance, no departure from it is permissible.

Provision for adjusting the valve clearance is made in the rocker arm by an adjustable screw and locknut.

The rocker adjusting screw is released by slackening the hexagon locknut with a spanner while holding the screw against rotation with a screwdriver. The valve clearance can then be set by carefully rotating the rocker screw while checking the clearance at the other end of the rocker with a feeler gauge. This screw is then relocked by tightening the hexagon locknut while again holding the screw against rotation.

It is important to note that, when setting the valve clearance, the tappet of the valve being operated upon must be on the back of its cam—that is, opposite the peak. As the position of the tappet on its cam cannot be observed, and to avoid cranking the engine more than is necessary, rocker adjustment is more easily carried out in the following order:

Adjust No. 1 rocker with No. 8 valve fully open.

"	"	3	"	"	6	"	"	"
"	"	5	"	"	4	"	"	"
"	"	2	"	"	7	"	"	"
"	"	8	"	"	1	"	"	"
"	"	6	"	"	3	"	"	"
"	"	4	"	"	5	"	"	"
"	"	7	"	"	2	"	"	"

### Section A.29

#### VALVE-TIMING CHECK

The pointer secured to the under side of the crankcase front cover and the timing disc mounted behind the crankshaft pulley are used to check the valve timing. The timing disc has two sets of graduations from 0 to 35° marked at 5° intervals, and it is the set of graduations with the zero mark identified 1.4 which is used for the valve-timing check. A pulley with timing marks on the periphery of the vibration damper is installed on later engines. The latest engine has a timing mark scribed on the pulley and a degree plate on the timing cover.

Set the valve rocker clearance of No. 1 cylinder inlet valve to .021 in. (.53 mm.).

Crank the engine and determine the exact point at which No. 1 cylinder inlet valve is about to open. A clock gauge mounted on the cylinder head, with its indicator in contact with the valve spring cap, will facilitate this operation. If the valve timing is correct and in accordance with the valve-timing diagram (see Fig. A.21), No. 1 piston will be at 5° B.T.D.C., as indicated by the alignment of the scribed line on the pointer with the 5° mark on the timing disc.

Do not omit to reset the inlet valve clearance to .015 in. (.381 mm.) when the timing check has been completed.

### Section A.30

#### REMOVING AND REPLACING THE CRANKCASE FRONT COVER

Drain the cooling system.

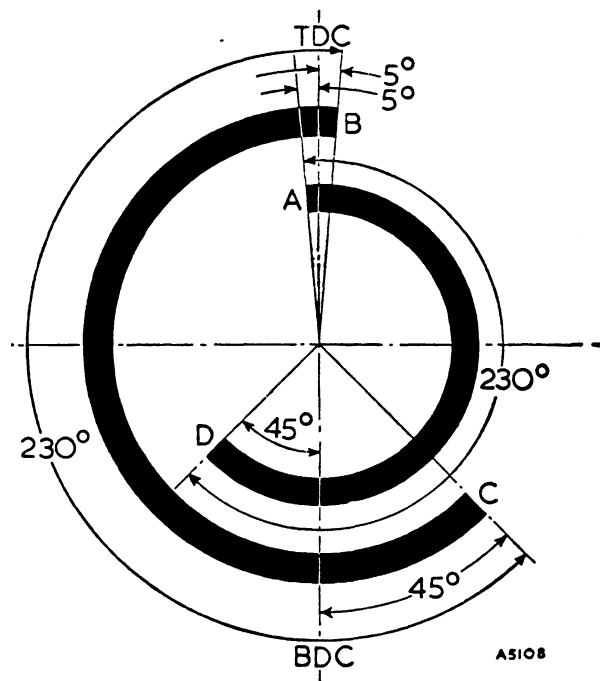


Fig. A.21

Valve-timing diagram with valve rocker clearance set at .021 in. (.53 mm.). Inlet valve opens at (A) and closes at (D). Exhaust valve opens at (C) and closes at (B)

and adaptor 18G134BD (see Fig. A.24). Pack the inner groove of the oil seal with grease to provide initial lubrication.

To reassemble, replace the oil thrower on the crankshaft with its concave side facing away from the engine. Fit a new joint washer and install the crankcase front cover, tightening the securing screws finger-tight. Centralize the crankcase front cover with the crankshaft, using tool 18G3 for early engines and tool 18G1046 for later engines, then tighten the set screws to secure the front cover in this position. Remove the centralizing tool and refit the crankshaft pulley.

Press back the starting-handle dog locking washer and, using spanner 18G98 (see Fig. A.22), unscrew the starting-handle dog from the crankshaft. Withdraw the crankshaft pulley, using tool 18G2 (see Fig. A.23).

Unscrew the nine set screws with plain and spring washers securing the crankcase front cover to the engine, noting the positions from which they are removed in order to facilitate reassembly. Withdraw the crankcase front cover and joint washer.

For safe keeping remove the oil thrower from the end of the crankshaft.

Remove the oil seal from the crankcase front cover and remove all traces of the joint washer from the joint faces of the front cover and the engine front mounting plate.

Insert a new oil seal into the crankcase front cover with the lip of the seal facing inwards, using tool 18G134

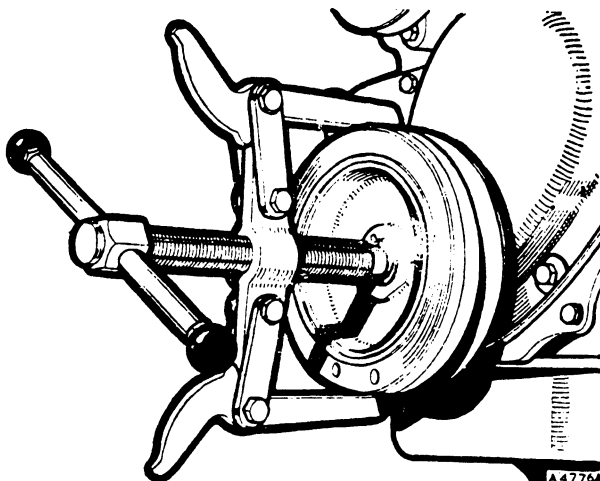


Fig. A.23

Withdrawing the crankshaft pulley, using Service tool 18G2

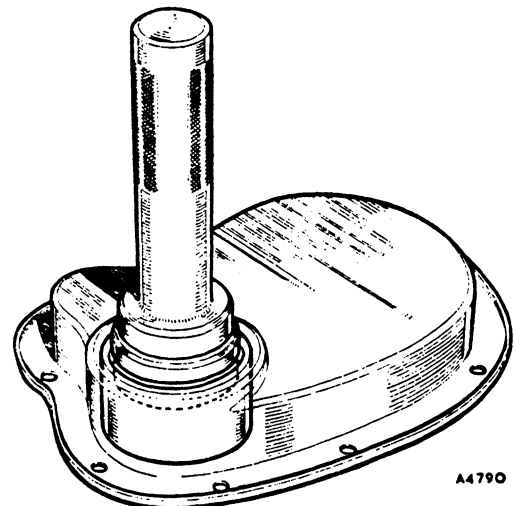


Fig. A.24

Replacing the oil seal in the crankcase front cover, using Service tool 18G134 and adaptor 18G134BD



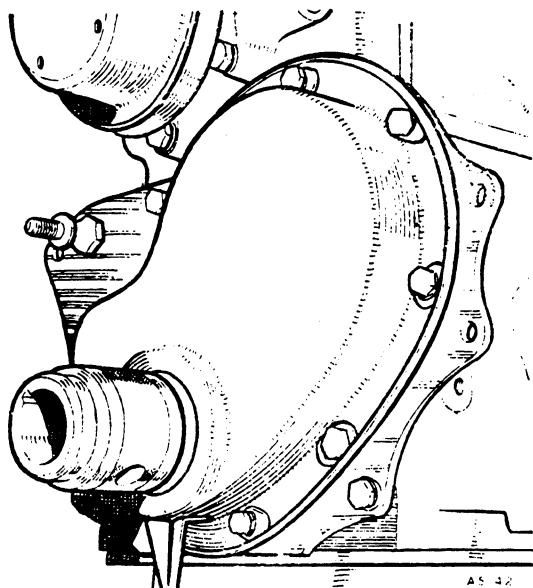


Fig. A.25

Install the securing screws finger tight and centralize the crankcase front cover with the crankshaft, using Service tool 18G3 for early engines and tool 18G1046 for later engines

Check the bore in the tensioner body for ovality. If ovality is greater than .003 in. (.0762 mm.) when measured on diameters near the mouth of the bore, then the complete chain tensioner should be renewed.

Inspect the slipper head for wear. If it is badly worn a new slipper head and cylinder assembly should be fitted to the existing body, provided the bore of the body is within the limit given above.

The components should be cleaned thoroughly in clean petrol, and the .125 in. (3.18 mm.) diameter inlet oil hole in the spigot and the .040 in. (1.02 mm.) outlet oil hole in the slipper should be cleaned with compressed air before reassembling.

When the tensioner is in operation and the engine is running, oil from the lubrication system enters the spigot on the back face under pressure and lubricates the bearing surface through a hole in the slipper pad. The pad is held against the chain by the coil spring.

Should the chain stretch with use, the slipper plunger rises and the limiting peg, bearing on the top of the helical slot, rotates the cylinder until the next recess in the lower edge of the slot comes into line with the limiting peg and prevents the plunger returning to its original position and allowing the timing chain to become slack again.

When reassembling, insert the spring in the plunger and place the cylinder on the other end of the spring.

Compress the spring until the cylinder enters the plunger bore, engaging the helical slot with the peg in the plunger. Hold the assembly compressed in this position and engage the Allen key. Turn the cylinder clockwise until the end of the cylinder is below the peg and the spring is held compressed. Withdraw the key and insert the plunger assembly in the body. Replace the

joint washer and the back plate and secure the assembly to the cylinder block.

After refitting the tensioner check the slipper head for freedom of movement and ensure that it does not bind on the back plate when it is moved in the body.

Release the tensioner, by inserting and turning the Allen key in a clockwise direction, until the slipper head moves forward under spring pressure against the timing chain.

**Do not attempt to turn the key anti-clockwise or force the slipper head into the chain by external pressure.**

Secure the bolts with the locking plate, replace the bottom plug, and lock with the tab washer.

## Section A.32

### REMOVING AND REPLACING THE TIMING CHAIN

Remove the crankcase front cover (Section A.30) and crank the engine until the timing marks on the chain wheels are opposite one another as shown in Fig. A.26. This will permit reassembly without the necessity to rotate either the crankshaft or the camshaft.

**It should be noted that the valves and pistons will foul and possibly damage each other if the crankshaft and, under certain conditions, the camshaft are rotated when the timing chain has been removed.**

If, owing to further dismantling of the engine, rotation of the crankshaft or camshaft is found necessary, the valve rocker shaft assembly should be removed as described in Section A.14.

Press back the locking tab and remove the plug from the base of the chain tensioner body. Insert a  $\frac{1}{4}$  in. Allen key to engage the tensioner cylinder and turn the key in a clockwise direction to retract the tensioner slipper into the unloaded position.

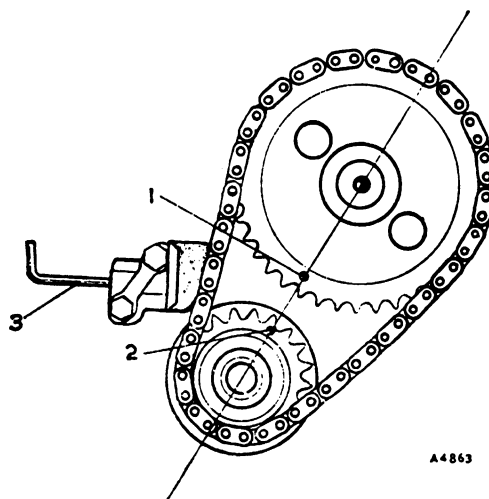


Fig. A.26

Crank the engine until the timing dimples (1) and (2) are opposite each other before removing the timing chain and chain wheels. The chain tensioner is retracted into the unloaded position by turning the Allen key (3) in a clockwise direction

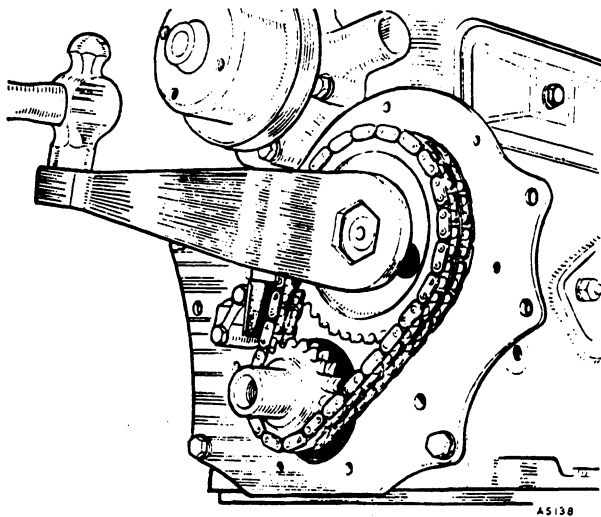


Fig. A.27

*Unscrew the camshaft chain wheel securing nut with spanner 18G98*

Knock back the lock washer and, using spanner 18G98, unscrew the camshaft chain wheel securing nut. Remove the nut lock washer, noting that its locating tag fits into the camshaft chain wheel keyway.

The camshaft and crankshaft chain wheels, complete with timing chain, may now be withdrawn by easing each chain wheel forward a fraction at a time with suitable small levers. As the crankshaft chain wheel is withdrawn, note the packing washers located on the crankshaft immediately behind the chain wheel. To remove these washers the two half-moon keys must first be withdrawn from the end of the crankshaft. The washers need only be removed when new crankshaft or camshaft components are to be fitted, in which case realignment of the chain wheels will be necessary. To determine the thickness of packing washers required assemble and secure the chain wheels to their respective shafts, using the starting-handle dog and a suitable distance piece to secure the crankshaft chain wheel. Press both shafts towards the rear of the engine to take up all end-float. Place a straight-edge across the sides of the camshaft chain wheel teeth and measure with a feeler gauge the gap between the straight-edge and the sides of the teeth on the crankshaft chain wheel (see Fig. A.28). Subtract .005 in. (.13 mm.) from the feeler gauge reading and add the resultant thickness of crankshaft gear packing washers.

When replacing the timing chain and wheels ensure that the keys in the crankshaft and camshaft are in the 12 o'clock and 1 o'clock positions respectively, as seen from the front. Assemble the wheels into the timing chain with the two dimples on the chain wheels opposite one another and in line with the chain wheel centres, as in Fig. A.26. Keeping the wheels in this position, push them onto the shafts as far as they will go. It may be necessary to rotate the camshaft slightly to align the camshaft key with the keyway in the camshaft chain wheel. Secure the camshaft chain wheel with its nut and

lock washer, using spanner 18G98 to tighten the nut. Release the chain tensioner as described in Section A.31 and reassemble the remaining components as detailed in Sections A.30 and CC.1.

## Section A.33

### REMOVING AND REPLACING THE FUEL INJECTION PUMP DRIVING SPINDLE

Remove the fuel injection pump as described in Section D.12. Unscrew the countersunk securing screw and withdraw the fuel injection pump hub and joint washer from the crankcase.

Withdraw the fuel injection pump driving spindle from the crankcase, turning the spindle in a clockwise direction to disengage it from the skew gear on the camshaft.

When refitting the driving spindle No. 1 piston must be at 22° B.T.D.C. on its compression stroke. The engine is set in this position by means of the timing disc on the crankshaft pulley and the pointer secured to the under side of the crankcase front cover (see Fig. A.20). It should be noted that the timing disc has two sets of timing marks, graduated from 0° to 35° in 5° divisions, and it is the set with the zero mark identified 1.4 which is used for this operation. Crank the engine until the inlet valve of No. 1 cylinder is just closed; No. 1 piston will now be commencing its compression stroke. Continue to crank the engine slowly until No. 1 piston is at 22° B.T.D.C. as indicated by the timing disc and pointer. Insert the fuel injection pump driving spindle into the crankcase with the master spline of the spindle in the 7 o'clock position. As the driving spindle engages the

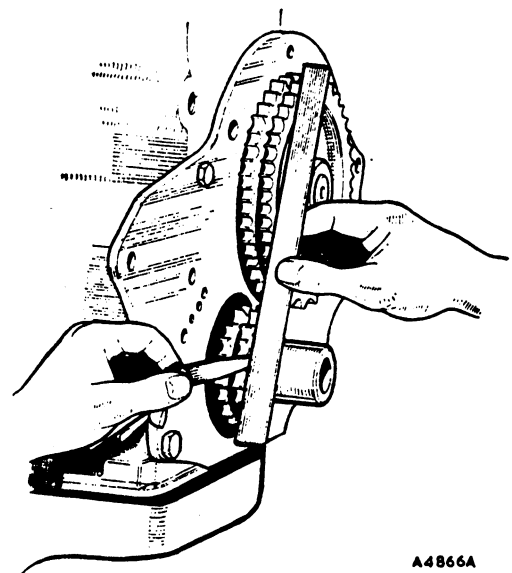


Fig. A.28

*Checking the chain wheel alignment with a straight-edge and feeler gauge*

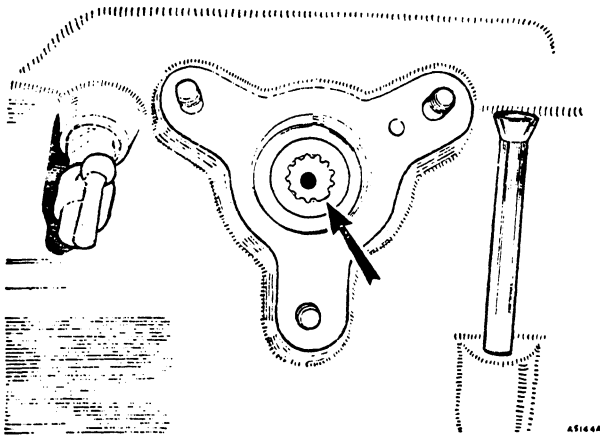


Fig. A.29

*Set No. 1 piston at 22° B.T.D.C. on its compression stroke and refit the injection pump driving spindle with the master spline in the 5 o'clock position*

skew gear on the camshaft it will turn in an anti-clockwise direction until the master spline is in the 5 o'clock position.

Refit the fuel injection pump hub, using a new joint washer, and replace the fuel injection pump as detailed in Section D.12.

Bleed the fuel system (Section D.10).

## Section A.34

### REMOVING AND REPLACING THE CAMSHAFT

Remove the fuel injection pump and driving spindle (Sections D.12 and A.33).

Remove the sump, oil pump, and oil pump driving spindle (Sections A.9 and A.11).

Remove the valve rocker shaft assembly, push-rods, and tappets (Sections A.14 and A.27).

Remove the fuel lift pump (Section D.3). Remove the crankcase front cover, timing chain, and chain wheels (Sections A.30 and A.32).

Unscrew the three securing screws with shakeproof washers to release the camshaft retaining plate and carefully withdraw the camshaft from the front of the crankcase.

Before reassembly, assemble the camshaft retaining plate and the chain wheel to the camshaft and check the camshaft end-float against the dimensions given in the 'GENERAL DATA' section by measuring the clearance between the retaining plate and the thrust face of the camshaft front journal.

If the end-float is excessive the retaining plate should be renewed.

A.26

Reassembly is a reversal of the dismantling procedure, noting the following:

- (1) Lubricate the camshaft journals liberally with clean engine oil.
- (2) Refit the timing chain and gears, realigning the gears if necessary, as described in Section A.32.
- (3) Centralize the crankcase front cover as described in Section A.30.
- (4) Install the fuel injection pump and the injection pump driving spindle as described in Sections A.33 and D.12.
- (5) Bleed the fuel system as described in Section D.10.

## Section A.35

### REMOVING AND REPLACING THE CAMSHAFT BEARING LINERS

If the camshaft bearing clearances are excessive new bearing liners must be fitted. Thinwall white-metal liners are used, and removing and refitting are facilitated by the use of tool 18G124A and adaptors 18G124B, 18G124C, 18G124F, and 18G124H. New liners should be line-reamed to give the correct running clearance (see 'GENERAL DATA'), using tool 18G123A with cutters 18G123B, 18G123E, and 18G123F, and pilots 18G123L, 18G123T, 18G123AB, 18G123AC, and 18G123AD.

#### Removing the front and rear liners

Insert the small end of the adaptor 18G124F into the camshaft front liner from the inside of the cylinder block, thread the body of the tool onto the centre screw, and pass the screw through the adaptor from the front of the block. Place the slotted washer on the flat at the rear of the centre screw and insert the tommy-bar into the centre screw behind the slotted washer.

Tighten up the wing nut to withdraw the worn liner.

The rear liner is withdrawn by the same method, using the adaptor 18G124B and withdrawing the liner from the rear of the block.

#### Removing the centre liner

Insert the stepped pilot adaptor 18G124H into the camshaft front liner bore from the inside of the block and the adaptor 18G124C into the centre liner from the rear, small end first.

With the body of the tool positioned on the centre screw, pass the screw through the pilot adaptor and the adaptor in the centre liner.

Place the slotted washer on the flat at the rear of the centre screw and insert the tommy-bar into the screw behind the slotted washer.

Tighten up the wing nut to withdraw the liner.

#### Replacing the front and rear liners

Place the new liner on the smallest diameter of the adaptor 18G124F and insert the adaptor into the camshaft front liner bore from the inside of the block, largest diameter first.

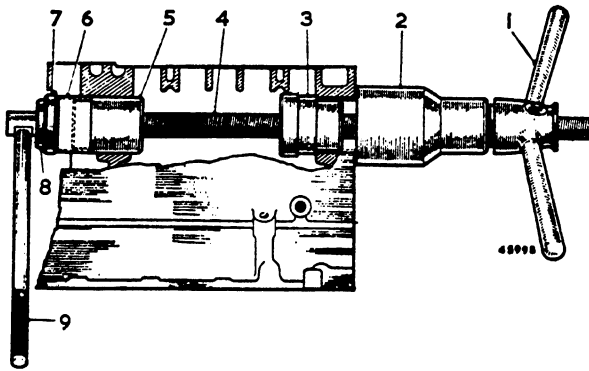


Fig. A.30

Replacing the camshaft centre bearing liner, using Service tool 18G124A with adaptors 18G124H and 18G124C

- |                     |                      |
|---------------------|----------------------|
| 1. Wing nut.        | 6. Bearing liner.    |
| 2. Body.            | 7. Large 'D' washer. |
| 3. Adaptor 18G124H. | 8. Slotted washer.   |
| 4. Centre screw.    | 9. Tommy-bar.        |
| 5. Adaptor 18G124C. |                      |

Line up the oil holes in the liner and the cylinder block and make certain they remain correctly positioned during the whole operation.

Thread the body of the tool onto the centre screw and pass the screw through the adaptor, located in the front liner, from the front of the block.

Position the larger of the two 'D' washers on the centre screw with the cut-away portion turned away from the butt joint of the liner; this joint **must** be covered by the washer.

Place the slotted washer on the flat at the rear of the centre screw and insert the tommy-bar into the screw behind the slotted washer.

Tighten the wing nut to pull the liner squarely into position.

The rear liner is replaced by the same method, using the adaptor 18G124B and pulling the liner into position from the rear of the block.

**Replacing the centre liner**

Insert the stepped pilot adaptor into the camshaft front liner from the inside of the block.

Place a new centre liner on the small end of the adaptor 18G124C and position the adaptor in the centre liner bore from the rear, largest diameter first. It should be noted that two types of centre liner are available. These liners are interchangeable, but the liner having a clinch-type joint, chamfered edges, and an arrow stamped on its outer surface must be fitted with the arrow pointing towards the front of the engine. Ensure that the oil holes in the liner and the cylinder block are lined up and remain so during the whole operation.

With the body of the tool positioned on the centre screw insert the screw through the pilot adaptor and the adaptor in the centre liner bore.

Position the larger of the two 'D' washers on the centre screw with the cut-away portion turned away from the butt joint of the liner; this joint **must** be covered by the washer.

Place the slotted washer on the flat at the rear of the centre screw and insert the tommy-bar into the centre screw. Tighten up the wing nut to pull the liner into position.

**Reaming the front and rear liners**

Insert the taper pilots 18G123AB and 18G123AC into the centre and rear liners respectively.

Place the plain pilot 18G123L on the arbor, followed by the cutter 18G123E.

Pass the arbor through the front liner and the pilot located in the centre liner.

Place the cutter 18G123B on the arbor and push the arbor through the taper pilot in the rear liner.

Secure the cutters in their respective positions shown in Fig. A.31, ensuring that the cutter locating pins are engaged in the correct numbered hole provided in the arbor.

The cutter for the front liner will cut first with the arbor piloting in the centre and rear liners. Clear away the swarf frequently during the operation. The cutter for the rear liner will follow with the arbor piloting in

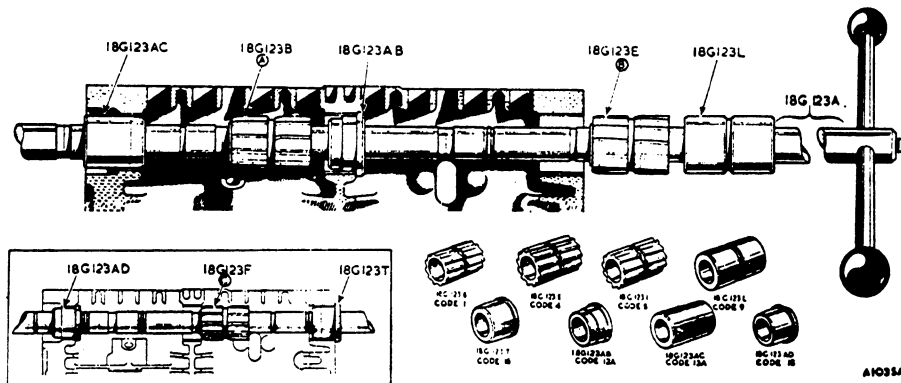


Fig. A.31

Cutters and pilots positioned for reaming the camshaft front and rear bearing liners. Shown inset are the pilots and cutter positioned for reaming the centre liner

- A. Position No. 6.                      B. Position No. 10.                      C. Position No. 9.

the front and centre liners. Clear away all the swarf before the plain pilot is allowed to enter the front liner.

When the cut in the rear liner is finished, free the cutters and withdraw the arbor.

#### Reaming the centre liner

Set up for the second part of the operation by inserting the pilots 18G123T and 18G123AD in the front and rear liners.

Pass the arbor through the pilot in the front liner and place the cutter 18G123F on the arbor. Push the arbor through the centre liner and the pilot located in the rear liner.

Secure the cutter in the position shown inset in Fig. A.31, ensuring that the locating pin of the cutter engages the correct numbered hole in the arbor.

Ream the centre liner, release the cutter, and withdraw the arbor.

**IMPORTANT.**—It is essential that the cutter flutes are kept clear of swarf at all times during the cutting operation, preferably with air-blast equipment. The cutter should be withdrawn from the liner half-way through the cut and the swarf removed from the cutter and the liner.

Feed the reamer very slowly and keep the cutters dry.

The arbor should be lightly lubricated before assembling the cutters and pilots.

## Section A.36

### REMOVING AND REPLACING THE FLYWHEEL

Remove transmission (Section     ).

Disconnect and label wires from starter motor and its solenoid.

Remove starter motor with solenoid.

Remove wiring bracket from top of bellhousing.

Remove nuts securing the rear mounting brackets to flexible mount.

Take the weight off the rear of the engine preferably with a sling attached to the rear lifting bracket. Do not jack up under sump.

Remove capscrews and lockwashers securing bell housing to back plate.

Remove damper plate.

Remove the 6 nuts and tab washers securing flywheel to the crankshaft and remove flywheel.

When reassembling, crank the engine until the 1.4 zero mark on the timing disc mounted on the crankshaft pulley is in line with the scribed line on the pointer located on the under side of the crankcase front cover. Nos. 1 and 4 pistons are now at T.D.C., and the flywheel should be installed with the T.D.C. 1.4 mark on its periphery at

A.28

the top of the flywheel. Tighten the flywheel securing nuts to the figure in the 'GENERAL DATA' section, using torque wrench 18G372.

Install the fuel injection pump as described in Section D.12, and bleed the fuel system as described in Section D.10.

## Section A.37

### REMOVING AND REPLACING THE ENGINE FRONT PLATE

Remove the nuts securing the engine front mounting brackets to their flexible mounts.

Remove the crankcase front cover, timing chain, and timing chain tensioner (Sections A.30, A.31, and A.32).

Attach the engine by means of a sling to an overhead lifting appliance and raise the engine to relieve the load on the engine front mountings.

Unscrew the three securing screws with shakeproof washers and remove the camshaft retaining plate. Remove the three set screws with spring washers and withdraw the front plate and joint washer.

