TECHNICAL MANUAL

WESTERBEKE

Marine Diesel Engines

MODEL FOUR-230 70hp

MODEL SIX-346 115hp

Marine Diesel Generators

MODEL WPDS30 30kw

MODEL WPDS45 45kw

Publication Number 13315

Issue Date June 1, 1975

Edition 2

WESTERBEKE

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

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INTRODUCTION

This manual describes the operation, adjustment and maintenance of the Westerbeke Model SIX-346 and FOUR-230 Marine Diesel Engines, and is designed to be a guide for those concerned with the operation and maintenance of these diesel engines.

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 one of the same general type as that of a gasoline engine; it has the same sort of valves, camshaft, pistons, connecting rods and lubricating system.

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

Therefore, it follows to a great extent that a diesel engine requires the same preventive maintenance as that which any intelligent and careful 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 "High Detergent" diesel lubricating oil designed specifically for diesel engines and continued use of the same brand of lubricating oil is recommended.

Unremitting care and attention at the factory have resulted in an engine capable of many thousands of hours of service. What the manufacturer cannot control however, is the treatment the product will receive in service. This part rests with you.

Whenever service parts are ordered, always give complete description and part numbers with engine model and number. The engine model and number is stamped on the nameplate affixed to the exhaust manifold.

Example:

SIX-346 Marine Diesel Engine No. 57PS/1641/20801

or

FOUR-230 Marine Diesel Engine No. 38PS/1641/39101

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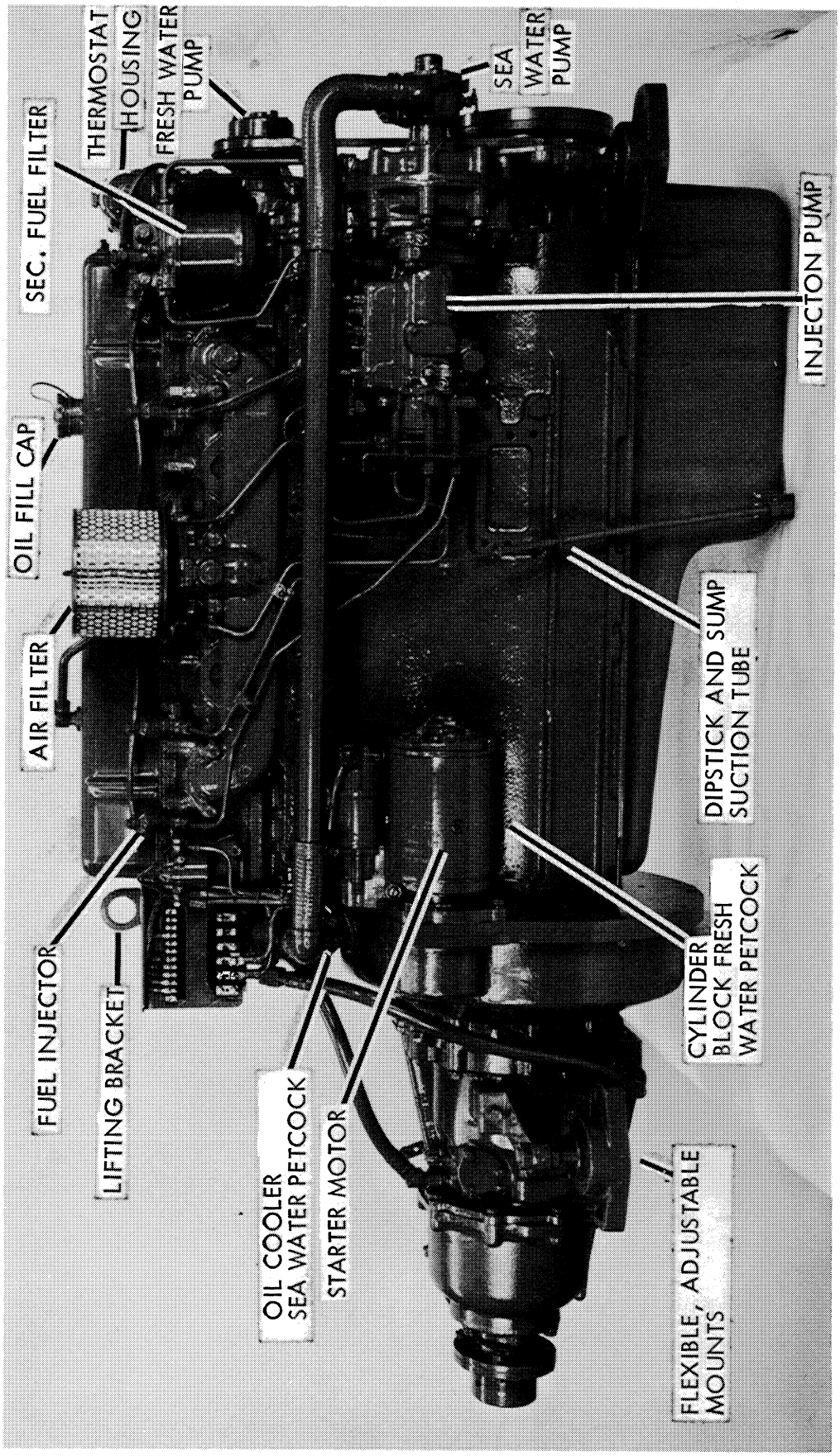
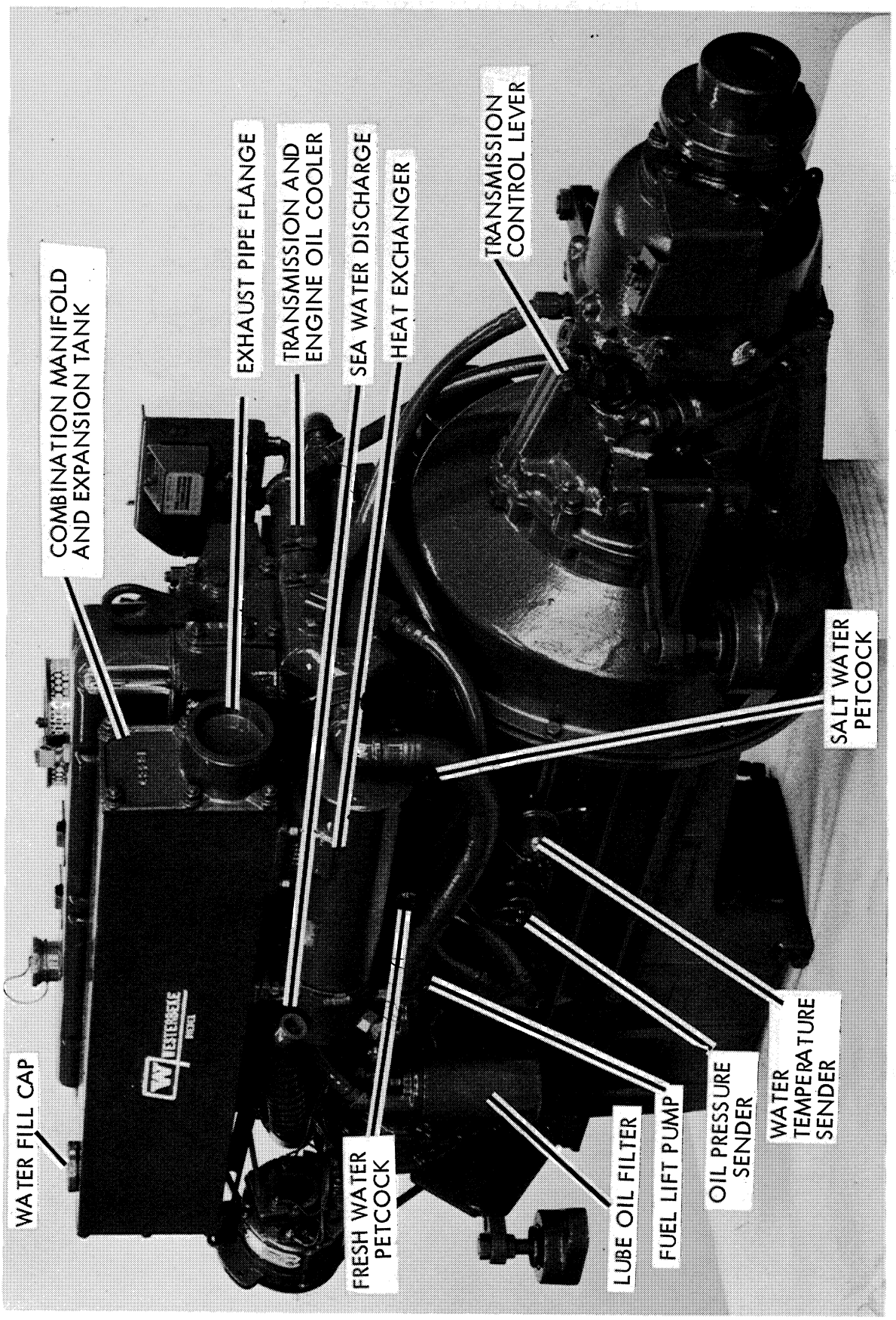


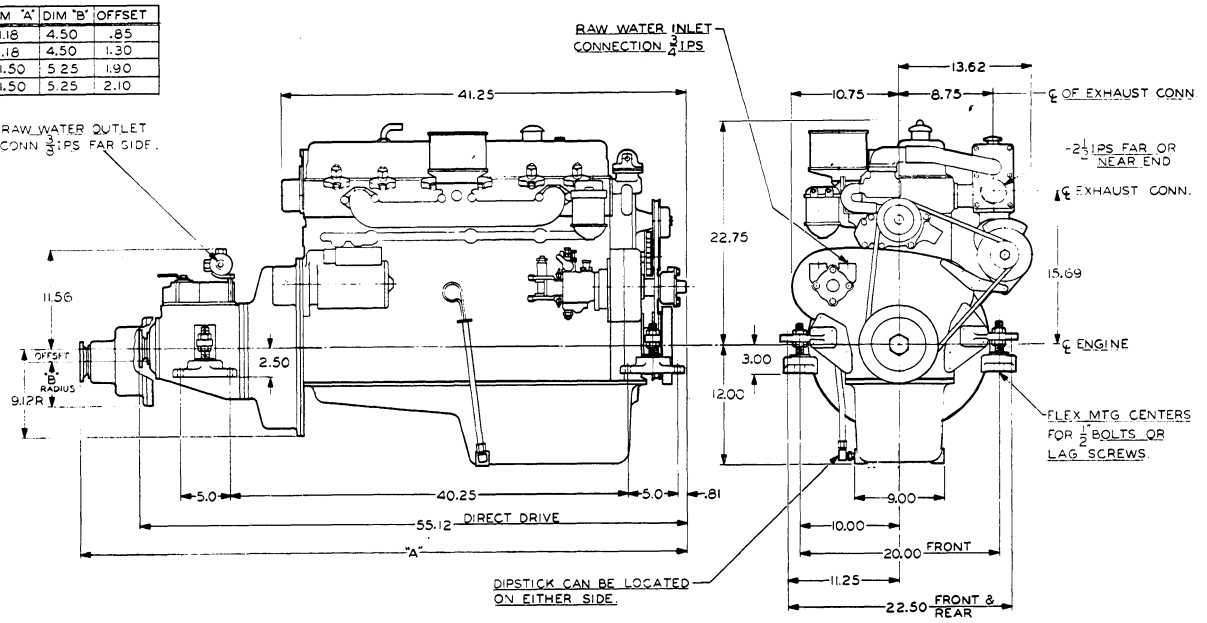
SIX-346 STARBOARD SIDE



SIX-346 PORT SIDE

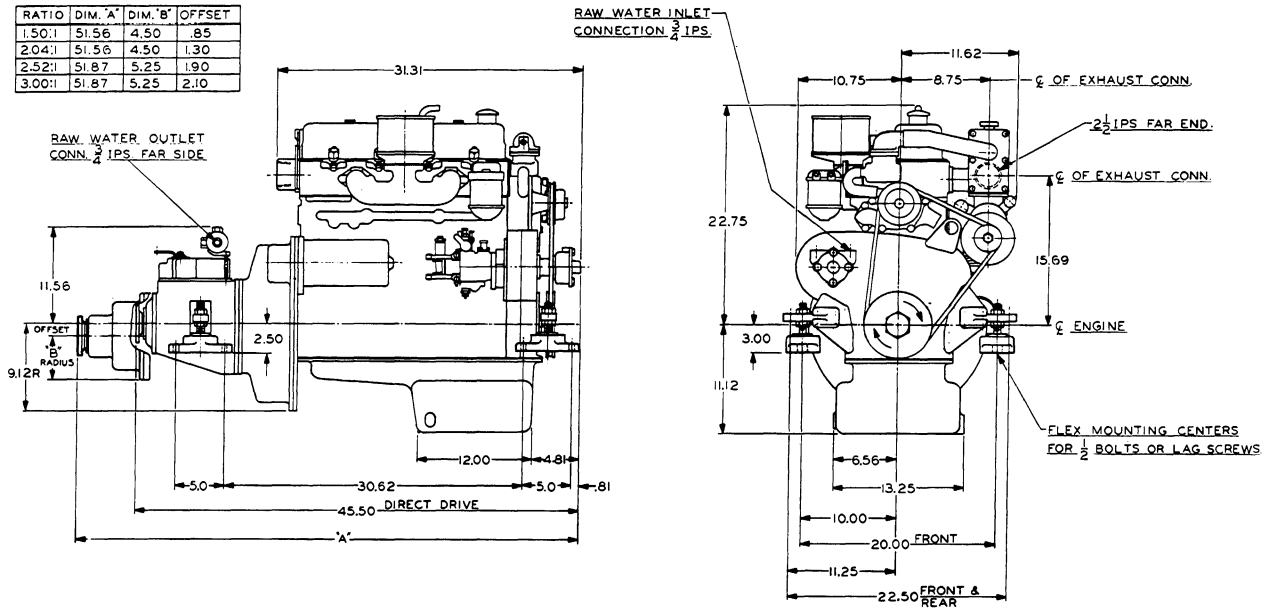
INSTALLATION DRAWINGS

RATIO	DIM. "A"	DIM "B"	OFFSET
1.50:1	61.18	4.50	.85
2.04:1	61.18	4.50	1.30
2.52:1	61.50	5.25	1.90
3.00:1	61.50	5.25	2.10



SIX-346

RATIO	DIM. "A"	DIM. "B"	OFFSET
1.50:1	51.56	4.50	.85
2.04:1	51.56	4.50	1.30
2.52:1	51.87	5.25	1.90
3.00:1	51.87	5.25	2.10



FOUR-230

ENGINE DESCRIPTION

The Westerbeke Six-346 and Four-230 Marine Diesel engines are direct injection, six cylinder, four stroke units and four cylinder, four stroke units respectively.

"Right hand side" or "left hand side" means the side of the engine as seen from the flywheel end.

CYLINDER BLOCK AND CRANKCASE

The cylinder block and crankcase is a one piece casting, employing detachable wet liners, sealed at their lower end by synthetic rubber O rings.

CYLINDER HEAD AND VALVES

The cylinder head carries the valves, valve rocker gear and injectors; it is completely water jacketed around the ports and injector sleeves. The air induction manifold and the exhaust manifold are mounted on opposite sides of the cylinder head. The valves are set vertically in the cylinder head and are operated through the medium of the rocker gear, push-rods and tappets from the camshaft. The inlet valves are larger in diameter than the exhaust valves and are shrouded to assist air swirl on induction.

CAMSHAFT

The camshaft is mounted in the crankcase, running directly in the crankcase bores with the exception of the front, which runs in a white-metal bearing. Camshaft end-float is controlled by a thrust plate between the camshaft shoulder and the camshaft timing gear.

CRANKSHAFT

The crankshaft for the Six-346 engine is mounted on seven replaceable main bearings, and the Four-230 engine is mounted on five replaceable main bearings in the crankcase. End thrust of the crankshaft is taken by thrust washers on the front main bearing. A torsional vibration damper is fitted to the front of the crankshaft (Six-346 engine only) to absorb crankshaft vibrations. A lip type oil seal mounted in a one-piece housing seals the rear main bearing.

TIMING GEARS AND TIMING CASE

A train of gears is utilized to drive the camshaft and the fuel injection pump. The camshaft drive gear is mounted on the steel camshaft by means of a separate hub and nut. An idler gear transmits the drive from the gear on the crankshaft to both the camshaft and the fuel injection pump drive gears.

PISTONS AND PISTON PINS

The pistons are attached to the connecting rods by fully floating piston pins, and are equipped with three compression and one scraper ring. The top compression ring on each piston is chromium inserted to give greater wear resistance, rapid seating, and extended life.

LUBRICATING OIL SUMP

The oil sump is fitted with a suction tube extension (combined with the dipstick tube) from which the oil may be removed by a suction pump.

LUBRICATING SYSTEM

The rotor-type oil pump, gear-driven from the front of the crankshaft, is mounted on the front main bearing cap and incorporates an oil pressure relief valve in the pump body.

Oil is drawn from the sump, through a strainer, to the oil pump. From the pump the oil is passed through an external oil filter via a housing attached to the crankcase. From the outlet side of the filter, oil is fed under pressure through the oil cooler to the main oil gallery. Drillings from the main gallery feed oil to the crankshaft main bearings and camshaft bearings, and a drilling across the front of the crankcase

feeds oil to the idler gear shaft to lubricate the idler gear bearings. An oil jet screwed into this drilling lubricates the train of timing gears.

From the crankshaft main bearings oil is fed through the crankshaft to the big-end bearings. Oil splash from the crankshaft lubricates the gudgeon pins and cylinder walls.

An external pipe feeds oil from the main gallery through drilling in the cylinder head and intermediate rocker brackets to the hollow centers of the rocker shafts. Oil pressure in the rocker shafts is controlled by a pressure relief valve fitted on the front intermediate rocker bracket. The rocker bearing surfaces are lubricated by oil from the rocker shafts, and oil mist in the rocker chamber provides the necessary valve guide lubrication.

Discharged oil from the valve rockers and relief valve drains down the push-rod tunnels and lubricates the tappets and cams before returning to the sump.

FUEL INJECTION SYSTEM

A distributor type fuel injection pump is flange mounted on the right hand side of the cylinder block, and driven by a splined shaft.

An automatic device is incorporated in the fuel injection pump to advance or retard the point of fuel injection according to changes of engine speed.

The engine speed is controlled by a mechanical type governor incorporated in the fuel injection pump, the speed control lever being located on top of the fuel pump together with an engine fuel stop lever.

A fuel lift pump of the diaphragm type and equipped for hand priming is fitted on the cylinder block on the left hand side of the engine. The pump is operated by an eccentric from the camshaft.

The atomisers (fuel injectors) are located on the right hand side of the cylinder head in an accessible position. They are retained in the head by flanges secured with nuts.

INDUCTION MANIFOLD

The induction manifold is made of die-cast aluminum, on the right hand side of the cylinder head, and an air filter is fitted in this manifold.

EXHAUST MANIFOLD

A water cooled exhaust manifold is fitted to the left hand side of the cylinder head. The water is not in direct contact with the exhaust gases but circulates in an outer jacket forming the coolant expansion tank.

COOLING SYSTEM

Two methods of indirect fresh water cooling are available according to customers requirements. Fresh water is circulated round the engine by a centrifugal type water pump and this water is in turn cooled by either a heat exchanger or keel cooling pipes.

ELECTRIC SYSTEM

Twelve volt electrical equipment is fitted to the engine.

The 12 volt, 55 ampere alternator is mounted on the left hand side of the engine, and is belt driven from the front end of the crankshaft. Belt tension is adjusted by means of an adjustable link and pivot pin.

The flange mounted starter motor is fitted on the right hand side of the engine in accessible position.

GENERAL DATA

Types	Six-346 (115 HP @ 2600 rpm)
	Four-230 (70 HP @ 2500 rpm)
Bore	3.937 in. (100 mm.).
Stroke	4.724 in. (120 mm.).
Capacity:	
Six-346	345.3 cu. in.
Four-230	231 cu. in.
Compression ratio:	
Six-346	16.8 : 1
Four-230	16.8 : 1
Torque:	
Six-346	255 lb. ft (35.26 kgm) @ 1750 rpm.
Four-230	174 lb. ft (24.06 kgm) @ 1400 rpm.
Cylinder liner bore diameter	3·7401 to 3·7409 in. (95·00 to 95·02 mm.).
Thickness of liner shims	·003 and ·005 in. (·076 and ·127 mm.).
Piston to bore clearance (on thrust face at bottom of skirt)	·0055 to ·007 in. (·139 to ·18 mm.).
Piston ring groove clearance	·0095 to ·011 in. (.24 to ·28 mm.).
Remainder	·002 to ·004 in. (·051 to ·102 mm.).
Piston ring fitted gap	·014 to ·020 in. (·36 to ·51 mm.).
Remainder	·011 to ·016 in. (·279 to ·406 mm.).
Gudgeon pins:	
Fit in piston	·0005 in. (·013 mm.) interference to ·00025 in. (·006 mm.) clearance.
Pin to small-end bush clearance	·0005 in. to ·0013 in. (·013 to ·033 mm.).
Connecting rods:	
Length between centres	8·185 to 8·187 in. (207·90 to 207·95 mm.).
Permissible out of parallel of big- and small-ends	·0001 in. per inch (·0001 cm. per cm.) effective mandrel length.
Big-end bearing to crankpin clearance	·0015 to ·0030 in. (·04 to ·08 mm.).
Connecting rod to crankshaft side-clearance	·008 to ·012 in. (·2 to .3 mm.).
Little-end bush (bi-metal wrapped type) inner diameter	1·37525 to 1·37575 in. (34·931 to 34·944 mm.).
Crankshaft and main bearings:	
Journal diameter	3·2495 to 3·250 in. (82·54 to 82·55 mm.).
Crankpin diameter	2·6245 to 2·6250 in. (66·66 to 66·67 mm).
Undersizes	—·015 in. —·030 in., —·045 in. (—·381 mm., —·762 mm., —1·143 mm.).
Bearing to crankshaft journal clearance	·002 to ·004 in. (·05 to ·10 mm.).
Rear oil seal cover to oil return thread clearance	·0070 to ·0085 in. (·178 to ·216 mm.). all round.
End float (controlled by thrust washers):	
Four-230	·006 to ·010 in. (·15 to ·25 mm.).
Six-346	·006 to ·013 in. (·15 to .33 mm.).

Camshaft and bearings:		
Bearing to camshaft clearance:		
No. 1 (bush)		·0015 to ·0040 in. (·038 to ·102 mm.).
Remainder		·00275 to ·00475 in. (·0698 to ·1206 mm.).
No. 1 (bush) inner diameter (finished in position)		1·9995 to 2·0010 in. (50·787 to 50·825 mm.).
End-float (controlled by thrust plate)		·002 to ·012 in. (·051 to ·305 mm.).
Cam lift:		·261 in. (6·63 mm.).
Timing gears:		
Backlash		·004 to ·006 in. (·102 to ·152 mm.).
Number of teeth:		
Crankshaft gear		25.
Camshaft gear		50.
Fuel injection pump gear		50.
Idler gear		58.
Idler gear bush inner diameter (finished in position)		1·125 to 1·1255 in. (28·575 to 28·588 mm.)
Idler gear bush to shaft clearance		·001 to ·002 in. (·025 to ·051 mm.).
Thickness of idler gear thrust washer		·068 to ·070 in. (1·73 to 1·78 mm.).
Oil feed jet diameter		·062 in. (1·59 mm.).
Cylinder head and valve mechanism		
Valve timing:	Six-346, with ·021 in. (·53 mm.) rocker clearance Four-230, with ·019 in. (·48 mm.) rocker clearance	
Inlet valve: Opens		2-1/2° B. T. D. C.
Closes		42-1/2° A. B. D. C.
Exhaust valve: Opens		37-1/2° B. B. D. C.
Closes		7-1/2° A. T. D. C.
Valve seat angle (cylinder head and valve)		45°
Valve seat face width		·055 to ·070 in. (1·40 to 1·78 mm.).
Valve stem to guide clearance		·001 to ·0025 in. (·025 to ·064 mm.).
Valve stem to rocker clearance - hot or cold		·013 in. (·33 mm.).
Valve lift:		·430 in. (10·92 mm.).

	Inner	Outer
Valve springs:		
Free length	1·8 in. (45·72 mm.)	2·25 in. (57·15 mm.)
Fitted length	1·594 in. (40·487 mm.)	1·875 in. (47·625 mm.)
Load to compress to fitted length (valve open)	40 lb. (18·14 kg.)	90 lb. (40·82 kg.)

Rocker to rocker shaft clearance		·001 to ·002 in. (·025 to ·051 mm.).
Rocker spacer sizes:		
Six-346		·243 to ·250, ·340 to ·343, and ·8055 to ·8125 in. (6·17 to 6·35, 8·64 to 8·71, and 20·46 to 20·64 mm.).
Four-230, between each rocker and bracket		·290 to .297 in. (7·37 to 7·53 mm.)
between each pair of rockers		·8055 to ·8125 in. (20·46 to 20·64 mm.)
Tappet to guide clearance		·0005 to ·0023 in. (·013 to ·058 mm.).
Flywheel and starter ring:		
To fit starter ring to flywheel heat to	(Six-346).	275°C. (527°F.)
	(Four-230)	350°C. (662°F.)

Injection pressure	175 atmospheres. (2570 psi)
Add 5 atmospheres to the opening pressure when setting new injectors or fitting new springs, to allow for settling of the components.	
Injector securing bolts	144 lb. in. (1.7 kg. m.)
Oil pump:	
Driving shaft to pump body clearance	·0025 in. (·063 mm.) maximum
End-float of pump rotors	·0020 to ·0045 in. (·051 to ·114 mm.).
Backlash between driving and driven gears	·004 in. (·102 mm.).
Pump body to bearing cap shim thicknesses	·002 and ·003 in. (·051 and ·076 mm.).
Number of teeth on driving and driven gears	46.
Main oil relief valve:	
Spring free length	2-17/64 in. (57·6 mm.).
Spring fitted length	2 in. (50·8 mm.).
Load to compress spring to fitted length	11 lb. 12 oz. (5·33 kg.).
Rocker gear oil relief valve:	
Spring free length	3/4 in. (19 mm.).
Spring fitted length	5/8 in. (15·9 mm.).
Load to compress to fitted length	3 oz. (85 gm.).
Diameter of ball	·236 in. (6 mm.).
Oil pressure (engine hot):	
Idling speed	10 to 15 lb./sq. in. (·7 to 1·05 kg./cm.^{2})
Normal running speed	35 to 60 lb./sq. in. (2·46 to 4·22 kg./cm^2)
Oil capacity:	
Six-346	11.5 qts.
Four-230	8 qts.

COOLING SYSTEM

Water pump:	
Fan hub pump spindle fit	·0015 to ·0028 in. (·04 to ·07 mm.) interference.
Impeller to pump spindle fit	·0010 to ·0023 in. (·03 to ·06 mm.) interference.
Impeller vane to impeller housing clearance	·010 to ·021 in. (·25 to ·53 mm.).
Thermostat:	
Opening temperature:	
Bellows type	77 to 80° C. (170 to 176° F.).
Fully open temperature:	
Bellows type	94° C. (201° F.).

TORQUE WRENCH SETTINGS

Cylinder head nuts	1,200 lb. in. (13·8 kg. m.). Cold 1,080 lb. in. ( ). Hot
Crankshaft pulley nut (Four-230)	3,000 lb. in. (34·56 kg. m.).
Main bearing bolts (Four-230)	1,200 lb. in. (13·8 kg. m.).
Big end bolts (Four-230)	720 lb. in. (8·3 kg. m.).
Main bearing studs	600 lb. in. (7·0 kg. m.).

Main bearing nuts:	
Slotted type	1,000 lb. in. (11·5 kg. m.).
'Nyloc' type	1,200 lb. in. (13·8 kg. m.).
Connecting rod bolts	700 lb. in. (8·1 kg. m.).
Exhaust manifold nuts (Six-346)	350 lb. in. (4 kg. m.).
(Four-230)	600 lb. in. (6·91 kg. m.).
Valve rocker bracket bolts:	
5/16 in. diameter	180 lb. in. (2·1 kg. m.).
3/8 in. diameter	350 lb. in. (4 kg. m.).
Flywheel bolts	1,200 lb. in. (13·8 kg. m.).
C.A.V. starter motor pinion stop nut	40 to 50 lb. ft. (5·6 to 7·0 kg. m.).
C.A.V. 'distributor' injection pump:	
Cam advance screw	400 lb. in. (4·6 kg. m.).
Transfer pump rotor	65 lb. in. (·75 kg. m.).

RECOMMENDED LUBRICANTS

ENGINE

Climatic conditions	Castrol	Esso	Mobil	Shell	BP	Filtrate	Sternol	Duckham's
*Above 32° C. (90° F.)	Castrol CRI 30	Essofleet HDX 30	Delvac 1130	Shell Rotella S. Oil 30	Vanellus SAE 30	Filtrate Diesel 30	Panther 30	Fleetol HDX 30
*32° C. (90° F.) down to—12° C. (10° F.)	Castrol CRI 20	Essofleet HDX 20	Delvac 1120	Shell Rotella S. Oil 20/20W	Vanellus SAE 20	Filtrate Diesel 20	Panther 20	Fleetol HDX 20
*—12° C. (10° F.) down to—18° C.	Castrol CRI 10	Essofleet HDX 10W	Delvac 1110	Shell Rotella S. Oil 10W	Vanellus SAE 10W	Filtrate Diesel 10W	Panther 10	Fleetol HDX 10
Below—18° C. (0° F.)	Castrol CR 5W/20	Esso Extra Motor Oil 5W/20	Mobiloil 5W/20	Shell Winter Special Motor Oil or Shell Super Motor Oil 5W/30		Filtrate 5W/20	Sternol WW Multigrade 5W/20	Q5-30

*In addition to the lubricants listed we approve the use of the appropriate multigrade oil, supplied by the above companies, for the particular condition prevailing down to —18° C. (0° F.). Below —18° C. (0° F.) use a 5W/20 oil or the current practice of the country concerned.

TRANSMISSIONS AND VEE DRIVE	
Hydraulic Transmissions	Automatic Transmission Fluid Type "A"
Vee Drive	Heavy Duty Motor Oil SAE-30

INSTALLATION

FOREWORD

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 ensure good operating conditions for the engine and correct procedure in servicing the engine.

INSPECTION OF SHIPMENT

The engine is shipped from the factory mounted upon heavy skids and properly crated. Accessory equipment is shipped in a separate small box, usually packed with the engine crate. Immediately upon arrival, the shipment should be inspected for possible accidental damage in transit and for any possible shortage in parts and equipment. Before accepting any shipment from the transportation company, the crate should be opened and an inspection for concealed damage made. If either visible or concealed damage is noted, require the delivering agent to sign "Received in damaged condition." This is your protection against loss. Claims for such damage must be made to the carrier, not to J. H. Westerbeke Corp.

FOUNDATION FOR ENGINE

A good engine bed contributes much towards the satisfactory operation of the engine. The engine bed must be of rigid construction and neither deflect nor twist when subjected to engine weight or the position the boat may have to take under the effects of rough seas. The bed must not only support the engine firmly in exact position but 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 bearing in the engine and finally to the engine bolts and engine bed.

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

The temptation to install the engine on a pair of fiberglas "angle irons" should be resisted. Such construction will allow engine vibrations to pass through to the hull. Flexible mounts require a firm foundation against which to react if they are to do their job.

RIGGING AND LIFTING

The engine is fitted with two lifting rings, designed so that the engine may be lifted without damage. Rope or chain slings should be attached to the rings and the engine lifted by means of a tackle attached to this short sling. The lifting rings have been designed to carry the full weight of the engine, therefore auxiliary slings are not required or desired.

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 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 or the entrance of dirt where openings have been made. The parts which have been removed should be returned to position as soon as the restricted opening 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 come. 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 nuts on top of the lag bolts are used to tighten the engine down or are loosened to permit the engine to be moved. 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.

PROPELLER COUPLING

Each Westerbeke Diesel engine is fitted with a suitable coupling for connecting the propeller shaft to the engine. The coupling is very carefully machined for accurate fit. The forward end of the propeller shaft has a long, straight keyway and any burrs should be removed from this 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 fit the coupling over the shaft, the coupling can be expanded by heating it in a pail of boiling water. The face of the propeller coupling must be exactly perpendicular to the center line or axis of the propeller shaft.

PROPELLER

The type and size of propeller varies with 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 on full throttle. This can be determined only by actual trials of the pilot model.

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 alignment at frequent intervals and to correct any errors when they may appear.

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

One particularly annoying result of misalignment may be leakage of

transmission oil through the rear oil seal. While it is possible for this type of leakage to be caused by defective parts, one should always first check 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. 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 0.001 in. if possible. However, the maximum allowable tolerance must not exceed 0.001 in. per inch of coupling O. D.

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 degrees 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 degrees from the next one.

The engine alignment should be re-checked 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. 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.

WATER CONNECTIONS

Seacocks and strainers should be of the full flow type and of a size at least equal to the inlet pipe of the sea water pump (see installation drawing). The strainer should be of the type which may be withdrawn for cleaning while the vessel is at sea.

Water lines can be either copper tubing or reinforced rubber hose. In any case use a section of flexible hose (hose that will not collapse under suction) between the hull inlet and engine and outlet before it enters the exhaust line so as to take up vibrations and permit the engine to be moved slightly when it is being realigned. All pipe and fittings should be of bronze or brass. Use sealing compound at all connections to prevent air leaks. The neoprene impeller in the sea (raw) water pump should never be run dry.

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. Cast iron or wrought iron pipe is recommended for the exhaust line. The exhaust line must be at least as large as the engine exhaust manifold flange (refer to Installation Drawing).

To insure vibration doesn't transmit to hull use a flexible section preferably of stainless steel, no less than 12 in. overall threaded at each end and installed as close to the engine as possible. This flexible section should be installed with no bends and be asbestos covered. 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 support for the rubber hose to prevent sagging, bending, and formation for 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.

FUEL TANK AND FILTERS

Fuel tanks should preferably be of plain steel or terne plate; reinforced glass-fiber is also suitable. Be certain that the interior is gel-coated to prevent fibers from contaminating the fuel system. 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.

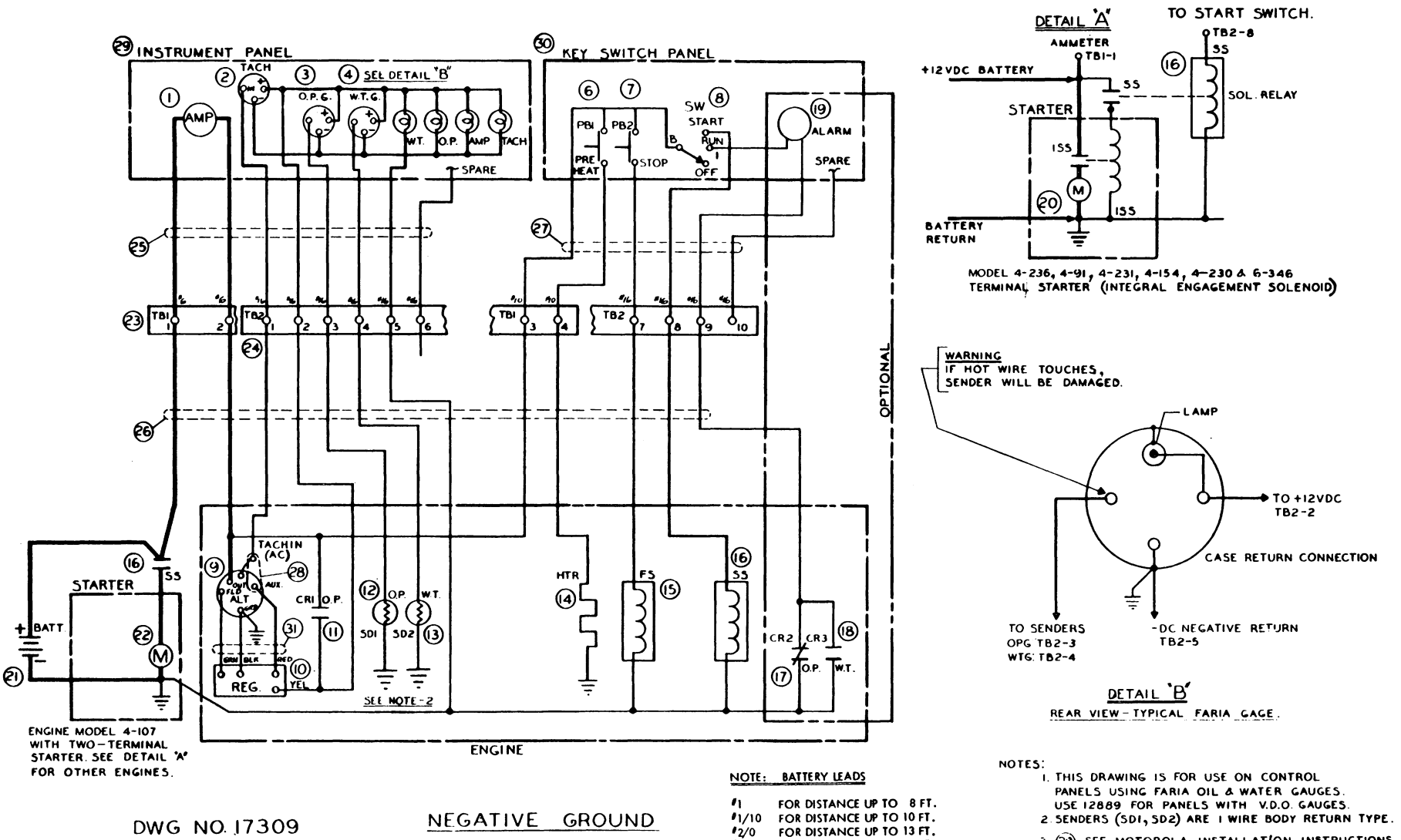
A primary fuel filter of the water collecting type should be installed between the fuel tank and the fuel lift pump. A recommended type is available from the list of optional extras. The main fuel filter is fitted on the engine between the fuel lift pump and the injection pump and has a replaceable element.

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.

ELECTRICAL EQUIPMENT

Starter batteries should be situated as close to the engine as possible, to avoid voltage drop through long leads. It is a bad practice to use the starter batteries for other services in the boat unless these are light or very intermittent. In cases where there are substantial loads from lights, refrigerators, radio, depth sounders, etc., it is essential to have a complete separate system, and to provide charging current to this from an auxiliary generator driven from the power take off at the front of the engine. Starter batteries must be of a type which permit a high rate of discharge (Diesel starting).

Carefully follow the recommended wire size shown in the wiring diagrams. (Fig. 1). Plan the installation so the battery is close to the engine and use battery cable sizes as indicated.



MODEL 4-236, 4-91, 4-231, 4-154, 4-230 & 6-346 TERMINAL STARTER (INTEGRAL ENGAGEMENT SOLENOID)

DETAIL 'B'

REAR VIEW - TYPICAL FARIA GAGE.

NOTE: BATTERY LEADS

#1	FOR DISTANCE UP TO 8 FT.
#1/10	FOR DISTANCE UP TO 10 FT.
#2/0	FOR DISTANCE UP TO 13 FT.
#3/0	FOR DISTANCE UP TO 16 FT.

NOTES:

1. THIS DRAWING IS FOR USE ON CONTROL PANELS USING FARIA OIL & WATER GAUGES. USE 12889 FOR PANELS WITH V.D.O. GAUGES.
2. SENDERS (SD1, SD2) ARE 1 WIRE BODY RETURN TYPE.
3. (28) SEE MOTOROLA INSTALLATION INSTRUCTIONS.

DWG NO. 17309

NEGATIVE GROUND

Fig. 1 WIRING DIAGRAM

PREWIRING AND OPTIONS

1. Pre-Wiring

Pre-wiring includes the installation and wiring of the following devices: alternator, regulator, starting motor, starter solenoid, instrument senders, connecting terminal blocks, pressure and temperature switches separate key switch panel, electric panel wiring harness and engine harness. The two interconnecting cables between engine, key switch panel and all electric panel meet or exceed ABYC Standards. Chief advantages of prewiring are elimination of wiring mistakes and minimum installation time.

ALL ELECTRIC PANEL

Marine instruments used include ammeter, water temperature gauge and oil pressure gauge. The instruments are back lighted, vented and negative grounded. The instrument panel should be mounted so that it is protected from direct contact with salt spray.

2. Factory Installed Engine Alarm System (Optional)

This alarm system, to indicate the existence of high water temperature or low oil pressure, is designed and installed on your Westerbeke diesel at the factory. It consists of an audible alarm to indicate either failure, the alarm being part of the key switch panel. The high water temperature and low oil pressure switches are set for compatibility with the engine. The alarm system is energized by the key switch at the key switch panel and can be de-energized by the same key switch, should the operator wish to turn off the alarm.

CONTROLS

Throttle control and stop-run control: The fuel supply to the engine and the engine speed is controlled by two small levers on top of the fuel injection pump which is mounted on the right-hand side of the engine (refer to Fig. 2). The recommended practice is to have the stop-run lever loaded to the run position, and controlled by a Bowdoin wire or flexible sheathed cable to a push-pull knob at pilot station adjacent to starter button or key switch and the throttle lever connected to a Morse type lever at pilot station by a flexible sheathed cable. Refer below to transmission control.

Transmission Control: The control lever on the transmission housing has three positions with detents for Forward (F), Neutral (N), and Reverse (R). This control lever may be connected to the pilot station by a flexible sheathed cable and controlled by Morse Type lever(s). The single Morse control lever gives clutch and throttle control, with full throttle range in the neutral position. The two lever Morse control provides clutch control with one lever and throttle control with the other.

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

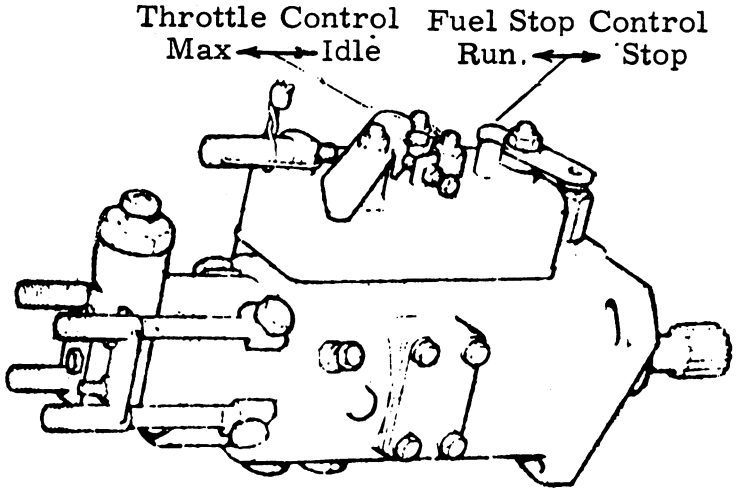


Fig. 2 FUEL INJECTION PUMP

OPERATION

OPERATION

Preparation for starting engine after installation. The engine is shipped "dry", that is, with lubricating oil drained from the crankcase and transmission. The following procedure should be checked methodically before starting the engine for the first time.

1. Remove engine lubricating oil filler cap and fill oil sump with diesel lubricating oil to the highest mark on the dipstick. Select an approved grade listed in "General Data" and continue to use it. Do not overfill. Replace filler cap.

2. Remove transmission breather cap 3/4 in. hex fitting (Paragon transmission) or filler plug (Warner transmission), and fill housing with Automatic transmission fluid Type "A" to high mark on dipstick. Do not overfill.

3. Remove expansion tank filler cap and fill tank, with fresh, clean water and/or antifreeze (refer to "Cold Weather Precaution") to within one inch of top of tank. Replace filler cap. Ensure cylinder block drain tap and heat exchanger petcocks are closed.

4. Ensure storage battery water level is at least 3/8 in. above 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 No. 2 clean Diesel Fuel Oil. 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, with a fine mesh wire strainer.

6. Open valves in fuel line and bleed fuel system, refer to "Bleeding Fuel System."

BLEEDING THE FUEL SYSTEM

One possible cause of the engine failing to start, or erratic engine acceleration is that air may have entered the system, in which case "bleeding" of the system will be necessary. Before bleeding the system, first insure that there is an adequate supply of fuel in the tank and that the fuel supply is turned on.

1. Slacken the bleeder screw securing the fuel injectors return pipe to secondary fuel filterhead. Operate the priming lever (refer to note below) on the fuel lift pump, when fuel oil issues from the bleeder screw, free of air bubbles, tighten bleeder screw.

NOTE: If the engine camshaft cam driving the fuel lift pump is on maximum lift, it will not be possible to obtain a full pumping stroke with the priming lever, and the engine should be turned with starter motor one complete revolution.

2. Slacken the air bleed screw on the side of the fuel injection pump, situated directly above the pump nameplate. Operate the lift pump priming lever, and when fuel flows free of air bubbles, tighten the bleed screw.

3. Slacken the air bleed screw on back of the fuel injection pump cover, behind the throttle lever. Operate the lift pump priming lever, and when fuel flows free of air bubbles tighten the bleed screw.

4. Slacken the union nuts at injector end of each of the high pressure pipes.

5. IMPORTANT: Position transmission shift lever in neutral as engine may start when completing Step 8.

6. Ensure fuel STOP/RUN push-pull control is in full run position.

7. Advance throttle to maximum open position (for maximum fuel flow).

8. Turn key switch to START position, and in sequence when fuel oil free of air bubbles issues from each injector pipe union, tighten each union. If engine should start during this procedure immediately move throttle to idle speed.

TO START ENGINE

1. Position shift lever to neutral.

2. Position fuel stop-run control to full run position.

3. Advance throttle to maximum (to obtain maximum fuel for easier starting).

4. Turn key switch to START position and hold. Release when engine starts. (See note below.)

5. Immediately upon starting, position throttle to idle setting.

NOTE: Never operate the cranking motor continuously for more than 15 seconds. If engine has not started, stop cranking for 15 seconds. The engine should start within a few revolutions of the crankshaft if battery is charged and the engine is receiving fuel.

The cranking motor turning over fast indicates the battery is charged. If a battery is charged and engine doesn't start, check fuel system as follows:

a. Ensure the fuel valve between tank and engine is open.

b. Ensure the stop-run and throttle control levers on the injection pump are in their full run positions.

c. Check for leaks in fuel lines and at gaskets of fuel filters.

d. Determine if fuel is reaching injectors refer to "Bleeding Fuel System", Steps 4 to 8. If fuel oil doesn't issue from union nuts at injectors, bleed complete system.

