TEMPEST

2.5

MARINE & INDUSTRIAL ENGINES MANUAL

CONTENTS

SECTION H

RECOMMENDED LUBRICANTS

Industrial Engines

Engine, Air Cleaner and Oilcan

Climatic Conditions	Castrol	Esso	B.P.	Duckhams	Mobil	Shell	Filtrate	Sternol
Above 32°C (90°F)	Castrol CRI 30	Essolube HDX 30	Vanellus SAE 30	Fleetol HDX 30	Delvac 1130	Shell Rotella S. Oil 30	Filtrate Diesel 30	Panther 30
32°C (90°F) down to —12°C (10°F)	Castrol CRI 20	Essolube HDX 20	Vanellus SAE 20	Fleetol HDX 20	Delvac 1120	Shell Rotella S. Oil 20/20W	Filtrate Diesel 20	Panther 20
—12°C (10°F) down to —18°C (0°F)	Castrol CRI 10	Essolube HDX 10W	Vanellus SAE 10W	Fleetol HDX 10	Delvac 1110	Shell Rotella S. Oil 10W	Filtrate Diesel 10W	Panther 10
Below —18°C (0°F)	Castrol CR5W/20	Esso Extra Motor Oil 5W/20	Super Viscostatic 5W/20	Q5-30	Mobiloil 5W/20	Shell Winter Special Motor Oil or Shell Super Motor Oil 5W/20	Filtrate 5W/20	Sternol WW Multigrade 5W/20
Gearbox								
Above —12°C (10°F)	Castrol Hypoy	Esso Gear Oil G.P.90/ 140 or G.P.90	B.P. Gear Oil SAE 90 E.P.	Duckhams Hypoid 90	Mobilube G.X.90	Spirax 90 E.P.	Filtrate E.P. Gear 90	Ambroleum E.P. 90
Below —12°C (10°F)	Castrol Hypoy Light	Esso Gear Oil G.P.80	B.P. Gear Oil SAE 80 E.P.	Duckhams Hypoid 80	Mobilube G.X.80	Spirax 80 E.P.	Filtrate E.P. Gear 80	Ambroleum E.P. 80
Lubricating Nipples and Water Pump								
All Conditions	Castrolease LM	Esso Multipurpose Grease H	Energrease L.2	Duckhams LB 10 Grease	Mobilgrease M.P.	Shell Retinax A	Filtrate Super Lithium Grease	Ambroline L.H.T.

In addition to the lubricants listed we approve the use of the appropriate multigrade oils for the particular conditions 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.

Overcentre Clutch (P.T.O.)

Climatic Conditions	Esso	Mobil	Shell	B.P.	Filtrate	Duckhams	Castrol	Sternol
All Conditions			Shell Alvania No. 2 grease					

INTRODUCTION

This Workshop Manual has been prepared to assist not only the operator, or user, of Marine and Industrial engines, but also to enable the skilled Service Engineer to undertake more detailed maintenance and overhaul.

The manual is divided into sections, as listed under 'Contents', Sections A and B containing the relevant information for the basic 1·5 litre and 2·5 litre engines. Running instructions and routine maintenance procedures are given at the beginning of Section A with variations included in Section B.

Special Service Tools are listed in Section G and it should be appreciated that some overhaul procedures can only be undertaken with the appropriate tools to hand, and in every instance where a service tool is referred to, the operation is simplified if that particular tool is used.

GENERAL INFORMATION

Newage Marine and Industrial engines are reliable units, and provided they are correctly installed, aligned, and maintained, should give virtual trouble free service. In the event of trouble or breakdown the local or nearest Newage Dealer should be consulted. Failing this contact the Company direct, quoting the engine serial number.

Claims under Warranty

Claims for the replacement of parts, under warranty, must always be submitted to the supplying dealer, or when this is not possible, to the nearest dealer, informing them of the supplying dealer's name and address. ALWAYS QUOTE THE ENGINE SERIAL NUMBER.

Service Parts

Illustrated Parts Lists are available for each size and type of engine, and full instructions for ordering spare parts are contained therein.

GENERAL DATA

ENGINE (1.5 LITRE)

Type		15 VD
Number of cylinders		4
Bore		2·8745 to 2·876 in. (73·012 to 73·05 mm)
Stroke		3·5 in. (88·9 mm)
Capacity		1489 cm^3
Compression ratio		23 : 1
Firing order		1, 3, 4, 2
Idling speed		500 to 600 rev/min
Maximum governed light running speed		Refer to pump nameplate
Crankshaft		
Journal diameter		2·0005 to 2·001 in. (50·813 to 50·825 mm)
Clearance in main bearings		0·001 to 0·0027 in. (0·0254 to 0·0686 mm)
Crankpin diameter		2·0005 to 2·001 in. (50·813 to 50·825 mm)
Clearance in big end bearings		0·001 to 0·0027 in. (0·0254 to 0·0686 mm)
Undersizes (Journals and crankpins)		
First		0·010 in. (0·254 mm)
Second (maximum)		0·020 in. (0·508 mm)
Endfloat		0·002 to 0·003 in. (0·051 to 0·076 mm)
Endfloat adjustment		Selective thrust washer assembly
Cylinder bore		
Standard		2·8745 to 2·876 in. (73·012 to 73·05 mm)
Oversizes		
First		0·010 in. (0·254 mm)
Second (maximum if linered)		0·020 in. (0·508 mm)
Third		0·030 in. (0·762 mm)
Fourth (maximum)		0·040 in. (1·016 mm)
Pistons and rings		
Piston type		Aluminium alloy with solid skirt
Piston to bore clearance at bottom of skirt		0·0035 to 0·0043 in. (0·089 to 0·109 mm)
Ring/groove clearance		
Top compression		0·0035 to 0·0055 in. (0·089 to 0·140 mm)
2nd and 3rd compression		0·0025 to 0·0045 in. (0·063 to 0·114 mm)
Oil control		0·002 to 0·004 in. (0·051 to 0·102 mm)
Ring gap		
Top compression		0·012 to 0·017 in. (0·305 to 0·432 mm)
Remainder		0·008 to 0·013 in. (0·203 to 0·330 mm)
Camshaft		
Journal diameter		
Front		1·78875 to 1·78925 in. (45·434 to 45·447 mm)
Centre		1·72875 to 1·72925 in. (43·910 to 43·922 mm)
Rear		1·62275 to 1·62325 in. (41·218 to 41·231 mm)
Clearance in bearings		0·001 to 0·002 in. (0·0254 to 0·0508 mm)
End float		0·003 to 0·007 in. (0·0762 to 0·1778 mm)
End float adjustment		Renew locating plate
Gudgeon pins		
Type		Fully floating
Diameter		0·9998 to 1·0 in. (25·39 to 25·4 mm)
Fit in piston		0·0002 in. (0·005 mm) clearance to 0·0002 in. (0·005 mm) interference
Fit in connecting rod		0·0002 in. to 0·0009 in. (0·005 to 0·023 mm) clearance
Chain wheel alignment		Crankshaft chain wheel face 0·005 in. (0·127 mm) rearwards of camshaft chain wheel face
Method of adjustment		Shims behind crankshaft chain wheel
Cylinder head		
Valve seat angle		45°
Valve seat face width		0·089 in. (2·261 mm)
Valves		
Stand-down		0·018 to 0·038 in. (0·457 to 0·965 mm)
Lift		0·317 in. (8·05 mm)
Head diameter		
Inlet		1·370 to 1·375 in. (34·8 to 34·9 mm)
Exhaust		1·151 to 1·156 in. (29·2 to 29·4 mm)
Stem diameter		
Inlet		0·3422 to 0·3427 in. (8·69 to 8·70 mm)
Exhaust		0·002 to 0·003 in. (0·051 to 0·076 mm)
Stem to guide clearance		
Inlet		0·0015 to 0·0025 in. (0·038 to 0·064 mm)
Exhaust		0·002 to 0·003 in. (0·051 to 0·076 mm)
Seat angle		44½°
Seat face width		0·090 ± 0·010in. (2·286 ± 0·254 mm)

Valve springs	Inner	Outer
Free length	1·875 in. (47·63 mm)	2·2343 in. (56·75 mm)
Fitted length	1·4375 in. (36·512 mm)	1·5625 in. (39·687 mm)
Pressure (valve closed)	20 ± 1 lb. (9·07 ± 0·454 kg)	50·5 ± 2 lb. (22·907 ± 0·907 kg)

Working coils	6½	5½
Wire diameter	0·104 in. (2·641 mm)	0·144 in. (3·658 mm)
Core diameter	0·715 in. to 0·730 in. (18·161 to 18·542 mm	0·993 to 1·007 in. (25·222 to 25·579 mm)

Valve seat inserts
Refer to Section A, sub-section A16 for cylinder head machining dimensions

Valve guides
- Length .. 2·203 in. (56 mm)
- Outside diameter .. 0·5635 to 0·564 in. (14·313 to 14·326 mm)
- Outside diameter (oversize guide) .. 0·5735 to 0·574 in. (14·567 to 14·580 mm)

Valve rockers
- Bush bore diameter (reamed in position) .. 0·6255 to 0·626 in. (15·888 to 15·90 mm)
- Clearance on shaft .. 0·0005 to 0·002 in. (0·0127 to 0·051 mm)

Valve rocker clearance (cold) .. 0·015 in. (0·381 mm)

Tappets
- Diameter .. 0·81125 to 0·81175 in. (20·606 to 20·618 mm)
- Oversizes .. 0·010 and 0·020 in. (0·254 and 0·508 mm)
- Clearance in crankcase .. 0·0005 to 0·0020 in. (0·0127 to 0·051 mm)

Valve timing

	Opens	Closes
Inlet valve ..	5° B.T.D.C.	45° A.B.D.C.
Exhaust valve ..	45° B.B.D.C.	5° A.T.D.C.

Timing marks .. Dimples on chain wheels, and notch on crankshaft pulley with degree plate on timing cover.

Injection timing .. 22° B.T.D.C. (Fully retarded)

Timing marks .. Timing pointer on injection pump hub and timing mark on injection pump housing

Timing chain tensioner .. Maximum permissible body bore ovality 0·003 in. (0·076 mm)

Lubrication

Oil pump
- Type .. Eccentric rotor
- Rotor end float .. 0·005 in. (0·127 mm) maximum
- Outer rotor to pump diametrical clearance .. 0·010 in. (0·254 mm)
- Rotor lobe clearance .. 0·006 in. (0·152 mm)

Oil pressure relief valve spring
- Free length .. 2·859 in. (72·628 mm)

Oil pressure (engine hot)
- Idling .. 15 lb.in² (1·05 kg.cm²)
- Normal running .. 50 lb.in² (3·52 kg.cm²)

COOLING SYSTEM

Marine engines .. Pressurised and thermostatically controlled closed circuit system using either a heat exchanger or keel cooler.

Industrial engines .. Pressurised and thermostatically controlled closed circuit system with radiator

Thermostat
- Operating temperature .. Stamped on thermostat in degrees F

Pressure cap
- Release valve opening pressure .. Stamped on cap in lb.in²

Drive belt
- Tension .. ⅛ in. (3·175 mm) lateral movement in centre of longest run under finger pressure
- Adjustment .. Slacken dynamo or alternator mountings and vary position

FUEL SYSTEM

Lift pump .. A.C. mechanical U type
- Static pressure (no delivery) .. 5 lb.in² (0·35 kg.cm²)

Injection pump .. Type CAV DPA 3246857
- Roller to roller dimension .. 50·29 mm

Injectors .. Type CAV Pintaux
- Nozzle .. BDN. O. SPC. 6389
- Nozzle holder .. BKB. 35. SD. 5188
- Auxiliary hole diameter .. 0·008 in. (0·20 mm)
- Needle lift .. 0·024 to 0·029 in. (0·6 to 0·75 mm)
- Nozzle seat angle .. 59°
- Valve seat angle .. 60°
- Opening pressure .. 135 atmospheres

Main filter .. Type CAV bowl less FS.5836020

CLUTCH (Automotive industrial engines only)	
Type	Borg and Beck single dry plate 8 in. (203 mm)
Colour of damper springs	Black and light green
Pressure plate springs	
Free length	2·16 in. (54·86 mm)
Fitted length	1·56 in. (39·62 mm)
Rate	266 lb.in. (46·5 kg.cm)
Identification colour	Light grey
Clutch release bearing minimum permissible height above bearing housing	1/16 in. (1·587 mm)
ELECTRICAL EQUIPMENT	
Dynamo	Lucas Type C40 12-volt
Voltage regulator	Lucas RB106-2
Starter motor	Lucas Type M45G
Minimum brush length	5/16 in. (7·937 mm)
Brush spring pressure	43 oz. (1·22 kg) minimum on new brush
Commutator minimum diameter	1·5 in. (38 mm)
Mandrel diameter (fitting bushes)	Shaft diameter plug 0·0005 in. (0·013 mm)
Pinion setting (pinion engaged position)	0·005 to 0·015 in. (0·127 to 0·381 mm) between pinion face and thrust washer
Adjustment	Engagement lever pivot pin
Solenoid resistance	
Closing coil	0·13 to 0·15 ohm
Hold-on coil	0·63 to 0·73 ohm
Heater plugs	Champion AG 32
OIL CAPACITIES	
Sump (including filter)	8½ imp. pints (4·68 litres)
Filter	1¾ imp. pints (0·7 litre)
COOLING CAPACITIES	
Keel cooler } Marine engines	18 pints (10·2 litres) approx
Heat exchanger } Marine engines	14 pints (8 litres) approx
TORQUE WRENCH SETTINGS	
Cylinder head nuts	71 lbf.ft (9·8 kgf.m)
Rocker bracket nuts	25 lbf.ft (3·4 kgf.m)
Manifold nuts	15 lbf.ft (2·1 kgf.m)
Big end bolts	35 lbf.ft (4·85 kgf.m)
Main bearing nuts	75 lbf.ft (10·36 kgf.m)
Flywheel bolts	37 lbf.ft (5·1 kgf.m)
Rear distance piece bolts 5/16 in. (7·937 mm) 3/8 in. (9·525 mm)	20 lbf.ft (2·8 kgf.m)
Fuel injection pump	
Advance unit cap nut	130 lbf.in. (1·5 kgf.m)
Advance unit cap nut stud	60 lbf.in. (0·69 kgf.m)
Advance unit spring cap and end plug	250 lbf.in. (2·9 kgf.m)
Cam ring advance screw	450 lbf.in. (6·13 kgf.m)
Drive plate screws	
Direct torque	160 lbf.in. (1·85 kgf.m)
Indirect torque (using tool 18G55A)	140 lbf.in. (1·62 kgf.m)
End plate studs	45 lbf.in. (0·52 kgf.m)
Fuel inlet connection	450 lbf.in. (6·13 kgf.m)
Governor housing securing screws	40 lbf.in. (0·46 kgf.m)
High pressure connections	270 lbf.in. (3·1 kgf.m)
Hydraulic head locating bolt	350 lbf.in. (4·05 kgf.m)
Hydraulic head locking screws	170 lbf.in. (1·96 kgf.m)
Rotor end plug	28 lbf.in. (0·32 kgf.m)
Transfer pump rotor	65 lbf.in. (0·75 kgf.m)
Injectors	
Nozzle nut	50 lbf.ft (7·0 kgf.m)
Securing nuts	12 lbf.ft (1·7 kgf.m)
Starter motor (type M45G)	
Through bolts	8 lbf.ft (1·1 kgf.m)
Solenoid fixing nuts	4·5 lbf.ft (0·62 kgf.m)
Nuts on solenoid copper terminals	24 lbf.in. (0·27 kgf.m)

ENGINE (2·5 LITRE)	
Type	25 VD
Number of cylinders	4
Bore and stroke	3·5 in. (89 mm) × 4·00 in. (101·6 mm)
Capacity	2520 cm³
Compression ratio	19·5 : 1
Firing order	1, 3, 4, 2
Idling speed	500 rev/min
Maximum governed light running speed	Refer to pump nameplate
Crankshaft	
Journal diameter	2·4780 to 2·4785 in. (62·941 to 62·954 mm)
Clearance in main bearing	0·0015 to 0·002 in. (0·038 to 0·051 mm)
Crankpin diameter	2·2480 to 2·2485 in. (57·099 to 57·112 mm)
Clearance in big end bearings	0·002 to 0·0035 in. (0·051 to 0·089 mm)
Undersizes (journals and crankpins)	
First	0·010 in. (0·254 mm)
Second	0·020 in. (0·508 mm)
Third	0·030 in. (0·762 mm)
Fourth	0·040 in. (1·016 mm)
End float	0·002 to 0·003 in. (0·051 to 0·076 mm)
End float adjustment	Selective thrust washer assembly
Cylinder bore	
Standard	3·4995 to 3·501 in. (88·89 to 88·93 mm)
Oversizes	
First	0·010 in. (0·254 mm)
Second (maximum if linered)	0·020 in. (0·508 mm)
Third	0·030 in. (0·762 mm)
Bore size for fitting liners	3·642 to 3·6425 in. (92·507 to 92·520 mm)
Pistons and rings	
Piston type	Aluminium alloy with solid skirt
Clearance: Bottom of skirt	0·0045 to 0·0051 in. (0·1143 to 0·1295 mm)
Ring/groove clearance:	
Top and 2nd (compression)	0·0026 to 0·0046 in. (0·066 to 0·117 mm)
3rd (stepped scraper)	0·0026 to 0·0046 in. (0·066 to 0·117 mm)
4th (slotted scraper)	0·0025 to 0·0045 in. (0·064 to 0·114 mm)
Ring gap	
Top compression	0·014 to 0·019 in. (0·36 to 0·48 mm)
Remainder	0·010 to 0·015 in. (0·25 to 0·38 mm)
Gudgeon pins	
Type	Fully floating
Diameter	1·1248 to 1·1250 in. (28·57 to 28·58 mm)
Fit in piston	0·0003 in. (0·008 mm) clearance to 0·0001 in. (0·003 mm) interference
Fit in connecting rod	0·0005 to 0·0012 in. (0·013 to 0·030 mm) clearance
Little-end bushes	
Inside diameter (reamed in position)	1·1255 to 1·1260 in. (28·588 to 28·60 mm)
Camshaft	
Journal diameter	
Front	1·78875 to 1·78925 in. (45·43 to 45·45 mm)
Centre	1·74875 to 1·74925 in. (44·42 to 44·43 mm)
Rear	1·62275 to 1·62325 in. (41·22 to 41·23 mm)
Clearance in bearings	0·001 to 0·002 in. (0·03 to 0·05 mm)
End float	0·003 to 0·006 in. (0·076 to 0·152 mm)
Method of adjustment	Renew locating plate
Chain wheel alignment	Crankshaft and camshaft chain wheel teeth faces in line
Method of adjustment	Shims behind crankshaft chain wheel
Injection pump chain wheel	Injection pump chain wheel self-aligning
Chain wheel bearing bore (finished in position)	1·75025 to 1·75075 in. (44·46 to 44·47 mm)
Clearance on chain wheel hub	0·001 to 0·002 in. (0·03 to 0·05 mm)
Cylinder head	
Valve seat angle	45°
Valve seat inserts	Refer to Section B, sub-section B15 for cylinder head machining dimensions
Valves	
Face angle: Inlet and exhaust	45°
Face width	
Inlet	0·195 ± 0·0025 in. (4·953 ± 0·063 mm)
Exhaust	0·199 ± 0·0025 in. (5·005 ± 0·063 mm)
Head diameter	
Inlet	1·557 to 1·562 in. (39·55 to 39·67 mm)
Exhaust	1·307 to 1·312 in. (33·20 to 33·32 mm)
Stem diameter: inlet and exhaust	0·34175 to 0·34225 in. (8·68 to 8·69 mm)
Lift: Inlet and exhaust	0·39 in. (9·9 mm)
Stand-down: Inlet and exhaust	0·010 in. (0·25 mm) stand-down to 0·003 in. (0·076 mm) stand-proud

GENERAL DATA (continued)

Valve springs		
	Inner	Outer
Free length	2·187 in. (55·55 mm)	2·5 in. (63·5 mm)
Fitted length	1·5 in. (38·1 mm)	1·703 in. (43·26 mm)
Pressure (valve closed)	23 to 25 lb (10·43 to 11·34 kg)	56·5 to 60·5 lb (25·63 to 27·44 kg)
Working coils	7½	5½
Wire diameter	0·104 in. (2·65 mm)	0·156 in. (3·96 mm)
Core diameter	0·75 to 0·765 in. (19·05 to 19·43 mm)	1·125 to 1·140 in. (28·58 to 28·96 mm)
Valve guides		
Length:		
Inlet	2·14 in. (54·36 mm)	
Exhaust	2·5 in. (63·5 mm)	
Inside diameter:		
Inlet (reamed in position)	0·3438 to 0·3443 in. (8·733 to 8·745 mm)	
Exhaust (reamed in position)	0·3433 to 0·3438 in. (8·720 to 8·733 mm)	
Outside diameter:		
Inlet and exhaust	0·5635 to 0·5640 (14·313 to 14·326 mm)	
Valve rockers		
Bush bore diameter (reamed in position)	0·8115 to 0·8125 in. (20·61 to 20·64 mm)	
Clearance on shaft	0·0005 to 0·0025 in. (0·013 to 0·064 mm)	
Valve rocker clearance (cold):		
Inlet	0·012 in. (0·30 mm)	
Exhaust	0·015 in. (0·38 mm)	
Tappets		
Outside diameter	0·99875 to 0·99925 in. (24·47 to 24·48 mm)	
Oversizes	0·010 and 0·020 in. (0·254 and 0·508 mm)	
Clearance in crankcase	0·0005 to 0·00175 in. (0·013 to 0·044 mm)	
Valve timing with 0·021 in. (0·53 mm) rocker clearance		
	Opens	Closes
Inlet valve	5° B.T.D.C.	40° A.B.D.C.
Exhaust valve	60° B.B.D.C.	5° A.T.D.C.
Timing marks	Dimples on chain wheels, and either degree plate on timing cover with notch or mark on crankshaft pulley, or timing indicator on flywheel housing with timing mark on flywheel	
Injection timing	25° B.T.D.C. (fully retarded)	
Timing marks	Timing pointer on injection pump chain wheel hub and timing mark on injection pump housing	
Timing chain tensioner	Maximum permissible body bore ovality 0·003 in. (0·076 mm) maximum	
Lubrication		
Oil Pump		
Type	Eccentric rotor	
Rotor end float	0·005 in. (0·13 mm) maximum	
Outer rotor to body diametrical clearance	0·010 in. (0·25 mm) maximum	
Rotor lobe clearance	0·008 in. (0·2 mm) maximum and 0·006 in. (0·15 mm) maximum (see diagrams)	
Oil pressure relief valve spring		
Free length	3 in. (76·2 mm)	
Oil pressure (engine hot)		
Idling	15 lb.in² (1·05 kg.cm²)	
Normal running	50 lb. in² (3·52 kg.cm²)	

COOLING SYSTEM

Marine engines	Pressurised and thermostatically controlled closed circuit system using either a heat exchanger or keel cooler.
Industrial engines	Pressurised and thermostatically controlled closed circuit system with radiator
Thermostat	
Operating temperature	Stamped on thermostat in degrees F
Pressure cap	
Release valve opening pressure	Stamped on cap in lb.in²
Drive belt	
Tension	½ in. (9·52 mm) lateral movement in centre of longest run under finger pressure
Adjustment	Slacken alternator mountings and vary position.

FUEL SYSTEM

Lift pump	A.C. mechanical U type
Static pressure (no delivery)	5 lb. in² (0·35 kg.cm²)
Injection pump	Type CAV DPA 3248F80 A
Roller to roller dimension	1·979 in. (50·37 mm)
Governor link length	2·064 ± 0·039 in. (52·5 ± 1 mm)

GENERAL DATA (continued)

Injectors	Type CAV Pintaux
Nozzle	Type BDN.O.SPC 6209
Nozzle holder	Type BKB.35.SD. 5283
Auxiliary hole diameter	1·008 in. (0·20 mm)
Nozzle seat angle	59°
Valve seat angle	60°
Needle lift	0·024 to 0·029 in. (0·61 to 0·74 mm)
Opening pressure	135 atmospheres
Main filter	Type CAV. FS 5836130

CLUTCH (Automotive industrial engines only)

Type	Borg and Beck single dry plate 10 in. (254 mm)
Colour of damper springs	Black and cream
Pressure plate springs	
Free length	2·5625 in. (65·09 mm)
Identification colour	Light green

ELECTRICAL EQUIPMENT

Alternator	Lucas Type 11AC
Output	43 amperes
Minimum brush length	5/32 in. (3·969 mm)
Brush spring pressure	
25/32 in. (19·844 mm) compressed length	4 to 5 oz (113·40 to 141·75 g)
13/32 in. (10·319 mm) compressed length	7½ to 8½ oz (212·62 to 240·97 g)
Field winding	
Resistance	3·77 ± 0·18 ohms
Current flow at 12 volts	3·2 amps
Control unit	Model 4TR
Relay	Model 6RA
Starter motor	Type M45G
Minimum brush length	5/16 in. (7·937 mm)
Brush spring pressure	43 oz (1·22 kg) minimum on new brush
Commutator minimum diameter	1·5 in. (38 mm)
Diameter of mandrel for fitting bushes	Shaft diameter plus 0·0005 in. (0·013 mm)
Pinion setting (pinion in engaged position)	0·005 to 0·015 in. (0·127 to 0·381 mm) between pinion face and thrust washer
Adjustment	Engagement lever pivot pin
Solenoid resistance	
Closing coil	0·13 to 0·15 ohms
Hold-on coil	0·63 to 0·73 ohms
Heater plugs	Champion AG32

TORQUE WRENCH SETTINGS

Cylinder head nuts	75 lbf.ft (10·37 kgf.m)
Rocker bracket nuts	25 lbf.ft (3·46 kgf.m)
Manifold nuts	22 lbf.ft (3·04 kgf.m)
Big end bolts	50 lbf.ft (6·9 kgf.m)
Main bearing bolts	100 lbf.ft (13·82 kgf.m)
Flywheel bolts	50 lbf.ft (6·9 kgf.m)
Fuel injection pump	
Advance unit cap nut	130 lbf.in. (1·5 kgf.m)
Advance unit cap nut stud	60 lbf.in. (0·69 kgf.m)
Advance unit spring cap and end plug	250 lbf.in. (2·9 kgf.m)
Back leakage connection	180 lbf.in. (2·06 kgf.m)
Cam ring advance screw	300 lbf.in. (3·45 kgf.m)
Control bracket screw	21 lbf.in. (0·24 kgf.m)
Control cover studs	60 lbf.in. (0·69 kgf.m)
Control cover stud cap nuts	40 lbf.in. (0·46 kgf.m)
Drive plate screws:	
Direct torque	160 lbf.in. (1·85 kgf.m)
Indirect torque (using tool 18G655A)	140 lbf.in. (1·61 kgf.m)
Drive shaft screw	285 lbf.in. (3·3 kgf.m)
End plate screws	45 lbf.in. (0·52 kgf.m)
Hydraulic head locating bolt	350 lbf.in. (4·05 kgf.m)
Hydraulic head locking screws	170 lbf.in. (1·95 kgf.m)
Inlet connection	450 lbf.in. (5·18 kgf.m)
Rotor end plug	28 lbf.in. (0·32 kgf.m)
Transfer pump rotor	65 lbf.in. (0·75 kgf.m)
Injector nozzle nut	50 lbf.ft (6·9 kgf.m)
Injector securing nuts	12 lbf.ft (1·7 kgf.m)
Alternator	
Through bolts	45 to 50 lbf.in. (0·513 to 0·675 kgf.m)
Diode heat sink fixings	25 lbf.in. (0·288 kgf.m)
Brush box fixing screws	10 lbf.in. (0·115 kgf.m)
Starter motor	
Through bolts	8 lbf.ft (1·1 kgf.m)
Solenoid fixing nuts	4·5 lbf.ft (0·62 kgf.m)
Nuts on solenoid copper terminal	24 lbf.in. (0·276 kgf.m)

OIL CAPACITIES

Sump (including filter industrial engines)	10 pints (5·67 litres)
(marine engines)	12 imp pints (6·82 litres)
Filter	$1\frac{1}{4}$ imp pints (0·7 litre)

COOLING CAPACITIES

Keel cooler } Marine engines	25 pints (14·2 litres)
Heat exchanger } Marine engines	21 pints (12 litres)