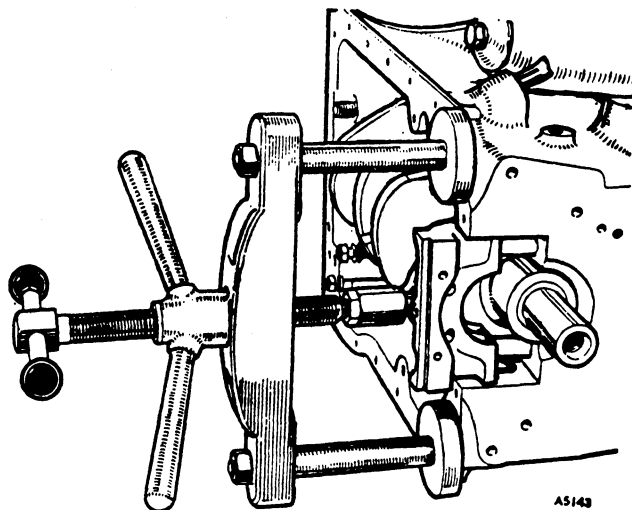


Fig. A.32

Withdrawing the front main bearing cap, using  
Service tool 18G42A and adaptor 18G42B

Reassembly is a reversal of the foregoing procedure, following the instructions given in Sections A.30, A.31, and A.32 when installing the timing gears and the crankcase front cover.

## Section A.38

### REMOVING AND REPLACING THE FLYWHEEL HOUSING BACK PLATE

Remove the transmission, the starter, the flywheel housing, and the flywheel. The back plate is now exposed and the capscrews and locks may be removed. Tap the back plate to loosen it from the dowels and gasket. Before replacing, clean gasket surface carefully and use a new gasket.

It may be noticed that the back plate has a slight warp when removed from the engine. This is of no concern as it will straighten when the affixing screws are tightened to the block and to the flywheel housing.

When assembling be sure all dowels are in place to assure alignment of parts.

## Section A.39

### REMOVING AND REPLACING THE CRANKSHAFT AND MAIN BEARINGS

Remove the crankcase front cover, timing chain, and timing chain wheels (Sections A.30 and A.32).

Remove the starter motor, the flywheel, and the gearbox distance piece (Sections N.3, A.33, and A.38).

Remove the sump, oil pump, and oil strainer (Sections A.9, A.10, and A.11). Slacken the nuts securing the fuel injectors sufficiently to relieve the engine compression and so facilitate rotation of the crankshaft.

Remove the valve rocker shaft assembly (Section A.14) to prevent the pistons and valves fouling each other when the crankshaft is rotated. The push-rods should be removed for safe keeping as detailed in Section A.18.

Disconnect the connecting rods from the crankshaft as described in Section A.13, pushing each rod and piston to the top of its cylinder bore as soon as it is disconnected.

Unscrew and remove the six self-locking nuts and spring washers from the main bearing cap studs. Withdraw the main bearing caps, using tool 18G42A with adaptor 18G42B, noting the lower halves of the crankshaft thrust washers located on each side of the centre main bearing cap. The centre main bearing cap is stamped with the word 'FRONT' to assist reassembly.

Lift the crankshaft out of the crankcase and remove the upper halves of the crankshaft thrust washers.

Remove the bearing liners from the bearing caps and the housings in the crankcase, marking the bearing liners so that they may be replaced in their original positions. A punch should not be used for this purpose.

The bearing liners are located in their housings by a small tag on one side of the liner engaging a corresponding groove in the bearing housing and cap.

In the case of a run bearing, the oilways in the crankshaft and cylinder block should be cleaned thoroughly with petrol or paraffin and then blown clean with compressed air. The oil pump and oil strainer should also be dismantled and cleaned (Sections A.10, A.11, and A.12), and the fuel injection pump driving gear lubricator filter gauze should be removed and cleaned (Section A.6). It is also advisable to renew the external oil filter element (Section A.5) to ensure that all bearing metal is removed from the lubricating system.

Thoroughly clean the thrust faces of the crankshaft centre main journal, the bearings, and the thrust washers and install them in the crankcase. Mount a dial gauge on the front end of the crankcase with its indicator resting on the front face of the crankshaft front main journal. Press the crankshaft as far as possible to the rear, and, holding it in this position, zero the dial gauge. Now press the crankshaft forward as far as possible and note the reading on the dial gauge, the difference from zero being the amount of crankshaft end-float.

If necessary, renew the thrust washers, fitting them by selective assembly and ensuring that the oil grooves face outwards towards the crankshaft webs. Thrust washers .003 in. (.076 mm.) oversize are available.

When installing new bearings no scraping is required as the bearings are machined to give the correct diametrical clearance.

Reassembly is a reversal of the dismantling procedure, noting the following points:

- (1) If any of the crankshaft components are renewed, do not forget to align the crankshaft chain wheel with the camshaft chain wheel as detailed in Section A.32.
- (2) Coat the rear main bearing cap to cylinder block horizontal joint surface with Hylomar SQ32 jointing compound.
- (3) Tighten the main bearing cap nuts to the figure given in the 'GENERAL DATA' section, using torque wrench 18G372.
- (4) Remove the fuel injection pump, and check, and adjust if necessary, the injection pump drive timing as detailed in Section D.12.

## Section A.40

### REMOVING AND REPLACING THE FLYWHEEL STARTER RING

To remove the old starter ring from the flywheel drill holes through the flange of the gear and then split the gear, using a hammer and chisel and taking care not to damage the flywheel.

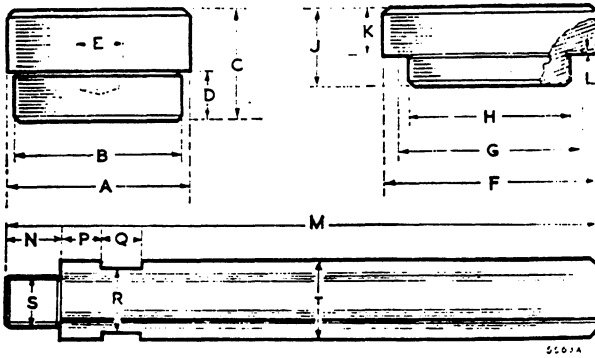


Fig. A.33

Cylinder liner pilots should be made to the above dimensions from case hardening steel and case hardened. The pilot extension should be made from 55-ton hardening and tempering steel, hardened in oil, and then tempered at a temperature of 550° C. (1,020° F.)

**Pressing-out pilot**

- A.  $2\frac{1}{4} \pm \begin{smallmatrix} +.005 \\ -.000 \end{smallmatrix}$  in. ( $75.8 \pm \begin{smallmatrix} +.127 \\ -.000 \end{smallmatrix}$  mm.).
- B.  $2.862 \pm \begin{smallmatrix} +.000 \\ -.005 \end{smallmatrix}$  in. ( $72.69 \pm \begin{smallmatrix} +.000 \\ -.127 \end{smallmatrix}$  mm.).
- C.  $1\frac{1}{2}$  in. (44.45 mm.).
- D.  $\frac{1}{2}$  in. (19.05 mm.).
- E.  $\frac{1}{2}$  in. B.S.W. thread.

**Pressing-in pilot**

- F.  $3\frac{3}{8}$  in. (87.31 mm.).
- G.  $3\frac{1}{2}$  in. (77.39 mm.).
- H.  $2.850 \pm \begin{smallmatrix} +.000 \\ -.005 \end{smallmatrix}$  in. ( $72.39 \pm \begin{smallmatrix} +.000 \\ -.127 \end{smallmatrix}$  mm.).
- J.  $1\frac{1}{2}$  in. (31.75 mm.).
- K.  $\frac{1}{2}$  in. (19.05 mm.).
- L. .015 in. (.38 mm.).

**Pilot extension**

- M.  $14\frac{1}{2}$  in. (36.83 cm.).
- N.  $\frac{7}{8}$  in. (22.22 mm.).
- P.  $\frac{5}{8}$  in. (15.87 mm.).
- Q.  $\frac{5}{8}$  in. (15.87 mm.).
- R. 1 in. (25.4 mm.) flats.
- S.  $\frac{1}{2}$  in. B.S.W. thread.
- T.  $1\frac{1}{2}$  in. (31.75 mm.).

Make certain that the bore of the new ring and its mating surface on the flywheel are free from burrs and are perfectly clean.

To fit the new ring it must be heated to a temperature of 200 to 230° C. (392 to 446° F.). Do not exceed this temperature, otherwise the temper of the teeth will be adversely affected. The use of a thermostatically controlled furnace is recommended. Place the heated ring on the flywheel with the lead on the ring teeth uppermost.

The expansion will allow the ring to be fitted without force by pressing or tapping it lightly until the ring is hard against its register.

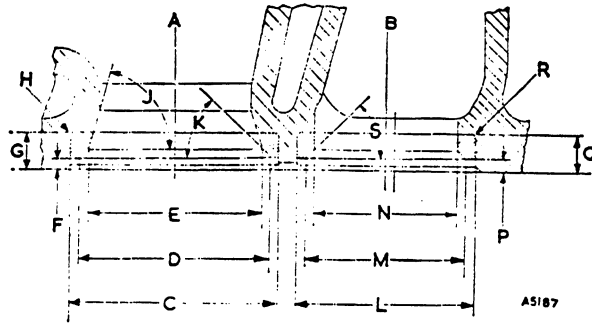


Fig. A.34

**Valve seat machining dimensions**

**Inlet (A).**

- C. 1.4965 to 1.4975 in. (38.011 to 38.036 mm.).
- D. 1.375 to 1.380 in. (34.93 to 35.05 mm.).
- E. 1.250 in. (31.75 mm.).
- F. .085 to .090 in. (2.16 to 2.29 mm.).
- G. .273 to .276 in. (6.93 to 7.01 mm.).
- H. Maximum radius .015 in. (.38 mm.).
- J. 75°.
- K. 45°.

**Exhaust (B).**

- L. 1.2775 to 1.2785 in. (32.448 to 32.474 mm.).
- M. 1.156 to 1.161 in. (29.36 to 29.49 mm.).
- N. 1.031 in. (26.19 mm.).
- P. .085 to .090 in. (2.16 to 2.29 mm.).
- Q. .273 to .276 in. (6.93 to 7.01 mm.).
- R. Maximum radius .015 in. (.38 mm.).
- S. 45°.

This operation should be followed by natural cooling, when the 'shrink fit' will be permanently established and no further treatment required.

### Section A.41

#### FITTING CYLINDER LINERS

Should the condition of the cylinder bores be such that they cannot be cleaned up to accept the recommended oversize pistons, dry cylinder liners can be fitted. This operation may be carried out by the use of specialized proprietary equipment or with a power press, using pilot adaptors to the dimensions shown in Fig. A.33. The press must be capable of 3 tons (3048 kg.) pressure to fit new liners and 5 to 8 tons (5080 to 8128 kg.) to remove old liners. If liners have not previously been fitted the bores must be machined and honed to the dimensions given in the table below.

**To remove worn liners**

Dismantle the engine and remove the cylinder head studs.

Machine bores of cylinder block to this dimension before fitting liner	Outside diameter of liner	Interference fit of liner in cylinder block bore	Machine liner bore to this dimension after fitting
3.0165 to 3.017 in. (76.619 to 76.631 mm.)	3.0185 to 3.01925 in. (76.669 to 76.688 mm.)	.0015 to .00275 in. (.038 to .069 mm.)	2.8745 to 2.876 in. (73.01 to 73.04 mm.)

Place the cylinder block face downwards on suitable wooden supports on the bed of the press, making sure that there is sufficient space between the block and the bed of the press to allow the worn liner to pass down. Insert the pilot complete with extension into the bottom of the liner and carefully press the liner from the bore.

**To press in new liners**

Thoroughly clean the inside of the bores and the outside of the liners. Stand the cylinder block upright on the bed of the press insert the pilot guide in the top of the liner, and position the liner with its chamfered end in the top of the bore. Make certain that the liner is square with the top of the block and that the ram of the press is over the centre of the pilot. Press the liner into the bore.

Finally, bore the cylinder liners to the dimensions given in the table at the bottom of page A.30.

**Section A.42****FITTING VALVE SEAT INSERTS**

Should the valve seatings become so badly worn or pitted that the normal workshop cutting and refacing tools cannot restore them to their original standard of efficiency, special valve seat inserts can be fitted. To fit the inserts machine the seating in the cylinder head to the dimensions given in Fig. A.34 and press in the inserts, which have an interference fit of  $\cdot0025$  to  $\cdot0045$  in. ( $\cdot063$  to  $\cdot114$  mm.). Finally, grind or machine the seatings to the dimensions given in Fig. A.34. The throat of each valve seat must blend into the throat in the cylinder head. Normal valve grinding may be necessary to ensure efficient seating, and before reassembly the valve 'stand-down' should be checked as detailed in Section A.23.



## Section D.1

## DESCRIPTION

The fuel is drawn from the supply tank by a mechanical diaphragm-type lift pump, which is operated by the engine camshaft. It is imperative that the fuel is absolutely free from foreign matter, and in addition to the gauze-type filters in the fuel lift and injection pumps a filter of the renewable paper element type is installed in the feed line from the lift pump to the injection pump.

The injection pump, which is of the C.A.V. distributor type, meters and forces fuel under high pressure via Pintaux injection nozzles into the combustion chambers. The Pintaux nozzle, which is of the pintle type embodying an auxiliary hole to facilitate starting, has been designed expressly for use with the Ricardo Comet V type combustion chamber which is employed in this engine. The use of these designs ensures easy starting under arctic conditions, especially when used in conjunction with the heater plugs which are fitted.

The accelerator is connected to the control lever on the injection pump, which embodies a governor and automatic advance unit, both of which are hydraulically operated.

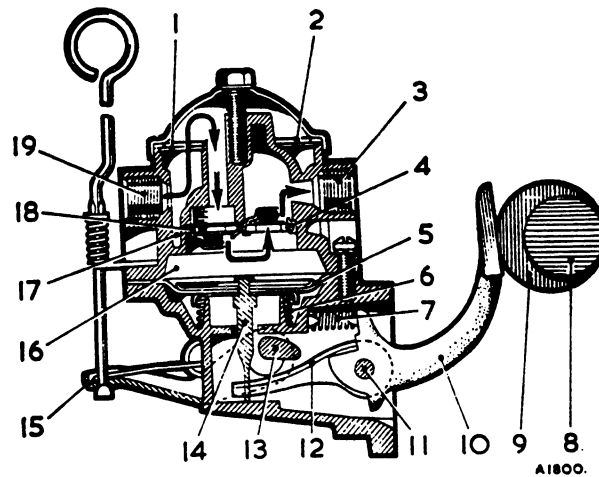


Fig. D.1

## Section through the fuel lift pump

- |                        |                         |
|------------------------|-------------------------|
| 1. Filter gauze.       | 11. Pivot pin.          |
| 2. Sealing ring.       | 12. Link.               |
| 3. Outlet port.        | 13. Priming cam.        |
| 4. Delivery valve.     | 14. Pull-rod.           |
| 5. Diaphragm.          | 15. Hand priming lever. |
| 6. Diaphragm spring.   | 16. Pumping chamber.    |
| 7. Rocker arm spring.  | 17. Sediment chamber.   |
| 8. Engine camshaft.    | 18. Inlet valve.        |
| 9. Camshaft eccentric. | 19. Inlet port.         |
| 10. Rocker arm.        |                         |

## Section D.2

## DESCRIPTION OF THE FUEL LIFT PUMP

The fuel lift pump is mounted on the left-hand side of the crankcase and is operated by an eccentric on the engine camshaft. A hand priming lever permits pumping a supply of fuel through the main fuel filter to the injection pump for bleeding the system of air whenever any component has been dismantled or disconnected.

As the engine camshaft revolves, the eccentric lifts the pump rocker arm, which moves the pull-rod together with the diaphragm downwards against the spring pressure, thus creating a partial vacuum in the pumping chamber.

Fuel drawn from the tank enters the sediment chamber and then passes through the filter gauze and the suction valve into the pumping chamber. On the return stroke the spring pressure pushes the diaphragm upwards, forcing the fuel from the pumping chamber through the delivery valve and port to the main fuel filter.

When the main fuel filter is full a pressure is created in the pump chamber. This pressure will hold the diaphragm downwards against the spring pressure, and it will remain in this position until the main fuel filter requires further fuel. The rocker arm operates the connecting link, which allows an idling movement of the rocker arm when there is no movement of the fuel pump diaphragm.

A spring keeps the rocker arm in constant contact with the eccentric, thus eliminating noise.

D.4

## Section D.3

REMOVING AND REPLACING  
THE FUEL LIFT PUMP

Unscrew the banjo-type union bolts to release the two fuel pipes from the lift pump. The fuel feed pipe from the supply tank should be plugged to prevent the loss of fuel.

Remove the two nuts and spring washers which secure the pump to the crankcase and withdraw the pump complete with its gasket.

Before replacing the pump, which is a reversal of the procedure to remove, lubricate the rocker arm and the rocker arm pin with clean engine oil.

Renew the gasket between the pump and the cylinder block, and to facilitate the fitting of the pump crank the engine to bring the eccentric on the camshaft into the extreme released position so that its small side will contact the rocker arm.

After installation bleed the fuel system of air as described in Section D.10. Start the engine and check the pump and its fuel line connections for leaks. After correcting any leaks the fuel system should be re-bled.

## Section D.4

DISMANTLING AND REASSEMBLING  
THE FUEL LIFT PUMP

Before dismantling, thoroughly clean the exterior of the pump and scribe a mark across the upper to lower half body joint flanges for guidance when reassembling.

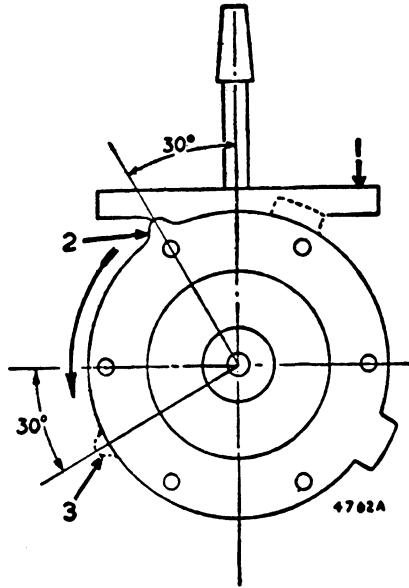


Fig. D.2

Diaphragm assembly diagram

1. Pump mounting flange.
2. Initial position of diaphragm locating tab.
3. Final position of diaphragm locating tab.

Remove the set bolt and fibre washer securing the domed cover to the lift pump body; detach the domed cover and its sealing ring and lift off the filter gauze.

Unscrew the set screws and separate the two halves of the pump body.

Release the valve retaining plate from the upper half of the pump body by removing the two securing screws and lift out the inlet and outlet valves. Carefully remove the valve gasket.

Lightly press the centre of the diaphragm downwards to take the weight of the return spring; turn the diaphragm assembly clockwise through an angle of  $90^\circ$  to release the diaphragm pull-rod from the operating link fork and withdraw the diaphragm assembly and its return spring.

Remove the retaining clips from the ends of the rocker arm pin and press the pin out of the body to release the rocker arm, rocker arm distance washers, rocker arm spring, and link.

Detach the spring from the priming lever and body assembly.

Further dismantling of the body is not advisable as the priming lever is secured to its spindle by riveting.

Before reassembling, thoroughly clean all components in paraffin and blow clean the cavities in the pump body with compressed air.

Check the body castings for cracks and, using a straight-edge, ensure that the diaphragm and engine mounting flanges are true. If they are found to be distorted they may be lapped to restore their flatness.

Examine the two valve assemblies for signs of wear and renew them if they are not in perfect condition.

Very little wear should be tolerated on the rocker arm pin and rocker linkage. Slight wear on the working face

of the rocker arm which engages the camshaft is permissible, but if it exceeds  $.010$  in. ( $.254$  mm.) the rocker arm should be renewed.

The diaphragm spring seldom requires renewing, but should it be necessary, ensure that the new spring bears the same identification colour as the original spring.

Reassembly is a reversal of the dismantling procedure, noting the following.

To install the valves, first place a new gasket in position and then insert the outlet valve, spring end foremost, into its port. The inlet valve cannot be installed incorrectly owing to a restriction in the port.

The rocker arm should be a tap fit in the body, and if, due to wear, it is freer than this the holes in the body may be closed by peening to restore the fit.

When installing the diaphragm and pull-rod assembly ensure that the upper end of the diaphragm return spring is centred properly in the diaphragm lower protector washer and place the diaphragm in the pump body with its locating tab in the 11 o'clock position (see Fig. D.2). Press the diaphragm downwards and turn it anti-clockwise through an angle of  $90^\circ$  to engage the slots in the pull-rod with the link fork. This will place the pull-rod in the correct working position and at the same time align the holes in the diaphragm with those in the pump body flange.

To assemble the two pump body sub-assemblies, push the rocker arm towards the pump body until the diaphragm is level with the body joint flange. Place the upper half of the pump in position, ensuring that the marks scribed on the joint flanges during dismantling coincide, and install the body securing screws finger tight. Press the rocker arm towards the pump body to position the diaphragm at the bottom of its stroke. With the diaphragm held in this position tighten the body securing screws in diagonal sequence.

## Section D.5

### TESTING THE FUEL LIFT PUMP

Before installing an overhauled pump it should be tested for performance and air leaks. In the absence of special test equipment the pump may be tested in the following simple but effective manner.

Immerse the pump in a bath of clean paraffin and flush it through by operating the rocker arm six to eight times. Remove and empty the pump; seal the suction side of the pump by placing a finger firmly over the inlet union (marked 'in') and operate the rocker arm several times. Upon removal of the finger from the inlet union a distinct sucking noise should be heard, denoting that the pump has developed a reasonable degree of suction.

In a similar manner, seal the delivery side of the pump and press the rocker arm inwards to charge the pumping chamber with air. If the pump is in good condition the air in the pumping chamber should be held under compression for two or three seconds. Repeat this test, but immediately the pumping chamber is charged with air

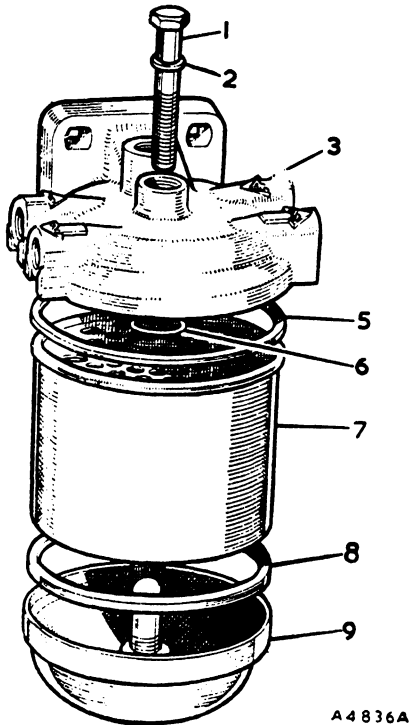


Fig. D.3

*Main fuel filter components*

- |                    |                  |
|--------------------|------------------|
| 1. Retaining bolt. | 6. 'O' ring.     |
| 2. Washer.         | 7. Element.      |
| 3. Head casting.   | 8. Sealing ring. |
| 5. Sealing washer. | 9. Base casting. |

immerse the pump in a bath of clean paraffin and inspect the diaphragm clamping flanges for signs of air leakage.

Finally, flush the pump through with clean fuel oil to remove all traces of paraffin.

## Section D.6

### DESCRIPTION OF THE MAIN FUEL FILTER

The main fuel filter, which is mounted at the front of the exhaust manifold, is a C.A.V. bowl-less-type—that is, the paper element, which is contained in a thin metal canister, is clamped between the filter head and base castings.

The filter components are held together by a split bolt arrangement, comprising a centre stud mounted in the filter base and a threaded bolt, which passes through the filter head to screw into the centre stud.

Synthetic rubber rings located in the filter head and base castings effect a seal between the outer rims of the element and the head and base castings. An 'O' ring located in an annular groove in the centre boss of the filter head, and over which the centre tube of the element fits, seals the dirty side of the filter from its clean side.

The head casting is provided with two inlet, two outlet, and a single vent connection. One outlet con-

D.6

nection is not required and is fitted with a sealing plug, while the second inlet connection allows fuel oil surplus to the injection pump requirements to return to the dirty side of the filter. This connection is fitted with a non-return valve to ensure that unfiltered fuel cannot find its way into the injection pump body.

Passages in the filter head connect the filter inlet connections to the centre tube of the filter element. As the upper end of the centre tube is sealed, fuel at lift pump pressure passes down the centre tube into the base casting and then upwards through the filter element to the outlet connection in the filter head.

An auxiliary pipe connects the vent connection on the top of the filter head to the injector leak-off pipe, providing continuous air-venting of the filter during operation.

The paper element is not intended to be washed or cleaned in any way and should be renewed at the recommended intervals.

## Section D.7

### REMOVING AND REPLACING THE FUEL FILTER

Thoroughly clean the outside of the filter.

Disconnect the fuel inlet and outlet pipes and the fuel leak-off pipe from the filter head, taking care not to lose the sealing washer positioned on each side of the banjo-type unions.

Unscrew the two bolts and nuts securing the filter to the mounting bracket on the exhaust manifold and withdraw the filter from the engine.

When replacing the filter, which is a reversal of the above procedure, ensure that the washers positioned on each side of the banjo-type unions are in good condition and will make fuel-tight joints. Upon completion the fuel system must be bled to remove all air, as described in Section D.10.

## Section D.8

### DISMANTLING AND REASSEMBLING THE FUEL FILTER

Unscrew the retaining bolt and sealing washer from the centre of the head casting and detach the base casting from the filter.

Remove the filter element, using a twisting movement to release the element from the head casting. Withdraw the three sealing rings from their locations in the head and base castings.

Unscrew and remove the blanking plug with washer, and the non-return valve from the head casting.

Wash the filter head and base castings, the blanking plug, and the non-return valve in petrol and allow them to dry. Do not use cotton waste or cloth wipers to dry them. Ensure that no residue is left in the passages in

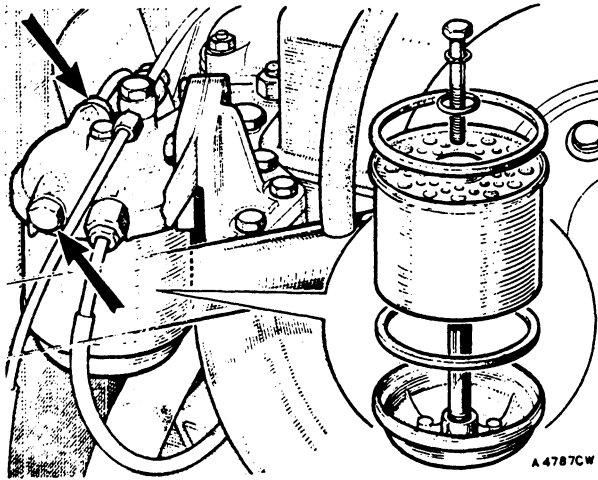


Fig. D.4  
Main fuel filter air bleed points

the head casting by blowing them clear with compressed air.

Discard the filter element and sealing rings, which should be renewed as normal routine procedure.

Check the operation of the non-return valve.

Assemble the sealing plug and washer to (outlet) connection No. 3 and the non-return valve to (inlet) connection No. 4 in the head casting.

Fit new sealing rings to the head casting, ensuring that they are properly located in their grooves. Assemble a new element, strengthened rim uppermost, to the head casting, using a twisting movement to seat it on the seals.

Place the base casting in position, using a new sealing ring to make the joint between the element and the casting, and secure the assembly with the retaining bolt and washer.

## Section D.9

### RENEWING THE FUEL FILTER ELEMENT

Thoroughly clean the outside of the filter.

Support the filter base casting and unscrew the retaining bolt with copper seal washer located in the centre of the filter head casting. Detach the base casting and, using a twisting movement, separate the element from the head casting. Remove the three sealing rings from their locations in the head and base castings.

Wash the base casting in gasoline, and when dry remove any residue.

Reassemble, using a new element and sealing rings, fitting the element with its strengthened rim uppermost.

After reassembly bleed the fuel filter and the fuel injection pump as described in Section D.10.

## Section D.10

### AIR-VENTING (BLEEDING) THE FUEL SYSTEM

The following procedure should be used to air-vent the fuel system after first ensuring that there is an adequate supply of fuel in the fuel tank.

- (1) Slacken the union nut at the filter end of the injection pump feed pipe. Operate the lift pump, and when the fuel passing the union is free from air bubbles tighten the union nut.
- (2) Unscrew the blanking plug in the unused outlet connection on the filter head sufficiently to allow fuel at lift pump pressure to pass the thread on the plug. Operate the lift pump, and when the fuel issuing from around the plug thread is free from air bubbles tighten the plug.
- (3) Slacken the two air bleed valves on the fuel injection pump. One bleed valve is located on the governor housing, while the other is incorporated on one of the hydraulic head locking screws. Operate the lift pump, and when the fuel flowing from both bleed valves is free from air bubbles tighten the valves.
- (4) Slacken the union nut at the injector end of any two high-pressure pipes. Ensure that the stop control is in the 'run' position, and set the accelerator in the fully open position. Crank the engine until the fuel flowing from both pipes is free from air bubbles, then tighten the pipe union nuts.
- (5) Start the engine and allow it to run until it is firing on all cylinders.