WHEN ENGINE STARTS

1. Check the Sea Water Flow. Look for water at exhaust outlet. Do this without delay. (Heat Exchanger Cooling System.)

2. Check Oil Pressure immediately Normal oil pressure is approximately 10 to 15 psi. when idling, 35 to 60 psi. at operating speeds.

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 a 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.

5. Check temperature gauge. Normal operating temperature is below 190°F.

6. Recheck expansion tank water level. (This applies after cooling system has been drained and refilled.) Stop engine after engine has reached operating temperature of 170 to 180°F, add water and/or antifreeze as required 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 counterclockwise until the resistance of the safety stops is felt. Leave the cap in

this position until all pressure is released. Press the cap downwards against the spring to clear the safety stops, and continue turning until it can be lifted off.

7. Warm-Up Instructions. As soon as possible engage the forward clutch and run the engine at reduced speed of 800 to 900 rpms, until oil pressure gauge indicates approximately 35 to 50 psi, and water temperature gauge indicates 170 to 180°F. (Warming up with clutch in neutral takes an unnecessarily long time).

8. Avoid prolonged idling.

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

TO STOP ENGINE

1. Move throttle lever to idle position.

2. Position shift lever to neutral.

NOTE: Idle engine for a few minutes to dissipate heat gradually before shutdown.

3. Position fuel push-pull (stop-run) control to stop. Control in stop position functions by stopping fuel flow to the injectors.

NOTE: Key switch panel with STOP push-button switch, depress push button and hold until engine stops.

4. Turn key switch to OFF position.

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 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 lack of proper 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 interruptions than any other factor.

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

9. Do not be alarmed if temperature gauges show a high reading following a sudden stop after engine has been operating under 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, temperature will quickly return to normal when engine is operating.

COLD WEATHER PRECAUTIONS

1. Precautions against damage by freezing should be taken if the engine is to be left exposed to inclement weather by adding an anti-freeze of reputable make and incorporating a suitable corrosion inhibitor. As these engines are equipped with high temperature thermostats, a permanent type anti-freeze with an Ethylene Glycol Base should be used. Do not use alcohol solutions.

2. Draining Cooling System. Remove pressure cap from expansion tank and open the drain tap (turn counterclockwise) on right-hand side of cylinder block, next to flywheel housing.

3. Filling Cooling System. Determine capacity of cooling system (including keel pipes if installed) and fill cooling system with the correct amount of antifreeze and water for the degree of protection required, to within one inch from the top of the tank. Ensure drain tap is closed. Start engine to circulate antifreeze and when temperature gauge indicates normal operating temperature, stop engine and add coolant as necessary.

NOTE: The strength of the anti-freeze solution must be maintained by topping off with anti-freeze if necessary (use tester when in doubt).

4. Fuel filters must be checked more often, particularly the primary filter to remove all the moisture and condensation separated from the fuel, otherwise this may freeze and stop the fuel flow.

MAINTENANCE

MAINTENANCE

POST-DELIVERY CHECKOVER

After a customer has taken delivery of his engine, it is advisable, in his own interests, that a general checkover of the engine be carried out after the first 25 to 50 hours in service.

This checkover should comprise the following points:

1. Renew sump lubricating oil and lubricating oil filter. Refer to "Filter Maintenance-Lubricating Oil Filter".

2. If necessary, adjust slow running speed.

3. Check external nuts for tightness.

4. Check cylinder head nuts are to the correct torque and check valve clearances.

5. Check for fuel and lubricating oil leaks, and rectify if necessary.

6. Check cooling system water level and inspect system for leaks.

7. Check alternator belt tension.

8. Carry out test to check general performance of engine.

9. Check engine mounting bolts for tightness.

10. Check all electrical connections and wiring for tightness and chafing.

11. Check engine alignment to propeller shaft coupling.

Thereafter maintenance periods should be in accordance with those given under "Periodical Attentions".

PERIODICAL ATTENTIONS

KEEP ENGINE CLEAN

Daily

Check sea water strainer.
Check cooling system water level.
Check oil level in sump.
Check oil level in transmission.
Check fuel level in fuel tank.

Every 100 Hours

Renew sump lubricating oil and lubricating oil filter. (Refer to "Filter Maintenance - Lubricating Oil Filter.")
Clean air intake filter.
Check alternator belt tension.
Clean fuel filter water trap.
Clean battery terminals and apply protective coating to terminal and connectors.
Check level of electrolyte in battery.

Every 300 Hours or Once a Season

Renew final fuel filter.
Renew transmission lubricating fluid. Remove breather cap 3/4 in. hex fitting. Insert pump hose in breather fitting opening and pump fluid out of housing into a waste container. Fill housing with Automatic Transmission fluid Type "A" to high mark on dipstick. Do not overfill.

NOTE: Warner Transmission has filler plug.

FILTER MAINTENANCE

Air Filter

The time period for cleaning the air filter depends on operating conditions, therefore, under dirty conditions, the time period of 100 hours recommended for cleaning should be decreased. The correct maintenance of the air filter will greatly assist in reducing bore wear thereby extending the life of the engine.

To clean the air filter proceed as follows:

1. Unscrew the thumb screw securing the air filter to its manifold and remove filter.

2. The element may be cleaned by blowing compressed air from the inside to the outside. Do not attempt to clean the element by any other means.

A strong light directed into the inside of the element and viewed from the outside will reveal any damage to the paper corrugations. If the element is damaged or shows a large deposit of dirt, replace element.

Fuel Oil Filters

It is essential to use clean diesel fuel oil free from water or contamination. Provided clean fuel oil is used, no trouble should be experienced with the fuel system.

1. The first filter should be a gauze trap in the filler of the fuel tank; this must not be removed when fuel is being poured into the tank. It should be taken out every 500 hours, cleaned, washed in fuel oil, and immediately replaced. If there is no filter in the filler of the fuel tank the fuel should be poured through a fine gauze strainer or a piece of chamois.

2. A primary fuel filter of the water collecting or separating type should be installed between the fuel tank and the fuel lift pump. The filter should be checked and cleaned every 100 hours. A recommended type is available from Westerbeke.

3. The secondary fuel filter (Fig. 3) is mounted to a bracket on the front right side of the engine. It is an element type filter and must be replaced every 300 hours unless the condition of the fuel warrants more regular attention. To remove filter element, proceed as follows:

a. Unscrew the center bolt on top of the filter head and detach the base and filter element. Discard element.

b. Remove the sealing ring from filter base and the sealing ring and "O" ring from filter head.

c. Wash base of filter in clean kerosene.

d. Install new filter element, sealing rings and "O" ring in reverse order, above.

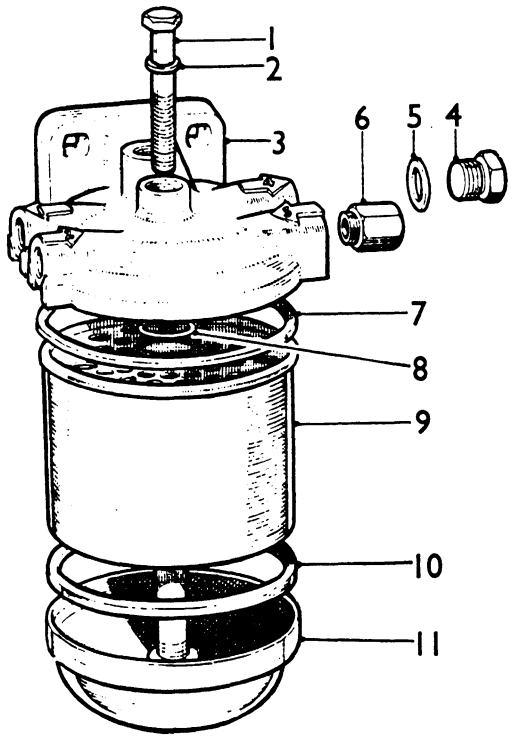


Fig. 3

Main fuel filter components

1. Centre bolt.
2. Washer.
3. Filter head.
4. Sealing plug.
5. Copper washer.
6. Non-return valve.
7. Sealing ring.
8. 'O' ring.
9. Element.
10. Sealing ring.
11. Filter base.

Lubricating Oil Filter

The importance of clean lubricating oil cannot be stressed too highly. If the time period specified (100 hours) for replacement of the spin-on-type filter element and the use of the same brand of oil is used during oil changes, a very long life can be obtained from the engine. The spin-on-type filter is secured to its filter head on the left hand side of the cylinder block. To replace filter, proceed as follows:

1. Run engine until oil is hot.

2. Remove dipstick, and with the aid of the hoses and pump supplied, fit the 3/8 in. I. D. hose over the dipstick tube and pump the oil from sump into a waste container.

3. Place a drip pan under filter or a polyethylene bag completely over filter canister, and turn spin on filter counter-clockwise to remove. Discard filter.

4. To replace filter, coat the gasket on the filter with oil. Place the filter in position and hand tighten filter until the gasket contacts the filter head; then advance one-half turn.

5. Fill sump with the "Approved Lubricating Oil" being used, to high mark on dipstick. Do not overfill.

Oil Capacity	Six-346	11.5 Qts.
	Four-230	8.0 Qts.

6. Start engine, run until normal operating temperature is reached, checking that filter joint is tight. Shut engine down, and add oil as required.

PRESERVATION OF LAID UP ENGINE

When a craft which is powered by a diesel engine is to be laid up for several months, it is advisable that some measure of protection be afforded the engine to ensure that it suffers no ill effects during storage.

Just before hauling (laying up) top off the fuel tank completely, so that no air space remains, thereby preventing water formation or condensation.

Start engine and run until normal operating temperature is reached, shut engine down.

Remove dipstick, and with the aid of the hoses and pump supplied, fit the 3/8 in. I.D. hose over the dipstick tube and pump the oil from the sump into a waste container.

Remove breather cap 3/4 in. fitting. Insert pump hose through breather fitting opening to bottom of housing and pump the oil out of the transmission. (Warner gear has a filler plug.)

Remove and Replace Lubricating Oil Filter: Place a drip-pan under filter and turn filter counter-clockwise to remove. Hand tighten filter until the gasket contacts the adapter face then advance filter one-half turn.

Fill Sump: Fill sump with high-detergent diesel lubricating oil to the high mark on dipstick. Do not overfill. Refer to "Recommended Lubricants," and always use the same brand of oil.

Sump Capacity	Six-346	11.5 Qts.
	Four-230	8.0 Qts.

Fill Transmission: Fill housing with Automatic Transmission Fluid Type "A", to high mark on dipstick. Do not overfill.

Drain Cooling System. Remove pressure cap from expansion tank and open drain tap (turn counter-clockwise) on right hand side of cylinder block, next to flywheel housing.

Filling Cooling System. Determine the capacity of cooling system (including keel pipes if installed) and fill system with the correct amount of anti-freeze and water for the degree of protection required, to within one inch from top of tank. Ensure drain tap is closed.

Remove the hex screw plug from side of heat exchanger and determine if zinc rod in the plug needs replacing. The zinc rod takes care of any electrolysis in the salt water system and should be checked every three months. Replace plug with new rod if necessary.

NOTE: All threaded screw fittings must have sealing compound on threads when replaced to prevent leakage.

Start Engine. Run engine until normal operating temperature is reached, to ensure proper mixing of, and circulation of anti-freeze. During this procedure exercise transmission in forward and reverse several cycles below 800 rpm to ensure that the new transmission fluid is properly circulated. Also check new lube oil filter mating surface for leakage.

After shutdown check oil level in sump, add lube oil if required to high mark on dipstick. Check lubricating fluid in transmission, add fluid if required to high mark on dipstick. Check level of

anti-freeze solution in expansion tank, add anti-freeze solution if required to within one inch from top of expansion tank.

To ensure that any sea water left in the sea water cooling will not freeze, an anti-freeze solution should be run through the system and expelled at the exhaust pipe outlet as follows: Close input through-hull fitting seacock. Disconnect hose from the seacock at its next connection. Attach and secure a separate length of hose to this connection (the same I. D. as hose removed) with its other end in a container of 50 percent anti-freeze and water, approximately two gallons. Start engine. Immediately check for flow of anti-freeze solution at exhaust outlet. Before end of hose in container of anti-freeze is uncovered, stop engine. Remove hose from connection and reconnect and secure original hose. Drain exhaust pipe by removing drain plug (if installed) at the water cooled section. Replace drain plug.

Remove air filter. Clean air intake filter, refer to "Filter Maintenance." Carefully seal air intake opening with a waterproof adhesive tape or some other suitable medium.

Seal the exhaust outlet at transom.

Change and clean all fuel filters.

Close all seacocks.

Disconnect batteries and store fully charged in a cool location. Before storing the battery, the battery terminals and cable connectors should be treated to prevent corrosion. Recharge battery every 30 days when in storage.

If winterization is performed by owner, notify yacht yard that engine is winterized and should not be run.

PREPARING THE ENGINE FOR RETURN TO SERVICE

1. Clean external parts of the engine.

2. Remove adhesive tape from air intake and install air filter.

3. Remove adhesive tape from exhaust outlet.

4. Connect batteries, fully charged, into circuit.

5. Open valves in fuel line.

6. Bleed fuel system, refer to "Operation - Bleeding Fuel System".

COOLING SYSTEM

COOLING SYSTEM

1. General

The Westerbeke Six-346 and Four-230 Marine diesel engines are equipped with a fresh water (closed circuit) cooling system. With this system a heat exchanger or keel pipes are utilized to cool the fresh water after it has circulated round the water jackets.

2. Heat Exchanger

Transfer of heat from the fresh water (closed system) circuit to the sea water is accomplished by a heat exchanger, similar to an automobile radiator; it differs because salt (raw) water, not air, cools the engine's fresh water. Heat rejected in combustion, as well as heat developed by friction is absorbed by the fresh water, which flows from the expansion tank into the heat exchanger, where it is cooled and discharged into the engine block and cylinder head by means of a centrifugal fresh water pump. Openings in the water jacket around the cylinder bores connect with corresponding openings in the cylinder head, where the fresh water then passes out through the thermostat into the expansion tank and the circuit repeats.

The engine is indirectly cooled by the unrestricted fast-flowing stream of raw water which absorbs the heat from the fresh water via the heat exchanger. This raw water is picked up from the sea by a powerful neoprene impeller sea water pump, and after passing through the dual oil cooler (engine and transmission) and through the heat exchanger, is discharged overboard. The dual oil cooler above conducts heat away from the bearings and other frictional surfaces by the flow of lubricating oil which is circulated by oil pressure pumps and cooled by the flow of raw water through the tubes of the cooler.

3. Keel Pipes

When keel pipes are used, which is a simplified version of the heat exchanger system described above, the fresh water (closed system) circuit is drawn from the keel pipes through the dual oil cooler, movement being assisted by a centrifugal type water pump, where it is circulated around the cylinder liners and cylinder head water jacket, to the combination expansion tank and exhaust manifold, and finally returns to the keel pipes that are cooled by the sea water outside the hull.

4. Drain Cooling System

To drain fresh water cooling system, remove expansion tank filler cap and open drain tap (turn counter-clockwise) on right hand side of cylinder block next to flywheel housing and fresh water drain tap on heat exchanger.

Two drain taps are installed on bottom of the exchanger, the forward tap for raw water and the center tap for fresh water.

5. Fresh Water Pump

The water is circulated by a centrifugal pump which is mounted on the front of the cylinder block and driven by a "V"-belt from the crankshaft.

To Remove Pump:

Loosen the set bolt securing the alternator to its mounting bracket. Slacken the alternator adjustment strap bolts and swing alternator toward the cylinder block to release tension of the belt. Remove the belt. Remove the four nuts securing the water pump body to the impeller housing, and withdraw the water pump, noting the pump body to impeller housing gasket.

Disconnect the inlet and by-pass hoses from the impeller housings. Unscrew the six bolts and remove the impeller housing and its joint washer from the cylinder block.

To Dismantle:

a. Withdraw the pulley hub from the water pump spindle, using an extractor.

b. Extract the bearing retaining clip through the hole in the top of the pump body, and drive the spindle and bearing assembly rearwards out of the body.

c. Withdraw the impeller from the spindle, using an extractor, and remove the water seal.

To view and overhaul:

a. Check the spindle and bearing assembly for wear and ensure that the bearing seals are in good condition.

b. Check that the interference of the pulley hub, and the impeller, on the spindle has not been destroyed.

c. Inspect the water seal for damage and wear.

To Reassemble:

Reassembly is a reversal of the procedure "To Dismantle", noting the following:

a. Ensure that the hole in the bearing coincides with the lubricating hole in the pump body.

b. Assemble the pulley hub and the impeller to the dimensions given in Figure 4

To Install

Reverse the procedure "To Remove", tensioning the drive belt so that it can be pressed in one in. (25.4 mm.) at the center of its vertical run.

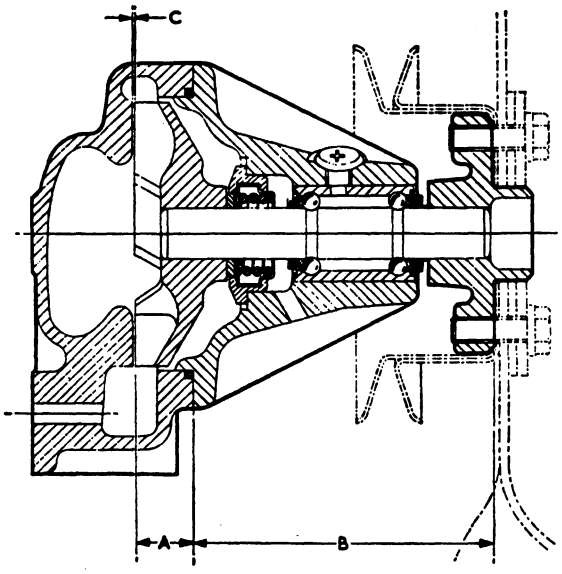


Fig. 4

Water pump assembly dimensions

A = ·731 to ·738 in. (18·57 to 18·74 mm.).
B = 3·670 to 3·700 in. (93·22 to 94·00 mm.).
C = ·010 to ·021 in. (·25 to ·53 mm.).

6. Thermostat

A thermostat is installed in the thermostat housing mounted on the front of the cylinder head above the fresh water pump. The thermostat impedes the circulation of the fresh water into the expansion tank until it has reached a predetermined temperature in the cylinder block and so provides a more rapid warming up of the engine.

Normal operating temperature is 170 to 190°F (77 to 87°C).

To Remove:

a. Drain the cooling system.

b. Disconnect the outlet hose from the outlet pipe.

c. Release the two set bolts and remove the outlet pipe from the thermostat housing.

d. Lift out the thermostat from its housing.

To View and Overhaul:

a. Test the thermostat by immersing it in water and heat up, checking the temperature. The thermostat valve should start to open between 170 and 176°F (77 and 80°C), and be fully open at 201°F (94°C). If the valve does not open between the given temperatures, or it sticks in the fully open position, the thermostat should be renewed. No attempt should be made to repair the thermostat.

b. Clean the joint face of the water outlet pipe and thermostat housing.

To Install:

The installation of the thermostat is a reversal of the procedure "To Remove". Fit a new joint gasket between the thermostat housing and the water outlet pipe.

7. Alternator V Belt Adjustment

The purpose of the following adjustment is to maintain the performance of the alternator and fresh water pump at their maximum, and consists of moving the alternator in relation to the cylinder block to adjust the tension of the belt. Proceed as detailed below. Other specific performance faults should be diagnosed by referring to "FAULT DIAGNOSIS."

a. Referring to Fig. 5 , slacken the alternator securing bolt (A). Support the alternator with one hand and release the set bolt (B) and nut (C).

b. Using a hard hand pressure, press on the alternator sufficiently to swing it away from the side of the cylinder block, thereby taking up any slackness in the belt.

c. The belt should be adjusted so that when securing bolts are finally locked up, the long run of the belt can be pressed in 1 inch (25 mm.) at the center by normal thumb pressure.

NOTE: It is important that the fan belt is always run taut as any slackness will cause slip and rapid wear of the belt.

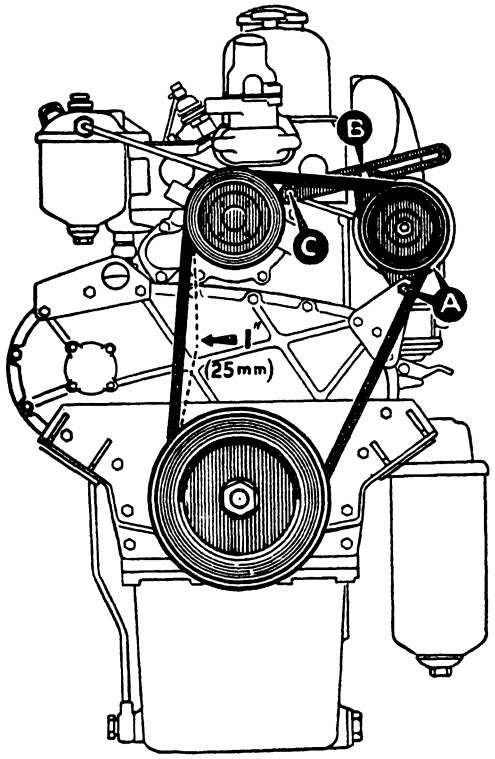


Fig. 5
Fan belt adjustment

8. Sea Water Pump

The sea water pump contains a neoprene impeller and is mounted on the timing gear case cover and is driven by the timing gear train. The pump is self-priming.

To Remove Pump:

Remove set screw on underside of pump and drain.

Uncouple inlet and outlet hose connections.

Unscrew the four capscrews, and lift pump away from timing gear case cover.

Remove gasket between pump and gear case cover.

Replace pump by reversing the above procedure. Use new gasket between pump and gear case cover. Use sealing compound when replacing drain set screw.

NOTE: The sea water system must be completely free of air leaks. Refer to "Cooling System Check."

To Dismantle:

Remove cover and cover gasket.

Remove impeller from pump shaft by means of suitable pliers. Drive key need not be removed.

Remove the large retainer ring from drive end of pump.

A suitable press may be used to drive the shaft, seal, and seat out the impeller end of pump.

Remove the retainer ring and bearing from inside pump body.

Clean, inspect and replace any parts that show damage or wear.

Reverse the procedure above, coating impeller with a thin coat of glycerine or a good grade of water pump grease.

Replace cover with new gasket.

Secure pump to timing gear cover by reversing the procedure "To Remove."

9. Electrolysis Control

Located on the left rearside of the heat exchanger is a zinc electrode, which detects stray electrical currents often resulting from faulty ground connections and corroded terminals in other parts of the electrical circuits. This electrode should be checked at least once a month and if it disintegrates rapidly, all terminals and ground connections should be cleaned by scraping or sandpapering and tightened. Normal life of the electrode in salt water should be at least 3 months.

10. Cooling System Test

The fresh and raw (salt) water systems must be completely free of air leaks. Air in the system will reduce pump lubrication and shorten the sea water pump neoprene impeller life.

To check the raw water system for leaks, disconnect the outlet water hose from the pump and insert it in a bucket of water. Run the engine and watch for air bubbles in the discharge. Any bubbles indicate an air leak in the raw water cooling system which can damage the pump impeller, rubber exhaust line or a neoprene rubber muffler if installed.

NOTE: Do not run engine for more than one minute.

FUEL INJECTION SYSTEM

The principal components of the equipment for delivering the fuel oil to the engine cylinders are as follows:

Fuel Filters.
Fuel Lift Pump.
Fuel Pump.
Injection nozzles.

The fuel lift pump "lifts" the fuel from the tank to the fuel pump, which conveys it in measured quantities, and at appropriate intervals, to the injection nozzles.

In the fuel system the normal course of the fuel from the tank to the engine is first to the Primary fuel oil filter; then the Secondary fuel oil filter; and finally the fuel injection pump and injection nozzles.

Two conditions are essential for efficient operation.

First, because the fuel oil ignites by heat of compression, it must be clean, free from suspended dirt, sand and other foreign matter.

Second, that the fuel reaches the fuel pump in a perfectly clean state.

Fuel should be filtered before entering the tank.

Given these conditions, ninety per cent at least of potential engine troubles would be eliminated. Attention, therefore, should be earnestly directed towards the section of this handbook which refers to the care and upkeep of the filtering apparatus.

The Fuel Lift Pump.

The lift pump is of the diaphragm type. It is fitted to the tappet inspection cover on the off-side of the engine and is driven by a cam on the engine camshaft.

A hand primer is fitted for use if the supply of fuel from the tank has at any time failed.

To use this primer, pump by hand until pipes, lift pump, filters and fuel pump are full of fuel oil.

Fuel Pump.

The fuel pump is an instrument of precision. Its working parts are made to extremely fine limits, and mishandling in any shape or form, or the entry of the smallest particle of dirt into its working parts may damage it and diminish its accuracy of operation. Hence the importance of making sure that the fuel is thoroughly filtered before the pump is reached.

When requesting information regarding the fuel pump, the type and number should be quoted. This can be obtained from a plate fitted to the pump gallery above the inspection plate.

Where service is required, the matter should be referred to the fuel pump manufacturer's agents.

Injection Nozzles.

Injection nozzles and holders are attached to the cylinder head with a two-bolt flange and two hex head nuts.

The connection between the nozzle holder and cylinder head is made with a special copper washer between the lower face of the nozzle cap nut and the recess in the cylinder head.

When putting the nozzle holders in place in the cylinder head, care should be taken that only this type of copper washer is used. The recess in the cylinder head, the faces of the copper washer and the corresponding face of the nozzle cap should be perfectly clean if a leak-proof joint is to result.

It is always advisable to fit a new copper washer when the nozzle holder is replaced, after having been removed for any reason.

Make sure the old washer has been removed from the cylinder head or nozzle holder.

The joint washer should be an easy, but not loose fit for the injection nozzle, and it is because this is such an important feature that only wash-

ers especially made for the puspose should be used and none other. Under no conditions should an ordinary spark plug type washer be used.

The nozzle holders can now be fitted in place. Before tightening down it should be ascertained that the nozzle holder is correctly placed and that the fuel pipes can be fitted without bending them.

Fuel Pipes.

No two of the pressure pipes from the fuel pump to the injection nozzles are alike. Keep this in mind when replacing.

Place in position the pipe to the fuel pump and injection nozzle unions to check that the pipe fits square at both ends. Do not fit one end and then bend the pipe to square it with the other union.

When fitting the pipe, tighten the unions alternatively a little at a time, first one end and then the other.

If the pipe is square to the unions at each end as described above, no force will be needed to make a good joint. No force should be used.

When changing an injection nozzle, always remove the pipe entirely. Never take off only one end, leaving the other tight. Never bend the pipe.

Maintenance.

Injection nozzles should be taken out for examination at regular intervals. How long this interval should be is difficult to advise, because of the different conditions under which the engine operates.

When combustion conditions in the engine are good and the fuel tank and filtering system are maintained in first class order, it is often sufficient if the nozzles are tested twice yearly or every 1000 hours.

Nozzles should not be removed for checking unless a nozzle tester is available or spare nozzles are on hand for replacement.

With the cooling system maintained in good condition and absolutely clean fuel are used, the less attention the nozzles will need, and so their efficient life. In this connection, since there is no other item of the equipment upon which the performance of the engine depends so much, it pays the user to see that the engine never runs with any of the nozzles out of order.

Troubles in Service.

The first symptoms of injector nozzle trouble usually fall in one or more of the following headings:

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

Often the particular nozzle or nozzles causing trouble may be determined by releasing the pipe union nut on each nozzle in turn, with the engine running at approximately 1,000 rev/min. This will prevent fuel being pumped through the nozzle to the engine cylinder, thereby altering the engine revolutions. If after slackening a pipe union nut, the engine revolutions remain constant, this denotes a faulty nozzle.

The complete unit should then be withdrawn from the cylinder head and turned round, nozzle outwards, on its pipe, and the unions retightened.

After slackening the unions of the other injection pipes (to avoid the possibility of the engine starting), the engine should be turned until the nozzle sprays into the air, when it will be seen at once if the spray is in order. If the spray is unduly "wet" or "streaky" or obviously to one side, or the injection nozzle "dribbles" then the complete unit should be replaced (See Fig. 110). The faulty unit then being securely wrapped in clean greaseproof paper or rag with the protection cap on the nozzle for attention on the maintenance bench.

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

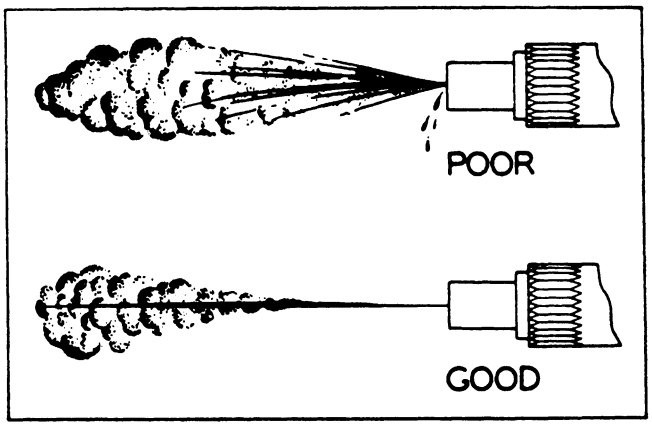


Fig. 110–Nozzle Spray Pattern

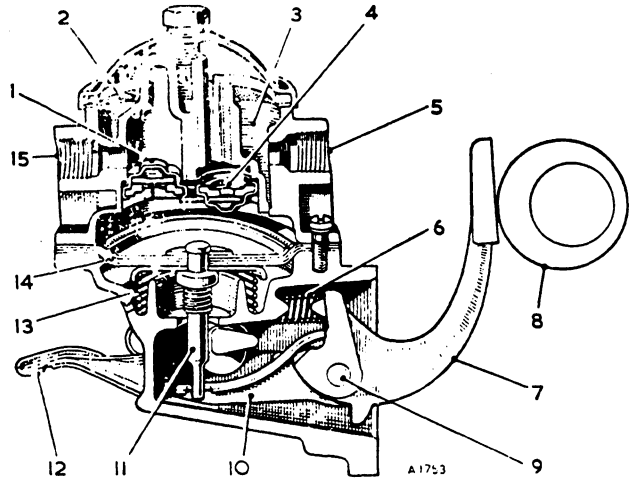


Fig. Da.1

Fuel lift pump components

1. Delivery valve.
2. Filter gauze.
3. Sediment chamber.
4. Inlet valve.
5. Inlet port.
6. Rocker arm spring.
7. Rocker arm.
8. Camshaft eccentric.
9. Pivot pin.
10. Link.
11. Pull-rod.
12. Hand priming lever.
13. Diaphragm spring.
14. Diaphragm.
15. Outlet port.

Section Da.1

DESCRIPTION OF THE FUEL LIFT PUMP

The fuel lift pump is mounted on the crankcase and is operated by an eccentric on the engine camshaft. A hand priming lever permits pumping a supply of fuel for testing purposes.

When the lift pump output is greater than the fuel injection pump requirements the fuel in the pumping chamber holds the diaphragm against the pressure of the diaphragm spring, and the connecting link allows an idling movement of the rocker arm. A spring maintains the contact between the rocker arm and the eccentric thus eliminating noise.

Section Da.2

REMOVING AND REPLACING THE FUEL LIFT PUMP

Disconnect the two fuel pipes from the body of the pump, unscrew the two set bolts securing the pump to the crankcase and withdraw the pump and its joint washer.

Before replacing the pump, which is a reversal of the foregoing procedure, the pump should be tested. In the absence of special test equipment the pump may be tested as follows:

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, 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.

In a similar manner seal the delivery side of the pump (marked 'OUT') 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. Finally repeat this test, but immediately the pumping chamber is charged with air immerse the pump in a bath of clean paraffin and inspect the diaphragm clamping flanges for signs of air leakage.

Lubricate the rocker arm and the rocker arm pin with clean engine oil and after replacing the pump bleed the fuel system

Section Da.3

DISMANTLING AND REASSEMBLING THE FUEL LIFT PUMP

Scribe a mark across the pump body joint flanges for guidance when reassembling.

Remove the set bolt, detach the dome cover and its sealing ring, and lift off the filter gauze.

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

Remove the two screws and withdraw the retaining plate, inlet and outlet valves, and valve gasket from the upper half of the pump body.

Press the diaphragm downwards and turn it clockwise through an angle of 90° to release the diaphragm pull-rod from the connecting link. Withdraw the diaphragm and its return spring from the lower half of the pump body.

Remove the rocker arm pin retaining clips and with-

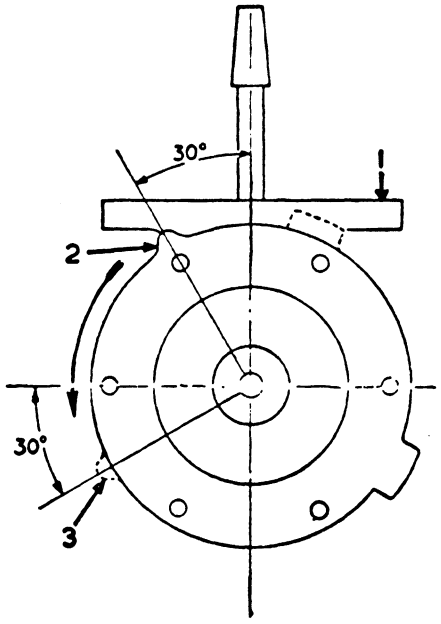
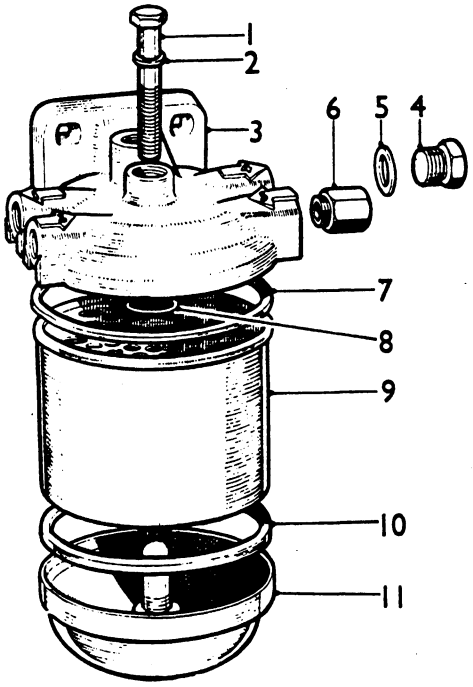


Fig. Da.2

Diaphragm assembly diagram

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



Main fuel filter components

1. Centre bolt.
2. Washer.
3. Filter head.
4. Sealing plug.
5. Copper washer.
6. Non-return valve.
7. Sealing ring.
8. 'O' ring.
9. Element.
10. Sealing ring.
11. Filter base.

draw the pin to release the rocker arm, distance washers, spring, and connecting link.

Detach the spring from the priming lever.

Reassembly is a reversal of the foregoing procedure noting the following.

(1) Ensure that the diaphragm and pump mounting flanges are true. They may be lapped to restore their flatness.

(2) Check that the wear on the rocker arm working surface does not exceed ·010 in. (·25 mm.).

(3) The rocker arm pin should be a tap fit in the pump body; this may be restored by peening the holes in the body.

(4) Locate the diaphragm return spring in the diaphragm lower protector washer and insert the diaphragm into the pump body with its locating tab in the 11 o'clock position (see Fig. Da. 2). Press the diaphragm downwards and turn it anticlockwise through an angle of 90° to engage the diaphragm pull-rod with the connecting link.

(5) When assembling the two halves of the pump body ensure that the marks scribed on the joint flanges before dismantling coincide. Hold the diaphragm, by means of the rocker arm, level with the joint flange and secure the two halves of the pump body, leaving the screws finger-tight. Push the rocker arm towards the pump body to position the diaphragm at the bottom of its stroke and tighten the securing screws diagonally.

(6) Test the pump as described in Section Da. 2.

Section Da.4

DESCRIPTION OF THE MAIN FUEL FILTER

The main fuel filter is of the cross-flow type employing a resin impregnated paper as the filtration medium.

The main parts of the unit are a die-cast head and a lower plate assembly; clamped between which is a metal canister containing the filter element.

An 'O' ring located in an annular groove in the centre boss of the filter head seals the dirty side of the filter from its clean side.

The air bleed point, which is on the clean side of the filter, is connected to the fuel injector leak-off pipe and provides continuous air-bleeding of the filter during operation.

Section Da.5

REMOVING AND REPLACING THE MAIN FUEL FILTER

Disconnect the fuel pipe and leak-off connections from the filter head.

Remove the two bolts and nuts securing the filter to its bracket and withdraw it from the engine.

The installation of the fuel filter is a reversal of the removal procedure.

Bleed the fuel system

Section Da.6

DISMANTLING AND REASSEMBLING THE MAIN FUEL FILTER

Unscrew the bolt from the centre of the head casting and detach the bottom plate 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 bottom plate.

Thoroughly clean all components, excepting the element, in petrol and allow them to dry.

Reassembly is a reversal of the foregoing procedure, using a new element and sealing rings. The element is fitted with its strengthened rim uppermost.

Section Da. 7

DESCRIPTION OF THE FUEL INJECTORS

The fuel injectors each comprise two main parts, the nozzle and the nozzle holder, which are clamped together axially by a nozzle nut. The mating faces of both the nozzle and the nozzle holder are lapped to ensure a high pressure seal.

The nozzle is of the long-stem type, having four equally spaced holes at an angle of 20° from the nozzle centre line and positioned to give a spray cone angle of 140°. The nozzle valve is accurately lapped into the nozzle body to give the closest possible fit within which it will operate freely.

The nozzle holder contains a spindle and spring which retains the nozzle valve on its seat. The upper end of the spring is located in an adjustable cap nut by which the opening pressure of the nozzle is set.

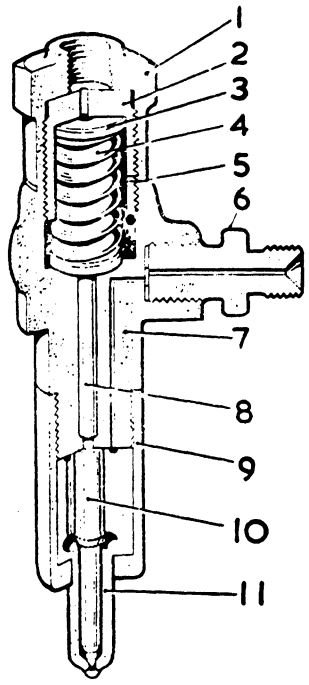


Fig. Da.18

Fuel injector

1. **Cap nut.**
2. **Spring cap nut.**
3. **Spring plate.**
4. **Spring.**
5. **Joint washer.**
6. **Feed-pipe union.**
7. Nozzle holder.
8. Spindle.
9. Nozzle nut.
10. Needle valve.
11. Nozzle body.

Lubrication is by back leakage of fuel past the nozzle valve and a leak-off connection on the nozzle holder returns this fuel to the fuel tank.

Section Da. 8

REMOVING AND REPLACING AN INJECTOR

Disconnect the injector feed pipe union nut and all the injector leak-off unions.

Remove the two set bolts securing the injector to the cylinder head and withdraw the injector, using tool 18G 491 A.

If the injector is to be stored for any length of time seal its inlet union, using sealing cap 18G 216.

Thoroughly clean the copper sleeve in the cylinder head, ensuring that all carbon is removed from its bottom face.

Place the injector in position in the cylinder head and tighten the securing bolts, using torque wrench 18G 537 set to the figure given in **'GENERAL DATA'.**

Connect the fuel feed pipe and leak-off unions.

Section Da. 9

DISMANTLING AND REASSEMBLING THE INJECTORS

As in the case of injection pump dismantling, absolute cleanliness is essential when work is being carried out on the injectors.

Mount the injector in dismantling fixture 18G 388, unscrew the injector cap nut, and remove the copper joint washer. Unscrew the spring cap nut and remove the spring plate, spring, and spindle.

Using spanner 18G 210, remove the nozzle nut and nozzle, taking care not to let the valve drop out of the nozzle body.

NOTE.—Each nozzle body and valve are a mated assembly and should always be kept together.

Thoroughly clean the injector components, using cleaning kit 18G 487 when dealing with the nozzles.

Using the brass wire brush, remove all carbon from the nozzle body and nozzle valve. Examine the valve for scoring and scratches, and for blueing due to overheating.

Clean out the internal feed passages, the annular gallery, and the valve seat, using the brass scrapers, and clear the spray holes with an appropriate size cleaning wire fitted to the probing tool.

Assemble the nozzle body into adaptor 18G 109 E with the nozzle tip towards the inlet connection. Connect the adaptor to testing machine 18G109 A, and reverse-flush the nozzle (See Fig. Da.25) to clear all loose carbon from the internal passages.

Where the carbon build-up is particularly hard it may be softened in the following manner:

Prepare a 10 per cent. solution of caustic soda with an added detergent by dissolving 2 oz. (56 gm.) of caustic soda in 1 pint (·57 litre) of water and add ½ oz. (14 gm.) of an ordinary washing detergent. Place the nozzle bodies in the liquid, bring it to the boil, and allow it to boil for a minimum of 1 hour and not more than 1½ hours. Take care not to allow the water to evaporate too much, because if the percentage of caustic soda rises above 15 per cent. the surface of the nozzle bore and sealing face may be roughened, making it impossible for the injectors to be serviced correctly.

Remove the nozzle bodies from the solution, wash them in running water, and then immerse them in a dewatering oil such as Shell Ensis 254. Remove the surplus oil by draining or compressed air.

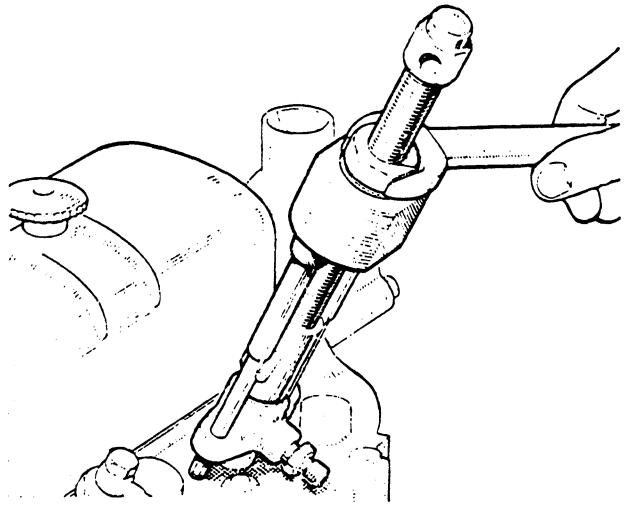


Fig. Da.19

Withdrawing an injector, using tool 18G 491 A

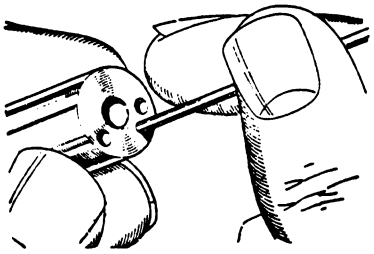


Fig. Da.20

Clearing the feed channel bores

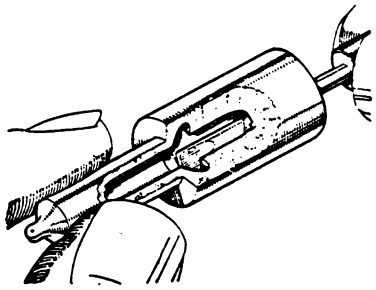


Fig. Da.21

Cleaning the carbon from the fuel gallery

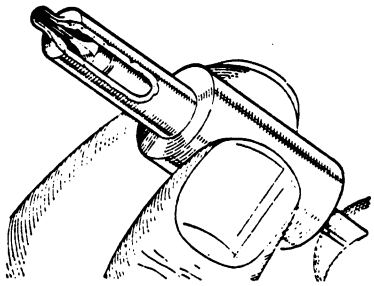


Fig. Da.22

Decarbonizing the dome cavity

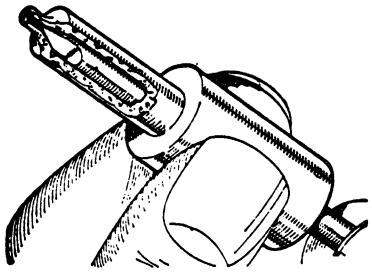


Fig. Da.23

Cleaning the valve seat

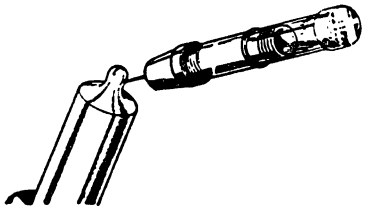


Fig. Da.24

Clearing the spray holes

The carbon may now be removed, using cleaning kit 18G 487 as already described.

To reassemble the injector, thoroughly wash all the injector components in clean calibration fluid. Immerse the nozzle body and valve in a bowl of clean calibration fluid and assemble them under the liquid. The valve should fit easily and without any tightness.

Mount the nozzle holder in fixture 18G 388, make sure the mating faces of the nozzle holder and nozzle body are perfectly clean and undamaged, and place the nozzle assembly in position on the nozzle holder. Fit the nozzle nut and tighten carefully, using spanner 18G 210 and torque wrench 18G 372 set to the figure given in **'GENERAL DATA'. Do not overtighten the nozzle nut.**

Reassemble the spindle, spring, and spring plate, and fit the spring cap nut and the injector cap nut with its copper joint washer.

Test and set the injector as described in Section Da. 10

Section Da 10

TESTING AND ADJUSTING THE INJECTORS

To test or adjust the injectors it is necessary to use testing machine 18G 109 A, and an oil such as Shell Calibration Fluid 'C', which will not affect the skin of the operator, should be used in the machine.

WARNING.—When an injector is being tested the spray holes in the nozzle should always be turned away from the operator.

Before removing an injector from the testing machine, close the check valve to the pressure gauge in order to prevent damage, which may result from a sudden drop in pressure.

Checking and adjusting the nozzle opening pressure

Connect the injector to the testing machine, open the check valve and operate the pump lever. Note the reading on the pressure gauge at the instant the nozzle sprays.

If the pressure is incorrect (see **'GENERAL DATA'**), adjust the spring cap nut until the correct injection pressure is obtained.

Check the tightness of the injector cap nut and make sure that the copper joint washer is in position.