SECTION A

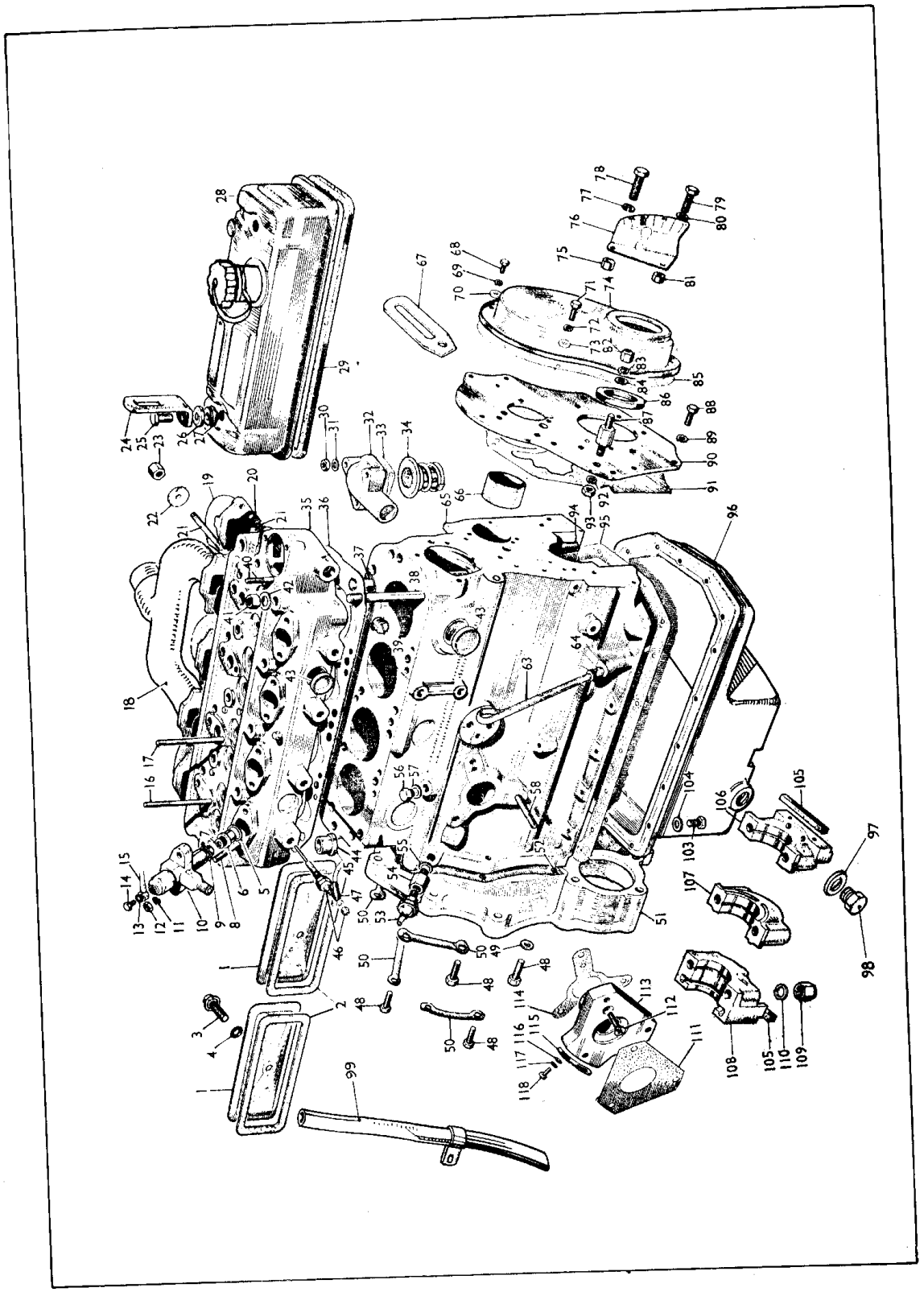


FIG.1 - 1.5 LITRE DIESEL - BASIC ENGINE ASSEMBLY

No.	Description
1	Cylinder side cover
2	Gasket for side cover
3	Screw for side cover
4	'O' ring
5	Joint washer for heat shield
6	Heat shield
7	Atomizer seal washer
8	Stud for injector
9	Joint washer for injector
10	Injector
11	Washer for nut
12	Nut for injector stud
13	Washer for banjo bolt
14	Banjo bolt for leak-off pipe (spill rail)
15	Leak-off pipe for injector
16	Long stud for rocker bracket
17	Short stud for rocker bracket
18	Inlet manifold
19	Exhaust manifold
20	Gasket for manifolds
21	Stud for manifold
22	Yoke for manifold
23	Nut for manifold stud
24	Engine sling bracket
25	Cap nut for rocker cover
26	Cup washer
27	Rubber bush
28	Valve rocker cover
29	Gasket for rocker cover
30	Nut for water outlet elbow
31	Washer for nut
32	Water outlet elbow
33	Gasket for outlet elbow
34	Thermostat
35	Cylinder head
36	Gasket for cylinder head
37	Cylinder head stud (long)

No.	Description
38	Cylinder head stud (short)
39	Plug for thermal transmitter boss
40	Stud for outlet elbow
41	Nut for cylinder head stud
42	Washer for nut
43	Core plug
44	Combustion chamber insert
45	Ball for insert
46	Heater plug
47	Cable for heater plug
48	Screw for gearbox distance piece
49	Washer for screw
50	Lock washer for screw
51	Gearbox distance piece
52	Gasket for distance piece
53	Oil pressure switch
54	Adaptor
55	Washer for adaptor
56	Plug for oil gallery
57	Washer for plug
58	Stud for injection pump
63	Oil dipstick
64	Guide tube for dipstick
65	Cylinder block
66	Camshaft bearing liner
67	Adjusting link for dynamo or alternator
68	Screw for timing cover
69	Spring washer for screw
70	Plain washer for screw
71	Screw for timing cover and front plate
72	Spring washer for screw
73	Plain washer for screw
74	Timing cover
75	Distance piece for timing plate (wide)
76	Timing plate
77	Washer for screw
78	Screw for timing plate

No.	Description
79	Screw for timing plate
80	Washer for screw
81	Distance piece for timing plate(narrow)
82	Nut for pillar
83	Spring washer for nut
84	Plain washer for nut
85	Gasket for timing cover
86	Crankshaft front oil seal
87	Pillar for alternator adjusting link
88	Screw for front plate
89	Washer for screw
90	Front plate
91	Gasket for front plate
92	Washer for nut
93	Nut for pillar
94	Stud for main bearing cap
95	Gasket for sump
96	Sump
97	Washer for drain plug
98	Drain plug for sump
99	Crankcase vent pipe
103	Screw for sump
104	Washer for screw
105	Joint for front and rear main bearing cap
106	Front main bearing cap
107	Centre main bearing cap
108	Rear main bearing cap
109	Nut for main bearing cap
110	Washer for nut
111	Gasket for injection pump
112	Countersunk screw for hub
113	Hub for injection pump
114	Gasket for hub
115	Timing pointer
116	Plain washer for screw
117	Spring washer for screw
118	Screw for timing pointer

Index to 1.5 Litre Diesel Engine Assembly

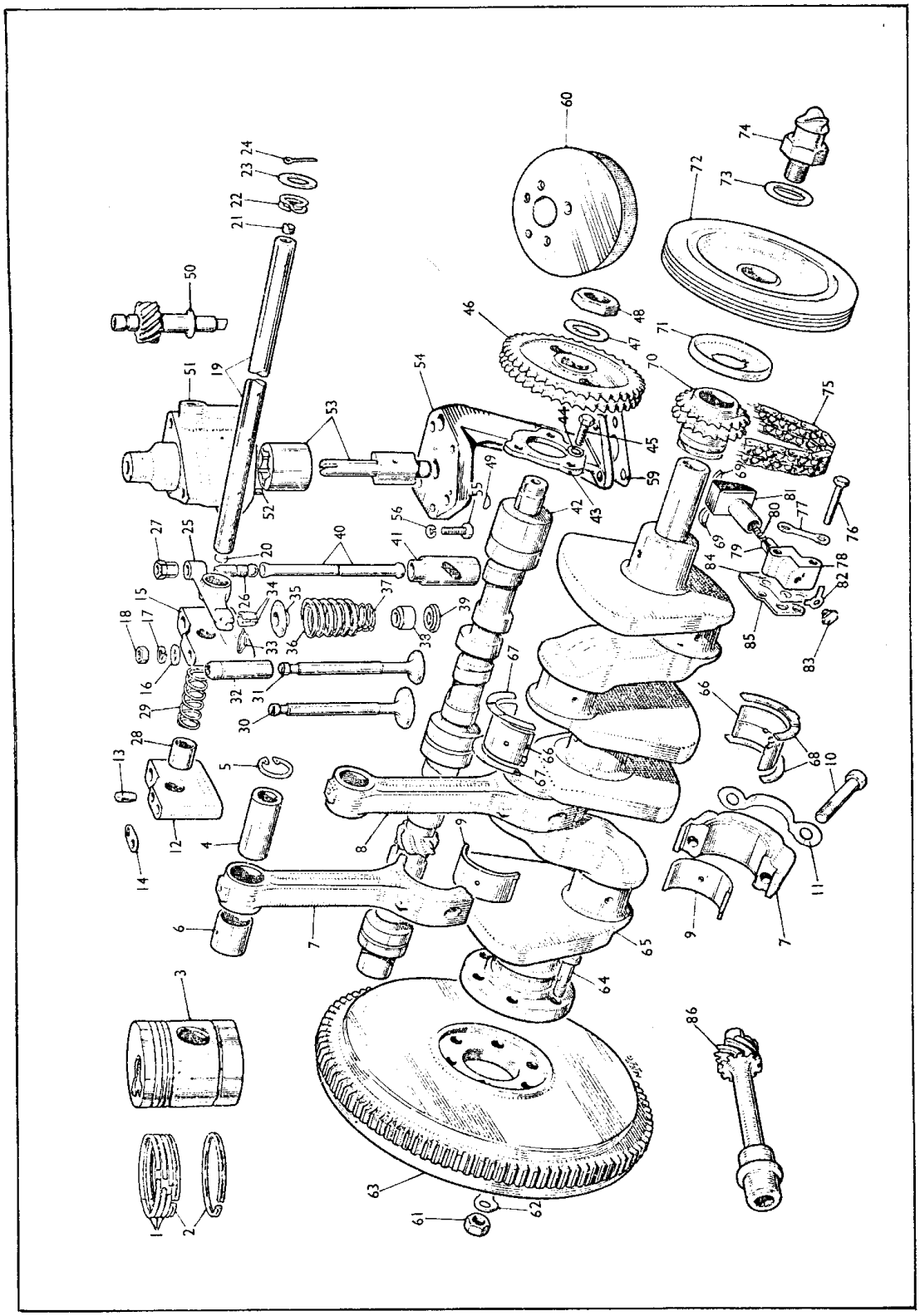


FIG.2 - 1.5 LITRE DIESEL ENGINE CRANKSHAFT - CAMSHAFT ASSEMBLIES

No.	Description
1	Piston rings (compression)
2	Piston rings (oil control)
3	Piston
4	Gudgeon pin
5	Circlip for gudgeon pin
6	Little-end bush for connecting rod
7	Connecting rod and cap (Nos.2 and 4)
8	Connecting rod and cap (Nos.1 and 3)
9	Big-end bearing for connecting rod
10	Bolt for connecting rod
11	Lock washer for bolt
12	Rocker bracket (tapped)
13	Rocker shaft locating screw
14	Locking plate for screw
15	Rocker bracket (plain)
16	Plain washer for rocker bracket stud
17	Spring washer for rocker bracket stud
18	Nut for rocker bracket stud
19	Rocker shaft
20	Plain plug for rocker shaft
21	Screwed plug for rocker shaft
22	Double-coil spring washer
23	Rocker shaft washer
24	Split pin
25	Valve rocker
26	Adjusting screw for rocker
27	Locknut for screw
28	Bush for rocker
29	Spacing spring for rocker
30	Inlet valve
31	Exhaust valve
32	Valve guide
33	Circlip for valve cotter
34	Valve cotter
35	Valve spring cap
36	Outer valve spring
37	Inner valve spring
38	Valve oil seal
39	Valve spring bottom collar
40	Push-rod
41	Tappet
42	Camshaft
43	Camshaft locating plate
44	Washer for screw
45	Screw for locating plate
46	Camshaft chain wheel
47	Lock washer for nut
48	Camshaft nut
49	Key for camshaft
50	Oil pump driving spindle
51	Oil pump body
52	Dowel for oil pump
53	Oil pump rotor assembly
54	Oil pump cover
55	Screw for cover
56	Washer for screw
59	Gasket for oil strainer
60	Oil strainer
61	Nut for flywheel bolt
62	Lock washer for nut
63	Flywheel
64	Flywheel bolt
65	Crankshaft
66	Main bearing
67	Crankshaft thrust washer (upper)
68	Crankshaft thrust washer (lower)
69	Key for crankshaft
70	Crankshaft chain wheel
71	Crankshaft oil thrower
72	Crankshaft pulley
73	Lock washer for starting nut
74	Starting nut
75	Timing chain
76	Bolt for chain tensioner
77	Lock washer for bolt
78	Chain tensioner body
79	Chain tensioner cylinder
80	Chain tensioner spring
81	Chain tensioner slipper
82	Lock washer for plug
83	Plug for tensioner body
84	Gasket for tensioner body
85	Chain tensioner back-plate
86	Injection pump driving spindle

Index to 1.5 Litre Engine Crankshaft - Camshaft Assemblies

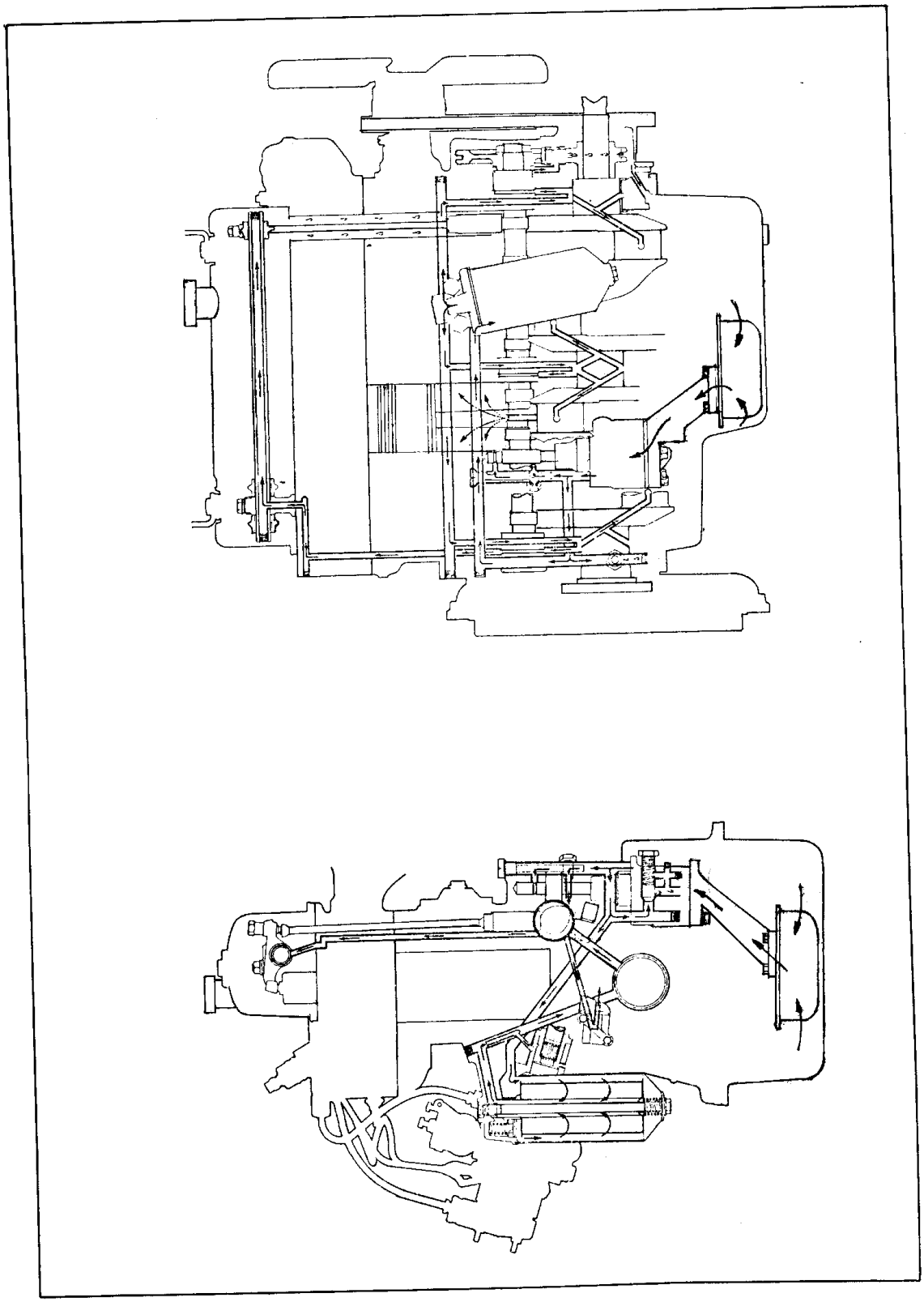


FIG.3 - 1.5 LITRE DIESEL ENGINE LUBRICATING SYSTEM

1·5 LITRE ENGINE

A.1

DESCRIPTION

The 1·5 litre diesel engine is a water cooled four cylinder overhead valve unit with cylinders and crankcase cast in one piece ensuring maximum rigidity and strength. Full-length water jackets are provided so that even cylinder temperatures and high resistance to wear are assured.

The cylinder head carries the valve rocker gear, fuel injectors and heater plugs. The valves are set vertically in the cylinder head and are operated by the camshaft through the tappets, pushrods and rockers. Large circulation passages are cut in the head ensuring adequate cooling; the combustion chambers are the Ricardo Comet V type. Both the air inlet and exhaust manifolds are carried on the left hand side of the head and on the automotive industrial version provision is made for connecting a vehicle heater.

The forged steel counterbalanced crankshaft which drives the dynamo and water pump/s is supported by three steel shell type bearings lined with lead-copper. Crankshaft end float is taken up by steel-backed white metal thrust washers fitted on each side of the centre main bearing. The connecting rod big end and small end bearings are renewable and like the main bearings the big end bearings are of the steel shell type. The big ends are diagonally split to permit the pistons and connecting rods to be withdrawn upwards through the cylinder bores.

Aluminium pistons of the solid skirt type with three compression rings and two oil control rings are fitted, the piston crowns being specially shaped to match the characteristics of the combustion chambers. The top compression ring is chromium plated, while the peripheries of the other two are tapered to assist bedding in.

The camshaft which drives the eccentric rotor type oil pump, the fuel lift pump and the distributor type fuel injection pump is supported by three white metal bearings. Special cam profiles are designed to prevent surge and to give quiet operation of the valve gear. The timing chain is of the double-roller type and a slipper-type, oil-fed timing chain tensioner is fitted.

The cooling system is the closed circuit thermostatically controlled fresh water type using a conventional circulating pump and, for the Captain marine engine either a Heat exchanger or Keel cooler unit. For most Captain applications a positive displacement pump is also fitted to pump raw, or sea water through the gearbox oil cooler (where fitted) the exhaust manifold and pipe. (See Cooling Systems Section C.)

Standard electrical equipment comprises a dynamo and conventional regulator and a solenoid operated pre-engaged starter motor.

Transmission include, where specified, a four speed forward and reverse speed gearbox for the industrial engine, and for the Captain the choice of either a PRM100 or Borg Warner hydraulically operated forward/reverse gearbox or a mechanically operated epicyclic gearbox.

A.2

LUBRICATION

All bearing surfaces and moving parts are pressure lubricated by an eccentric rotor non-draining type oil pump, located on the left hand, or port, side of the crankcase and gear driven from the camshaft. Oil is drawn through a gauze strainer mounted inside the sump and forced through drilled passages in the crankcase to the fuel injection pump drive gear lubricator and the oil pump driving spindle via a pencil type filter gauze; also to a non-adjustable, plunger type, release valve, and on through a drilling across the rear of the crankcase and a horizontal feed gallery in the starboard side of the crankcase to the external full-flow type oil filter.

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

A.3

RUNNING INSTRUCTIONS

Starting the Engine

1. Ensure that the gearbox, where fitted, is in neutral, the seacock, where fitted, is open (Marine engine installation only) and that the engine stop control is fully home.
2. Turn on the fuel supply and set the throttle control in the fully open position.
3. Turn the key operated switch on the instrument panel to the fully clockwise position to actuate the starter motor. Immediately the engine fires release the key and close the throttle control. If the engine fails to start within five or six seconds, release the key and allow a short interval between each attempt to start. This is to ensure that the engine is stationary thereby preventing possible damage to the starter motor pinion or flywheel ring gear.
4. If the engine has been idle for any length of time, or in cold conditions, switch on the heater plugs for a few seconds, turning the key operated switch clockwise to the third (heater) position, before attempting to start the engine. In extreme cold conditions the length of time the plugs are switched on should be 15 to 30 seconds. Failure of an engine to start, or erratic engine acceleration, may be the result of air in the fuel system. This can be caused by allowing the fuel tank to become empty, by a leaking joint, or by dismantling any part of the fuel system. If this condition is suspected, and after every occasion when part of the fuel system has been dismantled air must be removed from the system by bleeding as described in Section D.
5. Once the engine starts, check that the dynamo, or alternator is charging satisfactorily. The ammeter reading will drop considerably after a short space of time if the battery is in a good state of charge. Should the ammeter show a heavy discharge reading and there is virtually no electrical equipment in use, immediate attention should be given to the electrical system. Refer to the wiring diagram in Section E.
6. Check the engine oil pressure; this should be indicated on the oil pressure gauge within 30 seconds of the engine starting. Extensive flickering of the gauge needle when the engine is warm would indicate a faulty gauge which should be checked by substitution.

A low reading on the gauge could be caused by a choked oil filter element or oil pump strainer, a faulty oil pressure release valve or a defective oil pump, provided there is sufficient oil in the sump and the engine bearings are not suspect. See General Data for oil pressures.

For the marine engine fitted with a seawater pump, check that there is a flow of water from the exhaust pipe. If this is not evident a choked seacock is indicated and immediate action should be taken to remove the obstruction. Where the exhaust manifold includes a 'tell tale' cock a circulation check may be made before examining the seacock.

Running-in Speed

The treatment given to a new engine during the first 25 to 50 running hours will have an important bearing on its subsequent life. During this period the speed must be restricted so that racing of the engine does not occur. The speed must be increased gradually and progressively until at least 50 running hours have been completed. Labouring the engine must also be avoided, and 'warming up' should be done at a fairly fast speed, approximately 1500 rev/min, so that the engine attains its correct working temperature in the shortest possible time. Allowing the engine to run slowly when in a cold condition leads to excessive cylinder wear.

Stopping the Engine

To stop the engine pull out the 'stop' control to its fullest extent. This will stop the engine by cutting off the supply of fuel to the injectors. Turn the key operated master switch anti-clockwise to the 'off' position.

On a marine installation, before leaving the boat turn off the seacock.

WARNING: Failure to turn off the seacock has frequently led to a boat filling with water and ultimately sinking, due to a leak in the cooling system.

A.4

MAINTENANCE ATTENTIONS

The following maintenance instructions have been prepared in order to show in a clearly arranged and concise manner the attentions required to maintain the engine in an efficient condition under normal conditions of work and climate, and are based on the assumption that the lubricants used are in accordance with the recommendations given under 'Recommended Lubricants'. Extreme climatic or operating conditions may, however, necessitate alteration to the intervals at which some of the attentions are given, and it must, therefore, be left to the discretion of the operator to vary these intervals to suit local conditions.

Daily Service

Before starting the engine check the level of coolant in the radiator (industrial installations only) Heat exchanger or Keel cooler header tank (marine installations only) and top up, if necessary. Where an anti-freeze solution is used care should be taken to ensure the correct consistency is maintained.

Remove the engine oil level indicator from the engine crankcase and check the level. Maintain the level at the MAX mark on the indicator and never allow it to fall below the MIN mark. Use one of the recommended lubricants when topping up.

Check the fuel level.

On marine engines fitted with a sea/river water pump give the greaser half a turn; also the stern tube greasers, and if necessary replenish with grease.

Initial Servicing – after 25 hours running

During the early life of the engine the oil picks up numerous minute particles of foreign matter, which it is impossible to eliminate during the course of manufacture. The working parts of the engine also settle down, with the result that certain clearances and adjustments will require checking and if necessary re-setting.

The following maintenance instructions should be carried out as soon as the engine has completed 25 hours running, and it will be appreciated that this attention, given during the critical period in the life of the engine will make all the difference to its subsequent life and performance.

1. Drain the engine of oil and refill with one of the recommended lubricants.
   Renew the oil filter element (See sub-section A.7).
2. Where a gearbox is fitted, drain the oil and refill with one of the recommended lubricants. For marine engines using a Borg Warner gearbox, clean the screen before refilling the box with fluid and where a separate reduction gear is fitted drain the oil and refill. Gearbox servicing, after the initial draining and refilling, should be in accordance with the Manufacturer's instructions.
3. Renew the main fuel filter element as described in Section D.
4. Remove the cap screw from the domed cover of the fuel lift pump (located on the left hand or port side of the engine).
   Lift off the cover and, remove the cork gasket and filter gauze. Wash the gauze in petrol (gasoline) with a stiff brush, renew the cork gasket if damaged and re-assemble.
5. Withdraw the driving gear lubricator and filter gauze from the port side of the crankcase and wash in petrol. Use a stiff brush to clean the gauze and blow out the lubricator with compressed air. Check that the copper joint washers are serviceable and re-assemble. After running the engine, check for oil leaks.
6. Check, and, if necessary, tighten the manifold stud nuts with a torque spanner set to 15 lbf.ft (2·1 kgf.m).
7. *Disconnect the breather pipe from the hose on the valve rocker cover, remove the two cover nuts, cap washers and sealing bushes and lift off the cover, taking care not to damage the cork gasket. Check, and if necessary tighten the cylinder head nuts with a torque spanner set to 71 lbf.ft (9·7 kgf.m).
8. Check, and if necessary re-set the valve rocker clearances (See General Data for clearance and sub-section A.12 for procedure).
9. Re-set the torque spanner to 25 lbf.ft (3·4 kgf.m) and if necessary tighten the rocker shaft bracket nuts. Replace the rocker cover.
10. Check the fan and dynamo driving belt for correct tension. It should be possible to deflect the belt $\frac{1}{2}$ in. (12·7 mm) at the centre of its longest run by normal thumb pressure. Re-adjust if necessary as described in Section E.
11. Remove the vent plugs from the battery cells and examine the level of the electrolyte in each cell. If necessary add sufficient distilled water to bring the level just above the top of the separators. Do not overfill and never use tap water. Wipe away all dirt and moisture from the top of the battery.
    WARNING: Never use a naked light when examining the cells.
12. Remove the leads from the heater plugs and unscrew each plug from the cylinder head. Insert a twist drill of $^{11}/_{64}$ in. (4·37 mm) diameter into each hole, in turn, and turn the drill by hand to remove the carbon build up. Withdraw the drill and remove any particles of carbon from the conical seating in the cylinder head. Refit the heater plugs and leads.

**On the industrial engine the breather pipe is connected to the crankcase.*

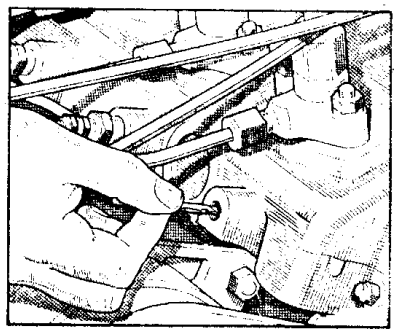


Fig.4 - Removing carbon from heater plug seating

Every 50 hours duty – or weekly

1. Check the level of the battery electrolyte.
2. Oil all the controls and fairleads. Check all water pipe and fuel pipe connections for leaks and tighten clips, union nuts etc as necessary.
3. On marine installations (where applicable) clean the seacock and filter.
4. Give the external reduction gear (where fitted) coupling flange greaser one turn and when necessary replenish with one of the recommended greases.
5. Give the sea/river water pump and stern tube half a turn and when necessary replenish with one of the recommended greases. Do not overgrease.

Every 200 hours

Repeat the 25 hours and 50 hours procedures and include the following:—

1. Remove the air cleaner and withdraw the element. Wash the element in paraffin (kerosene) and allow it to dry. Wet the element with engine oil and allow all surplus oil to drain.

Every 400 hours

Repeat the 200 hours service and include lubrication of the dynamo commutator (Captain and 1·5) bearing by injecting two or three drops of one of the recommended oils into the central hole in the commutator bearing plate.