After renewing the main fuel filter element, **providing the engine is not cranked during this operation**, it is only necessary to bleed the fuel filter as described in operations (1) and (2) before starting the engine.

**WARNING.**—Lubrication of the injection pump mechanism is effected by fuel oil under pressure, therefore no attempt should be made to bleed the fuel system by towing the vehicle in gear as this may result in serious damage to the injection pump.

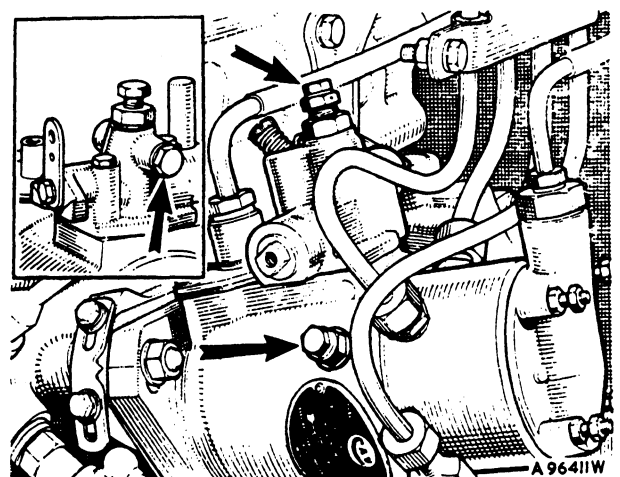


Fig. D.5  
Fuel injection pump air bleed points. The location of the air bleed point on the later-type governor is shown inset

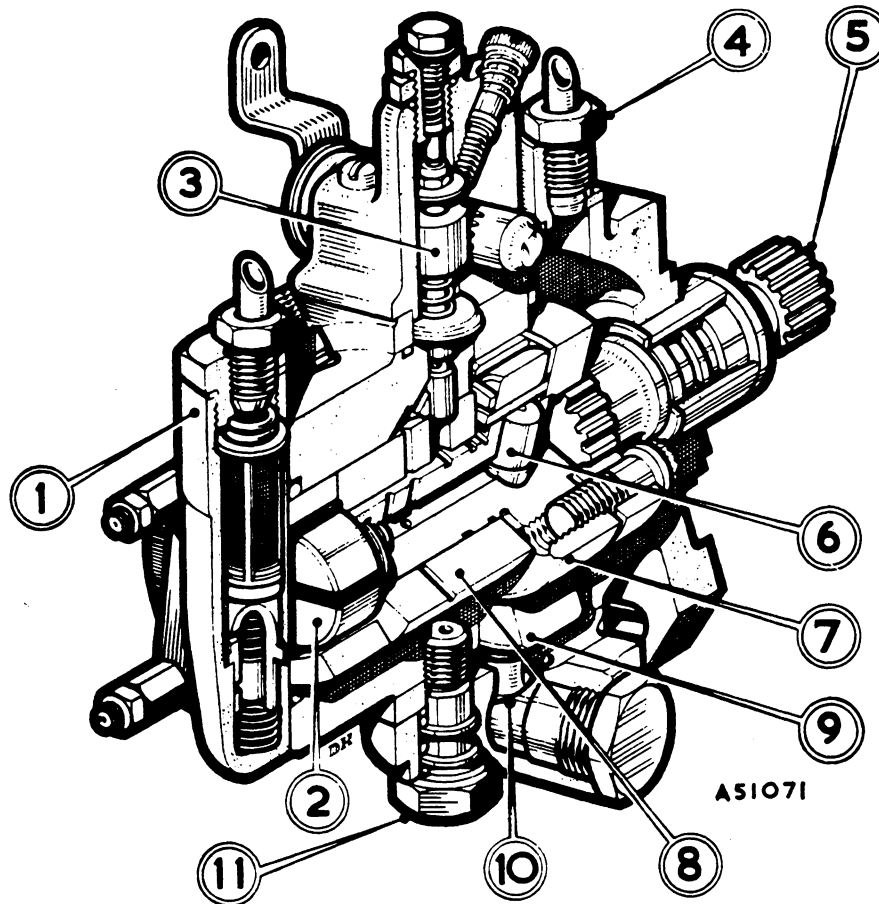


Fig. D.6

## Section through the fuel injection pump

- |   |                                    |   |
|---|------------------------------------|---|
| 1. End plate and regulating valve.        | 5. Drive shaft.                    | 9. Cam ring.                                    |
| 2. Transfer pump.                         | 6. Pumping plunger.                | 10. Automatic advance device.                   |
| 3. Metering valve and hydraulic governor. | 7. Pumping and distributing rotor. | 11. Head locating fitting and non-return valve. |
| 4. Back-leakage connection.               | 8. Hydraulic head.                 |   |

## Section D.11

## DESCRIPTION OF THE FUEL INJECTION PUMP

The injection pump is a single-cylinder, opposed-plunger, inlet-metering, distributor-type pump fitted with a governor and an automatic advance mechanism, both of which are hydraulically operated.

The pump, the main features of which are shown in Fig. D.6, is flange-mounted on the engine and is driven by a splined shaft, having a master spline at each end to ensure correct location.

A central rotating member forms the pumping and distributor rotor; this is driven by splines from the drive shaft, and in turn drives a sliding-vane-type transfer pump, which is mounted on the outer end of the rotor.

The transfer pump raises the fuel pressure to an intermediate level, and as its capacity is many times the maximum requirements of the injection pump, a regulating valve housed in the pump end plate allows the excess fuel to be by-passed back to the suction side of the transfer pump.

The pressure regulating valve, in addition to regulating

the pressure of the fuel from the transfer pump, also provides a means of by-passing the transfer pump when hand-priming the injection pump. Referring to Fig. D.7, it will be seen that the valve is cylindrical and contains a small 'free' piston, the travel of which is limited by two light springs. When priming the injection pump, fuel at lift pump pressure enters the central port in the regulating valve sleeve and moves the 'free' piston against the pressure of the piston retaining spring to uncover the priming port in the lower end of the valve sleeve. The priming port is connected by a passage in the end plate to the delivery side of the transfer pump, thus enabling the fuel to by-pass the stationary transfer pump and prime the injection pump.

When the injection pump is in operation fuel at transfer pressure enters the lower end of the valve sleeve, forcing the 'free' piston upwards against the regulating spring. As the engine speed increases, the transfer pressure rises, moving the piston against the pressure of the regulating spring to progressively uncover the regulating port in the valve sleeve and allow a metered flow of fuel to by-pass back to the inlet side of the transfer pump.

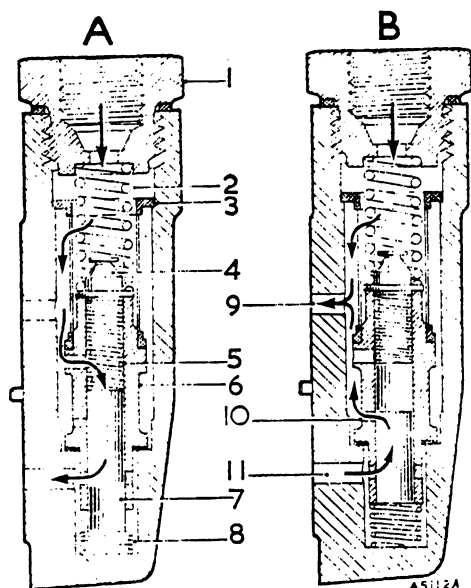


Fig. D.7

Section through the end-plate and regulating valve

- |                             |   |
|-----------------------------|---|
| A. Priming.                 | 7. Regulating piston.                     |
| B. Regulating.              | 8. Piston retaining spring.               |
| 1. Inlet connection.        | 9. Fuel passage to transfer pump inlet.   |
| 2. Sleeve retaining spring. | 10. Regulating port.                      |
| 3. Nylon filter.            | 11. Fuel passage to transfer pump outlet. |
| 4. Sleeve guide plug.       |   |
| 5. Regulating spring.       |   |
| 6. Regulating sleeve.       |   |

The transfer pressure, therefore, is controlled by a balance between the regulating spring pressure and the requirements of the injection pump at any moment.

The pumping and distributing rotor revolves, and is a close fit, in the stationary hydraulic head. The pumping section of the rotor has a transverse bore containing twin opposed pumping plungers. These plungers are operated by means of a cam ring, carried in the pump housing, through rollers and shoes which slide in the rotor. The cam ring has four internal lobes operating in diagonally opposite pairs. The opposed plungers have no return springs but are moved outwards by fuel under pressure from the transfer pump, the flow of fuel and outward displacement of the plungers being determined by the setting of the metering valve and the speed at which the pump is rotating. As a result the rollers, which operate the plungers, do not follow the contour of the internal cam ring entirely, but will contact the cam lobes at points which will vary according to the amount of plunger displacement.

An automatic advance control mechanism is fitted which operates by rotating the cam ring within the pump body. A ball-ended lever, screwed into the cam ring, is operated by a piston sliding in a cylinder. One side of the piston is spring-loaded, while the other side is subject to fuel at transfer pressure, which is admitted to the cylinder through a port and the hollow locating bolt to progressively move the cam ring into the fully advanced position. Any tendency for the cam ring to return to the retarded position, due to the impact of the plunger

rollers on the cam lobes, is prevented by the fuel in the cylinder being trapped by a non-return ball valve in the locating bolt. When the engine stops the advance mechanism is allowed to return to the retarded position under the influence of the piston springs, by normal leakage of fuel between the piston and the cylinder.

Machined on each lobe of the cam ring, immediately after the peak of the cam, is a retraction curve. Under running conditions, when the injection cycle is completed the distributor port in the rotor and the outlet port in the hydraulic head are still in partial alignment with each other. As the plunger rollers move off the peaks of the cams the retraction curves allow the plungers to move slightly outwards. This movement of the plungers effects a sudden reduction of pressure in the injection line, so preventing secondary injection and allowing the injection nozzle needle valve to snap onto its seating to terminate the spray of fuel into the combustion chamber without 'dribble'.

The distributor part of the rotor has a central axial passage which connects the pumping space between the plungers with the four inlet ports and single distributing port drilled radially in the rotor. The radial hole at the outer end of the rotor is the distributing port, and as the rotor turns, this port is aligned successively with the outlet ports in the hydraulic head, from which the injectors are fed via external high-pressure pipes. The inlet or charging ports are equally spaced around the rotor at an intermediate position, and as the rotor turns these are aligned successively with the inlet or metering port

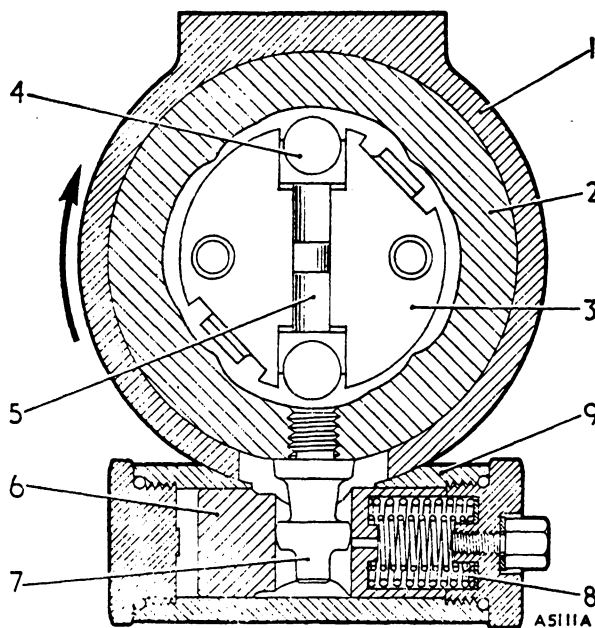


Fig. D.8

Automatic advance mechanism

- |                                    |                               |
|------------------------------------|-------------------------------|
| 1. Pump housing.                   | 5. Pumping plunger.           |
| 2. Cam ring.                       | 6. Automatic advance piston.  |
| 3. Pumping and distributing rotor. | 7. Cam advance screw.         |
| 4. Roller.                         | 8. Piston springs.            |
|                                    | 9. Automatic advance housing. |

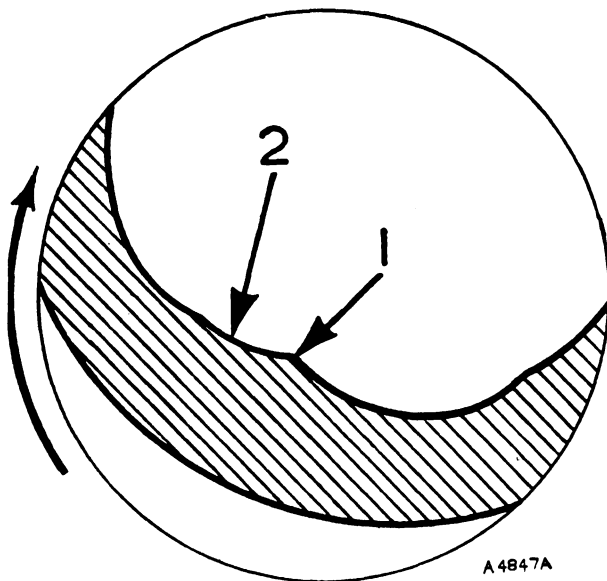


Fig. D.9

*Enlarged view of a cam ring lobe*

1. Cam peak.                      2. Retraction curve.

in the hydraulic head. This port admits fuel to the rotor under control of the metering valve, which is hydraulically governed.

The hydraulic governor is housed in the casting which carries the pump control and shut-off levers. The control lever is mounted on a pinion shaft which meshes with a rack which is free to move on the metering valve stem.

The metering valve slides in a transverse bore in the hydraulic head, into which bore the diagonally drilled metering port opens. A damping valve is carried on the metering valve stem against a shoulder, and the governor spring is held between the damping valve and the rack. The damping valve slides in a cylindrical bore in the pump body which is filled with the fuel and acts as a dashpot to damp out any violent movement of the metering valve. A flat machined on the pinion shaft and an adjustable stop screw mounted on the governor housing limits the rotation of the pinion shaft to control the maximum speed of the engine.

Idling speed is controlled by the spring-loaded screw on the governor housing, which limits the movement of the rack on the metering valve stem towards the stop position. At idling speed the upper end of the metering valve bears against a spring-loaded plunger, incorporated in the hydraulic governor housing air vent valve, which damps out any oscillations of the metering valve to maintain the idling speed.

The governor is operated by fuel at transfer pressure which is fed from the annular groove surrounding the pump rotor. The fuel passes through the hollow metering valve into an annular space around the valve via holes drilled transversely in the valve.

Endwise movement of the metering valve varies the area of the metering port in the hydraulic head which registers with the annulus around the valve, the effective

D.10

area of the port being that part which is uncovered by the inner edge of the annulus.

When the control lever is moved to give increased speed the metering valve is pushed to the fully open position by the governor spring. As the engine speed increases, transfer pressure increases also, and this pressure will move the metering valve back against the governor spring pressure, until a balance is reached, to reduce the effective area of the metering port.

Should the engine speed drop, the consequent reduction in transfer pressure will allow the governor spring to reassert itself and move the metering valve towards the fully open position to stabilize the engine speed.

Movement of the control lever towards the idling stop reduces the compression of the governor spring, and equilibrium is reached when the force exerted on the metering valve by the fuel at transfer pressure is balanced by compression of the governor spring. The governor spring compression becomes progressively less as the control lever is moved towards the idling stop, and this enables the reduced transfer pressure, at low speeds, to operate the metering valve and perform the governing function throughout the idling range.

Operation of the shut-off lever rotates a spindle, the inner end of which is machined to form a 'cam'. This cam engages the under side of the shut-off washer, secured to the top of the metering valve by a self-locking nut, and lifts the valve to a position where the metering port in the hydraulic head is blanked off and so stops the engine.

In operation fuel at lift pump pressure enters the pump through the connection on the pump end plate and passes through a fine nylon gauze filter to the inlet side of the transfer pump.

From the transfer pump the fuel passes through a passage in the hydraulic head to an annular groove

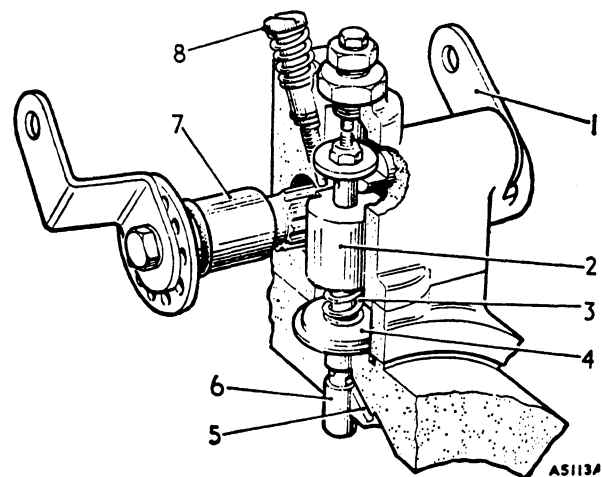


Fig. D.10

*Section through the hydraulic governor*

- |                     |                       |
|---------------------|-----------------------|
| 1. Shut-off lever.  | 5. Metering port.     |
| 2. Rack.            | 6. Metering valve.    |
| 3. Governor spring. | 7. Pinion shaft.      |
| 4. Damping valve.   | 8. Idling stop screw. |

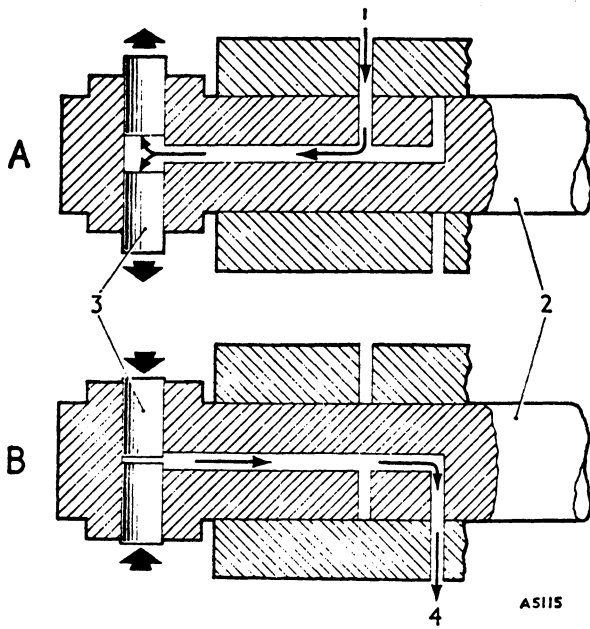


Fig. D.11  
The injection cycle

- |                      |                                    |
|----------------------|------------------------------------|
| A. Inlet stroke.     | 2. Pumping and distributing rotor. |
| B. Injection stroke. | 3. Pumping plungers.               |
| 1. Fuel inlet.       | 4. Fuel to injector.               |

surrounding the rotor, and thence to the governor metering valve. The position of the metering valve depends upon the setting of the control lever, which varies the governor spring pressure on the valve. Any variation in pump speed is accompanied by an increase or decrease in transfer pressure, which will move the metering valve to increase or decrease the effective area of the metering port, and so regulate the flow of fuel at metering pressure into the pumping section of the rotor. The volume of fuel passing into the pumping element is thus controlled by the transfer pressure, the position of the metering valve, and the time during which an inlet port in the rotor is aligned with the metering port in the hydraulic head.

When one of the rotor inlet ports is aligned with the metering port in the hydraulic head fuel at metering pressure flows into the rotor and forces the pumping plungers apart, the amount of plunger displacement being governed by the quantity of fuel which can flow into the rotor while the ports are aligned. As the rotor turns, the inlet port is cut off and the pump plungers begin to be forced inwards by their rollers bearing on a pair of cam lobes. This causes an immediate rise in pressure, and as the single distributor port in the rotor comes into register with an outlet port in the hydraulic head the plungers force the fuel up the central bore of the rotor and out to the respective injector.

The maximum amount of fuel delivered at one charge is controlled by limiting the maximum outward movement of the plungers. In Fig. D.12 is shown an end-on view of the rotor, and it will be seen that the cam rollers are carried in shoes which bear against the ends of the

plungers. The roller shoes, which slide in slots in the rotor, have specially shaped projecting 'ears' which engage eccentric slots in the top and bottom adjusting plates. Two lugs on the top adjusting plate engage slots in the bottom adjusting plate to locate the plates one to the other.

The top adjusting plate is clamped to the rotor by the drive plate, the adjusting plate being cut away in the areas of the drive plate securing screws to permit adjustment of the plates by rotation. The maximum outward travel of the pump plungers is limited by the 'ears' of the roller shoes coming into contact with the curved slot sides in the adjusting plates. As the slots are eccentric, rotation of the adjusting plates relative to the rotor provides a means of adjusting the maximum plunger stroke.

### Section D.12

#### REMOVING AND REPLACING THE FUEL INJECTION PUMP

Thoroughly clean the exterior of the fuel injection pump, unstrap the wiring harness from the high-pressure pipes, and disconnect the pipes from the injection pump and the fuel injectors. Withdraw the pipes complete with clamp and damper bushes, and seal the injection pump outlet unions and the fuel injector inlet unions with sealing caps 18G216.

Remove the external oil filter by unscrewing the two bolts which secure it to the crankcase.

Disconnect the accelerator and stop controls from the levers on the pump and unscrew the two nuts to release the stop control abutment bracket from the end of the fuel injection pump.

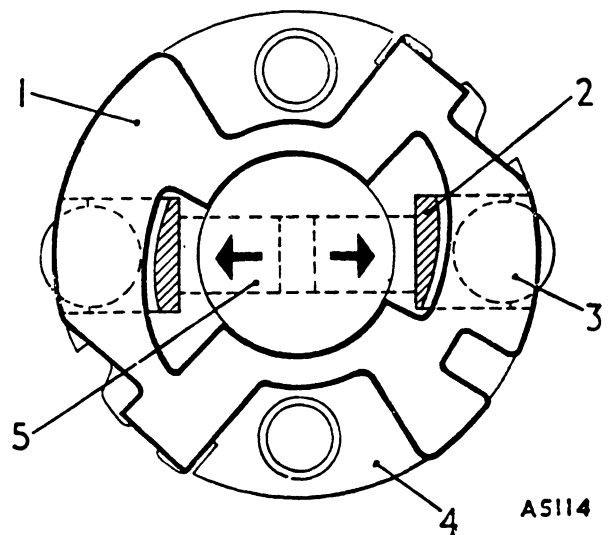


Fig. D.12  
Maximum fuel adjustment

- |                         |                          |
|-------------------------|--------------------------|
| 1. Top adjusting plate. | 4. Pumping end of rotor. |
| 2. Roller shoe ear.     | 5. Pumping plunger.      |
| 3. Roller.              |                          |



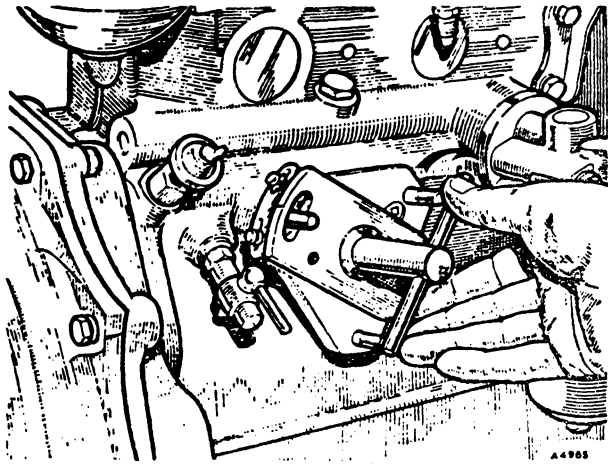


Fig. D.13

*Checking the position of the injection pump timing pointer, using timing gauge 18G629*

Disconnect the fuel feed and return pipes from their unions on the fuel injection pump and plug these unions to prevent the ingress of foreign matter.

Unscrew the three securing nuts with plain washers and withdraw the pump from the engine.

When replacing the fuel injection pump on the engine it is necessary to set the static injection timing so that the commencement of injection occurs when the pistons are at 22° B.T.D.C. on their compression strokes.

To ensure correct timing relationship between the injection pump and the engine the injection pump drive shaft and the drive coupling on the engine are provided with master splines; also, a timing mark is scribed on the mounting flange of the fuel injection pump and a timing pointer is secured to the injection pump hub in the crankcase.

Before fitting the injection pump the position of the timing pointer on the injection pump drive hub should be checked, and adjusted if necessary, with injection timing gauge 18G629. Crank the engine in the normal direction of rotation until the master spline in the injection pump drive coupling is in the 4 o'clock position; No. 1 piston will now be on its compression stroke. Continue to crank the engine slowly until No. 1 piston is at 22° B.T.D.C. on its compression stroke, as indicated by the timing disc or timing mark on the crankshaft pulley, or on later engines the timing plate (see Fig. A.20). Note that the timing disc has two sets of graduations, and it is the set, the zero mark of which is identified 1.4, which is used for this operation. Check the position of the master spline in the injection pump drive coupling, which should now be at 5 o'clock (see Fig. A.29).

Insert timing gauge 18G629 into the injection pump drive hub, engaging the splined end of the gauge with the internal splines of the drive coupling. The master spline in the drive coupling will allow the gauge to engage the coupling in one position only. Turn the gauge by hand (undue force is not necessary) in a clockwise

direction to take up any backlash in the injection pump drive. Hold the gauge in this position and check that the timing pointer on the injection pump drive hub is in line with the mark on the edge of the gauge. If necessary, slacken the two set screws and move the pointer to line it up with the mark on the gauge. Tighten the set screws to secure the pointer in the correct position and remove the timing gauge.

**NOTE.**—After every occasion of injection pump removal, or attention to the crankshaft, camshaft, or timing gear, the position of the timing pointer on the injection pump drive hub should be checked, and adjusted, if necessary, as described above.

Rotate the injection pump drive shaft and position the master spline on the drive shaft at 7 o'clock, when looking on the drive end of the pump, with the hydraulic governor housing uppermost. This will facilitate the entry of the drive shaft into the drive coupling on the engine.

Place a new joint washer in position on the pump mounting studs and offer up the injection pump to the engine, engaging the pump drive shaft with the drive coupling on the engine and fitting the lower securing nut and washer finger tight as the pump is pushed onto the mounting studs. Fit the remaining two securing nuts and washers finger tight, and then rotate the body of the injection pump about its axis to line up the timing mark on the pump mounting flange with the timing pointer. Tighten the three nuts to secure the injection pump in this position.

Reassemble the remaining components, reversing the order of dismantling and ensuring that both the accelerator and the stop control levers on the injection pump have a full range of movement when their respective controls are operated.

Bleed the fuel system, as described in Section D.10, and start the engine.

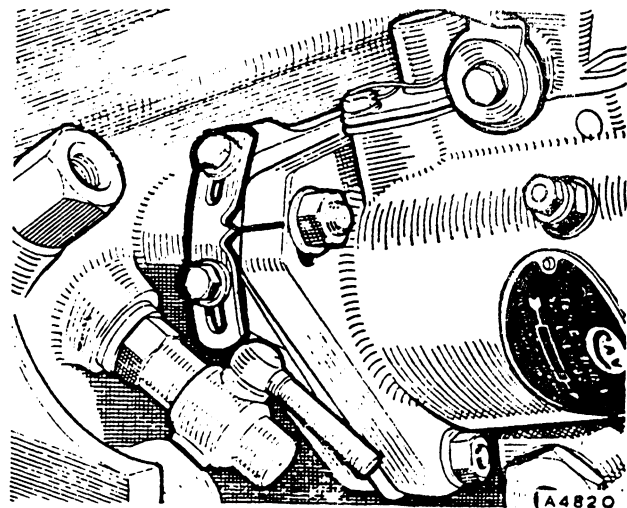


Fig. D.14

*Align the timing mark on the injection pump mounting flange with the timing pointer on the drive hub*

**Maximum and idling speed adjustments**

Before making these adjustments it is imperative that the air cleaner is correctly serviced and fitted, and the engine run until it has attained its normal running temperature.

**Maximum speed**

- (1) Slacken the locknut and unscrew the idling damper, located on the top of the governor housing, two complete turns. Tighten the locknut to secure the damper in this position. This will prevent the idling damper interfering with the operation of the metering valve during the setting of the maximum speed.
- (2) Using a tachometer to check the engine speed, adjust the maximum speed stop screw to give an engine maximum light running speed of 2500 r.p.m. Fit the rubber plug, plug retaining plate, and set screw (early pumps), or locking sleeve (later pumps), and seal the screw with wire and lead seal, using sealing pliers 18G 541. Check and adjust the idling speed.