Checking the nozzle spray

Close the check valve to cut out the pressure gauge and operate the pump lever at the rate of 60 strokes per minute. There should be four equal sprays from the nozzle, evenly distributed, and each spray should persist for about 6 in. (15 cm.) without any visible core or jets of

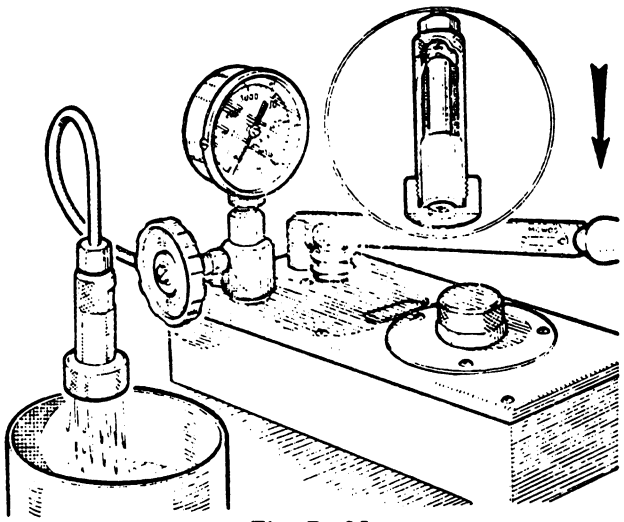


Fig. Da.25

Reverse flushing an injector nozzle, using testing machine 18G 109 A and adaptor 18G 109 E. Shown inset is a sectioned adaptor with the nozzle in position.

After 30 seconds lapping time withdraw the nozzle, clean the lap, and examine the conical lap tip. There will be a mat surface where the lap has been in contact with the nozzle seat, and in the early stages of lapping this mat surface will probably be narrow or have a bright circumferential ring in the middle. These markings indicate the extent of the wear on the nozzle seat.

The lap should be refaced, as already described, after every 1½ minutes of lapping time, but in the case of a badly worn nozzle seat it may be necessary to reduce this time.

Wipe the lap stem clean and recoat it with tallow. Recharge the tip of the lap with lapping paste and continue lapping until the seat is free from scores and grooves. When the seat appears satisfactory after a few seconds lapping with a freshly ground lap, charge the lap with fine lapping paste and continue lapping until a smooth mat surface is produced over the entire seat. Throughout the lapping operation the lap should be cleaned and examined after every 30 seconds of lapping time.

Thoroughly clean the nozzle by 'reverse-flushing' as described in Section Da. 9 , and dry out with compressed air. Make a final inspection of the nozzle seat under the microscope.

Examine the conical valve face of the nozzle valve under the microscope for scoring and pitting. The most critical part of the valve face is the angle formed by the conical face and the parallel stem on which the conical face is formed. This angle should be sharp and clearly defined with no 'rounding' or wear breaking the 'knife-edge' anywhere on its diameter. The reason for this is to ensure a high pressure, fuel proof line-contact between the nozzle valve and seat. If wear is evident the conical valve face should be refaced on the nozzle grinding and lapping machine.

Ensure that the grinding-wheel is dressed correctly and that the refacing angle is set for the nozzle valve (see **'GENERAL DATA').**

Mount the valve in the lathe of the machine and reface the conical tip in the same way as already described for the nozzle body lap.

Remove only the absolute minimum of material; sufficient to change the colour of the valve face is enough, otherwise the needle lift will be affected. As a guide, there should be no sparks or audible hiss from the grinding-wheel when carrying out this operation.

The operation is best observed through a magnifying-glass, the point of focus being the surface of the conical face away from the grinding-wheel.

In the event of the nozzle valve being a tight fit in the nozzle body, due to slight distortion or deposits on the guide surface of the valve, it is possible to restore the fit.

Mount the nozzle valve in the lapping chuck of the machine, using a suitable adaptor chuck, and apply a very small quantity of fine lapping paste to the guide surface of the valve. Start the machine and thread the lapping collet, supplied with the machine, over the rotating valve. Oscillate the collet over the valve guide surface and after every 10 to 15 seconds of lapping time clean the valve and test it for correct fit in the nozzle body. A correctly fitting valve should just slide into the nozzle body under its own weight when lubricated with fuel oil.

After attention to the nozzle body valve seat or to the valve seat face on the nozzle valve, check the nozzle valve lift (needle lift) against the figure given in **'GENERAL DATA'.** If the needle lift is excessive it may be restored by lapping the joint face of the nozzle body on a surface lapping plate.

When lapping the nozzle face, extreme care should be taken to avoid tilting the nozzle, as this face makes a high pressure joint with the nozzle holder and must therefore be true and at right angles to the nozzle axis.

Reassemble the injector as described in Section Da 9 and test and adjust it as described in Section Da. 10

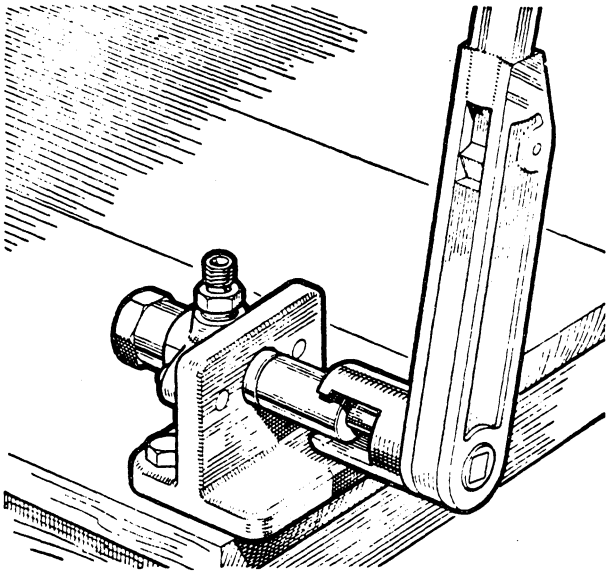


Fig. Da.26

Reassembling an injector, using fixture 18G 388 and spanner 18G 210 with torque wrench 18G 372

unatomized fuel. If the spray is not correct, or if any leaks or dribble occur wipe the nozzle dry and repeat the test to locate the cause.

Checking the pressure tightness of seatings

Open the check valve, wipe the nozzle dry, and depress the pump lever slowly until a pressure of 160 atmospheres is obtained. Hold this pressure for 10 seconds and then check the nozzle tip for dryness—slight dampness is permissible. If in doubt, maintain the 160 atmospheres pressure for 60 seconds while holding a piece of blotting-paper below the nozzle tip. The diameter of the wet spot on the paper should not exceed ½ in. (13 mm.).

Checking the back-leakage

Depress the pump lever slowly until a pressure of 160 atmospheres is obtained, then check the time taken for the pressure to drop from 150 to 100 atmospheres. For a new nozzle the time taken should be 12 to 30 seconds. A nozzle which has been in service will show a faster pressure drop but as this does not seriously affect engine performance a nozzle may be considered serviceable until a time factor of less than 5 seconds is recorded.

Section Da 11

RECLAIMING INJECTOR NOZZLES

If after dismantling, cleaning and testing, as described in Sections Da. 9 and Da. 10 an injector is found to be unsatisfactory, it is usually possible to recondition the nozzle providing it has been found satisfactory when **'Checking the back-leakage'.**

To recondition a nozzle the use of a nozzle grinding and lapping machine is required. A nozzle microscope is also necessary for inspection of the nozzle body and valve during the reclaiming process.

Select a suitable lap from those supplied with the grinding and lapping machine. The bore diameter varies slightly from one nozzle to another, and it is necessary to choose a lap which fits the nozzle body in the same manner as the nozzle valve. This will ensure concentricity of the valve seat in the body with the body bore after lapping.

Mount the lap in the lathe of the nozzle grinding and lapping machine and grind the conical tip to the correct nozzle body seat angle as given in **'GENERAL DATA'.** The lap should be passed slowly backwards and forwards across the surface of the grinding-wheel, feeding-in the lap very gradually until its conical surface is entirely cleaned up. Inspect the lap under the nozzle microscope to ensure that its ground surface is smooth. If the surface appears rough the grinding-wheel should be dressed.

Fit the lap into the lapping chuck of the machine and apply a coating of tallow to the guide surface of the lap for lubrication purposes. Apply a very small quantity of lapping paste to the tip of the lap, taking care that the paste does not extend to the top of the cone.

NOTE.—If any lapping paste is allowed to get between the guide surfaces of the lap and the nozzle body, the clearance between the nozzle body and valve will be increased and the nozzle will probably be made unserviceable.

Start the machine and carefully slide the nozzle over the rotating lap. Oscillate the nozzle on the lap, in very short strokes, at a rate of 20 to 30 strokes per minute. engaging the nozzle seat with the lap at the end of each stroke. The lap should not remain in contact with the nozzle seat for more than five seconds at a time and the pressure applied to the nozzle should be light. Excessive pressure will cause grooving of the nozzle seat.

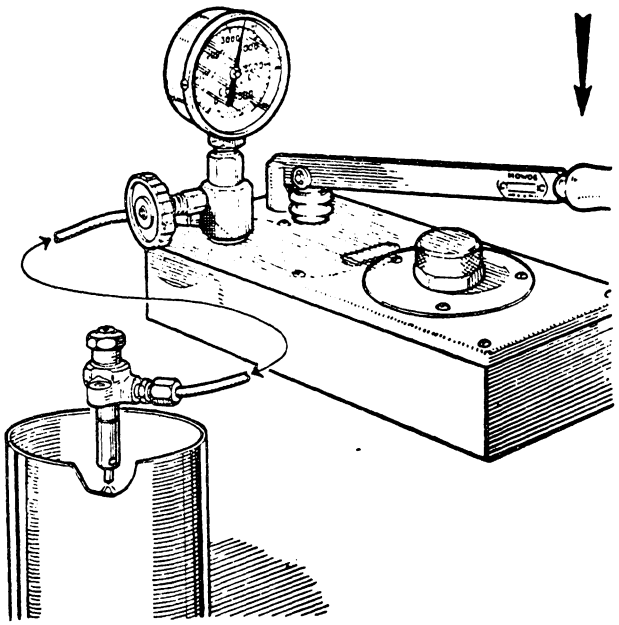


Fig. Da.27

An injector assembled to machine 18G 109 A ready for spray testing

D. P. A. TEST DATA

Pump Type: 3248880A - 3248889A

Engine: FOUR-230

BASIC PUMP SPECIFICATION

Mechanical governor, with Anti-stall device
Light load advance device
Rotation (looking on drive end) - Clockwise
Governor link length 52.5 mm ± 1 mm nominal
Governor control spring No. 2 hole control arm and No. 2 hole throttle lever link
Roller to roller dimension 50.37 mm
Plunger diameter 6.5 mm

TEST PROCEDURE

Fit auto-advance measuring device and set scale to zero before commencing test. Where marked thus use 30 seconds glass draining time and allow fuel to settle for 15 seconds before taking reading.

Shimming of Light Load Advance Device.

A 0.5 mm shim is fitted to the piston cap on assembly. This must NOT be removed. No further shimming is necessary. Throttle idle and maximum speed screw fully retracted.

Test No.	Description	R. P. M.	Requirements
1	Priming	100 max.	Fuel delivery from all injectors.
2	Transfer pump vacuum	100	Note time to reach 16 in. (406 mm) Hg. Max. time allowed 60 secs.
3	Transfer pressure	100	11 lb/in^2 (0.8 kg/cm^2) min.
4	Transfer pressure	1250	48 to 60 lb/in^2 (3.4 to 4.2 kg/cm^2)

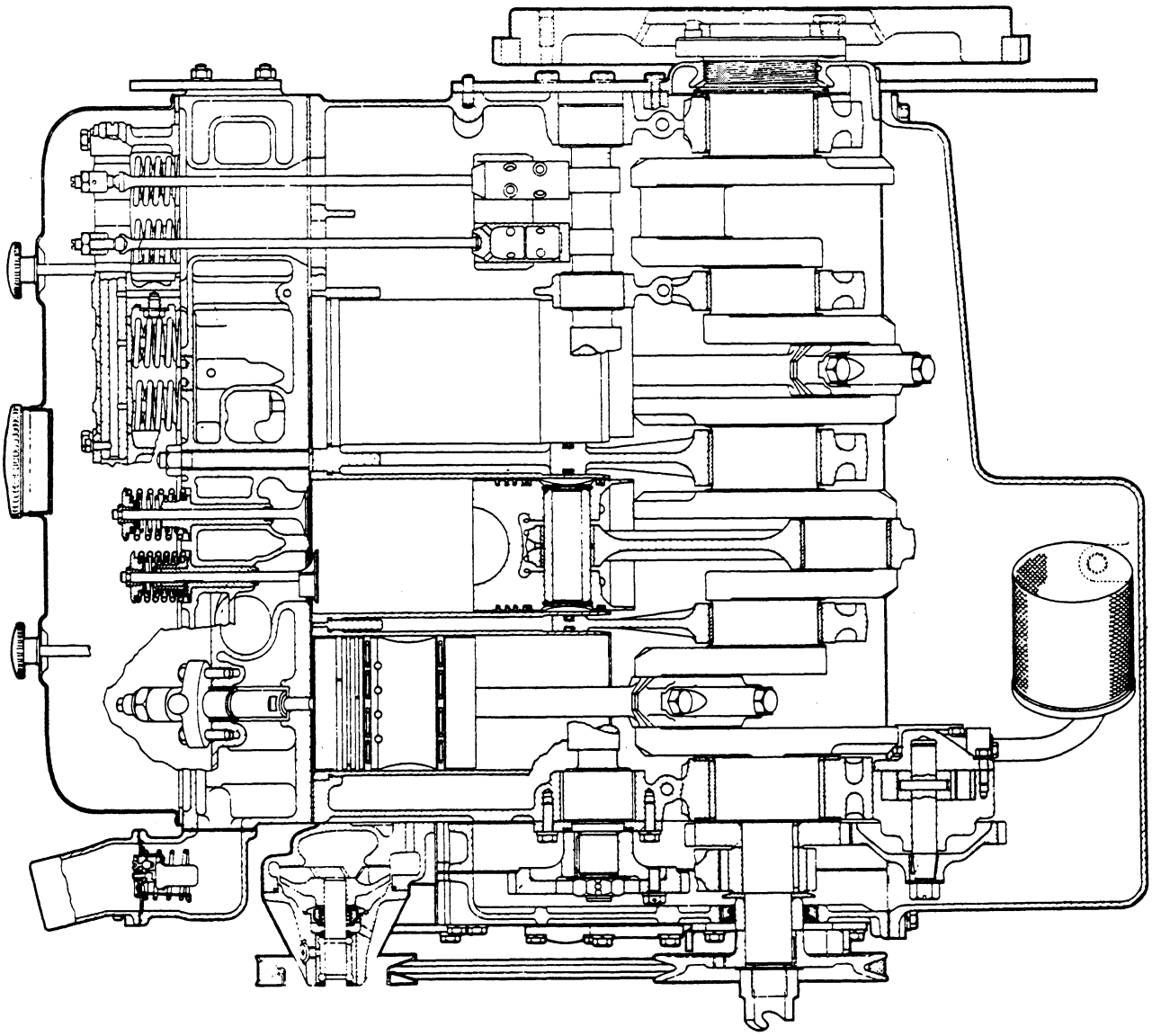
NOTE: on tests 5 and 6. To obtain the required degree of advance use the metering valve adjuster on the end of the governor housing.

5	Delivery setting	1250	Fit shut-off lever adjustment tool to pump. Obtain average delivery 6.0 to 6.8 cc by shut-off lever adjustment. Note- Advance indicator must show zero.
6	Advance setting	1250	With shut-off lever as at (5) set external adjustment to obtain 1-3/4° to 2-1/4° advance
7	Delivery check	1250	With shut-off lever and external adjustment as at (5) and (6) average delivery to be 6.0 to 6.8 cc.
8	Advance check	1250	With shut-off lever fully closed, advance to be 3-1/2° to 4-1/2°.

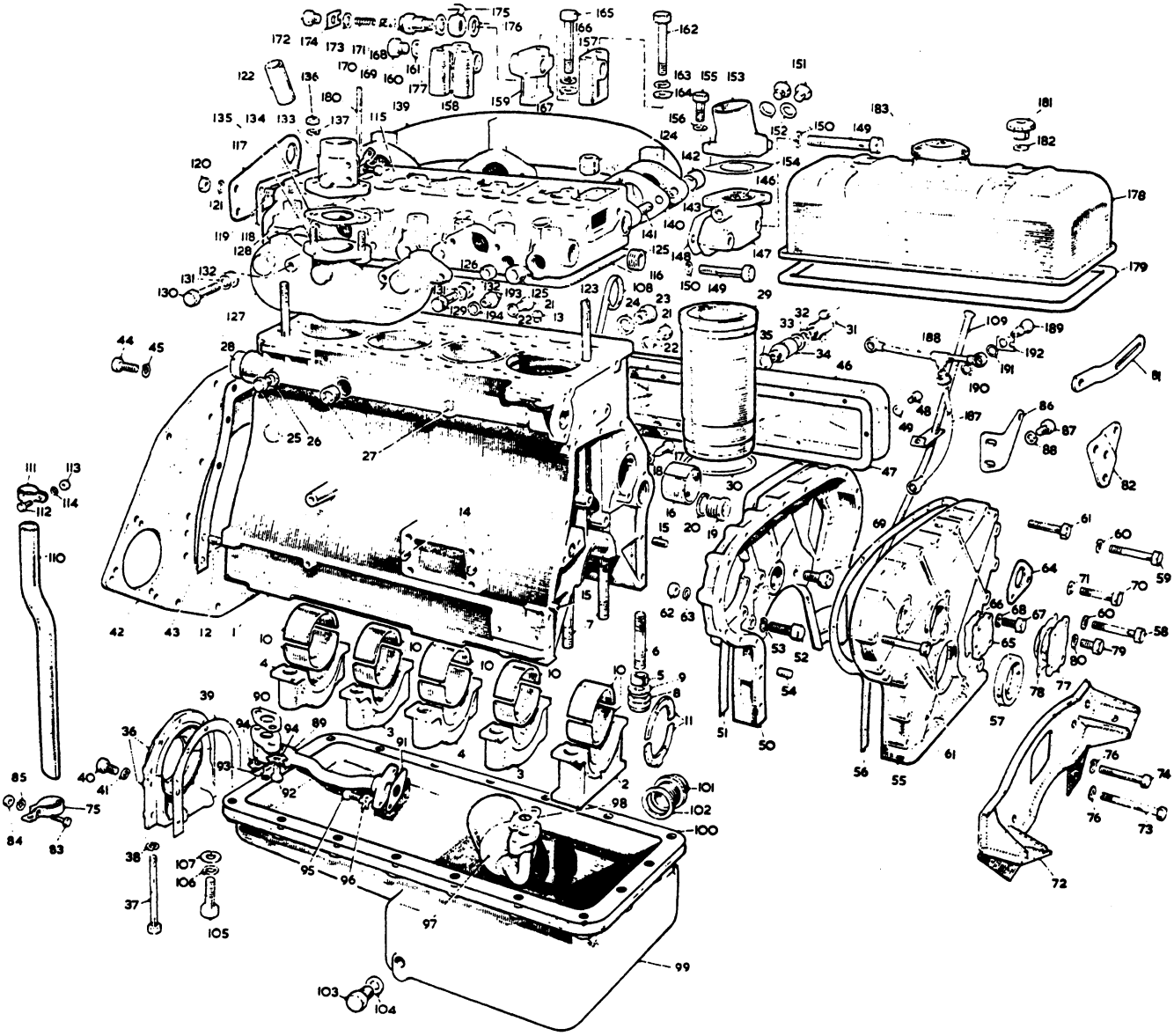
Test No.	Description	R. P. M.	Requirements
9	Back leakage Throttle lever fully closed	700	5 to 50 cc for 100 stroke time cycle.
10	Max. fuel delivery	700	Set to 8.2 ± 0.1 cc. Spread between lines not to exceed 0.8 cc. Note - Advance indicator must show zero.
11	Max. fuel delivery check	100	Average delivery to be not less than average at (10) minus 1.0 cc.
12	Cut-off operation. Shut-off lever closed	200	Average delivery not to exceed 1.5 cc.
13	Throttle operation Throttle lever closed	200	Screw back anti-stall device and lock to give delivery not exceeding 0.8 cc.
14	Fuel delivery check	1700	Record average delivery.
15	Governor setting	1950	Set throttle by maximum speed adjustment screw to give maximum average delivery of 1.5 cc. No line to exceed 2.5 cc. Lock stop screw.
16	Fuel delivery check	1700	With throttle set as at (15) average delivery to be not less than average at (14) minus 0.4 cc.
17	Timing		Using outlet 'V' (30 ats pressure) set indexing tool to 86° and scribe line on housing flange.

ENGINE

FOUR-230-LITRE DIESEL ENGINE
(Longitudinal Section)



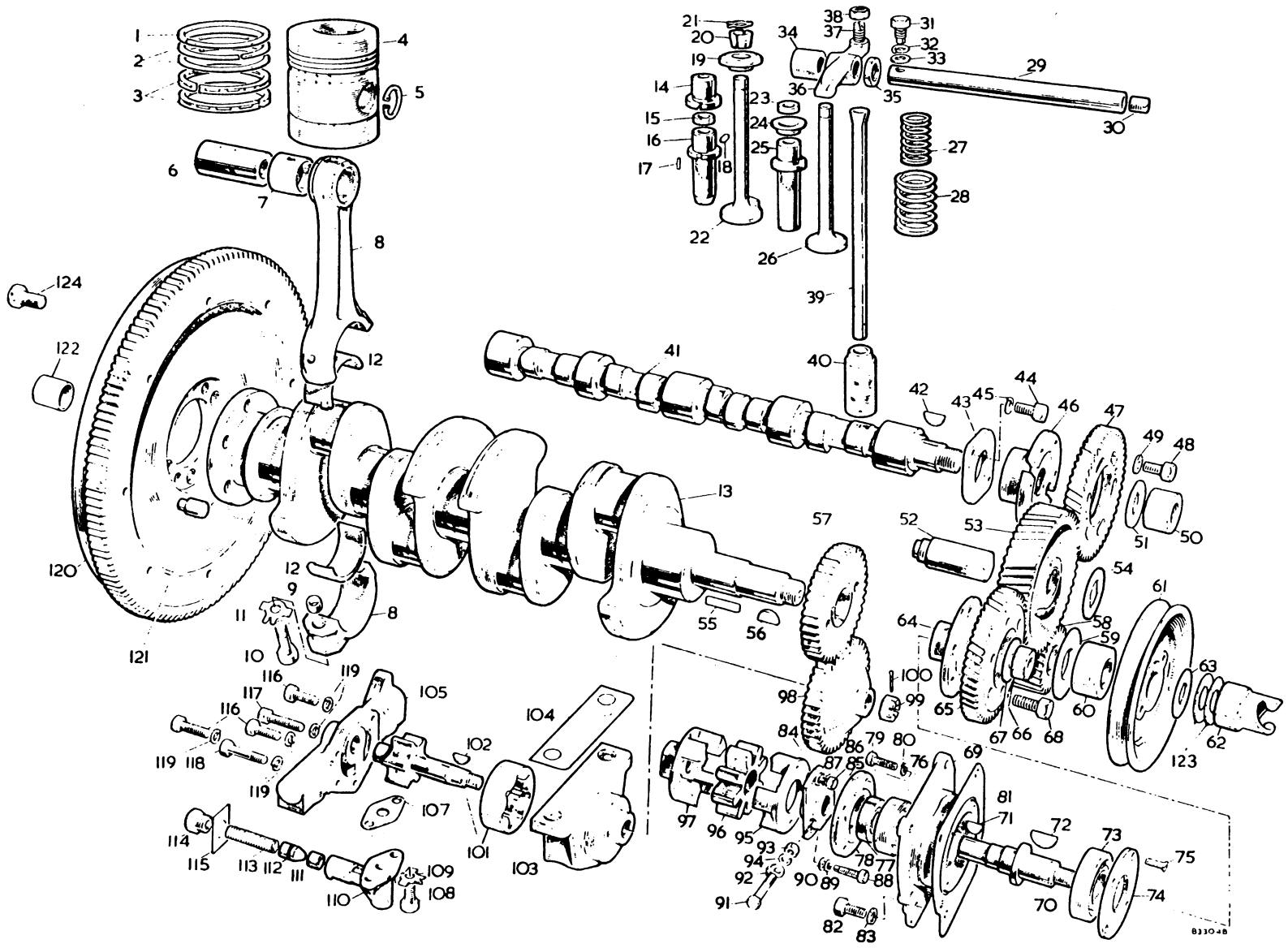
FOUR-230 DIESEL ENGINE EXTERNAL COMPONENTS



FOUR-230 DIESEL ENGINE EXTERNAL COMPONENTS

No.	Description
1.	Cylinder block.
2.	Main bearing cap (front).
3.	Main bearing cap (intermediate).
4.	Main bearing cap (centre and rear).
5.	Dowel for main bearing cap.
6.	Stud for main bearing cap (short).
7.	Stud for main bearing cap (long).
8.	Nut for stud.
9.	Washer for nut.
10.	Main bearings.
11	Crankshaft thrust washers.
12.	Dowel for flywheel housing.
13.	Dowel for cylinder head.
14.	Dowel for injection pump bracket.
15.	Dowel for rear half of timing case.
16.	Front camshaft bearing.
17.	Locating screw for bearing.
18.	Seloc washer for screw.
19.	Oil gallery plug (front and rear).
20.	Washer for plug.
21.	Oil gallery plug (brass).
22.	Washer for plug.
23.	Oil gallery plug (tapped).
24.	Washer for plug.
25.	Water gallery plug (brass).
26.	Washer for plug.
27.	Water gallery plug (steel).
28.	Water gallery core plug.
29.	Cylinder liner.
30.	Cylinder liner sealing ring.
31.	Cylinder block water drain tap.
32.	Shim for drain tap.
33.	Washer for drain tap.
34.	Adaptor for drain tap.
35.	Washer for adaptor.
36.	Rear cover plate and oil seal.
37.	Bolt for plate.
38.	Spring washer for bolt.
39.	Joint for cover plate.
40.	Screw—cover plate to block.
41.	Spring washer for screw.
42.	Sandwich plate.
43.	Joint for sandwich plate.
44.	Bolt—plate to block.
45.	Spring washer for bolt.
46.	Valve tappet cover.
47.	Joint for tappet cover.
48.	Bolt—tappet cover to block.
49.	Washer for bolt.
50.	Timing gear case.
51.	Joint for timing gear case.
52.	Bolt—timing case to cylinder block.
53.	Spring washer for bolt.
54.	Dowel for timing gear case cover.
55.	Timing gear case cover.
56.	Joint for timing gear case cover.
57.	Crankshaft oil seal.
58.	Bolt—timing case and cover to block.
59.	Bolt—dynamo bracket, case and cover to block.
60.	Spring washer for bolt.
61.	Bolt—timing gear cover to case.
62.	Nut for bolt.
63.	Spring washer for nut.
64.	Front lifting plate.
65.	Timing cover blanking plate.
66.	Joint for blanking plate.
67.	Screw—blanking plate to cover.
68.	Spring washer for screw.
69.	Oil feed jet for timing gears.
70.	Bolt—lifting plate to cover and case.
71.	Spring washer for bolt.
72.	Engine front support bracket.
73.	Bolt—support bracket, cover and case to block.
74.	Bolt—support bracket to cover and case.
75.	Steady for breather pipe.
76.	Spring washer for bolt.
77.	Outrigger bearing for idler gear shaft.
78.	Joint for bearing.
79.	Screw—bearing to timing cover.
80.	Spring washer for screw.
81.	Dynamo adjusting link.
82.	Dynamo bracket—front.
83.	Bolt for steady.
84.	Nut for bolt.
85.	Spring washer for nut.
86.	Dynamo bracket—rear.
87.	Bolt—bracket to cylinder block.
88.	Spring washer for bolt.
89.	Oil delivery pipe.
90.	Joint—delivery pipe to block.
91.	Joint—delivery pipe to pump.
92.	Bolt—delivery pipe to block (short).
93.	Bolt—delivery pipe to block (long).
94.	Tab washer for bolt.
95.	Bolt delivery pipe to pump.
96.	Tab washer for bolt.
97.	Oil strainer.
98.	Joint for oil strainer.
99.	Oil sump.
100.	Gasket for sump.
101.	Drain plug.
102.	Washer for drain plug.
103.	Blanking plug.
104.	Washer for blanking plug.
105.	Bolt—sump to block.
106.	Spring washer for bolt.
107.	Plain washer for bolt.
108.	Oil level indicator.
109.	Guide tube for indicator.
110.	Breather pipe.
111.	Clip for breather pipe.
112.	Bolt for clip.
113.	Nut for bolt.
114.	Spring washer for nut.
115.	Cylinder head.
116.	Gasket for cylinder head.
117.	Engine rear lifting plate.
118.	Joint for lifting plate.
119.	Stud for lifting plate.
120.	Nut for stud.
121.	Spring washer for nut.
122.	Injector sleeve.
123.	Cylinder head stud.
124.	Nut for stud.
125.	Core plug (steel).
126.	Plug (brass).
127.	Air inlet manifold.
128.	Joint washer for manifold.
129.	Bolt—manifold to head (short).
130.	Bolt—manifold to head (long).
131.	Spring washer for bolt.
132.	Plain washer for bolt.
133.	Throttle unit (Venturi).
134.	Joint washer for throttle unit.
135.	Stud for throttle unit.
136.	Nut for stud.
137.	Spring washer for nut.
139.	Exhaust manifold.
140.	Joint washer for manifold.
141.	Stud for manifold.
142.	Nut for stud.
143.	Spring washer for nut.
146.	Thermostat.
147.	Thermostat body.
148.	Joint for thermostat body.
149.	Bolt—body to cylinder head.
150.	Spring washer for bolt.
151.	Plug for thermostat body.
152.	Fibre washer for plug.
153.	Water outlet pipe.
154.	Joint for water outlet pipe.
155.	Bolt—outlet pipe to thermostat body.
156.	Spring washer for bolt.
157.	Rocker shaft bracket (front and rear).
158.	Rocker shaft bracket (centre).
159.	Rocker shaft bracket (intermediate).
160.	Plug for intermediate bracket.
161.	Washer for plug.
162.	Bolt for bracket.
163.	Spring washer for bolt.
164.	Plain washer for bolt.
165.	Bolt for intermediate bracket.
166.	Spring washer for bolt.
167.	Plain washer for bolt.
168.	Relief valve body.
169.	Relief valve ball.
170.	Relief valve spring.
171.	Seat for relief valve spring.
172.	Plug for relief valve body.
173.	Plain washer for plug.
174.	Tab washer for plug.
175.	Overflow pipe for relief valve.
176.	Washer for overflow pipe (small).
177.	Washer for overflow pipe (large).
178.	Valve rocker cover.
179.	Gasket for rocker cover.
180.	Stud for rocker cover.
181.	Hand nut for stud.
182.	Fibre washer for nut.
183.	Oil filler cap.
187.	Oil feed pipe to rockers (lower).
188.	Oil feed pipe to rockers (upper).
189.	Pin for feed pipe banjo.
190.	Washer for pin (small).
191.	Washer for pin (large).
192.	Tab washer for pin.
193.	Union for oil gauge pipe.
194.	Washer for union.

FOUR-230 DIESEL ENGINE INTERNAL COMPONENTS



FOUR-230 **DIESEL ENGINE INTERNAL COMPONENTS**

No.	*Description*
1.	Compression ring (taper sided, chrome face).
2.	Compression ring (taper face).
3.	Scraper ring (slotted).
4.	Piston.
5.	Gudgeon pin clip.
6.	Gudgeon pin.
7.	Small end bush.
8.	Connecting rod.
9.	Hollow dowel.
10.	Connecting rod bolt.
11.	Tab washer for bolt.
12.	Big-end bearing.
13.	Crankshaft.
14.	Inlet valve thimble.
15.	Inlet valve oil seal.
16.	Inlet valve guide.
17.	Thimble locating dowel.
18.	Inlet valve key.
19.	Valve spring collar.
20.	Retainer for collar.
21.	Spring clip for retainer.
22.	Inlet valve.
23.	Exhaust valve oil seal.
24.	Retainer for exhaust valve oil seal.
25.	Exhaust valve guide.
26.	Exhaust valve.
27.	Inner valve spring.
28.	Outer valve spring.
29.	Valve rocker shaft.
30.	Plug for shaft.
31.	Shaft locating screw.
32.	Spring washer for screw.
33.	Plain washer for screw.
34.	Valve rocker spacing washer—thick.
35.	Valve rocker spacing washer—thin.
36.	Valve rocker.
37.	Valve rocker adjusting screw.
38.	Lock nut for screw.
39.	Push rod.
40.	Tappet.
41.	Camshaft.
42.	Key—hub to camshaft.
43.	Camshaft locating plate.
44.	Bolt—locating plate to block.
45.	Spring washer for bolt.
46.	Camshaft gear hub.
47.	Camshaft gear.
48.	Bolt—camshaft gear to hub.
49.	Washer for bolt.
50.	Locking nut—hub to camshaft.
51.	Tab washer for nut.
52.	Idler gear shaft.
53.	Idler gear.
54.	Idler gear thrust washer.
55.	Key—gear to crankshaft.
56.	Key—pulley to crankshaft.
57.	Oil pump driving gear.
58.	Crankshaft timing gear.
59.	Oil thrower.
60.	Distance piece.
61.	Crankshaft pulley.
62.	Jaw—starting handle.
63.	Tab washer for jaw.
64.	Injection pump driving gear hub.
65.	Injection pump driving gear.
66.	Locking nut—hub to injection pump drive shaft.
67.	Tab washer for nut.
68.	Bolt—driving gear to hub.
69.	Injection pump drive housing.
70.	Injection pump drive shaft.
71.	Key—driving flange to drive shaft.
72.	Key—hub to drive shaft.
73.	Drive shaft bearing (large).
74.	Cover plate for bearing.
75.	Cover plate retaining screw.
76.	Drive shaft bearing (small).
77.	Drive shaft oil seal.
78.	Drive housing end cover.
79.	Screw—end cover to drive housing.
80.	Spring washer for screw.
81.	Joint—drive housing to timing case.
82.	Screw—drive housing to timing case.
83.	Spring washer for screw.
84.	Driving flange.
85.	Screw—driving flange to dog flange.
86.	Spring washer for screw.
87.	Plain washer for screw.
88.	Dowel screw—driving flange to dog flange.
89.	Spring washer for screw.
90.	Plain washer for screw.
91.	Driving flange clamping bolt.
92.	Tab washer for bolt.
93.	Nut for bolt.
94.	Spring washer for nut.
95.	Coupling dog flange.
96.	Coupling insert.
97.	**Coupling pump flange.**
98.	Oil pump driven gear.
99.	Nut—oil pump gear to oil pump shaft.
100.	Split pin for nut.
101.	**Oil pump rotor and shaft assembly.**
102.	Key—oil pump gear to shaft.
103.	Oil pump body.
104.	Adjusting shim—oil pump to bearing cap.
105.	Oil pump cover.
107.	Joint—relief valve to pump.
108.	Bolt—relief valve body to oil pump.
109.	Washer for bolt.
110.	Oil relief valve body.
111.	Oil relief valve seat.
112.	Oil relief valve.
113.	Oil relief valve spring.
114.	Oil relief valve plug.
115.	Tab washer for plug.
116.	Screw—cover to oil pump body (short).
117.	Screw—cover to oil pump body (long).
118.	Bolt—cover to oil pump body.
119.	Spring washer for bolt and screw.
120.	Flywheel.
121.	Dowel—flywheel to crankshaft.
122.	Bush for crankshaft.
123.	Shims for starting jaw nut.
124.	Bolt—flywheel to crankshaft.