Every 800 hours

Repeat the above and also fit a new oil filler cap. Since the oil filler cap incorporates an air filter which cannot be cleansed, it is advisable to renew the cap at the interval

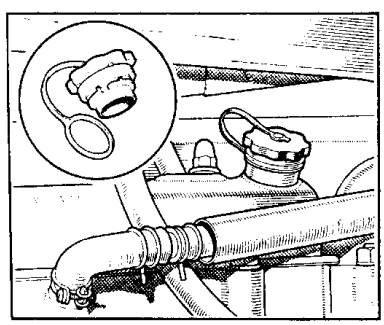


Fig.5 - Oil filler cap and filter

recommended. On marine engines fitted with a heat exchanger also include the following:—

1. Dismantle, clean and re-assemble the Heat exchanger.
2. Remove the plug from the fresh water pump body (all engines) and add a few drops of one of the recommended oils. Replace the plug.

MAINTENANCE AND OVERHAUL PROCEDURES

A.5

REMOVING AND REFITTING THE ENGINE

In order to remove the engine assembly from the installation for major overhaul it will first be necessary to remove or disconnect all external units and assemblies, guards etc; peculiar to the particular installation. Suitable lifting slings and pulleys will also be necessary to lift the engine unit from its mounting. With the external items disconnected or removed continue as follows:—

1. Drain the engine oil.
2. Drain the cooling system (Section C). If an anti-freeze solution has been added to the water, drain the contents into a suitable container. For information on the correct amount of anti-freeze required for different degrees of frost refer to Section C.
3. Disconnect the relevant water pipes and on industrial engines remove, as applicable, the radiator cowl, radiator and oil cooler. For marine engines remove the Heat exchanger or Keel cooler header tank.
4. Disconnect the H.T. cables from the battery and the starter motor solenoid.
5. Disconnect the L.T. cables from the starter motor solenoid, the cables to the dynamo or alternator, the cable from the 4-position switch to the heater plugs and the cable or cables from the 4-position switch to any auxiliaries mounted on the engine.
6. Uncouple and remove the oil gauge pipe. Where an oil pressure switch is fitted, disconnect the lead from the generator relay (alternator fitting only).
7. Disconnect the throttle and stop control cables from the respective levers on the fuel injection pump and
8. Disconnect the fuel supply pipe from the fuel lift pump and the return pipe from the main fuel filter. If necessary disconnect both pipes from the fuel tank and remove.
9. Uncouple the exhaust pipe from the exhaust manifold flange.
10. Disconnect the drive coupling, or alternatively, where a gearbox is fitted support the gearbox and remove the bolts securing the gearbox bell housing or adaptor plate to the engine back plate or flywheel housing.
11. Remove the engine mounting bolts.
12. Using the lifting pulleys and sling support the engine beneath the mounting brackets at the front and rear of the engine. Finally before lifting the engine clear of the installation check that all relevant pipes and cables are disconnected.

    NOTE: Where the installation includes a gearbox and the engine is being removed without the box, there must be sufficient clearance to withdraw the engine forward on the level until the gearbox input shaft is clear of the engine damping plate or gearbox primary shaft clear of the clutch driven plate.

To refit the engine, reverse the foregoing procedure, and when complete bleed the fuel system, as described in Section D.

A.6

SUMP

Removing and Replacing

1. While the engine is warm unscrew the drain plug on the side of the sump and allow the engine oil to drain into a suitable container (industrial only).
   For the marine engine operate the hand pump mounted at the rear of the exhaust manifold, first ensuring that the two-way cock at the base of the pump is set to the forward position. After draining, disconnect the pipe from the sump to the pump. Remove the oil level dipstick.
2. Support the sump and remove the set bolts securing it to the crankcase. Detach the sump and gasket from the engine. If the engine is removed from the installation it may be convenient to remove the bolts while the engine is suspended, providing the unit is kept rigid. On the marine engine it may only be possible to remove the sump when the engine is removed from the installation.
3. Clean the sump thoroughly and inspect it for cracks and damage. Ensure that the joint flanges of the sump and crankcase are clean and free from scores and burrs.
4. Inspect the front and rear main bearing cap cork seals and if worn or damaged, renew.
5. Install the sump using a new gasket, and tighten the set bolts in diagonal sequence.
6. Refit the sump drain plug (industrial) or pump drain pipe (marine) and dipstick and fill the sump with one of the recommended grades of engine oil.

A.7

OIL FILTER

Dismantling and Replacing

1. Release the filter bowl by unscrewing the central bolt which secures it to the filter head, and withdraw the bowl complete with element.
2. Remove and discard the element and detach the filter bowl joint from the filter head.
3. Extract the circlip from the central securing bolt and dismantle the filter bowl components.
4. Wash all components in paraffin (kerosene) and allow to dry.
5. Reassemble the bowl components ensuring that the felt washer fitted between the pressure plate and steel washer is in good condition. Install a new element.
6. Check that the filter bowl joint washer is in good condition and fit to the filter head.
7. Refit the bowl and element assembly to the filter head, run the engine until the oil is thoroughly warm and examine the filter for leaks.

A.8

F.I.P. DRIVING GEAR LUBRICATOR AND LUBRICATOR FILTER

Removing and Replacing

The Fuel injection pump lubricator and lubricator filter are located at the rear of the crankcase on the left hand, or port side, as illustrated.

1. Unscrew the hexagons and remove both components.
2. Wash in paraffin (kerosene), blow out the lubricator with compressed air and replace, ensuring that the copper joint washers are in good condition and will make oil tight joints.

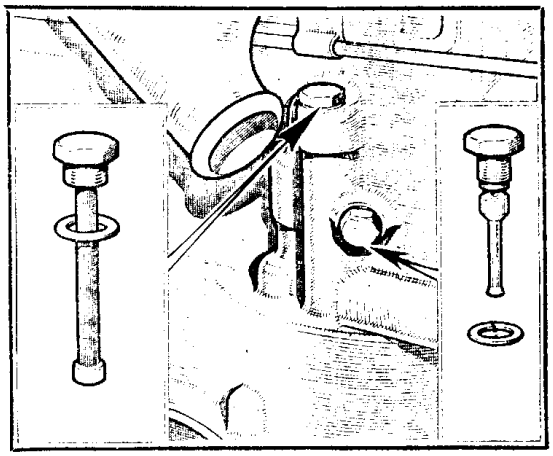


Fig.6 - Fuel injection pump driving gear lubricator and filter

A.9

OIL PRESSURE RELEASE VALVE

Removal, Inspection and Replacement

The non-adjustable oil pressure release valve is situated at the rear end of the crankcase on the left hand, or port side and is held in position by a large hexagon nut sealed by a fibre washer.

1. Remove the assembly with the oil pressure relief valve grinding-in tool 18G69.
2. Check that the spring has not lost its tension and that its free length measurement is 2·859 in. (72·628 mm).
3. Examine the valve cup for score marks or signs of wear. Renew both components as necessary.
4. Apply engineer's blue to the conical face of the valve, and test the valve seat for continuous marking. Should the seating be damaged, restore by 'lapping in' using the service tool 18G69.

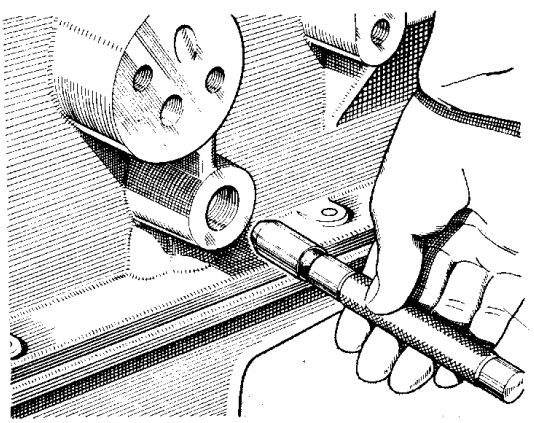


Fig.7 - Lapping the oil pressure relief valve

A.10

OIL PUMP AND STRAINER

Removing and Replacing

1. Remove the sump.
2. Unscrew and remove the three nuts with plain and spring washers securing the pump to the crankcase and withdraw the pump. It it is necessary to withdraw the oil pump driving spindle the fuel injection pump and the fuel injection pump driving spindle must be removed. (See sub-section A21 and Section D.)
3. Remove the pump to crankcase joint washer.
4. When replacing the pump fit a new pump to crankcase joint washer.

Dismantling

1. Remove the three setscrews and spring washers which secure the strainer to the oil pump cover.
2. Remove the two screws securing the oil pump cover, and detach the cover taking care not to lose or misplace the locating dowels.
3. Extract the shaft and rotor assembly.
4. Thoroughly wash all components in paraffin (kerosene).

Inspection

1. Install the rotors in the pump body, place a straight-edge across the joint face of the pump body, and measure the clearance between the top face of the rotors and the underside of the straight edge. The clearance should not exceed 0·005 in. (0·127 mm), but if it does careful lapping of the body face may effect an improvement.
2. Check the diametrical clearance between the outer rotor and the rotor pocket in the pump body. If this exceeds 0·010 in. (0·254 mm) and cannot be remedied by the renewal of either the pump body or the rotors, then the pump assembly should be renewed.
3. Measure the clearance between the rotor lobes; if this exceeds 0·006 in. (0·152 mm) the rotors must be renewed.

Reassembling

1. Lubricate the shaft and rotor assembly and ensure that the outer rotor is installed in the body with its chamfered end at the driving end of the rotor pocket in the pump body.
2. Ensure the two dowels are in position and refit the pump cover.
3. Refit the strainer.
4. Check the pump shaft for freedom of movement.

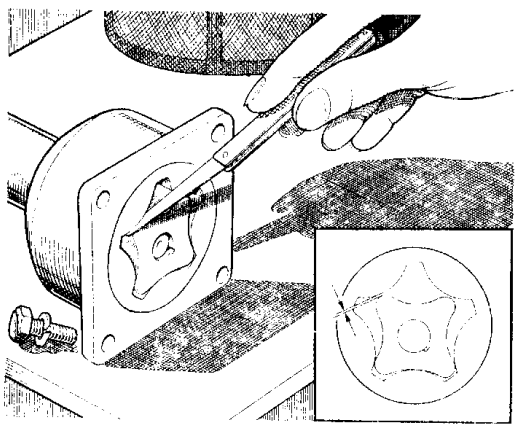


Fig.8 - Checking the oil pump rotor clearance (1st position)

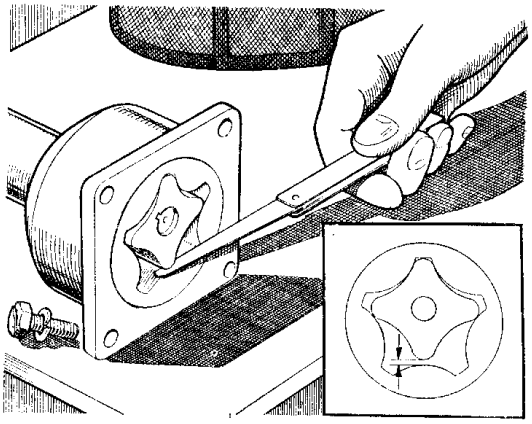


Fig.9 - Checking the oil pump rotor clearance (2nd position)

A.11

ROCKER SHAFT ASSEMBLY

Removing and Replacing

1. Drain the cooling system.
2. Disconnect the breather pipe from the hose on the valve rocker cover (captain).
3. Remove the rocker cover taking care not to damage the cork gasket.
4. Slacken the cylinder head nuts, a turn at a time, in the sequence shown in Fig. 10 until the load has been released. It will be found more convenient to use the Cylinder head nut spanner 18G694 with Torque wrench 18G372 to turn the three nuts located below the rocker shaft, numbers 1, 7 and 8 on the diagram.

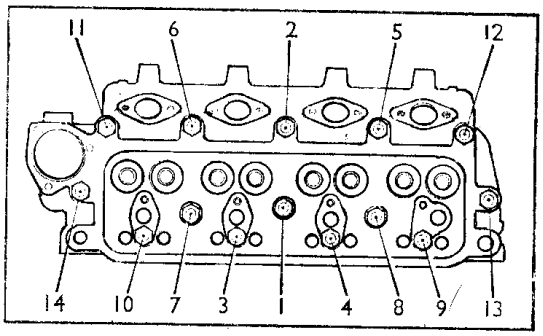


Fig.10 - Cylinder head nut slackening and tightening sequence

5. Remove the rocker shaft bracket nuts and washers and lift off the shaft assembly.
6. Refit the rocker shaft assembly to the cylinder head ensuring all rocker adjusting screws are fully slackened and the bracket nuts only finger tight.
7. Using the cylinder head spanner and torque wrench tighten the cylinder head nuts in the same sequence, to a torque of 71 lbf.ft (9·7 kgf.m). Reset the torque spanner to 25 lbf.ft (3·4 kgf.m) and tighten the bracket nuts.
8. Adjust the valve to rocker clearance (sub-section A.12) fit a new cover joint if the existing one is damaged and replace the rocker cover.

9. Reconnect the breather pipe (Captain), re-fill the cooling system, run the engine and check the cover joint for oil leaks.
   NOTE: Since four of the bracket nuts also serve to assist in retaining the cylinder head, the need for slackening **all** the head nuts is necessary to avoid the possibility of distortion. It is also necessary to drain the cooling system to prevent any water leaking into the cylinder and sump.

Dismantling and Reassembling

1. Remove the rocker shaft locating screw from the rocker shaft rear mounting bracket.
2. Withdraw the split pins, plain and spring washers from each end of the shaft, and slide off the rockers, brackets and spacing spring.
3. Unscrew the plug from the front end of the shaft; the plug in the rear end of the shaft is a drive fit and should not normally be removed.
4. Wash all components thoroughly with paraffin (kerosene), dry off and then clear the oilway in the rear rocker bracket, rocker shaft and rockers with compressed air.
5. Fit the rear rocker bracket to the shaft and position it with the locating screw.
6. Fit the remaining components to the shaft, positioned as shown in Fig. 11.

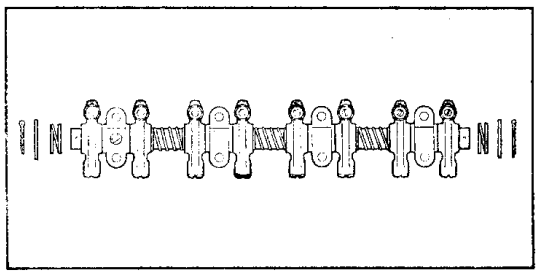


Fig.11 - Rocker shaft assembly

Fitting new bushes

If the rocker bushes are badly worn and renewal is necessary, it is advisable to use the special Valve rocker bush remover and replacer 18G226.

1. Place the rocker on the anvil and drive out the worn bush (Fig. 12).

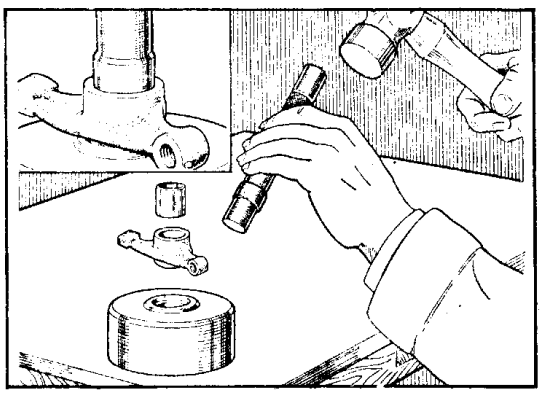


Fig.12 - Removing and replacing a valve rocker bush

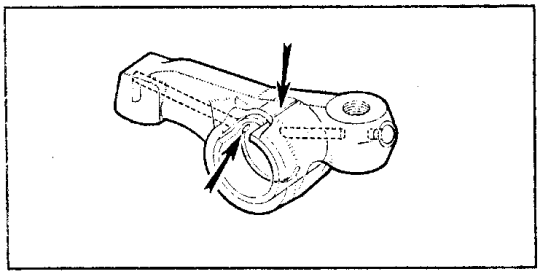


Fig.13 - Correct position of rocker bush when fitted

2. Position a new bush so that when pressed in the rocker the butt joint will be at the top and the oil groove at the bottom as shown in Fig. 13. Drill oil holes in the bush to coincide with the oilways in the rockers.
3. Place the bush on the service tool drift and gently drive the bush into position in the rocker.
4. Burnish ream the bush to the dimensions given in General Data.

A.12

VALVE ROCKER CLEARANCE

The clearance between the ends of the valve stems and the valve rockers should be checked when the engine is cold by means of feeler gauges in the following way:—

1. Crank the engine until No. 8 valve is fully open and check the clearance of No. 1 valve which will now be fully closed.
2. Hold the adjusting screw with a screwdriver and slacken the locknut (Fig. 14).

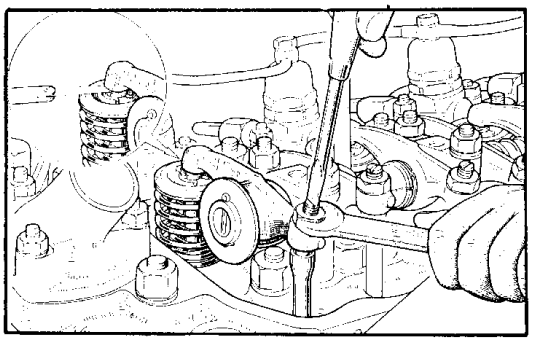


Fig.14 - Adjusting the valve rocker clearance

3. Insert a 0·015 in. (0·381 mm) feeler gauge as shown and rotate the adjusting screw until the clearance between the valve stem and rocker is correct. Hold the adjusting screw against rotation, lock it in position with the locknut and then re-check the clearance.
4. Check the remaining clearances by reference to the following table:—
   No. 1 valve with No. 8 valve fully open
   No. 3 valve with No. 6 valve fully open
   No. 5 valve with No. 4 valve fully open
   No. 2 valve with No. 7 valve fully open
   No. 8 valve with No. 1 valve fully open
   No. 6 valve with No. 3 valve fully open
   No. 4 valve with No. 5 valve fully open
   No. 7 valve with No. 2 valve fully open
   NOTE: The clearances should be checked at the intervals recommended.

A.13

CYLINDER HEAD

Removing and Replacing

1. Drain the cooling system.
2. Remove the canopy and radiator cowl, where applicable, and disconnect the hose from the water outlet elbow and the by-pass hose (where fitted) from the thermostat housing (industrial). Disconnect the sea water and fresh water pipes from the Heat exchanger or keel cooler header tank (Captain). The header tank is integral with the exhaust manifold.
3. Remove the Heat exchanger (where applicable).
4. Remove the air cleaner, the breather pipe (Captain) and the rocker cover and gasket.
5. Remove the valve rocker shaft assembly (sub-section A.11) and withdraw the pushrods. As each pushrod is withdrawn it should be labelled and numbered to ensure replacement in its original position.
6. Remove the bolts securing the exhaust outlet chamber to the exhaust manifold (Captain) and where a Heat exchanger is used disconnect the water pipe.
7. Disconnect the exhaust pipe from the manifold (industrial).
8. Remove the manifold stud nuts and withdraw both the induction and exhaust manifolds.
9. Disconnect the high pressure pipes from the fuel injection pump and the injectors and remove complete with clamps and damper bushes. It is advisable to seal off the injection pump outlets with sealing caps 18G216 to prevent the ingress of foreign matter.
10. Disconnect the fuel pipes from the main fuel filter and remove the filter and bracket.
11. Remove the injectors from the cylinder head (Section D).
12. Remove the cylinder head nuts, and lift the head with a direct pull to withdraw it evenly up the studs. On no account should a screwdriver or similar tool be used as a wedge between the cylinder head and the cylinder block.
13. Remove the cylinder head gasket.

NOTES: 1. 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.

2. The combustion chamber inserts are a loose fit in the cylinder head. They must be refitted in their original positions because the cylinder head face is machined with the inserts installed.

Refitting

1. Check the condition of the cylinder head gasket. If there is any doubt about its serviceability, fit a new one.
2. Remove any excess carbon from the faces of the cylinder block and head, with a blunt soft metal scraper.
3. If a new gasket is being fitted, check the FRONT and TOP markings on one side of the gasket and fit accordingly.
4. Refit the cylinder head and valve rocker gear and tighten the cylinder head nuts and rocker bracket nuts to the torque figures given in General Data and sub-section A.11.
5. Adjust the valve rocker clearances, refit the rocker cover and include a new cover joint if the one in use is defective.
6. Re-assemble the remaining components, and bleed the fuel system (Section D).
7. Start the engine and allow it to run at a fast idling speed until it is thoroughly warm. Check for oil leaks, remove the rocker cover, re-tighten the cylinder head nuts, re-check the valve rocker clearances and adjust as necessary. Replace the rocker cover.

A.14

VALVES

Removing and Replacing

1. Remove the cylinder head as described in A.13.
2. Detach the spring clips from the valve spring collar retainers.
3. Using the Valve spring compressor 18G45, compress, in turn, each set of valve springs and remove the collar retainers. Release the compressor and remove the collars, valve springs and oil seal from each valve stem. Withdraw the valves, check that they are numbered, and place to one side in order of removal.
4. Remove all carbon deposits from the valves, valve ports, valve guides and cylinder head. Thoroughy clean the cylinder head and ensure that all traces of carbon dust are removed. The carbon can be removed from the guides by dipping the valve stems in petrol (gasoline) or paraffin (kerosene) and moving it up and down the guide until it is free. If excessive wear is evident renew the guides as described in sub-section A.17.
5. Inspect the valve faces and seats, and recondition as necessary (sub-section A.15).
6. Check the length and tension of each valve spring against the figures given in General Data, and renew as necessary.
7. Place the valves in their respective seats in the cylinder head, fit the bottom collars and then fit new oil seals to the valve stems. Re-assemble the remaining components, as shown in Fig. 15.

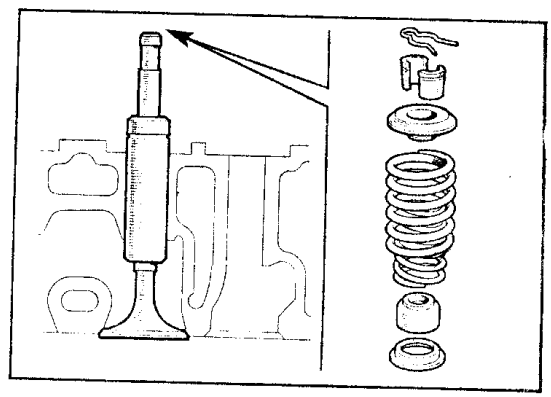


Fig.15 - Assembly of valve and springs

A.15

VALVE GRINDING

The valve faces and seats, if only slightly pitted, can be reconditioned by grinding in with abrasive compound.

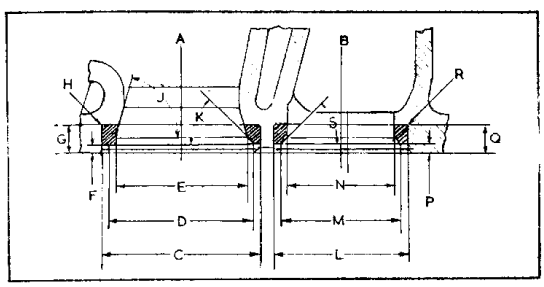
1. Smear the valve face lightly with grinding compound and lap the valve on to its seat using the Valve grinding-in tool 18G29 and Suction pad 18G29A.
2. When a dull even matt surface, free from pits, is produced on both the valve face and seat, clean away all traces of compound, and check the valve seating 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. If the valve face and seat cannot be corrected by lapping, the valve should be refaced to an angle of 45 degrees on a valve grinding machine and the valve seats recut.

Tools required for valve seat recutting are as listed below :—

INLET
Valve seat cutter and pilot handle 18G27
Valve seat glaze breaker 18G25A
Valve seat narrowing cutter (bottom) 18G25C
Valve seat narrowing cutter (top) 18G25B
Valve seat finishing cutter 18G25

EXHAUST
Valve seat cutter pilot 18G174D
Valve seat glaze breaker 18G167A
Valve seat narrowing cutter (bottom) 18G167C
Valve seat narrowing cutter (top) 18G167B
Valve seat finishing cutter 18G167

3. 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.
4. 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.
5. Check that the valve head stand-down is within the limits 0·018 in. (0·457 mm) to 0·038in. (0·965 mm). If stand-down is excessive, fit new valves as necessary, but where this does not reduce the stand-down to below 0·038 in. machine the cylinder head and fit new inserts. Inserts should also be fitted if normal refacing will not restore the seats. For the cylinder head machining dimensions refer to Fig. 16.



Inlet (A)

C. 1.4965 to 1.4975 in. (38.028 to 38.053 mm)
D. 1.375 to 1.380 in. 34.927 to 35.05 mm)
E. 1.250 in. (31.75 mm)
F. .085 to .090 in. (2.159 to 2.286 mm)
G. .273 to .276 in. (6.936 to 7.012 mm)
H. Max. radius .015 in. (.381 mm)
J. 75°
K. 45°

Exhaust (B)

L. 1.2775 to 1.2785 in. (32.463 to 32.489 mm)
M. 1.156 to 1.161 in. (29.362 to 29.485 mm)
N. 1.031 in. (26.187 mm)
P. .085 to .090 in. (2.159 to 2.286 mm)
Q. .273 to .276 in. (6.936 to 7.012 mm)
R. Max.radius .015 in. (.381 mm)
S. 45°

Fig.16 - Cylinder head machining dimensions

A.16
VALVE SEAT INSERTS

To fit an insert, first machine the seating in the cylinder head to the dimensions given, and then proceed :—
1. Press a new insert into the cylinder head.
2. Check the area of contact between the new seat and its valve with marking blue, and if necessary lap the valve on to its seat.

A.17
VALVE GUIDES
Removing and Replacing
1. Drive the valve guides out through the upper face of the cylinder head.
2. Fit new valve guides, to the dimensions given in General Data, through the ports and drive them into the position shown in Fig. 17.

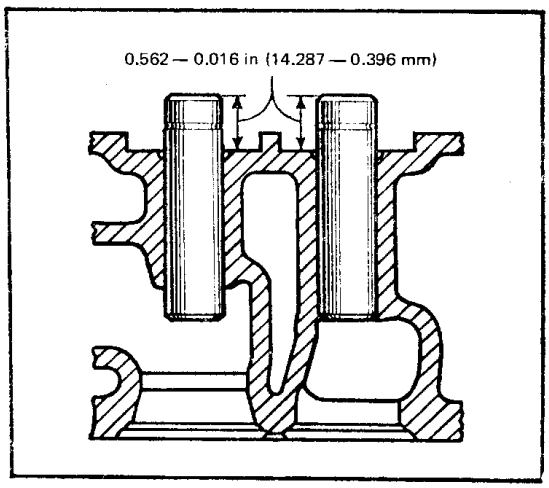


Fig.17 - Valve guides - fitted position

A.18
TIMING GEAR CASE COVER
Removing and Replacing

In the event of an oil leak from the timing gear case cover due to a faulty seal or joint, remove and replace the cover in the following way :—
1. Drain the cooling system and remove the radiator and oil cooler (industrial only).
2. Slacken the alternator mounting bolts and remove the fan belt.
3. Remove the fan blades (industrial only).
4. Remove the crankshaft nut using Starting nut spanner 18G98A, and withdraw the crankshaft pulley using Crankshaft gear and pulley remover 18G2.
5. Unscrew and remove the screws securing the timing cover to the front plate and withdraw the cover taking care not to damage the joint. For safe keeping remove the oil thrower from the end of the crankshaft.
6. If the oil seal is defective use the Bearing and oil seal replacer 18G134 and Oil seal replacer adaptor 18G134 BD to renew the seal.
7. If the joint is broken or defective remove all traces of the joint from the cover and front plate and fit a new joint.
8. Replace the oil thrower on the crankshaft and refit the cover, with the securing screws finger tight.
9. Centralise the cover with the crankshaft using the Engine front cover centraliser 18G1046, and tighten the securing screws.
10. Refit the crankshaft pulley and fan belt, and for industrial engines refit the fan blades, radiator and oil cooler. Refill the radiator.

A.19

TIMING CHAIN, CHAIN WHEELS AND TENSIONER

Removing and Replacing

1. Remove the timing gear case cover as described in A.18.
2. Crank the engine until the timing marks on the two chain wheels are opposite one another as shown. This will permit re-assembly without the necessity to rotate the crankshaft or the camshaft.