**Idling speed**

- (1) With the engine stopped, unscrew the idling damper until it is known to be out of contact with the metering valve. Tighten the locknut to secure the damper in this position.
- (2) Start the engine and adjust the idling stop screw to give an engine idling speed of 800 rpm.
- (3) Screw in the idling damper until the idling speed is increased slightly, then unscrew the damper one-third of a turn, and tighten the locknut to secure it in position.
- (4) Run the engine at about 2500 r.p.m. and release the throttle to test for stalling and slow deceleration.
  - (a) If the engine stalls, screw in the idling damper slightly and carry out a further test.
  - (b) If deceleration is slow, the idling damper should be unscrewed slightly and a further test carried out.
- (5) Check the operation of the shut-off control.

**NOTE.**—After every adjustment of the idling damper always ensure that the engine is not idling directly on the idling damper.

**Section D.15****DESCRIPTION OF THE FUEL INJECTORS**

The fuel injectors are of the Pintaux type, developed for use with the Ricardo Comet V combustion chamber to assist starting under cold conditions. The Pintaux nozzle is a pintle-type nozzle having an auxiliary spray hole which directs a spray of fuel into the hottest zone of the combustion chamber.

The nozzle consists of two parts, the nozzle valve and the nozzle body. The nozzle valve takes the form of a plunger accurately lapped into the nozzle body to the closest possible fit, within which it will work freely. The inner end of the valve is reduced in diameter to produce a stem upon which a valve face is formed, the stem being extended to form a pin or pintle which fits into a comparatively large-diameter hole in the nozzle body. The auxiliary spray hole is drilled in the nozzle body at an angle to the pintle hole, entering the nozzle seating below the line of contact between the valve and seat. Fuel is fed to the mouth of the nozzle through vertical drillings in the nozzle body which terminate in an annular gallery just above the valve seating.

The nozzles are held in position in the cylinder head by suitably designed holders, a nozzle nut securing the

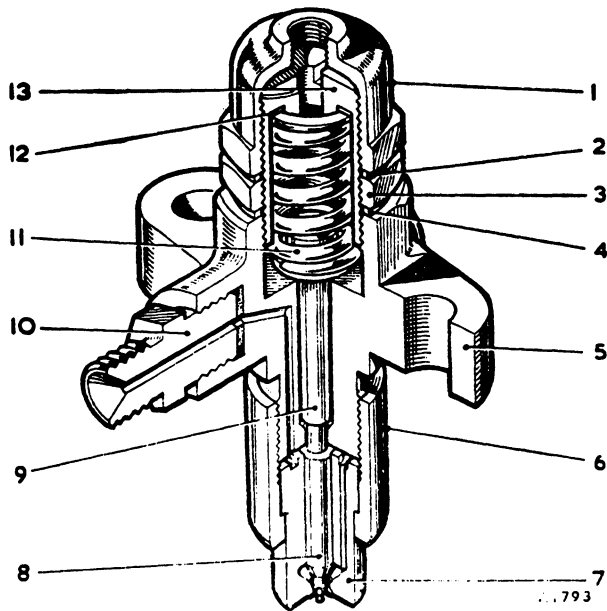


Fig. D.27

## Section through a fuel injector

- |                      |                     |
|----------------------|---------------------|
| 1. Injector cap nut. | 8. Nozzle valve.    |
| 2. Joint washer.     | 9. Spindle.         |
| 3. Locknut.          | 10. Inlet union.    |
| 4. Joint washer.     | 11. Spring.         |
| 5. Nozzle holder.    | 12. Washer.         |
| 6. Nozzle nut.       | 13. Spring cap nut. |
| 7. Nozzle body.      |                     |

two components together, the faces of which are lapped to form a high-pressure seal.

Each holder contains a spindle and spring which serve to retain the nozzle valve on its seating. The upper end of the spring is located in an adjustable cap nut, enabling the pressure at which the valve is forced off its seating to be regulated. A fuel inlet connection is provided to accept the high-pressure piping from the injection pump and the body of the holder is drilled to allow passage of the fuel to the gallery in the nozzle body. A leak-off pipe is connected to the small tapped hole in the top of the cap nut to return the accumulation of fuel which leaks past the nozzle valve to the low-pressure side of the fuel system. This slight leakage of fuel also serves to lubricate the nozzle valve.

In operation, the pressure in the annular gallery in the nozzle body is built up by the delivery of fuel from the injection pump. When the pressure in the gallery reaches injection pressure, determined by the spindle and spring in the nozzle holder, the valve is raised from its seating in the nozzle body and fuel is forced through the pintle and auxiliary holes in the form of a finely atomized spray. As the pressure in the gallery drops, injection into the combustion chamber is terminated by the snap return of the nozzle valve onto its seating.

At engine starting speed, when the injection pressure is low, the valve is not lifted sufficiently to clear the pintle hole and the bulk of the fuel is discharged through the auxiliary hole. At normal running speed the injection

D.22

pressure is higher and the valve is withdrawn from the pintle hole, allowing the bulk of the fuel to be discharged through it. A small proportion of fuel continues to be discharged through the auxiliary hole, which does not affect the engine performance, and prevents the formation of carbon in the hole.

## Section D.16

REMOVING AND REPLACING  
THE FUEL INJECTORS

Disconnect the high-pressure feed pipes from the unions on the nozzle holder bodies.

Unscrew the bolts, noting the copper sealing washers positioned on each side of the banjo-type unions, to release the fuel leak-off pipe from the injector nozzle holder cap nuts and the union on the main fuel filter head.

Unscrew and remove the cap nut from each injector nozzle holder.

Remove the eight nuts and spring washers securing the nozzle holders to the cylinder head and withdraw each injector in turn, using tool 18G491A. Assemble the tool, using the appropriate centre screw adaptor and the unthreaded legs. Place the leg locating sleeves over the nozzle holder studs and position the tool with the legs in the sleeves. Screw the centre screw adaptor onto the spring cap nut. Insert the tommy-bar into the small hole in the adaptor, ensuring that its free end bears against one of the legs to prevent the adaptor turning, and tighten the centre screw nut to withdraw the injector nozzle assembly.

If the injectors are to be removed for any considerable length of time, seal off the fuel feed unions, using sealing caps 18G216, and then wrap each injector assembly in greaseproof paper.

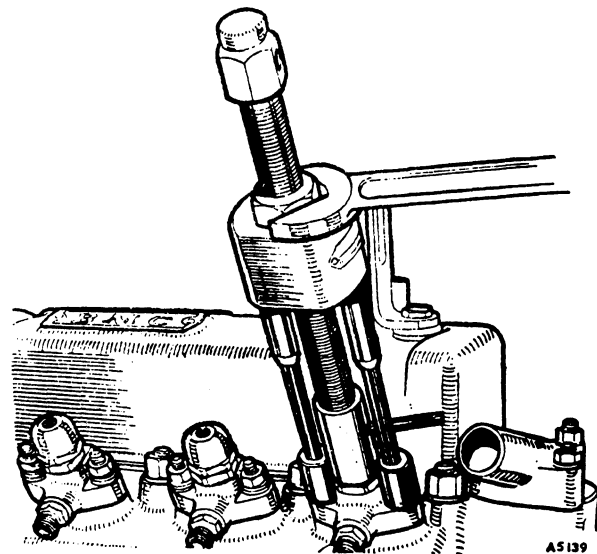
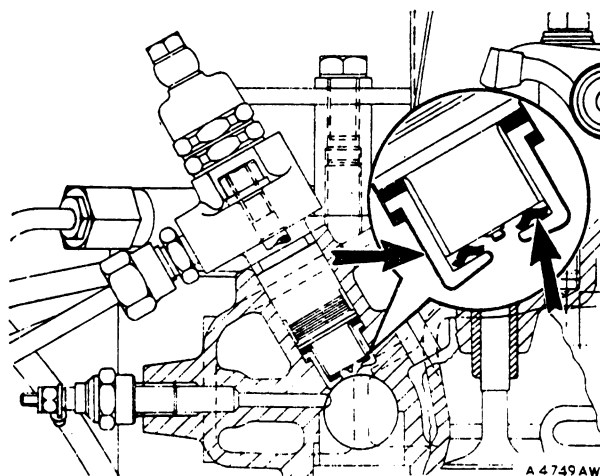


Fig. D.28

Withdrawing an injector nozzle, using Service tool 18G491A



*Fig. D.29*

*Section through the cylinder head, showing an injector nozzle heat shield and atomizer seal washer*

Remove the atomizer seal washers from inside the injector nozzle heat shields and the nozzle holder sealing washers from the cylinder head. If necessary, withdraw the injector nozzle heat shields and sealing washers from the injector bores in the cylinder head. Should difficulty be experienced in removing the heat shields, it may be found necessary to remove the cylinder head and withdraw the combustion chamber inserts, as detailed in Section A.18, when the heat shields can be driven out from the inside of the combustion chambers.

Plug the injector bores in the cylinder head to prevent the ingress of foreign matter into the combustion chambers and cylinders.

When replacing, thoroughly clean the injector bores in the cylinder head and ensure that the copper sealing washers are in good condition and will make a gas-tight joint. Renew the atomizer seal washers, fitting them with their two edges pointing downwards as shown in Fig. D.29.

Place the injector assemblies in position and tighten the securing nuts evenly to the figure given in the 'GENERAL DATA' section, using torque wrench 18G537.

Reconnect the high-pressure feed pipes to the unions on the nozzle holder bodies and refit the fuel leak-off pipe, ensuring that the copper sealing washers are positioned on each side of the banjo-type unions.



# OTHER OVERHAUL

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MARINE ENGINE ELECTRICAL SYSTEM.....	Q	
Activation by Keyswitch (1980 onwards).....		Q.2
Activation by Fuel Pressure.....		Q.4
Activation by Lube Oil Pressure.....		Q.6
COOLING SYSTEM (EXTERNAL).....	R	
TRANSMISSIONS.....	S	
Type SA0 Manual.....		S.9
SA1 and SA0 Clutch Adjustments.....		S.21
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Paragon P-21 Series, Hydraulic.....		S.29
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Short Profile Sailing Gear.....		S.41

**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.

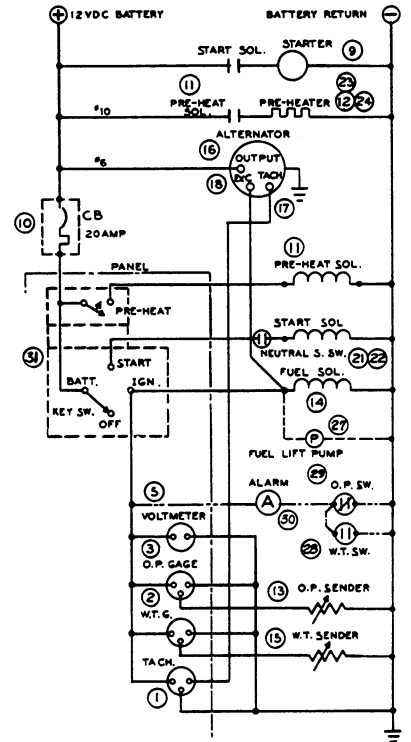
**CAUTION** - the builder/owner must ensure that the instrument panel, wiring and engine are installed so that electrical devices cannot come in contact with seawater.

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.

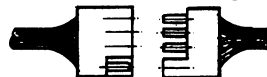
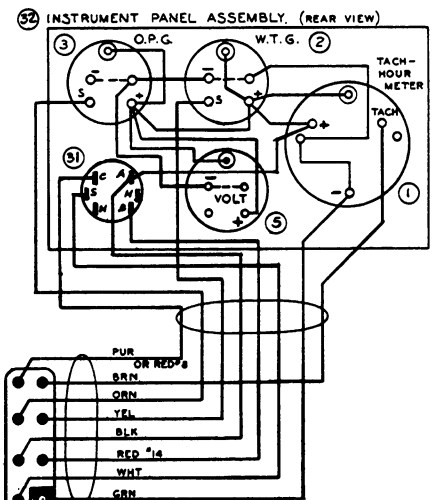
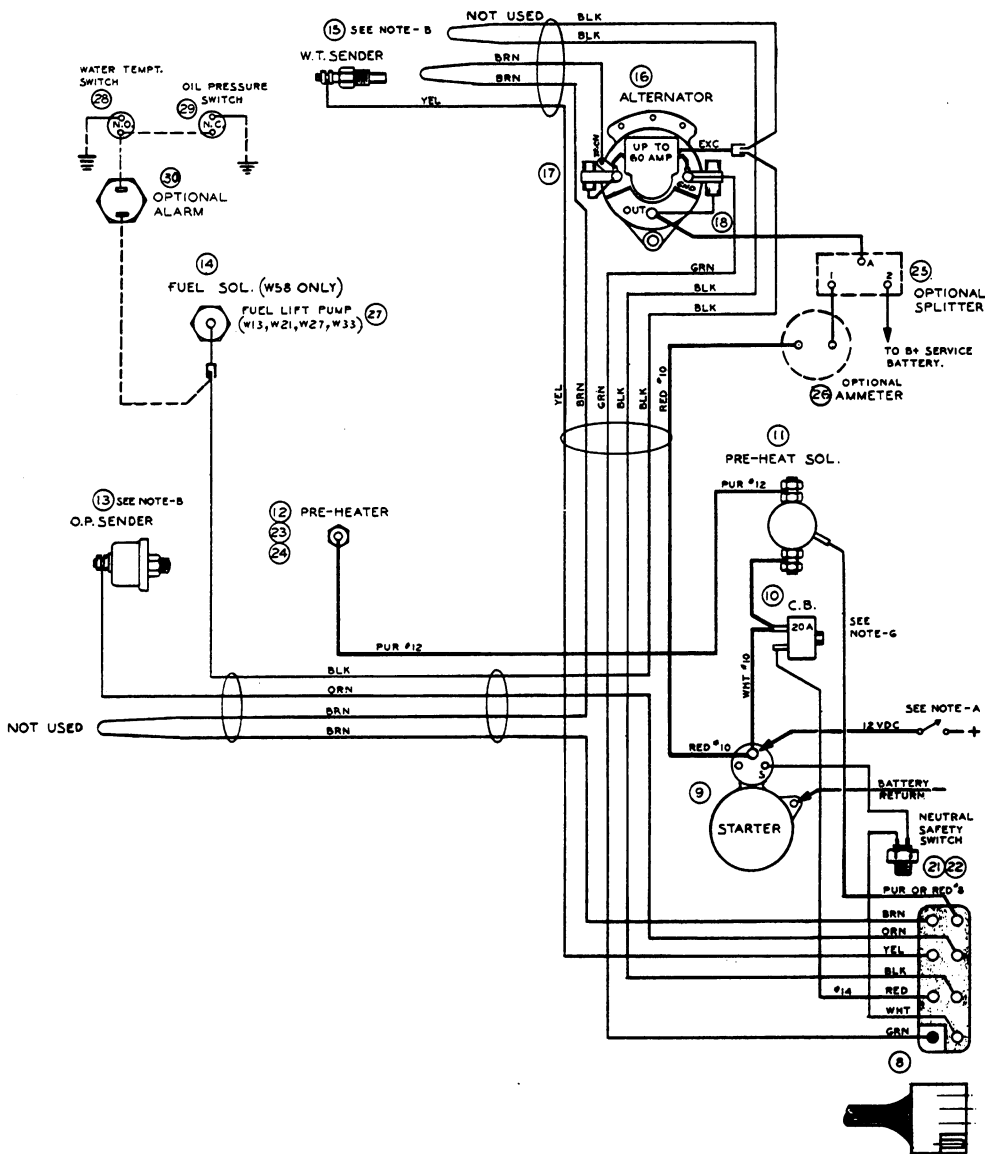
# ACTIVATION BY KEYSWITCH

# 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 pre-heating 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)

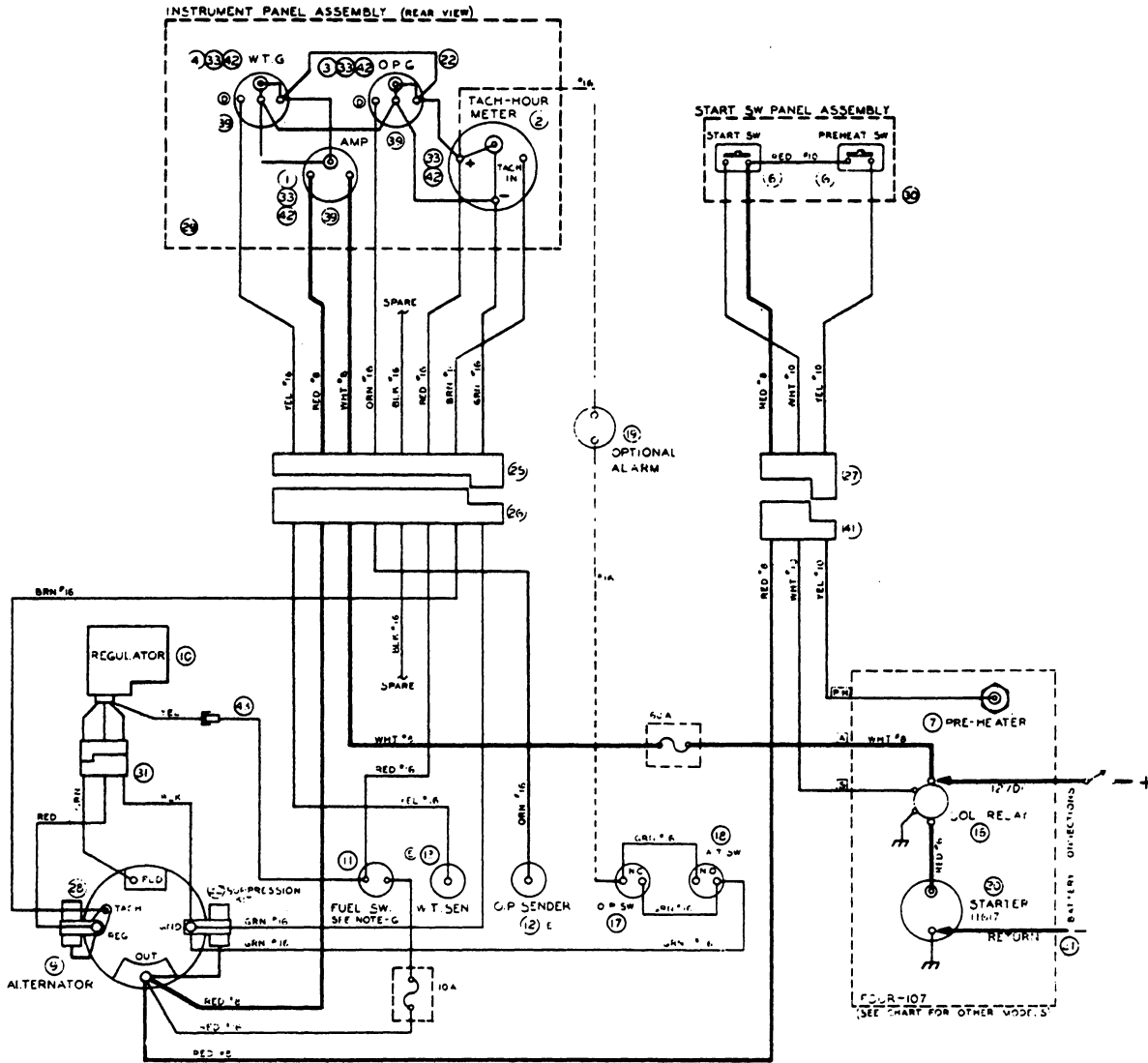
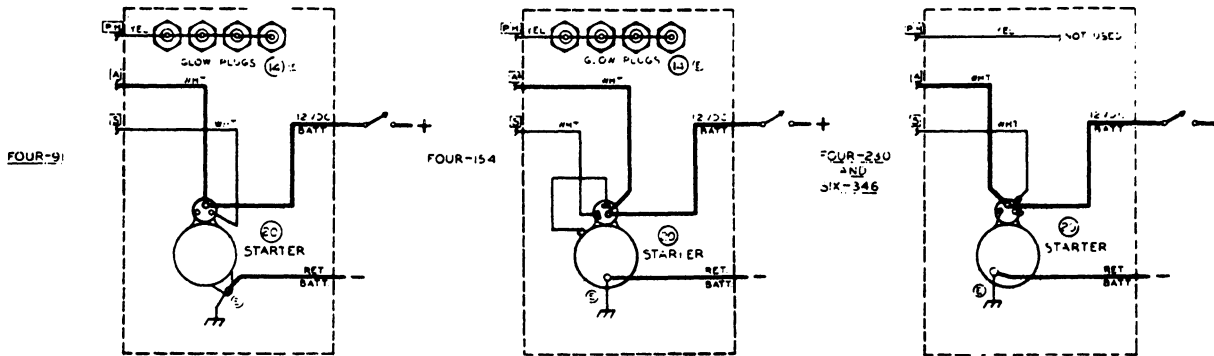


CHART FOR STARTER MOTORS AND HEATERS



## 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.

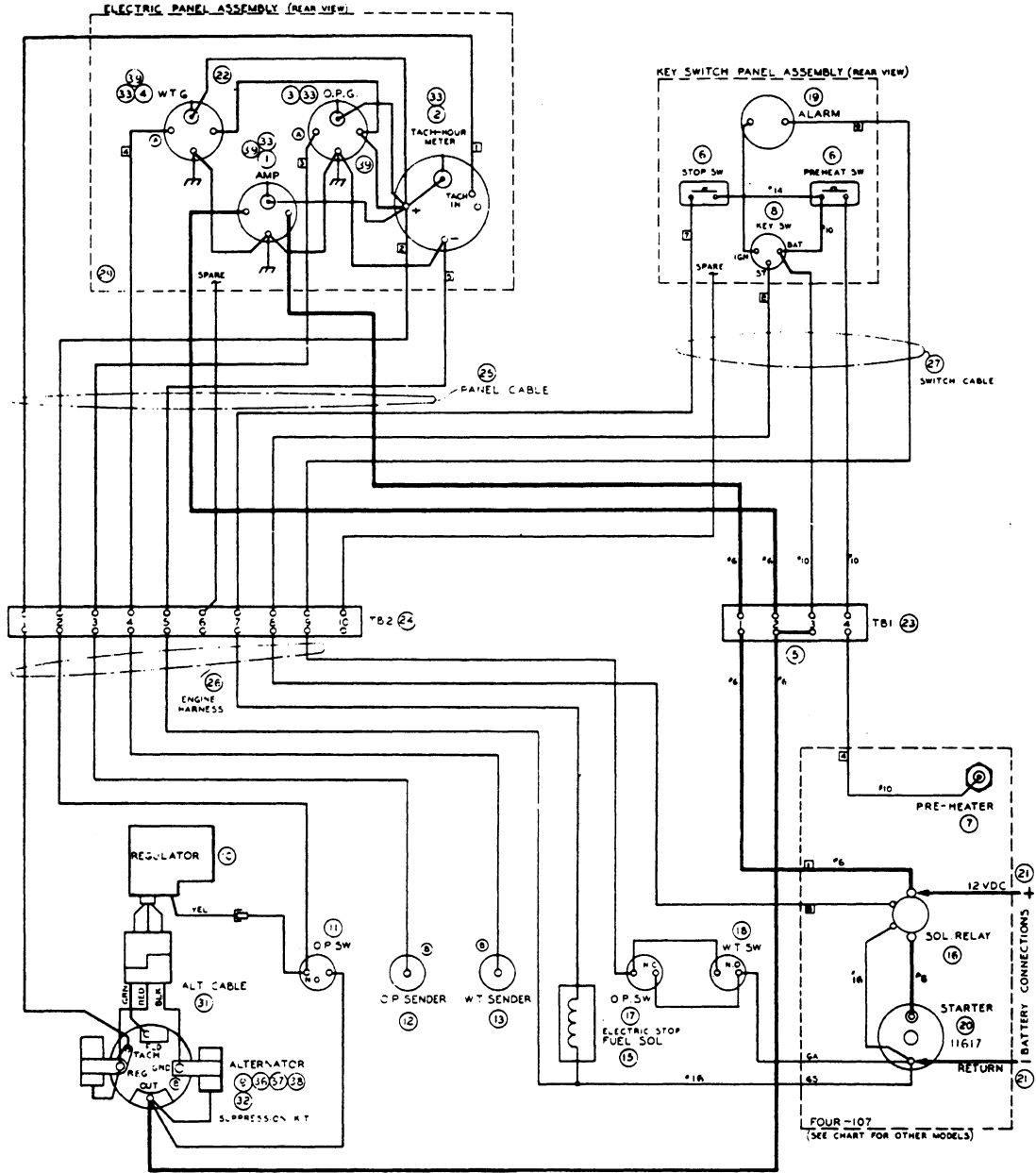
When the engine develops oil pressure, voltage is supplied to the alternator for excitation and to all instruments. Whenever the engine stops, loss of oil pressure removes voltage from these devices.

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

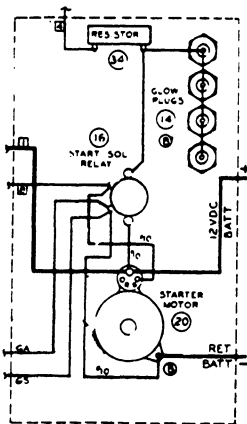
When an engine is furnished with an electric stop solenoid, it is energized by a separate push button at the key switch panel.

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.

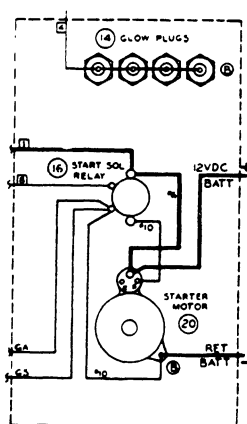
# ACTIVATION BY LUBE OIL PRESSURE (KEYSWITCH START)



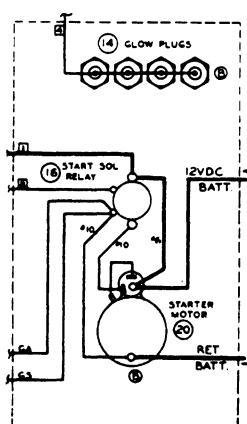
FOUR-60



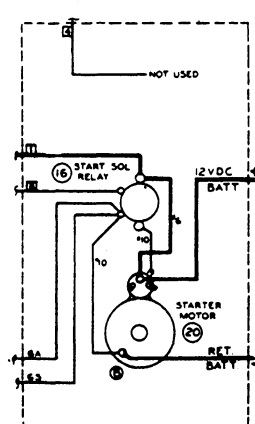
FOUR-91



FOUR-154



FOUR-230 & SIX-346



Q.8

# 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 perhaps a V drive will be piped on the suction side of the sea water pump. Generally it is better to have as few devices on the suction side of the sea water pump as possible to preclude priming difficulties. Usually sea water flows directly from the dis-

charge 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.