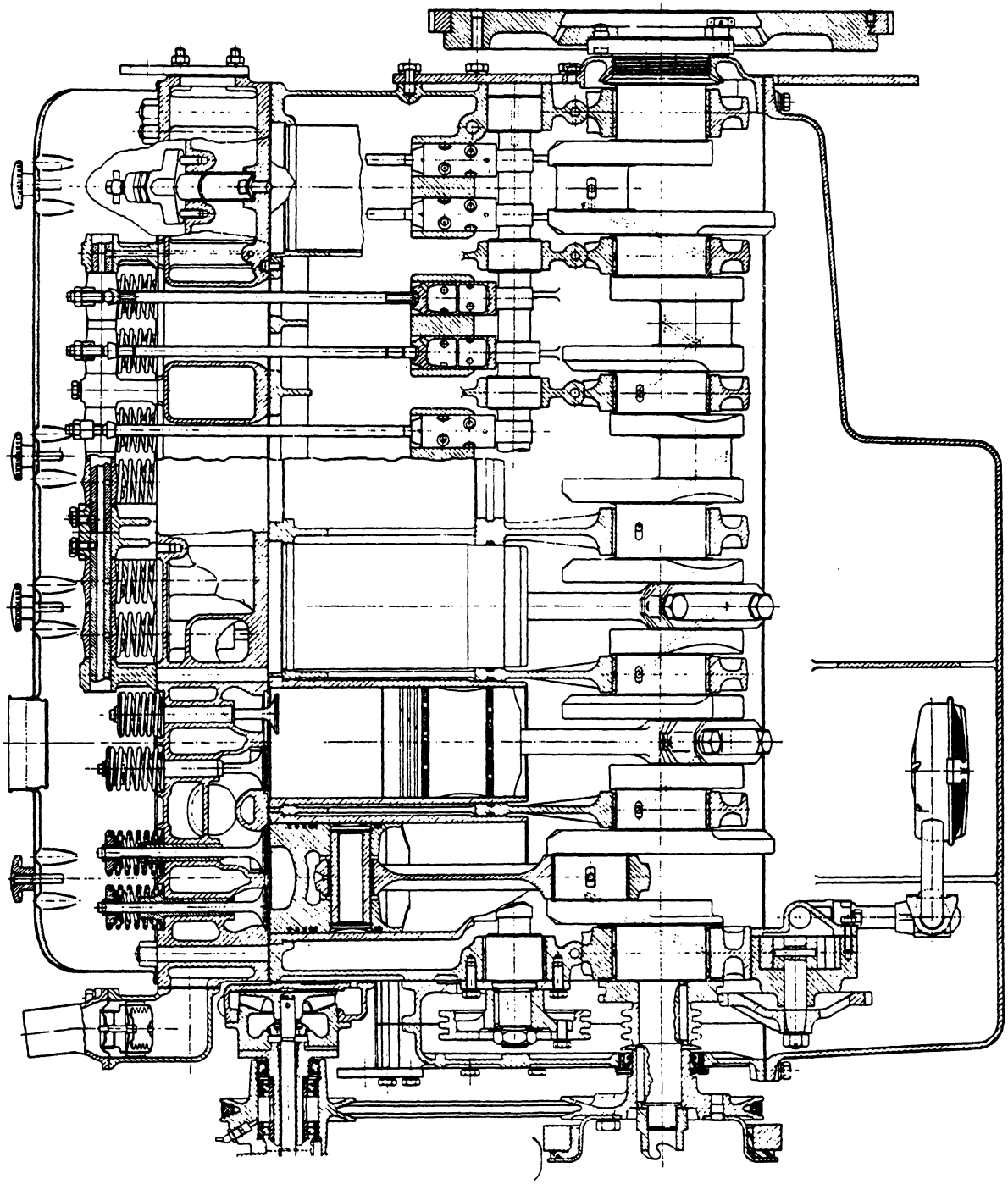


Fig. E.2
SIX-346 *Engine—longitudinal section*

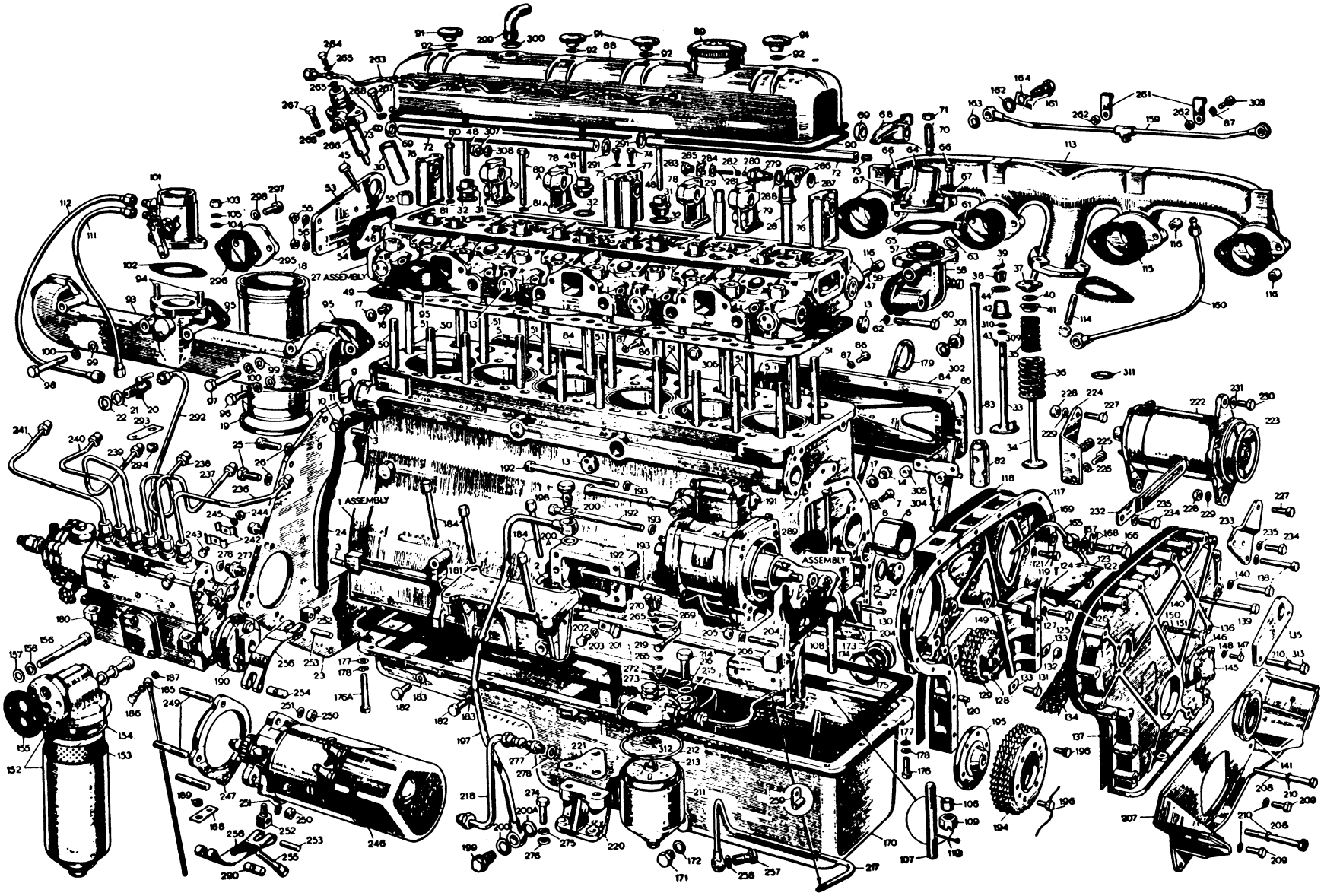


Fig. E.4

SIX-346 *Engine—external components*

KEY TO FIG. E.4. ENGINE—EXTERNAL COMPONENTS

1. Cylinder block assembly.
2. Dowel—injection pump support bracket.
3. Dowel—sandwich plate.
4. Dowel—timing case—rear half.
5. Dowel—cylinder head.
6. Camshaft bearing bush.
7. Locating screw for bush.
8. Spring washer for screw.
9. Core disc for water gallery.
10. Plug—brass—for water gallery.
11. Washer for plug.
12. Plug—for oil gallery ⅜ in. gas circular head.
13. Core plug—steel—for water gallery.
14. Plug—for oil gallery ¼ in. gas.
15. Joint for plug (No. 12).
16. Union for oil gauge pipe.
17. Washer for plug (No. 14) and union
18. Cylinder liner. [(No. 16).
19. Sealing ring (rubber) for liner
20. Drain tap for cylinder block.
21. Shim for drain tap.
22. Washer for drain tap.
23. Sandwich plate.
24. Joint for sandwich plate.
25. Set bolt for sandwich plate.
26. Spring washer for sandwich plate.
27. Cylinder head and valve guides assembly.
28. Valve guide—exhaust.
29. Valve guide—inlet.
30. Injector sleeve.
31. Core plug—square head.
32. Joint—copper—for core plug.
33. Inlet valve.
34. Exhaust valve.
35. Valve spring—inner.
36. Valve spring—outer.
37. Collar for valve.
38. Retainers for collar.
39. Spring clip for retainers.
40. Oil seal for valve.
41. Retainer for oil seal.
42. Thimble for inlet valve.
43. Locating peg for thimble.
44. Seat for inner valve spring—inlet.
45. Decompressor screw.
46. Stud—rear cover-plate.
47. Stud—exhaust manifold.
48. Stud—valve rocker cover.
49. Gasket for cylinder head.
50. Stud—short—for cylinder head.
51. Stud—long—for cylinder head.
52. Nut for cylinder head studs.
53. Lifting and rear cover-plate.
54. Joint for plate.
55. Nut for plate.
56. Spring washer for plate.
57. Thermostat.
58. Body for thermostat.
59. Joint for thermostat body.
60. Set bolt for thermostat body.
61. Plug for thermostat body.
62. Spring washer for set bolt.
63. C/A washer for plug.
64. Water outlet pipe.
65. Joint for water outlet pipe.
66. Set bolt for water outlet pipe.
67. Spring washer for set bolt.
68. Valve rocker.
69. Spacing washer for valve rocker (thick).
70. Adjusting screw for valve rocker.
71. Locknut for adjusting screw.
72. Shaft for valve rockers.
73. Plug for valve rocker shaft.
74. Locating screw for rocker shaft
75. Spring washer for locating screw.
76. Support bracket—front and rear—for rocker shaft.
77. Support bracket—centre—for rocker shaft.
78. Support bracket (plain)—intermediate—for rocker shaft.
79. Support bracket (drilled) intermediate—for rocker shaft.
80. Set bolt—support brackets to cylinder head
80a. Set bolt—support brackets to cylinder head
81. Spring washer for set bolt (⅜ in.). [(½ in.).
81a. Spring washer for set bolt (½ in.).
82. Valve tappet.
83. Push-rod.
84. Cover for push-rods.
85. Joint—cover to cylinder block.
86. Set bolt—cover to cylinder block (short).
87. Spring washer for set bolt.
88. Valve gear cover.
89. Oil filler cap.
90. Gasket for valve gear cover.
91. Nut for valve gear cover.
92. Washer (fibre) for valve gear cover nut.
93. Air manifold.
94. Stud for air manifold.
95. Joint—air manifold to cylinder head.
96. Set bolt—short—air manifold to cylinder head.
97. Set bolt—medium—air manifold to cylinder head.
98. Set bolt—long—air manifold to cylinder
99. Plain washer for bolts. [head.
100. Spring washer for bolts.
101. Venturi control unit (C.A.V.).
102. Joint—venturi to air manifold.
103. Locknut—venturi to air manifold.
104. Plain washer—venturi to air manifold.
105. Spring washer—venturi to air manifold.
106. Hollow dowel for main bearing caps.
107. Stud—short—for main bearing caps.
108. Stud—long—for main bearing caps.
109. Nut for studs.
110. Split pin for nuts.
111. Vacuum pipe—short.
112. Vacuum pipe—long.
113. Exhaust manifold.
114. Stud for exhaust manifold.
115. Joint for exhaust manifold (pipe).
116. Nut for exhaust manifold.
117. Casing—timing chain—rear half.
118. Joint—casing to cylinder block.
119. Set bolt—casing to cylinder block.
120. Dowel—timing case to cover.
121. Spring washer for set bolt.
122. Guide bracket and pad for timing chain.
123. Pad for guide bracket.
124. Rivet for pad.
125. Set bolt—guide bracket to cylinder block.
126. Set screw—guide bracket to cylinder block.
127. Spring washer for bolts and screws.
128. Tensioner for timing chain.
129. Chain wheel for tensioner.
130. Stud for chain tensioner (in cylinder block).
131. Set bolt for chain tensioner.
132. Nut for stud.
133. Tab washer for stud and bolt.
134. Timing chain.
135. Lifting plate—front.
136. Cover for timing case—front half.
137. Joint—cover to casing.
138. Set bolt—cover to casing.
139. Set bolt—cover and casing to cylinder
140. Spring washer for set bolts. [block.
141. Oil seal.
145. Blanking plate for front cover.
146. Joint—blanking plate to front cover.
147. Set screw—blanking plate to front cover.
148. Spring washer for set screw.
149. Distance piece for front cover.
150. Set bolt for distance piece.
151. Spring washer for set bolt.
152. Oil filter.
153. Oil filter element.
154. Oil filter gasket.
155. Joint—filter to cylinder block.
156. Set bolt—filter to cylinder block.
157. Plain washer for set bolt.
158. Spring washer for set bolt.
159. Oil pipe—on cylinder head for rocker lubrication.
160. Oil pipe—oil gallery to pipe on cylinder
161. Pin for banjo of pipes. [head.
162. Joint washer for pin.
163. Joint washer for pin.
164. Tab washer for pin.
165. Oil pipe—in timing case for chain lubrica-
166. Pin for banjo of pipe. [tion.
167. Washer for pin.
168. Tab washer for pin.
169. Clip for pipe.
170. Oil sump.
171. Blanking plug.
172. Washer for plug.
173. Drain plug for sump.
174. Joint washer for plug.
175. Joint—sump to crankcase.
176. Set bolt—short—sump to crankcase.
176a. Set bolt—long—sump to crankcase.
177. Plain washer for set bolt.
178. Spring washer for set bolt.
179. Dip rod for oil level.
180. Fuel injection pump.
181. Bracket for fuel injection pump.
182. Set bolt for fuel injection pump bracket.
183. Spring washer for set bolt.
184. Set screw—injection pump to bracket.
185. Overflow pipe for injection pump.
186. Pin for banjo of pipe.
187. Washer for pin.
188. Steady for overflow pipe.
189. Ferrule for overflow pipe.
190. Driving coupling for injection pump.
191. Exhauster.
192. Bolt for exhauster.
193. Spring washer for bolt.
194. Timing chain gear.
195. Hub for chain wheel.
196. Set bolt—hub to chain wheel.
197. Oil feed pipe—sump to exhauster.
198. Banjo pin—pipe to exhauster.
199. Banjo pin—pipe to sump.
200. C/A washer for pins.
201. Clip for oil feed pipe.
202. Set bolt for clip.
203. Spring washer for bolt.
204. Stud—exhauster to timing chain casing.
205. Nut for stud.
206. Spring washer for stud.
207. Front support bracket.
208. Set bolt—long—for bracket.
209. Set bolt—short—for bracket.
210. Spring washer for bolts.
211. Fuel filter
212. Element for filter.
213. Joint for cover.
214. Set bolt—filter to bracket.
215. Plain washer for set bolt.
216. Spring washer for set bolt.
217. Fuel pipe—lift pump to filter.
218. Fuel pipe—filter to injection pump.
219. Leak-off pipe—auxiliary.
220. Bracket for fuel filter
221. Steady plate for fuel filter.
222. Dynamo.
223. Pulley for dynamo.
224. Bracket for dynamo—rear.
225. Set bolt—rear dynamo bracket to cylinder
226. Spring washer for set bolt. [block.
227 Bolt—brackets to dynamo.
228. Nut for bolt.
229. Spring washer for bolt.
230. Set screw—dynamo flange to adjusting
231. Plain washer for set screw. [link.
232. Adjusting link for dynamo
233. Bracket for dynamo—front.
234. Bolt for dynamo bracket to timing chain
235. Spring washer for bolt. [cover.
236. Fuel pipe—injection pump to No. 1 cylinder.
237. Fuel pipe—injection pump to No. 2 cylinder.
238. Fuel pipe—injection pump to No. 3 cylinder.
239. Fuel pipe—injection pump to No. 4 cylinder.
240. Fuel pipe—injection pump to No. 5 cylinder.
241. Fuel pipe—injection pump to No. 6
242. Clamp for fuel pipes. [cylinder.
243. Bolt for clamp.
244. Nut for bolt.
245. Spring washer for bolt.
246. Starter.
247. Distance piece—starter to sandwich plate.
249. Stud—starter to clutch housing.
250. Nut for stud.
251. Spring washer for stud.
252. Anchor pin for starter strap.
253. Pin—strap to anchor pin.
254. Pin—tapped—for strap.
255. Screw—pin (No. 254) to pin (No. 290).
256. Strap for starter.
257. Banjo pin for banjo of pipe to pump.
258. Fibre washer for banjo pin.
259. Clip for pipe.
261. Clip for pipe—oil gallery to cylinder head
262. Distance piece for clip.
263. Main leak-off pipe.
264. Banjo pin for pipe—short.
265. Washer for pin.
266. Fuel injector.
267. Set bolt for injector.
268. Spring washer for set bolt.
269. Banjo pin—leak-off to fuel filter.
270. Banjo pin—long—for banjo of leak-off pipes.
272. Adaptor for pipe—auxiliary leak-off to
273. Copper washer for adaptor. [fuel filter.
274. Set bolt—fuel filter support bracket to
275. Spring washer for bolt. [cylinder block
276. Plain washer for bolt.
277. Adaptor for fuel oil filter.
278. Copper washer for adaptor
279. Body—relief valve.
280. Ball—relief valve.
281. Spring for ball.
282. Seat for spring.
283. Plug for body.
284. Packing washer for body.
285. Tab washer for body.
286. Overflow pipe for relief valve.
287. Washer—small hole—for banjo.
288. Washer—large hole—for banjo.
289. Joint—exhauster to timing chain casing.
290. Pin—plain—for starter strap.
291. Spacing washer for valve rocker (thin).
292. Drain tap tube.
293. Steady for drain tap tube.
294. Grommet for drain tap tube.
295. Cylinder block blanking plate.
296. Joint for blanking plate.
297. Bolt for blanking plate.
298. Valve cover vent pipe.
300. Nut for cover vent pipe.
301. Water drain plug.
302. Washer for plug.
303. Set screw for oil pipe on cylinder head.
304. Guide tube assembly for dip-rod.
305. Spacing washers for guide.
306. Plug—brass.
307. Plug for intermediate rocker bracket.
308. Washer for plug.
309. Oil seal for thimble.
310. Washer for oil seal.
311. Valve spring cup.

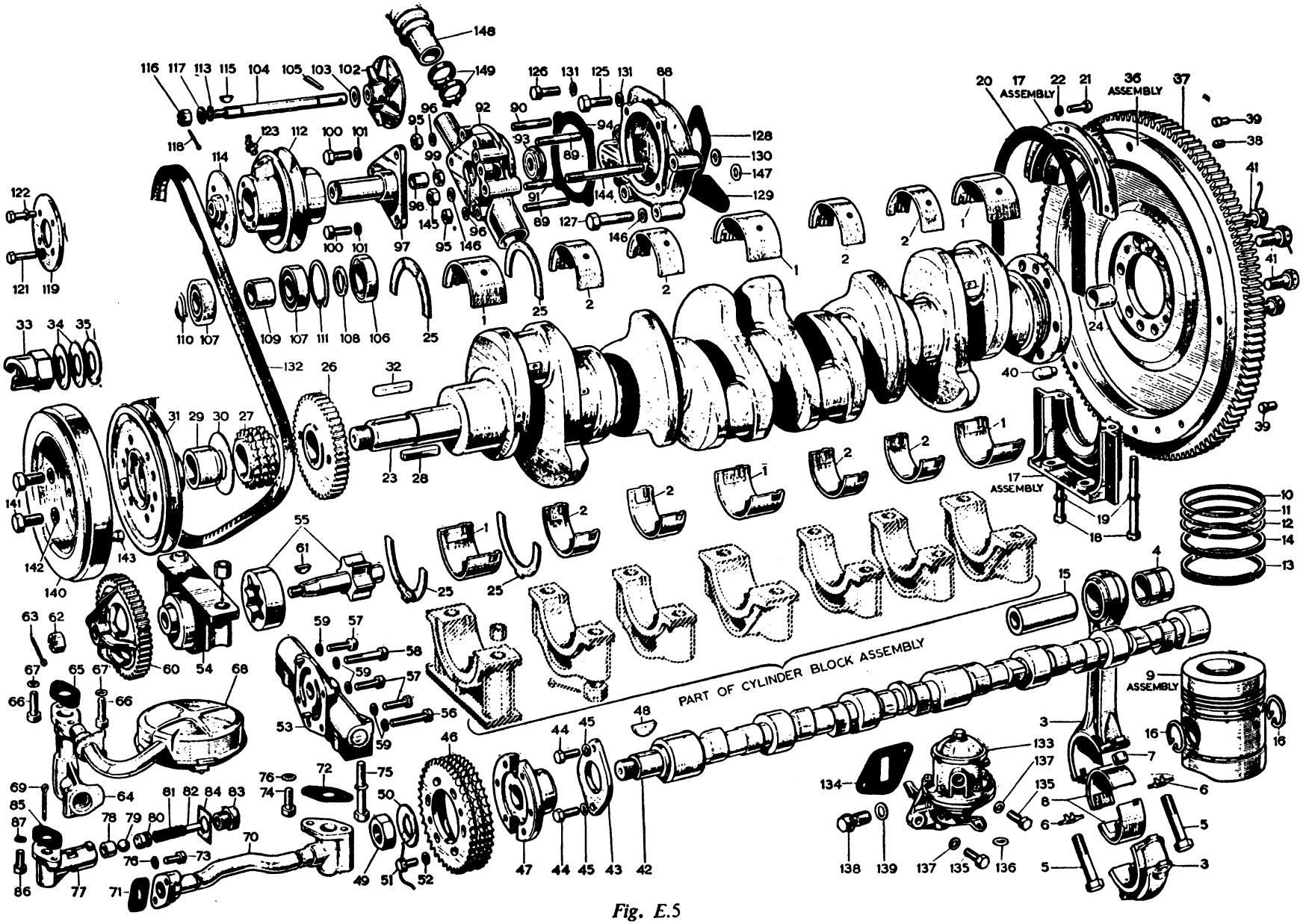


Fig. E.5

SIX-346 *Engine—internal components*

KEY TO FIG. E.5. ENGINE—INTERNAL COMPONENTS

1. Main bearing—front, centre, and rear.
2. Main bearing—intermediate.
3. Connecting rod and cap assembly.
4. Bush for small-end.
5. Bolt for connecting rod cap.
6. Tab washer for bolt.
7. Hollow dowel.
8. Big-end bearing.
9. Piston assembly.
10. Ring—chromium-plated.
11. Ring—plain.
12. Ring—taper face.
13. Ring—slotted scraper.
14. Ring—slotted scraper (oxidized).
15. Gudgeon pin.
16. Clip for gudgeon pin.
17. Oil seal and rear cover-plate assembly for crankshaft.
18. Set bolt for oil seal and cover-plate assembly.
19. Spring washer for bolt.
20. Joint for oil seal and cover-plate to block.
21. Set bolt for oil seal and cover-plate to block.
22. Spring washer for set bolt.
23. Crankshaft—bushed.
24. Bush for crankshaft.
25. Thrust washer.
26. Driving gear for oil pump.
27. Chain wheel.
28. Key for chain wheel.
29. Distance piece—chain wheel to pulley.
30. Oil thrower—crankshaft.
31. Pulley for crankshaft.
32. Key for pulley.
33. Jaw for starting handle.
34. Shims for jaw.
35. Tab washer for jaw.
36. Flywheel and starter ring assembly.
37. Starter ring.
38. Screw—starter ring to flywheel.
39. Dowel—clutch to flywheel.
40. Dowel—flywheel to crankshaft.
41. Set bolt—flywheel to crankshaft.
42. Camshaft.
43. Locating plate for camshaft (front end).
44. Set bolt (locating plate to cylinder block).
45. Spring washer for set bolt.
46. Chain wheel for camshaft.
47. Hub for chain wheel.
48. Key for chain wheel hub.
49. Locknut for chain wheel hub.
50. Tab washer for chain wheel hub.
51. Set bolt—hub to chain wheel.
52. Washer for set bolt.
53. Cover—plugged (complete).
54. Body for oil pump.
55. Rotors and shaft.
56. Set screw (long).
57. Set screw (short).
58. Set bolt.
59. Spring washer for set bolts.
60. Driven gear for oil pump.
61. Key for driven gear.
62. Nut for driven gear.
63. Split pin for nut.
64. Oil pipe—suction.
65. Gasket—suction pipe to pump.
66. Set bolt—suction pipe to pump.
67. Spring washer for set bolt.
68. Floating oil strainer (complete).
69. Split pin for strainer.
70. Oil pipe—delivery.
71. Gasket for oil pipe flange.
72. Gasket for connection to cylinder block.
73. Set bolt—$\frac{7}{8}$ in. long.
74. Set bolt—$\frac{5}{8}$ in. long.
75. Set bolt—$2\frac{1}{8}$ in. long.
76. Spring washer for set bolts.
77. Body for relief valve.
78. Seat for relief valve.
79. Ball for relief valve.
80. Plunger for relief valve.
81. Spring for relief valve.
82. Steady for spring.
83. Plug for relief valve.
84. Washer for plug.
85. Joint for relief valve.
86. Set bolt for relief valve.
87. Spring washer for bolt.
88. Body—water pump (rear half).
89. Stud—$2\frac{1}{4}$ in. long—for body.
90. Stud—$1\frac{7}{8}$ in. long—for body.
91. Stud—$1\frac{1}{4}$ in. long—for body.
92. Body—water pump (front half).
93. Seal for body—front half.
94. Joint for body—front half to rear half.
95. Nut for body—front half to rear half.
96. Spring washer for nut.
97. Pulley and fan support (bushed).
98. Bush for pulley.
99. Sealing ring.
100. Set screw—pulley and fan support to body.
101. Spring washer for set screw.
102. Impeller.
103. Washer for impeller.
104. Spindle.
105. Taper pin (impeller to spindle).
106. Oil seal for fan pulley.
107. Ball bearing for fan pulley.
108. Distance collar for ball bearings.
109. Distance piece for ball bearings.
110. Circlip—internal.
111. Circlip—external.
112. Fan pulley.
113. Circlip for end cover (on spindle).
114. End cover for fan pulley (on spindle).
115. Woodruff key—end cover to spindle.
116. Nut—end cover to spindle.
117. Washer for nut.
118. Split pin for nut.
119. Nave plate for fan.
120. Cap for fan.
121. Set screw for fan.
122. Spring washer for set screw.
123. Lubricating nipple.
124. Fan blades.
125. Set bolt—$1\frac{1}{2}$ in. long (water pump to block).
126. Set bolt—$1\frac{1}{4}$ in. long (water pump to block).
127. Set bolt—2 in. long (water pump to block).
128. Joint—small (water pump to block).
129. Joint—large (water pump to block).
130. Packing washer (water pump to block).
131. Spring washer for set bolts.
132. Fan belt.
133. Fuel lift pump.
134. Joint—lift pump to cylinder block.
135. Set bolt—lift pump to cylinder block.
136. Fibre washer for set bolt to cylinder block.
137. Spring washer.
138. Pin for fuel pipe.
139. Washer for pin.
140. Vibration damper.
141. Set bolt—damper to pulley.
142. Spring washer for set bolt.
143. Dowel for damper.
144. Stud—$4\frac{1}{4}$ in. long (water pump to cylinder block).
145. Nut for stud ($\frac{1}{4}$ in.).
146. Spring washer ($\frac{1}{4}$ in.).
147. Packing washer—fibre.
148. Hose for water by-pass.
149. Clip for hose.

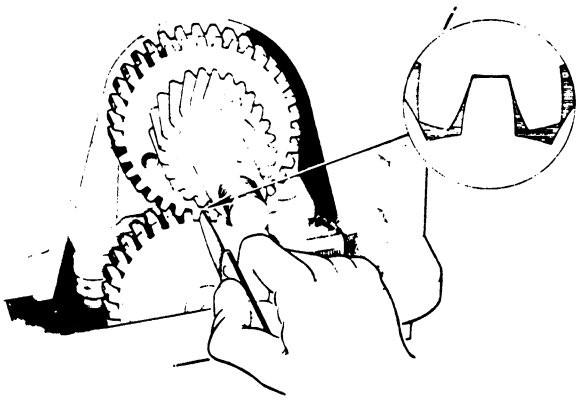


Fig. Aa.4
Checking the oil pump drive backlash

Section Aa.6

REMOVING AND REPLACING THE OIL PUMP AND STRAINER

Remove the sump.

Unscrew the two set bolts securing the oil delivery pipe to the cylinder block.

Remove the nuts securing the oil pump to the front main bearing cap and withdraw the pump, complete with delivery pipe, oil strainer, and pressure relief valve, noting the shims between the bearing cap and oil pump.

To replace the oil pump, reverse the above procedure and fit a new gasket to the delivery pipe flange. Tighten the oil pump securing nuts to the figure given in **'GENERAL DATA'** using torque wrench 18G 372.

Check that the backlash on the oil pump drive gears is as given in **'GENERAL DATA'** and, if necessary, adjust the backlash by means of the shims between the oil pump and main bearing cap.

The oil strainer can be removed with the oil pump still **in situ** by unscrewing the two set bolts which secure the oil suction pipe flange to the oil pump.

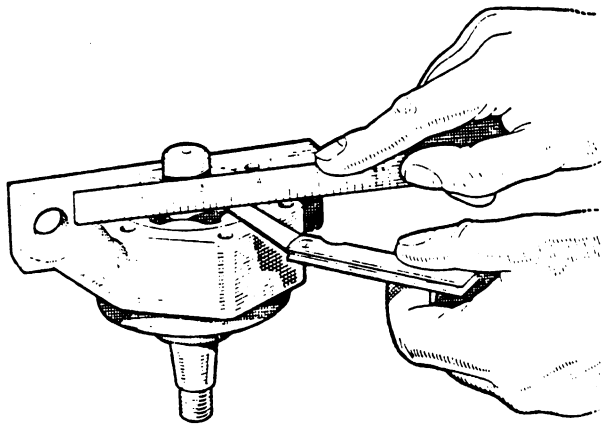


Fig. Aa.5
Checking the oil pump rotor end-float

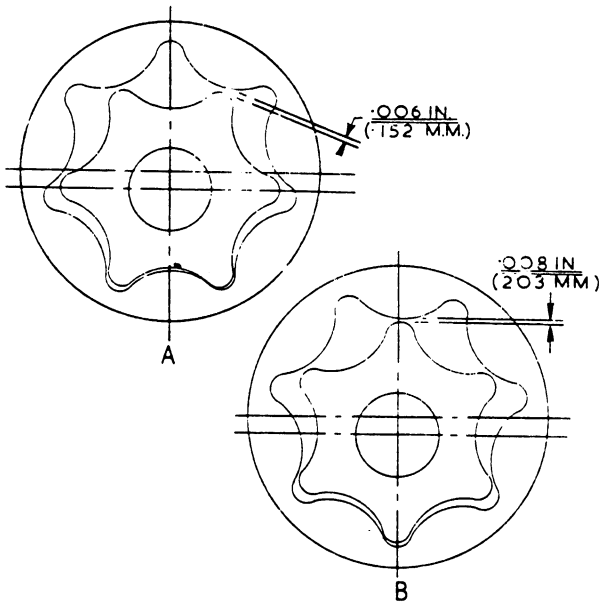


Fig. Aa.6
Check the oil pump rotor lobe clearance with the rotors in positions A and B. The dimensions given are for the maximum clearance

Section Aa.7

DISMANTLING AND REASSEMBLING THE OIL PUMP

Disconnect the delivery pipe, oil strainer, and pressure relief valve from the oil pump.

Remove the gear and key from the end of the pump shaft.

Unscrew the set bolts, separate the oil pump cover from the body, and remove the pump shaft complete with inner and outer rotors.

Thoroughly clean and inspect all the dismantled components.

Check the rotor end-float and driving shaft clearance against the figures given in **'GENERAL DATA'**. Excessive rotor end-float can be remedied by lapping the pump body face.

Measure the rotor lobe clearance as illustrated in Fig. Aa.6.

Reassemble the oil pump by reversing the dismantling procedure, noting that the chamfered end of the outer rotor should be fitted towards the bottom of the rotor pocket. During reassembly smear all working parts with new engine oil.

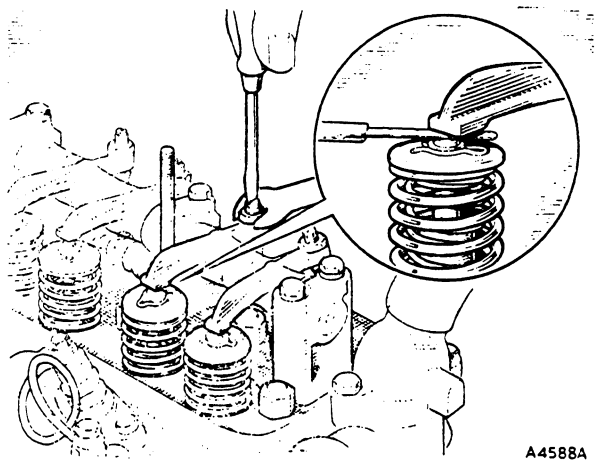


Fig. Aa.7

Adjusting the valve to rocker clearance

Section Aa.8

OIL PRESSURE RELIEF VALVE

The pressure relief valve is mounted on the outlet flange of the oil pump, facing towards the front of the engine.

Release the locking washer and remove the oil pressure relief plug, locking washer, and valve seat from cover.

Examine the valve seat and the plunger for wear or score marks, and check the spring against the specification in "GENERAL DATA."

When reassembling, which is a reversal of the dismantling procedure, renew the body plug locking washer, and the mounting flange gasket.

Unscrew the set bolts from the center rocker bracket and separate the rocker shafts from the center bracket.

Section Aa.9

REMOVING AND REPLACING THE ROCKER SHAFT ASSEMBLY

Remove the valve rocker cover.

Slacken the rocker adjusting screws until all pressure is relieved from the valve springs.

Remove the set bolts securing the rocker brackets to the cylinder head and lift off the rocker shaft assembly.

Refit the rocker shaft assembly to the cylinder head with all rocker adjusting screws fully slackened. Using torque wrench 18G 537 set to the figure given in 'GENERAL DATA' tighten the $\frac{7}{16}$ in. diameter rocker bracket set bolts, then reset the torque wrench (see 'GENERAL DATA') and tighten the $\frac{3}{8}$ in. diameter bolts.

Adjust the valve rocker clearance (Section Aa.11) and replace valve rocker cover.

Start the engine and inspect the rocker cover joint for oil leaks.

Section Aa.10

DISMANTLING AND REASSEMBLING THE ROCKER SHAFT ASSEMBLY

Unscrew the set bolts from the centre rocker bracket and separate the rocker shafts from the centre bracket.

Remove the rockers and distance collars and the remaining brackets from the rocker shafts, and unscrew the blanking plug from the end of each shaft.

Release the tab washer from the oil relief valve drain pipe on the front intermediate bracket and unscrew the relief valve from the bracket.

Remove the plug from the relief valve body and withdraw the spring, spring seat, and relief valve ball.

Clean all the dismantled components, paying particular attention to the oilways.

Inspect the components and check them against their specifications in 'GENERAL DATA'.

When reassembling, which is a reversal of the dismantling procedure, smear all moving parts with new engine oil, renew the tab washer and copper gaskets on the oil pressure relief valve, and fit the drain pipe so that it is directed down the push-rod tunnel. Also ensure that the rocker shaft distance collars are correctly positioned (see 'GENERAL DATA').

Section Aa.11

VALVE ROCKER CLEARANCE

The clearance between the ends of the valve stems and the valve rockers is checked by means of a feeler gauge. FOUR-230

Crank the engine until No. 8 valve is fully open and check the clearance of No. 1 valve, which will now be fully closed.

To adjust the clearance, hold the adjusting screw with a screwdriver and slacken the locknut (Fig. Aa.7). Rotate the adjusting screw until the clearance between the valve stem and rocker is as given in 'GENERAL DATA'. Hold the adjusting screw against rotation, lock it in position with the locknut, and then re-check the clearance.

Check the remaining rocker clearances by references

to the following table:

No. 1 valve (ex.) with No. 8 valve fully open.
„ 3 „ (in.) „ „ 6 „ „ „
„ 5 „ (ex.) „ „ 4 „ „ „
„ 2 „ (in.) „ „ 7 „ „ „
„ 8 „ (ex.) „ „ 1 „ „ „
„ 6 „ (in.) „ „ 3 „ „ „
„ 4 „ (ex.) „ „ 5 „ „ „
„ 7 „ (in.) „ „ 2 „ „ „

The valve rocker clearance should be checked periodically at the intervals recommended.

SIX-346

Crank the engine until No. 12 valve is fully open and check the clearance of No. 1 valve, which will now be fully closed.

To adjust the clearance, hold the adjusting screw with a screwdriver and slacken the locknut (Fig. Aa.7). Rotate the adjusting screw until the clearance between the valve stem and rocker is as given in 'GENERAL DATA'. Hold the adjusting screw against rotation, lock it in position with the locknut, and then re-check the clearance.

Check the remaining rocker clearances by references to the following table:

Check and adjust No. 1 valve (ex.) with No. 12 valve fully open
„ „ „ „ 7 „ (in.) „ „ 6 „ „ „
„ „ „ „ 9 „ (ex.) „ „ 4 „ „ „
„ „ „ „ 2 „ (in.) „ „ 11 „ „ „
„ „ „ „ 5 „ (ex.) „ „ 8 „ „ „
„ „ „ „ 10 „ (in.) „ „ 3 „ „ „
„ „ „ „ 12 „ (ex.) „ „ 1 „ „ „
„ „ „ „ 6 „ (in.) „ „ 7 „ „ „
„ „ „ „ 4 „ (ex.) „ „ 9 „ „ „
„ „ „ „ 11 „ (in.) „ „ 2 „ „ „
„ „ „ „ 8 „ (ex.) „ „ 5 „ „ „
„ „ „ „ 3 „ (in.) „ „ 10 „ „ „

The valve rocker clearance should be checked periodically at the intervals recommended.

Section Aa.12

REMOVING AND REPLACING THE CYLINDER HEAD

Drain cooling system.

Remove hoses connected to thermostat housing.

Remove the four bolts securing thermostat housing and engine lifting bracket from cylinder heads.

Remove water hose between fresh water pump and heat exchanger, at pump.

Remove water hose between heat exchanger and the dual oil cooler, at cooler.

Disconnect the water discharge hose from side of heat exchanger.

Remove the two bolts securing the dual oil cooler to the engine lifting bracket and move cooler away from engine.

Disconnect exhaust pipe from expansion tank/exhaust manifold.

Remove the expansion tank/exhaust manifold from the cylinder head, and lift away with heat exchanger attached.

Release the "T" connection in the rocker feed pipe. Seal ends to prevent entrance of dirt.

Remove the two bolts securing the wiring bracket to the cylinder head.

Disconnect the fuel pipe unions and leak off unions at fuel injectors. Seal off all pipes and injectors to prevent the entry of dirt.

Remove the six bolts securing the intake manifold to cylinders head. Remove intake manifold.

Remove the injectors from the cylinder head.

NOTE: The injectors should not be left in position in the cylinder head as the nozzle tips protrude below the bottom face of the head and are liable to sustain damage.

Working in the order shown in Fig. Aa.8 (A) for the four-230, or Aa.8(B) for the six-346, slacken each cylinder head nut a quarter of a turn only, then unscrew each nut a further amount in the same order until loose. Remove the cylinder head nuts and lift off the cylinder head.

On no account should a screwdriver or similar tool be used as a wedge between the cylinder head and block. A suitable method of removing the cylinder head is to place a sling round the exhaust manifold studs on one side, and round two high-tensile $\frac{3}{8}$-in. UNF. set bolts screwed into the air inlet manifold bolt holes on the other side. When lifting the head a direct pull should be given to lift it evenly up the studs.

Unscrew the two locating dowels and remove the cylinder head gasket.

Check the cylinder head joint face for flatness, using a straight-edge.

If there is any doubt as to the condition of the cylinder head gasket, it should be discarded and a new one fitted, plain side downwards.

Replace the remaining components by reversing the removal procedure. The cylinder head nuts should be tightened in the order shown in Fig. Aa.8.

Adjust the valve rocker clearance as described in Section Aa.11.

Bleed the fuel system of air

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, and retighten the cylinder head nuts in the order shown in Fig. Aa.8.

Recheck the valve rocker clearance as described in Section Aa. 11.

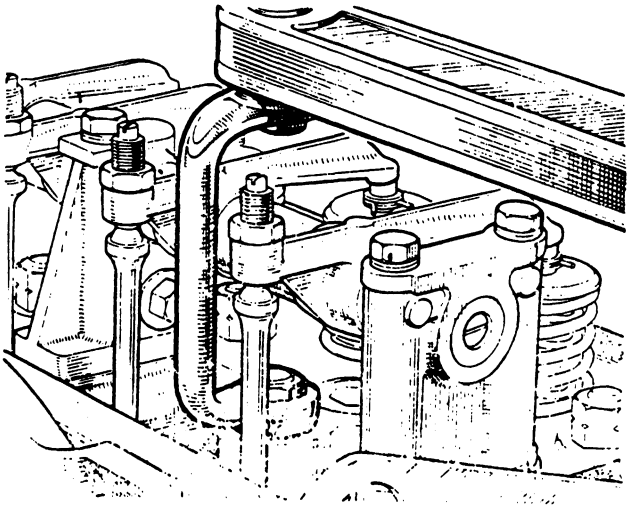


Fig. Aa.9

Using spanner 18G 396 and torque wrench 18G 372 to tighten the cylinder head nuts

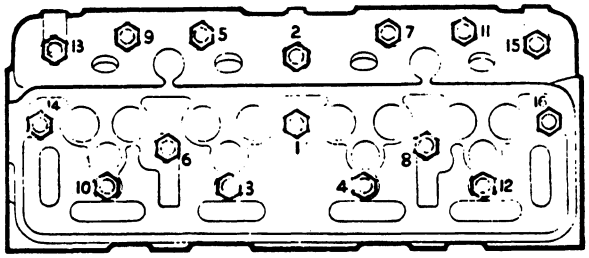


Fig. Aa. 8A (FOUR-230)

Cylinder head nut slackening and tightening sequence

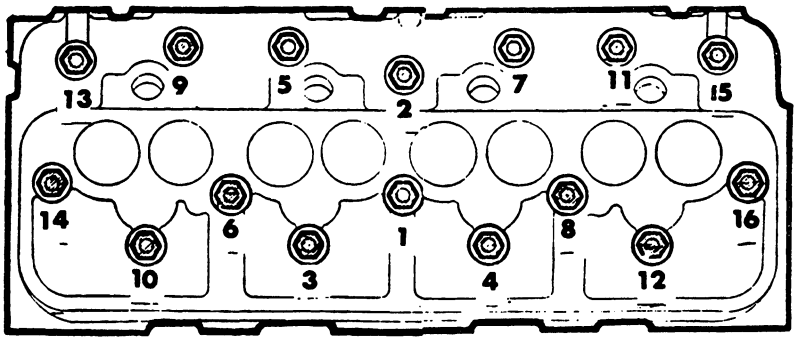


Fig. Aa. 8B (SIX-346)

Cylinder head nut slackening and tightening sequence

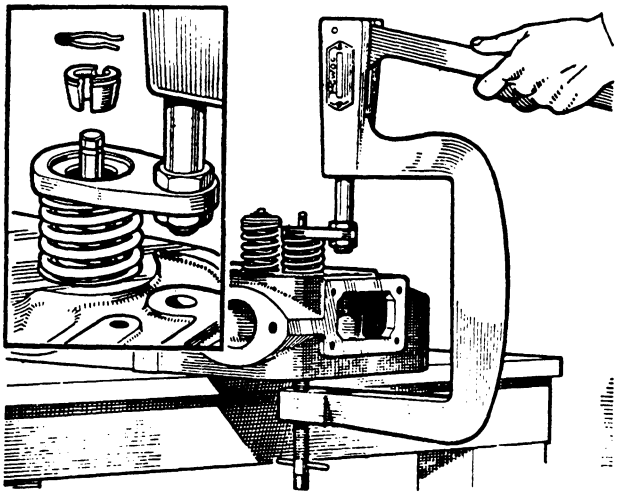


Fig. Aa.10

Compressing the valve springs, using tool 18G 106

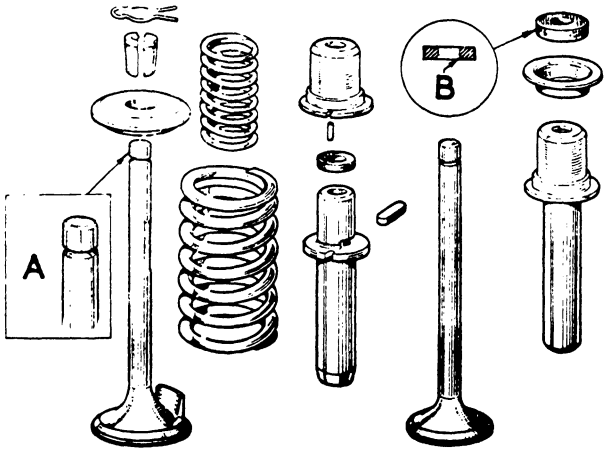


Fig. Aa.11

Engine valve components showing the locating flat (A) on the inlet valve and the chamfered bore (B) of the exhaust valve oil seal

Recheck the valve rocker clearance as described in Section Aa.11.

Section Aa.13

REMOVING AND REPLACING THE VALVES

Remove the valve rocker shaft assembly (Section Aa.9).

Drain the cooling system

Remove the cylinder head (Section Aa.12).

Detach the spring clips from the valve spring collar retainers. Compress each set of valve springs, using tool 18G 106 and remove both halves of the spring collar retainer. Release the compressing tool and remove the valve spring collar, oil seal, and retainer (exhaust valve only), valve springs, and the exhaust valve. Withdraw the thimble from the inlet valve stem, detach the valve key from its slot in the inlet guide and remove the inlet valve. Remove the inlet valve oil seal from inside the thimble.

Clean the valves and guides. The carbon can be removed from the guides by dipping the valve stem in petrol or paraffin and moving it up and down in the guide until it is free. If excessive wear is disclosed the valve guides should be renewed (Section Aa.15).

Inspect the valve faces and seats, and recondition them as necessary (Section Aa.14).

Check the valve springs against the specification in **'GENERAL DATA'** and ensure that the ends of the springs are square with the spring axis.

A new oil seal should be fitted to each valve during reassembly to avoid the loss of oil tightness which will result from re-fitting the old seals. It will be found that the seals are more easily fitted if they are soaked in engine oil before use.

Lubricate the valve stems and guides with new engine oil and replace the valves, which are numbered, in their original positions in the cylinder head. Position the **inlet valves so that the small flat (Fig. Aa.11) on the** top of the valve stem is in line with the valve guide locating peg. Insert the valve key into position in the inlet guide slot and replace the thimble complete with oil seal. Fit the inner and outer valve springs, the exhaust valve oil seal (chamfer downwards) and retainer, and the valve spring collar. Compress the valve springs with tool 18G 106, and refit the spring collar retainers. Release the compressing tool and replace the spring clips on the collar retainers.

Check that the valve head 'stand-down' below the cylinder head face is in accordance with the figures in **'GENERAL DATA.'** If the valve head 'stand-down' is excessive, fit new valves, and in the event of the 'stand-down' being excessive with new valves, fit new **valves seat inserts as described in Section Aa.16.**

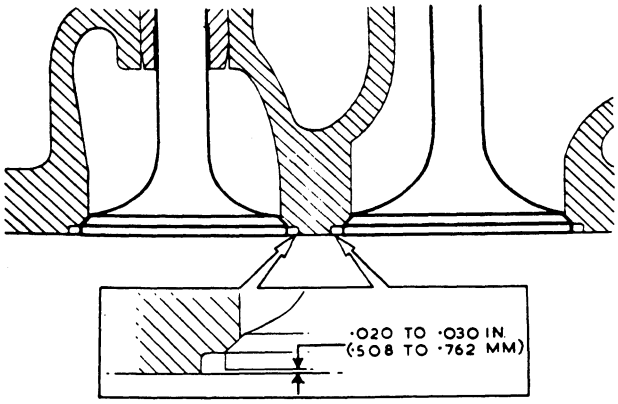


Fig. Aa.12

*Fit the valves with their top faces standing down below the cylinder head joint face to the dimension **shown inset***

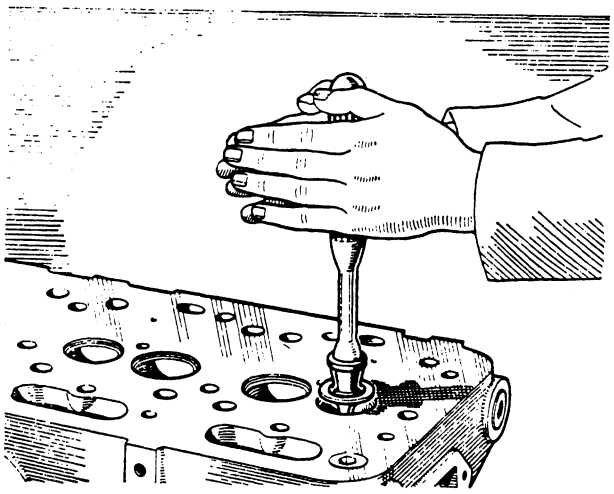


Fig. Aa.13

Grinding-in a valve, using tool 18G 29

Section Aa.14

VALVE-GRINDING

If only slightly pitted the valve faces and seats can be reconditioned by grinding-in with fine grinding compound. Smear the valve face lightly with grinding compound and lap the valve on to its seat, using a semi-rotary motion, with tool 18G 29. This operation is not complete until a dull, even, mat surface, free from blemish is produced on both the valve face and seat.

After cleaning away all traces of grinding compound the valve seating can be checked by applying a spot of marking blue to the valve face and rotating the valve about one turn on its seat; the marking should be completely reproduced on the valve seat. A final lapping, using oil only, is recommended.

When the valve faces and seats cannot be corrected by lapping the valves should be refaced to the correct angle (see **'GENERAL DATA'**) on a valve grinding machine, and the valve seats recut, using tools 18G 27, 18G 28, 18G 28 A, 18G 28 B, 18G 28 C, 18G 174, 18G 174 A, 18G 174 B, 18G 174 C, and 18G 230. Use the glaze-breaker to prepare the seat surface and recut the seats, removing only as little metal as is necessary to ensure a true seat. Restore the seats to their correct width (see **'GENERAL DATA'**) by using the narrowing cutters. Finally, lap the valves onto their seats as already described.

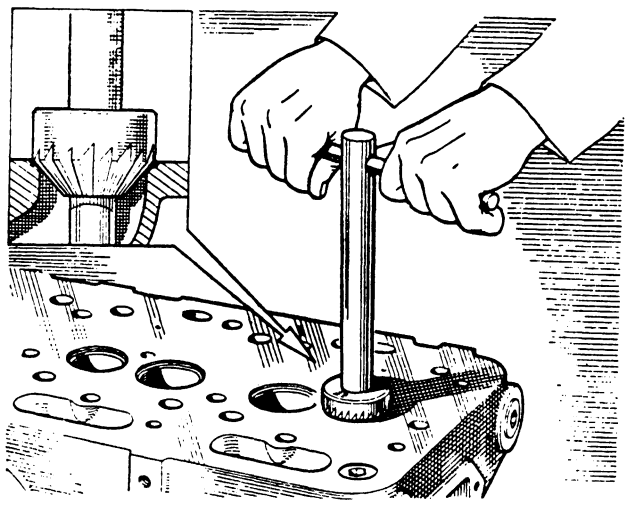


Fig. Aa.14

Badly pitted valve seats should be refaced, using tools 18G 27, 18G 28, 18G 28 A, 18G 28 B, 18G 28 C, 18G 174, 18G 174 A, 18G 174 B, 18G 174 C, and 18G 230

Section Aa.15

REMOVING AND REPLACING THE VALVE GUIDES

Remove the valve rocker shaft assembly (Section Aa.9). Drain the cooling system. Remove the cylinder head (Section Aa.12) and the valves (Section Aa.13).

Drive the valve guides out of the cylinder head, using tool 18G 228 inserted into the guide from the port end.

New valve guides should be driven into position with tool 18G 228 until the shoulder on the guide is flush against the cylinder head. When fitting the inlet valve guides ensure that the locating peg slot in the valve guide shoulder is in line with the locating peg in the cylinder head before driving the guide into position.

Finish ream new valve guides, using tool 18G 229A, then ensure that the valve seatings are concentric with the valve guide bores, recutting the seatings if necessary (Section Aa.14).

Replace the remaining components by reversing the

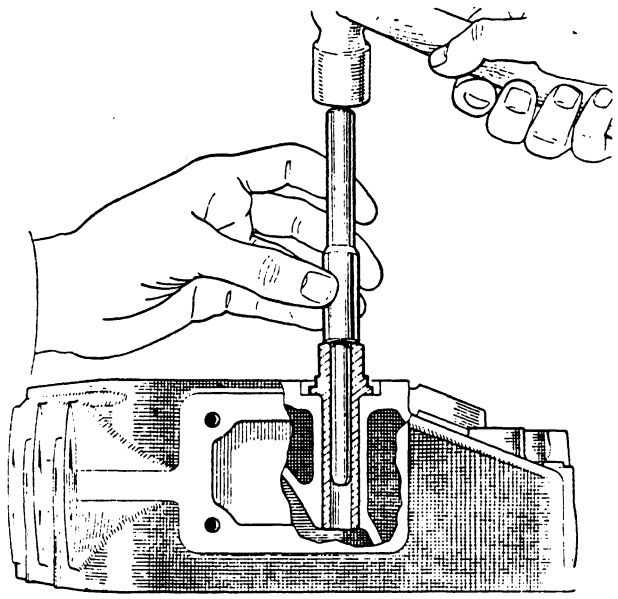


Fig. Aa.15

Driving a valve guide into position, using tool 18G 228

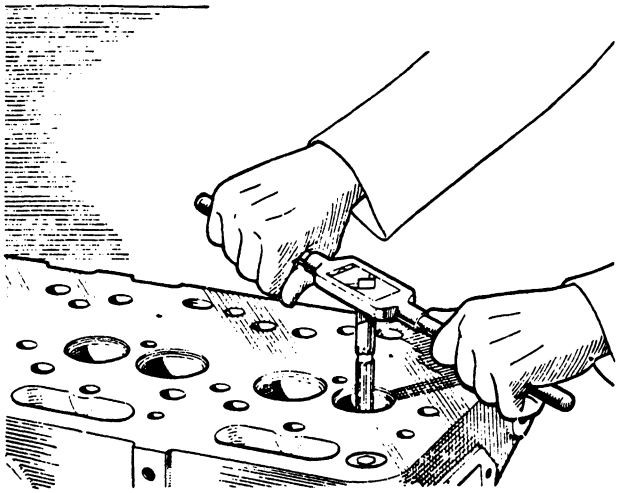


Fig. Aa.16
Reaming a valve guide using tool 18G 229A

removal procedure, and adjust the valve rocker clearance (Section Aa.11).

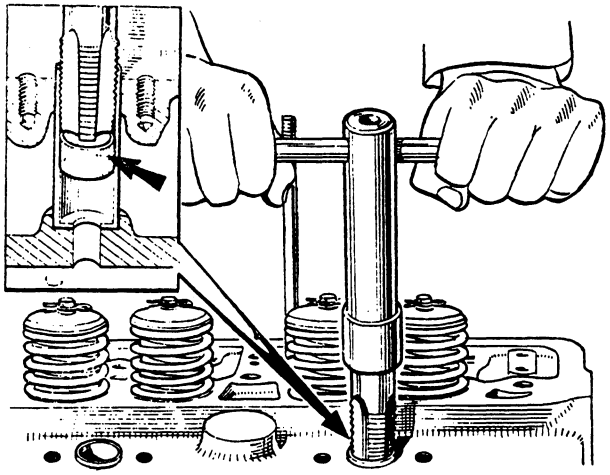


Fig. Aa.18
Cutting a thread in an injector sleeve, using tool 18G 213 A, to enable the sleeve to be withdrawn by tool 18G 213. Shown inset is the 'Alkathene' plug inserted in the sleeve to prevent swarf entering the cylinder bore

Section Aa.16

VALVE SEAT INSERTS

If a valve seating cannot be restored with the normal cutting and refacing tools, or if valve head stand-down is excessive with a new valve, a valve seat insert should be fitted.

To fit an insert, machine the seating in the cylinder head to the dimensions given in Fig. Aa.17, and press the insert, which has an interference fit of ·002 to ·004 in. (·051 to ·102 mm.), into the cylinder head. Finally, grind or machine the new seat to the dimensions given in Fig. Aa.17, ensuring that the throat of the new seat blends into the throat in the cylinder head.

Check the area of contact between the new seat and its valve with marking blue, and if necessary lap the valve onto its seat (Section Aa.14).