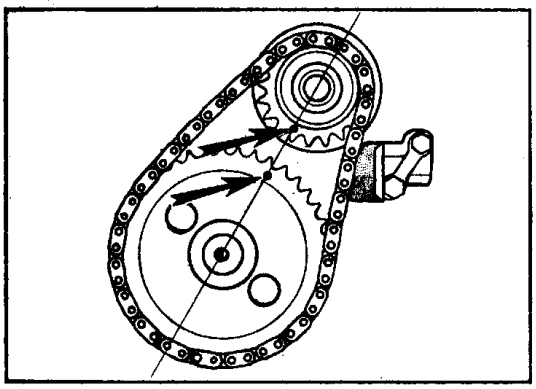


Fig.18 - Valve timing marks

3. Remove the camshaft nut using the starting nut spanner.
4. Press back the locking tab and remove the plug from the base of the tensioner body. Insert a ⅛ in. Allen key to engage the tensioner cylinder and turn the key in a clockwise direction to retract the tensioner slipper into the unloaded position.
5. Draw the two chain wheels with chain off the shafts.
6. If the chain tensioner is to be overhauled or renewed, unlock and remove the two setbolts and withdraw the assembly, backplate and joint washer from the engine. Refit the chain tensioner to the engine using a new joint and lock the setbolts.
7. Ensure the half round keys in the crankshaft are in the 12 o'clock and 1 o'clock positions respectively, as seen from the front.
8. If the chain wheels have been separated in order to fit a new chain, re-assemble them in the chain with the two dimples on the chain wheels opposite one another and in line with the chain wheel centres as shown. Should the existing chain be refitted the same procedure applies.
9. Keeping the wheels in this position, push them evenly onto the shafts as far as they will go. It may be necessary to rotate the camshaft slightly to align the camshaft key with the keyway in the camshaft chain wheel.
10. Secure the camshaft chain wheel with its nut and lock washer
11. Release the chain tensioner by inserting the Allen key and turning it in a clockwise direction until the slipper head moves forward under the spring pressure against the chain. DO NOT ATTEMPT TO TURN THE KEY COUNTER CLOCKWISE OR FORCE THE SLIPPER HEAD INTO THE CHAIN BY EXTERNAL PRESSURE.

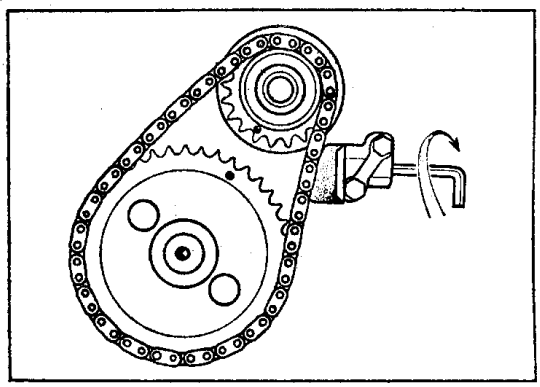


Fig.19 - Chain tensioner and Allen key

12. Refit the tensioner body plug.
13. Re-assemble the remaining components.

Dismantling and Re-assembling the tensioner

1. Withdraw the plunger and slipper assembly from the tensioner body and engage the lower end of the cylinder with the Allen key. Turn the key clockwise, holding the key and plunger securely until the cylinder and spring are released from inside the plunger.
2. Check that the bore in the tensioner body is not excessively oval. If it is greater than 0·003 in. (0·076 mm) when measured on diameters near the mouth of the bore, then the complete chain tensioner must be renewed.
3. Inspect the slipper head for wear. If it is badly worn a new slipper head and cylinder assembly must be fitted to the existing body provided the bore of the body is within the limit given above.
4. Thoroughly wash the components in clean petrol (gasoline) or paraffin (kerosene) and use an air line to clean the 0·125 in. (3·18 mm) diameter inlet hole in the spigot and the 0·040 in. (1·02 mm) outlet oil hole in the slipper.
5. Insert the spring in the plunger and place the cylinder on the other end of the spring.
6. Compress the spring until the cylinder enters the plunger bore, engaging the helical slot with the peg in the plunger.
7. Hold the assembly compressed in this position and engage the Allen key. Turn the cylinder clockwise until the end of the cylinder is below the peg and the spring is held compressed.
8. Withdraw the key and insert the plunger assembly in the body.
   After refitting the tensioner check the slipper head for freedom of movement and ensure that it does not bind on the backplate when it is moved in the body.

A.20

VALVE TIMING

To check the valve timing remove the valve rocker cover and proceed as follows:—

1. Set the valve rocker clearance of No. 1 cylinder inlet valve to 0·021 in. (0·53 mm) with the engine cold, as described in Sub-section A.12.
2. Crank the engine and determine the exact point at which No. 1 cylinder inlet valve is about to open. A clock gauge mounted on the cylinder head, with its indicator in contact with the valve spring cap, will facilitate this operation. If the valve timing is correct

No. 1 piston will be at 5° B.T.D.C. as indicated by the alignment of the notch on the crankshaft pulley with the 5° mark on the timing cover degree plate.
DO NOT OMIT TO RESET THE INLET VALVE CLEARANCE TO 0·015 in. (0·381 mm) WHEN THE TIMING CHECK HAS BEEN COMPLETED.

A.21

FUEL INJECTION PUMP DRIVING SPINDLE

Removing and Refitting

1. Remove the fuel injection pump. (Section D.)
2. Remove the countersunk screw and withdraw the fuel injection pump hub from the crankcase.
3. Withdraw the driving spindle from the crankcase, turning it clockwise to disengage from the camshaft.
4. Set No. 1 piston at 22° B.T.D.C. on its compression stroke. The engine is set in this position by means of the degree plate on the timing cover and the notch on the crankshaft pulley.
5. Refit the driving spindle with the master spline of the spindle in the 7 o'clock position. As the driving spindle engages the skew gear on the camshaft it will turn in a counterclockwise direction until the master spline is in the 5 o'clock position.
6. Refit the fuel injection pump hub, insert the Injection timing gauge 18G629 into the driving spindle, and set as shown. Eliminate slack in the drive by applying gentle clockwise pressure on the gauge before setting the timing pointer in line with the gauge marker.
7. Remove the gauge, refit the injection pump with the mark on its mounting flange aligned with the timing pointer.
8. Bleed the fuel system and if necessary adjust the governed speed, as described in Section D.

A.22

CAMSHAFT AND FRONT PLATE

Removing

The following procedures apply to both the camshaft and the front plate, but if the front plate is not to be removed instructions 9 to 11 do not apply.

1. Drain the cooling system and on the industrial versions remove the radiator grill (where applicable), radiator and oil cooler.
2. Slacken the dynamo or alternator mounting bolts and remove the fan belt. If the front plate is to be removed, withdraw the dynamo or alternator complete.
3. On the industrial versions remove the fan blades; withdraw the crankshaft pulley.
4. Remove the timing cover and oil thrower.
5. Remove the camshaft nut, using the Starting nut spanner 18G98A.
6. Position the timing marks as shown in Fig. 18, retract the chain tensioner slipper and draw both chain wheels, and chain off the shafts.
7. Remove the camshaft locating plate.
8. Remove the chain tensioner.
9. On the marine version support the engine with a sling and suitable lifting pulleys and raise the engine to relieve the load on the front mountings.
10. Slacken and remove the front rubber mounting bolts or setscrews and remove the front support brackets.
11. Remove the bolts securing the front plate to the crankcase and withdraw the plate from the crankcase.
12. Remove the valve rocker cover, slacken the cylinder head nuts in correct sequence, remove the bracket nuts and the rocker shaft assembly. Withdraw the push rods.
13. Remove the injection pump and hub. Withdraw the injection pump driving spindle.
14. Remove the fuel lift pump.
15. Remove the cylinder side covers and lift out the tappets.
16. Remove the starter motor.
17. Drain and remove the sump.
18. Remove the oil pump and oil pump driving spindle.
19. Withdraw the camshaft.

Refitting

Reverse the above procedures and at the relevant assembly stages, include the following:—

(a) Check the camshaft end float and if outside the limits 0·003 to 0·007 in. (0·076 to 0·178 mm) renew the locating plate.
(b) Check the chain wheel alignment. The crankshaft chain wheel face should be 0·005 in. (0·127 mm) rearwards of the camshaft chain wheel face. If adjustment is necessary, add or remove shims to correct.
(c) If necessary, renew the crankshaft front oil seal.
(d) When refitting the injection pump and driving spindle ensure the master spline of the spindle is in the 5 o'clock position, with No. 1 piston set at 22° B.T.D.C. on its compression stroke, and that the timing is correct.
(e) Tighten the cylinder head nuts in correct sequence and to the correct torque.
(f) Adjust the valve rocker clearance. (A.12.)
(g) Bleed the fuel system and adjust the governed speed. (Section D.)

A.23

CAMSHAFT BEARING LINERS

Should it be necessary to renew the camshaft bearing liners it will be found more convenient to remove the engine from the installation and dismantle.

1. Withdraw the front bearing liner, using the Camshaft liner remover 18G124A (basic tool) and adaptor 18G124F, as illustrated Fig. 20.

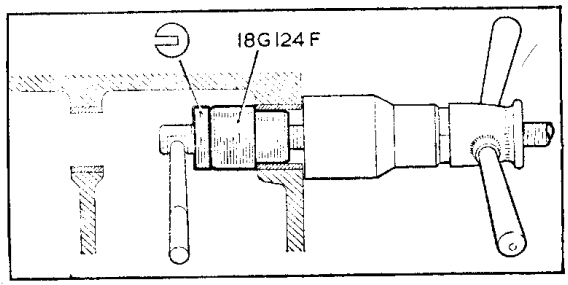


Fig.20 - Front bearing liner - withdrawal procedure

2. In a similar way withdraw the rear bearing liner using the basic tool with adaptor 18G124B as shown.

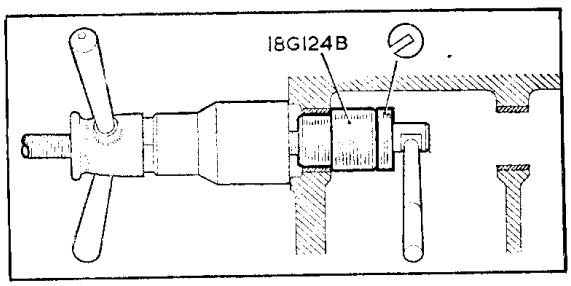


Fig.21 - Rear bearing liner - withdrawal procedure

3. Withdraw the centre bearing liner using the basic tool with adaptors 18G124C and 18G124H as shown.

4. Fit a new front bearing liner, as shown, ensuring the oil holes in the liner are aligned with those in the crankcase, Fig. 23.

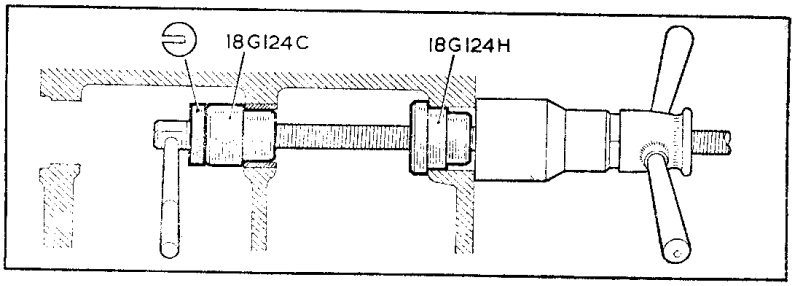


Fig.22 - Centre bearing liner - withdrawal procedure

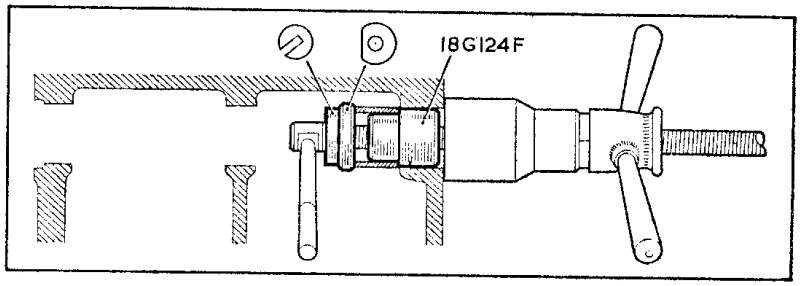


Fig.23 - Front bearing liner - fitting procedure

5. Fit a new rear bearing liner in a similar way, first ensuring the oil holes will line up with the respective oil holes in the crankcase when the bearing is fitted.

6. Fit a new centre bearing as shown, again ensuring the oil holes will line up with their respective crankcase oil holes when the bearing is fitted.

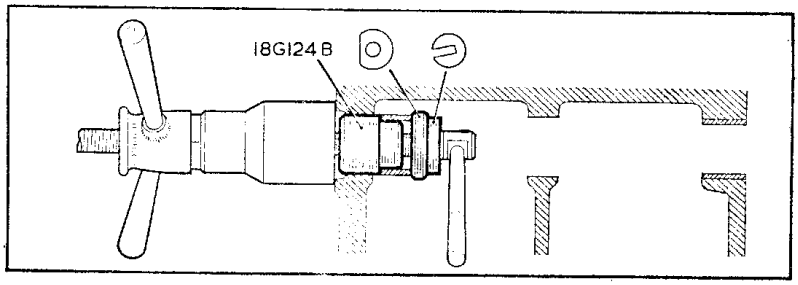


Fig.24 - Rear bearing liner - fitting procedure

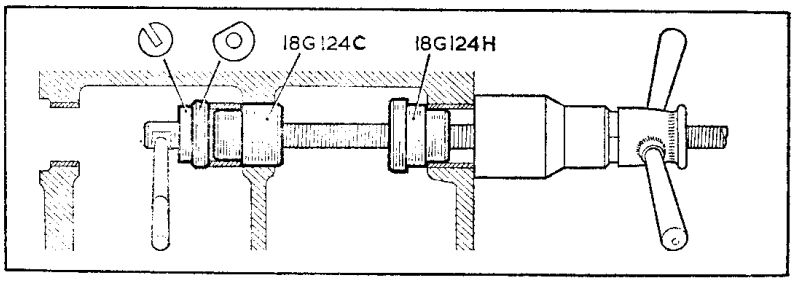


Fig.25 - Centre bearing liner - fitting procedure

7. Ream the front and rear bearing liners, using the reamer pilots and cutters illustrated, Figs. 26 and 27.
8. Ream the centre bearing in a similar way.

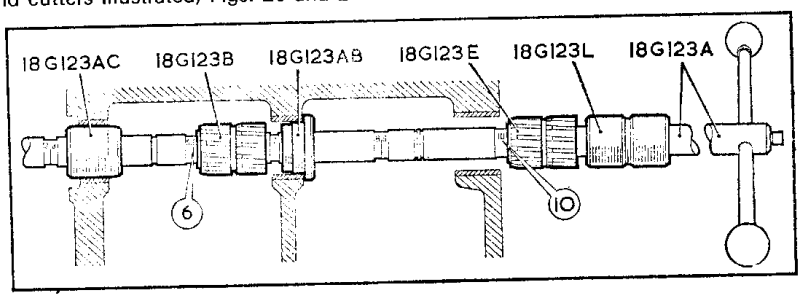


Fig.26 - Reamers for front and rear bearing liner

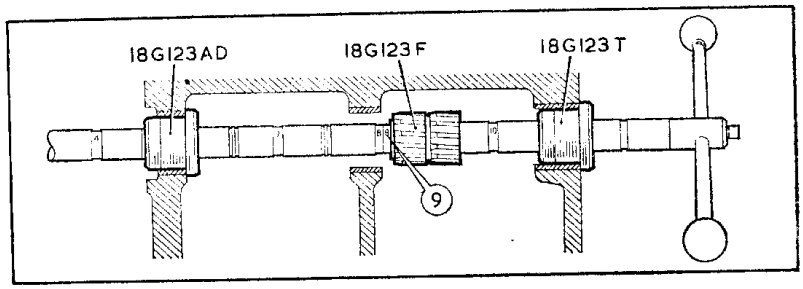


Fig.27 - Reamer for centre bearing liner

A.24

FLYWHEEL AND STARTER RING

Removing and Refitting

1. Remove the gearbox and clutch (as applicable). Alternatively uncouple and remove the generator (generating set) or any auxiliary for which the engine may be required to provide the motive power.
2. Remove the starter motor from the flywheel housing or back plate.
3. Unlock and remove the flywheel retaining nuts.
4. Mark the flywheel in relation to one of the retaining bolts.
5. Using a hard wood drift tap the flywheel off its flange through the flywheel housing or backplate, turning the flywheel through 90° after each blow.
6. If the starter ring is to be renewed drill holes through the flange of the gear and then split the gear, using a hammer and chisel, taking care not to damage the flywheel.
7. Ensure the bore of the new ring and its mating surface on the flywheel are free from burrs and are perfectly clean.
8. Heat the new ring to a temperature of 200° to 230°C (392° to 446°F); the strip of temperature indicating paint on the ring will change from pink to grey at the correct temperature.
9. Fit the starter ring with the tooth chamfer facing away from the flywheel register.
10. When the flywheel and starter ring have cooled naturally, refit the flywheel to the crankshaft. Tighten the nuts to a torque of 37 lbf.ft (5·2 kgf.m) and lock.
11. Refit the starter motor and re-assemble the transmission and driven member.

A.25

CONNECTING RODS AND PISTONS

Removing

1. Remove the cylinder head as described in A.13.
2. Disconnect and remove the starter motor from the engine.
3. Drain the oil and remove the sump.
4. Remove the oil pump and strainer assembly.
5. Remove the big end bearing caps and check that they are numbered.
6. Withdraw the connecting rod and piston upwards through the cylinder.

Dismantling and Re-assembling

Before dismantling a piston and connecting rod assembly, check that the rods are numbered to correspond with the numbers on the bearing caps.

1. Separate the piston from the connecting rod by removing the gudgeon pin circlips and pressing out the pins.
2. Remove the bearing halves from the connecting rod and cap. If the bearing is to be used again it should be marked to ensure re-assembly in its original position.
3. Remove the rings from the piston and place them in the order in which they were removed.
4. Thoroughly clean all the dismantled parts and inspect them for damage. Check that the piston is standard or oversize. If oversize it will be stamped either 0·010 in. (0·254 mm), 0·020 in. (0·508 mm), 0·030 in. (0·762 mm) or 0·040 in. (1·016 mm).
5. Check the cylinder bore for scoring and wear. If the diameter of the bore is worn in any place above the corresponding limits given below the cylinder should be rebored and the correct oversize piston fitted.

Where the cylinders have been bored out to their maximum limits new liners should be fitted.

6. Insert each piston ring into the cylinder bore and measure the piston ring gap as shown in Fig. 28.

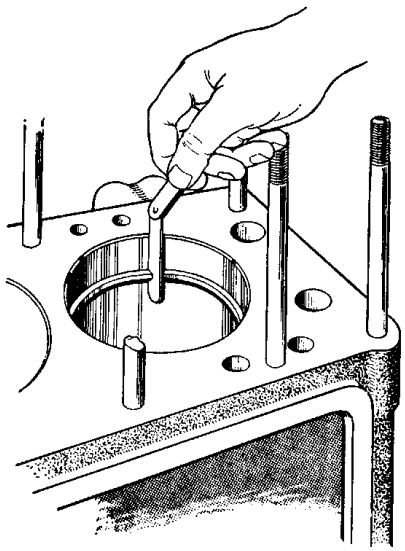


Fig.28 - Measuring a piston ring gap

Check that the top compression ring is 0·012 to 0·017 in. (0·305 mm to 0·432 mm) and the remainder 0·008 to 0·013 in. (0·203 to 0·330 mm).

7. Check the clearance of each ring in its own groove as shown. The top compression ring should be 0·0035 to 0·0055 in. (0·089 to 0·140 mm), the second and third compression rings should be 0·0025 to 0·0045 in. (0·064 to 0·114 mm) and the oil control ring 0·002 to 0·004 in. (0·051 to 0·102 mm).

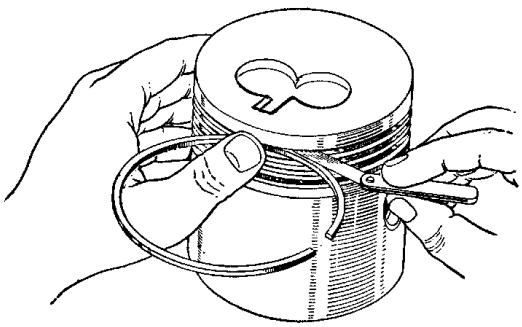


Fig.29 - Measuring a piston ring clearance

8. Replace the gudgeon pin in the small end bush and check the clearance does not exceed 0·0009 in. (0·023 mm).
9. Where the clearance does exceed the figure given, a new bush with the join on the cap side of the connecting rod as illustrated.

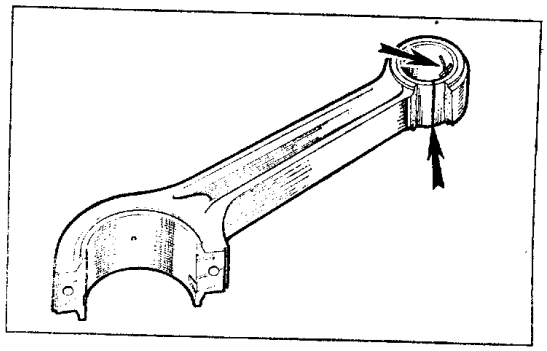


Fig.30 - Fitted position for gudgeon pin bush

10. Finish ream the bush to a diameter of 1·0002 to 1·0007 in. (25·405 to 25·418 mm).
11. Re-assemble the piston to the connecting rod, with the combustion cavity and oil jet hole in line as illustrated.

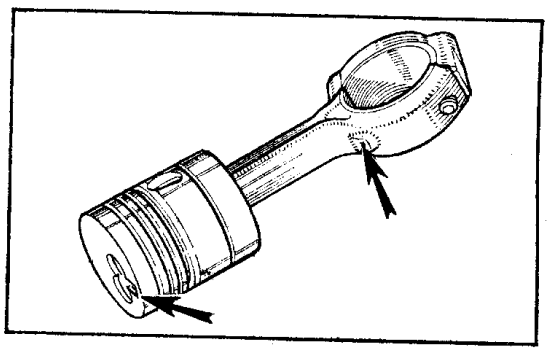


Fig.31 - Alignment of combustion cavity and oil jet hole

12. Refit the piston rings in the correct order, or renew as necessary.
13. Refit the bearing halves to the connecting rod and cap respectively, or renew as necessary.
14. Repeat the procedures for each piston and connecting rod assembly.

Refitting

1. Position the compression rings around the piston so that the gaps are equally spaced, and lubricate the piston and cylinder bore with clean engine oil.
2. Compress the rings with Piston ring compressor 18G55A, and insert the connecting rod and piston downwards into the cylinder bore with the connecting rod offset towards the camshaft, as illustrated.
3. Repeat for each piston.
4. Lubricate the crankshaft journals and the bearings, and then refit each bearing cap. Tighten the bolts to a torque of 35 lbf.ft (4·8 kgf.m).
5. Refit the oil pump and strainer assembly.
6. Fit a new sump joint and replace the sump.
7. Refit the starter motor.

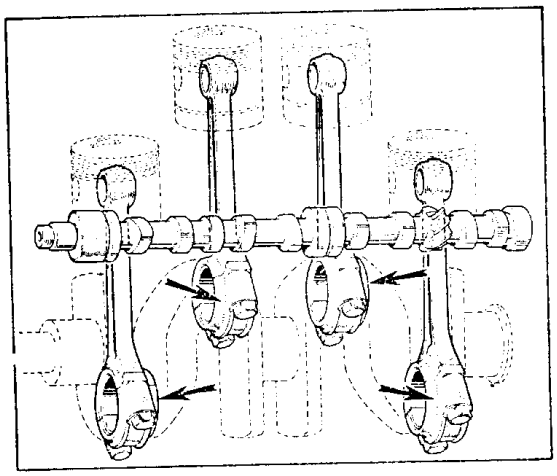


Fig.32 - Connecting rods - indicating big end fitted position

8. Refit the cylinder head and refill the sump with one of the lubricants listed under 'Recommended Lubricants'.

A.26

CRANKSHAFT AND MAIN BEARINGS

Removing

1. Remove the engine from the installation.
2. Remove the fan belt and blades (industrial) and fresh water pump pulley.
3. Remove the crankshaft nut and withdraw the crankshaft pulley.
4. Remove the timing cover.
5. Remove the oil thrower.
6. Remove the camshaft nut.
7. Retract the chain tensioner slipper and remove the chain tensioner.
8. Draw both chain wheels, and chain, off the shafts.
9. Remove the camshaft locating plate and the engine front plate.
10. Remove the starter motor.
11. Remove the clutch (as applicable) and flywheel.
12. Remove the flywheel housing or backplate (as applicable).
13. Remove the sump, oil pump and strainer assembly.
14. Remove the big end bearing caps.
15. Remove the main bearing caps using the Impulse extractor 18G284 and the Main bearing cap remover adaptor 18G284A. Alternatively, a Main bearing cap remover 18G42A with adaptors 18G42B can be used as shown.
16. Lift out the crankshaft and collect the main bearing halves and thrust washers into sets and place in re-assembly order. Clean, or wash in paraffin (kerosene) components as necessary.

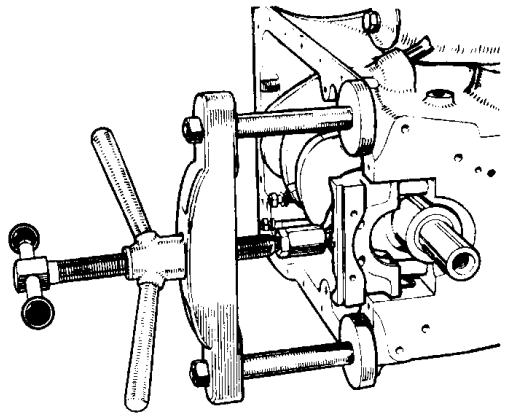


Fig.33 - Main bearing cap - withdrawal procedure

Refitting

1. Refit or fit new main bearing shells and re-assemble the crankshaft to the cylinder block and connecting rods. Note that bearings are always fitted in sets. Tighten the big end bolts to a torque of 35 lbf.ft (4·84 kgf.m) and the main bearing nuts to a torque of 75 lbf.ft (10·38 kgf.m).
2. Mount a dial gauge on the front end of the crankcase with its indicator resting on the front face of the crankshaft front main journal. Press the crankshaft as far as possible to the rear, and holding it in this position, zero the dial gauge.
   Press the crankshaft forward as far as possible and note the reading on the gauge, the difference from zero being the amount of crankshaft end float. If the end float is outside the limits 0·002 to 0·003 in. (0·05 to 0·08 mm), renew the thrust washers, fitting them by selective assembly and ensuring that the oil grooves face outwards towards the crankshaft webs.
3. Refit the oil pump and strainer assembly, and then the sump, including a new sump joint.
4. Refit the flywheel housing or backplate and then the flywheel. The flywheel should be fitted so that its T.D.C. 1·4 mark is at the top when Nos. 1 and 4 pistons are at T.D.C.
5. Refit (as applicable) the clutch and starter motor.
6. Replace the camshaft locating plate.
7. Re-assemble the chain wheels and timing chain with the timing marks correctly positioned. Release the chain tensioner slipper and check the chain wheel alignment.
8. If necessary renew the crankshaft oil seal, replace and centralise the timing cover.
9. Refit the crankshaft pulley, water pump pulley and (as applicable) fan blades.
10. Refit the engine to the installation and refill the sump with one of the recommended lubricants; also the cooling system with coolant.

A.27

CYLINDER LINERS

Should the condition of the cylinder bores be such that they cannot be cleaned up at the maximum oversize, the cylinders should be bored out to the dimensions given in General Data, and dry liners fitted.

Removing worn liners

1. Dismantle the engine and remove the cylinder head studs.
2. With the engine dismantled and the cylinder head studs removed place the cylinder block face downwards on suitable wooden supports on the bed of a press, making sure there is sufficient space between the block and the bed of the press to allow the worn liners to pass down.
3. Insert the pressing-out pilot complete with extension into the bottom of the liner and carefully press the liner from the bore.

Fitting new liners and pistons

1. Thoroughly clean the inside of the cylinder bores and the outside of the liners.
2. Stand the cylinder block upright on the bed of the press, insert the pressing-in pilot guide in the top of the liner and position the liner with its chamfered end in the top of the bore. Ensure the liner is square with the top of the block and that the ram of the press is over the centre of the pilot. Press the liner into the bore.
3. Finally, bore the cylinder liners to the standard bore size.
4. Fit new standard size pistons to the connecting rods and re-assemble the engine.