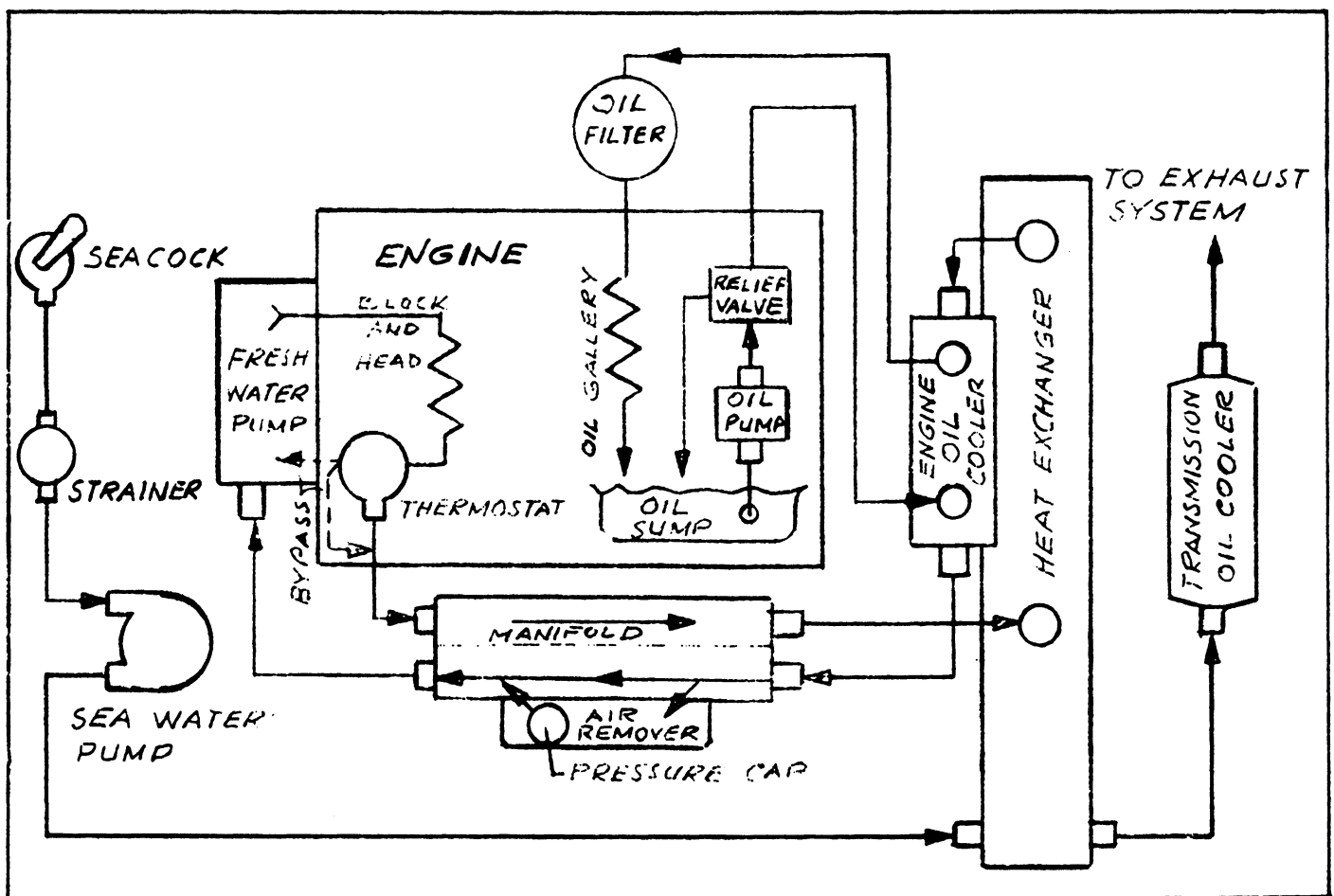
#### 10. TRANSMISSION OIL COOLER:

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

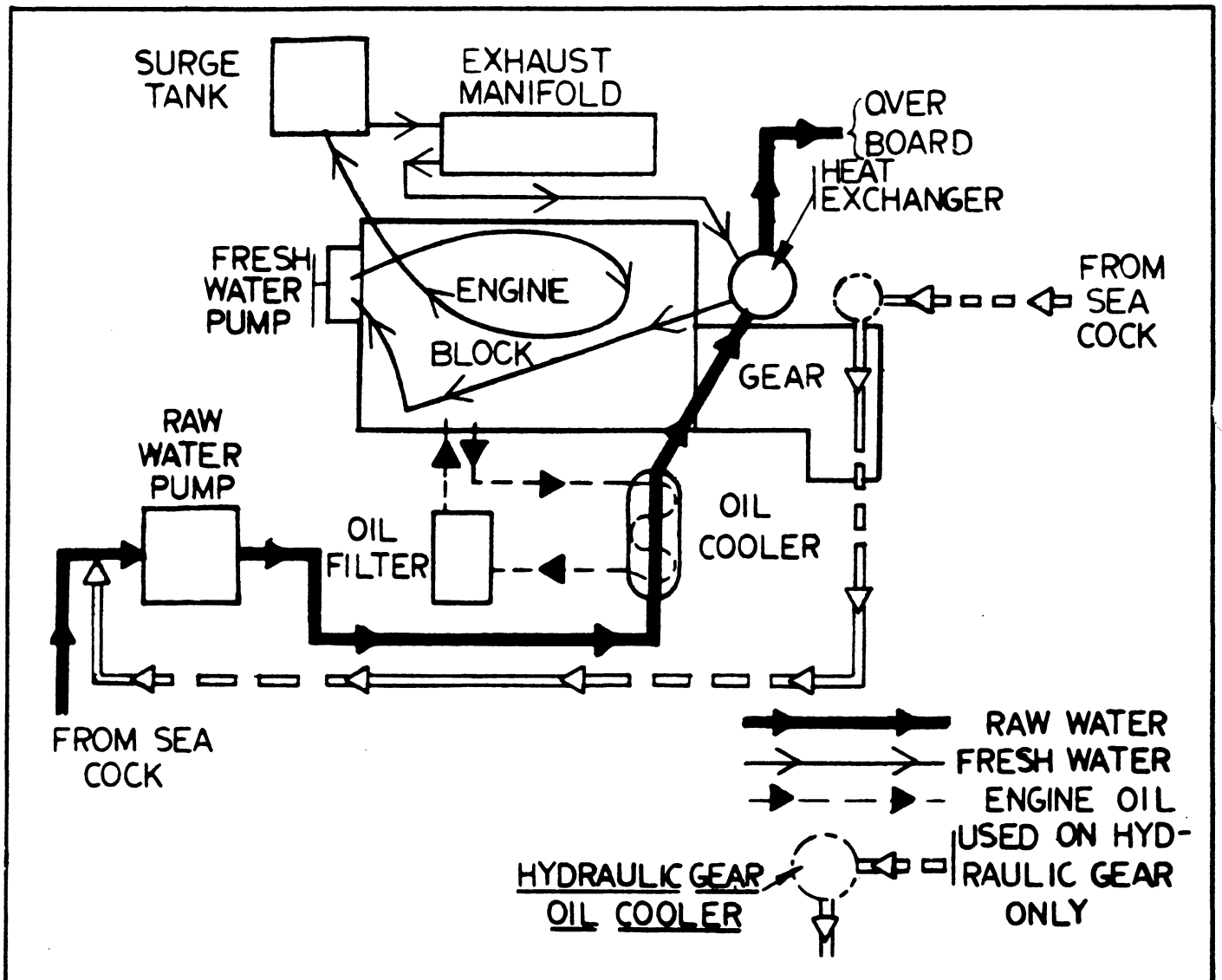
Note: Drawing is indicative only. Specific models may vary in detail.





# SINGLE PASS MANIFOLD

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



**TRANSMISSIONS**

# 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

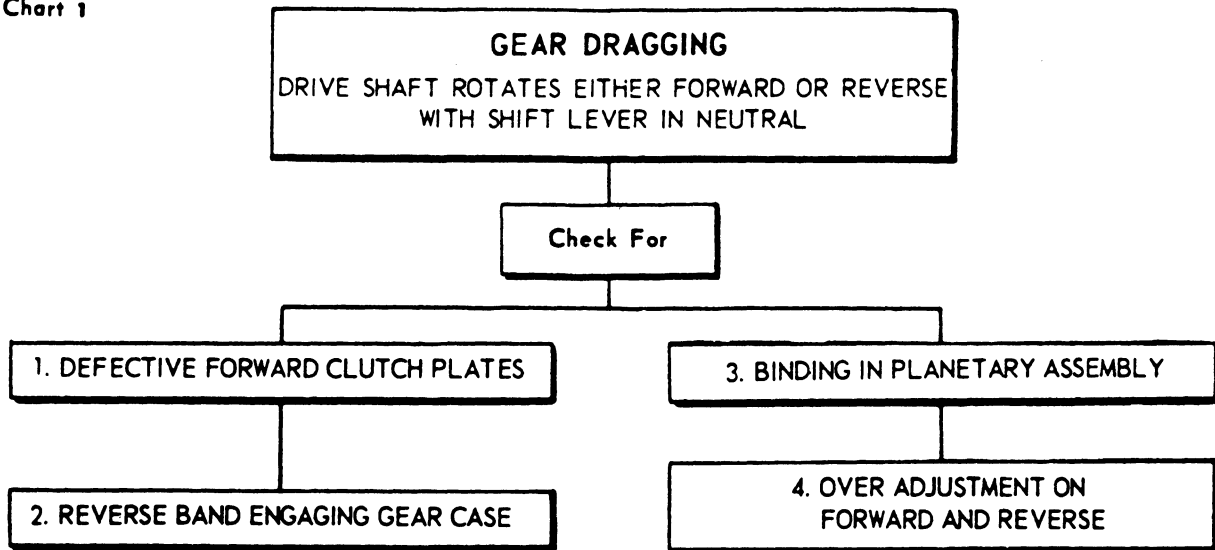
As in any servicing operation, cleanliness is a must and all rules for good workmanship apply. Some of these rules are as follows:

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 cap-screws.
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

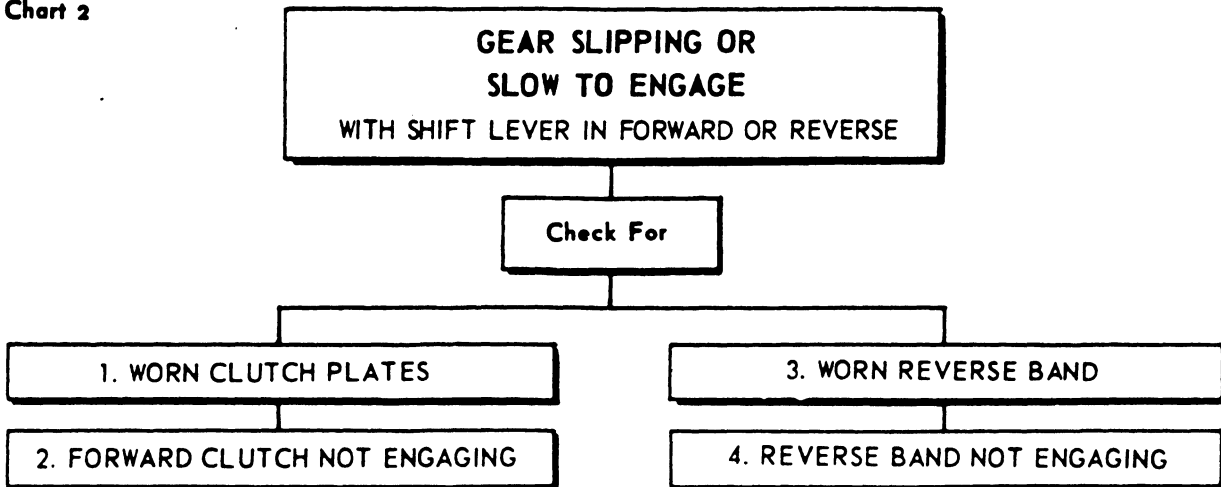
Chart 1



REMEDY

- |  |   |
|--|---|
| <p>1. Forward clutch plate warped and sticking. Remove and replace clutch plates.</p> <p>2. Improper reverse band adjustment. Adjust reverse band as outlined under adjustment.</p> <p>3. Check the following items:</p> <p style="margin-left: 20px;">a. Bearings and gears worn excessively in gear case. Replace necessary parts.</p> | <p>b. Engine gear bearings worn excessively, causing misalignment of engine shaft. Replace necessary parts. Check misalignment of engine gear.</p> <p>4. Over-adjustment of either forward and reverse or both will result in loss of neutral. Check and readjust as outlined under adjustment.</p> |
|--|---|

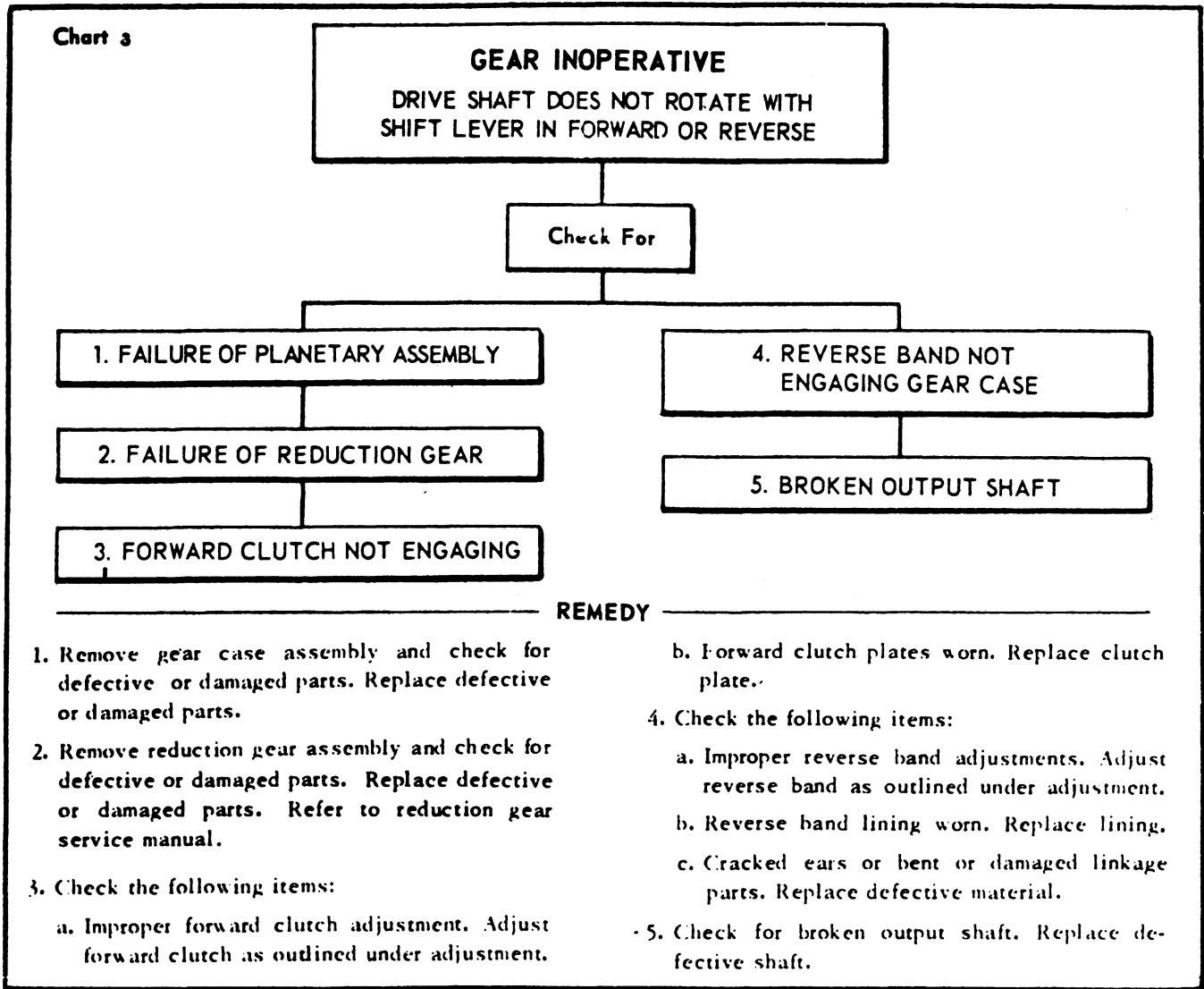
Chart 2



REMEDY

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

TROUBLE SHOOTING CHART



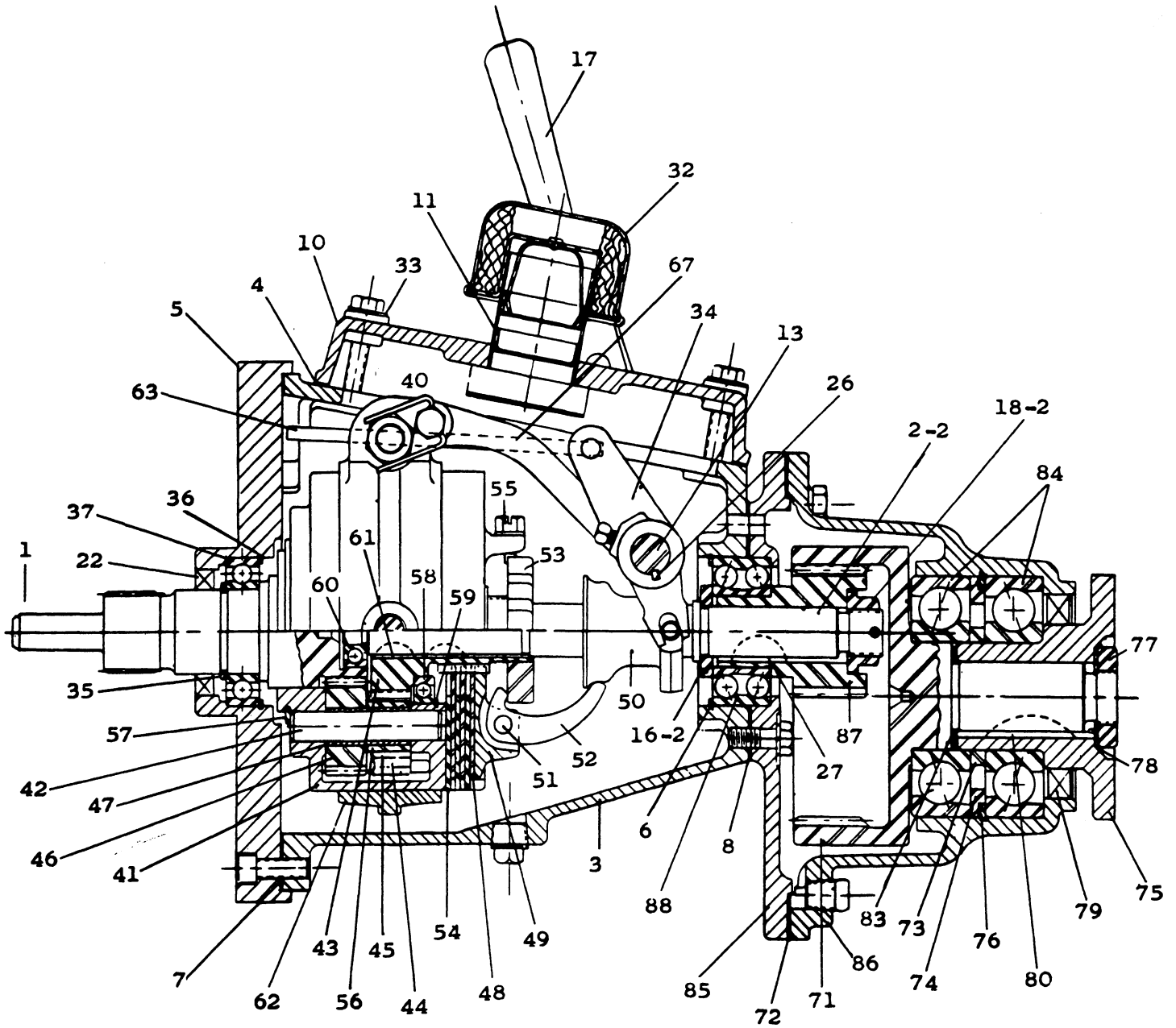
**NOTE:** Disassembly need be carried out only as far as is necessary to correct those difficulties which interfere with proper marine gear operation.

**REMOVAL OF REDUCTION GEAR ASSEMBLY FROM REVERSE GEAR HOUSING IF INSTALLED**

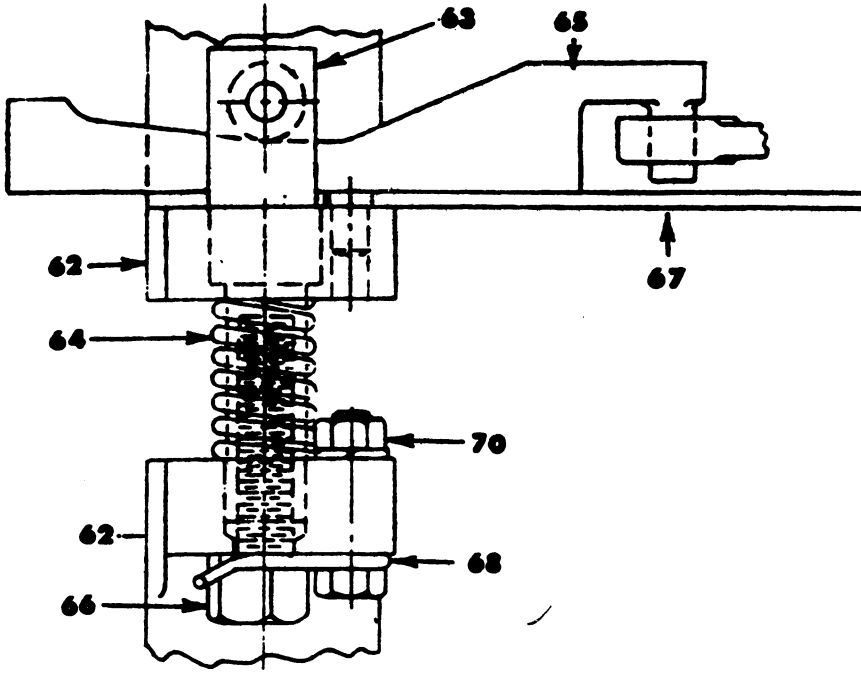
**NOTE:** Remove the reverse gear with reduction gear attached as a complete unit before draining oil, to avoid fouling the bilges.

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.

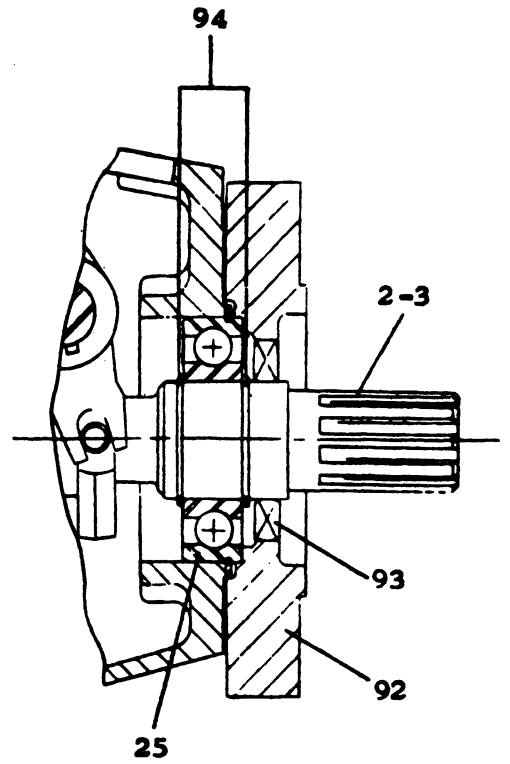
(Refer to "Reduction Gear" section of manual for disassembly and assembly of reduction unit.)



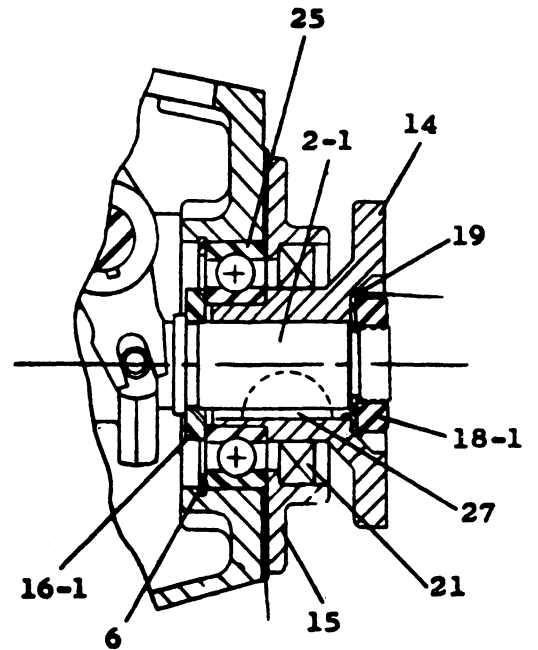
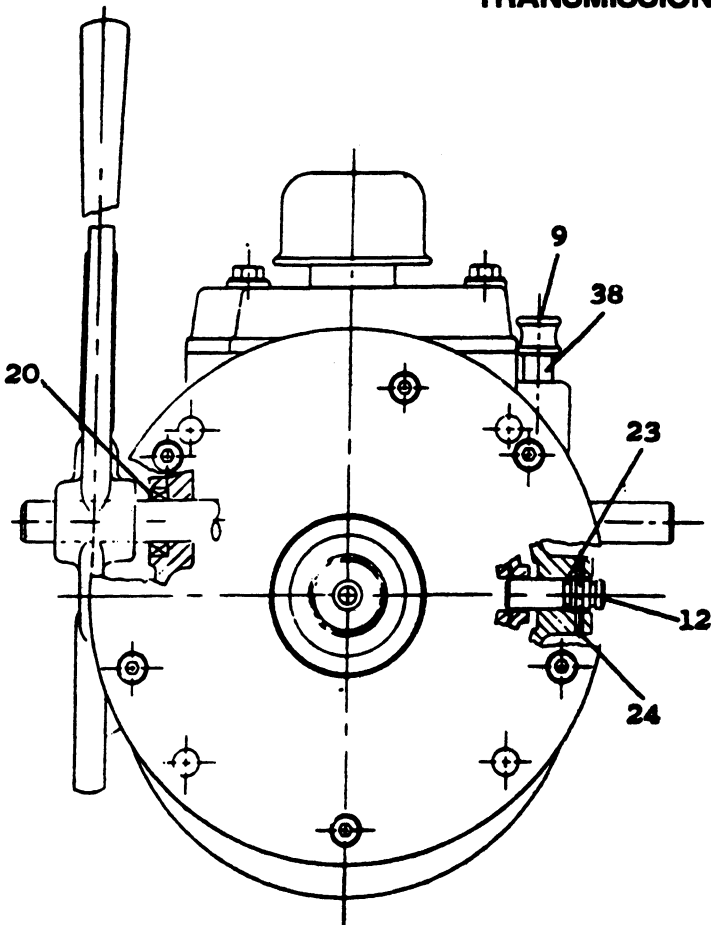
**SA0 MANUAL  
TRANSMISSION**



**SAO MANUAL TRANSMISSION**



DIRECT DRIVE FOR WALTER'S "Y" DRIVE



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), lock-washer 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 centered 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", uneven 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

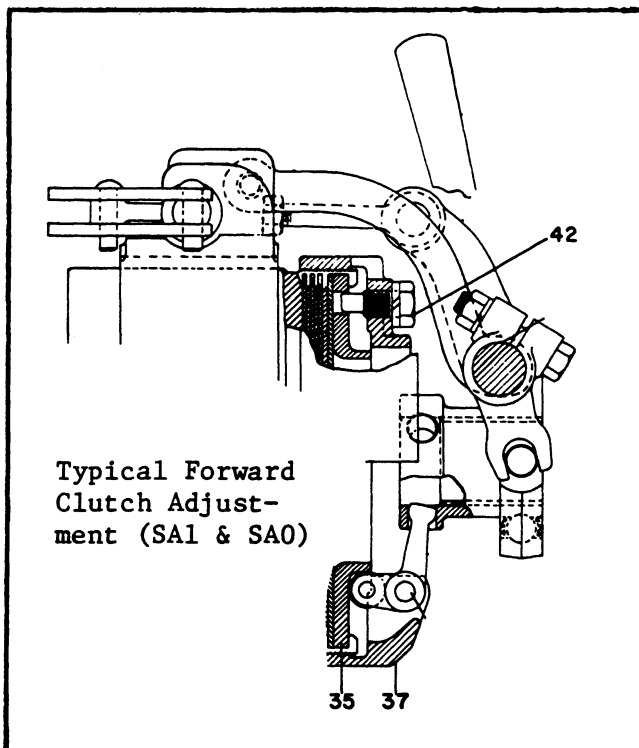
With the transmission secured to the engine, replace all water lines, etc. However, do not connect the shifting linkage until all the adjustments have been made and are satisfactorily tested:

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.

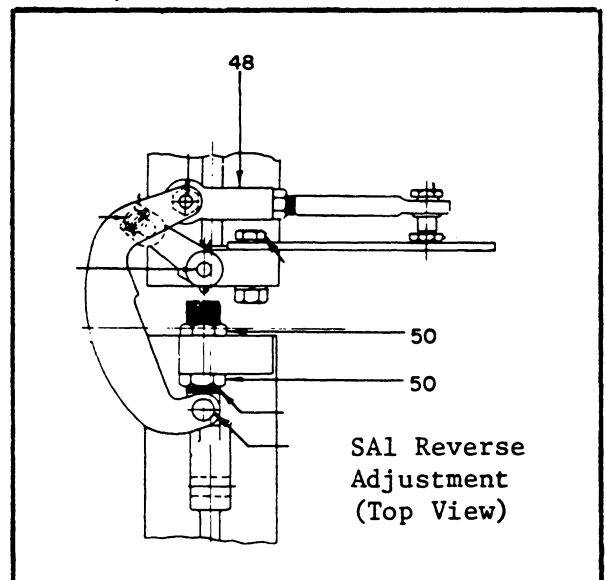
The transmission should be filled with new oil as specified under lubrication.

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 --



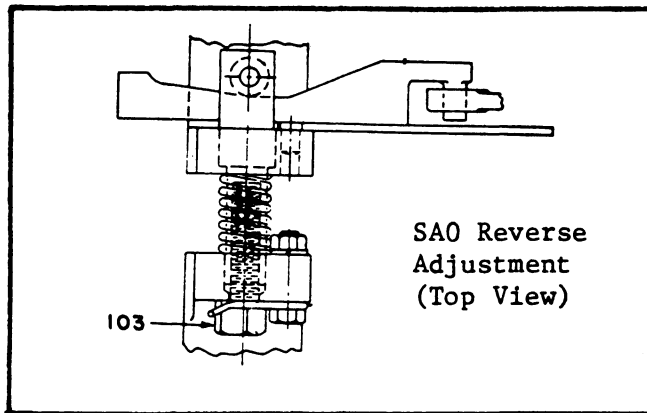
1. Back out the lock screw (42) until the dog on the end of the lock screw is clear of the hole in the pressure plate (35).
2. Rotate the screw Collar (37) to the right until the lock screw (42) is opposite the next hole in the pressure plate (35).
3. Tighten the lock screw making certain that the dog 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).