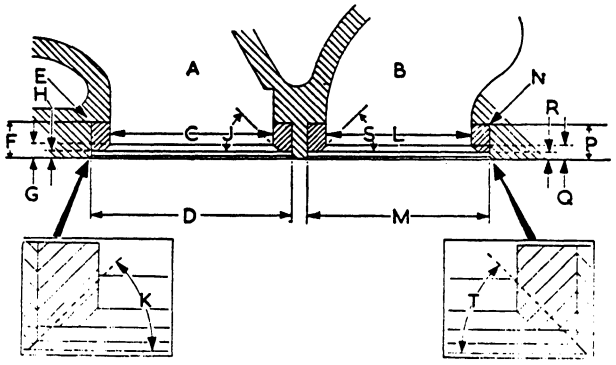


Fig. Aa.17
Valve seat machining dimensions

Inlet (A)

- C. Nominal diameter 1·450 in. (36·8 mm.).
- D. 1·775 to 1·776 in. (45·076 to 45·102 mm.).
- E. Maximum radius ·015 in. (·38 mm.).
- F. ·325 to ·328 in. (8·25 to 8·33 mm.).
- G. ·135 to ·140 in. (3·43 to 3·56 mm.).
- H. ·070 to ·080 in. (1·78 to 2·03 mm.).
- J. 45°
- K. Chamfer ·020 to ·030 in (·508 to ·762 mm.). at 45°.

Exhaust (B)

- L. Nominal diameter 1·290 in. (32·75 mm.).
- M. 1·625 to 1·626 in. (41·27 to 41·30 mm.).
- N. Maximum radius ·015 in. (·38 mm.).
- P. ·325 to ·328 in. (8·25 to 8·33 mm.).
- Q. ·135 to ·140 in. (3·43 to 3·56 mm.).
- R. ·070 to ·080 in. (1·78 to 2·03 mm.).
- S. 45°.
- T. Chamfer ·020 to ·030 in. (·508 to ·762 mm.) at 45°.

Section Aa.17

DECARBONIZING

Remove the valve rocker shaft assembly (Section Aa.9).

Drain the cooling system.

Remove the cylinder head (Section Aa.12) and the valves (Section Aa.13).

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

If special equipment for decarbonizing is not available it will be necessary to remove the carbon deposit from the piston crown and cylinder head by scraping. A length of copper tubing with the end flattened and filed up makes an ideal scraper which will not scratch.

The ridge of carbon in the top of each cylinder bore should not be disturbed and a ring of carbon should also be left round the periphery of each piston crown. An old piston ring sprung into the bore and resting on the top of the piston will facilitate this operation.

Remove the carbon deposit from the valves, valve ports, valve guides, and cylinder head. Thoroughly clean the cylinder head and ensure that all traces of

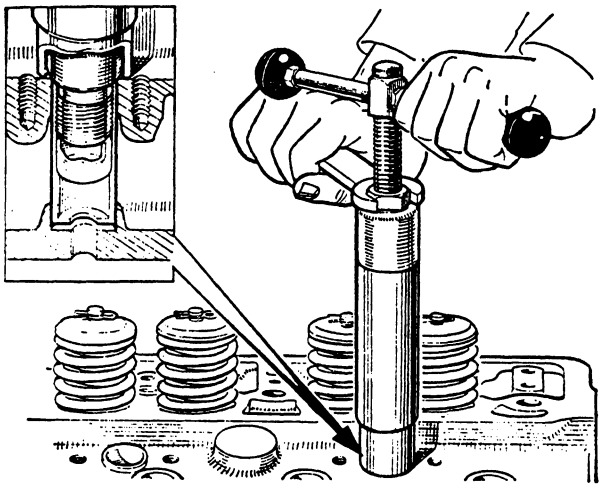


Fig. Aa.19

●*Withdrawing an injector sleeve, using tool* 18G 213 D●

carbon dust are removed from the head and cylinder bores.

Replace the components, reversing the removal procedure, and adjust the valve rocker clearance **(Section Aa.11).**

Section Aa.18

REMOVING AND REPLACING THE INJECTOR SLEEVES

If it is found necessary to renew an injector sleeve the operation can be carried out without removing the cylinder head.

Remove the injector.

●Insert an 'Alkathene' plug, supplied with tool 18G 213 A, into the injector sleeve to prevent swarf entering the cylinder. Using tool 18G 213 A, cut a thread on the inside of the sleeve. Remove the tool but leave the plug in position. Screw tool 18G 213 D into the injector sleeve and withdraw the sleeve (Fig. Aa.19).●

Remove the 'Alkathene' plug from the injector sleeve.

Crank the engine to position the piston, in the cylinder being operated on, at B.D.C.

Coat the new injector sleeve with sealing compound part number AKF 1702 on those surfaces which contact the cylinder head and drive it into position using tool 18G 561.

Section Aa.19

REMOVING AND REPLACING A CONNECTING ROD AND PISTON

Drain and remove the sump.

Remove the valve rocker shaft assembly (Section **Aa.9).**

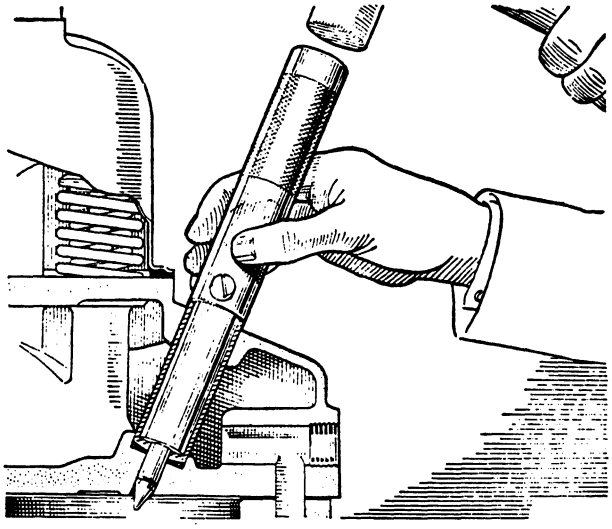


Fig. Aa.20

Installing an injector sleeve, using tool 18G 561

Drain the cooling system.

Remove the cylinder head.

If No. 1 connecting rod is to be removed detach the oil strainer and suction pipe from the oil pump.

Remove the cap and the bottom half of the big-end bearing.

Clean the carbon deposit from the top of the cylinder bore and withdraw the connecting rod and piston upwards through the cylinder.

NOTE.—Each connecting rod and cap is stamped with the number of the cylinder from which it was removed (Fig. Aa.22).

Lubricate the cylinder bore and piston with clean engine oil, space the compression ring gaps equally round the circumference of the piston, and compress the rings, using tool 18G 55 A.

Insert the connecting rod and piston downwards through the cylinder bore, so positioned that the **connecting rod cap will be towards the left-hand side of**

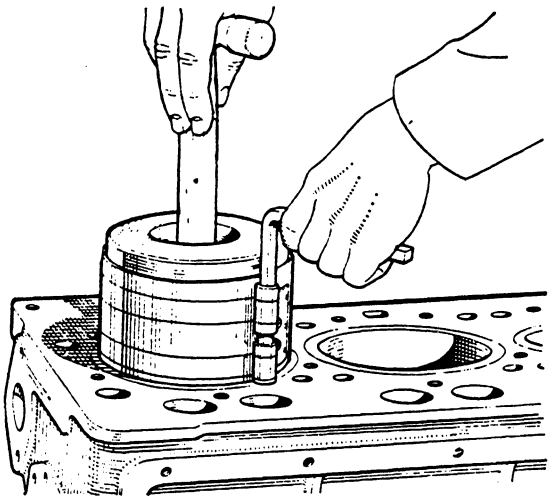


Fig. Aa.21

Installing a piston and connecting rod assembly using tool 18G 55 A

1. Connecting rod.
2. Cap.
3. Bearing.
4. Bolts.
5. Tab washer.
6. Hollow dowel.
7. Little-end bush.

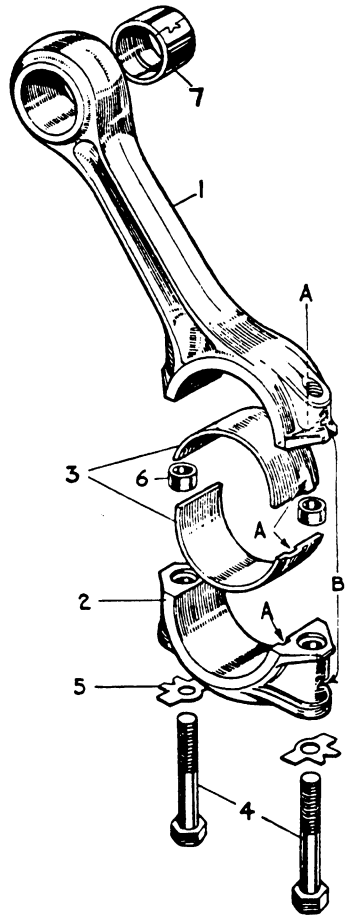


Fig. Aa.22

The arrows (A) indicate the bearing locating tags and grooves. The arrows (B) indicate the cylinder number from which the connecting rod was removed

the engine. The cavity in the piston crown should now be offset towards the right-hand side of the engine.

Ensure that the connecting rod and cap, the bearing, and the crankpin are absolutely clean. Fit the two halves of the bearing to the connecting rod and cap.

Each half bearing has a tag which locates in a groove in the connecting rod and cap (Fig. Aa.22). If the old bearing is being used the two halves should be replaced in their original positions. Lubricate the bearing and crankpin with clean engine oil, position the hollow dowels between the connecting rod and cap, and fit the cap into position with the stamped numbers on rod and cap adjacent to each other. Fit new tab washers under the big-end bolts and tighten the bolts to the figure given in **'GENERAL DATA,'** using torque wrench 18G 372. Lock the bolts in position with the tab washers.

Replace the remaining components, reversing the removal procedure, and adjust the valve rocker clearance (Section Aa.11).

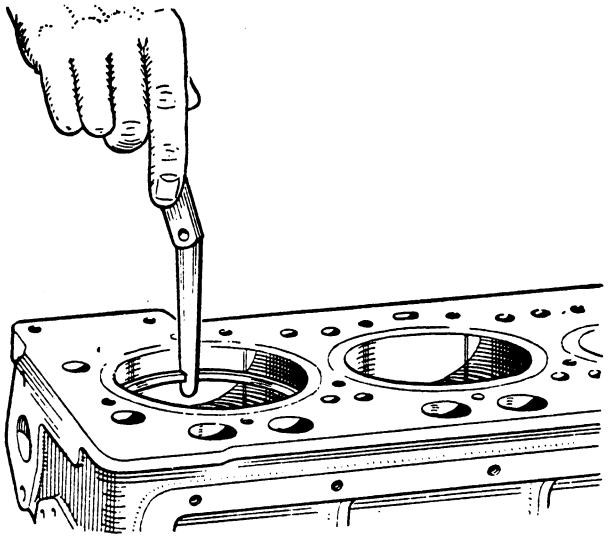


Fig. Aa.23

When checking the gap clearance of a new piston ring ensure that the ring is inserted into an unworn part of the cylinder bore

Section Aa.20

DISMANTLING AND REASSEMBLING A CONNECTING ROD AND PISTON

Remove the bearing halves from the connecting rod and cap. If the bearing is to be re-used it should be marked to ensure reassembly in its original position.

Using tool 18G 1004, withdraw the two circlips from the piston and press the gudgeon pin out. Mark the piston and gudgeon pin to ensure correct reassembly.

Remove the rings from the piston and place them in the order in which they are removed, to assist in reassembling them in their original grooves.

Thoroughly clean all the dismantled components and inspect them for damage.

Check the cylinder bore for scoring and for wear (see **'GENERAL DATA'**). If the diameter of the bore is worn in any place by ·010 in. (·254 mm.) or more, a new

NOTE: On the VD series of the four and six cylinder engines there are two grooves, one above and one below the wrist pin, for two scraper rings. For the VD series engines, both of these scraper rings are used.

For the 98 series engines both grooves are present but only the upper scraper ring may be installed. If a lower ring is installed, the piston will be starved for lubrication.

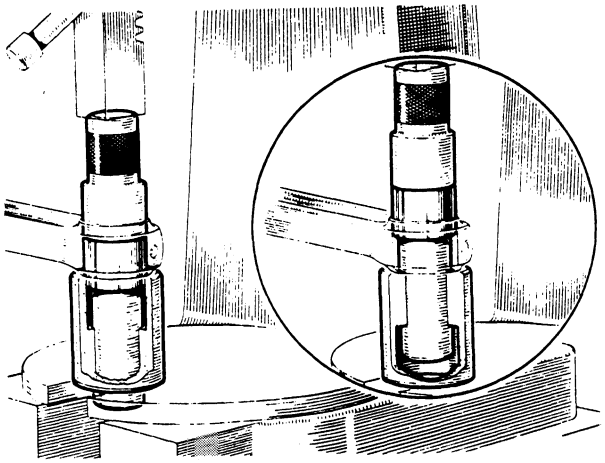


Fig. Aa.25

Removing and replacing a connecting rod little-end ***bush using tool 18G 616***

liner and piston should be fitted (Section Aa.21). In the event of a water leak at the bottom of the cylinder liner, the cylinder liner sealing ring should be renewed (Section Aa.21).

Check the piston to cylinder bore clearance (see **'GENERAL DATA'**).

Insert each piston ring into the cylinder bore and measure the piston ring gap (Fig. Aa.23) against the figure in **'GENERAL DATA.'** The ring should be placed in an unworn part of the bore and the piston used to position the ring square to the cylinder bore axis.

Check the clearance of each ring in its own groove (Fig. Aa.24) against the figure in **'GENERAL DATA.' The top ring is taper-sided, and to check its groove** clearance the ring should be fitted to the piston and inserted into an unworn cylinder liner. Push the piston into the liner until about three-quarters of the piston ring width has entered the liner, then check the ring groove clearance.

If it is decided to fit new piston rings in a used cylinder, the glaze should be removed from the cylinder bore.

Check the fit of the gudgeon pin in the piston (see **'GENERAL DATA'**).

Measure the gudgeon pin to small-end bush clearance (see **'GENERAL DATA'**), and, if necessary, renew the bush (Fig. Aa.25), using tool 18G 616. Before pressing in a new bush, line up the oil hole in the bush with the hole in the top of the connecting rod.

Check the connecting rod alignment against the figure in **'GENERAL DATA.'**

Fit the rings into their respective grooves in the piston, ensuring that Nos. 2 and 3 compression rings, which are taper-faced, are installed with the side marked 'TOP' uppermost.

Reassemble the remaining components, reversing the dismantling procedure, noting that the cavity in the piston crown should be offset to the connecting rod on the opposite side to the big-end cap.

Section Aa.21

REMOVING AND REPLACING A CYLINDER LINER

Drain and remove the sump

Remove the valve rocker shaft assembly (Section **Aa.9).**

Drain the cooling system

Remove the cylinder head (Section Aa.12).

Withdraw the connecting rods and pistons (Section **Aa.19).**

Using tool 18G 227 C, withdraw the cylinder liner **upwards from the cylinder block (Fig. Aa.26).**

Remove the cylinder liner sealing ring from its groove in the bottom of the cylinder block.

NOTE.—The sealing ring should be renewed on all occasions of cylinder liner removal.

Inspect the cylinder liner seating in the top of the cylinder block for signs of burrs, carbon, or rust accumulation. Thoroughly clean the seating, being careful not to remove any metal, otherwise a water leak is liable to occur. If the old liner is to be refitted, clean the locating flange at the top of the liner exercising the same care as for the liner seating.

Thoroughly clean the sealing ring groove in the cylinder block.

Insert the cylinder liner into the cylinder block without fitting the sealing ring, and clamp the liner in the fully-home position.

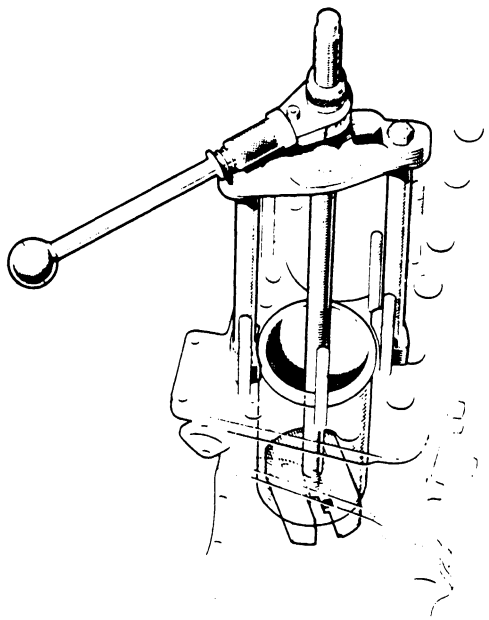


Fig. Aa.26

Withdrawing a cylinder liner, using tool 18G 227 C

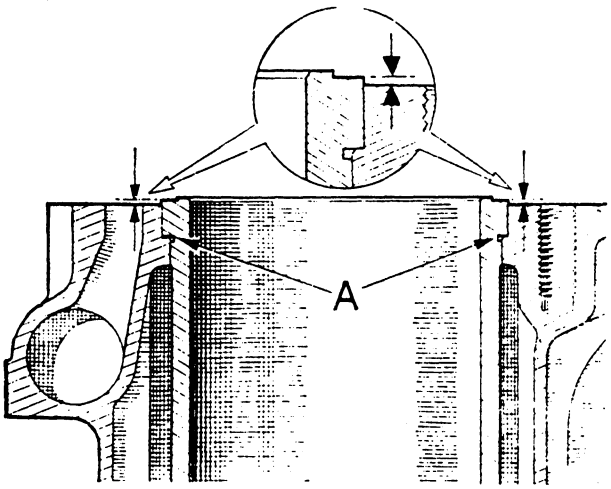


Fig. Aa.27

Insert shims at (A) to adjust the standing height of the early cylinder liner. Shown inset are the faces of the cylinder block and the liner from which the standing height is measured

Check the standing height of the cylinder liner against the dimension in **'GENERAL DATA.'** The top face of the liner is stepped and the standing height should be measured between the lower face of the step and the top face of the cylinder block. If necessary, the standing height of early liners can be increased by fitting shims (see **'GENERAL DATA'** for thickness) under the cylinder liner flange.

Remove the liner, install a new sealing ring in the groove in the bottom of the cylinder block, and apply a coating of Hylomar SQ32 jointing compound to the reduced diameter at the lower end of the liner. Install the liner, using a semi-rotary motion to prevent the sealing ring becoming twisted or dislodged. Press the liner fully home then check its bore for ovality in the area adjacent to the sealing ring. If the ovality exceeds ·00175 in. (·04 mm.), withdraw the liner and check that the sealing ring is seating correctly. It may be necessary to exchange the sealing ring to reduce the liner ovality to an acceptable limit.

Replace the remaining components, reversing the removal procedure, and adjust the valve rocker clearance **(Section Aa.11).**

Section Aa.22

REMOVING AND REPLACING THE TIMING GEAR CASE COVER

Take the weight of the engine at the front, preferably with a sling, but do not lift directly under the sump.

Release the engine front support bracket from its mountings

Unlock and unscrew the nut from the front of the crankshaft, using spanner 18G 97.

Withdraw the crankshaft pulley, using tool 18G 231 and adaptor 18G 231 A, and extract the pulley key from the end of the crankshaft. The crankshaft oil seal may be removed and replaced, using tool 18G 1111.

Remove the engine front support bracket from the timing gear case.

Unscrew the remaining bolts securing the timing gear case cover to the timing gear case, and detach the engine front lifting bracket and the alternator support bracket.

Remove the set bolts securing the front of the sump to the timing case cover and slacken the remaining sump bolts two complete turns.

Pull the timing case cover, complete with crankshaft oil seal and distance piece, off the two locating dowels at the lower end of the timing gear case, taking care not to damage the sump gasket.

Cover the open end of the sump to prevent the ingress

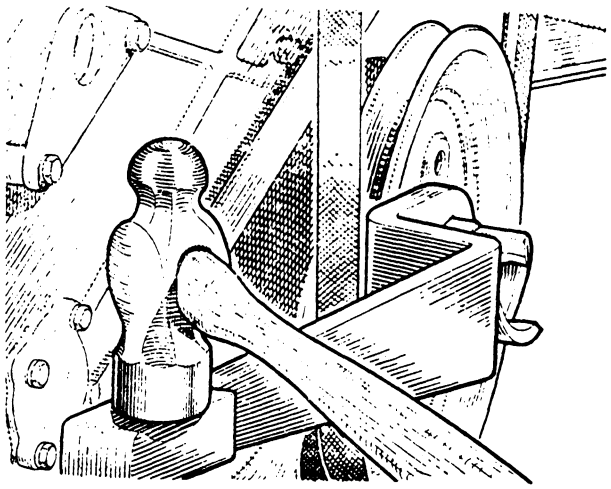


Fig. Aa.28

Removing the starting handle jaw nut, using tool 18G 97

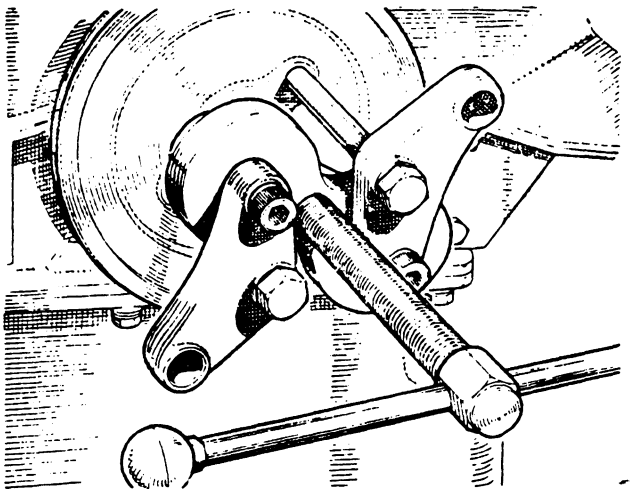


Fig. Aa.29

Withdrawing the crankshaft pulley, using tools 18G 231 and 18G 231 A

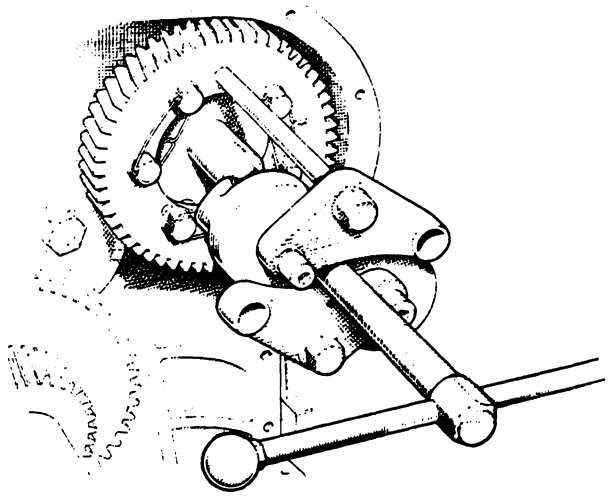


Fig. Aa.30
Withdrawing the camshaft gear, using tools 18G 231, 18G 231 C, and 18G 231 D

of foreign matter.

Clean the joint faces of both timing case and cover, and examine them for burrs. Inspect the crankshaft oil seal and renew it, if necessary. Ensure that the crankshaft distance piece is free from burrs and scratches where it contacts the crankshaft oil seal.

When replacing the components, which is a reversal of the foregoing procedure, fit a new gear case cover gasket but do not use jointing compound. The groove between the sealing lips of the crankshaft oil seal should be filled with high melting point grease before assembly.

Section Aa.23

REMOVING AND REPLACING THE TIMING GEARS

Before removing the timing gears check the gear backlash against the figure in **'GENERAL DATA.'**

Four-230

Refit the crankshaft nut and rotate the crankshaft, using spanner 18G 97, until Nos. 1 and 4 pistons are at T.D.C. with No. 4 piston commencing its induction stroke. This will correctly position the timing marks on the crankshaft and camshaft gears for reassembly.

Six-346

Refit the crankshaft nut and rotate the crankshaft, using spanner 18G 97, until Nos. 1 and 6 pistons are at T.D.C. with No. 6 piston commencing its induction stroke. This will correctly position the timing marks on the crankshaft and camshaft gears for reassembly.

Press back the locking washers and unscrew the nuts from the camshaft and the injection pump drive shaft. Remove the thrust washer and withdraw the idler gear from its shaft.

NOTE.—After the idler gear has been removed, neither the crankshaft or camshaft should be rotated unless all the valve rocker adjusting screws are completely slackened off to allow all the valves to remain fully closed. If this condition is not observed the valves may foul the pistons and cause serious damage.

Remove the oil thrower from the end of the crankshaft.

Withdraw the oil pump driving gear and crankshaft gear, using tool 18G 231 and adaptor 18G 231 B.

Using tool 18G 231 and adaptor 18G 231 C, withdraw the gears from the camshaft and the injection pump

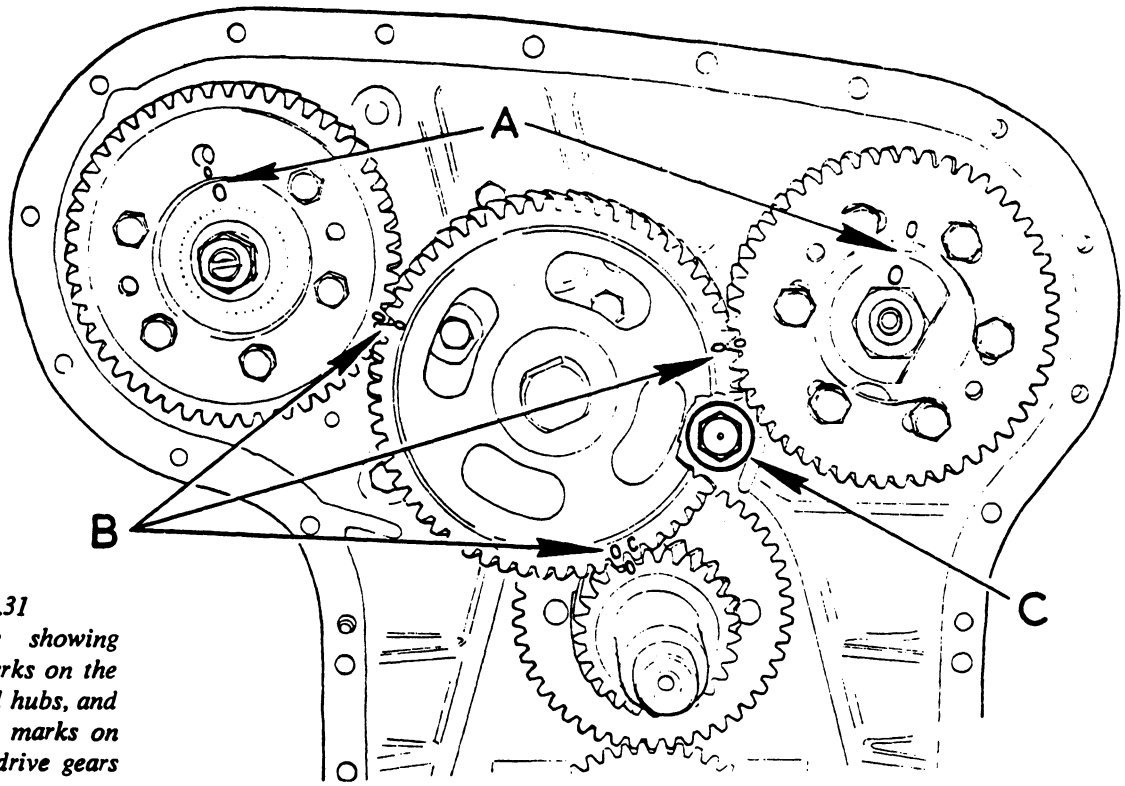


Fig. Aa.31
Timing gears showing (A) the 'O' marks on the drive gears and hubs, and (B) the timing marks on the idler and drive gears

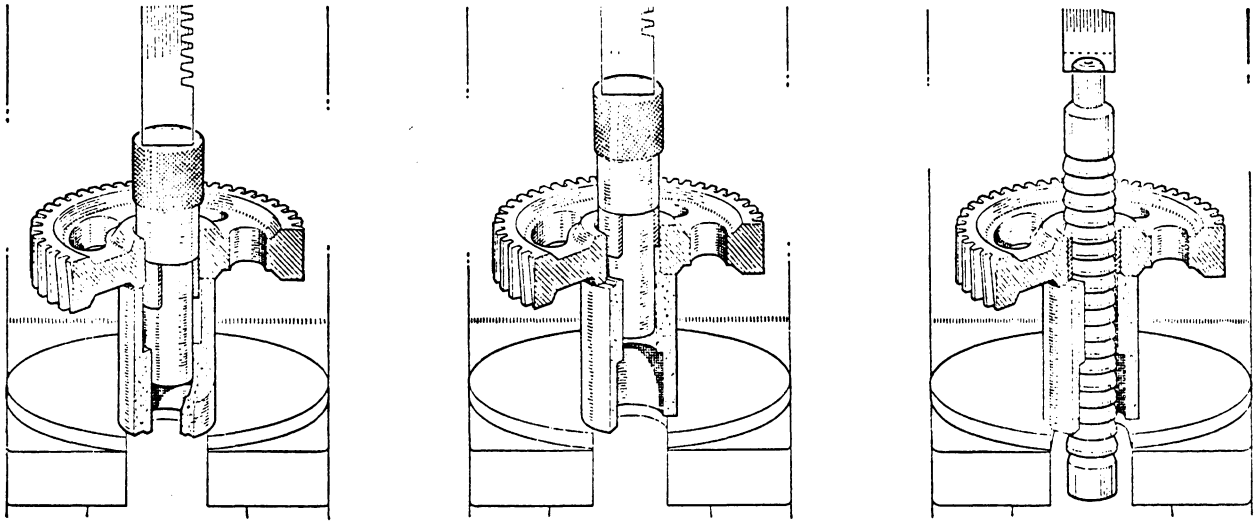


Fig Aa.32

Removing, replacing, and broaching to size the timing idler gear bush, using tool 18G 683

drive shaft. Thrust pads 18G 231 D and 18G 231 E should be used for the camshaft gear and injection pump drive gear respectively.

Thoroughly clean and inspect all the dismantled components.

Check the idler gear thrust washer thickness and the idler gear bush to shaft clearance against the figures given in **'GENERAL DATA.'** If necessary, renew the **bush, as described in Section Aa.24.**

Refit the gears to the camshaft, crankshaft, and injection pump drive shaft and ensure that the timing marks on the teeth of these gears are in the position **shown in Fig. Aa.31. Slide the idler gear onto its shaft** and engage the teeth with those of the other gears so **that the timing marks line up as shown in Fig Aa.31,** noting that the double mark on the idler gear is lined up with the timing mark on the crankshaft gear.

Tighten the nuts on the camshaft and injection pump drive shaft and secure them with the locking washers.

Check the valve timing as described in Section Aa.26.

Fit the idler gear thrust washer to the shaft, with the oil groove towards the gear.

Refit the crankshaft oil thrower with the chamfered side towards the gear.

Replace the remaining components in the reverse order to that in which they were removed.

Check the injection timing as described in Section Da.

Section Aa.24

DISMANTLING AND REASSEMBLING THE TIMING GEARS

Two of the timing gears—those fitted to the camshaft and the injection pump drive shaft—can be dismantled from their hubs without removing the hubs from their shafts.

Position the crankshaft so that the Four-230 No. 4 piston or the Six-346 No. 6 piston is just commencing its induction stroke as described in Section Aa. 23.

Remove the thrust washer and idler gear from its shaft, and the camshaft gear and injection pump drive gear from their hubs.

If the idler gear bush is to be removed, press the old bush out, using tool 18G 683, with the larger bore of the tool support uppermost. Reverse the tool support so that its lipped end is uppermost when pressing in a new bush. This will ensure that the bush is correctly positioned with its ends equidistant from the sides of the gear. With the tool support still in this latter position, broach the bush after first lubricating the broach liberally with clean paraffin.

Reassemble the camshaft gear and the injection pump drive gear to their hubs so that the timing mark on the inner face of each gear lines up with the timing mark **on its hub as in Fig. Aa.31.**

Refit the idler gear to its shaft so that the timing marks on all four timing gears are in the relationship **shown in Fig. Aa.31, noting that the double mark on** the idler gear is lined up with the timing mark on the crankshaft gear.

Tighten and rewire the securing screws on the injection pump drive gear, but leave the securing screws on the camshaft gear finger-tight.

Adjust the valve timing as described in Section Aa.26.

Refit the idler gear thrust washer with the oil groove towards the gear.

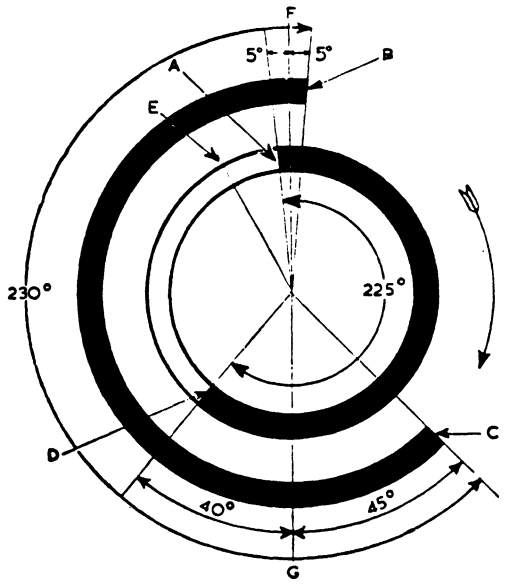


Fig. Aa.33

Valve timing diagram Four-230

A. Inlet valve opens.
B. Exhaust valve closes.
C. Exhaust valve opens.
D. Inlet valve closes.
E. Fuel injection timing 28 B.T.D.C.
F. Top dead centre.
G. Bottom dead centre.

Section Aa.25

REMOVING AND REPLACING THE TIMING GEAR CASE

Remove the timing gear case cover (Section Aa.22).

Withdraw the idler gear and the camshaft gear as **described in Section Aa.23.**

Unscrew the idler gear shaft, which has a lefthand thread, and the timing gear oil feed jet complete with copper seal washer.

Remove the set screws securing the gear case to the **crankcase and pull the gear case, complete with** injection pump drive and the driving half of the injection pump coupling, off the three locating dowels on the crankcase.

If necessary, remove and dismantle the injection **pump drive as described in Sections Aa.27 and Aa.28.**

Thoroughly clean and inspect all the dismantled components.

When replacing the components, which is a reversal of the foregoing procedure, fit a new gasket between the crankcase and timing gear case, coating the crankcase joint face with sealing compound.

Ensure that the injection pump drive coupling is assembled correctly. The coupling dowel bolt must engage the hole in the pump drive flange.

The idler gear shaft should only be tightened sufficiently to retain it in position.

Section Aa.26

VALVE TIMING

Four-230 Engine

When timing pin AMK 9990 engages the flywheel, No. 4 piston is at 25° B.T.D.C. and the degree plate must be set at 25° before zero.)

With the timing marks on the gears correctly related as in Fig. Aa.31, and the valve rocker clearance adjusted as in Section Aa.11, final adjustment of the valve timing (see **'GENERAL DATA'** and Fig. Aa.33) is made by rotating the camshaft drive gear in relation to its hub, the securing bolt holes in the camshaft gear being elongated for this purpose.

Rotate the crankshaft in the normal direction or rotation until the 5° A.T.D.C. mark is at the top of the flywheel in the vertical position with No. 1 piston commencing its firing stroke and No. 4 piston commencing its induction stroke.

Slacken the six set bolts securing the camshaft gear to its hub and rotate the camshaft in the normal direction of rotation until the exhaust valve (No. 8) of No. 4 cylinder is just closed.

A clock gauge, mounted on the engine with its indicator contacting the valve spring collar, will facilitate this operation. Tighten the camshaft gear securing bolts, recheck the valve timing, and rewire the gear securing bolts.

An alternative method of setting the crankshaft at 5° A.T.D.C. is to use a degree plate and pointer in conjunction with timing pin AMK 9990, as follows:

(1) Rotate the crankshaft in the normal direction of rotation until the inlet valve (No. 2) of No. 1 cylinder is just closed. No. 1 piston will now be commencing its compression stroke and No. 4 piston will be on its exhaust stroke.

(2) Insert timing pin AMK 9990 through the reamed hole in the lower half of the engine sandwich plate and, while maintaining pressure on the pin, rotate the crankshaft slowly until the pin engages the timing hole in the flywheel.

(3) Mount the degree plate on the front end of the crankshaft, attach the pointer in a suitable position to the engine, and set the degree plate at 28° (25° on engines with a Simms Minimec injection pump) before zero.

(4) Remove the timing pin and rotate the crankshaft to bring the 5° after zero mark on the degree plate in line with the timing pointer. The crankshaft will now be at 5° A.T.D.C., with No. 4 piston on its induction stroke.

Six-346

To facilitate retiming, one tooth on each gear, with the exception of the idler gear, is marked with an 'O' or drill dimple (see Fig. 28). The corresponding teeth on the idler gear which mesh with the marked tooth on the camshaft drive gear and the fuel injection pump/exhauster drive gear are identified with similar marks, while the corresponding teeth which mesh with the marked tooth on the crankshaft gear are marked with 'OC' or twin drill dimples. Also, the faces of the fuel injection pump drive hub, the camshaft flange or drive hub, and their drive gears are stamped with 'O' marks to ensure correct timing relationship between these components.

Assemble the drive gear to the fuel injection pump drive hub, lining up the 'O' mark on the face of the hub with the 'O' mark on the face of the gear. In a similar manner, assemble the drive gear to the camshaft, lining up the 'O' marks on the faces of the gear and the camshaft flange or drive hub, but do not lock the securing bolts at this stage as final adjustment of the valve timing has still to be carried out.

If necessary, after first ensuring that the valve rocker adjusting screws are fully released, rotate the crankshaft to position No. 6 piston at T.D.C. on its induction stroke. The tooth with the timing mark on the crankshaft gear will now be between 11 and 12 o'clock (see Fig. 31).

Rotate the camshaft to position the gear tooth with the timing mark between eight and nine o'clock and then turn the fuel injection pump drive gear so that its tooth with the timing mark is between three and four o'clock (see Fig. 31).

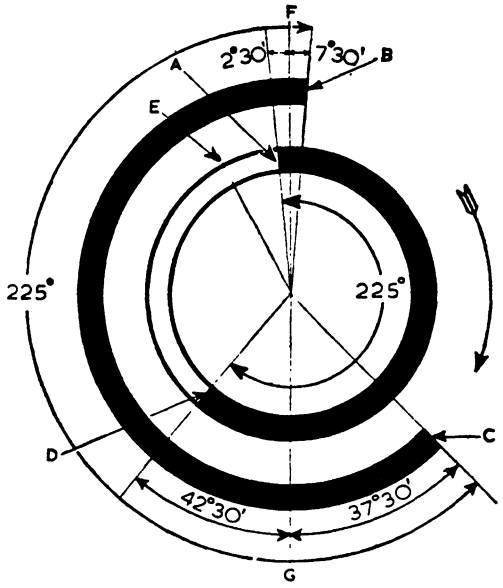
Fit the idler gear to its shaft with the marked teeth on the drive gears engaging the corresponding teeth on the idler gear as shown in Fig. 31

Fit the idler gear thrust washer with the oil groove in the washer next to the gear.

The valve timing may be checked, using a degree plate and pointer, a dial-gauge, and timing pin AMK 9990, as follows:

(1) Set No. 6 cylinder inlet valve clearance to ·021 in. (·53 mm.) then crank the engine until No. 6 piston is on its firing stroke.

(2) Insert timing pin AMK 9990 through the reamed hole in the lower half of the engine sandwich plate. Maintain pressure on the head of the pin, and crank the engine until the pin engages the timing hole in the flywheel. No. 6 piston is now 14° B.T.D.C. on its exhaust stroke.



Valve timing diagram—Engine type Six-346

A. Inlet valve opens.
B. Exhaust valve closes.
C. Exhaust valve opens.
D. Inlet valve closes.
E. Fuel injection timing (fully retarded) 14° B.T.D.C.
F. Top dead centre.
G. Bottom dead centre.

(3) Mount the degree plate on the front end of the crankshaft and attach the pointer in a suitable position on the timing case. Set the degree plate at 14° before zero then remove timing pin AMK 9990.

(4) Mount the dial gauge on the cylinder head with its indicator resting on the collar of No. 6

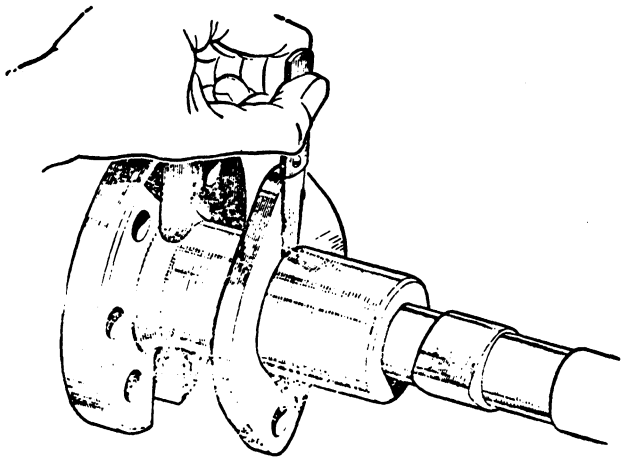


Fig. Aa.34
Checking the camshaft end-float

Section Aa.27
REMOVING AND REPLACING THE INJECTION PUMP DRIVE

Remove the injection pump (Section Da).

Remove the blanking plate from the timing gear case cover, and unlock and unscrew the nut from the injection pump drive shaft.

Remove the six set bolts securing the injection pump drive to the timing gear case and withdraw the injection pump drive, using tool 18G 1008B to separate the drive shaft from its drive gear.

When replacing the drive housing ensure that the joint faces of the timing gear case and the drive housing are clean. Smear the joint face on the rear of the timing gear case with jointing compound, and fit a new drive housing gasket.

Replace the remaining components by reversing the removal procedure.

Bleed the fuel system as described in Section Da.

Section Aa.28
DISMANTLING AND REASSEMBLING THE INJECTION PUMP DRIVE

Slacken the clamp bolt nut on the coupling driving flange and withdraw the flange from the drive shaft.

Extract the coupling key from the drive shaft and remove the end cover, complete with oil seal, from the drive housing.

Remove the cover plate from the front of the drive housing and press the shaft out of the housing in a forward direction The large bearing will be ejected from the housing as the drive shaft is pressed out.

Extract the drive gear key from the drive shaft.

Press the small ball bearing out of the rear of the housing and remove the oil seal from the end cover.

Clean and inspect all the dismantled components.

Commence reassembly by pressing the large ball bearing into the front of the housing. Refit the front cover plate and when the countersunk screws are fully tightened, lock them in position by peening.

Fit the drive gear key to the front of the shaft and insert the shaft into the housing from the rear end until the flange on the shaft is against the bearing.

Pass the small ball bearing over the shaft and press the bearing into the housing until it contacts the shoulder in the housing.

Fit the oil seal into the end cover so that its sealing lip faces towards the bearings.

Smear the joint face of the end cover with sealing compound and refit the end cover to the drive housing, being careful not to damage the oil seal.

Refit the coupling key and driving flange.

Inject a liberal quantity of clean engine oil through the hole in the top of the drive housing to provide initial lubrication until the oil in the engine is circulating.

Section Aa.29
REMOVING AND REPLACING THE CAMSHAFT

Remove the timing gear case cover (Section Aa.22).

Withdraw the camshaft drive gear (Section Aa.23).

Remove the rocker cover and slacken fully the valve rocker adjusting screws. Withdraw the pushrods.

Remove the fuel lift pump

Disconnect the external oil pipe from the main oil gallery and cylinder head.

Remove the tappet and pushrod cover and the oil level indicator guide from the side of the cylinder block.

Lift out the tappets.

Remove the camshaft thrust plate and withdraw the camshaft, being careful to avoid damage to the bearing surfaces as the camshaft is withdrawn.

Thoroughly clean and inspect all the dismantled parts.

Check the camshaft bearing clearance against the dimensions in 'GENERAL DATA.'

Fit the thrust plate and the drive gear to the camshaft, tighten the camshaft nut, and check the **camshaft end-float as shown in Fig. Aa.34 against the** dimension given in **'GENERAL DATA.'**

If necessary, remove the locating bolt and withdraw the camshaft front bearing from the cylinder block. Press a new bearing into position, plain edge first, aligning the two holes in the bearing with the two holes in the bearing housing. When the bearing is in position the holes can be tapped into final alignment, using a

soft drift against the aligning notch in the bearing. Fit the locating bolt and line-ream the bearing to the dimension given in **'GENERAL DATA.'**

Replace the remaining components, lubricating all the bearing surfaces with clean engine oil, by reversing the removal procedure.

Adjust the valve rocker clearance as described in **Section Aa.11 and bleed the fuel system of air.**

Section Aa.30

REMOVING AND REPLACING THE FLYWHEEL AND STARTER RING

Remove the Transmission

Unlock and remove all but two of the bolts securing the flywheel to the crankshaft flange. Unscrew the two remaining bolts sufficiently to allow the flywheel to be drawn off the crankshaft flange.

Withdraw the flywheel by screwing two $\frac{3}{8}$in. UNF. bolts into the withdrawal holes in the flywheel, and remove the two remaining flywheel bolts.

Examine the flywheel face and the starter ring teeth for wear against the figures given in **'GENERAL DATA.'**

If necessary, remove the starter ring by drilling a hole in the ring and splitting it across the hole with a hammer and chisel.

Ensure that the bore of the new starter ring and its mating surface on the flywheel are perfectly clean and free from burrs. Heat the starter ring uniformly to the temperature given in **'GENERAL DATA.'** The strip of temperature-indicating paint on the starter ring will change from greyblue to buff colour when the temperature is correct.

Place the heated starter ring, bore chamfer foremost, squarely on the flywheel. The expansion should allow the ring to be readily fitted by placing a piece of hardwood across the ring and pressing or tapping it until the starter ring is hard against its register. When the ring is cold the 'shrink' fit will be permanently established and no further treatment is necessary.

When replacing the flywheel check that the locating dowels are not a loose fit in their holes, and that they are free from burrs. The dowels are diagonally offset to ensure correct positioning of the flywheel.

Tighten the flywheel bolts in diagonal sequence to the torque figure given in **'GENERAL DATA.'**

Check the flywheel alignment with a clock gauge, against the figure given in **'GENERAL DATA.'**

Lock the flywheel bolts and replace the remaining components by reversing the removal procedure.

Section Aa.31

REMOVING AND REPLACING THE ENGINE SANDWICH PLATE

Remove the Transmission Section and the flywheel (Section Aa.30).

Remove the starter motor

Unscrew the set bolts securing the sandwich plate to the cylinder block, and pull the sandwich plate off the three dowels which locate it on the cylinder block. Remove the sandwich plate joint washer.

Replacement is a reversal of the foregoing procedure, using a new joint washer between the sandwich plate and the cylinder block.

Section Aa.32

REMOVING AND REPLACING THE CRANKSHAFT AND MAIN BEARINGS

Remove the sump Remove the oil pump (Section Aa.6), and the timing gear case cover (Section Aa.22).