SECTION B

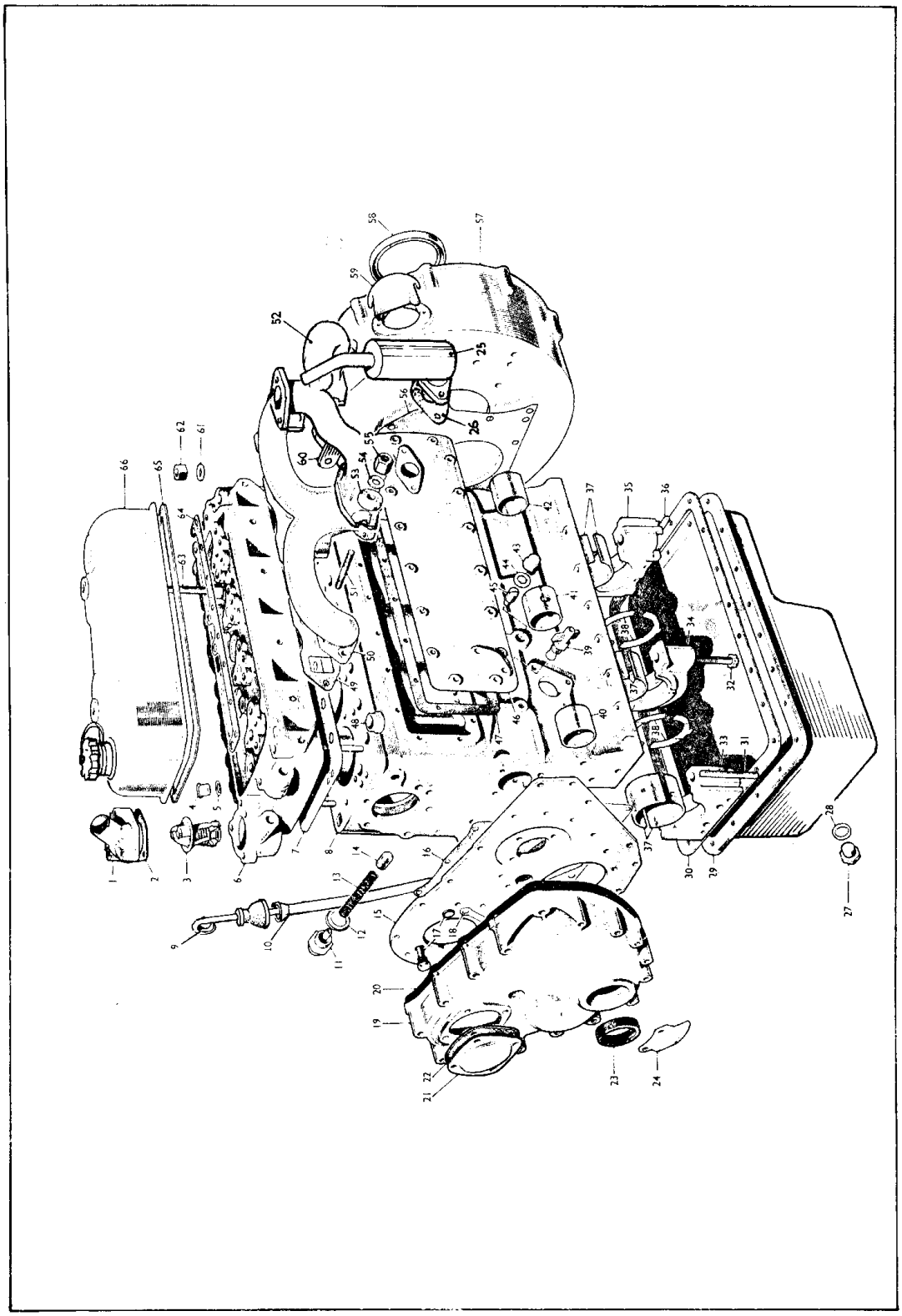


FIG. 1 - 2.5 LITRE DIESEL - BASIC ENGINE ASSEMBLY

No.	Description
1	Water outlet
2	Gasket
3	Thermostat
4	Heat shield for injector
5	Washer
6	Cylinder head
7	Gasket
8	Cylinder block
9	Oil dipstick
10	Dipstick tube
11	Plug for oil pressure relief valve
12	Washer
13	Spring
14	Oil pressure relief valve
15	Front plate
16	Gasket
17	Bolt for injection pump
18	Lock washer for front plate bolts
19	Timing cover
20	Gasket
21	Injection pump chain wheel cover
22	Gasket

No.	Description
23	Crankshaft front oil seal
24	Degree plate
25	Oil separator
26	Gasket
27	Sump drain plug
28	Washer
29	Sump
30	Gasket
31	Sealing plug for front and rear main bearing caps
32	Main bearing bolt
33	Front main bearing cap
34	Centre main bearing cap
35	Rear main bearing cap
36	Sealing strip for rear main bearing cap
37	Main bearings
38	Crankshaft thrust washers
39	Water drain tap
40	Camshaft bearing (front)
41	Camshaft bearing (centre)
42	Camshaft bearing (rear)
43	Cap nut
44	Washer

No.	Description
45	Oil pump locating screw
46	Cylinder side cover
47	Gasket
48	Combustion chamber insert
49	Manifold gasket
50	Exhaust manifold
51	Manifold stud
52	Inlet manifold
53	Yoke for manifold
54	Washer
55	Nut
56	Gasket for flywheel housing
57	Flywheel housing
58	Crankshaft rear oil seal
59	Ventilation cover for flywheel housing
60	Top gasket for flywheel housing
61	Washer
62	Cylinder head nut
63	Cylinder head nut and rocker cover stud
64	Push rod locating plate
65	Gasket
66	Rocker cover

Index to 2.5 Litre Diesel Engine Assembly

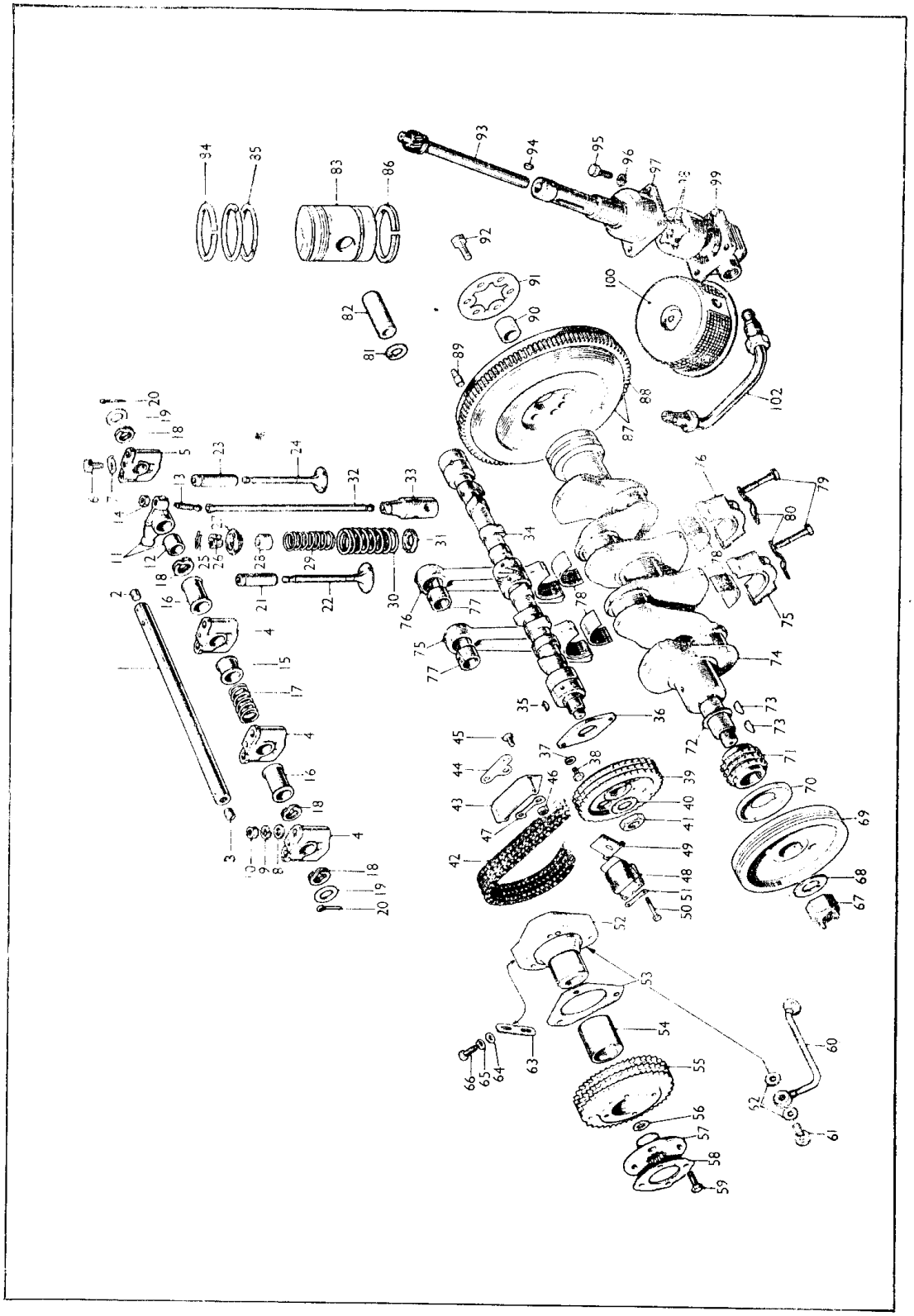


FIG. 2 - 2.5 LITRE DIESEL CRANKSHAFT - CAMSHAFT ASSEMBLIES

No.	Description
1	Rocker shaft
2	Plain plug for shaft
3	Screwed plug for shaft
4	Rocker bracket (plain)
5	Rocker bracket (tapped)
6	Locating screw for shaft
7	Lock washer
8	Plain washer
9	Spring washer
10	Nut
11	Valve rocker
12	Bush for rocker
13	Adjusting screw for rocker
14	Locknut
15	Distance piece (centre)
16	Distance piece (end)
17	Spacing spring
18	Spring washer
19	Plain washer
20	Split pin
21	Valve guide (inlet)
22	Valve (inlet)
23	Valve guide (exhaust)
24	Valve (exhaust)
25	Circlip for valve cotter
26	Valve cotter
27	Valve spring cup
28	Oil seal for valve
29	Valve spring (inner)
30	Valve spring (outer)
31	Valve spring collar
32	Push-rod
33	Tappet
34	Camshaft

No.	Description
35	Key for camshaft
36	Locating plate for camshaft
37	Spring washer
38	Bolt for locating plate
39	Camshaft chainwheel
40	Lock washer
41	Nut for camshaft
42	Timing chain
43	Vibration damper for chain
44	Shim for timing cover centre boss
45	Screw for damper
46	Nut
47	Lock washer
48	Tensioner for chain
49	Gasket for tensioner
50	Bolt for tensioner
51	Lock washer
52	Hub for injection pump chain wheel
53	Gasket for hub
54	Bearing for chain wheel
55	Injection pump chain wheel
56	Internal circlip for driving flange
57	Injection pump driving flange
58	Washer for flange
59	Bolt for flange
60	Oil feed pipe for hub
61	Banjo bolt
62	Washer for banjo
63	Injection timing pointer
64	Plain washer
65	Spring washer
66	Bolt for pointer
67	Nut for crankshaft
68	Lock washer

No.	Description
69	Crankshaft pulley
70	Oil thrower
71	Crankshaft chain wheel
72	Adjusting shim for chain wheel
73	Key for crankshaft
74	Crankshaft
75	Connecting rod and cap (Nos.2 and 4)
76	Connecting rod and cap (Nos.1 and 3)
77	Little end bush
78	Big-end bearing
79	Big-end bolt
80	Lock washer
81	Circlip
82	Gudgeon pin
83	Piston
84	Compression ring
85	Stepped scraper ring
86	Slotted oil control ring
87	Flywheel
88	Starter ring
89	Dowel
90	Bearing for primary shaft
91	Lock washer
92	Bolt for flywheel
93	Shaft for oil pump
94	Key for shaft
95	Bolt for oil pump
96	Spring washer
97	Oil pump body
98	Oil pump rotors
99	Oil pump cover
100	Oil strainer
102	Oil delivery pipe

Index to 2.5 Litre Engine Crankshaft - Camshaft Assemblies

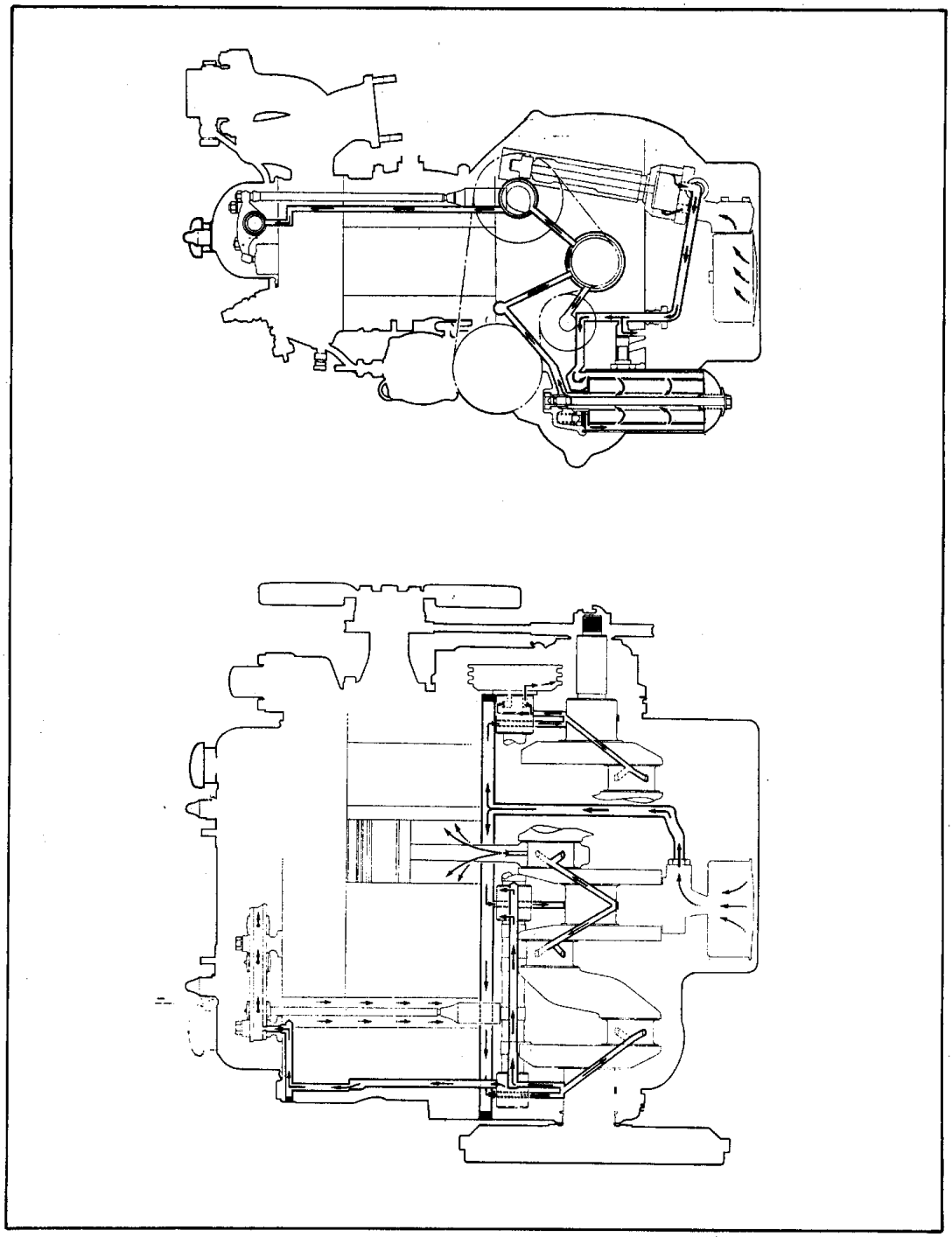


FIG. 3 - 2.5 LITRE DIESEL ENGINE LUBRICATING SYSTEM

2·5 LITRE ENGINE

B.1

DESCRIPTION

The 2·5 litre diesel engine is a four cylinder overhead valve unit similar in construction to the 1·5 litre engine, with the following differences.

1. The distributor type fuel injection pump incorporates a mechanical governor, is hub mounted to the engine front plate cover and driven via the timing gears from the crankshaft.
2. An alternator with transistorised control unit is fitted instead of the dynamo and conventional regulator.
3. The cooling system for the Commander is identical to that for the Captain and water cooling of the exhaust system is standard. The cooling system for the industrial versions is also the same as for the 1·5 litre counterparts.

Transmissions include a four speed forward and reverse speed gearbox, fitted when specified to the automotive industrial version, and either a hydraulically operated PRM100 gearbox or a Borg Warner Velvet Drive gearbox for the Commander.

B.2

LUBRICATION

All bearing surfaces and moving parts are pressure lubricated by an eccentric rotor non-draining type oil pump, located on the left hand, or port, side of the crankcase and gear driven from the camshaft. Oil is drawn through a gauze strainer attached to the base of the oil pump and passed through an internal delivery pipe to a non-adjustable plunger type relief valve, located at the front of the cylinder block on the right hand, or starboard side, and on through a feed gallery in the crankcase to the external full flow type oil filter. From the filter the oil is fed to the main oil gallery and then through drillings in the cylinder block to the fuel injection pump drive gear, crankshaft and camshaft bearings. Drillings in the crankshaft allow for lubrication of the main and big end bearings and two bleed holes in the front camshaft bearing allow for lubrication of the timing chain. Oil for the timing chain tensioner is fed through passages in the front of the cylinder block.

From the rear camshaft bearing oil at reduced pressure is fed to the valve rocker shaft and rockers. Surplus oil returning to the sump from the valve rockers lubricates the tappets. Lubrication of the cylinder bores is effected by jet holes drilled in the connecting rod big end bearings.

B.3

RUNNING INSTRUCTIONS

Refer to Section A sub section A.3.

B.4

MAINTENANCE ATTENTIONS

Refer to Section A subsection A.4.

Note that the torque figures for the manifold stud nuts are 22 lb.ft (3·04 kgf.m) and for the cylinder head nuts 75 lbf.ft (10·37 kgf.m). The reference to dynamo lubrication does not apply.

MAINTENANCE AND OVERHAUL PROCEDURES

B.5

REMOVING AND REFITTING THE ENGINE

Refer to Section A sub section A.5.

B.6

SUMP

Removing and Replacing

Follow the instructions in Section A sub section A.6, but before replacing the sump inspect the front and rear main bearing cap sealing plugs and the sealing strip for the rear main bearing cap. Renew as necessary.

B.7

OIL FILTER

Dismantling and Replacing

Follow the instructions in Section A sub section A.7.

B.8

OIL PRESSURE RELIEF VALVE

Removal, Inspection and Replacement

The instructions in Section A sub section A.9 apply, but the hexagon plug is located on the right hand, or starboard side of the crankcase. The free length of the relief valve spring is 3 in. (76·2 mm) as opposed to 2·859 in. (72·628 mm) on the 1·5 litre engine.

B.9

OIL PUMP AND STRAINER

Removing and Replacing

1. Drain the oil and remove the sump. Withdraw the dipstick.
2. Release the oil delivery pipe from the crankcase.
3. Remove the cap nut and dowel screw shown in Fig. 4 and withdraw the oil pump and strainer.

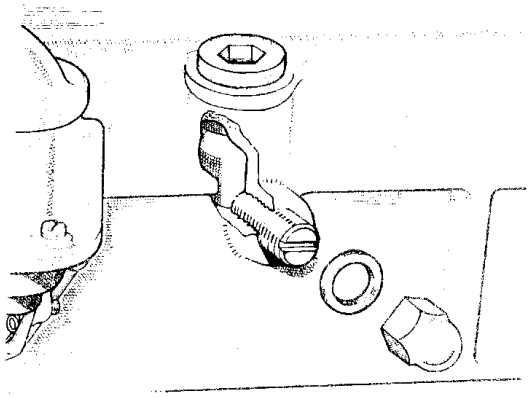


Fig.4 - Oil pump cap nut and dowel screw

Inspection

1. Remove the pump cover.
2. Check the rotor end-float does not exceed 0·005 in. (0·13 mm). Excessive end-float can be corrected by lapping the pump body face.
3. Check the diametrical clearance between the outer rotor and the pump body. If the clearance exceeds 0·010 in. (0·25 mm) renew the rotors or pump body or both, as necessary.
4. Check the rotor lobe clearance (in two positions) as shown. Renew the rotors if the clearance exceeds 0·008 in. (0·2 mm) and 0·006 in. (0·15 mm) respectively.

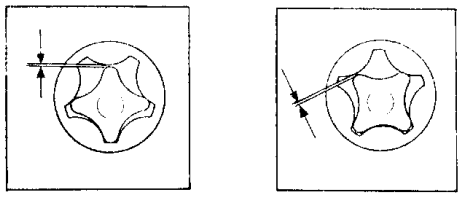


Fig.5 - Rotor lobe clearance - measuring position

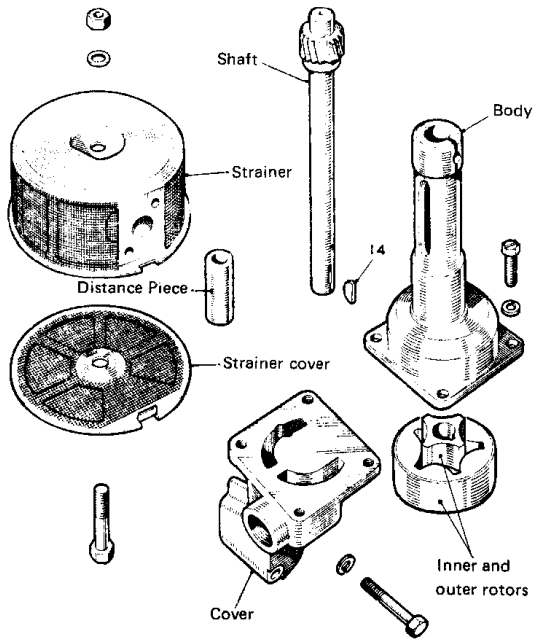


Fig.6 - Oil pump assembly

5. Re-assemble the components, ensuring that the chamfered end of the outer rotor is innermost in the pump body.

Re-assembling

1. Refit the oil pump assembly and secure with the dowel screw. Replace the cap nut and washer.
2. Reconnect the oil delivery pipe.
3. Refit the sump and include a new sump joint. Refill the sump with one of the recommended lubricants and replace the dipstick.

B.10

ROCKER SHAFT ASSEMBLY

Removing and Replacing

1. Drain the cooling system.
2. Disconnect the breather pipe from the air cleaner and rocker cover (Commander). On the industrial engine remove the air cleaner.
3. Remove the rocker cover taking care not to damage the cork gasket.
4. Slacken the cylinder head nuts, a turn at a time, in the sequence shown in Fig. 7 until the load has been released. It will be found convenient to use Cylinder head nut spanner 18G545 to remove the two nuts which also serve as rocker cover studs.

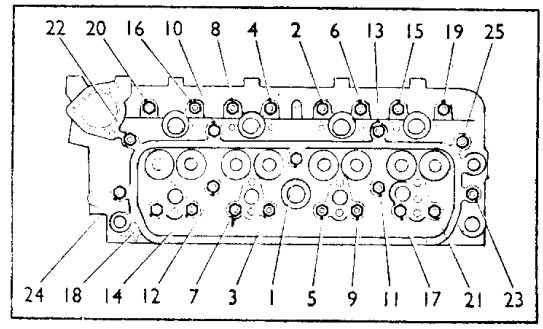


Fig.7 - Cylinder head nut slackening and tightening sequence

5. Remove the rocker shaft bracket nuts and washers and lift off the shaft assembly.
6. Refit the rocker shaft assembly to the cylinder head ensuring all rocker adjusting screws are fully slackened and the bracket nuts only finger tight.
7. Using the Cylinder head nut spanner, a suitable socket and torque wrench tighten the cylinder head nuts, in the sequence used for slackening off, to a torque of 75 lbf.ft (10·37 kgf.m). Tighten the rocker bracket nuts to a torque of 25 lbf.ft (3·46 kgf.m).
8. Adjust the valve to rocker clearance (sub section B.11) fit a new cover joint if the existing one is damaged and replace the rocker cover.
9. Reconnect the breather pipe (Commander) or refit the air cleaner (industrial), refill the cooling system, run the engine and check the cover joint for oil leaks.

Dismantling and Re-assembling

Follow the instructions in Section A subsection A.11.

Fitting new bushes

Follow the instructions in the above section using the Valve rocker bush remover and replacer 18G21.

B.11

VALVE ROCKER CLEARANCE

Refer to Section A sub section A.12 and follow the procedures and sequence laid down. The inlet valve clearance should be 0·012 in. (0·305 mm) and the exhaust valve clearance 0·015 in. (0·38 mm).

B.12

CYLINDER HEAD

Removing and Refitting

Follow the procedures in B10 above; also Section A sub section A13, but note the push rod positioning plate when

lifting the cylinder head off the studs. When refitting, tighten the cylinder head nuts to a torque of 75 lbf.ft (10·37 kgf.m), the manifold nuts to 22 lbf.ft (3·04 kgf.m) and the rocker bracket nuts to 25 lbf.ft (3·46 kgf.m).

B.13
VALVES

B.14
VALVE GRINDING

B.15
VALVE SEAT INSERTS

B.16
VALVE GUIDES

Follow the instructions in Section A, sub-section A.14, A.15, A.16 and A.17 for removing and replacing valves, valve grinding, and renewing valve seat inserts and valve guides. If the valve seats need to be recut the exhaust valve seats narrowing cutters used should be 18G28, 18G28A, 18G28B and 18G28C. The valve head stand-down should not exceed 0·010 in. (0·25 mm), but if it does fit new valves, as necessary. Should stand-down still be excessive, machine the cylinder head to the dimensions given and fit new inserts.

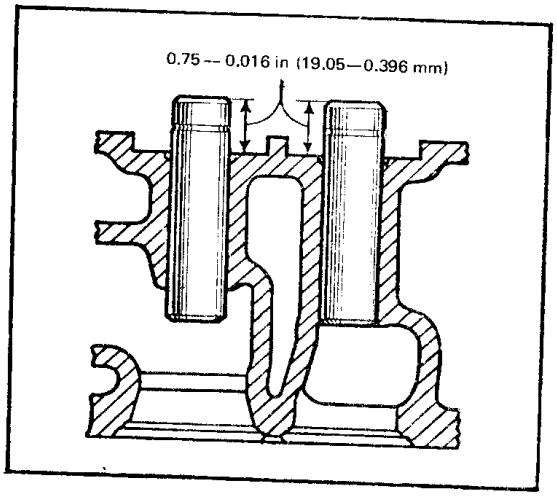
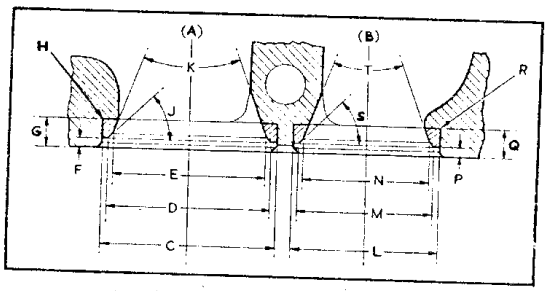


Fig.8 - Valve guides - fitted position



Inlet (A)

C. 1.6615 to 1.6625 in. (42.40 to 42.23 mm)
D. 1.540 to 1.545 in. (39.12 to 39.24 mm)
E. 1.46 in.(37.08 mm)
F. .090 to .095 in. (2.29 to 2.41 mm)
G. .278 to .281 in. (7.06 to 7.14 mm)
H. Max.radius .015 in. (.38 mm)
J. 45°
K. 40°

Exhaust (B)

L. 1.4215 to 1.4225 in. (36.11 to 36.13 mm)
M. 1.300 to 1.305 in. (33.02 to 33.15 mm)
N. 1.22 in. (30.99 mm)
P. .090 to .095 in. (2.29 to 2.41 mm)
Q. .278 to .281 in. (7.06 to 7.14 mm)
R. Max.radius .015 in. (.38 mm)
S. 45°
T. 40°

Fig.9 - Cylinder head machining dimensions

B.17
TIMING GEAR CASE COVER

Removing and Replacing

1. Drain the cooling system and remove the radiator and oil cooler (industrial only).
2. Slacken the alternator mounting bolts and remove the fan belt.
3. Remove the fan blades (industrial only) and fresh water pump pulley.
4. Remove the crankshaft nut using the Starting nut spanner 18G391, and withdraw the crankshaft pulley, using Gear and pulley remover 18G231 and Adaptors 18G231B.
5. Remove the degree plate from the timing cover, and then the timing cover from the engine front plate, taking care not to damage the joint.
6. Remove the oil thrower from the crankshaft.
7. If the oil seal is defective use the Bearing and oil seal replacer 18G134 and Oil seal replacer adaptor 18G134CR to renew the seal.
8. Refit the oil thrower to the crankshaft.
9. Renew the cover joint if broken or defective, ensuring the joint mating faces are clean before fitting the new joint.
10. Refit the cover, with the securing screws fingertight, and centralise the cover with the crankshaft, using the Engine front cover locating bush 18G3.
11. Refit the degree plate, water pump pulley, fan blades and fan belt. Adjust the belt and tighten the alternator mounting bolts.
12. Refit the radiator and oil cooler (industrial) and refill the cooling system.