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).





Replace the cover on the reverse gearhousing. 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 lock screw (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 lock screw. A half a step is made by taking the lock screw 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 lock screw. Make certain that the lock screw 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

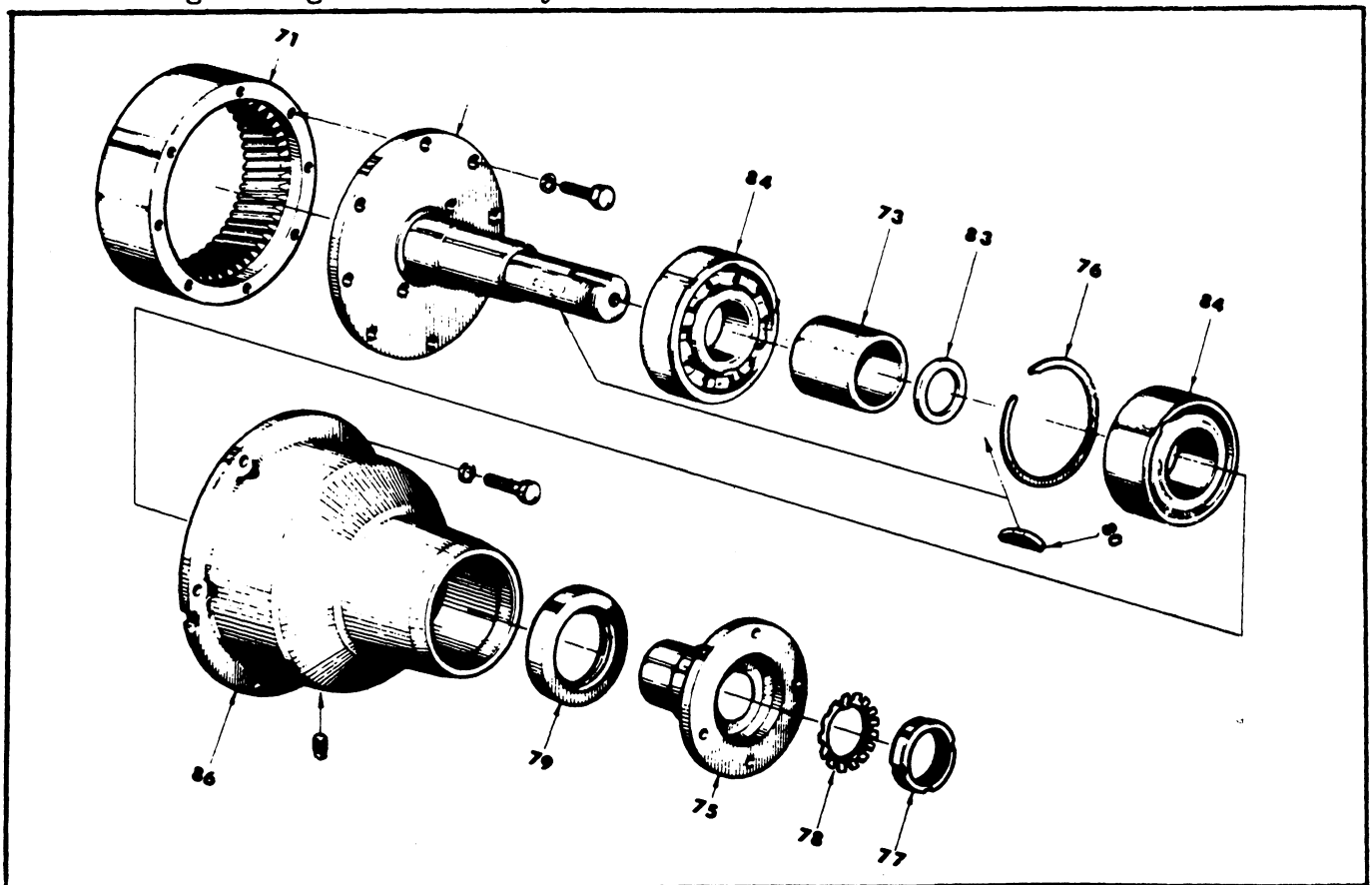
All parts should be thoroughly cleaned before inspection. Parts showing excessive wear should be replaced.

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.



# PARAGON P-21 SERIES HYDRAULIC

## I. SPECIFICATIONS

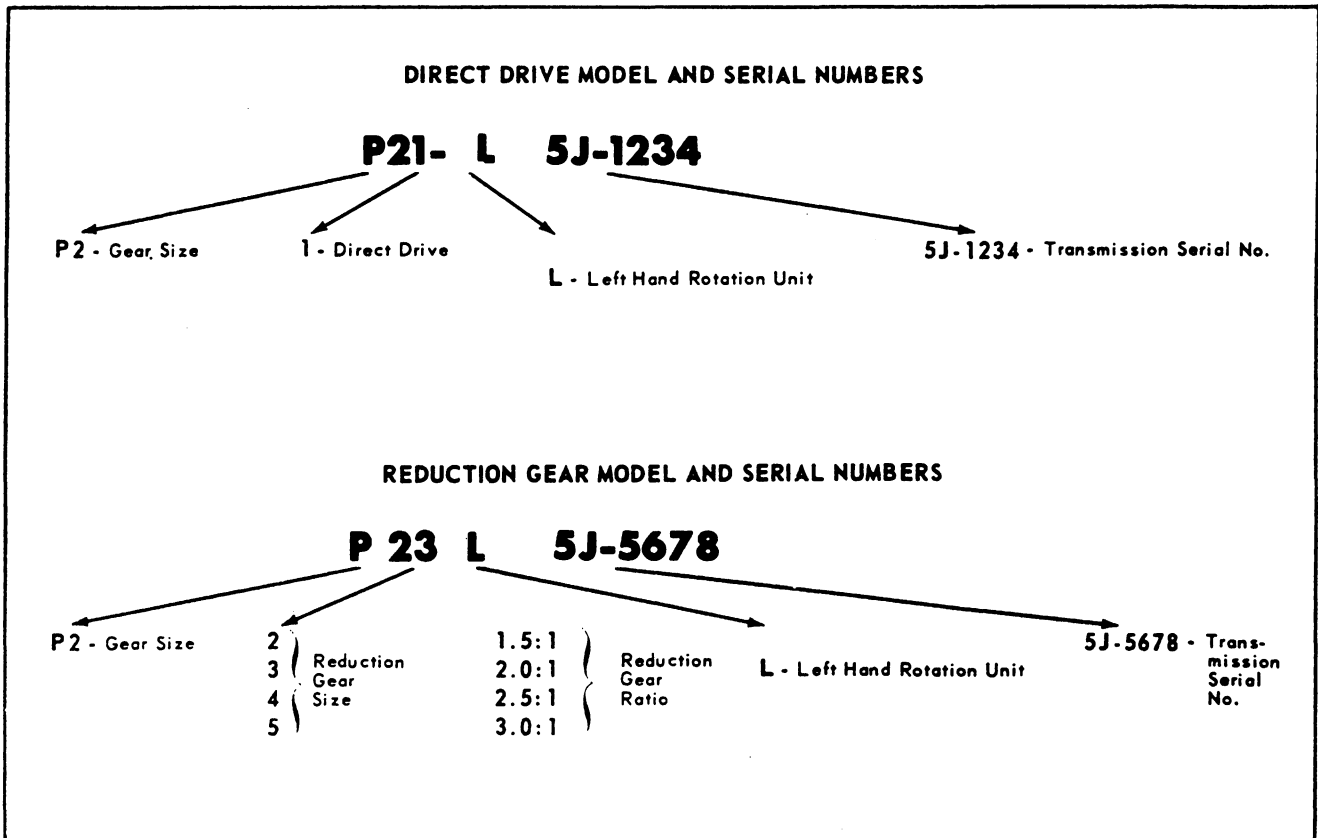
### A. Description Chart

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



## 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 for-

ward 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.

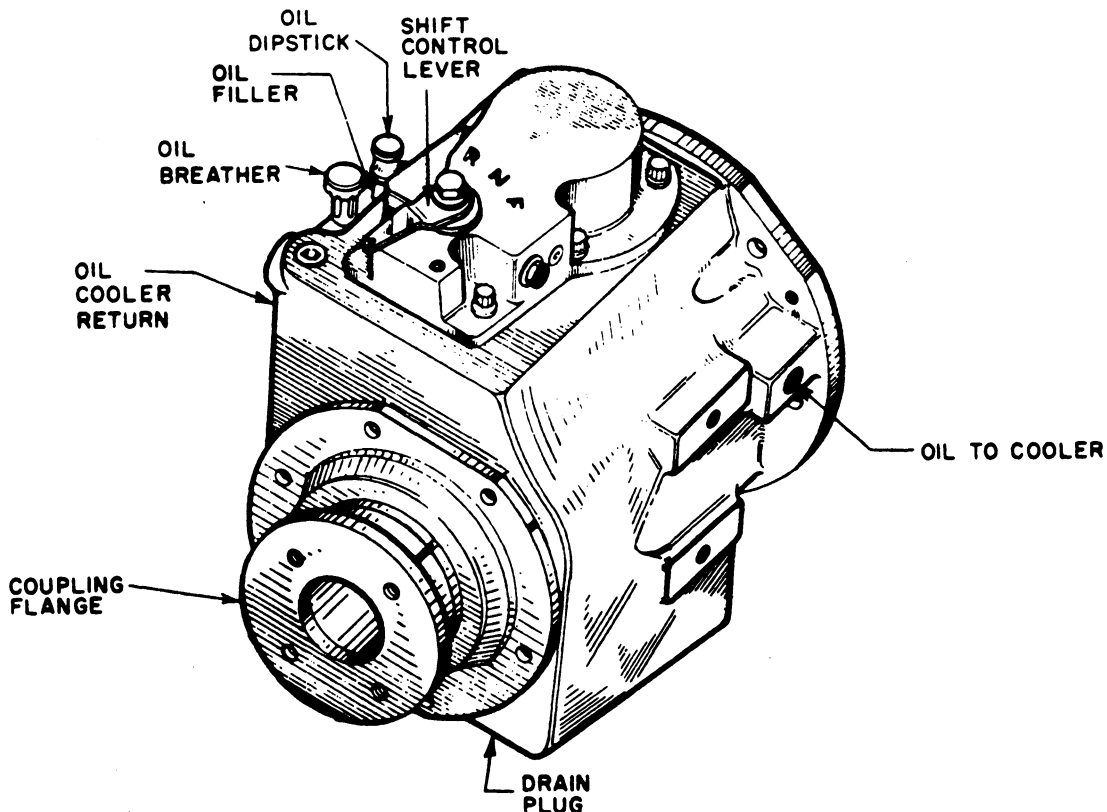
When filling for the first time or refilling after an oil change, check the level after running for a few minutes to make certain that the oil cooler and the various passages

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.



## C. Trouble Shooting Chart

PROBLEM	POSSIBLE CAUSES AND METHODS OF CORRECTION
<p><b>GEAR INOPERATIVE</b></p> <p>Drive Shaft does not operate with selector valve in forward or reverse.</p>	<ol style="list-style-type: none"> <li>1. <b>Low Oil Pressure.</b> <ol style="list-style-type: none"> <li>a. Low oil supply. Add oil, refer to lubrication.</li> <li>b. Faulty oil gauge. Replace gauge. Oil gauge slow to register, air or obstruction in oil gauge line. Clean and bleed oil gauge line.</li> <li>c. Plugged oil lines or passages. Clean lines or passages.</li> <li>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.</li> <li>e. Defective pistons and oil distributor seal rings. Replace seal rings.</li> <li>f. Defective oil pump. Check for wear and replace if necessary.</li> </ol> </li> <li>2. <b>High Oil Temperature</b> <ol style="list-style-type: none"> <li>a. Low oil supply. Add oil, refer to lubrication.</li> <li>b. Low water level in cooling system. Add water, and check for leaks.</li> <li>c. Plugged raw water inlet screen. Clean screen.</li> <li>d. Collapsed or disintegrated water inlet hose. Replace hose.</li> <li>e. Air leak in cooling water suction line. Replace suction line.</li> <li>f. Raw water pump impeller worn or damaged. Replace impeller.</li> <li>g. Clogged or dirty oil cooler element. Remove and clean</li> </ol> </li> <li>3. <b>Reverse Band not engaging Planetary Gear Cage.</b> <ol style="list-style-type: none"> <li>a. Reverse band lining worn out. Replace lining.</li> <li>b. Defective reverse piston "O" ring. Replace "O" ring.</li> </ol> </li> <li>4. <b>Failure of Planetary Assembly.</b> Remove gear case assembly, and check for defective or damaged parts. Replace defective or damaged parts.</li> <li>5. <b>Failure of Reduction Gear.</b> Remove reduction gear assembly and check for defective or damaged parts. Replace defective or damaged parts.</li> </ol>



PROBLEM	POSSIBLE CAUSES AND METHODS OF CORRECTION	
<p><b>GEAR DRAGGING</b></p> <p>Drive Shaft rotates either forward or reverse with Selector Valve in neutral position.</p>	<ol style="list-style-type: none"> <li>1. Defective forward Clutch Plates.</li> <li>2. Defective forward Clutch Piston Release Spring.</li> <li>3. Binding in Planetary Assembly.</li> </ol>	<p>Forward clutch plates warped and sticking. Remove clutch plates and replace.</p> <p>Forward clutch piston release spring broken or weak. Replace spring.</p> <ol style="list-style-type: none"> <li>a. Bearings and gears worn excessively in gear case. Replace necessary parts.</li> <li>b. Input shaft bearings worn excessively, causing misalignment of input shaft. Replace necessary parts.</li> </ol>
<p><b>GEAR SLIPPING OR SLOW TO ENGAGE</b></p> <p>With Selector Valve in forward or reverse position.</p>	<ol style="list-style-type: none"> <li>1. Low Oil Pressure.</li> <li>2. Worn forward Clutch Plates.</li> <li>3. Reverse Band not engaging Gear Case.</li> </ol>	<p>See "Gear Inoperative" (1).</p> <p>Remove forward clutch plates and check for wear excessively, replace clutch plates.</p> <p>See "Gear Inoperative", (3).</p>
<p><b>INTERNAL AND EXTERNAL LEAKS</b></p>	<ol style="list-style-type: none"> <li>1. Water in Lubricating Oil.</li> <li>2. Excessive Oil in Engine Crankcase or Flywheel Housing.</li> <li>3. Oil on Exterior of Marine Gear.</li> <li>4. Loss of Oil from Transmission.</li> </ol>	<ol style="list-style-type: none"> <li>a. Hole in oil cooler element permitting water to seep into oil compartment. Replace oil cooler element.</li> <li>b. Oil cooler gaskets. Check gaskets and replace.</li> </ol> <p>Defective front end plate oil seal. Replace oil seal.</p> <ol style="list-style-type: none"> <li>a. Oil seeping from breather. Check for too high oil level.</li> <li>b. Defective rear end oil seal. Replace oil seal.</li> </ol> <ol style="list-style-type: none"> <li>a. Check for defective gaskets and seal.</li> </ol>

# 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

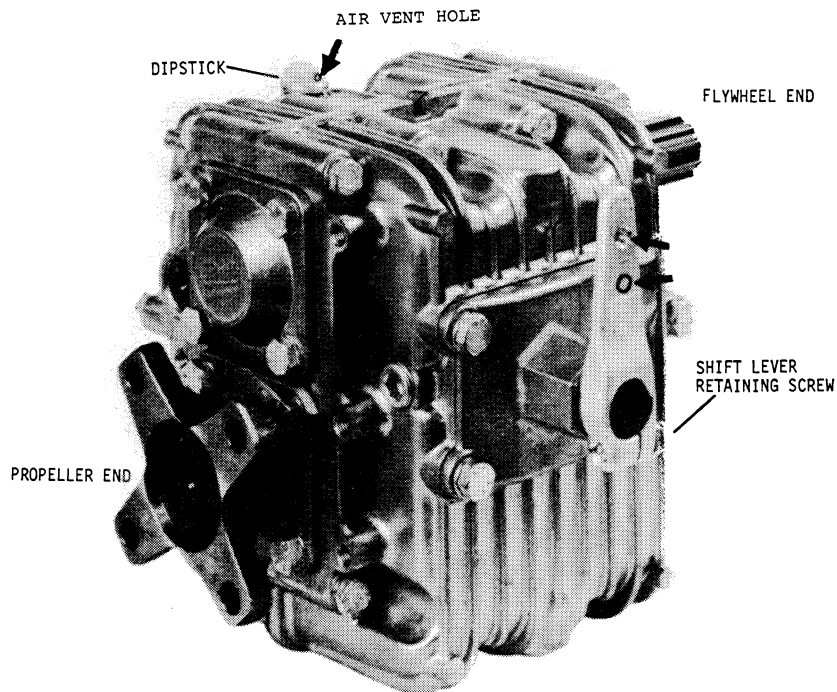
### 1.1 Brief description

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 accommodated 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.

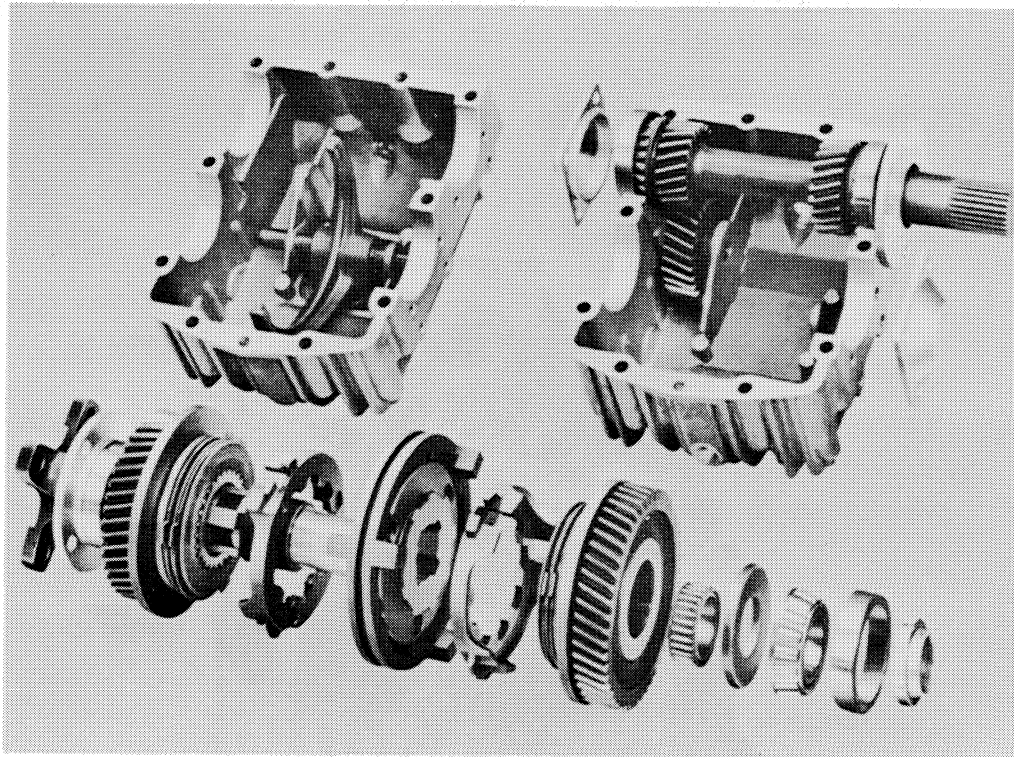
An oil filler screw with dipstick and an oil drain plug are screwed into the gear casing. The filler screw is provided with a breather hole.

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).

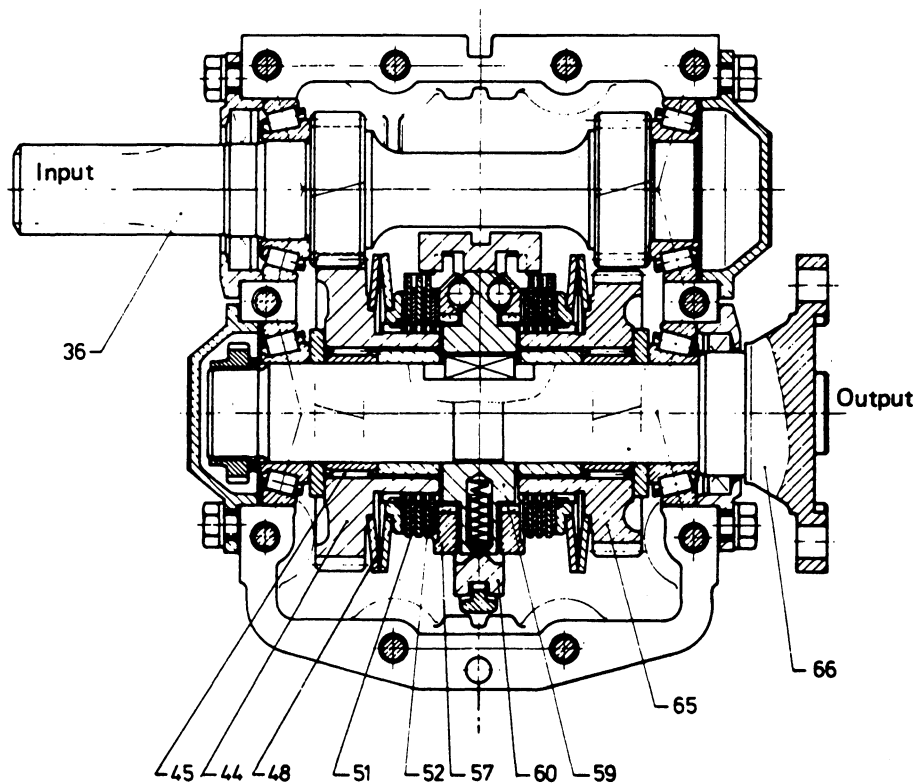
In shifting position B (see item 1.2), the torque is transmitted from the input shaft (36) via intermediate gear (26), gear (65), clutch discs (51 and 52) to the external disc carrier (57), the guide sleeve (59) and the output shaft (66).

### – 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.

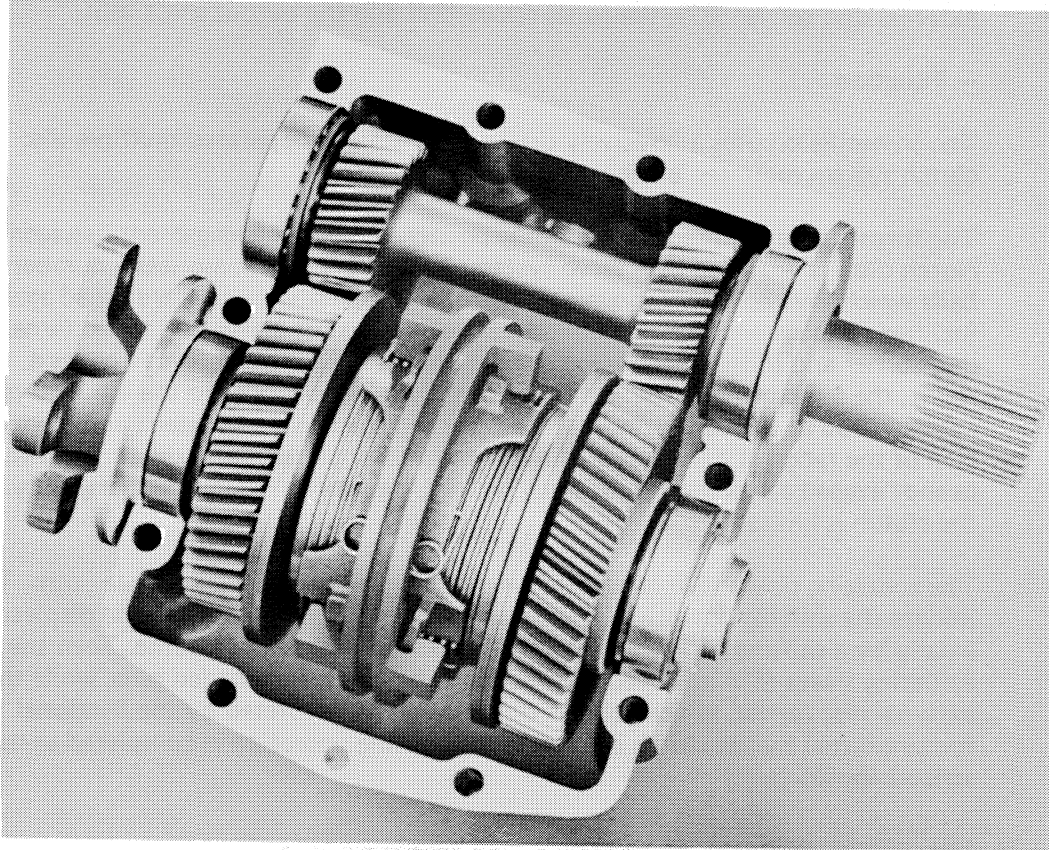
The actuating sleeve (60) is held in the middle position by spring-loaded pins. To initiate the shifting operation, the actuating sleeve (60) need merely be displaced axially by a shifting fork until the arresting force has been overcome. Then the actuating sleeve (60) is moved automatically by the spring-loaded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

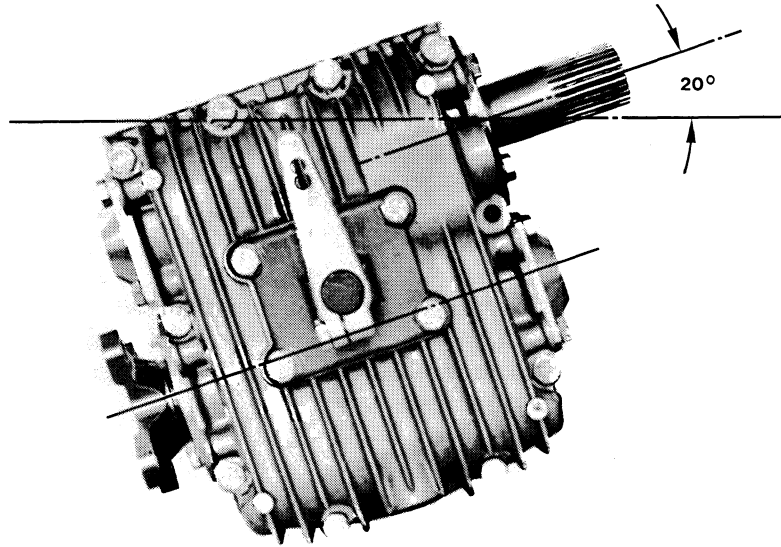
The oil drain plug of the gearbox should be conveniently accessible.

### **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

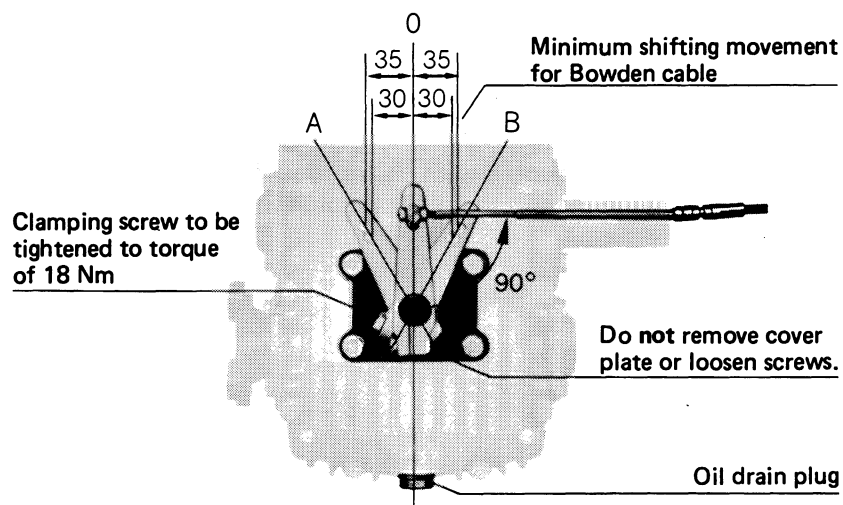
Gear changing requires only minimum effort. The gearbox is suitable for single lever remote control. Upon loosening the retaining screw, the actuating lever (see illustration) can be moved to any position required for the control elements (cable or rod linkage). Make certain that the lever does not contact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

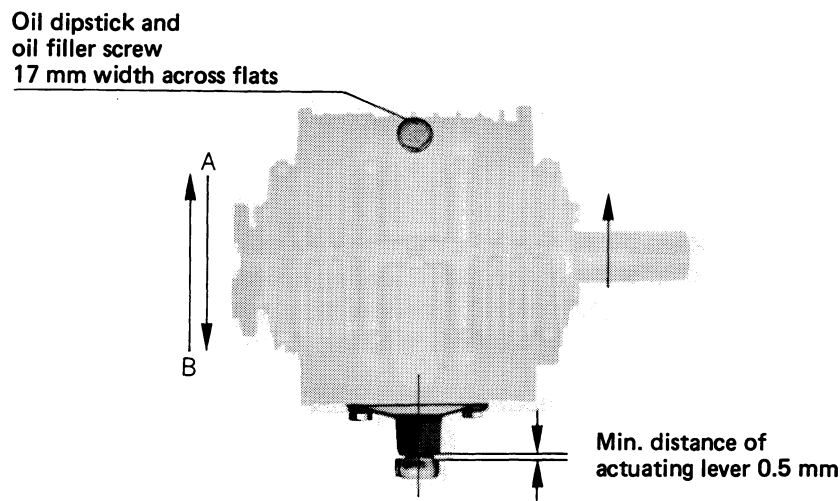
The control cable or rod should be arranged at right angles to the actuating lever in the neutral position of the lever.