Remove the oil thrower from the front end of the crankshaft and withdraw the oil pump driving gear and the crankshaft gear, using tool 18G 231 and adaptors 18G 231 B. Withdraw the two halves of the crankshaft thrust washer from the front main bearing.

Remove the flywheel (Section Aa.30) and the engine sandwich plate (Section Aa.31).

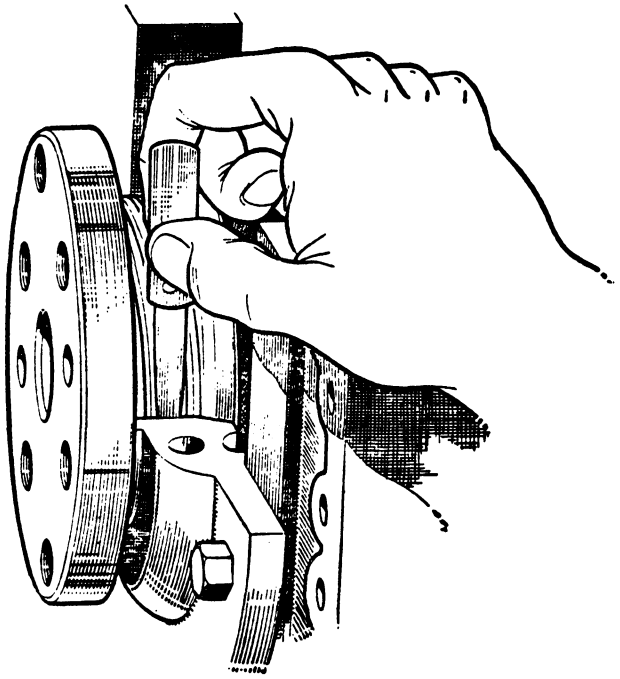


Fig. Aa.35

Checking the crankshaft rear oil seal cover to oil return thread clearance

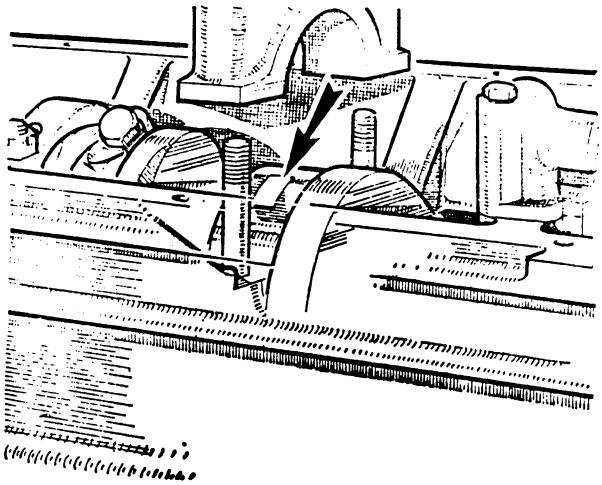


Fig. Aa.36

The arrow indicates the gauge paper used when checking the diametrical clearance of a crankshaft main bearing

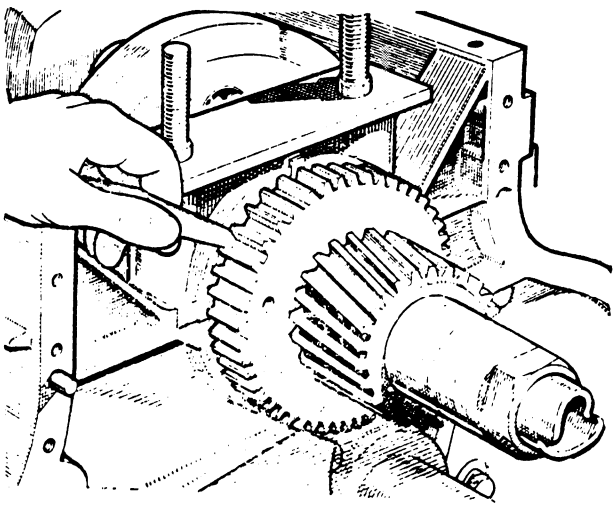


Fig. Aa.37

Checking the crankshaft end-float

Remove the connecting rod bearing caps and shells, keeping the shells with their respective caps for correct replacement, and separate the connecting rods from the crankshaft.

Unscrew the two bolts holding the two halves of the crankshaft rear oil seal cover together. Remove the bolts securing the bottom half of the cover to the crankcase and remove the bottom half cover, taking care not to damage the gasket. If the gasket is damaged in any way the top half of the cover should be removed and a new gasket fitted.

Remove the main bearing caps complete with the bottom halves of the main bearings. The crankcase and caps are marked for correct assembly, and the bearings and caps should always be replaced in their original positions.

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

Thoroughly clean and inspect all the dismantled components and examine all bearing surfaces for wear or scoring.

Check the crankshaft endfloat and main bearing clearance against the figures given in **'GENERAL DATA.'**

New bearings are prefinished to size and do not require any scraping or fitting.

When replacing the crankshaft lubricate all the bearings with clean engine oil and ensure that the hollow locating dowels are in position over the main bearing studs before fitting the bearing caps.

Refit the crankshaft rear oil seal cover and check that the clearance between the cover and the oil return thread on the crankshaft is in accordance with the figure in **'GENERAL DATA.'** The flat surface of the bottom half of the oil seal cover should be perfectly level with the crankcase surface to which the sump is mounted.

Before attaching the connecting rods to the crankshaft, align the marks on the timing gears as described in Section Aa.23.

Replace the remaining components by reversing the removal procedure, refill the sump with new engine oil, and bleed the fuel system of air as described in Section Da.

Section Aa.33

MODIFIED INLET VALVE LOCATING DETAILS

A new type inlet valve locating key and thimble, and a modified valve guide locating dowel have been introduced on later engines. These parts, which facilitate the assembly of the valves to their guides, are interchangeable in sets with their equivalent parts referred to in Section Aa.13.

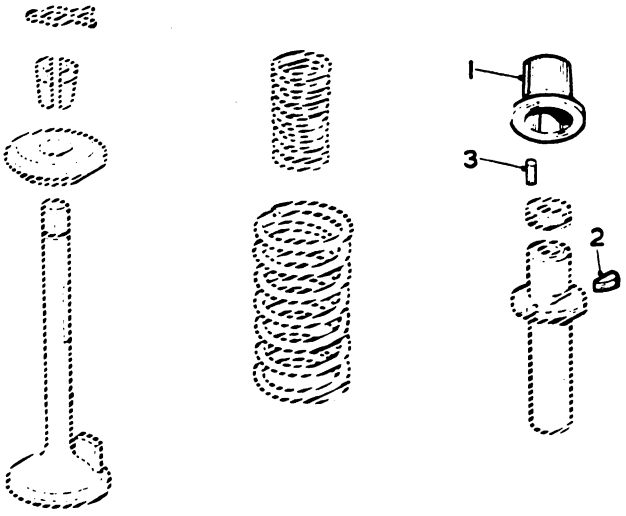


Fig. Aa.38

Modified inlet valve locating details

1 Thimble. 2 Key. 3 Dowel.

HYDRAULIC TRANSMISSIONS

I. SPECIFICATIONS

A. Description Chart

MODEL P200	MODEL P300	MODEL P400	REDUCTION RATIO	DIRECTION OF ROTATION
P21R	P31R	P41R	DIRECT	RIGHT
P21L	P31L	P41L	DIRECT	LEFT
P22R	P32R	P42R	1.5:1	RIGHT
P22L	P32L	P42L	1.5:1	LEFT
P23R	P33R	P43R	2.0:1	RIGHT
P23L	P33L	P43L	2.0:1	LEFT
P24R	P34R	P44R	2.5:1	RIGHT
P24L	P34L	P44L	2.5:1	LEFT
P25R	P35R	P45R	3.0:1	RIGHT
P25L	P35L	P45L	3.0:1	LEFT

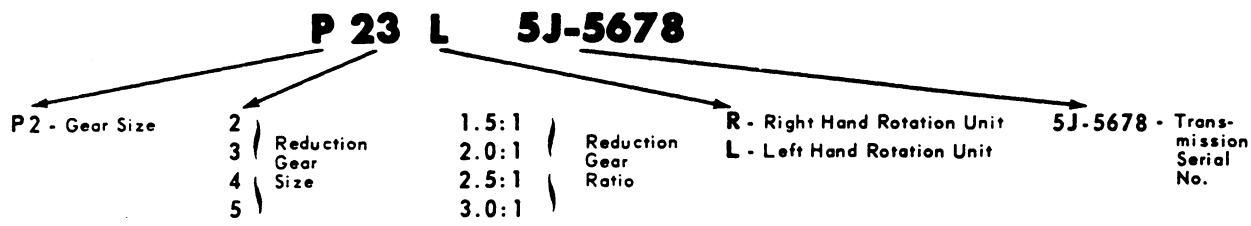
B. Model and Serial Numbers

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

MODEL AND SERIAL NUMBER CHART

DIRECT DRIVE MODEL AND SERIAL NUMBERS

REDUCTION GEAR MODEL AND SERIAL NUMBERS



II. INTRODUCTION

The Models P200, P300 and P400 hydraulic transmissions have been designed for smooth operation and dependability in marine use. The transmission is self-contained, having an oil pressure system and oil supply completely separated from engine lubricating oil systems.

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

III. INSTALLATION

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

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

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

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

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

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

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

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

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

E. Connect the oil cooler lines to the transmission.

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

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

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

IV. OPERATION

Principle of Operation

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

Starting Procedure

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

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

NOTE

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

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

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

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

V. MAINTENANCE

A. Lubrication

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

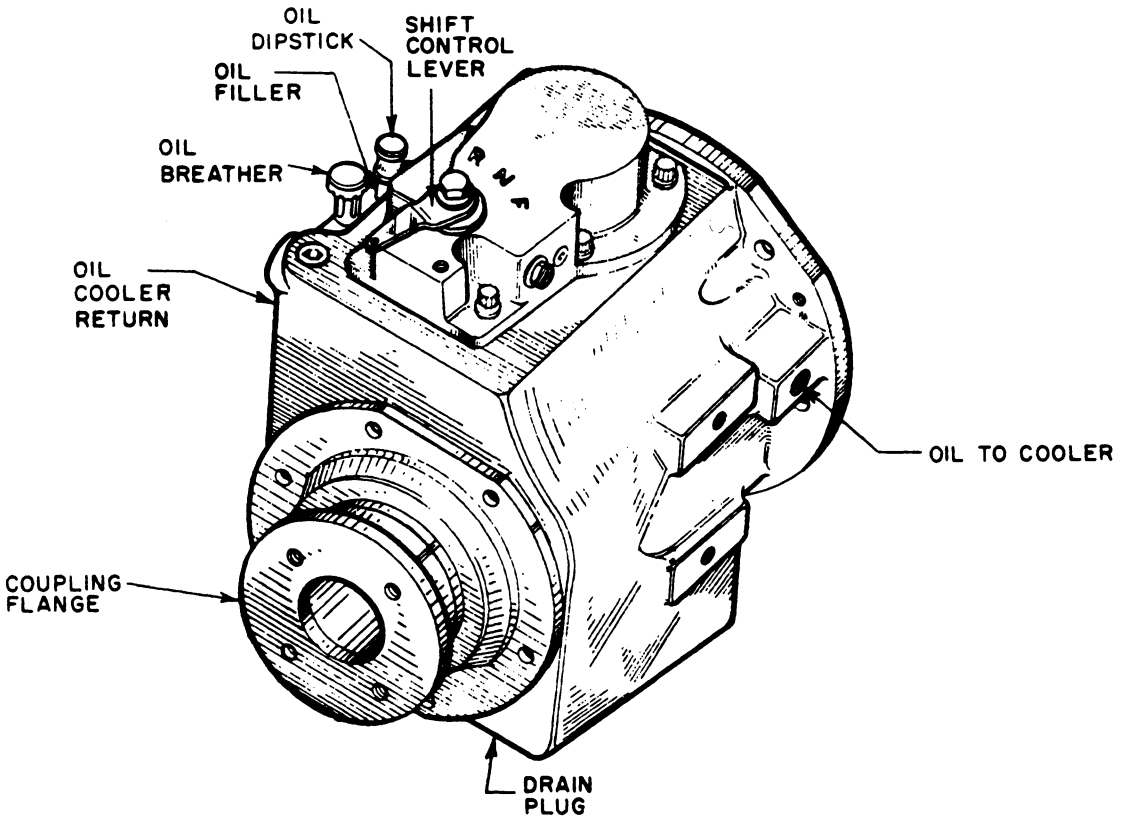
The quantity of oil depends upon the angle of installation, as well as the reduction model. The level must be maintained at the mark on the dipstick and should be checked periodically to ensure satisfactory operation.

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

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

B. Adjustments

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



PARAGON TRANSMISSION

C. Trouble Shooting Chart

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

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

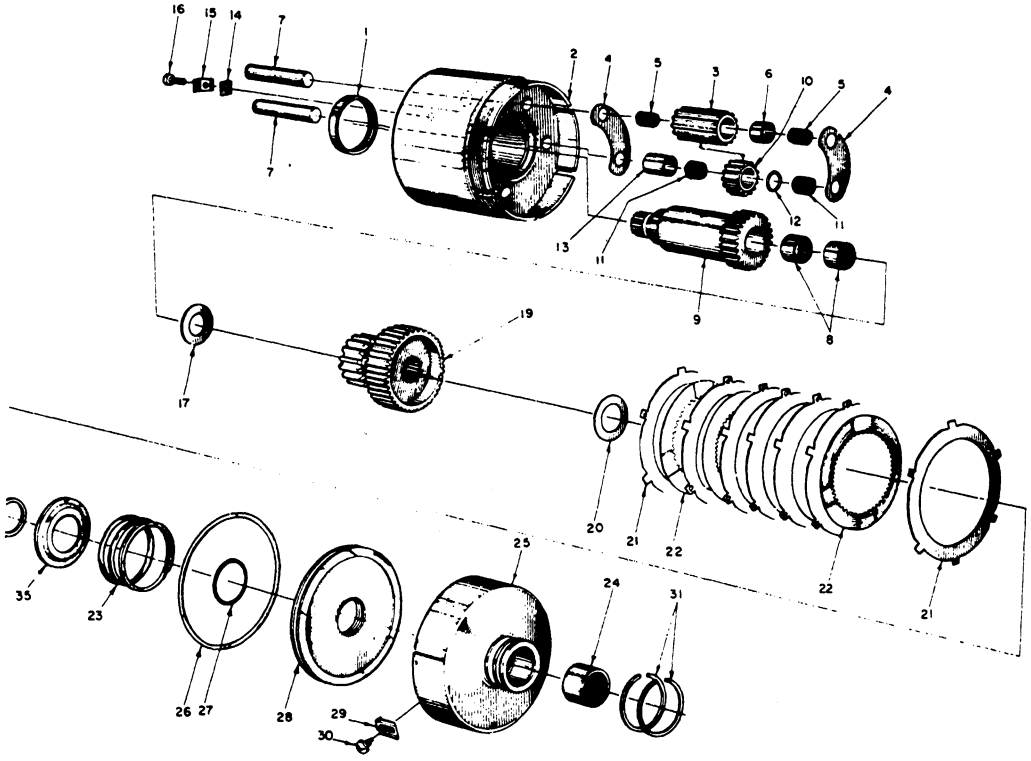
VI. PARTS

Each part illustrated in the exploded views has a key number and an arrow pointing from the key number to the part. Refer to the key number in the parts list to determine the part number and name.

ALWAYS GIVE THE PART NUMBER, PART NAME, TRANSMISSION MODEL NUMBER, AND TRANSMISSION SERIAL NUMBER WHEN ORDERING PARTS.

Key No.	Description
1	Gear Case - Needle Bearing
2	Gear Case
3	Long Pinion
4	Pinion Thrust Pad
5	Roller Bearing
6	Long Pinion Bearing Spacer
7	Pinion Shaft
8	Engine Gear - Roller Bearing
9	Engine Gear
10	Short Pinion
11	Roller Bearing
12	Short Pinion Bearing Spacer
13	Short Pinion Spacer
14	Pinion Shaft Locking Tab
15	Case Clip
16	Capscrew
17	Engine Gear Thrust Washer
18	Direct Drive Tailshaft
19	Propeller Gear
20	Propeller Gear Thrust Washer
21	Steel Clutch Plate
22	Bronze Clutch Plate
23	Screw Collar Spring
24	Screw Collar - Needle Bearing
25	Screw Collar
26	Forward Piston "O" Ring - Outer
27	Forward Piston "O" Ring - Inner
28	Forward Piston
29	Clip - Screw Collar
30	Lockscrew
31	Oil Distributor Seal Rings
32	Tailshaft Thrust Washer
33	Tailshaft Seal Washer
34	Woodruff Key
35	Spring Retainer
36	Retaining Ring
37	Cover Gasket
38	Distributor Tube
39	Tailshaft Needle Thrust Race
40	Tailshaft Needle Thrust Bearing
41	Retaining Ring
42	Ball Bearing
43	Reduction Pinion Tailshaft
44	Reduction Adapter Plate
45	Adapter Plate Seal
46	Capscrew
47	Gasket
48	Crescent
49	Plain Steel Washer
50	Lockwasher
51	Capscrew
52	Locknut
53	Lockwasher
54	Capscrew
55	Lockwasher
56	Ball Bearing
57	Direct Drive Plate
58	Oil Seal
59	Gear Half Coupling
60	Rear Gasket
61	Housing
62	Dipstick Tube
63	Front Gasket
64	Reverse Band Housing Pin
65	Baffle
66	Flat Head Socket Capscrew
67	Hold Down Spring
68	Socket Head Pipe Plug
69	Pipe Plug
70	Control Lever Pin
71	Capscrew
72	Lockwasher
73	Plain Washer
74	Control Lever
75	Control Lever Bushing
76	Control Lever Pawl
77	Control Valve "O" Ring
78	Control Valve
79	Control Valve Retaining Ring
80	Cover
81	Reverse Piston "O" Ring
82	Reverse Piston and Shaft Assembly
83	Piston Back Up Plate
84	Reverse Piston Shaft Pin
85	Retaining Ring
86	Reverse Band Roll Pin
87	Reverse Band Lever
88	Reverse Band Roll
89	Piston Back-Up Plate "O" Ring
90	Relief Valve Plug
91	Relief Valve Spring
92	Relief Valve Retaining Ring
93	Relief Valve "O" Ring
94	Relief Valve Pin
95	Relief Valve Housing
96	Front Plate Oil Seal
97	Front Plate
98	Front Plate Thrust Washer
99	Roller Bearing
100	Pump Port Plate
101	Pump Housing Pin
102	Inner Pump Gear
103	Outer Pump Gear
104	Pump Housing
105	Lockwasher
106	Capscrew
107	Dipstick
108	Flat Head Socket Capscrew
109	Breather
110	Pump Key
111	Reverse Band
112	Pipe Plug
113	Brass Washer
114	Brake Band Support Screw
115	External Socket Head Cap Screw
116	Detent Seal Washer
117	Detent Ball
118	Capscrew
119	Detent Spring
120	Lockwasher
121	Capscrew
122	Reduction Gear Housing
123	Pipe Plug
124	Oil Seal
125	Gear Half Coupling
126	Lockwasher
127	Locknut
128	Internal Gear
129	Bearing Assembly
130	Retaining Ring
131	"O" Ring
132	Suction Tube
133	Washer

GEAR CASE ASSEMBLY



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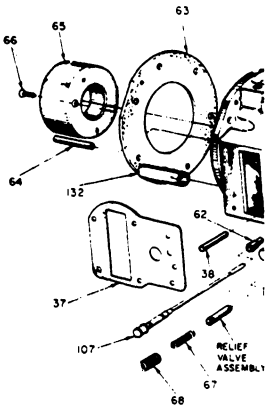
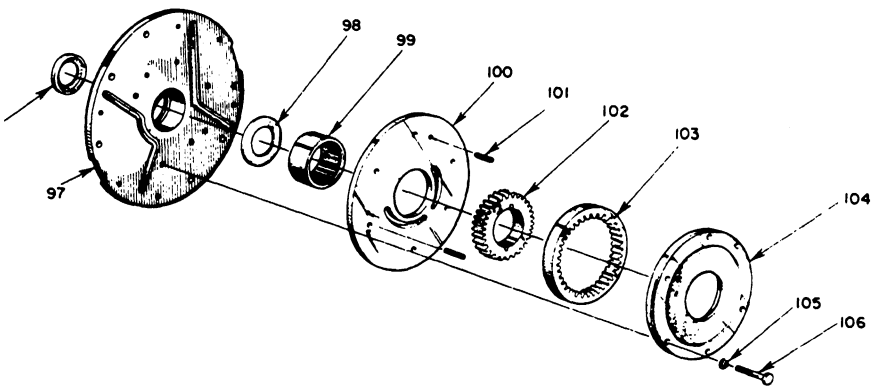


FRONT END PLATE AND PUMP ASSEMBLY



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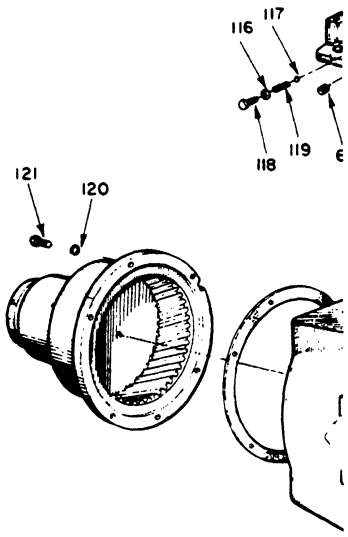
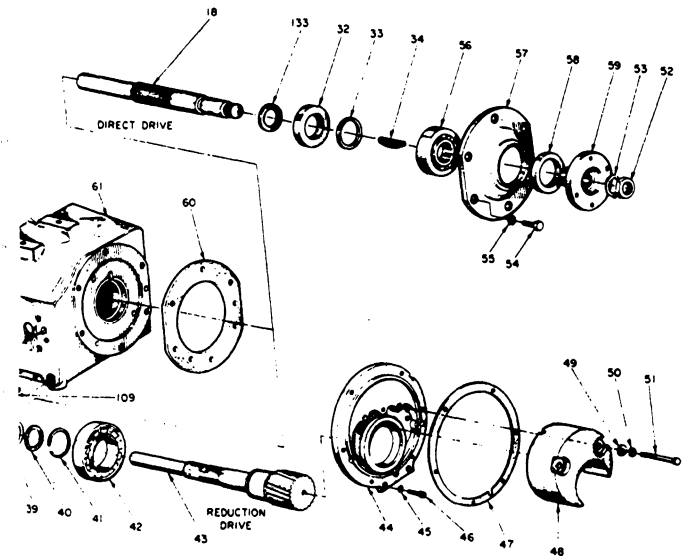
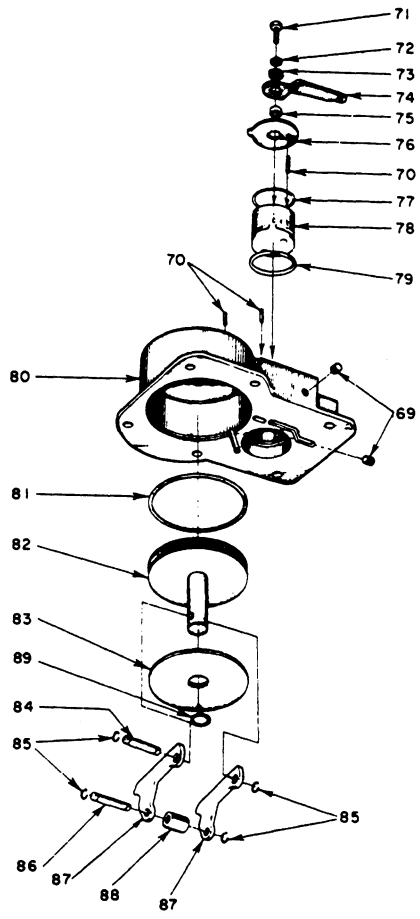


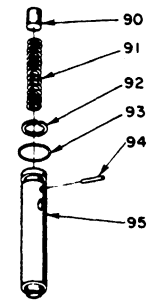
SE GEAR HOUSING ASSEMBLY



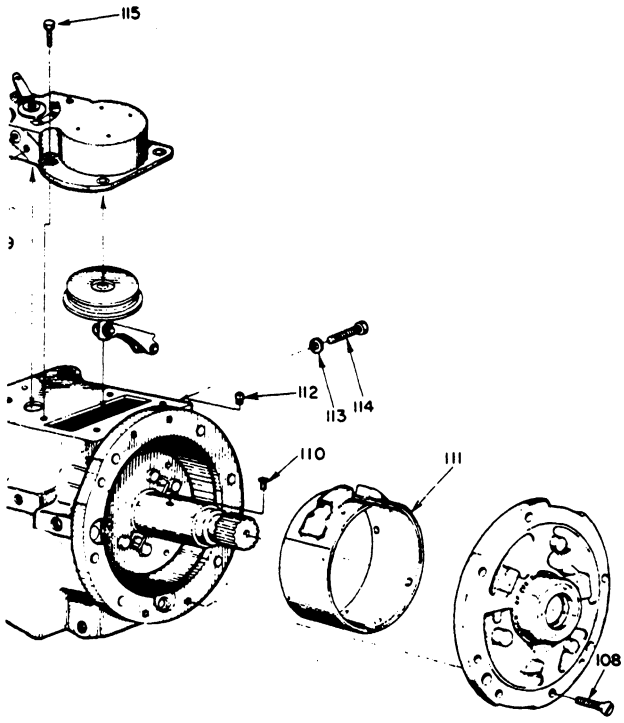
COVER ASSEMBLY



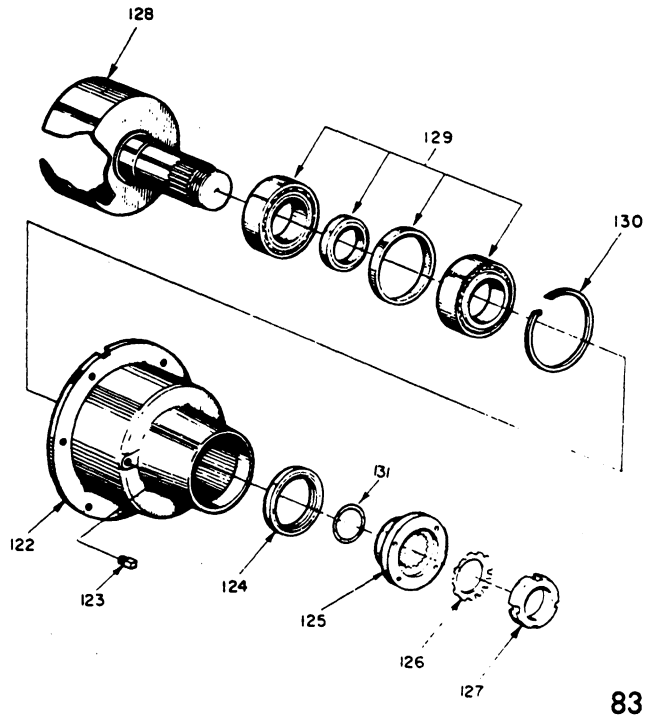
RELIEF VALVE ASSEMBLY



MPLETE ASSEMBLY



REDUCTION GEAR ASSEMBLY



REDUCTION GEARS

Description

The Westerbeke Paragon reduction gears consist of an internal ring gear and a drive gear that offers a variety of reduction ratios. The reduction units are used integrally with either manual or hydraulic reverse gears.

Model and Serial Numbers and Part Numbers

The model and serial numbers are on a plate affixed to the cover of the transmission.

The parts list accompanying the diagrams are intended only to identify the parts in regards to disassembly and assembly.

To order parts refer to "Parts List Manual" giving complete description and part number, with Model and Serial numbers of the transmission.

Lubrication

The reduction gears are lubricated with the same oil as used in the reverse gears. Refer to "General Data".

Adjustments

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

Disassembly of Reduction Unit

This manual is intended to serve as a guide in servicing the reduction gears, since these units are similar in most details except for size.

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 press a ball bearing so that the force is carried through the balls.**
4. **Never use a hammer to drive ball bearings in place.**
5. **Use only properly sized wrenches in removing or securing nuts and capscrews.**
6. **Replace gaskets with new material.**

ALWAYS GIVE MODEL NUMBER AND SERIAL NUMBER OF TRANSMISSION WHEN ORDERING PARTS.

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

Before removing the reduction unit from the reverse gear, drain all of the lubricating oil from the transmission and the reduction unit.

DISASSEMBLY NEED BE CARRIED OUT ONLY AS FAR AS NECESSARY TO CORRECT THOSE DIFFICULTIES WHICH INTERFERE WITH PROPER MARINE GEAR OPERATION.

DISASSEMBLY OF REDUCTION UNIT

1. Remove oil drain plug (1) from bottom of reduction gear housing (2) and drain oil from unit. Make certain that all lubricating oil is removed from reverse gear unit.

2. Remove capscrews (18) and lockwashers (17) 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 (15) away from locknut (16). Remove locknut using suitable wrench and lift lockwasher from shaft.

4. Remove gear half coupling (14) 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 (4) from groove next to ball bearing (3) inside reduction gear housing and press ball bearing (3) from housing.

7. If necessary to replace, remove oil seal (5).

8. Remove Woodruff key (13) from flanged shaft and remove seal washer (12) and spacer (11).

9. Press ball bearing (10) from flanged shaft using two holes in flange.

10. Remove capscrews (9) and lockwashers (8) from rim of flanged shaft and remove ring gear (7) from flanged shaft (6).

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 (1) into reduction gear housing (2).

2. Press ball bearing (3) into reduction

gear housing (2) and install retaining ring (4) into groove next to ball bearing.

3. If removed for replacement, press new oil seal (5) into reduction gear housing.

4. Place flanged shaft (6) over ring gear (7) and line up holes in flange with those in ring gear.

5. Place lockwasher (8) over capscrew (9) and insert capscrew into hole in flanged shaft and secure flanged shaft to ring gear.

6. Press ball bearing (10) onto flanged shaft. Place spacer (11) over shaft next to ball bearing and place seal washer (12) over shaft next to spacer.

7. Install Woodruff key (13) into keyway in flanged shaft.

8. Place reduction gear housing over small end of flanged shaft and start ball bearing (10) 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 (11) is seated against ball bearing (3) in reduction housing.

10. Support unit on inside of flanged shaft with large end of unit down and press gear half coupling (14) onto shaft end and into ball bearing (3) 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 (15) over end of flanged shaft with tang on inside of lockwasher in slot on flanged shaft. Place locknut (16) onto shaft and secure using suitable wrench.

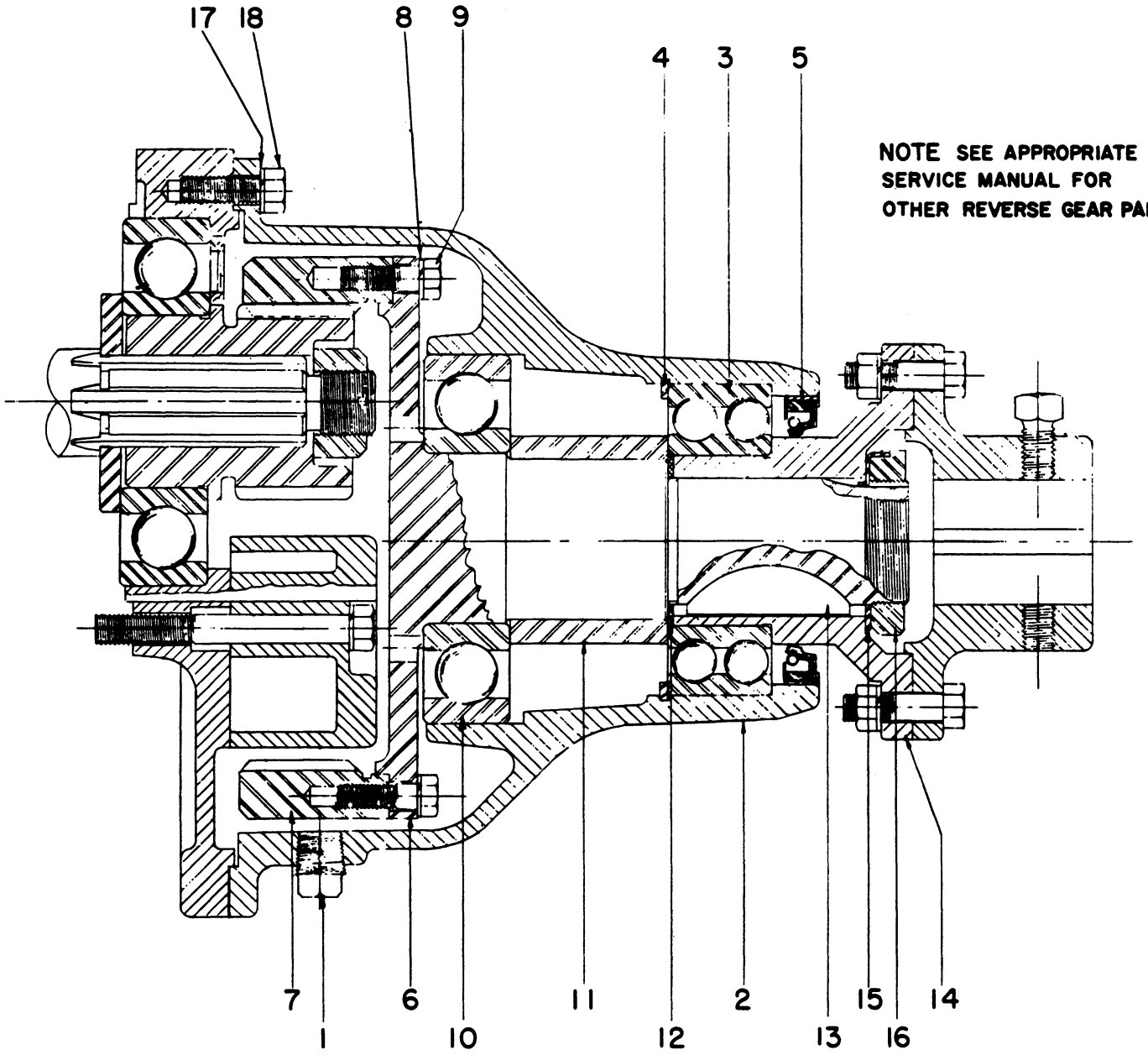
12. Bend one tang of lockwasher into slot on locknut.

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 (17) and capscrews (18) around flange of reduction gear housing and tighten uniformly.

REDUCTION ASSEMBLY DRAWING



PARTS LIST AND EXPLODED VIEW

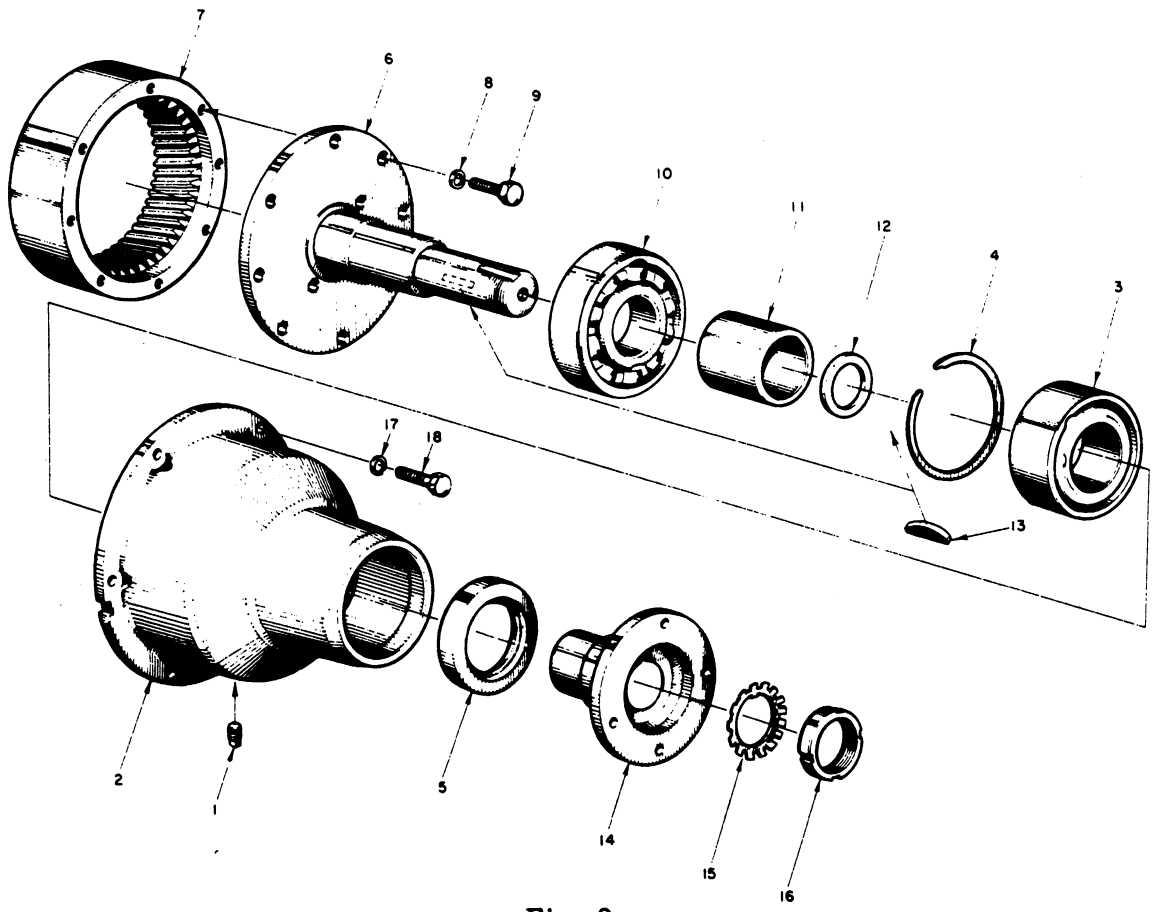


Fig. 2

KEY NO.	DESCRIPTION	KEY NO.	DESCRIPTION
1	Drain Plug	10	Ball Bearing
2	Reduction Gear Housing	11	Spacer
3	Ball Bearing	12	Seal Washer
4	Ball Bearing Retaining Ring	13	Woodruff Key
5	Oil Seal	14	Gear Half Coupling
6	Flanged Shaft	15	Lockwasher
7	Ring Gear	16	Locknut
8	Lockwasher	17	Lockwasher
9	Capscrew	18	Capscrew

WARNER HYDRAULIC TRANSMISSIONS

DESCRIPTION

The Westerbeke Six-346 and Four-230 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.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

GENERATOR

There are two generator designs used on the OK series. They are basically the same except for the method of field excitation.

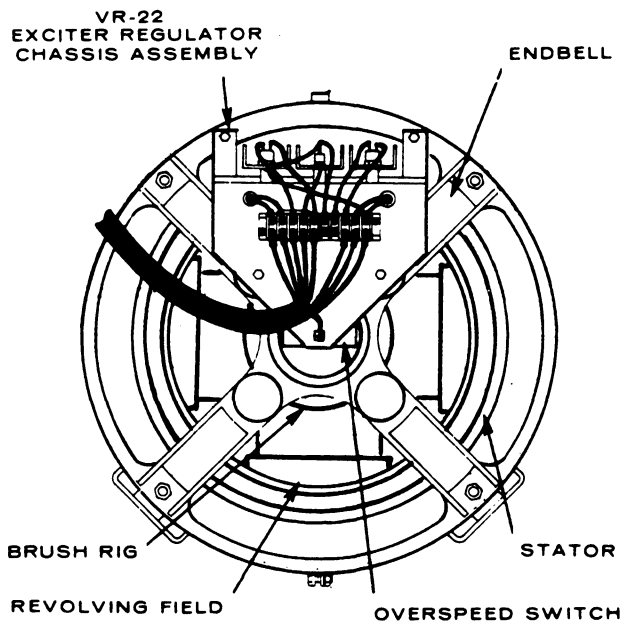
The **Static Exciter (brush type)** design uses a brush rig and collector rings for field excitation. This design was used on some of the earlier models within the range of 25 KW - 90 KW.

The **Brushless** design uses a rotating rectifier exciter assembly in place of the brush rig for field excitation. The brushless design is standard on all models from 25 KW - 175 KW.

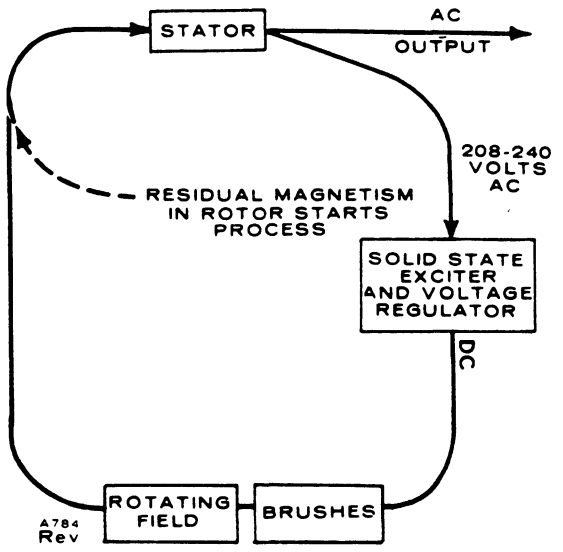
NOTE: *Unless otherwise specified, the tests in this section apply to both designs.*

To gain access to generator, remove grille section below control box.

1. Exciter-regulator chassis assembly VR22 mounts on the rear portion of the generator; SCR's (silicon controlled rectifiers) and diodes are easily accessible for testing. See Figures 1-3.
2. On static-excited generators, brushes attach to the brush rig inside of end bell housing; inspect through large access holes in the end bell. See Figure 1.
3. On brushless models, rotating exciter assembly mounts directly behind exciter-regulator chassis assembly with all diodes accessible for servicing. See Figure 2.
4. Voltage-regulator PC Board VR21 (Printed Circuit Board) mounts inside the control box on the rear panel (left side); turn 1/4 turn fasteners on front of control box to gain access. See Figure 4.



GENERATOR END VIEW (GRILLE REMOVED)



EXCITATION SCHEMATIC

FIGURE 1. STATIC EXCITER DESIGN

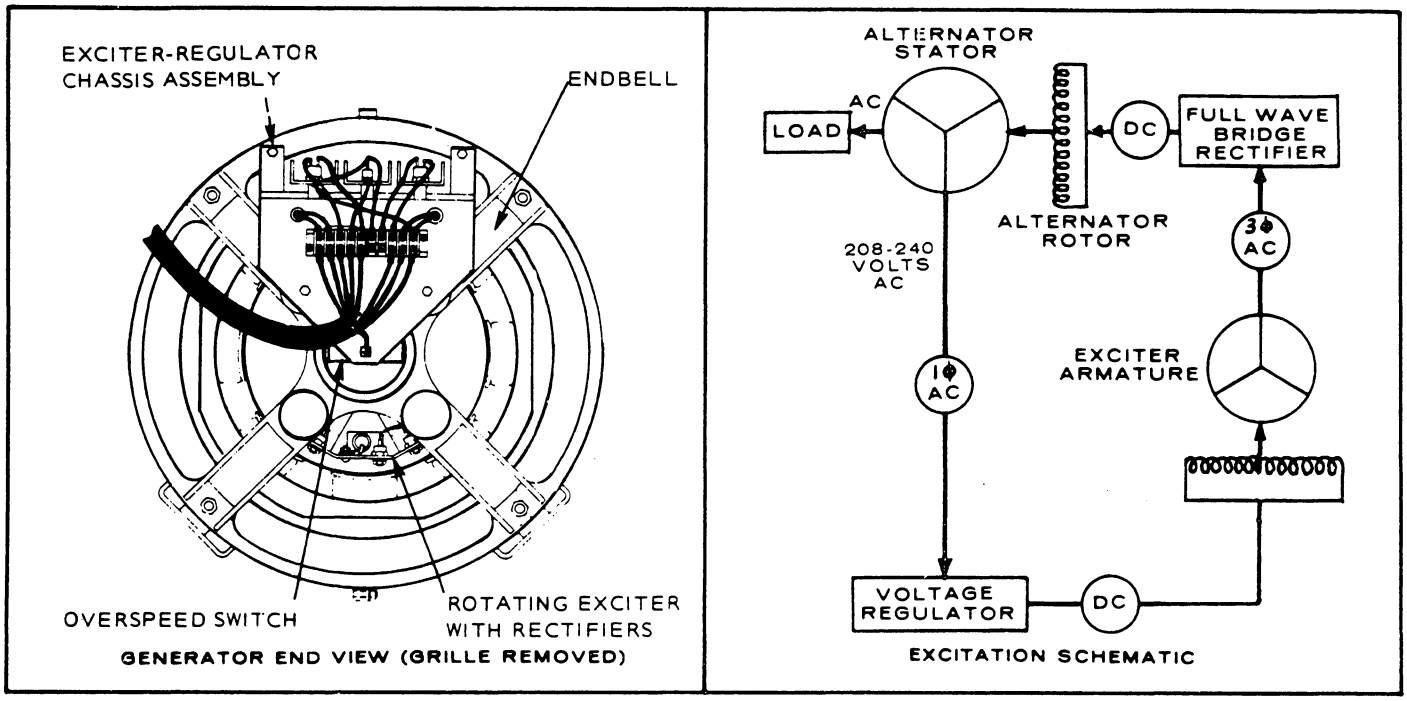


FIGURE 2. ROTATING (BRUSHLESS) EXCITER DESIGN

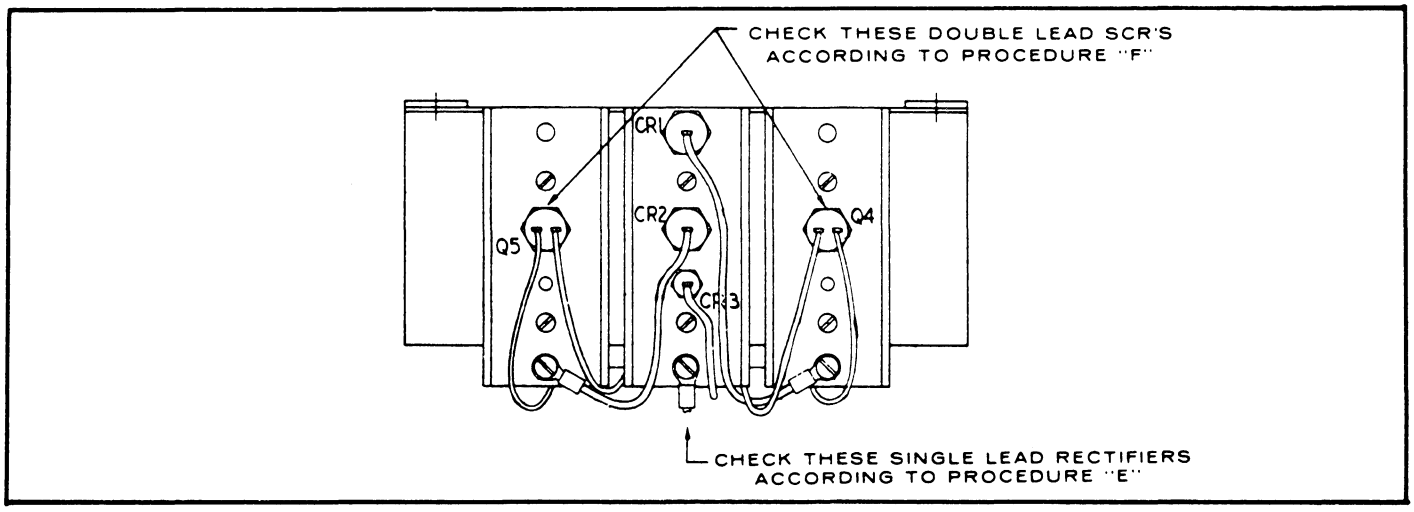


FIGURE 3. TOP VIEW OF EXCITER-REGULATOR CHASSIS ASSEMBLY

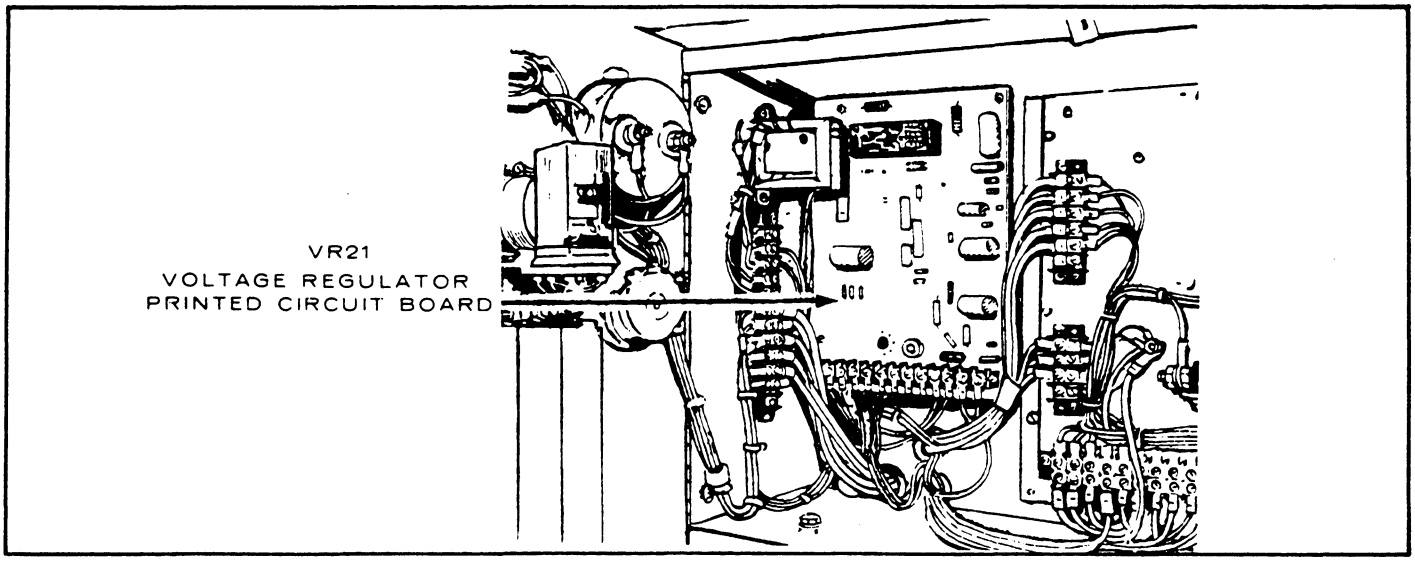


FIGURE 4. VOLTAGE REGULATOR PRINTED CIRCUIT BOARD LOCATION

VISUAL INSPECTION

Before proceeding with the troubleshooting on the following pages, a few simple checks can be made which could directly indicate the cause of trouble.