B.18
TIMING CHAIN, CHAIN WHEELS AND TENSIONER

Removing and Replacing

1. Remove the timing gear case cover.
2. Crank the engine until the timing marks on the chain wheels are positioned as shown.

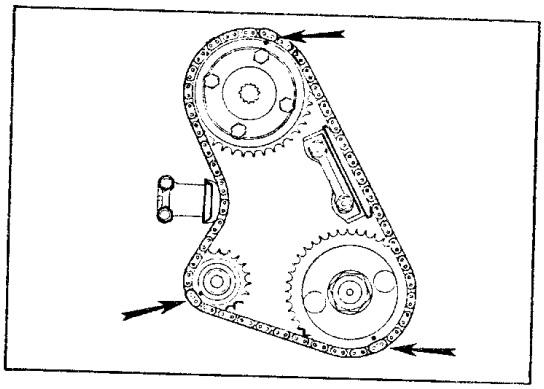


Fig.10 - Valve timing marks

3. Retract the chain tensioner slipper as shown.
4. If the chain tensioner alone requires attention remove it, but if other components are to be removed leave the tensioner in position.

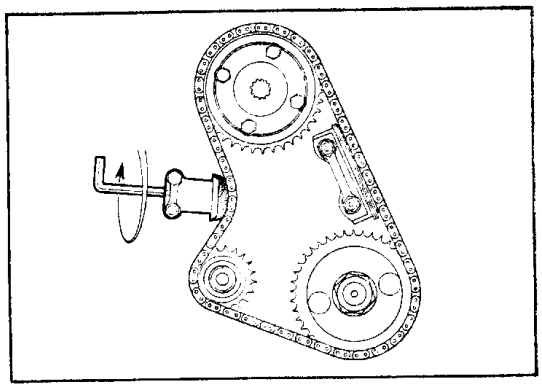


Fig.11 - Chain tensioner and Allen key

5. Remove the camshaft nut using the Starting nut spanner 18G98A.
6. Draw the three chain wheels with timing chain off the respective shafts and renew as necessary.
7. Check the injection pump chain wheel bearing for wear. The bearing bore should be within the limits 1·7503 to 1·7508 in. (44·46 to 44·47 mm) and the clearance on the chain wheel hub should be 0·001 to 0·002 in. (0·03 to 0·05 mm). If replacement is necessary renew in the following way:—
   (a) Remove the driving flange from the chain wheel.
   (b) Press out the old bearing and press in a new one from the chamfered end of the chain wheel bore. Finish ream the bore of the new bearing to the size given in General Data.

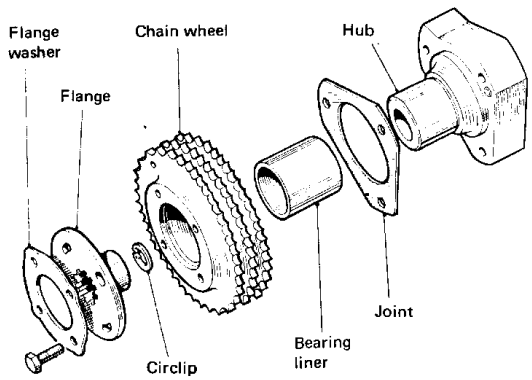


Fig.12 - Fuel injection pump drive assembly

   (c) Fit the driving flange to the chain wheel with the master spline and timing mark in the relative positions shown. Position the flange so that its securing bolts are central in the adjusting slots.
8. Position the chain wheels with the timing mark shown and refit the chain. Keeping the chain wheels so positioned push them evenly on to the respective shafts as far as they will go. It may be necessary to rotate the camshaft slightly to align the camshaft key with the keyway in the camshaft chain wheel.

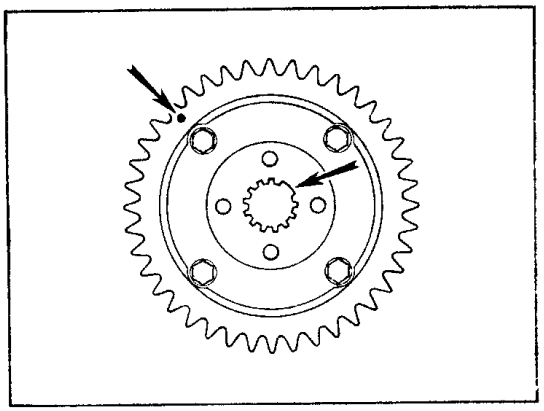


Fig.13 - Injection pump master spline and timing mark

9. Secure the camshaft chain wheel with its nut and lockwasher.
10. Check, and if necessary adjust the camshaft and crankshaft chain wheel alignment, by fitting shims behind the crankshaft wheel, as required.
11. Release the chain tensioner by inserting the Allen key and turning it in a clockwise direction until the slipper head moves forward under spring pressure against the chain. DO NOT ATTEMPT TO TURN THE KEY COUNTER CLOCKWISE OR FORCE THE SLIPPER HEAD INTO THE CHAIN BY EXTERNAL PRESSURE.
12. Refit the tensioner body plug and re-assemble the remaining components.

Dismantling and Re-assembling the tensioner

1. Withdraw the plunger and slipper assembly from the tensioner body and engage the lower end of the cylinder with the Allen key. Turn the key clockwise holding the key and plunger securely until the cylinder and spring are released from inside the plunger.
2. Check that the bore in the tensioner body is not excessively oval. If it is greater than 0·003 in. (0·0762 mm) when measured on diameters near the mouth of the bore, then the complete chain tensioner must be renewed.
3. Inspect the slipper head for wear. If it is badly worn a new slipper head and cylinder assembly must be fitted to the existing body provided the bore of the body is within the limits given above.
4. Thoroughly wash the components in clean petrol (gasoline) or paraffin (kerosene) and use an air line to clear the 0·125 in. (3·18 mm) diameter inlet oil hole in the spigot and the 0·040 in. (1·02 mm) outlet oil hole in the slipper.
5. Insert the spring in the plunger and place the cylinder on the other end of the spring.
6. Compress the spring until the cylinder enters the plunger bore, engaging the helical slot with the peg in the plunger.
7. Hold the assembly compressed in this position and engage the Allen key. Turn the cylinder clockwise until the end of the cylinder is below the peg and the spring is held compressed.
8. Withdraw the key and insert the plunger assembly in the body.

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

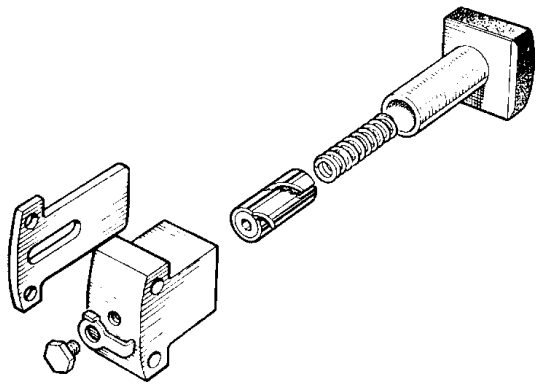


Fig.14 - Timing chain tensioner components

B.19

VALVE TIMING

Follow the instructions in Section A, sub section A.20.

B.20

CAMSHAFT AND FRONT PLATE

Removing

The following procedures apply to both the camshaft and the front plate, but if the front plate is not to be removed instructions 10 to 15 do not apply.

1. Drain the cooling system, and on the industrial versions remove the radiator grill, where applicable, radiator and oil cooler.
2. Slacken the alternator bolts and remove the fan belt. If the front plate is to be removed, withdraw the alternator completely.
3. On the industrial versions remove the fan blades and water pump pulley.
4. Remove the crankshaft pulley.
5. Remove the degree plate from the timing cover and then the timing cover from the engine front plate, taking care not to damage the joint.
6. Remove the oil thrower from the crankshaft.
7. Remove the camshaft nut using the Starting nut spanner 18G98A.
8. Position the chain wheel timing marks as shown in Fig. 10, retract the chain tensioner slipper and draw the three chain wheels and chain, off the shafts.
9. Remove the camshaft locating plate.
10. Remove the timing chain tensioner.
11. Disconnect the fuel feed and return pipes from the fuel injection pump.
12. Disconnect the high pressure pipes from the injection pump.
13. Remove the lubricating oil feed pipe from the crankcase and injection pump chain wheel hub.
14. Support the engine with a sling and suitable lifting pulleys and raise the engine to relieve the load on the front mountings. On the Commander it may be necessary to disconnect the propeller shaft from the gearbox and to lift the complete engine/gearbox unit from the installation in order to drop the sump.
15. Remove the front plate complete with injection pump.
16. Remove the cylinder side cover.
17. Withdraw the dipstick and release the dipstick tube from the sump.
18. Drain the sump, and on the Commander disconnect the drain pipe from the sump. Remove the sump.
19. Release the oil delivery pipe from the crankcase.
20. Remove the cap nut and washer and dowel screw from the left hand or port side of the crankcase and withdraw the oil pump and strainer.
21. Remove the rocker cover.
22. Remove the rocker shaft, withdraw the push rods and lift out the tappets.
23. Withdraw the camshaft.

Refitting

Reverse the foregoing procedures and at the relevant stages include the following:—

(a) When offering up the front plate, fit all bolts, which secure it to the cylinder block, before tightening any. This will ensure correct positioning of the plate.
(b) Check the camshaft end float, and if outside the limits 0·003 to 0·006 in. (0·076 to 0·152 mm) renew the locating plate.
(c) Assemble the chain and chain wheels to the respective shafts with the timing marks as shown.
(d) Check the chain wheel alignment. The crankshaft and camshaft chain wheel teeth faces should be in line. If adjustment is necessary, add or remove shims behind the crankshaft chain wheel. The injection pump chain wheel is self-aligning.
(e) Release the chain tensioner slipper.
(f) Ensure the crankshaft front oil seal is serviceable; if necessary renew. Centralise the timing cover as described in B.17.
(g) Adjust the valve rocker clearances (Refer to B.11).
(h) Bleed the fuel system (Section D).

B.21

CAMSHAFT BEARING LINERS

Should it be necessary to renew the camshaft bearing liners it will be found more convenient to remove the engine from the installation and dismantle.

1. Withdraw the front bearing liner, using the Camshaft Liner remover and replacer 18G124A (basic tool) and adaptor 18G124F, as illustrated.

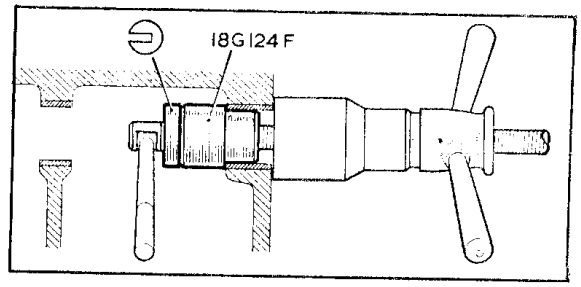


Fig.15 - Front bearing liner - withdrawal procedure

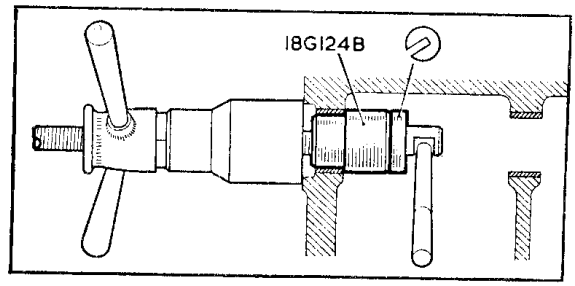


Fig.16 - Rear bearing liner - withdrawal procedure

2. Withdraw the rear bearing liner using the basic tool with adaptor 18G124B as shown.
3. Withdraw the centre bearing liner using the basic tool with adaptors 18G124D and 18G124H as shown.
4. Fit a new front bearing liner, first ensuring the oil holes will line up with those in the crankcase, when the bearing is fitted.

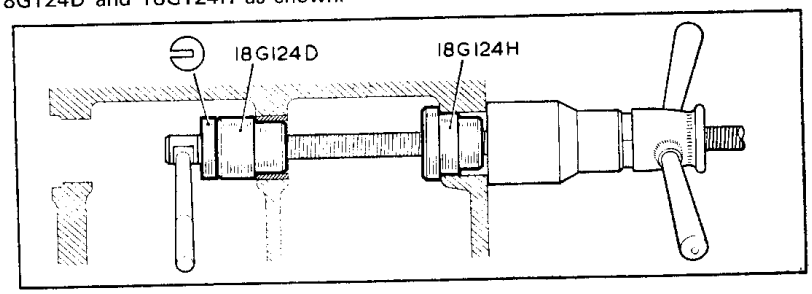


Fig.17 - Centre bearing liner - withdrawal procedure

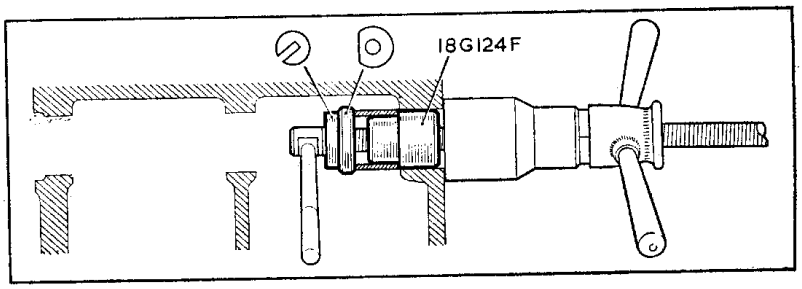


Fig.18 - Front bearing liner - fitting procedure

5. In a similar way fit a new rear bearing liner first ensuring the oil holes will line up with the respective crank case oil holes when the bearing is fitted.
6. Fit a new centre bearing liner again ensuring the oil holes will line up with the respective crankcase oil holes when the bearing is fitted.

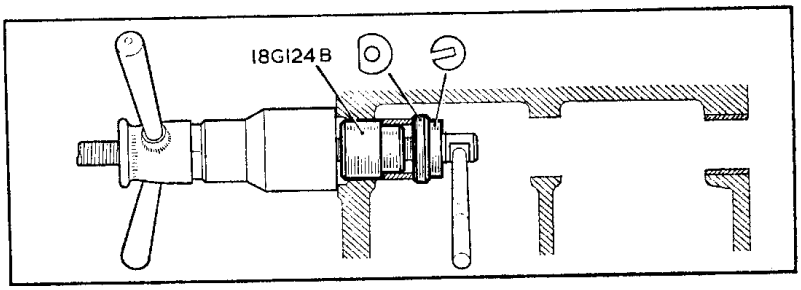


Fig.19 - Rear bearing liner - fitting procedure

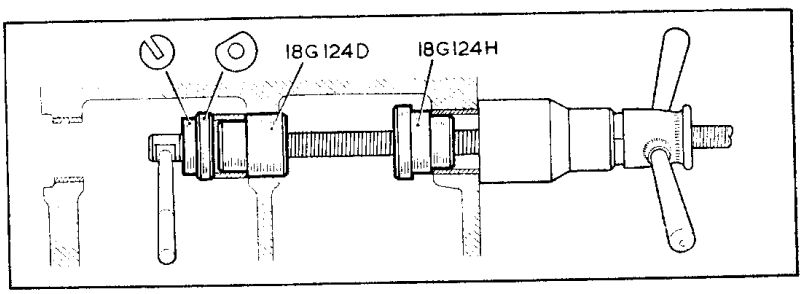


Fig.20 - Centre bearing liner - fitting procedure

7. Ream the front and rear bearing liners using the Camshaft liner reamer 18G123A with cutters and pilots as shown. The reamed diameter of the front bearing should be 1·78875 to 1·78925 in. (45·43 to 45·45 mm) and the rear bearing should be 1·62275 to 1·62325 in. (41·42 to 41·23 mm).

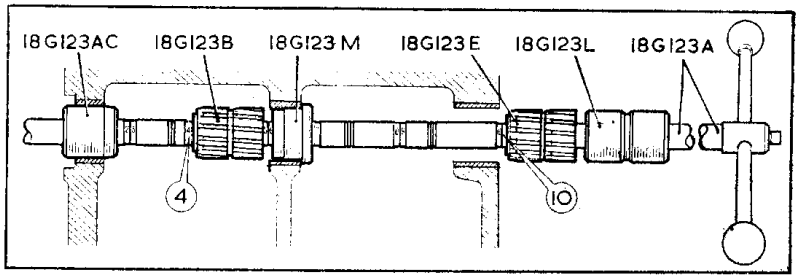


Fig.21 - Reamers for front and rear bearing liners

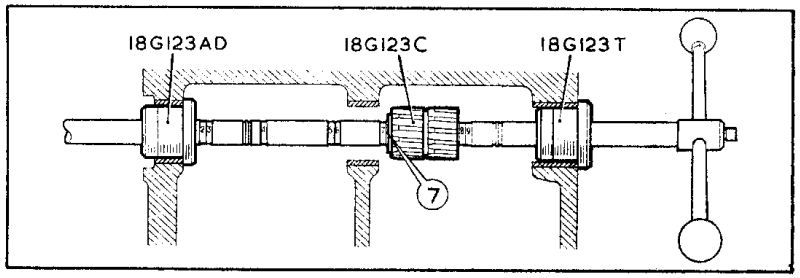


Fig.22 - Reamer for centre bearing liner

8. Ream the centre bearing liner using the basic tool 18G123A with cutters and pilots as shown. The reamed diameter should be 1·74875 to 1·74925 in. (44·42 to 44·43 mm).

B.22

FLYWHEEL AND STARTER RING

Removing and Refitting.

1. Remove the gearbox and clutch (as applicable). Alternatively uncouple and remove the generator (generating set) or any auxiliary for which the engine may be required to provide the motive power.
2. Remove the starter motor from the flywheel housing or backplate.
3. Mark the flywheel and one of the crankshaft dowels in relation to each other and remove the flywheel.
4. Remove the flywheel housing or backplate.
5. Remove the oil seal from the flywheel housing.
6. If the teeth on the starter ring are worn or damaged, remove by drilling a hole through the ring and splitting the ring across the hole with a hammer and chisel, taking care not to damage the flywheel.
7. Ensure the bore of the new ring and its mating surface on the flywheel are free from burrs and are perfectly clean.
8. Heat the new ring uniformly to a temperature of 200° to 230°C (392° to 446°F); the strip of temperature indicating paint on the ring will change from pink to grey at the correct temperature.
9. Fit the starter ring with the tooth chamfer facing away from the flywheel register.
10. Refit the flywheel housing or backplate and if necessary fit a new crankshaft oil seal using Bearing and oil seal replacer 18G134 and adaptor 18G134CQ.
11. When the flywheel and starter ring have cooled naturally refit the flywheel to the crankshaft.
12. Refit the starter motor and re-assemble the transmission and driven member. Where a clutch is fitted use alignment tool 18G554 to centralise the clutch plate.
13. Bleed the fuel system.

B.23

CONNECTING RODS AND PISTONS

To remove, dismantle and re-assemble and refit connecting rods and pistons follow the instructions in Section A, sub section A.25 but where dimensions occur refer to 'General Data' for the correct figures.

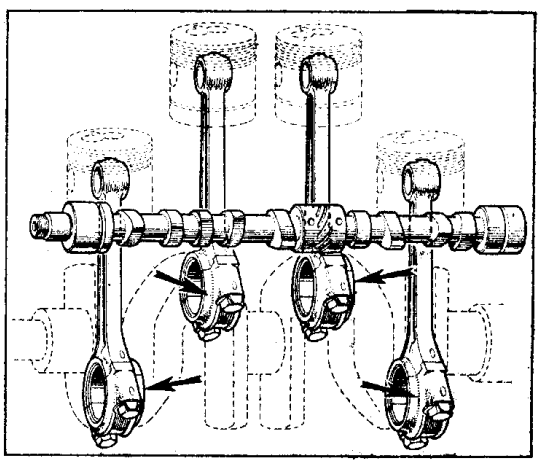


Fig.23 - Connecting rods - indicating big end fitted position

B.24

CRANKSHAFT AND MAIN BEARINGS

Removing

1. Remove the engine from the installation.
2. Remove the fan belt and blades (industrial) and fresh water pump pulley.
3. Remove the crankshaft nut and withdraw the crankshaft pulley.
4. Remove the timing cover.
5. Remove the oil thrower from the crankshaft.
6. Retract the timing chain tensioner slipper and remove the tensioner.
7. Remove the camshaft nut and draw the three chain wheels, together with the chain, off their shafts.,
8. Remove the camshaft locating plate.
9. Disconnect the fuel pipes from the fuel filter and remove as necessary. Remove the fuel filter.
10. Disconnect the high pressure pipes from the injection pump.
11. Remove the lubricating oil feed pipe from the crankcase and injection pump chain wheel hub.
12. Remove the front plate complete with injection pump.
13. Remove the oil filter and, where fitted the oil cooler and pipes.
14. Remove the starter motor and where applicable the clutch from the flywheel.
15. Mark the flywheel and one of the crankshaft dowels relative to each other and remove the flywheel.
16. Remove the flywheel housing, or backplate as applicable.
17. Remove the sump.
18. Release the oil delivery pipe from the crankcase.
19. Remove the domed nut and then the oil pump locating screw from the port or left hand side of the cylinder block. Withdraw the oil pump and the oil strainer assembly.
20. Remove the big end bearing caps and separate the connecting rods from the crankshaft.
21. Remove the main bearing caps using the Impulse extractor 18G284 and the Main bearing cap remover adaptor 18G284AJ.
22. Lift out the crankshaft and collect the main bearing halves and thrust washers into sets and place in re-assembly order.
23. Clean, or wash all components in paraffin (kerosene).

Refitting

1. Fit new bearing shells, as necessary, and re-assemble the crankshaft to the cylinder block and connecting rods. Note that bearings are always fitted in sets.
2. Tighten the big end bolts to a torque of 50 lbf.ft (6·9 kgf.m) and the main bearing bolts to a torque of 100 lbf.ft (13·82 kgf.m).
3. Mount a dial gauge on the front end of the crankcase with its indicator resting on the front face of the crankshaft front main journal.
4. Press the crankshaft forward as far as possible and note the reading on the gauge, the difference from zero being the amount of crankshaft end float. If the end float is outside the limits 0·002 to 0·003 in. (0·051 to 0·076 mm), renew the thrust washers, fitting them by selective assembly and ensuring that the oil grooves face outwards towards the crankshaft webs.
5. Refit the oil pump and strainer assembly. Reconnect the oil delivery pipe to the crankcase.
6. Refit the sump and include a new joint.
7. Refit the flywheel housing or backplate, as applicable. If the oil seal is suspect, renew.
8. Refit the flywheel, ensuring the marks on the flywheel and crankshaft dowel correspond.
9. Re-assemble the starter motor to the flywheel starter ring and flywheel housing, or backplate.
10. Where applicable refit the clutch. Renew the oil filter element and refit the oil filter with a new joint to the cylinder block; where applicable reconnect the oil cooler and pipes.
11. Offer up the front plate with injection pump to the cylinder block and loosely fit all the securing bolts to ensure correct positioning of the front plate. Tighten up when correct.
12. Reconnect the lubricating oil feed pipe to the crankcase and injection pump chain wheel hub.
13. Reconnect the high pressure fuel pipes to the injection pump.
14. Replace the fuel filter and reconnect the associated pipes.
15. Replace the camshaft locating plate.
16. Re-assemble the chain wheels, and timing chain with the timing marks correctly positioned.
17. Replace the chain tensioner and release the slipper.
18. Check the chain wheel alignment and replace the camshaft nut.
19. Replace the crankshaft oil thrower and refit the timing cover. If necessary fit a new oil seal.
20. Refit the crankshaft pulley, water pump pulley, fan belt and fan blades (industrial).
21. Refit the engine to the installation.

B.25

CYLINDER LINERS

To fit new cylinder liners follow the instructions in Section A sub section 27 but refer to General Data for cylinder bore and liner machining dimensions.

SECTION C

COOLING SYSTEMS

C.1

DESCRIPTION

The cooling system for the Captain and the Commander marine engines is a closed circuit pressurised and thermostatically controlled fresh water type employing either a Keel cooler unit or a Heat exchanger unit. A feature of the system is water cooling of the exhaust manifold, the manifold forming part of the closed circuit on engines using a Keel cooler and part of a separate open circuit on engines using a Heat exchanger. Raw water is drawn in and pumped by a positive displacement pump, through the heat exchanger element, the manifold and exhaust system and discharged overboard. A separate pump is also necessary for exhaust cooling where a keel cooler is fitted, raw water being drawn in and pumped direct to the exhaust pipe and then discharged overboard. The Commander also includes an oil cooler. Industrial engines feature the conventional pressurised and thermostatically controlled fresh water system, and, depending on the application, include a radiator and oil cooler.

Heat exchanger cooling

The Heat exchanger unit, with fresh water header tank integral with the body, is mounted on the front of the engine. When the engine is started from cold, the thermostat, which is housed at the front of the cylinder head, is closed and fresh water from the heat exchanger is circulated, via inbuilt passages, within the cylinder block and cylinder head by an impeller type water pump.

Once the water reaches the predetermined working temperature the thermostat opens and allows the water to be returned to the header tank.

Sea, or river water is drawn by a vane type positive displacement pump through a seacock and strainer, and passed through the element (tube stack) of the heat exchanger and the exhaust manifold and pipe to be discharged overboard.

Keel cooling

The Keel cooler unit is located on the underside of the boat, with the header tank forming an integral part of the exhaust manifold on the Captain and being mounted on the end of the exhaust manifold on the Commander.

Initially, with the engine running cold, fresh water is drawn from the cooling unit and circulated through the cylinder block and cylinder head by an impeller type fresh water pump. Once the water reaches the correct temperature the thermostat opens and the water passes into the header tank and the jacketed exhaust manifold to be returned to the cooling unit, where it is cooled by the surrounding sea or river water.

If the exhaust system is water cooled (wet exhaust) a separate positive displacement (sea water) pump is fitted, and sea or river water is drawn in via a suitable seacock and strainer and pumped directly to the exhaust outlet chamber. It is then passed through the exhaust pipe and discharged overboard.

MAINTENANCE AND OVERHAUL PROCEDURES

C.2

HEAT EXCHANGER

Removing and Replacing

1. Remove the filler cap from the heat exchanger, open the drain tap on the cylinder block, and drain the water, or anti-freeze solution into a suitable container.
2. Remove the drain plug from the heat exchanger and drain the contents into a suitable container. Open the drain tap at the rear of the exhaust manifold to drain the sea water.
3. Disconnect and remove the hoses and/or pipes from the end cover and the hose from the heat exchanger to the fresh water pump.
4. Remove the bolts securing the heat exchanger body to the supporting strut, or mounting brackets, and the setscrews securing the water outlet elbow to the

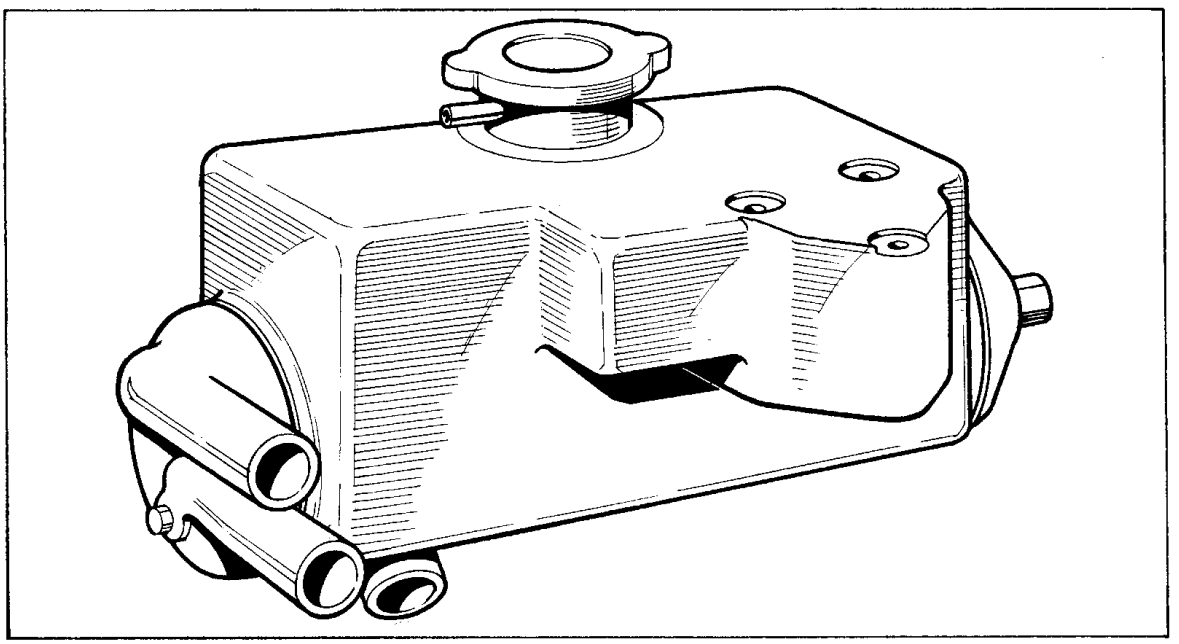


Fig.1 - Heat exchanger - Captain

body (Commander). On the Captain remove the three domed nuts securing the heat exchanger to the cylinder head thermostat housing. Lift off the heat exchanger.
5. Refit the water outlet elbow to the heat exchanger body (Commander), or the heat exchanger to the thermostat housing (Captain) and include a new joint, as appropriate.
6. Reconnect the hoses, and on the Commander re-connect the supporting strut.
7. Replace the drain plug, close the cylinder block drain tap and refill the unit with fresh water or anti-freeze solution. Replace the filler cap and run the engine to expel any air that may be trapped in the system. Top up with coolant, as necessary.