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 detrimental.

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





The position of the cover plate underneath the actuating lever is factory-adjusted to ensure equal lever travel from neutral position to A and B.

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.

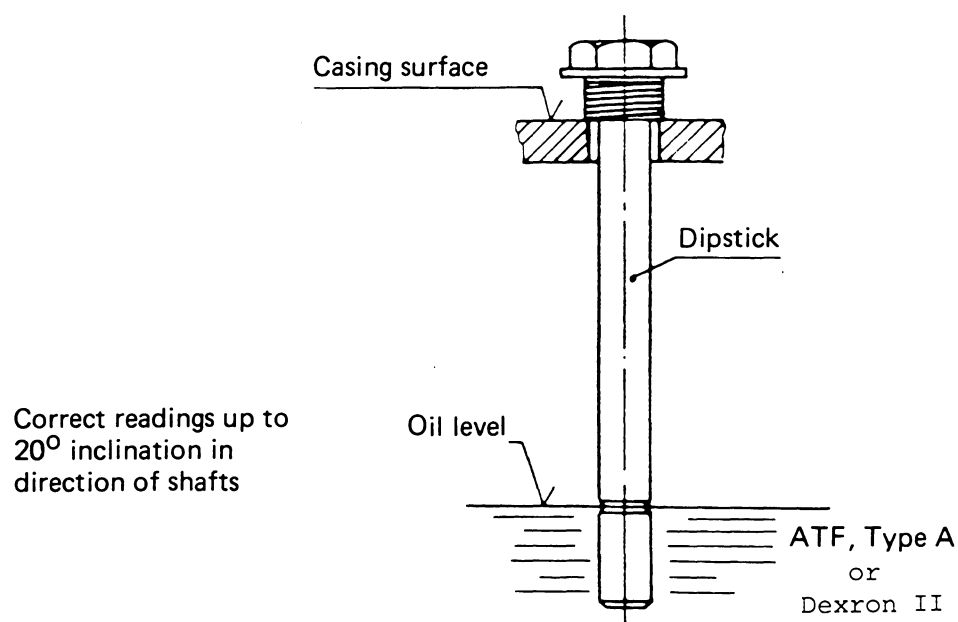
## 2.7 Engine-gearbox compartment

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 (O-A = O-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.



## **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.

# SERVICE BULLETIN

**DATE:** 6/15/69

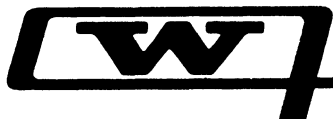
**BULLETIN NUMBER:** 20

**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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**P/N:** 11967

# SERVICE BULLETIN

V.3

**DATE:** Revised 7/29/81  
**MODEL:** W 30  
**SUBJECT:** Lubricating Oil Sump Capacity

**BULLETIN NUMBER:** 38

The proper lubricating oil sump capacity for the Model W30 engine is 4.5 quarts. Due to the varying angles of engine installation, the proper amount of oil in the engine may register as much as one inch above the full mark on the dipstick. The maximum installation angle for this engine is 12 degrees.

Therefore, it is important to go by the engine manual, rather than the dipstick, to determine the proper quantity of oil. After once properly filling the engine with oil in the specific hull, it is advised to mark the dipstick showing the actual full level.

It is important to keep the engine oil sump properly filled to insure sufficient engine lubrication under conditions of pitch and heel. Be careful not to overfill the oil sump.



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# 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.5

DATE: May 29, 1974

BULLETIN NUMBER: 72

MODEL: A11

SUBJECT: Non-Interchangeability between Manufacturers of Gauges and Senders

In recent years we have purchased gauges and senders from four different manufacturers.

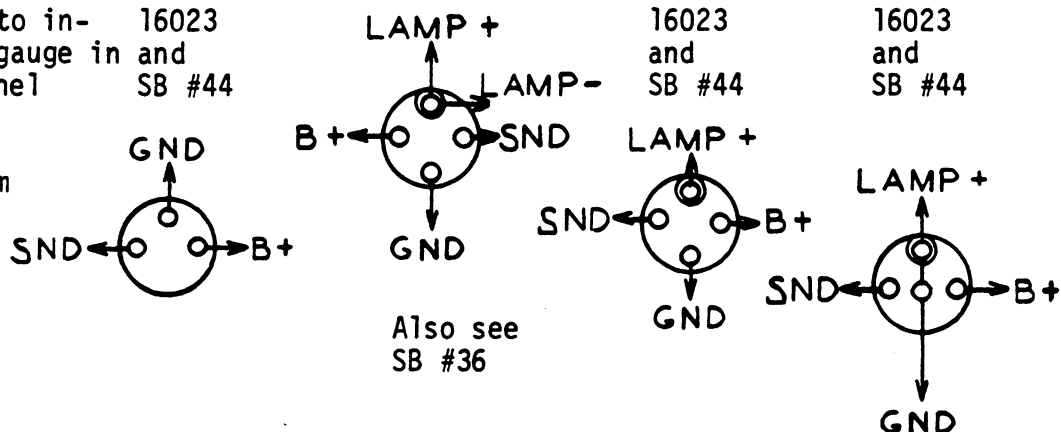
In no case may the gauge of one manufacturer be used with the sender of another manufacturer. In some cases the wiring of either or both the gauge and the sender varies by manufacturer.

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.

	<u>STEWART-WARNER</u> 2" DIA CASE	<u>VDO</u> 2 3/8" DIA CASE	<u>FARIA</u> 2" DIA CASE	<u>NOVOX</u> 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 and 2 3/8" dia panel cut-out	16023 SB #44		16023 and SB #44	16023 and SB #44

Wiring diagram



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P/N: 19190

# SERVICE BULLETIN

**DATE:** October 4, 1974

**BULLETIN NUMBER:** 74

**MODEL:** FOUR-91 and FOUR-60

**SUBJECT:** Air Filter Element Part 16010

On a few engines we find the air filter is very sensitive to a poor environment and clogs easily, sometimes in as few as 20 to 30 hours.

The symptoms are: Loss of RPM Loss of Power Black Smoking

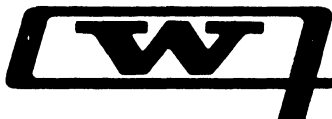
Check the air filter first -- remove it and see if situation clears.

Here are prime causes of air filter choking:

1. Leaking exhaust on exhaust piping allowing soot to be expelled and sucked into element.
2. Lint or fiberglass in engine compartment drawn into filter element.
3. Excessive oil contamination from crankcase breather.

It is not advisable to run without a filter even though removal appears to cure the problem. You run a great danger in drawing foreign matter right into the engine and ruining it. Likewise if the surge tank water cap is at all loose, you can draw water in through the manifold opening.

REPLACE THE FILTER - DON'T REMOVE IT.



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# SERVICE BULLETIN

V.7

**DATE:** August 27, 1975

**BULLETIN NUMBER:** 76

**MODEL:** Four-91, W-30

**SUBJECT:** Proper bleeding procedure for hydraulically governed fuel injection pumps incorporating an engine anti-stall device

An anti-stall device is incorporated on fuel injection pumps fitted to the Four-91 engines. This device is located on top of the fuel pump governor housing, just beneath the air vent bleed screw. In fact, the bleed screw and anti-stall device are a complete assembly incorporating parts #1, #2, and #3 as shown on the diagram.

The anti-stall device has a spring loaded pin which comes in direct contact, with the top end of the fuel injection pump (metering valve) preventing rapid upward movement of the metering valve to the fuel cutoff position, during rapid engine deceleration. Rapid deceleration or rapid retarding of the throttle without this device installed would normally cause engine stalling and/or stoppage.

It should be noted here that under normal bleeding procedures, it is only necessary to bleed the bleed screw #5 shown on the diagram.

However, if excessive air entering the injection pump makes it necessary to bleed screw #1 in the diagram during the fuel pump bleeding procedure, when loosening or tightening the bleed screw #1, two wrenches should be used. One is to loosen the bleed screw and one is to hold the anti-stall device body #2 to prevent it from turning and upsetting the adjustments. If during the bleeding procedure screw #2 shown in the diagram is inadvertently turned in or clockwise during bleeding the result will be excessive engine RPM which cannot be controlled by retarding the throttle.

If the adjustment of the anti-stall device has been disturbed or when installing a replacement pump, the procedure for resetting it is as follows:

1. Loosen the locknut (#3) sufficiently to enable the anti-stall device body (#2) to be unscrewed two complete turns.
2. Set engine idle speed with idling stop screw (#4) to 800 RPM.
3. Turn the anti-stall device body (#2) clockwise until there is a barely perceptible increase in the idling speed. Now hold device body (#2) with wrench and tighten locknut (#3).
4. Accelerate the engine to maximum no load RPM and return the throttle rapidly to the idling position. Should the period of return from maximum RPM to idling RPM speed exceed three seconds, this is an indication that the device has been screwed in too far. However, should engine stalling occur, this is an indication that the device



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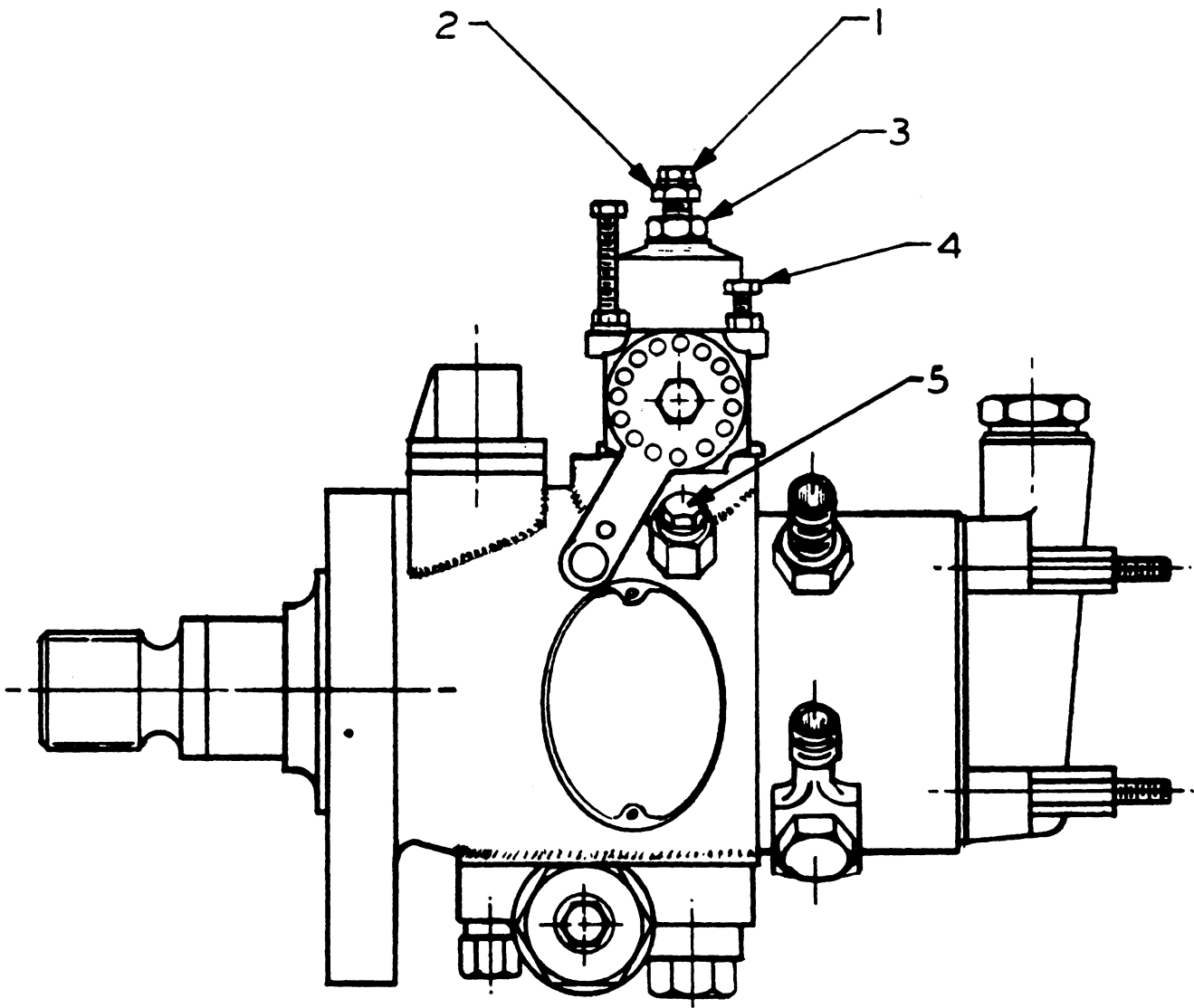
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CABLE: WESTCORP, AVON · TELEX: 92-4444

P/N: 19329

SERVICE BULLETIN #76 con't.

has not been screwed in far enough. In either case, re-adjustment should be made accordingly.

**CAUTION:** Use extreme caution when tightening the locknut or the bleed screw because the "threaded boss" that the assembly is screwed into is pressed into the governor housing. It is not an integral part. Therefore, if it is loosened or turned through over-torquing, replacement of the complete governor housing may become necessary.



On all prewired engines dating from early 1975 onwards bleed screw (#5) has been relocated to the opposite side of the fuel injection pump.

# SERVICE BULLETIN

V.9

DATE: May 19, 1980

BULLETIN NUMBER: 82

MODEL: A11

SUBJECT: Battery Recommendations

## BATTERY RECOMMENDATIONS

<u>MODEL</u>	<u>BATTERY AMPERE HOURS</u>	<u>VOLTAGE</u>
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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# SERVICE BULLETIN

DATE: September 4, 1975

BULLETIN NUMBER: 84

MODEL: A11

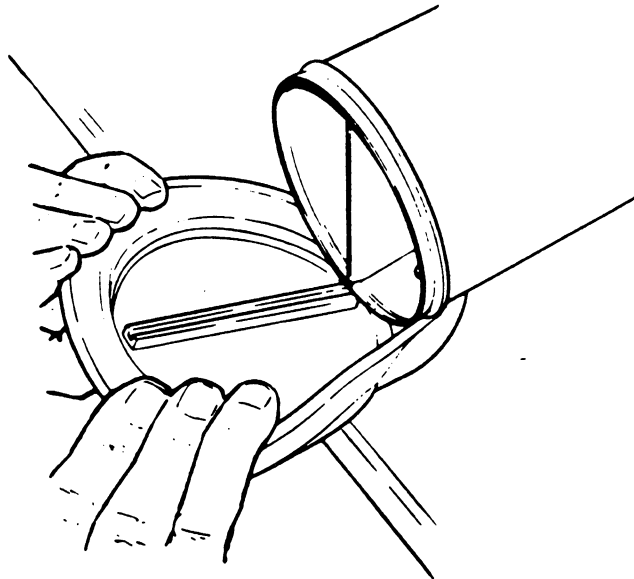
SUBJECT: Heat Exchanger Rubber End Cap

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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# SERVICE BULLETIN

V.11

DATE: April 4, 1983

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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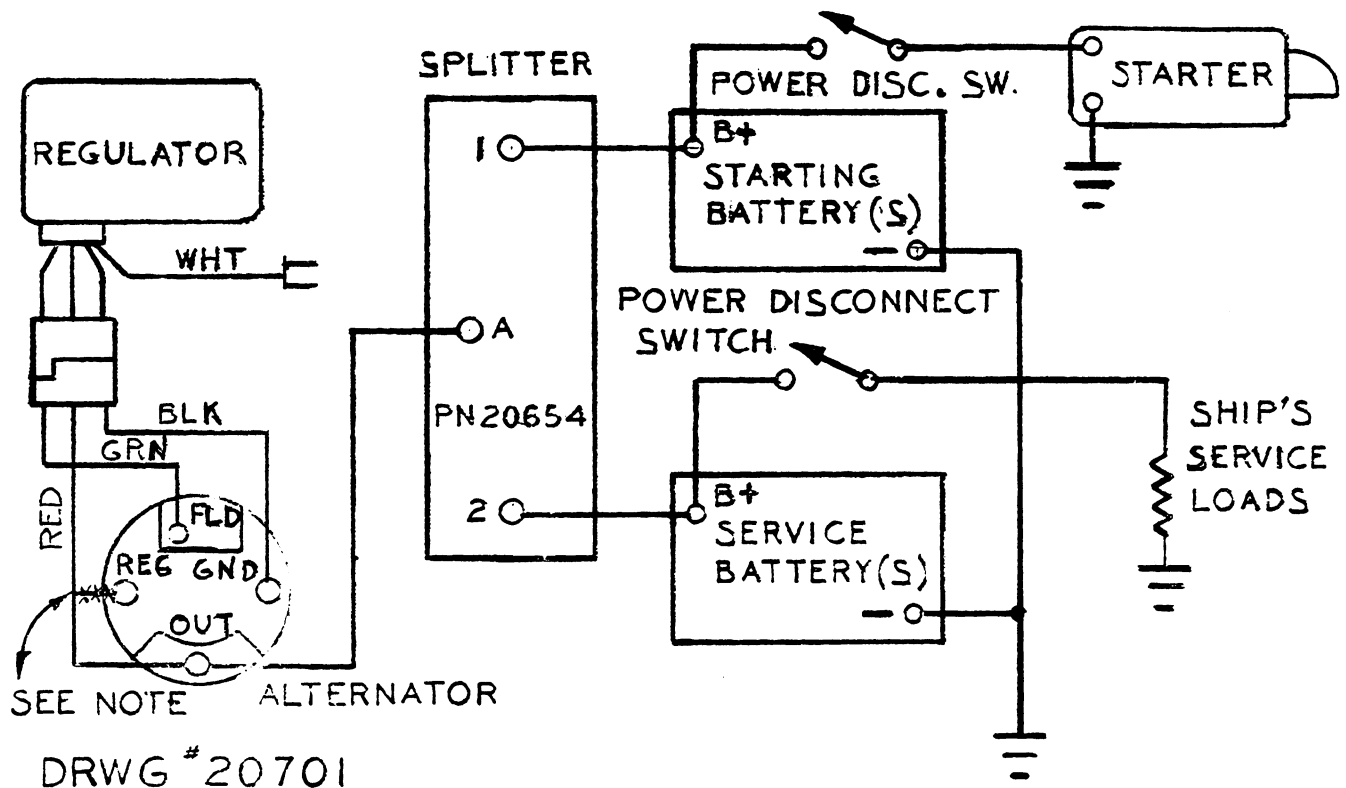
P/N: 20745



SERVICE BULLETIN #87 (Continued)  
(Alternator Output Splitter)

This unit is sealed for maximum life and is not repairable.

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.)



NOTE: On Alternators which have an isolation diode between their output and regulator terminals, such as the Motorola units used with most WESTERBEKE engines, the regulator wire should be removed from the REG terminal and reconnected to the OUTPUT terminal as shown. The diode in the splitter will provide an equivalent voltage drop.

# SERVICE BULLETIN

V.13

**DATE:** April 15, 1976  
**MODEL:** Westerbeke 30 (formerly 4-91)  
**SUBJECT:** Internal Changes Since Introduction

**BULLETIN NUMBER:** 89

There is a serial number nameplate riveted to the block behind and just below the lube oil cooler. It is best seen by shining a flashlight upwards from below. This basic block serial number is composed of a prefix and a suffix. The suffix is the last three to six characters following the last slash or hyphen. The prefix is all which precedes the last hyphen or slash.

Only the suffix has been transposed to the Westerbeke nameplate through April 1976. It becomes the first portion of the serial number on the Westerbeke nameplate; the last portion is a shipping code for internal use only.

Since the introduction of the engine in 1969, there have been four different suffixes used in part to denote various internal engineering changes to the block. When ordering parts, these suffixes are an integral part of the engine serial number and must be supplied.

Chronologically, the following changes have taken place: 1) a slight water pump change not affecting interchangeability, 2) a major water pump change requiring a new cylinder block, 3) enlarged water passages requiring a new block, head and head gasket implemented simultaneously with a new valve retention design eliminating the cotter retaining clip and the cylindrical seal. The main purpose of this bulletin is to outline these changes with their serial number cut off points. See the table on the reverse side of this Service Bulletin.

The new head gasket is usable on any previous engine and must be used from the change point onwards. The new water pump must be used from the change point onwards and cannot be used in an earlier engine block. The new valves must be used from the change point onwards and should be used as replacement parts along with the new cotter and top cup. We will only supply cylinder blocks and block assemblies from current production.

All this information is included in Edition 6 of the Westerbeke 30 Parts List being issued in April 1976.



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P/N: 18978

Description	ENGINEERING CHANGES		PART NUMBERS								
	Block Serial No.	Approx Years	Block	Water Pump	Head	Head Gasket	Exhaust Valve	Intake Valve	Valve Cotter	Valve Spring Top Cup	Valve Stem Seal
	15BB/U/* * = 1503 thru 4389	69-71	Not Avail.		14485	14601	14458	14457	14546	14575	14576
	AEH 1052/* * = 501 thru 600 and 56815 thru 56854	72,73									
	NO ENGINEERING CHANGES.										
Slight fresh water pump modification not affecting interchangeability.	AEH 1061/* * = 106 thru 326	73		14604							
Major water pump/block change - impeller diameter from 2-9/16" to 2-13/16" and new valve design requiring new valves, cotter & spring cup	15P/786A/* * = D101 thru D443	74,75	Not Avail.	17909			17626	17631	20716	20261	
Bigger water passages requiring new block, head and head gasket.	15P/786A/* * = D444 onwards	76	14470		17852	17892					

# SERVICE BULLETIN

V.15

**DATE:** April 28, 1976

**BULLETIN NUMBER:** 92

**MODEL:** A11

**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., proceed 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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**P/N:** 21616

# SERVICE BULLETIN

DATE: June 22, 1976

BULLETIN NUMBER: 93

MODEL: A11

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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# SERVICE BULLETIN

V.17

**DATE:** September 9, 1976

**BULLETIN NUMBER:**94

**MODEL:** A11

**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.

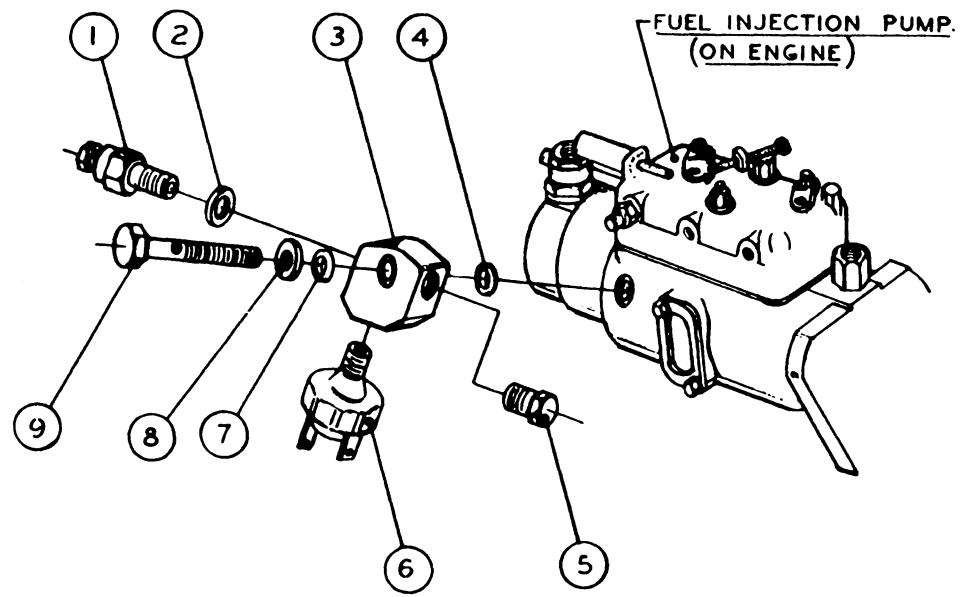


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P/N: 21564

DATE	BY	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 ASSY (BLEED)	1

<b>TOLERANCES</b> <small>(EXCEPT AS NOTED)</small>				<b>J. H. WESTERBEKE CORP.</b> AVON, MA. 02322	
DECIMAL	± ~	SCALE	ALL ENGINES	DRAWN BY	B. J. S.
FRACTIONAL	± ~	SCALE	NONE	APPROVED BY	
ANGULAR	± ~	DATE	9-9-76	DRAWING NUMBER	21743

# SERVICE BULLETIN

V.19

DATE: 7 July 80 Reissued

BULLETIN NUMBER: 95

MODEL: A11

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:

MODEL	HEATER		
	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.