1. Always be sure that connection of generator leads is correct. Whenever leads are reconnected for a different voltage, check the output with an independent voltmeter. Do not use the control panel meter since it could indicate that the voltage is correct even if connection is wrong.
2. Visually inspect the voltage regulator printed circuit board assembly (VR21) in the control box for burned components, broken wires, loose connections, dust, dirt or moisture. If dirty, clean with a suitable solvent and compressed air.
3. Visually inspect the exciter-regulator chassis assembly (VR22) for burned components, broken wires, loose connections, carbon tracks caused by arcing between parts or between parts and ground. Also check for shorted paths between terminals caused by dust, dirt and moisture.
4. Large banks of SCR (Silicon Controlled Rectifier) regulated loads can cause the generator voltage to increase as load is applied. If such loads exist, and the voltage increases more than 5 or 10%, consult the factory; an additional filter is available for the regulator circuit to correct the situation.

THE QUESTION AND ANSWER TROUBLESHOOTING GUIDE, BEGINNING ON PAGE 7, GIVES A STEP-BY-STEP PROCEDURE FOR CHECKING THE GENERATOR. THE FLOW-CHART TROUBLESHOOTING GUIDES ON PAGES 10 TO 16, ARE GIVEN AS A GENERAL GUIDE TO RESOLVE VARIOUS GENERATOR PROBLEMS. ALL CHARTS REFER TO PROCEDURES SHOWN AT THE END OF THIS SECTION (PAGES 17 TO 25).

QUESTION AND ANSWER TROUBLESHOOTING GUIDE

To correct a particular problem, answer the question either "yes" or "no" then proceed to the next step given in whichever column question was answered.

A. NO AC OUTPUT VOLTAGE – ENGINE RUNNING	YES	NO
1A. Is the circuit breaker on the meter panel in the "on" position?	3A	2A
2A. Switch the circuit breaker to the "on" position. Does the AC voltage build up? NOTE: If voltage builds up, but is high, low or unstable, or causes the circuit breaker on the meter panelto trip,refer to section "B", "C" or "D" of the troubleshooting guide.		3A
3A. Is the AC voltage at terminals 1 and 2 on VR21 voltage regulator printed circuit board and at terminals 9 and 10 on VR22 exciter-regulator chassis assembly 5 to 10 volts?	5A	4A
4A. Check continuity of wires and connections between terminal 1 on VR21 printed circuit board and terminal 9 on VR22 chassis assembly; and between terminal 2 on VR21 printed circuit board and terminal 10 on VR22 chassis assembly. Is there continuity between these connections?	–	10A
5A. Check for broken wires and loose connections on VR22 exciter-regulator chassis assembly. Replace or repair any that are defective and clean all dust, dirt and other foreign material from the assembly. Does the AC voltage now build up?	–	6A
6A. Is the DC voltage at terminals 4 and 5 on VR22 exciter-regulator chassis assembly 5 to 10 volts?	13A	7A
7A. Are diodes CR_1, CR_2 and CR_3 on VR22 exciter-regulator chassis assembly OK? (See Method E in Procedure section for checking diodes.)	8A	–
8A. Are SCR's Q_4 and Q_5 on VR22 exciter-regulator chassis assembly OK? (See Method F in Procedure section for checking SCR's.)	9A	–
9A. The trouble is probably caused by a defective component on the voltage regulator printed circuit board. REPLACE VR21 PRINTED CIRCUIT BOARD. (See Figure 4)	–	–
10A. With the circuit breaker on the meter panel in the "off" position, is the AC voltage at terminals 62 and 63 (on terminal board TB21 on the left side of control box) 5 to 10 volts?	14A	11A
11A. With the circuit breaker on the meter panel in the "off" position, flash the exciter field. (See Method B in Procedure section for field flashing.) Is the AC voltage at terminals 62 and 63 now 5 to 10 volts?	12A	13A
12A. Turn the circuit breaker on the meter panel to the "on" position. Does the AC output voltage build up? NOTE: If voltage builds up, but is high, low or unstable, or causes the circuit breaker to trip, refer to section B, C or D of this troubleshooting guide.	–	15A
13A. Is the brushless exciter stator winding OK? (See Method L in Procedure section for checking exciter.	17A	–
14A. With a jumper wire connected across the terminals of the circuit breaker on the meter panel, does the voltage build up? NOTE: If the voltage does build up, the circuit breaker CB21 is defective and MUST BE REPLACED.	–	15A
15A. Is L_1 commutating reactor mounted on the back side of VR22 exciter-regulator chassis assembly OK? (See Method D in Procedure section for checking L_1 reactor.)	16A	–
16A. Check continuity of wires and connections between TB21 terminal 62 on left side of control box and terminal 1 on VR21 printed circuit board. Also check between TB21 terminal 63 on the left side of control box and terminal 2 on VR21 printed circuit board.	–	–

A. NO AC OUTPUT VOLTAGE – ENGINE RUNNING (CONTINUED)	YES	NO
17A. Are the rotating diodes CR1, CR2, CR3, CR4, CR5 and CR6 on the brushless exciter rotor OK? (See Method E in Procedure section for checking diodes.)	18A	–
18A. Is the main generator field winding OK? (See Method H for checking generator field.)	19A	–
19A. Is the brushless exciter rotor winding OK? (See Method K for checking exciter rotor winding.)	20A	–
20A. Are the generator stator windings OK? (See Method J for checking stator windings.)	–	–

B. AC OUTPUT VOLTAGE BUILDS UP, BUT IS UNSTABLE – ENGINE RUNNING OK	YES	NO
1B. Are there any loose or broken wires or connections at VR21 printed circuit board terminals?	–	2B
2B. Does adjustment of R26* (damping control pot) on VR21 printed circuit board result in stable generator voltage? (See Method Q)	–	3B
3B. The trouble is probably caused by a defective component on VR21 voltage regulator printed circuit board. REPLACE VR21 PRINTED CIRCUIT BOARD. (See Figure 4)	–	–

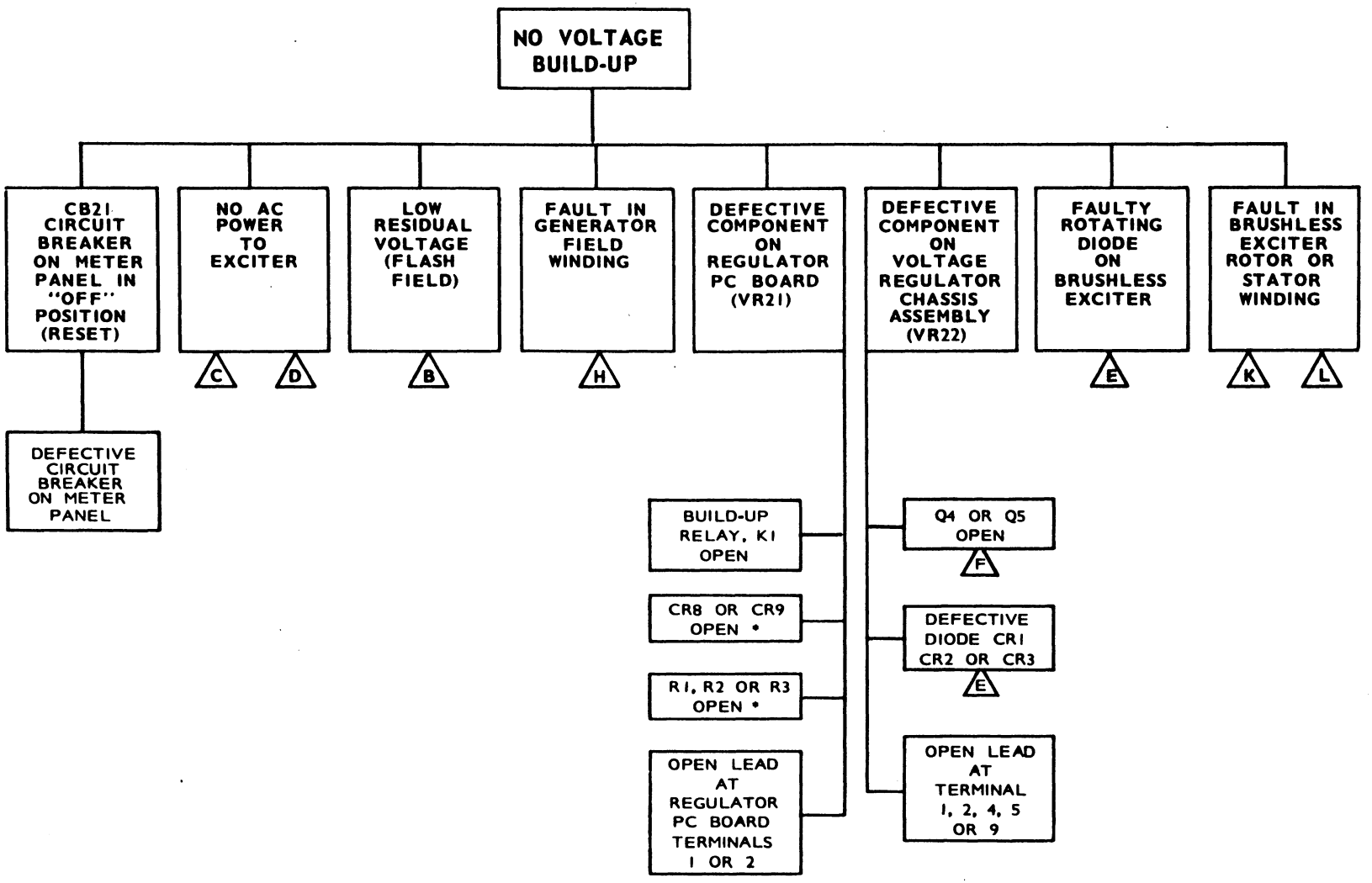
* R26 is used on brushless generators only.

C. AC OUTPUT BUILDS UP, BUT IS HIGH OR LOW – ENGINE RUNNING OK	YES	NO
1C. Does adjustment of R21 "Voltage Adjust" knob on the meter panel result in the correct voltage?	–	2C
2C. Does adjustment of R18 potentiometer on VR21 printed circuit board result in the correct voltage? (See Method Q in Procedure section.)	–	3C
3C. Is the correct voltage reference transformer tap on TB21 being used? (See Method M for choosing correct tap.)	4C	–
4C. Are generator output leads properly connected? (See Method M for proper connection of output leads.)	5C	–
5C. The trouble is probably caused by a defective component on VR21 voltage regulator printed circuit board. REPLACE VR21 PRINTED CIRCUIT BOARD.	–	–

D. GENERATOR VOLTAGE BUILDS UP, BUT CAUSES THE CIRCUIT BREAKER ON CONTROL PANEL TO TRIP – ENGINE RUNNING OK	YES	NO
1D. Does the AC output voltage build up to 150% or more of rated voltage before CB21 circuit breaker trips?	2D	7D
2D. Are there any loose or broken terminals or connections at VR21 voltage regulator printed circuit board terminals?	–	3D
3D. Is diode CR3 on center heat sink of VR22 exciter-regulator chassis assembly OK? (See Method E for checking diodes.)	4D	–
4D. Are the voltage regulator transformer (T21) windings and connections OK?	5D	–
5D. Are stator leads connected properly? (See Method M for correct connections.)	6D	–
6D. The trouble is probably caused by a defective component on VR21 voltage regulator printed circuit board. REPLACE VR21 PRINTED CIRCUIT BOARD. (See Figure 4.)	–	–
7D. Does the AC output voltage build up to rated voltage or less before tripping CB21 circuit breaker on the meter panel?	8D	–
8D. Are the rotating diodes CR1, CR2, CR3, CR4, CR5 and CR6 on the brushless exciter rotor OK? (See Method E for checking rotating diodes.)	9D	–
9D. Is the brushless exciter stator winding OK? (See Method L for checking exciter stator winding.)	10D	–
10D. Is the main generator field winding OK? (See Method H for checking generator rotor.)	11D	–
11D. Is the brushless exciter rotor winding OK? (See Method K for checking exciter rotor winding.)	–	–

E. UNBALANCED GENERATOR TERMINAL VOLTAGES*	YES	NO
1E. Remove load from generator terminals. Are generator terminal voltages still unbalanced?	2E	4E
2E. Are generator leads properly connected and/or grounded?	3E	–
3E. Is continuity of the generator stator windings OK? (See Method J for checking stator windings.)	–	–
4E. Is grounding procedure of generator and load correct?	5E	–
5E. Check for ground faults in load.	–	–

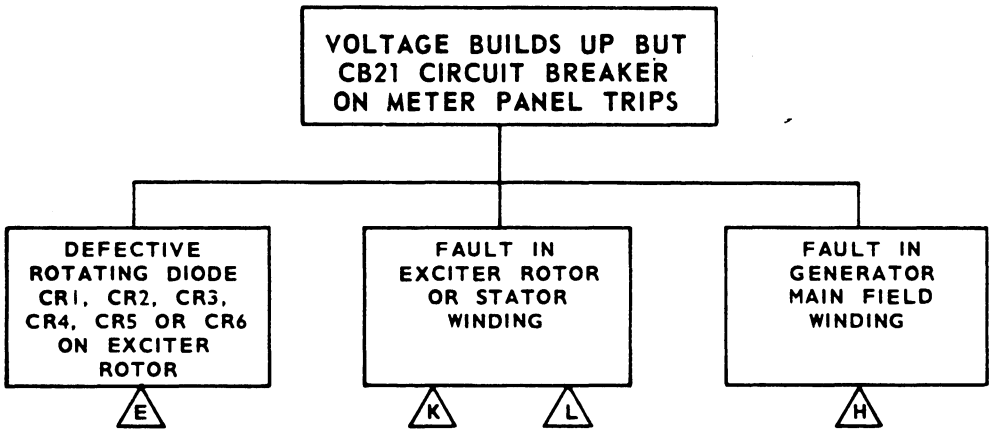
* NOTE: Unbalanced voltages of up to 5% will occur if unbalanced loads are applied to the generator terminals.



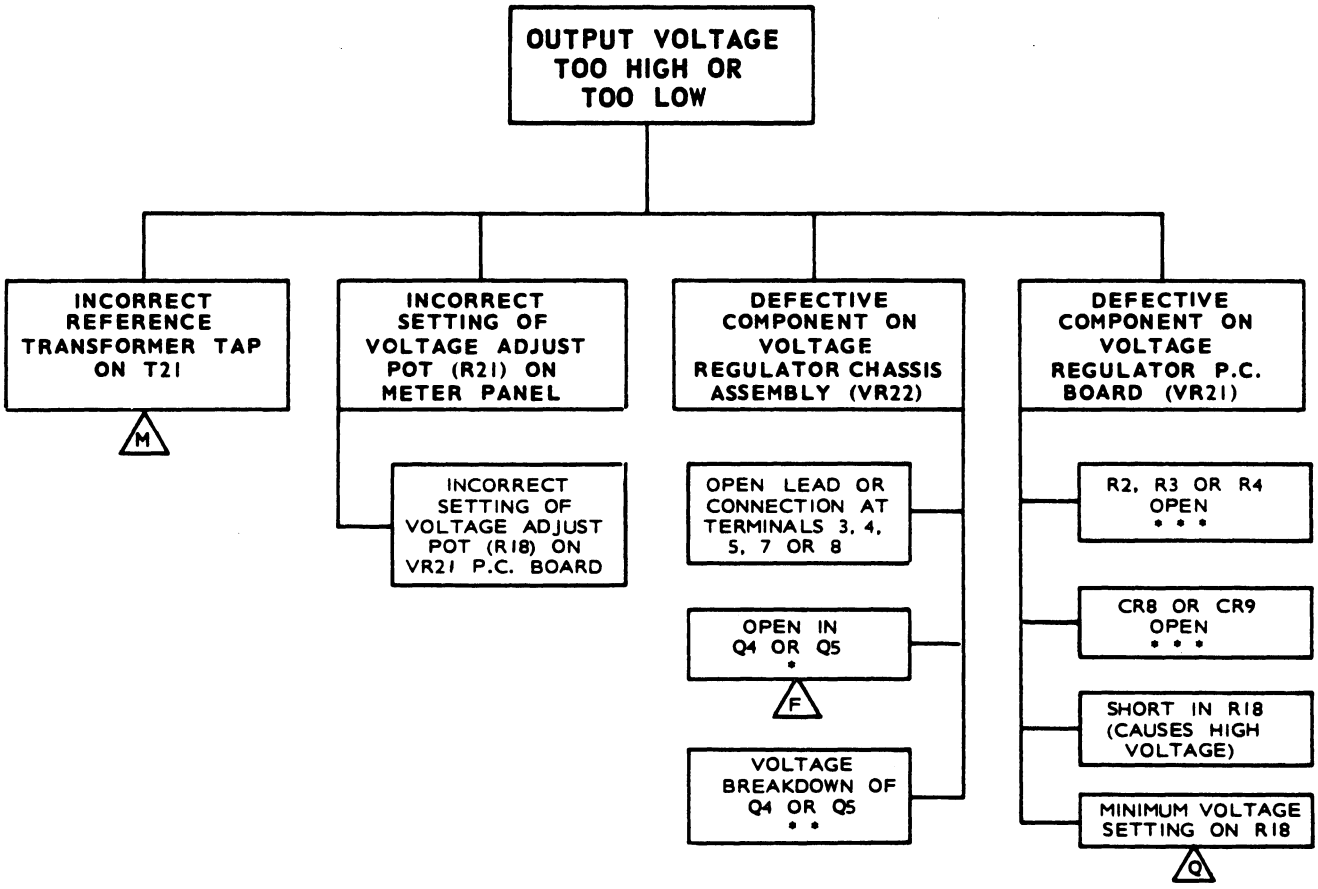
NOTE: Whenever a letter appears near the box, a separate procedure, corresponding to that letter, is given at the end of this section.

* Check SCR's, Q4 and Q5 on VR22 voltage regulator chassis assembly and replace (if defective) before repairing or replacing VR21 voltage regulator printed circuit board.

** Static excited generators only.



NOTE: Whenever a letter appears near the box, a separate procedure, corresponding to that letter, is given at the end of this section.

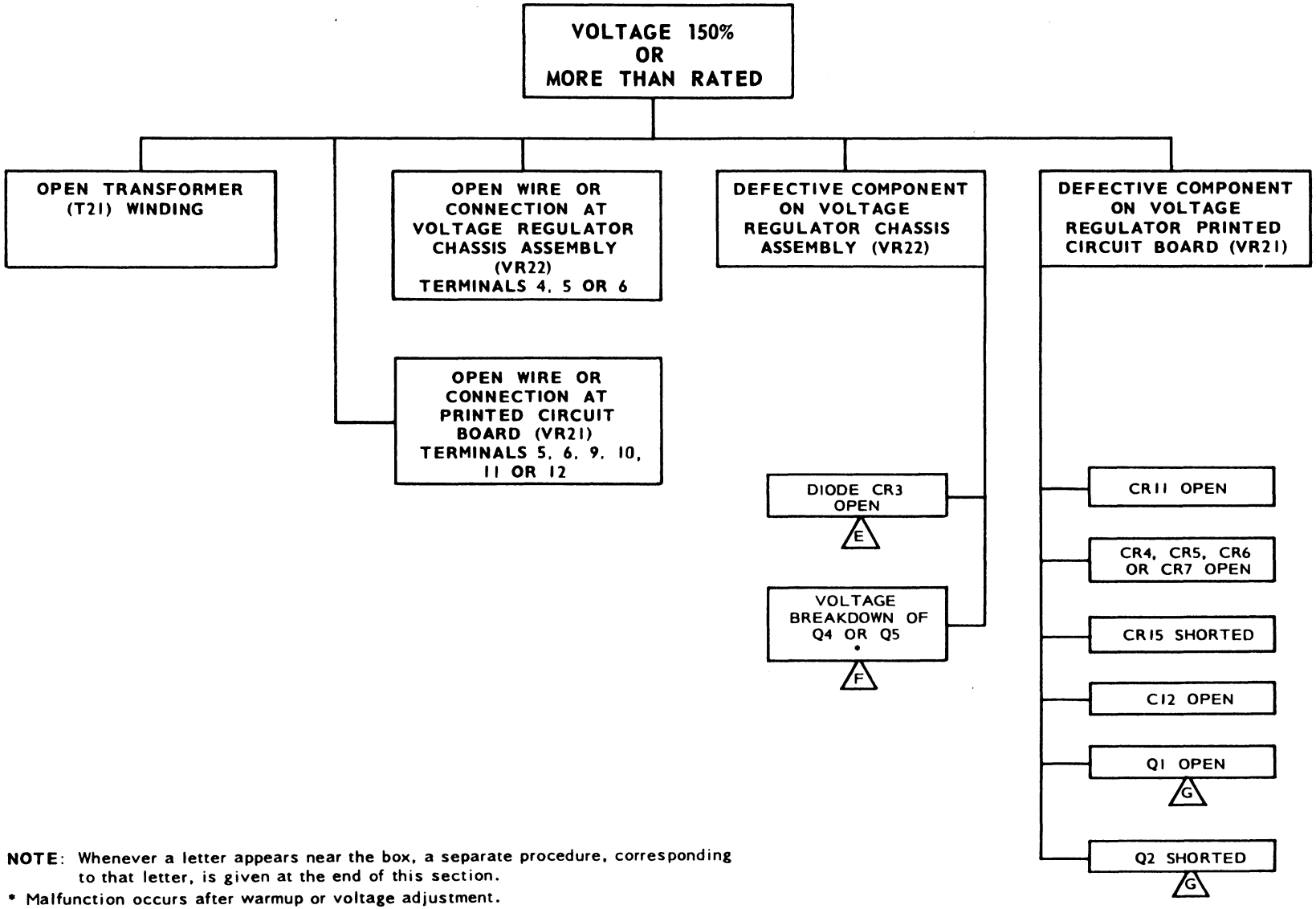


NOTE: Whenever a letter appears near the box, a separate procedure, corresponding to that letter, is given at the end of this section.

* Causes low voltage as load is applied.

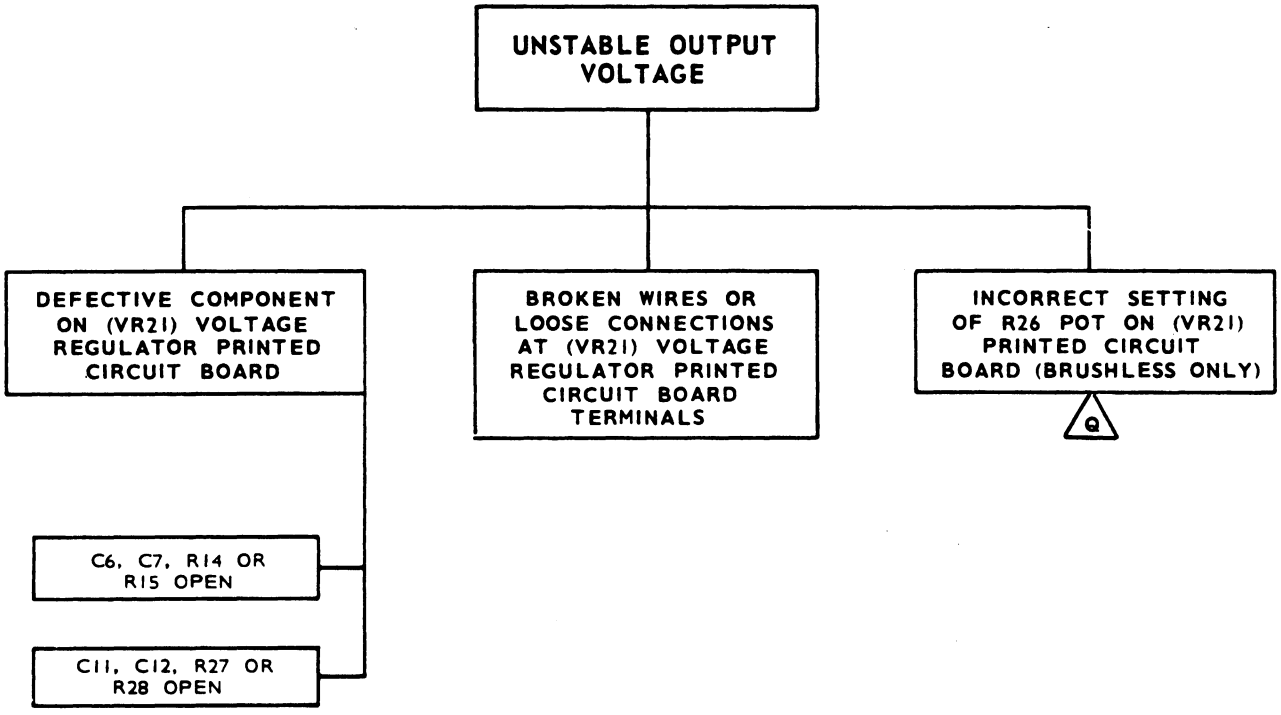
** Will cause voltage to increase after warmup or voltage adjustment.

*** Check SCR's Q4 and Q5 on VR22 voltage regulator chassis assembly (replace if defective) before repairing or replacing VR21 voltage regulator printed circuit board.

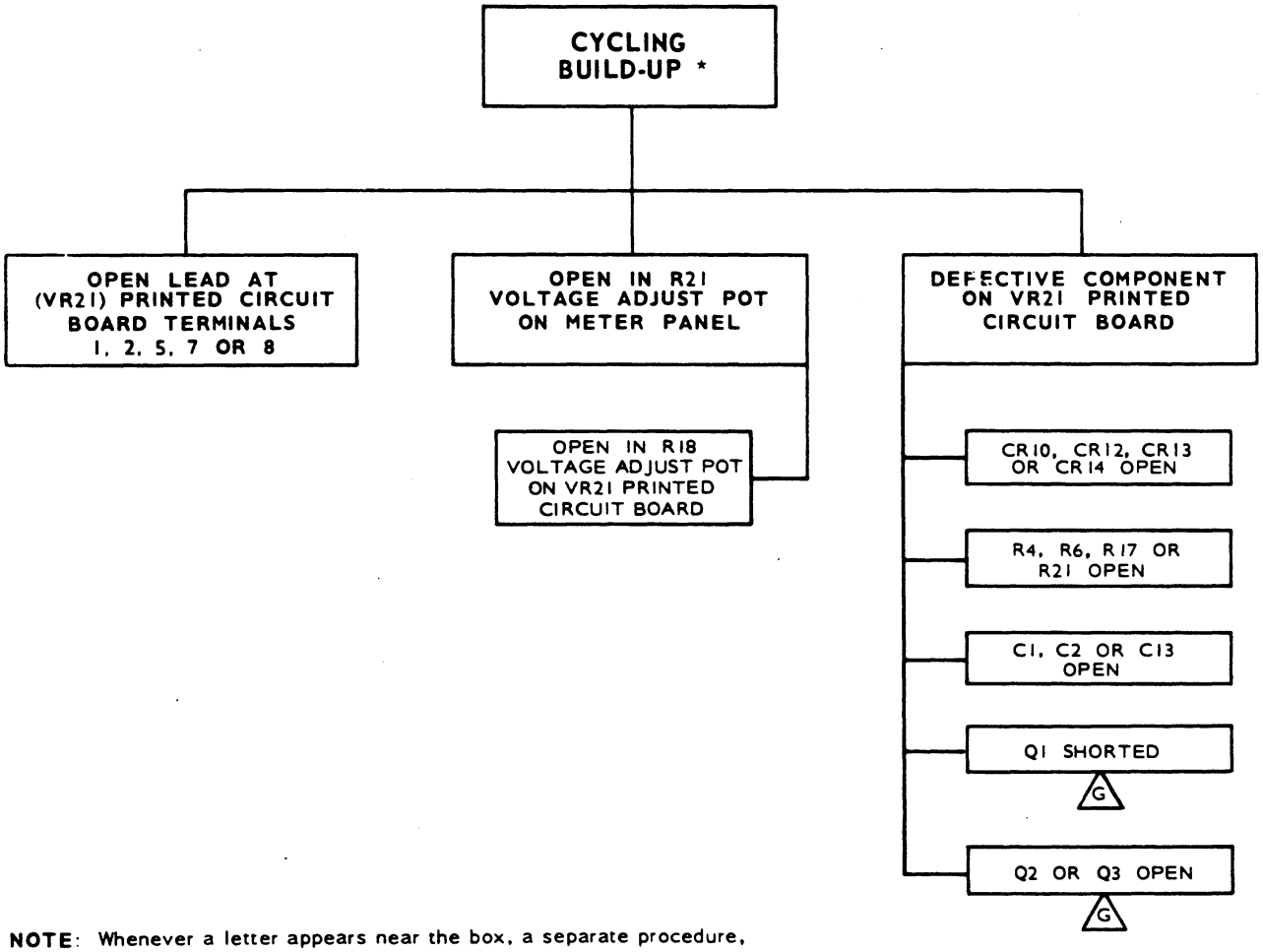


NOTE: Whenever a letter appears near the box, a separate procedure, corresponding to that letter, is given at the end of this section.

* Malfunction occurs after warmup or voltage adjustment.

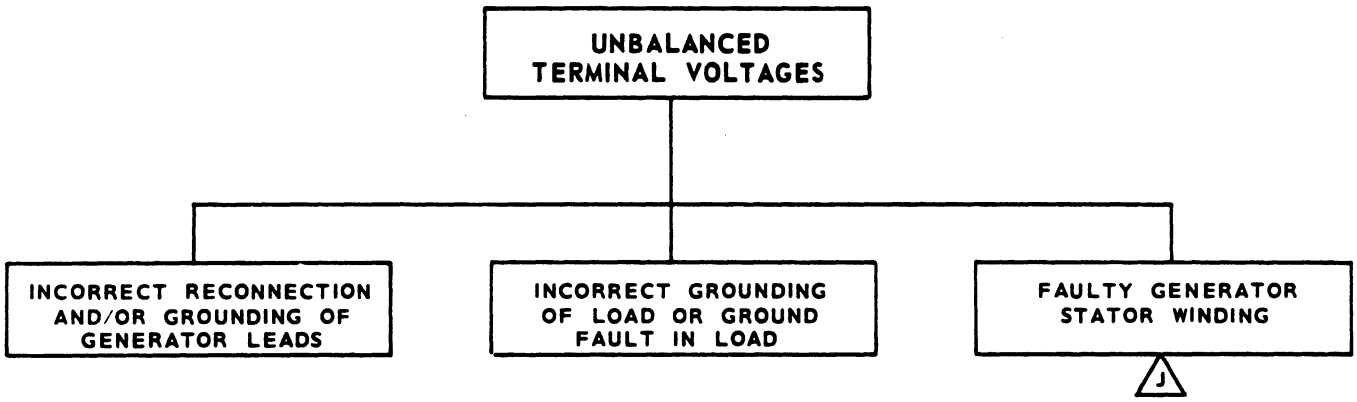


NOTE: Whenever a letter appears near the box, a separate procedure, corresponding to that letter, is given at the end of this section.



NOTE: Whenever a letter appears near the box, a separate procedure, corresponding to that letter, is given at the end of this section.

* Generator voltage builds up, then collapses, builds up, etc.



NOTE: Whenever a letter appears near the box, a separate procedure, corresponding to that letter, is given at the end of this section.

PROCEDURES

B

FLASHING THE FIELD (NO VOLTAGE)

If output voltage will not build up, it may be necessary to flash the field to restore residual magnetism.

1. Remove end grille to obtain access to exciter-regulator chassis assembly.
2. Use a six volt dry cell (lantern) battery with a ten ohm resistor as shown in Figure 7. If a lantern battery is not available, a 12 volt automotive battery can be used by increasing the 10-ohm resistor to 20-ohms; or a 24 volt automotive battery can be used by increasing the resistor to 40-ohms.

CAUTION *A ten ohm resistor* **MUST** *be used. Polarity must be observed.*

3. After starting the plant, touch the positive (+) lead to TB5 and the negative (–) lead to TB4; hold on terminals just long enough until voltage starts to build up or damage may occur to the exciter-regulator system.

WARNING *Be cautious when working on a generator that is running.*

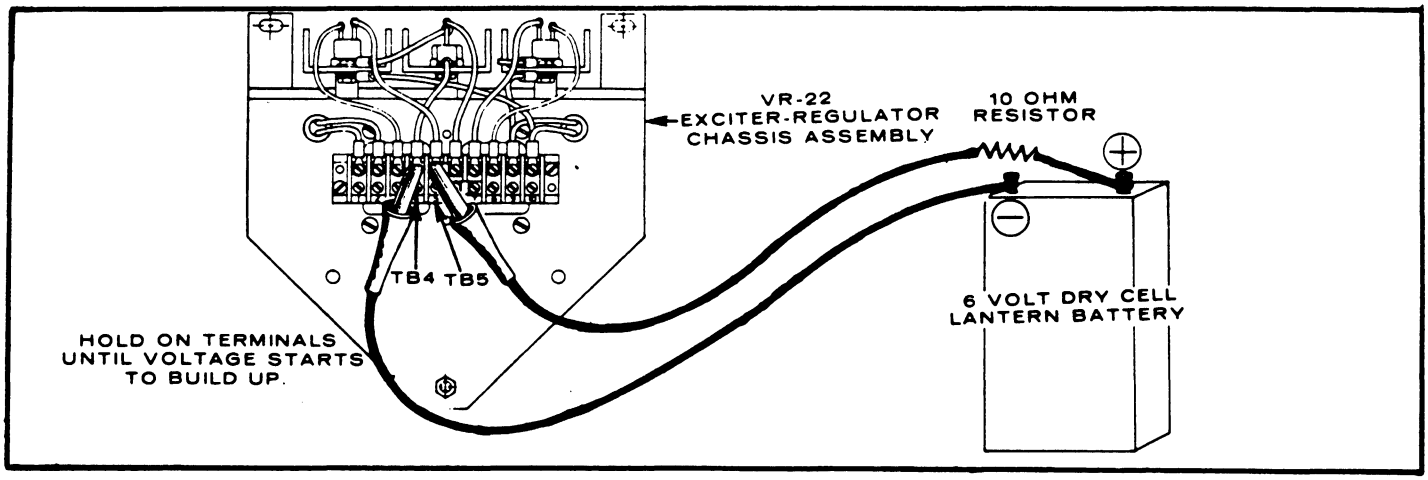


FIGURE 7. FLASHING THE FIELD

C

NO AC POWER TO EXCITER

NOTE: *Residual should be checked before the circuit breaker; the best place to check it is at the five leads 61 through 65 coming directly out of the stator. The combination of leads should be chosen by the wiring configuration of the stator, ie: 120/240 Delta, 120/208 Parallel Wye, 277/430 Series Wye. After checking residual, proceed to VR21 PC board and then check the circuit breaker CB21.*

If residual voltage is present, check AC voltage at terminals 1 and 2 on VR21 voltage regulator printed circuit board. Voltage should be 5-10 volts. The AC voltage at terminals 9 and 10 on VR22 exciter-regulator chassis assembly should be the same (5 to 10 volts). If not, check continuity between these points. If voltage is low, check L1 reactor.

D

TESTING L1 REACTOR

The L1 reactor mounts on the rear of VR22 exciter-regulator chassis assembly. Terminals are marked 1, 2, 3 and 4.

Terminals 1-2 and 3-4 are wound on the same iron core. Resistance between 1-2 and 3-4 should be equal. Resistance between 1-3, 2-3, 1-4 or 2-4 should be infinity. Resistance from any terminal to reactor frame should be infinity.

If any of the above conditions are not met, install a new reactor.

E

TESTING DIODES

Diodes mount on the center heat sink of the exciter-regulator chassis assembly. They are labeled CR1, CR2 and CR3 as shown in Figure 3. On brushless generators, six diodes mount on the rotating exciter assembly as shown in Figure 2. These six diodes are labeled CR1, CR2, CR3, CR4, CR5 and CR6. Test diodes as follows:

1. Disconnect lead from only one diode at a time or remove diode from heat sink. Test that diode and reconnect lead before proceeding to the next one.
2. Use an accurate ohmmeter to check the resistance of the diode. Connect one lead to the top of the diode and the other lead to the heat sink. Observe reading.
3. Now reverse leads and again observe reading. A good diode should have a higher reading in one direction than the other. If both readings are high, or if both readings are low, diode is defective and must be replaced with a new, identical part.

CAUTION *Excessive dust or dirt on diodes and other components will cause overheating and eventual failure. Keep these assemblies clean!*

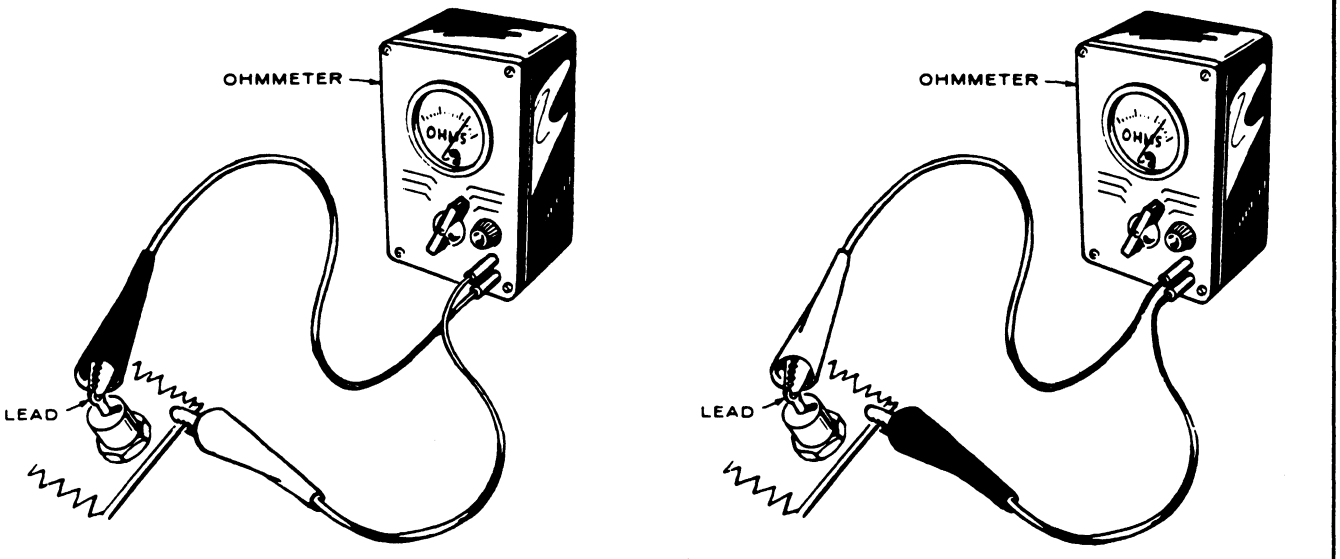


FIGURE 8. TESTING DIODES

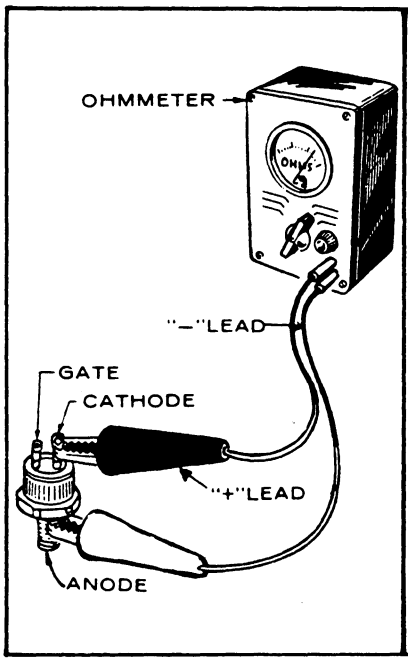


FIGURE 9. TESTING SCR's

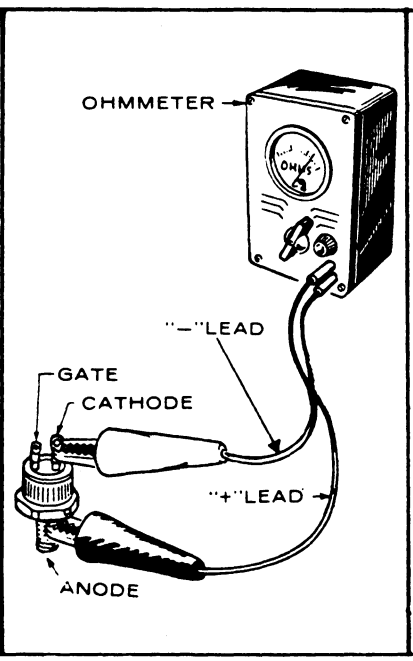


FIGURE 10. TESTING SCR's

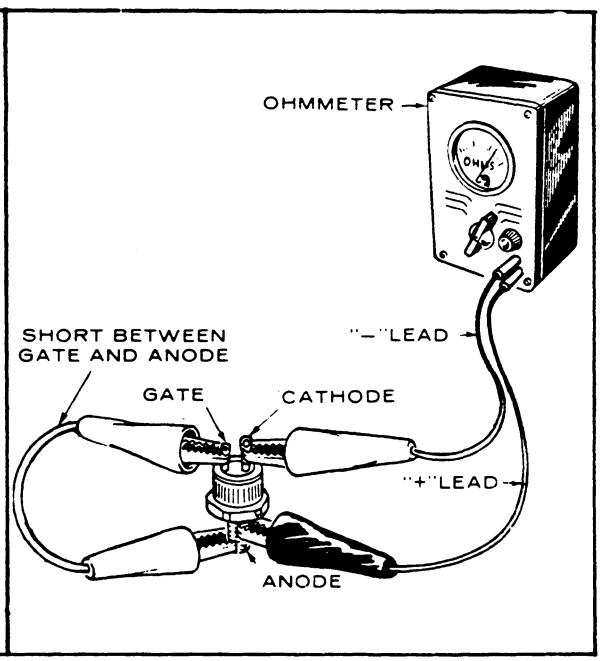


FIGURE 11. TESTING SCR's

F

TESTING SCR's

SCR's mount on the outer heat sinks of the exciter-regulator chassis assembly. They are labeled Q4 and Q5 as shown in Figure 3.

1. Remove the leads from both SCR's.
2. Determine polarity of ohmmeter leads. Connect the ohmmeter leads to the anode and cathode as shown in Figure 9. Use the high scale on the ohmmeter. The resistance should be 1 megohm or greater.

   NOTE: *The cathode is the longer lead, the gate is the shorter lead. The anode is the threaded stud.*
3. Reverse the leads as shown in Figure 10. The resistance again should be 1 megohm or greater.
4. With the leads connected as in Step 3, and using the low scale on the ohmmeter, short the gate to the anode as shown in Figure 11. The resistance should drop to a low value.
5. Remove the short between the anode and the gate. The resistance should remain at the same low value.