Dismantling, Cleaning and Re-assembling

1. Unscrew the hexagonal brass cap nut and remove both end covers; one has the two seawater connections and an attached brass tie rod, which is located in the centre of the element (tube stack).
2. Withdraw the 'O' seals from each end of the element and remove the assembly from the casing. If the element cannot be moved with normal hand pressure, a few gentle taps with a wooden mallet or similar object should release it.
3. If the tubes of the element are encrusted with salt water deposits, press a piece of $\frac{1}{8}$ in. (3·175 mm) diameter steel rod through each tube to remove the obstructing matter.

CAUTION: It is important when doing this to press the rod through the tubes in the opposite direction to that in which the sea water flows.
Should the element appear to be completely blocked, place the assembly in a hot, preferably boiling, caustic soda solution, to dissolve the obstructing matter.

4. Place the element in the body and refit the two 'O' seals over the ends of the element and into the recesses in the body casing. It is advisable to renew the seals if they are badly worn or deformed.
5. Ensure the end covers are clean, insert the tie rod in the element and press the attached end cover into position.
6. Replace the opposite end cover and secure the whole assembly by means of the hexagonal brass cap nut complete with copper and asbestos washer.

C.3

KEEL COOLER HEADER TANK (Commander only)

Removing and Replacing

1. Remove the filler cap and using suitable containers, drain the cylinder block and the exhaust manifold; a drain tap is provided at the rear end of the manifold.
2. Disconnect the hose from the top water outlet.
3. Remove the setscrews securing the header tank to the manifold.
4. Replace the tank, reconnect the hoses, close the drain taps and refill the tank with fresh water or coolant. Replace the filler cap and run the engine to expel any air that may be trapped in the system. Top up with coolant, as necessary.

C.4

RADIATOR

Removing and Replacing

1. Remove the canopy and cowl, where fitted, remove the radiator filler cap, open the radiator drain tap and cylinder block drain tap and drain the system.
2. Disconnect the top and bottom hoses and, where fitted, the two on the oil cooler.
3. Remove the two lower mounting nuts and the nuts from the upper supporting stays.
4. Lift out the radiator.
5. Replace the radiator, reversing the removal procedure, close the taps and refill the system until the level of the coolant is 1 in. (25·4 mm) below the bottom of the filler neck.

C.5

THERMOSTAT

For maximum efficiency the engine operating temperature is maintained within certain limits by a thermostat fitted in a housing at the front of the cylinder head.
The thermostat opening is set by the manufacturer and cannot be altered. It opens at the temperature marked on the body. During decarbonising it is policy to test this opening by immersing the thermostat in water raised to the requisite temperature. The valve should open under these conditions, but if it fails to open a new unit must be fitted.

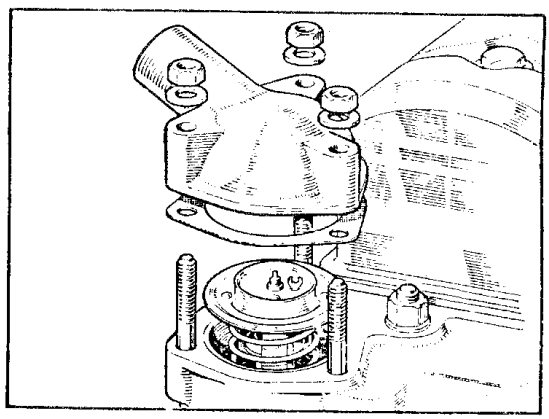


Fig.2 - Thermostat and housing

Removing and Replacing

1. Drain the cooling system.
2. Remove either the heat exchanger or keel cooler header tank. For industrial engines disconnect the top hose at the top water outlet connection.
3. Remove the top water outlet and lift the thermostat out of its housing.
4. Fit a new housing joint washer, replace or renew the thermostat and re-assemble.
5. Close the taps and refill the system with coolant.

C.6

FRESH WATER PUMP

Removing and Replacing

1. Drain the cooling system.
2. Slacken the alternator or dynamo mounting bolts and the adjusting link bolt. Pivot the alternator towards the engine to relieve the driving belt tension and remove the belt.
3. Remove the setscrews securing the pulley and fan blades (industrial only) to the pump hub.
4. Disconnect the hose from the pump body.
5. Remove the four setscrews and washers securing the pump body to the cylinder block and on the Captain

and 1·5 the mounting bolt to the dynamo or alternator. Withdraw the pump assembly.
6. Replace the pump and if necessary fit a new joint washer between the pump and cylinder block.
7. Adjust the tension of the driving belt so that at the centre of the vertical run it is possible to deflect the belt 1 in. (25·4 mm).
8. Close the drain taps and refill the system with coolant.

Dismantling

1. Withdraw the hub from the pump spindle using a suitable extractor.
2. Extract the locating wire through the hole in the top of the pump body, and drive the spindle and bearing assembly rearwards out of the pump body.
3. Withdraw the impeller from the spindle and remove the water seal.
4. Inspect each component, and renew as necessary.

Re-assembling

1. Refit the spindle and bearing assembly to the pump body. On the Captain and 1·5 ensure the lubricating hole in the bearing coincides with the hole in the pump body.
2. Refit the water seal to the spindle followed by the impeller.
3. Check the impeller clearance, A, and ensure it is within the limits given.
4. Refit the bearing retaining clip in the pump body and fit a new pulley hub to the spindle.
5. Check the 'B' dimensions and ensure it is within the limits given.

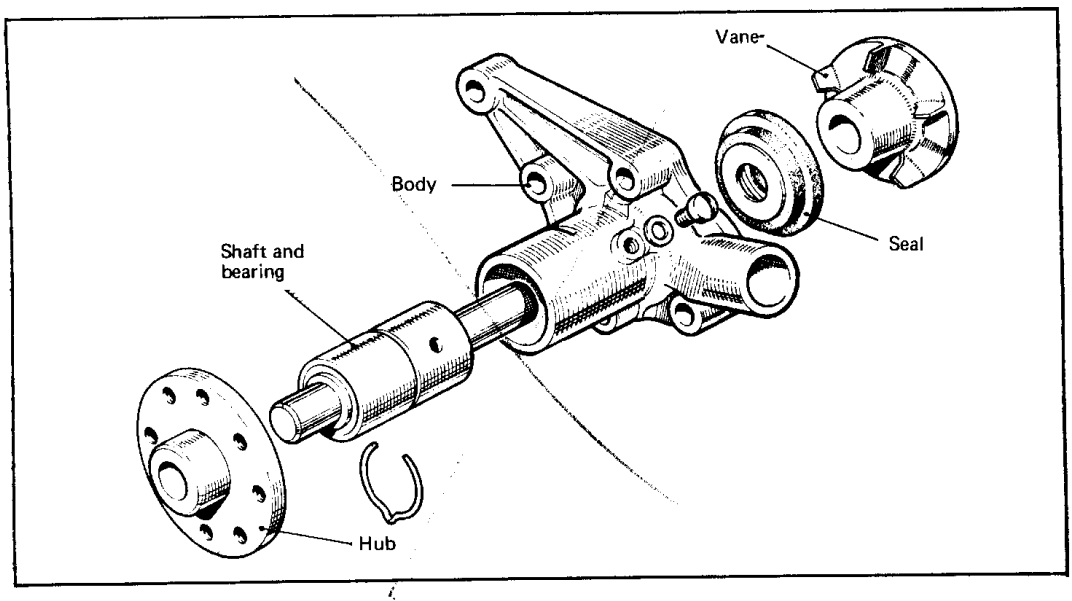


Fig.3 - Fresh water pump assembly (Captain)

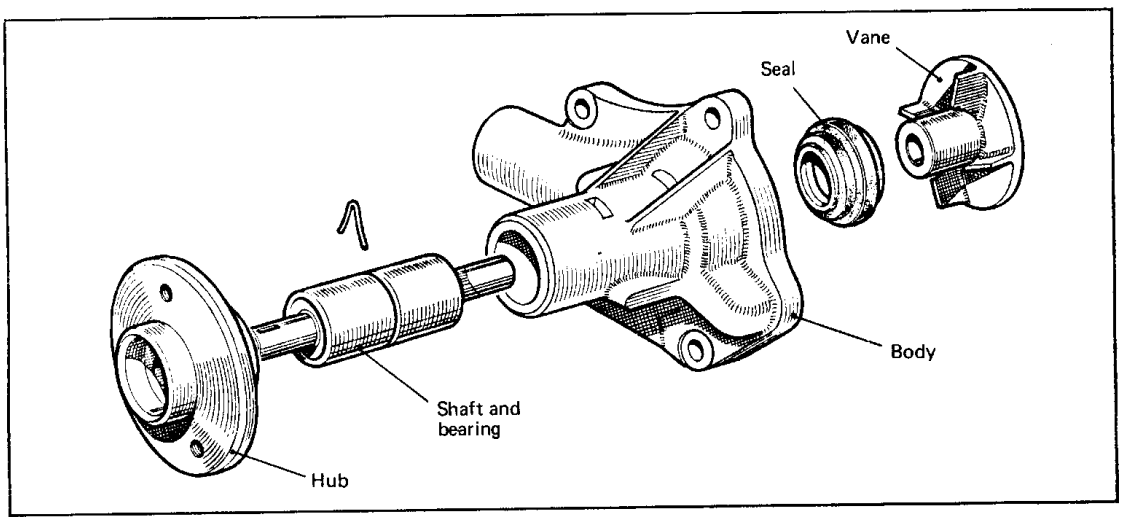


Fig.4 - Fresh water pump assembly (Commander)

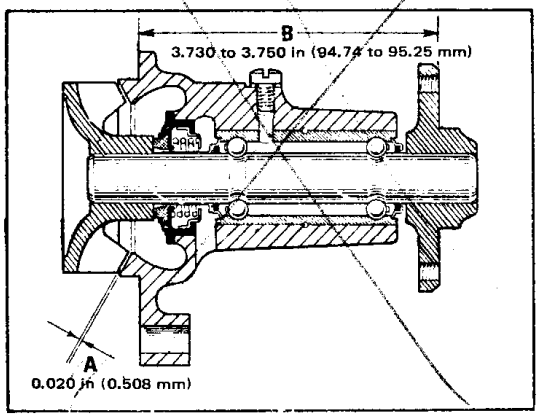


Fig.5 - Fresh water pump section (Captain)

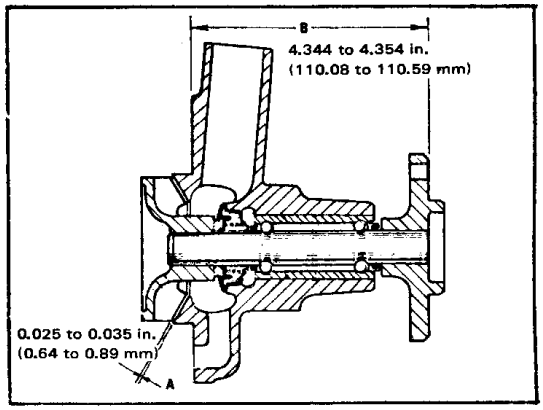


Fig.6 - Fresh water pump section (Commander)

C.7

SEAWATER PUMP

Removing and Replacing

1. Close the seacock and drain the cooling system.
2. Disconnect the inlet and outlet pipes from the body of the pump.
3. On the Captain remove the drive belt from the crankshaft pulley to the pump pulley.
4. Remove the nuts and washers securing the pump to the adaptor plate on the timing cover (Commander) or remove the nuts and bolts securing the pump to the mounting bracket (Captain) and remove the pump assembly.
5. Where applicable, fit a new pump to adaptor joint and replace the pump, reversing the above procedure.

Dismantling (Commander with Heat Exchanger)

1. Remove the six screws securing the end cover to the pump body; withdraw the cover and joint washer.
2. Withdraw the spline seal and impeller from the drive shaft.
3. Remove the cam screw and withdraw the cam from the body. Remove the old jointing compound by using a solvent, i.e. petrol.
4. Extract the impeller wear plate.
5. Press the shaft assembly from the body and withdraw the bearing and coupling.
6. Remove the 'O' ring, seals and slinger from the body.
7. Inspect each component and renew as necessary.

Re-assembling

1. Refit the seals, 'O' ring and slinger.
2. Refit the bearing to the shaft, and refit the shaft in the body.
3. Refit the coupling to the shaft.
4. Insert the wear plate in the body non-drive end.
5. Brush a non-setting jointing compound e.g. Hylomar on the cam screw thread and upper surface of the cam; when fitting the cam make sure it is flush with both ends of the body housing.
6. Refit the impeller and replace the spline seal.
7. Replace the end cover joint, refit the end cover and secure with the screws.

Dismantling (Commander with Keel Cooler and wet Exhaust)

1. Remove the end cover screws and withdraw the cover and joint washer.
2. Extract the impeller screw and withdraw the impeller.
3. Remove the cam screw and cam from the body. Remove the old jointing compound by using a solvent, i.e. petrol.
4. Remove the wear plate.
5. Press the shaft and coupling assembly out of the body.
6. Remove the seals and slinger from the body.
7. Inspect each component and renew as necessary.

Re-assembling

1. Refit the seals and slinger.
2. Press the shaft and coupling assembly into position in the body.
3. Locate the wear plate in the body.
4. Brush a non-setting jointing compound e.g. Hylomar on the cam screw thread and upper surface of the cam; when fitting the cam make sure it is flush with both ends of the body housing.
5. Refit the impeller and screw.
6. Replace the end cover joint, refit the end cover, and secure with the screws.

Dismantling (Captain with Keel Cooler and wet Exhaust)

1. Remove the end cover screws and withdraw the cover and joint washer.
2. Withdraw the pulley and slacken off the packing nut.
3. Extract the impeller screw and withdraw the impeller.
4. Remove the cam screw and withdraw the cam from the body.
5. Remove the packing nut, and extract the packing.
6. Press the shaft from the body.
7. Inspect each component and renew as necessary.

Re-assembling

1. Lubricate the shaft with machine oil and press the shaft back into the body.
2. Dip a new packing in a light machine oil and install. Replace the packing nut.
3. Brush a non-setting jointing compound e.g. Hylomar on the cam screw thread and upper surface of the cam; refit the cam.
4. Lubricate the impeller housing (pump body) with a good quality water pump grease and refit the impeller.
5. Replace the cover joint, refit the cover and secure with the screws.

Dismantling (Captain with Heat Exchanger)

1. Remove the end cover screws and withdraw the cover and joint washer.
2. Remove the pulley and loosen off the packing nut.
3. Withdraw the shaft and impeller assembly from the body.
4. Remove the impeller by sliding it towards the flattened end of the shaft.
5. Extract the cam screw and cam. Remove the old jointing compound by using a solvent, i.e. petrol.
6. Remove the packing nut and gland, and extract the old packing with a small screwdriver.
7. Inspect all components for wear or damage and replace as necessary.

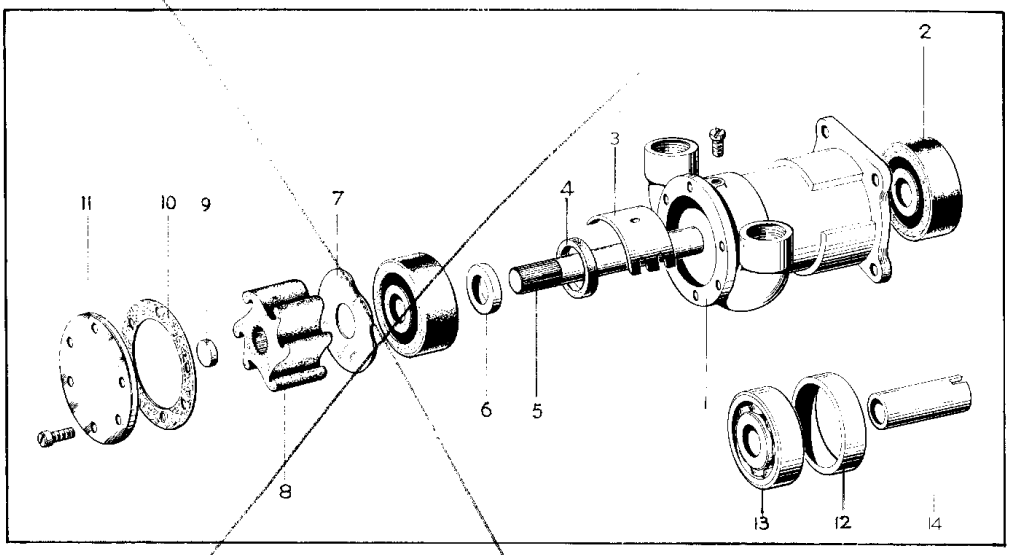


Fig.7 - Sea water pump (Commander with Heat exchanger)

1.	Body	6.	Slinger	11.	End cover
2.	Seal	7.	Wear plate	12.	Adaptor ring
3.	Cam	8.	Impeller	13.	Bearing
4.	'O' ring	9.	Seal spline	14.	Coupling
5.	Shaft	10.	Joint		

Re-assembling

1. Dip the new packing in a light machine oil and install the packing, packing gland and packing nut.
2. Coat the cam screw threads and the top of the cam with a non-setting jointing compound and install in the pump body.
3. Replace the key in the shaft and slide the impeller on the shaft from the flattened end.
4. Lubricate the impeller housing (pump body) with a good quality water pump grease, and the shaft with machine oil. Replace the shaft and impeller assembly in the body.
5. Replace the cover joint, refit the end cover, and secure with the screws. Hand tighten the packing nut during operation and gradually tighten until the pump stops dripping. Set the locking nut.

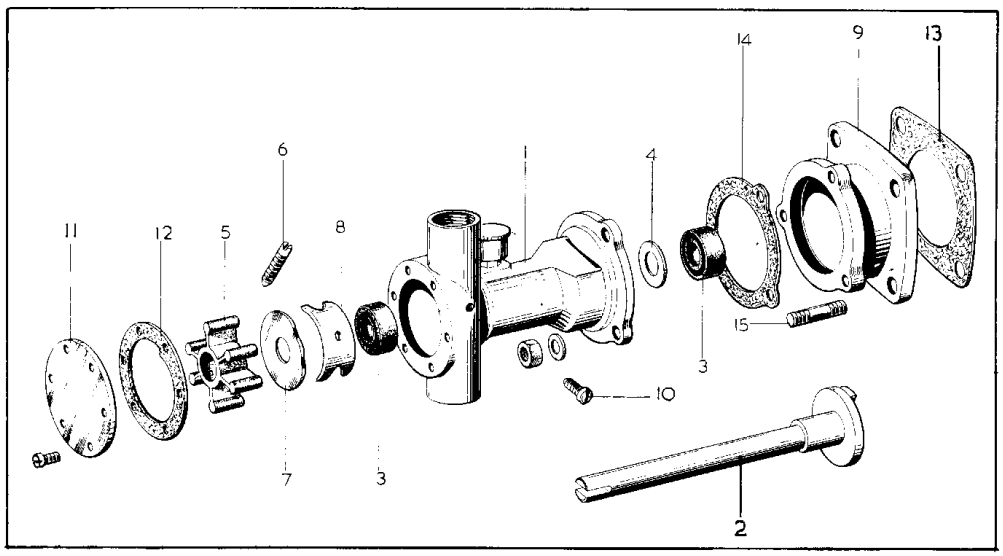


Fig.8 - Sea water pump (Commander with keel cooler)

1.	Body	6.	Impeller Screw	11.	End cover
2.	Shaft and coupling	7.	Wear plate	12.	Joint
3.	Seal	8.	Cam	13.	Joint
4.	Slinger	9.	Adaptor	14.	Joint
5.	Impeller	10.	Cam screw	15.	Stud

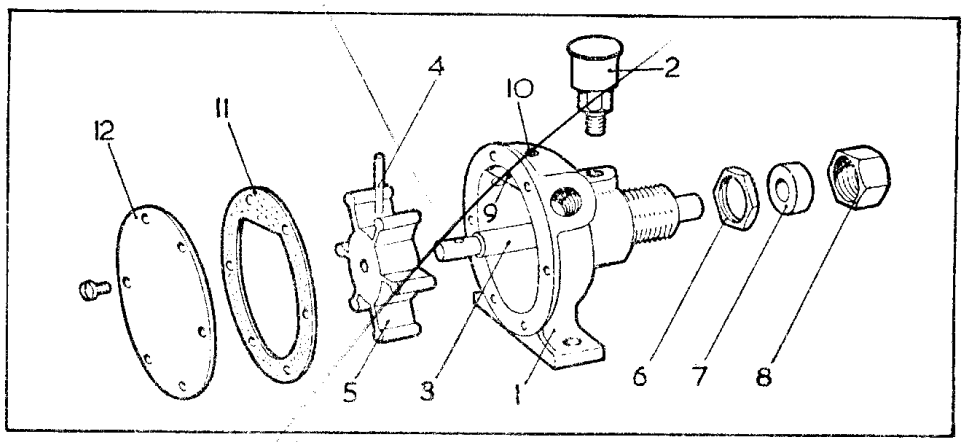


Fig.9 - Sea water pump (Captain with keel cooler)

1.	Body	7.	Packing
2.	Grease cup	8.	Packing nut
3.	Shaft	9.	Cam
4.	Impeller screw	10.	Cam screw
5.	Impeller	11.	Joint
6.	Lock nut	12.	Cover

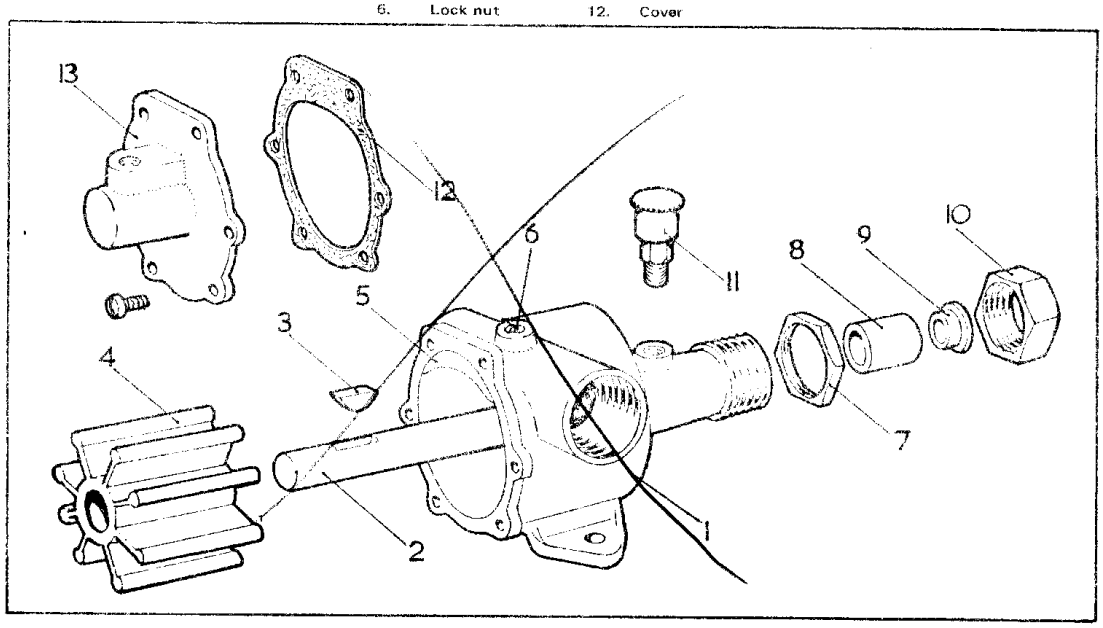


Fig.10 - Sea water pump (Captain with Heat exchanger)

1.	Body	8.	Packing
2.	Shaft	9.	Packing gland
3.	Key - impeller	10.	Packing nut
4.	Impeller	11.	Grease cup
5.	Cam	12.	Joint
6.	Cam screw	13.	Cover
7.	Lock nut		

C.8

COLD WEATHER PRECAUTIONS

When frost is expected, or when the engine is to stand idle in an unheated place, care should be taken to prevent damage to the cooling system/s and cylinder block. Such damage may be avoided by either draining the cooling system, or by adding anti-freeze solution to the cooling water.

Only anti-freeze of the ethylene glycol type, incorporating the correct type of corrosion inhibitor, is suitable, and owners are recommended to use anti-freeze conforming to specification BS.3151 or BS.3152. The percentages of anti-freeze solution for protection against different degrees of frost are:—

20% concentration Safe for 35°F (19°C) of frost
−3°F (−19°C)

25% concentration Safe for 47°F (26°C) of frost
−15°F (−26°C)

30% concentration Safe for 60°F (33°C) of frost
−28°F (−33°C)

Before introducing anti-freeze into the fresh water system it is advisable to drain and flush out the system.

SECTION D

THE FUEL SYSTEM

D.1

GENERAL DESCRIPTION

The fuel system for the Commander and Captain marine engines; also for the 2·5 litre and 1·5 litre industrial engines comprises the conventional mechanical diaphragm type lift pump, a single element fuel filter and a hydraulically governed or mechanically governed distributor type fuel injection pump.

Fuel is drawn from the fuel tank and fed by the lift pump to the injection pump via a C.A.V. fuel filter. Filtered fuel is then metered by the injection pump and forced, via four hole type injectors, into the engine combustion chambers in the form of a fine spray.

D.2

THE FUEL LIFT PUMP

Description

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.

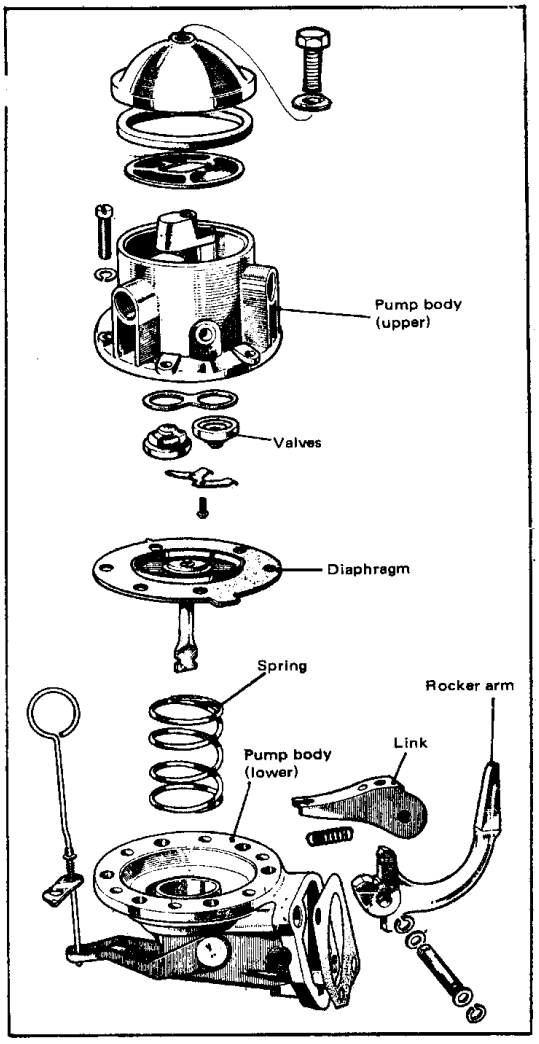


Fig.1 - Fuel lift pump (Captain and 1.5)

Removing and Replacing

1. 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. Seal the end of the pipe from the tank to prevent siphoning.
2. Before replacing the pump, which is a reversal of the foregoing procedure, test it in the following way:—
3. Immerse the pump in a bath of clean paraffin (kerosene) and flush it through by operating the rocker arm six to eight times.
4. 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.
5. 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.
6. 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 flanges for signs of air leakage.
7. Lubricate the rocker arm and the rocker arm pin with clean engine oil. Fit a new pump to cylinder block joint and refit the pump.
8. Bleed the fuel system as described in D.4 page 4

Dismantling and Re-assembling (Captain and 1·5 Industrial)

1. Scribe a mark across the pump body joint flanges for guidance when re-assembling.
2. Remove the set bolt and fibre washer securing the domed cover to the body; detach the cover and cork sealing ring and lift off the filter gauze.
3. Remove the setscrews securing the two halves of the pump body and separate the two sections.
4. Remove the two screws securing the valve retaining plate and withdraw the plate, inlet and outlet valves and valve gasket from the upper half of the pump body.
5. Press the diaphragm lightly downwards and turn it clockwise through an angle of 90° to release the diaphragm pull-rod from the operating link fork; withdraw the diaphragm and its return spring from the lower half of the body.
6. Remove the retaining clips from the ends of the rocker arm pin and press the pin out of the body to release the rocker arm, rocker arm distance washers, spring and link.
7. Wash all components in paraffin (kerosene) and blow the cavities clean with compressed air. Renew components which are worn or damaged. A new diaphragm must have the same identification colour as the original.