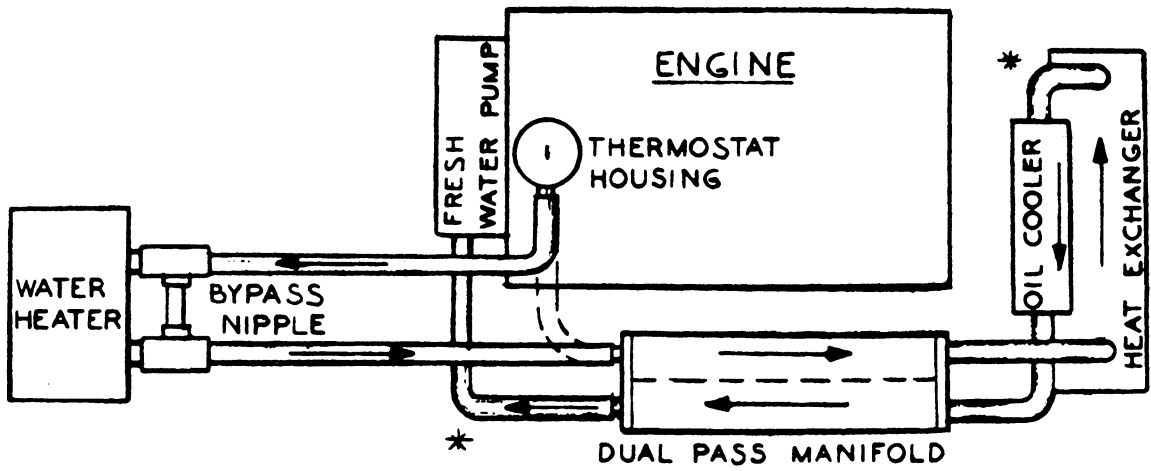


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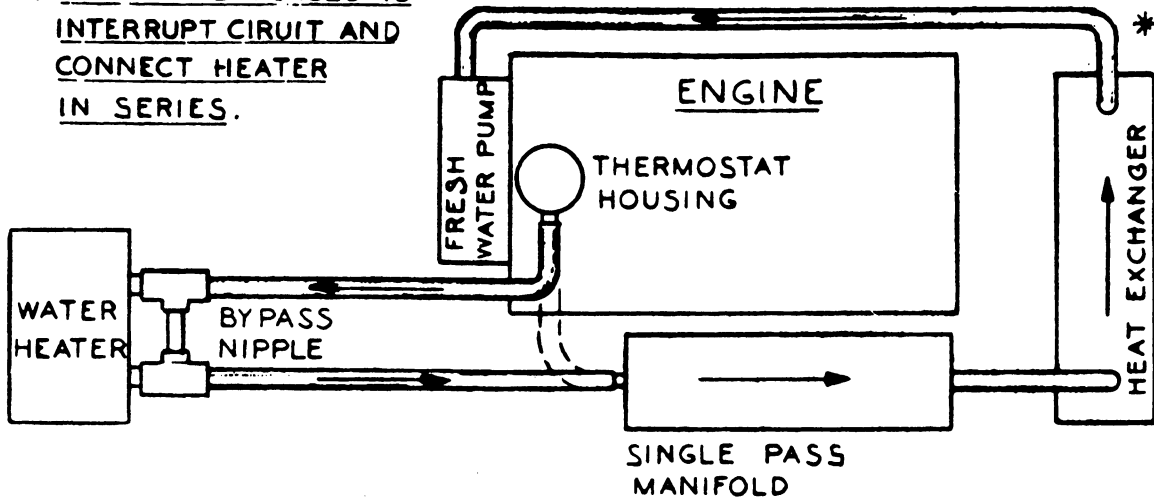
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P/N: 21814

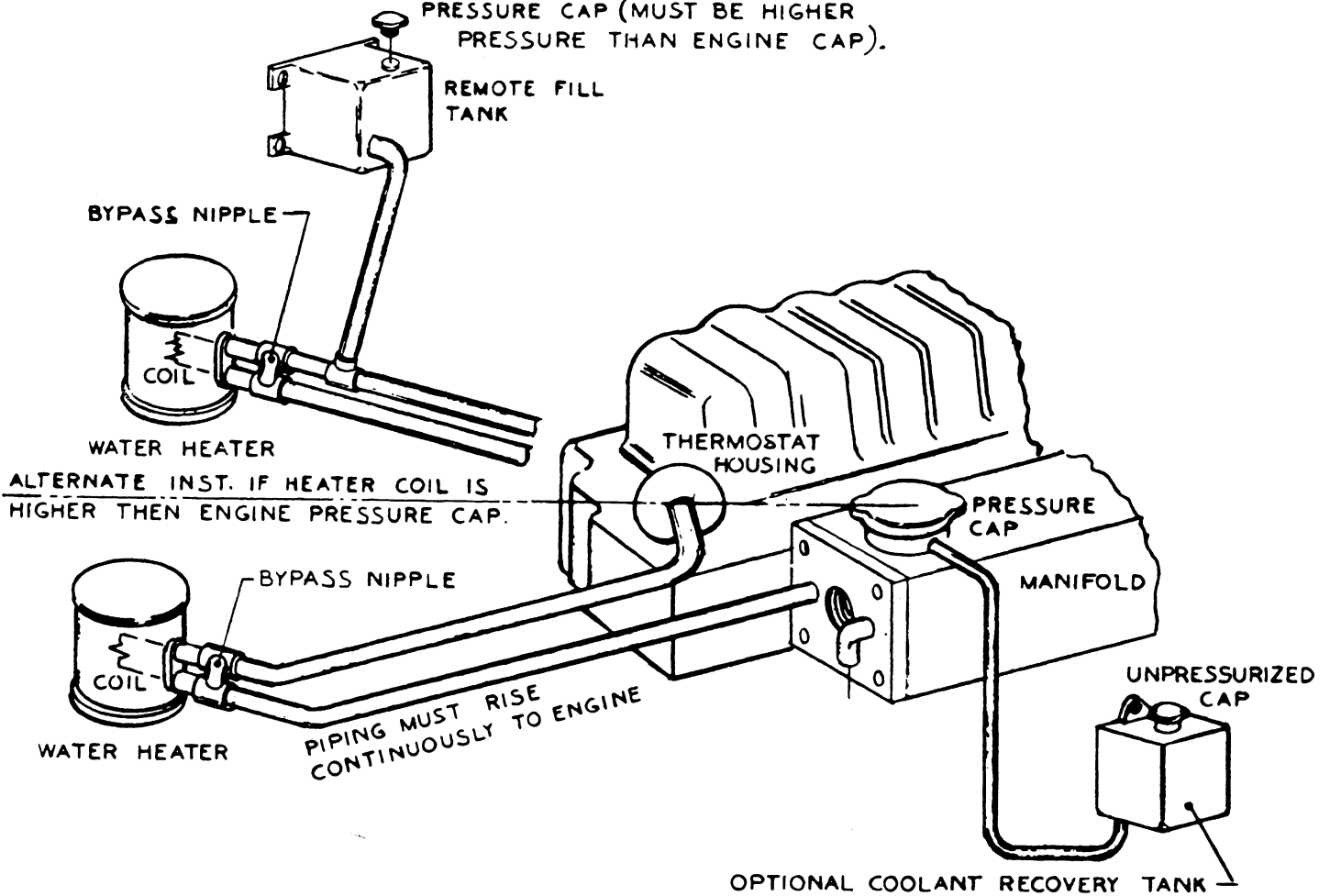




\* ALTERNATE PLACES TO INTERRUPT CIRCUIT AND CONNECT HEATER IN SERIES.



PRESSURE CAP (MUST BE HIGHER PRESSURE THAN ENGINE CAP).



# SERVICE BULLETIN

V.21

**DATE:** January 22, 1980

**BULLETIN NUMBER:** 102

**MODEL:** 4-91 Engines (Older Models)

**SUBJECT:** Paper Air Filter Element Replacement (P.N. 16010)

A metal airtscreen/silencer and attaching elbow is available for replacing paper airfilter elements in use on older Model 4-91 Westerbeke Engines. The use of this airtscreen/silencer will enable engine owners to vent the crankcase gases into the intake by connecting the vent on the engine rocker cover with a length of 1/2 I.D. hose to the 90° fitting on the metal airtscreen/silencer.

These parts may be purchased/ordered through any authorized Westerbeke dealer.

<u>Part</u>	<u>P/N</u>
Metal Airtscreen/Silencer	21536
Elbow	13335
Tubing (2½ inches)	16353
Hose 1/2 I.D. 6 inches	11775



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P/N: 24291

# SERVICE BULLETIN

**DATE:** January 22, 1980

**BULLETIN NUMBER:** 103

**MODEL:** Four-91 and W-30 Engines - Older Models

**SUBJECT:** Tach Drive Cover Plate

A tach drive cover plate and gasket are available for older Four-91 and W-30 engines:

Westerbeke Part #22123 - Plate

Westerbeke Part #14667 - Gasket

By removing the two hold-down bolts for the tach drive, it can be carefully lifted out with its gear and the cover plate and gasket put in its place and secured with the two bolts.

The parts may be purchased/ordered through any authorized Westerbeke dealer.



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# SERVICE BULLETIN

V.23

DATE: January 22, 1980

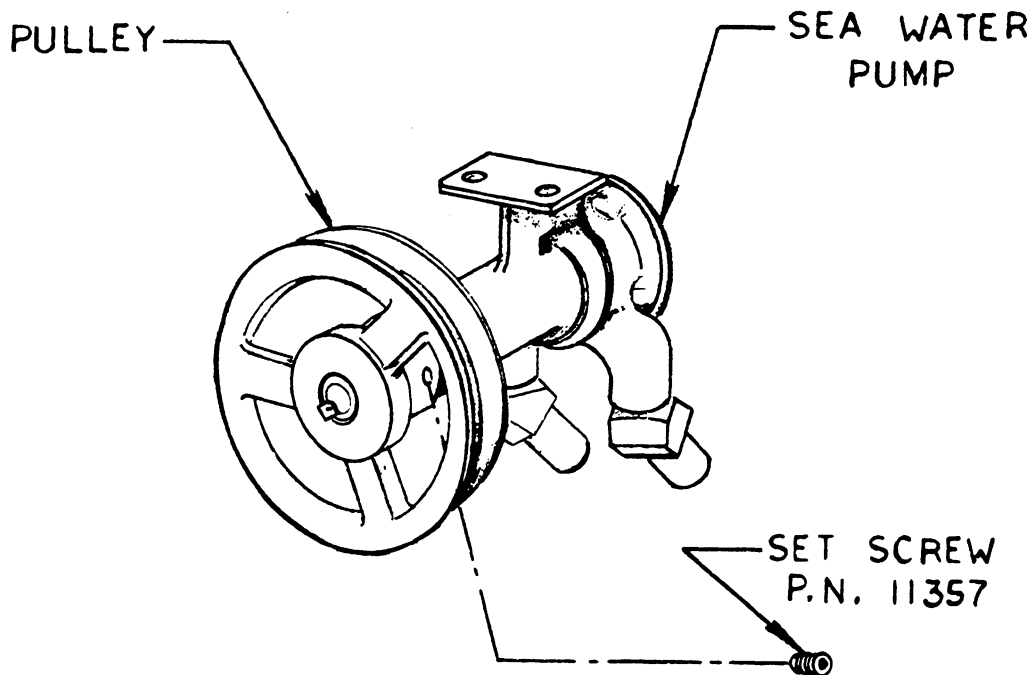
BULLETIN NUMBER: 104

MODEL: Westerbeke 30 and 50

SUBJECT: Sea Water Pump Pulley Set Screw P.N. 11357

The sea water pump pulley on the Westerbeke 30 and 50 engines is keyed to the sea water pump shaft and locked in position with a heat treated 5/32" Allen head set screw, Westerbeke P.N. 11357.

Particular attention should be paid to this set screw at the time of commissioning of the engine and during regular servicing of the engine. Ensure that it is tight. If not, remove the set screw and apply a good locking liquid to the set screw threads and reinstall and tighten with the aid of a 5/32" Allen wrench.



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P/N: 24293

# SERVICE BULLETIN

**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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# SERVICE BULLETIN

V.25

DATE: May 20, 1980

BULLETIN NUMBER: 110

MODEL: A11

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.

System Volts	Total Length of wire in feet	WIRE SIZE TABLE						
		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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P/N: 24737

# SERVICE BULLETIN

DATE: December 6, 1983

BULLETIN NUMBER:133

MODEL: W10Two, W13, W21, W27, W30, W33, W40, W50, W52, W58, W70,  
W80, W100, W120 (All Related Generators)

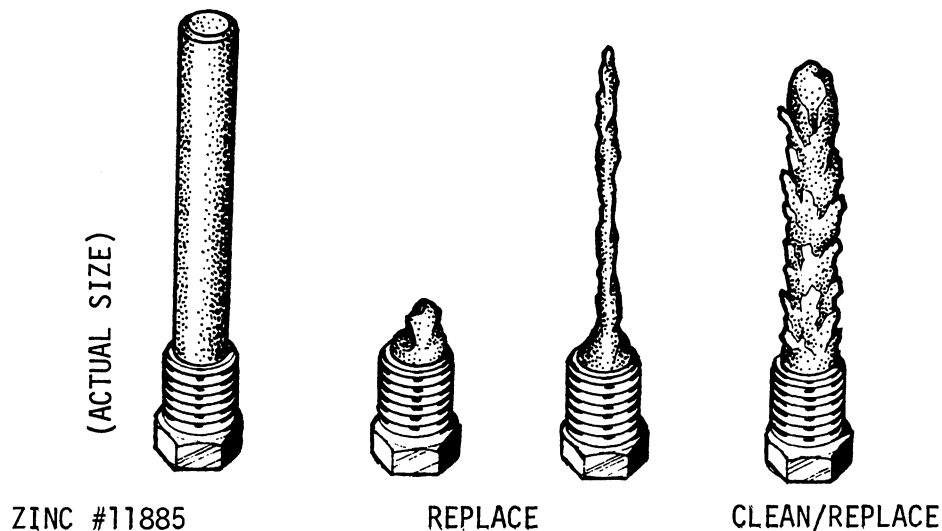
SUBJECT: Zinc Pencil - #11885

A zinc pencil PN 11885 is located in the sea water cooling circuit of all primary heat exchangers on the above models. The purpose of the zinc pencil is to sacrifice itself to electrolysis action taking place in the salt water cooling circuit. This zinc pencil should be periodically checked by unscrewing it from its mounting boss on the exchanger. For the location of the zinc on your model, refer to the cooling system section of your parts manual. Replace the zinc pencil as inspection dictates. (Refer to Illustration A.)

Should material be flaking off the zinc, it should be scraped clean, or be replaced by a good solid zinc pencil.

If it appears that a lot of material has been flaking off the zinc, then it is advised that the end cap of the exchanger be removed, and the flaked material be cleaned from that area of the exchanger. A new end cap gasket should be on hand in case it is needed when replacing the end cap.

Refer to Service Bulleting #84 when removing end caps made of rubber.



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# SERVICE BULLETIN

V.27

**DATE:** December 5, 1984

**BULLETIN NUMBER:** 139

**MODEL:** All Propulsion and Generator Models

**SUBJECT:** Hydro-Hush Muffler Installations

The illustrations shown with this text should be used as a guide when making an installation of a Hydro-Hush Muffler.

When used in conjunction with propulsion engine, the Hydro-Hush Muffler should be mounted close to the fore-aft center line of the boat. When used with a generator unit, the muffler should be as close as possible to the generator.

All installations should be such that the entry of water into the engine exhaust manifold and cylinders is prevented while under sail and at various angles of heel, from following seas, when backing down, or any other condition.

Units installed with the exhaust manifold/water injected exhaust elbow at or below the water line of the vessel must install a vent or syphon break in the sea water supply line to the water injected exhaust elbow. The seawater supply line must be looped above the water line a minimum of six (6) inches with the vent or syphon break installed at the top of this loop.

The vented loop, when used, can be a mechanical syphon break as shown in the illustration or a simple tee arrangement with a small hose or tube (3/16-1/4 inch I.D.) routed to the transom exhaust discharge or to a separate thru-hull fitting located above the water line. This hose or tube must be routed in such a way that it will drain of water when the engine is shut down and allow air into the sea water supply hose and injection elbow.

The syphon break or vent is installed to break the vacuum in the sea water cooling circuit and thereby discourage syphoning of sea water through this circuit, and subsequently filling of the exhaust and engine cylinders with sea water. When used, syphon breaks should be checked periodically for proper operation and should be installed in a location where, should they leak sea water, it would not leak onto the engine or its accessories.

The syphon break or vent must be located above the vessel's water line high enough so as to remain above the water line at all angles of vessel heel and pitch.

The Hydro-Hush Muffler remains approximately 30% full of water after engine shut-down when there is a maximum of 48 inches of lift on the discharge side.

The installation information given in this text is to be used as a guide only. Westerbeke cannot be responsible in any way for muffler installations. Westerbeke presumes the installer to have a basic knowledge of marine installation requirements.



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Use as few right angle fittings as possible. The use of wire reinforced hose is recommended and the hose should be routed to produce the bends needed.

The use of 90° and 45° fittings contribute to the rise of engine exhaust back pressure. (Refer to the Unit Technical Manual for back pressure specifications.)

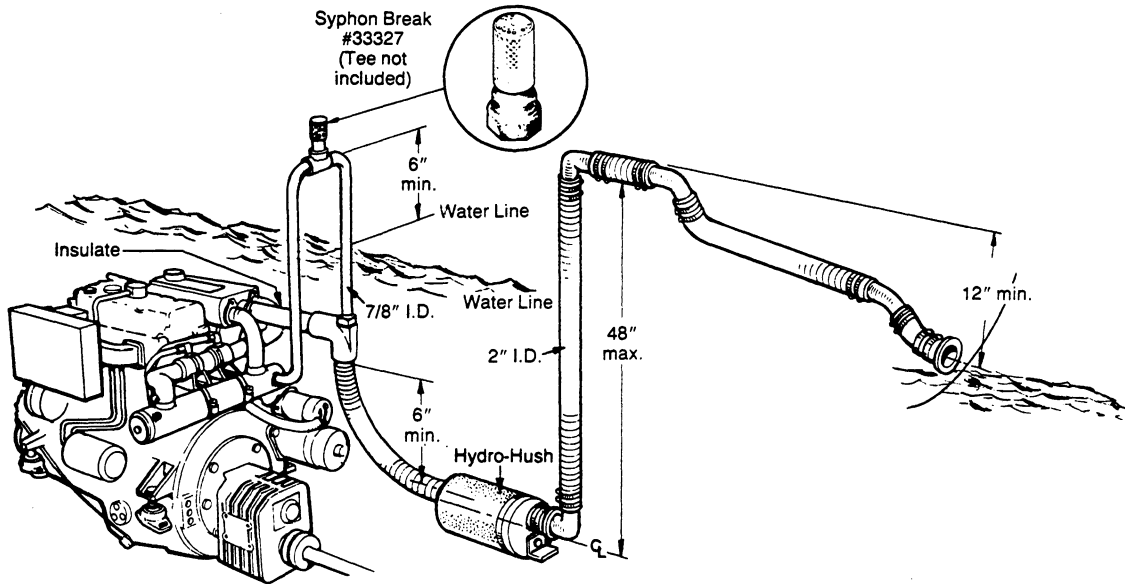
The exhaust hose diameters shown are minimums. Exhaust hose diameter for the discharge hose will have to be increased if the length of run from the Hydro-Hush Muffler to the thru-hull discharge is excessive (25' to 30' depending on the number of bends).

#### CAUTION

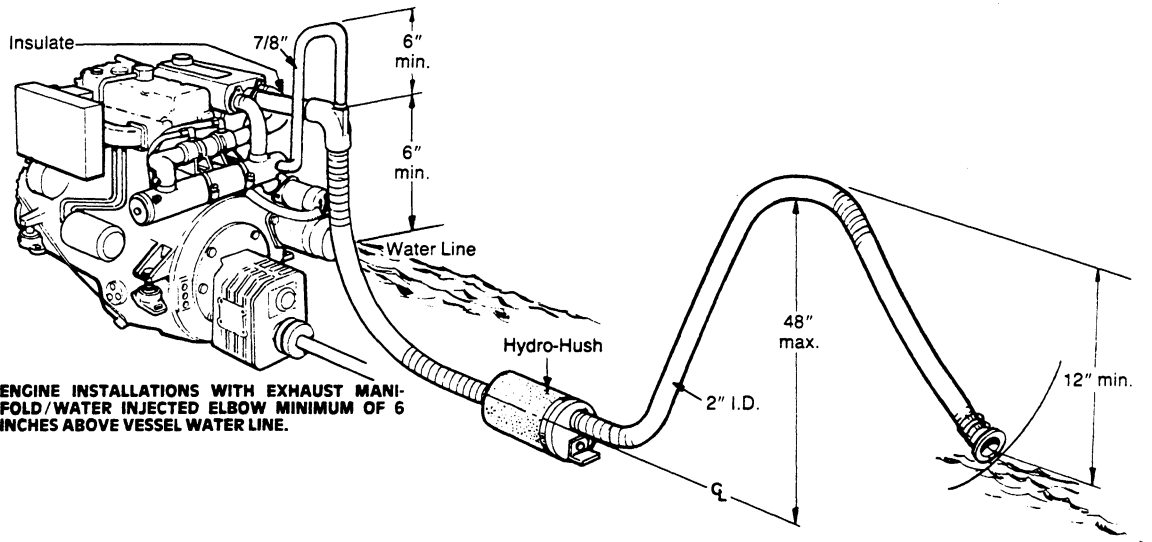
THE SEA WATER PUMP WILL CONTINUE TO FILL THE EXHAUST SYSTEM WITH SEA WATER DURING CRANKING. THE ENGINE EXHAUST PRESSURE DURING CRANKING MAY NOT BE STRONG ENOUGH TO EXPEL THE WATER FROM THE MUFFLER AND PREVENT THE SYSTEM FROM FILLING UP WITH SEA WATER AND ENTERING THE EXHAUST MANIFOLD AND CYLINDERS.

IF ENGINE CRANKING EXCEEDS 30-40 SECONDS APPROXIMATELY, CLOSE THE SEA WATER THRU HULL AND OPEN IT IMMEDIATELY AFTER THE ENGINE STARTS.

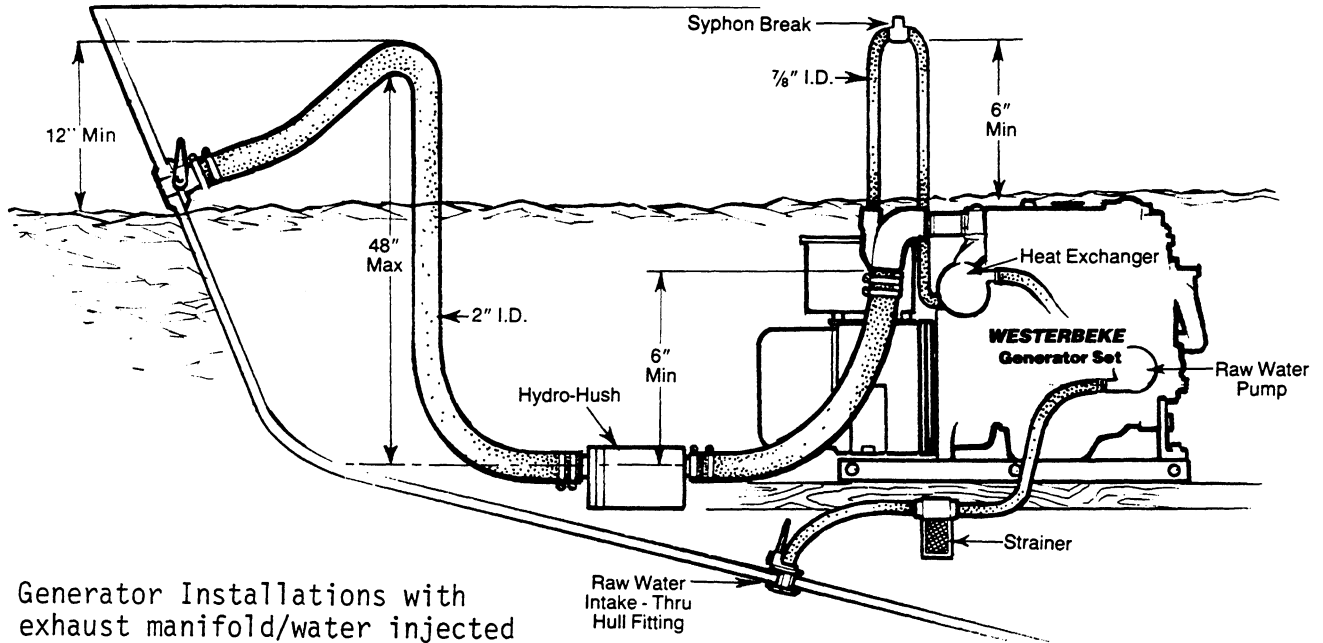
### ENGINE INSTALLATIONS



**ENGINE INSTALLATIONS WITH EXHAUST MANIFOLD/WATER INJECTED ELBOW AT OR BELOW VESSEL WATER LINE**

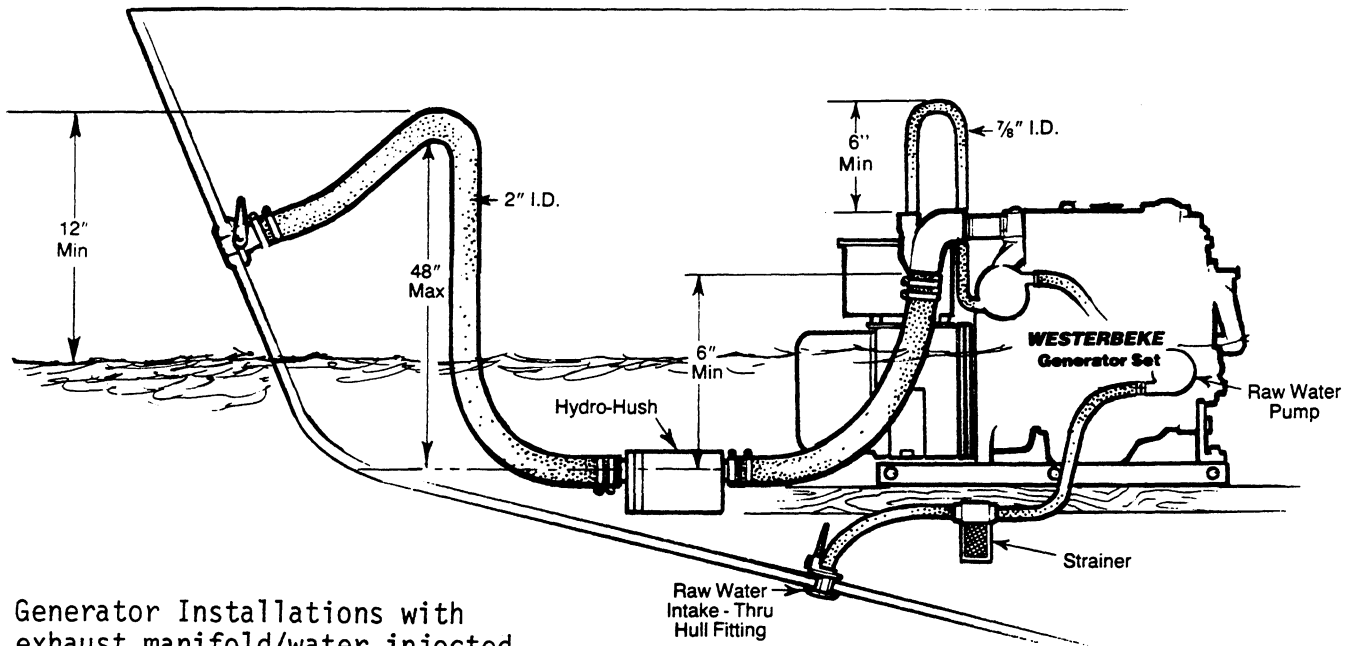


**ENGINE INSTALLATIONS WITH EXHAUST MANIFOLD/WATER INJECTED ELBOW MINIMUM OF 6 INCHES ABOVE VESSEL WATER LINE.**



Generator Installations with exhaust manifold/water injected elbow at or below vessel water line.

Generator Below Water Line



Generator Installations with exhaust manifold/water injected elbow minimum of 6 inches above vessel water line.

Generator Above Water Line

# SERVICE BULLETIN

V.31

DATE: 1/23/85

BULLETIN NUMBER: 148

MODEL: ALL PROPULSION ENGINES

SUBJECT: FIELD TROUBLESHOOTING TACHOMETER/HOURMETER PN 11917

The tachometer/hourmeter used in propulsion engine instrument panels contains two separate electrical circuits with a common ground. One circuit operates the hourmeter, and the other the tachometer. The hourmeter circuit operates on 12 volts/alternator charging voltage supplied to the (+) terminal on the back of the instrument.

The tachometer circuit operates on AC voltage 6-8 volts, fed from one of the diodes in the alternator and supplied to the "tach inp." terminal while the engine is running, and the alternator producing battery charging voltage 13.0-14.8 volts D.C.

The following are procedures to follow when troubleshooting a fault in either of the two circuits in the tachometer/hourmeter.

## HOURLMETER FAULT

### CHECK

1. Inoperative
  1. Check for proper DC voltage between (+) and (-) terminals.
    - A. Voltage present - meter defective - repair or replace.
    - B. Voltage not present - trace (+) and (-) electrical connections for fault. (Jump 12 Volts DC to meter (+) terminal to verify operation.)

## TACHOMETER FAULT

### CHECK

1. Inoperative
  1. Check for proper AC voltage between "Tach Inp." terminal and (-) terminal with engine running.
    - A. Voltage present - attempt adjusting meter through calibration access hole. No results, repair or replace meter.
    - B. AC voltage not present - check for proper alternator D.C. output voltage.
    - C. Check for A.C. voltage at tach terminal on alternator to ground.
    - D. Check electrical connections from "tach Inp." terminal to alternator connection.

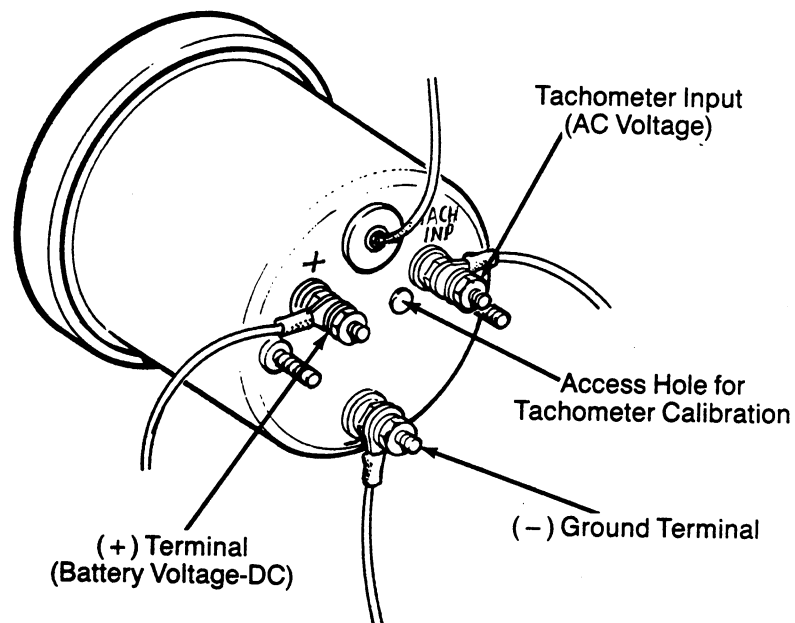


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2. Sticking
  1. Check for proper A.C. voltage between "tach inp." terminal and (-) terminal.
  2. Check for good ground connection between meter (-) Terminal and alternator.
  3. Check alternator is well grounded to engine block at alternator pivot bolt.
  
3. Inaccurate
  1. With hand-held tach on front crankshaft pulley retaining nut or strobe type tach read front crank shaft pulley R.P.M. Set engine R.P.M. with hand or strobe tach at 1500-1800 R.P.M.
  2. Adjust tachometer with small Phillips type screwdriver through calibration access hole in rear of tachometer covered with translucent plug. Zero tach and bring to R.P.M. set by strobe or hand tach. (Verify R.P.M. at idle and at high speed 2500-3000 R.P.M.) (Adjust tach as needed.)



LATE MODEL TACHOMETER

Replaces Earlier Model as Shown on Page 2 of this Bulletin