REPLACING RECTIFIERS (SCR'S AND DIODES)

1. Unsolder leadwires from terminals.
2. Use proper size wrenches to hold the body while removing the nut.
3. Push the rectifier free of its mounting hole in the heat sink.
4. Insert new rectifier into its mounting hole in the heat sink. Using nut and washer provided, secure rectifier to heat sink.
5. Torque the two large diodes on the center heat sink of exciter-regulator chassis assembly to 20-25 in. lb.
6. Torque the small diode on center heat sink of exciter-regulator chassis assembly to 12-15 in. lb.
7. Torque SCR's on outer heat sinks to 20-25 in. lb.
8. On brushless generators, torque diodes on rotating exciter assembly to 15 in. lb.
9. Solder leadwires to new rectifiers.

CAUTION *Use a 40 watt soldering iron and also hold a needlenose pliers between rectifier and soldering point to prevent destructive heating. Excessive heat on these components will destroy them.*

G

TESTING TRANSISTORS

In each of the following tests, it will be necessary to determine the polarity of the ohmmeter leads. (This is not necessarily the same as when used with voltage.)

Checking NPN Transistors (shown on regulator diagram as Q1 and Q2):

1. Place ohmmeter leads between E and C as shown in Figure 12. The resistance should be high.

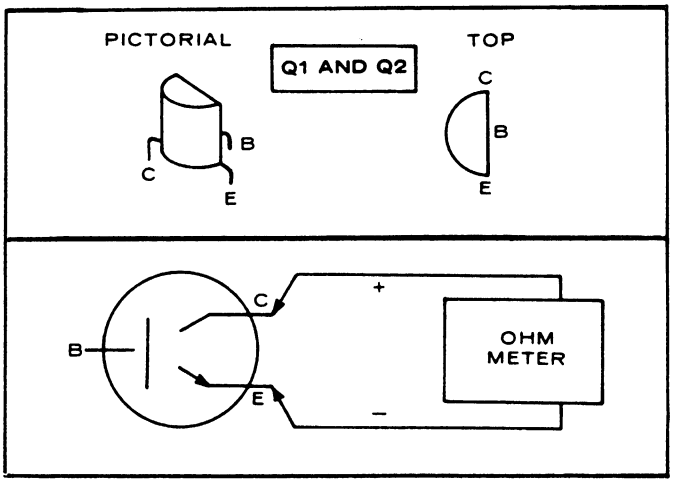


FIGURE 12.

2. Leave ohmmeter connected as in Figure 12, but short B and C as shown in Figure 13. The resistance should become less than it was in step 1.

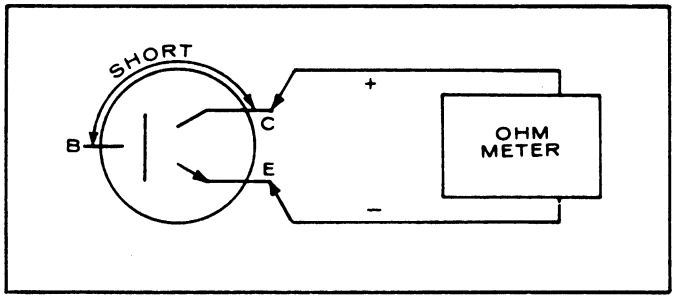


FIGURE 13.

3. Leave ohmmeter connected as in Figure 12, but now short B and E as shown in Figure 14. The resistance should be higher than in step 1.

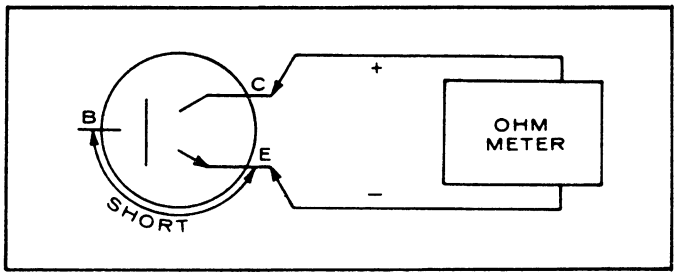


FIGURE 14.

Checking Unijunction Transistors (shown on regulator diagram as Q3):

1. With the negative lead on E, the resistance from E to B1 or from E to B2 should exceed 1 megohm. See Figure 15.

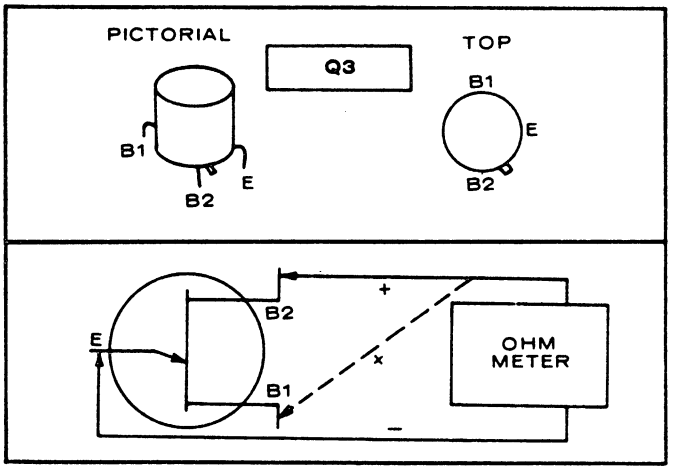


FIGURE 15.

2. With the positive lead on E, the resistance to either B1 or B2 should be between 500 and 10,000 ohms. See Figure 16.

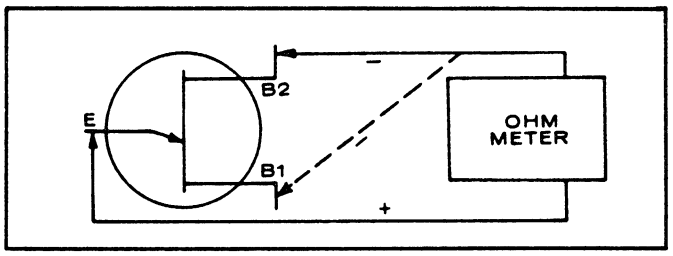


FIGURE 16.

3. Connect as shown in Figure 17. The resistance between B1 and B2 should be between 4,000 and 10,000 ohms. Reversing the leads should not change this value.

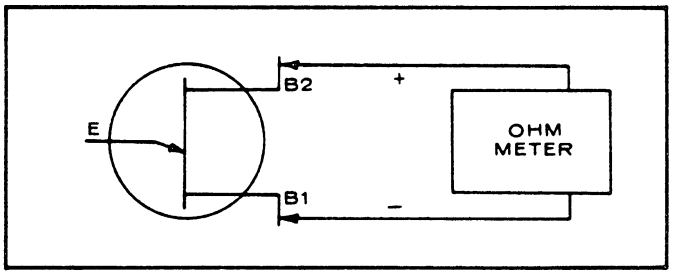


FIGURE 17.

H

TESTING GENERATOR ROTOR

For these tests, use an ohmmeter.

Testing For Grounds: remove F1 and F2 rotor leads from heat sink assembly. Check for grounds between each field lead and rotor shaft. Refer to Figure 18.

Testing for an Open Circuit: disconnect and test between F1 and F2 leads as shown in Figure 19. Replace the rotor if it is grounded or has an open or short.

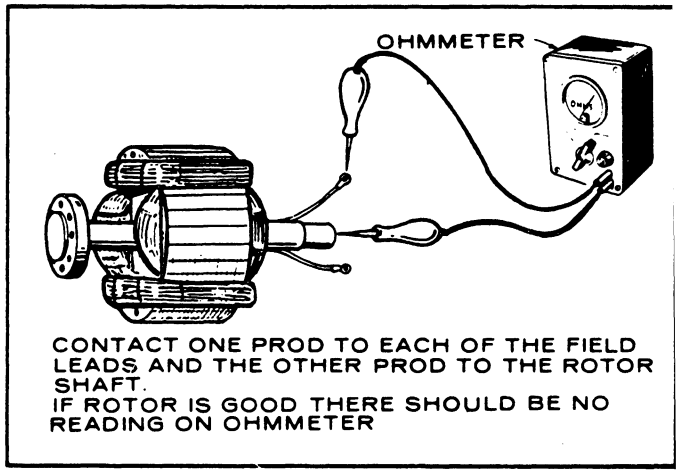


FIGURE 18. TESTING ROTOR FOR GROUNDS

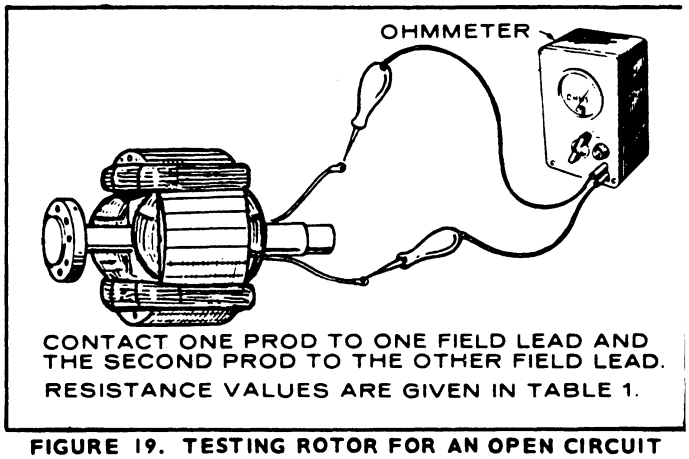


FIGURE 19. TESTING ROTOR FOR AN OPEN CIRCUIT

TABLE 1. RESISTANCE VALUES FOR ROTORS

All resistances should be ±10% of the values specified at 25C (77F). This includes readings between slip rings on static excited rotors and between field leads (with rectifiers disconnected) on brushless rotors. Use an ohmmeter for testing.

J

TESTING GENERATOR STATOR

Using an ohmmeter or 1500 volt hypot, check each winding of the stator for grounding to the laminations of the frame.

NOTE: *Some generators have ground connections to the frame. Check wiring diagram.*

Test each stator winding for shorts to laminations. A reading less than infinity indicates a short.

Test for continuity between coil leads shown in Figure 20; all should have equal resistance. Use an accurate instrument for this test such as a Kelvin Bridge. The proper resistance values are given in Table 2 according to KW ratings and voltage codes.

If any windings are shorted, open or grounded, replace the stator assembly. Before replacing the assembly, check the leads for broken wires or insulation.

NOTE: *Stator output leads T4, T7, T8, T9 and T10 are interconnected (within the stator) to five stranded (#10 aircraft) control wires. These wires are labeled 4, 7, 8, 9 and 10 respectively and terminate at TB21 (terminals 61-65).*

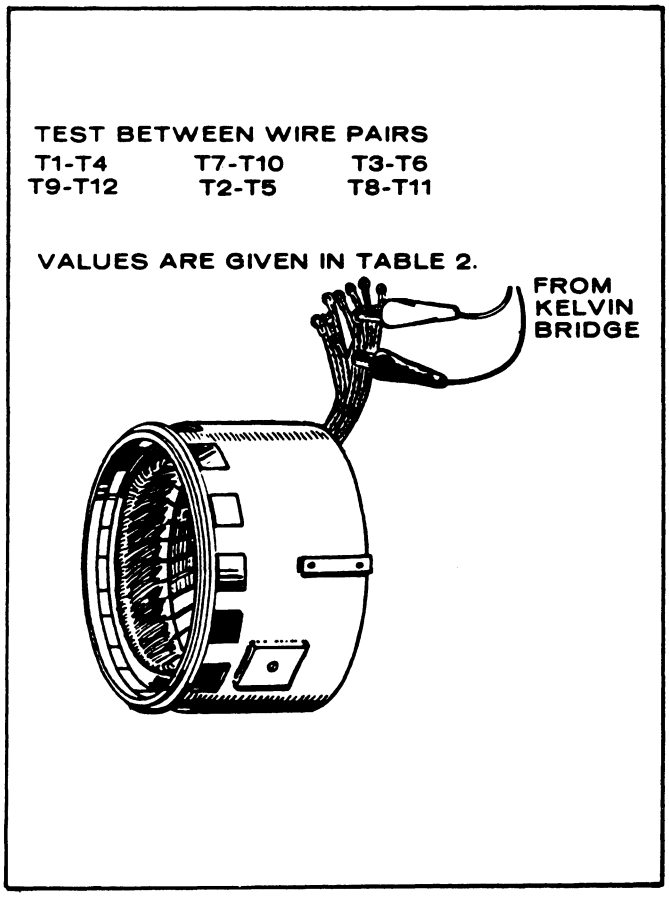


FIGURE 20. TESTING STATOR WINDINGS

TABLE 2. RESISTANCE VALUES FOR STATORS

All resistances should be ±10% of value shown at 25C (77F). Use an accurate instrument for this test such as a Kelvin Bridge. Test between the following coil leads:

T1-T4	T7-T10	T3-T6
T9-T12	T2-T5	T8-T11

K

TESTING BRUSHLESS EXCITER ROTOR (ARMATURE)

Use a Wheatstone Bridge for this test. Disconnect main rotor field leads which connect to heat sinks F1 and F2. Unsolder leadwires from diodes CR1, CR2, CR3, CR4, CR5 and CR6. Test between exciter lead pairs T1-T2, T2-T3 and T1-T3. Resistance should be .525-ohms (±10%) at 77°F.

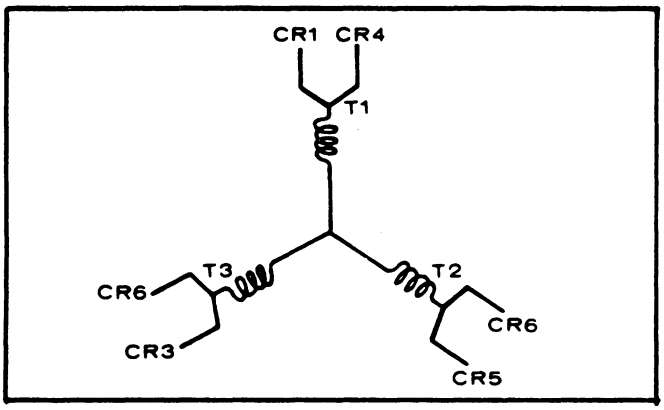


FIGURE 21. TESTING EXCITER ARMATURE

L

TESTING BRUSHLESS EXCITER STATOR

Check between F1 and F2 field leads with an ohmmeter. The resistance should be 20.2-ohms (±10%) at 77°F.

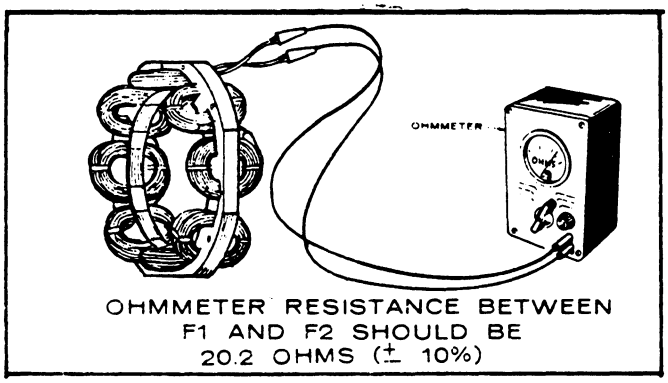


FIGURE 22. TESTING EXCITER FIELD

M

RECONNECTION

Figure 24 shows reconnection possibilities for the UR series generators. When reconnecting for a different voltage, be sure to also reconnect lead from terminal 63 (inside control box) to either H3, H4, H5 or H6. See Figures 23 and 24.

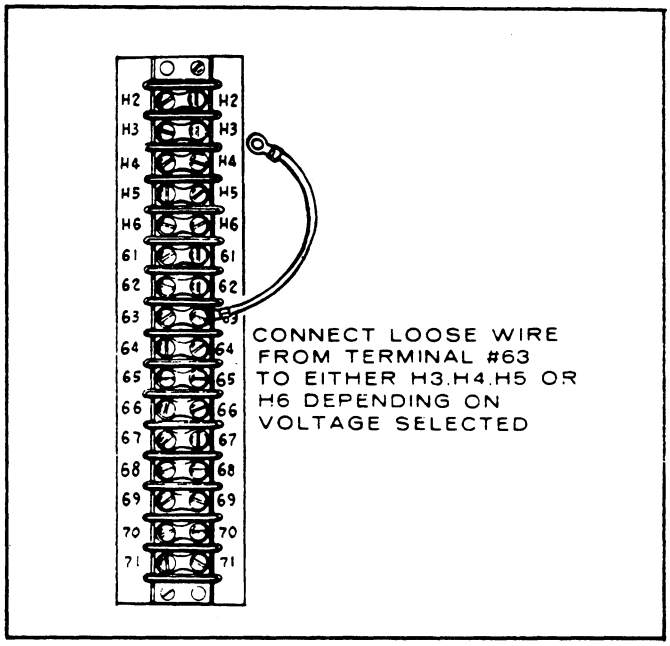


FIGURE 23. CONNECTING LEAD FROM TERMINAL 63

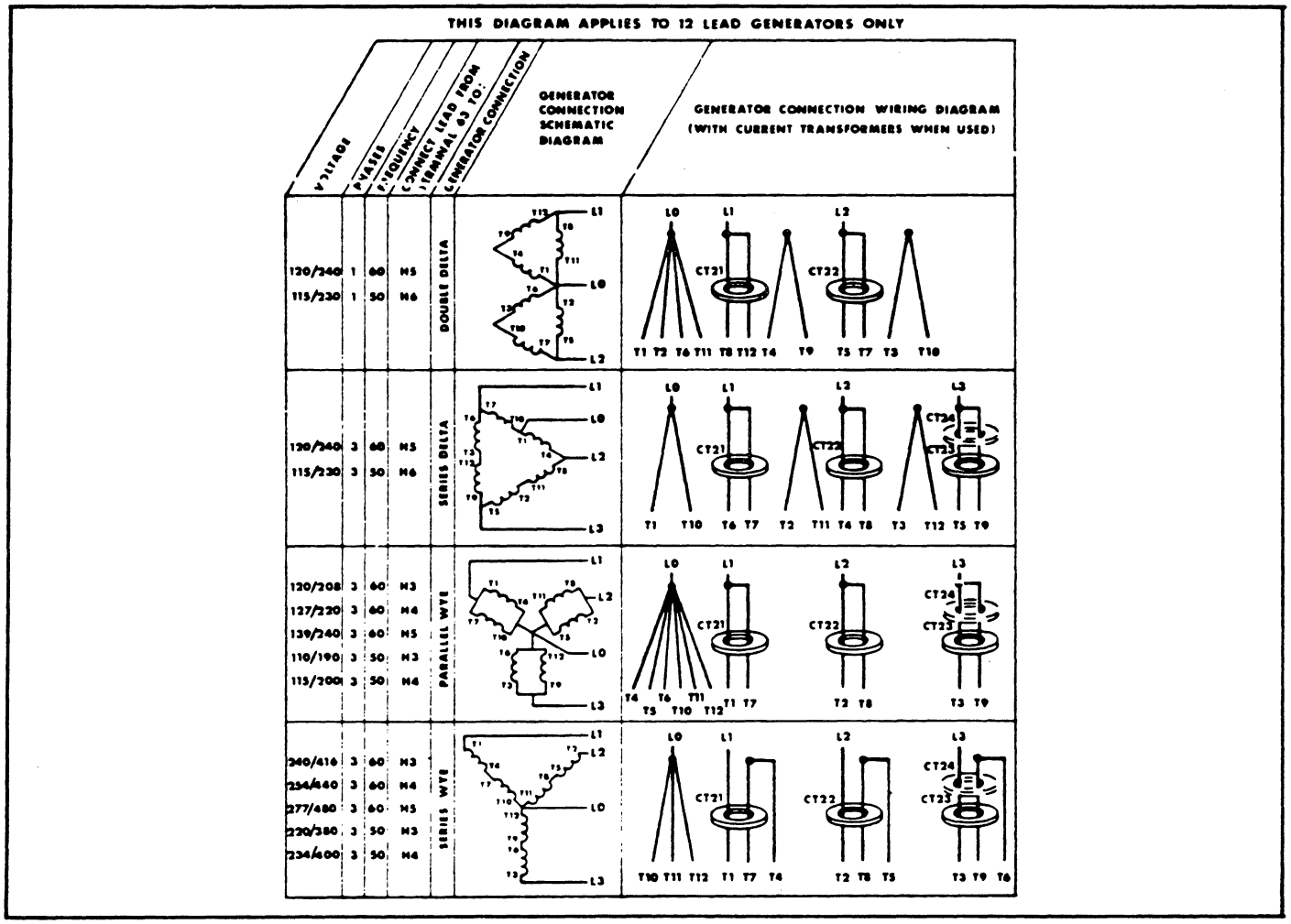


FIGURE 24. RECONNECTION DIAGRAM

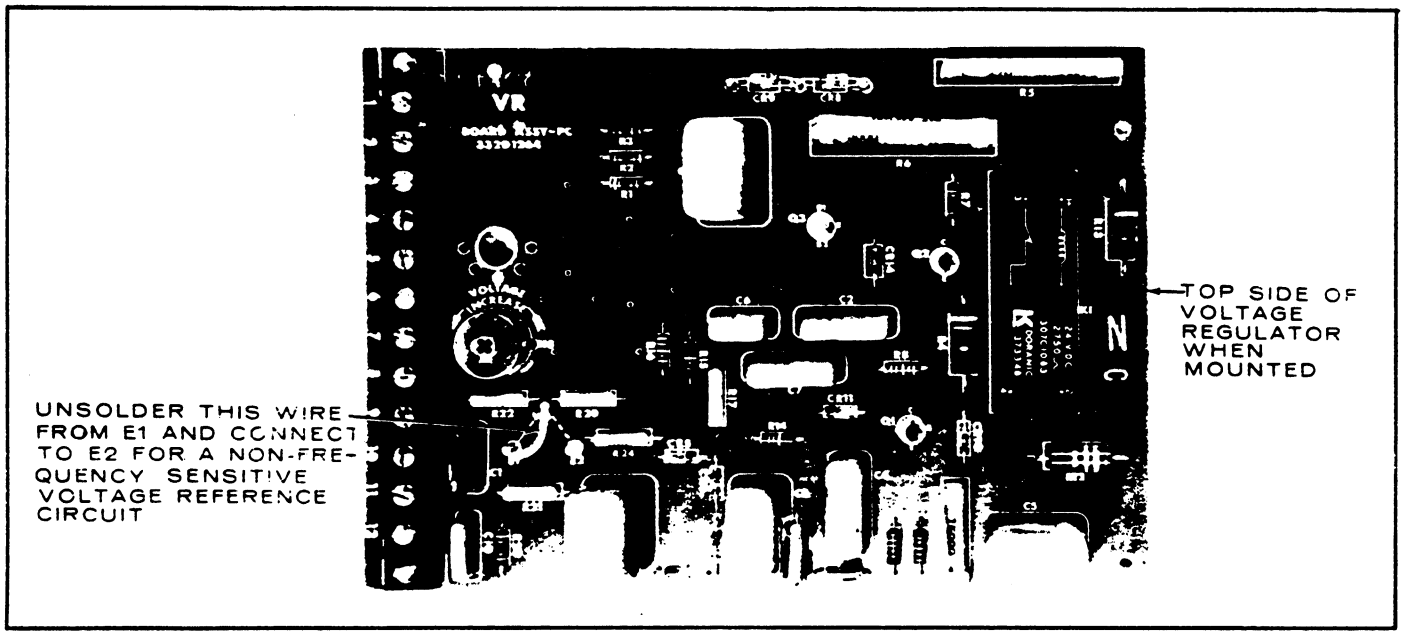


FIGURE 25. VR21 PRINTED CIRCUIT BOARD

N

VOLTAGE REFERENCE CIRCUIT

UR series regulators can be changed from frequency sensitive (voltage dips with speed) to non-frequency sensitive (voltage remains constant as frequency is reduced) by unsoldering one lead and connecting it to another terminal. (See Figure 25.) Following terminal change, readjust R18 rheostat on voltage regulator printed circuit board for correct voltage.

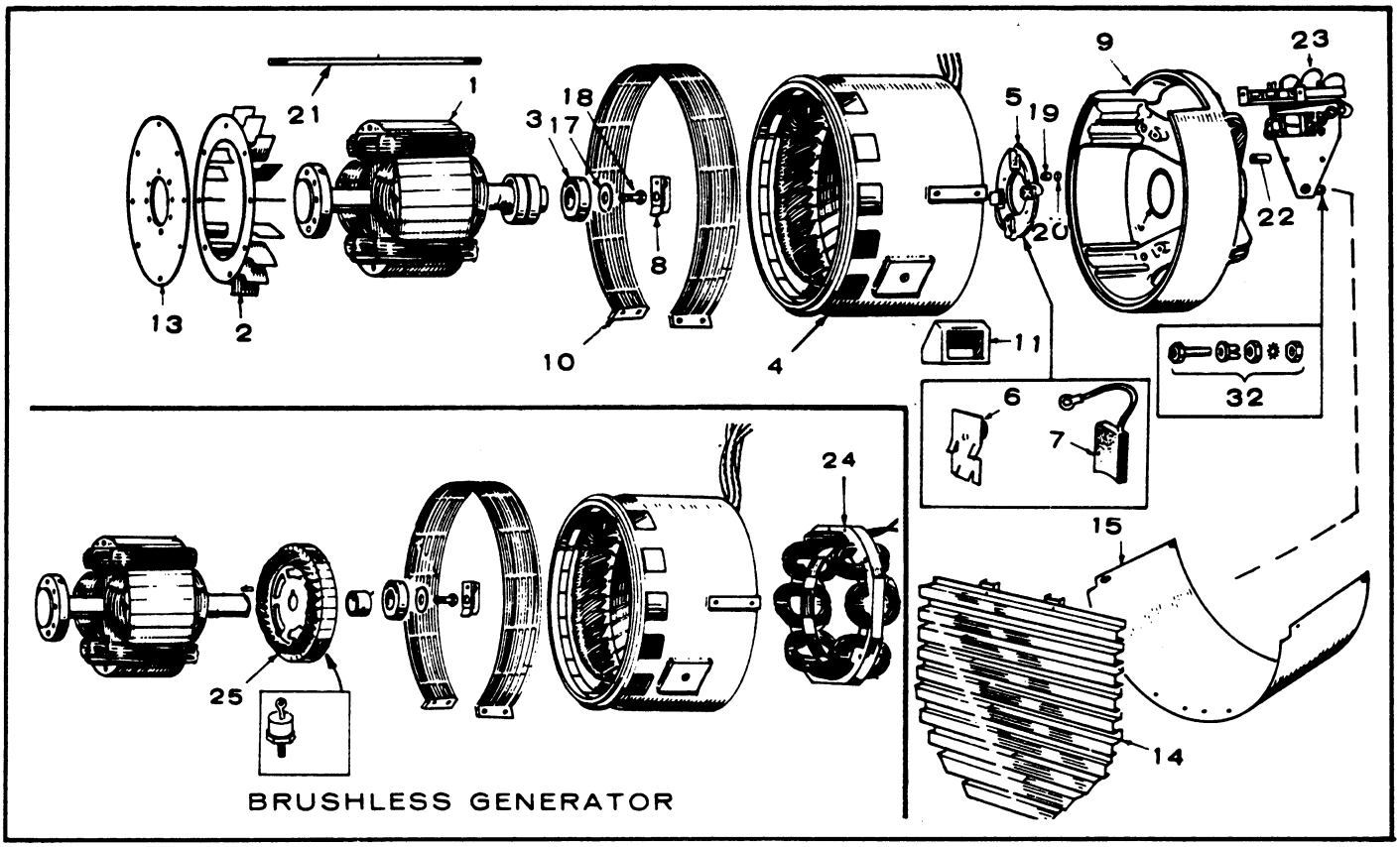


FIGURE 26. GENERATOR DISASSEMBLY

P

GENERATOR DISASSEMBLY

If generator testing determines that generator needs repair, remove and disassemble according to Figure 26 and the following instructions:

1. Disconnect and remove load wires.
2. Disconnect leadwires from the control box. Check wire markings for legibility to ease assembly. Arrange leads so they can be withdrawn easily from the control box.
3. Remove front grille (14) and sheet metal work.
4. Remove the four capscrews securing voltage regulator chassis (23) to end bell (9) and remove chassis assembly.
5. Remove the centrifugal switch (8) from end bell and rotor shaft.
6. Block the rear of the engine in place by supporting the flywheel housing. Remove the narrow generator band (10). Remove the large capscrews securing generator mounting pad (11) to the skid base. Remove the capscrews securing the stator assembly (4) to the engine flywheel housing.
7. Using an overhead hoist and sling, slide the stator assembly off the rotor assembly.
8. Remove end bell from stator assembly; disconnect and remove brush rig from end bell on static excited generators. On brushless models, remove exciter field (24) from end bell assembly if required.
9. Attach the hoist and sling to the rotor assembly (1) and apply a slight lift to support the rotor. Remove the capscrews securing the flexible drive coupling (13) to the engine flywheel and remove rotor from the engine.
10. Remove bearing capscrew (18) and washer (17) and remove bearing from shaft. If required, remove blower (2) from the rotor.
11. Disconnect rotor field leads from heat sinks F1 and F2 on the exciter armature. Remove exciter armature (25).

GENERATOR ASSEMBLY

Generator assembly is the reverse of disassembly procedure:

1. Always replace bearing with a new one; apply a layer of grease on end bell bearing hole before inserting bearing.
2. Torque bearing capscrew to 60-70 lb. ft.
3. Torque drive disc-to-rotor capscrews to 200-240 lb. ft.
4. Torque drive disc-to-flywheel capscrews to 45-50 lb. ft.
5. Torque generator through-stud nuts to 30-35 lb. ft.
6. Refer to parts catalog for replaceable parts and assemblies. Refer to wiring diagram for reassembly.

Q

VOLTAGE ADJUSTMENT

If VR21 voltage regulator printed circuit board has been replaced, it may be necessary to center the voltage adjust rheostat (R21) on meter panel.

1. Center the voltage adjust knob so pointer is in a vertical position.
2. Open meter panel doors. Start unit.
3. Using a screwdriver, turn R18 potentiometer on printed circuit board VR21 counterclockwise to increase the voltage or clockwise to decrease the voltage. Observe voltmeter on meter panel while making adjustment. Set voltage with no load connected to generator. (Example: For a 120/240 volt connection, set at no-load voltage or approximately 246 volts.)

If voltage is unstable or tends to hunt, turn R26 potentiometer on VR21 in the direction shown on printed circuit board to increase voltage sensitivity.

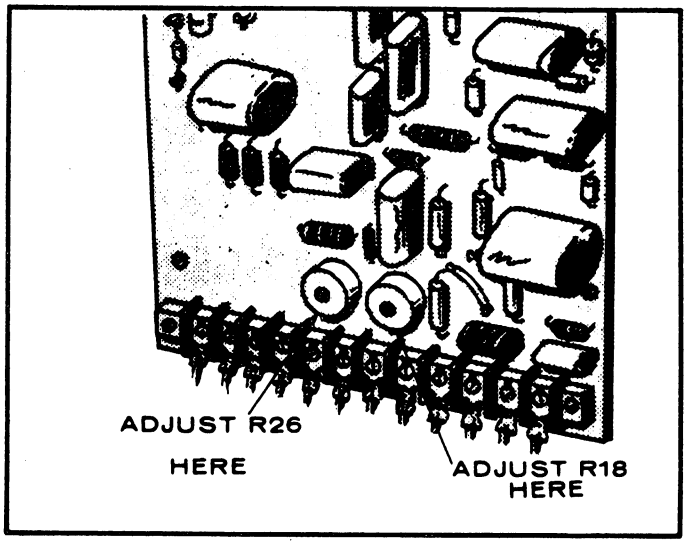
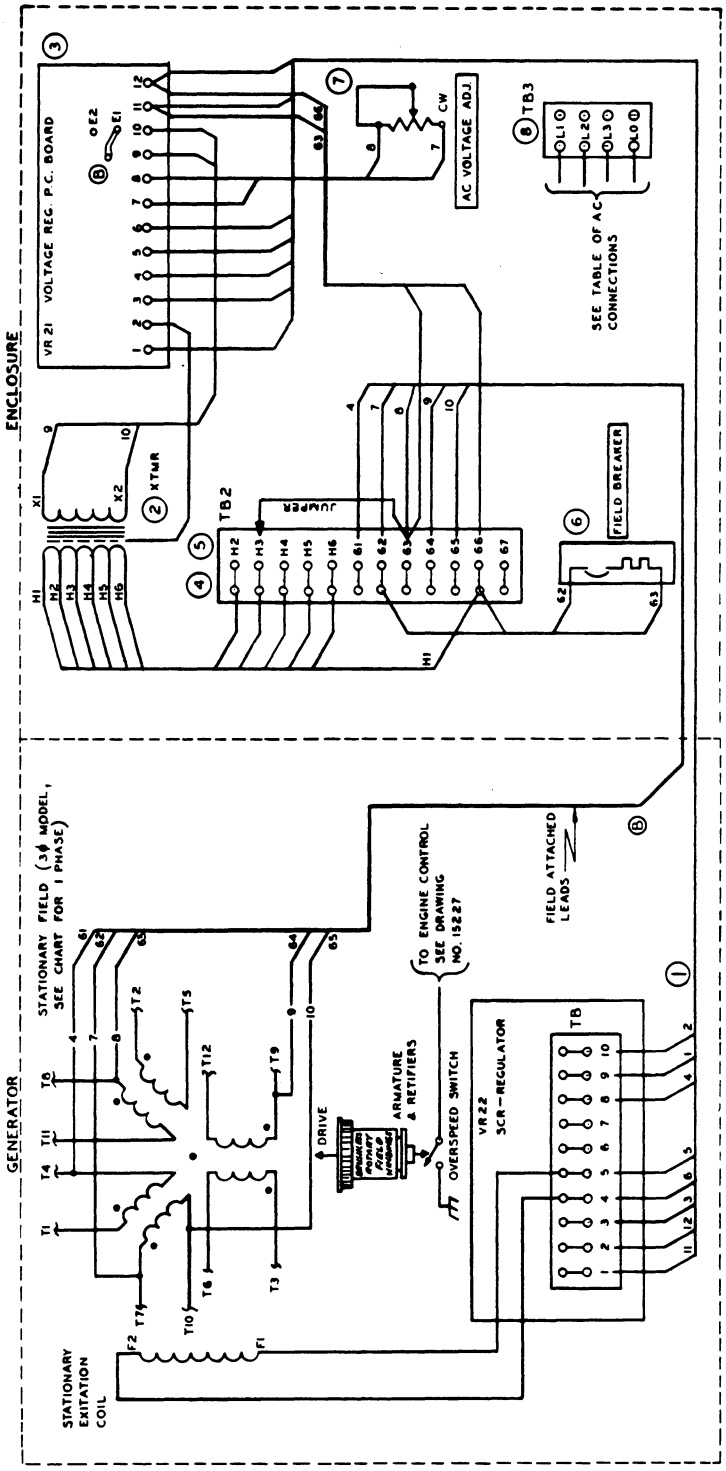


FIGURE 27. ADJUSTING VOLTAGE ON VR21

30 & 45KW: VOLTAGE REGULATOR & POWER CONNECTIONS



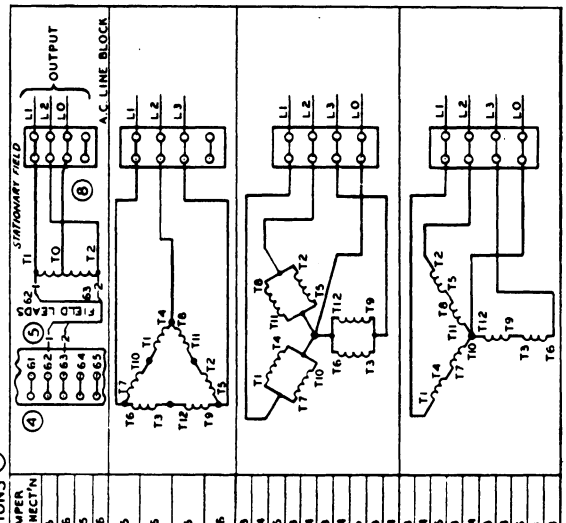
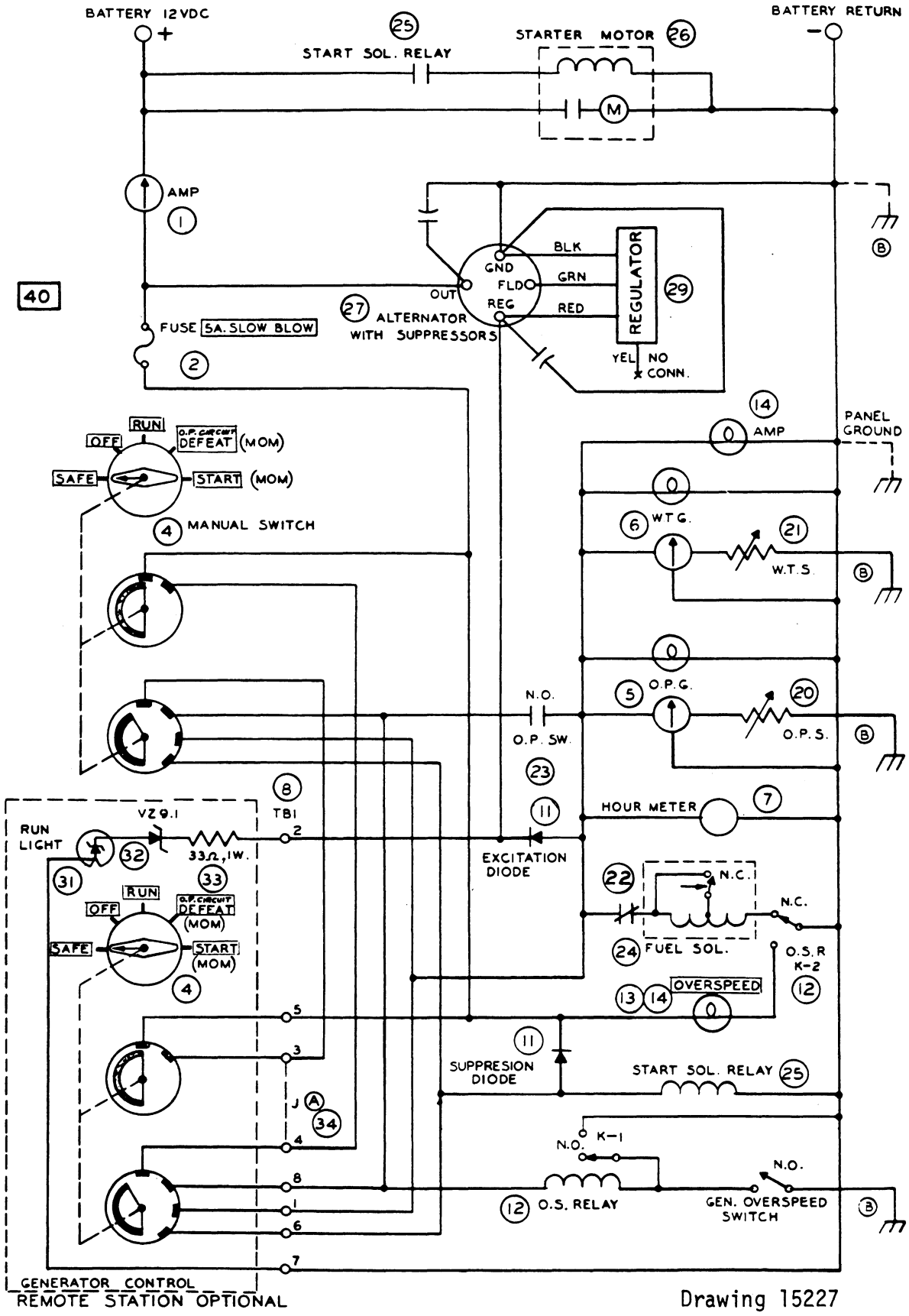


TABLE OF A.C. CONNECTIONS (A)

	GENERATOR MODEL	FREQ HZ	POWER KW	VOLTS RMS	MAX BAL KVA-0PF	LIMIT OF LINE AMP	JUMPER CONNECT'N
ONE PHASE FIXED CONNECTION	30.0UR-3N/1B	60	30.0	120/240	37.5	156.0	H5
		50	25.0	115/230	31.2	135.0	H6
	45.0 UR 3N/1B	60	45.0	120/240	56.2	234.0	H5
		50	37.5	115/230	46.8	203.0	H6
THREE PHASE RECONNECTABLE	30.0UR 215N/1B	60	30.0	240	37.5	52.0	H5
		50	25.0	230	31.2	45.0	H6
	45.0UR 215N/1B	60	45.0	240	56.2	78.0	H5
		50	37.5	230	46.8	68.0	H6
SERIES DELTA	30.0UR 215N/1B	60	30.0	120/208	37.5	104.0	H3
			30.0	127/220	37.5	98.5	H4
		50	30.0	139/240	37.5	90.0	H5
			25.0	110/190	31.2	95.0	H3
			25.0	115/200	31.2	90.0	H4
	45.0UR 215N/1B	60	45.0	120/208	56.2	156.0	H3
			45.0	127/220	56.2	148.0	H4
		50	45.0	139/240	56.2	135.0	H5
			37.5	110/190	37.5	143.0	H3
			37.5	115/200	37.5	118.0	H4
PARALLEL WYE	30.0UR 215N/1B	60	30.0	240/416	37.5	52.0	H3
			30.0	254/440	37.5	49.0	H4
		50	30.0	277/480	37.5	45.0	H5
			25.0	220/380	31.2	47.5	H3
			25.0	237/400	31.2	45.0	H4
	45.0UR 215N/1B	60	45.0	240/416	56.2	78.0	H3
			45.0	254/440	56.2	74.0	H4
		50	45.0	277/480	56.2	68.0	H5
			37.5	220/380	37.5	72.0	H3
			37.5	234/400	37.5	68.0	H4
SERIES WYE	30.0UR 215N/1B	60	30.0	240/416	37.5	52.0	H3
			30.0	254/440	37.5	49.0	H4
		50	30.0	277/480	37.5	45.0	H5
			25.0	220/380	31.2	47.5	H3
			25.0	237/400	31.2	45.0	H4
	45.0UR 215N/1B	60	45.0	240/416	56.2	78.0	H3
			45.0	254/440	56.2	74.0	H4
		50	45.0	277/480	56.2	68.0	H5
			37.5	220/380	37.5	72.0	H3
			37.5	234/400	37.5	68.0	H4

DRWG. 15555

30-45 KW: MANUAL STARTER DISCONNECT (ROTARY SWITCH)



Drawing 15227

MANUAL CONTROL OPERATION

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

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

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

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

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

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

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

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

ENGINE OPERATION

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

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

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

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

   A. The engine mounted switch must be on OFF.

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

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

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

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

SPECIAL CONTROLS ON WPDS 30 AND WPDS 45

The engine panels on these generators have four additional features.

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

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

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

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

MANUAL CONTROL TROUBLE SHOOTING HINTS

Nature of trouble	Probable cause	Verification
1. No panel indications or switch response	A. Remote or engine switch on SAFETY	1. Visual check
	B. Engine panel fuse	1. Check, replace 5 amp slow blow 2. Repeated blowing-check for short circuits and fuel solenoid bottoming.
	C. Battery	1. Check connections and disconnect switch. 2. Jump B+ to start solenoid coil. If cranks, battery is OK.
	D. Continuity, grounding or shorted circuits	1. Check voltage point by point from battery through ammeter. Tighten loose connections and locate any faults.
2. Doesn't crank, panels and voltages are OK	A. Start solenoid	1. Bypass solenoid with heavy wire. If cranks OK, start solenoid or coil input at fault.
	B. Crank by engine switch but not by remote panel	1. Remote cable wire too small for length of run. Open circuit.
	C. Starter jammed	1. Voltage drops and starter motor heats. Remove motor. Check pinion ring gear and engagement mechanism. Replace as required.
	D. Starter engagement - solenoid and switch	1. Apply voltage to (B) and (S) on starter. No response. Check starter motor return lines (R). Both connected to battery.
3. No ignition (cranks - doesn't start, fueled and primed)	A. Fuel solenoid	1. Check +12V on terminals at DEFEAT position. Check for free mechanical action. Adjust spring and linkages. Replace solenoid if weak, overheating or dead. 2. No voltage. Test with bypassed oil pressure switch then bypassed temperature switch. If no voltage, check wiring.
	B. Overspeed relay (30 and 45 KW)	1. Check solenoid return circuit through relay. Check relay movement and contacts. 2. A faulty overspeed circuit will hold relay closed. Reset with switch and isolate cause.

	C. Faulty fueling system	1. See engine maintenance section.
	D. Preheat not working (20 KW)	1. Check preheat solenoid relay and glowplugs. 2. Glowplugs burned out. Replace and check pressure switch shut off operation.
4. Failure to shut down	A. Fuel solenoid return spring	1. Stop engine by freeing fuel pump lever. That failing, shut off fuel. Check fuel solenoid linkage and repair for free movement.
	B. Control circuit or switch failure	1. Stop engine by removing fuse. Locate malfunction by voltage test after removing wire from the start solenoid relay and replacing fuse.
	C. Fuel injection pump failure	1. Stop engine with fuel line shut off. Repair or replace pump.
	D. Major engine fault	1. Stop engine with fuel line cutoff. That failing, plug air inlet with rags. Put maximum load on generator to attempt to stall engine.
5. Engine stops in RUN	A. Low oil pressure or overheated	1. Check oil, fresh water and sea water cooling.
	B. Low oil pressure switch fails to close	1. Check for satisfactory operation with switch bypassed.
	C. High water temperature switch open at too low a temperature	1. Same as above.
	D. Switch and wiring	1. Inspect all wiring for loose connections and short circuits.
6. Not charging battery	A. Alternator drive	1. Check drivebelt and its tension. Be sure alternator turns freely. Check for loose connections.
	B. Regulator unit and alternator	1. With engine running, momentarily connect B+ to field. A good alternator will produce a high charge (50 amps). If no response, replace alternator. Check for shorting of alternator output connections to ground.
7. Battery runs down	A. Oil pressure switch	1. Observe if gauges and panel light are on when engine is not running. Test the normally open oil pressure switch by disconnecting one lead. If lights go out, replace oil pressure switch.

B. High resistance leak to ground	1. Check wiring. Insert sensitive (0-.25 amp) meter in battery lines. (Do not start engine). Remove connections and replace until short is located.
C. Low resistance leak to ground	1. Check all wires for temperature rise to locate fault.
D. Alternator	1. Disconnect alternator at output, after a good battery charging. If leakage stops, replace alternator protective diode plate. That failing, replace alternator.