THE FUEL SYSTEM

D.1

GENERAL DESCRIPTION

The fuel system for the Commander and Captain marine engines; also for the 2·5 litre and 1·5 litre industrial engines comprises the conventional mechanical diaphragm type lift pump, a single element fuel filter and a hydraulically governed or mechanically governed distributor type fuel injection pump.

Fuel is drawn from the fuel tank and fed by the lift pump to the injection pump via a C.A.V. fuel filter. Filtered fuel is then metered by the injection pump and forced, via four hole type injectors, into the engine combustion chambers in the form of a fine spray.

D.2

THE FUEL LIFT PUMP

Description

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.

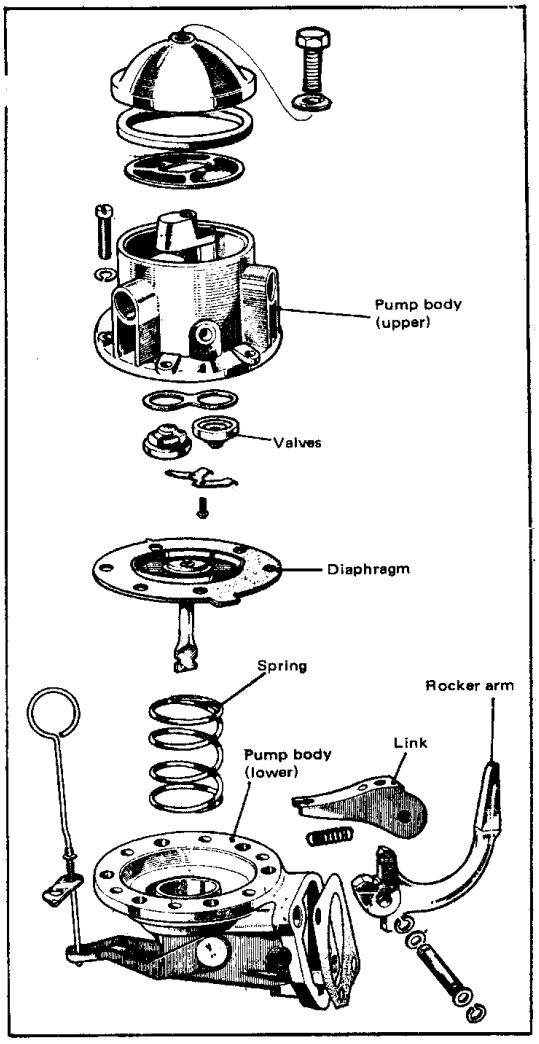


Fig.1 - Fuel lift pump (Captain and 1.5)

Removing and Replacing

1. 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. Seal the end of the pipe from the tank to prevent siphoning.
2. Before replacing the pump, which is a reversal of the foregoing procedure, test it in the following way:—
3. Immerse the pump in a bath of clean paraffin (kerosene) and flush it through by operating the rocker arm six to eight times.
4. 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.
5. 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.
6. 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 flanges for signs of air leakage.
7. Lubricate the rocker arm and the rocker arm pin with clean engine oil. Fit a new pump to cylinder block joint and refit the pump.
8. Bleed the fuel system as described in D.4 page 4

Dismantling and Re-assembling (Captain and 1·5 Industrial)

1. Scribe a mark across the pump body joint flanges for guidance when re-assembling.
2. Remove the set bolt and fibre washer securing the domed cover to the body; detach the cover and cork sealing ring and lift off the filter gauze.
3. Remove the setscrews securing the two halves of the pump body and separate the two sections.
4. Remove the two screws securing the valve retaining plate and withdraw the plate, inlet and outlet valves and valve gasket from the upper half of the pump body.
5. Press the diaphragm lightly downwards and turn it clockwise through an angle of 90° to release the diaphragm pull-rod from the operating link fork; withdraw the diaphragm and its return spring from the lower half of the body.
6. Remove the retaining clips from the ends of the rocker arm pin and press the pin out of the body to release the rocker arm, rocker arm distance washers, spring and link.
7. Wash all components in paraffin (kerosene) and blow the cavities clean with compressed air. Renew components which are worn or damaged. A new diaphragm must have the same identification colour as the original.

8. Check the body castings for cracks and, using a straight-edge, ensure that the diaphragm mounting flanges are true. If they are found to be distorted they may be lapped to restore their condition.
9. Check that the wear on the rocker arm working surface does not exceed 0·010 in. (0·25 mm). The rocker arm pin should be a tap fit in the pump body, and if, due to wear, it is loose, the holes in the body may be closed by peening. Refit, or renew the rocker arm, as necessary.
10. 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. 2). Press the diaphragm downwards and turn it anti-clockwise through an angle of 90° to engage the slots in the pull rod with the operating link fork.

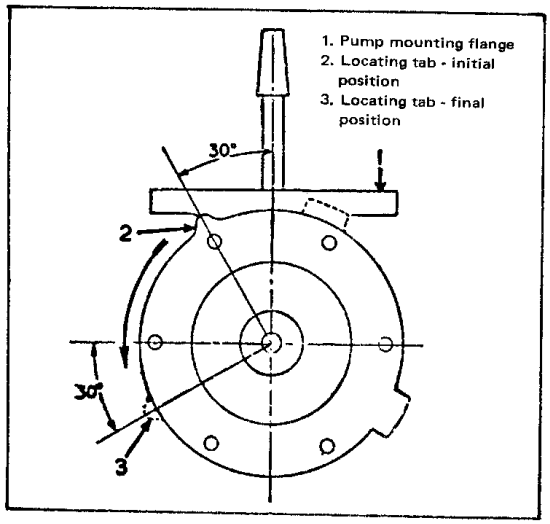


Fig.2 - Fuel lift pump diaphragm

11. Fit a new valve gasket and then install the inlet and outlet valves.
12. Position the diaphragm by means of the rocker arm so that it is level with the body joint flange. Place the upper half of the pump in position, ensuring that the marks scribed on the joint flanges during dismantling coincide, and secure the two halves of the body, leaving the screws finger tight.
13. Push the rocker arm towards the body to position the diaphragm at the bottom of its stroke. With the diaphragm held in this position tighten the screws in a diagonal sequence.
14. Replace the filter gauze, fit a new cover joint, and replace the domed cover and secure, but do not over tighten the setbolt.
15. Test the pump as described under 'Removing and Replacing'.

Dismantling and Re-assembling (Commander and 2·5 Industrial)

1. Scribe a mark across the body joint flanges.
2. Remove the domed cover, sealing ring and filter gauze.
3. Remove the setscrews securing the two halves of the pump body and separate the two sections.
4. Press the diaphragm lightly downwards, rotate it through 90° and withdraw the diaphragm, spring and oil seal.
5. Check the rocker arm pin and linkage for wear or damage. If necessary secure the rocker arm in a vice and tap the face of the pump mounting flange to dislodge the rocker arm pin retainers.
6. Wash the body and components in paraffin (kerosene) and blow the cavities in the casting clean with compressed air.

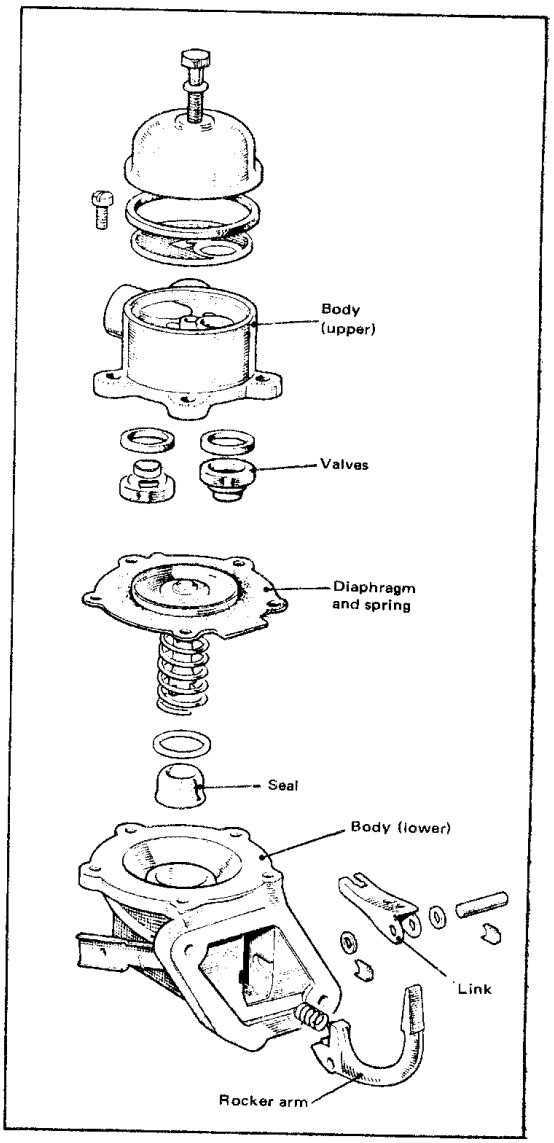


Fig.3 - Fuel lift pump (Commander and 2.5)

7. Renew components, as necessary, then assemble the rocker arm, operating link and packing washers on to the rocker arm pin. Place this assembly and the rocker arm return spring in position in the pump body and tap two new rocker arm pin retainers fully home in their grooves. Secure the retainers by staking the ends of the grooves.
8. Should the valves be suspect, lever them out carefully with a screwdriver. Renew the valve gaskets, press in the new valves and stake them in position.
9. If necessary renew the diaphragm and check that the free length of the diaphragm spring is 1⅛ in. (25·58

mm). When renewing the spring ensure the identification colour is green, the same as the original.

10. Renew the diaphragm rod oil seal and the seals for the domed cover and its screw.
11. Fit the new diaphragm rod oil seal and oil seal retainer, locate the diaphragm spring and insert the diaphragm into the pump body with its locating tab in the 11 o'clock position. Press the diaphragm downwards and turn it counter-clockwise through an angle of 90° to engage the slots in the pull rod with the operating link fork.
12. Position the diaphragm by means of the rocker arm, so that it is level with the body joint flange. Place the upper half of the pump in position, ensuring that the marks scribed on the joint flanges during dismantling coincide and secure the two halves of the body leaving the screws finger right.
13. Push the rocker arm towards the body to position the diaphragm at the bottom of its stroke. With the diaphragm held in this position tighten the screws in a diagonal sequence.
14. Replace or renew the filter screen, fit the new cover joint, replace the domed cover and secure, but do not over tighten the setscrew.
15. Test the pump as described under 'Removing and Replacing' page 2

D.3

MAIN FUEL FILTER

Description

The main fuel filter consists of three main parts, a head and a base casting between which is clamped a metal canister containing the paper filter element.
An 'O' ring located in an annular groove in the centre boss of the filter seals the dirty side of the filter from its clean side.

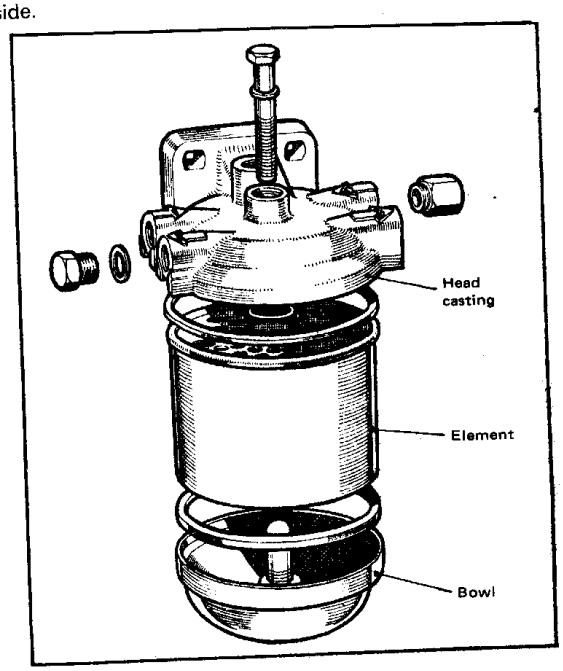


Fig.4 - Main fuel filter assembly

The head casting is provided with two inlets, two outlets and air vent connection. One outlet connection is not required and is fitted with a sealing plug. The second inlet connection returns fuel oil, surplus to injection pump requirements, to the dirty side of the filter.
An auxiliary pipe connects the vent connection on the top of the filter head to the injector leak-off pipe, providing continuous air venting of the fuel during operation.

Removing and Replacing

1. Thoroughly clean the filter externally.
2. Disconnect the three fuel pipes and the leak-off pipe from the filter head.
3. Remove the two bolts and nuts securing the filter to its mounting bracket and withdraw the filter from the engine.
   Replace in the reverse order, but upon completion bleed the fuel system, as described in D.4 operations 2 and 3.

Dismantling and Re-assembling

1. Unscrew the bolt from the centre of the filter head and detach the base casting.
2. Remove the filter element, using a twisting movement to separate the element from the filter head.
3. Withdraw the three sealing rings from their locations in the head and base castings: unscrew the blanking plug from the filter head.
4. Thoroughly clean all components, excepting the filter element and sealing rings, in petrol and allow them to dry.
5. Fit the blanking plug into connection No. 4.
6. Install a new element and sealing rings. The element is fitted with its strengthened rim uppermost.

D.4

BLEEDING THE FUEL SYSTEM

1. Ensure that there is an adequate supply of fuel in the fuel tank.
2. Slacken the union nut at the filter end of the injection pump feed pipe. Operate the lift pump, and when the fuel passing the union thread is free from air bubbles, tighten the union nut.
3. Unscrew the blanking plug in the unused outlet connection on the filter head, sufficiently to allow fuel at lift pump pressure to pass the thread on the plug. Operate the lift pump and when the fuel issuing from around the plug thread is free from air bubbles, tighten the plug.
4. Slacken the two air bleed valves on the fuel injection pump. One bleed valve is located on the governor or control cover, while the other is incorporated in the hydraulic head locking screw situated immediately above the pump nameplate. Operate the lift pump and when the fuel flowing from both bleed valves is free of air bubbles, tighten the valves.

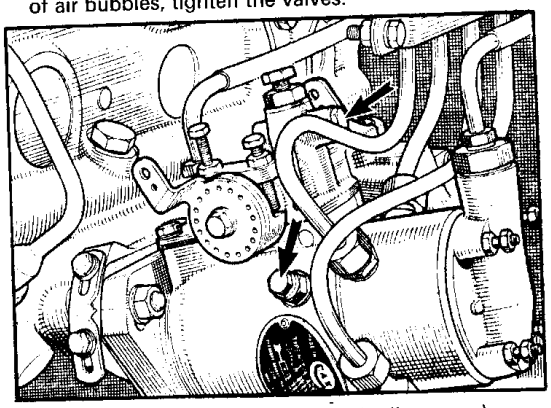


Fig.5 - Bleed valves (Pump with hydraulic governor)

mm). When renewing the spring ensure the identification colour is green, the same as the original.

10. Renew the diaphragm rod oil seal and the seals for the domed cover and its screw.
11. Fit the new diaphragm rod oil seal and oil seal retainer, locate the diaphragm spring and insert the diaphragm into the pump body with its locating tab in the 11 o'clock position. Press the diaphragm downwards and turn it counter-clockwise through an angle of 90° to engage the slots in the pull rod with the operating link fork.
12. Position the diaphragm by means of the rocker arm, so that it is level with the body joint flange. Place the upper half of the pump in position, ensuring that the marks scribed on the joint flanges during dismantling coincide and secure the two halves of the body leaving the screws finger right.
13. Push the rocker arm towards the body to position the diaphragm at the bottom of its stroke. With the diaphragm held in this position tighten the screws in a diagonal sequence.
14. Replace or renew the filter screen, fit the new cover joint, replace the domed cover and secure, but do not over tighten the setscrew.
15. Test the pump as described under 'Removing and Replacing' page 2

D.3

MAIN FUEL FILTER

Description

The main fuel filter consists of three main parts, a head and a base casting between which is clamped a metal canister containing the paper filter element.
An 'O' ring located in an annular groove in the centre boss of the filter seals the dirty side of the filter from its clean side.

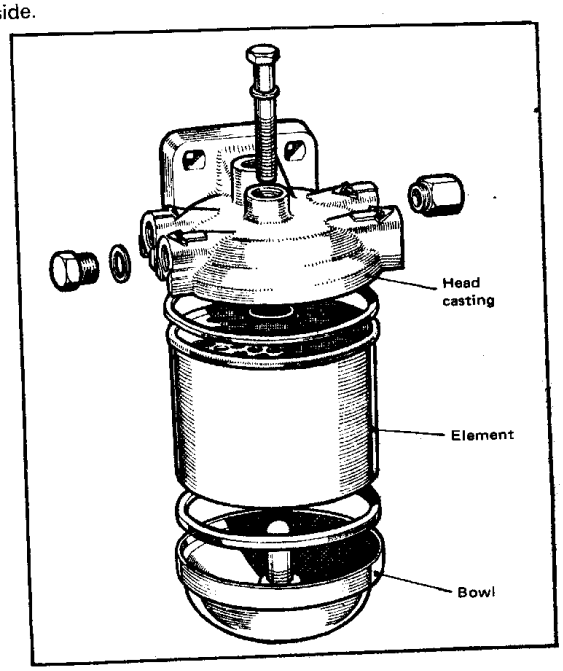


Fig.4 - Main fuel filter assembly

The head casting is provided with two inlets, two outlets and air vent connection. One outlet connection is not required and is fitted with a sealing plug. The second inlet connection returns fuel oil, surplus to injection pump requirements, to the dirty side of the filter.
An auxiliary pipe connects the vent connection on the top of the filter head to the injector leak-off pipe, providing continuous air venting of the fuel during operation.

Removing and Replacing

1. Thoroughly clean the filter externally.
2. Disconnect the three fuel pipes and the leak-off pipe from the filter head.
3. Remove the two bolts and nuts securing the filter to its mounting bracket and withdraw the filter from the engine.
   Replace in the reverse order, but upon completion bleed the fuel system, as described in D.4 operations 2 and 3.

Dismantling and Re-assembling

1. Unscrew the bolt from the centre of the filter head and detach the base casting.
2. Remove the filter element, using a twisting movement to separate the element from the filter head.
3. Withdraw the three sealing rings from their locations in the head and base castings: unscrew the blanking plug from the filter head.
4. Thoroughly clean all components, excepting the filter element and sealing rings, in petrol and allow them to dry.
5. Fit the blanking plug into connection No. 4.
6. Install a new element and sealing rings. The element is fitted with its strengthened rim uppermost.

D.4

BLEEDING THE FUEL SYSTEM

1. Ensure that there is an adequate supply of fuel in the fuel tank.
2. Slacken the union nut at the filter end of the injection pump feed pipe. Operate the lift pump, and when the fuel passing the union thread is free from air bubbles, tighten the union nut.
3. Unscrew the blanking plug in the unused outlet connection on the filter head, sufficiently to allow fuel at lift pump pressure to pass the thread on the plug. Operate the lift pump and when the fuel issuing from around the plug thread is free from air bubbles, tighten the plug.
4. Slacken the two air bleed valves on the fuel injection pump. One bleed valve is located on the governor or control cover, while the other is incorporated in the hydraulic head locking screw situated immediately above the pump nameplate. Operate the lift pump and when the fuel flowing from both bleed valves is free of air bubbles, tighten the valves.

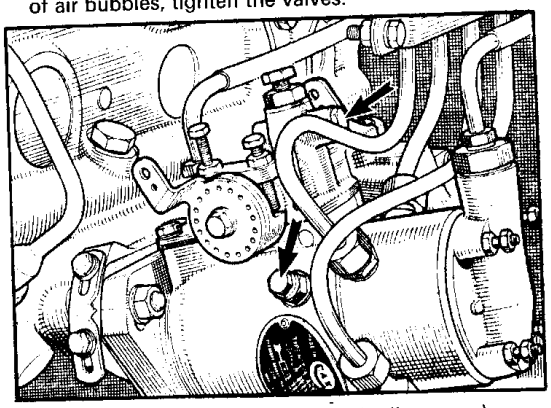


Fig.5 - Bleed valves (Pump with hydraulic governor)

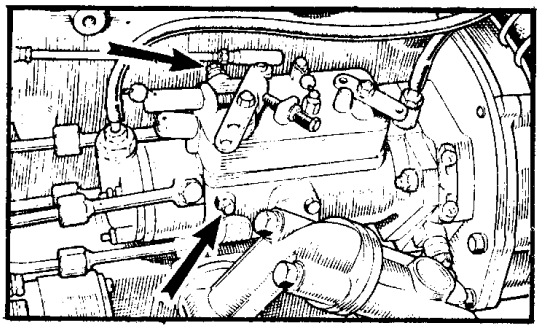


Fig.6 - Bleed valves (Pump with mechanical governor)

5. Slacken the union nuts at the injector ends of any two high pressure pipes. Ensure that the stop control is in the 'run' position, and set the throttle in the fully open position. Crank the engine until the fuel flowing from both pipes is free from air bubbles, then tighten the pipe union nuts.
6. Start the engine and allow it to run until it is firing on all cylinders. After renewing the main fuel filter element it will only be necessary to bleed the filter as described in operations 2 and 3, providing the engine is not cranked during this operation.

D.5

THE FUEL INJECTION PUMP

Description

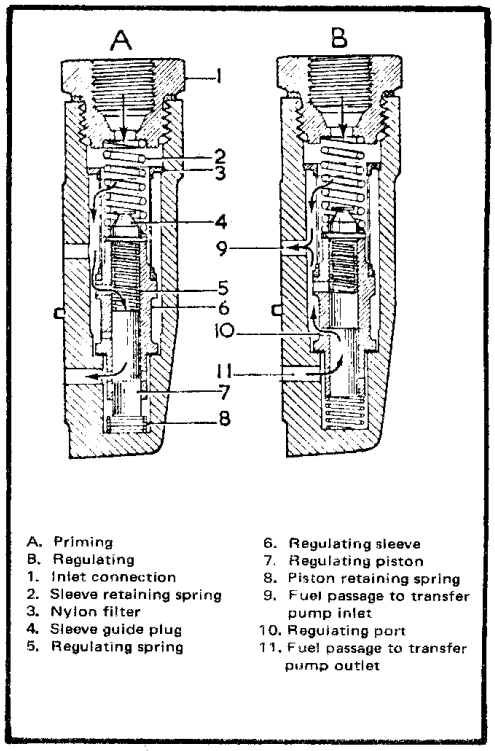
The C.A.V. DPA type fuel injection pump is a single cylinder, opposed plunger, inlet metering distributor type, incorporating either a mechanical or a hydraulic governor and an automatic advance device which is hydraulically operated. The pump illustrated in Figs. 11 and 12 consists essentially of three main rotating members, the drive shaft, a pumping and distributing rotor and a sliding vane type transfer pump, arranged on a common axis so that they rotate as one. The rotor, spline coupled to the drive shaft, carries at its outer end the transfer pump which is covered by an end plate housing the transfer pump pressure regulating valve. Where a mechanical type gover nor is fitted, a quill shaft is interposed between the drive gear hub on the engine and the drive shaft, the two shafts being coupled by a splined drive hub.

Transfer Pump and Pressure Regulating Valve

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

The pressure regulating valve, in addition to regulating the pressure of the fuel from the transfer pump, also provides a means of by-passing the transfer pump when priming the injection pump.

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



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

Fig.7 - Pressure regulating valve

When the injection pump is in operation, fuel at transfer pressure enters the lower end of the valve sleeve, forcing the 'free' piston upwards against the regulating spring to progressively uncover the regulating port in the valve sleeve and allow a metered flow of fuel to by-pass back to the inlet side of the transfer pump. The transfer pressure therefore, is controlled by a balance between the regulating spring pressure and the requirements of the injection pump at any moment. On the pump fitted with a hydraulic governor the maximum movement of the piston is restricted by a screw, in order to increase the rate at which transfer pressure rises. The screw, referred to as a transfer pressure adjuster, is set during manufacture to suit the application concerned.

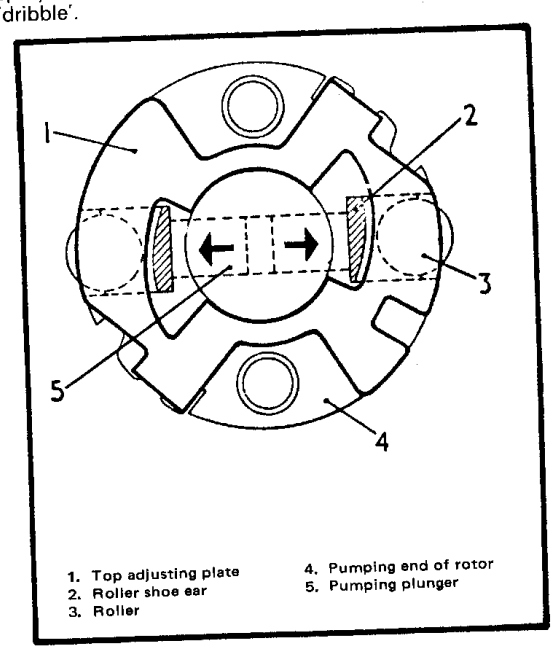
Pumping and Distributing Rotor

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

The distributor part of the rotor contains a central axial passage which connects the pumping space between the plungers with the four inlet ports and a single distributing port drilled radially in the rotor. The inlet, or charging, ports are equally spaced around the rotor at an intermedi-

ate position, and as the rotor turns, these ports are aligned successively with the inlet or metering port in the hydraulic head. This port admits fuel to the rotor under control of the metering valve. The radial hole at the outer end of the rotor is the distributing port, and as the rotor turns, this port is aligned successively with the outlet ports in the hydraulic head, from which the injectors are fed via external high-pressure pipes.

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



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

Fig.8 - Pumping and distributing rotor

Automatic Advance Control

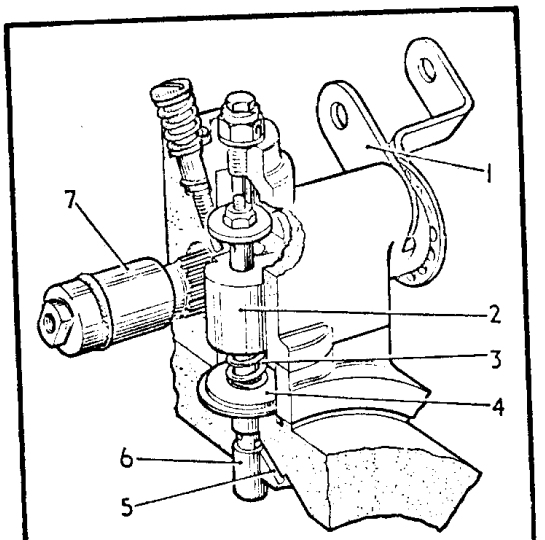
An automatic advance control mechanism is fitted, which operates by rotating the cam ring within the pump body. A ball-ended cam screw, screwed into the cam ring is operated by a piston sliding in a cylinder.

One side of the piston is spring loaded, while the other side is subjected to fuel at transfer or drain pressure, according to engine load, which is admitted to the cylinder through the hollow locating bolt and a port in the cylinder wall. The pressure of fuel is controlled by the rotary and/or endwise movement of the metering valve.

Fuel Metering with Hydraulic Governor

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

The metering valve slides in a bore in the hydraulic head into which bore the diagonally drilled metering port opens. A damping valve is carried on the metering valve stem



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

Fig.9 - Hydraulic governor

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

Idling speed is controlled by the spring-loaded screw on the governor housing, which limits the movement of the rack on the metering valve stem towards the stop position. Later pumps feature a re-designed governor housing and throttle shaft. A machined flat on the end of the shaft and a chamfered control sleeve on the metering valve perform a similar function to the rack and pinion shaft. Maximum and idling speeds are controlled by the respective screws in conjunction with a stop plate on the throttle shaft. The governor is operated by fuel at transfer pressure which is fed from the annular groove surrounding the pump rotor. The fuel passes through the hollow metering valve into the annular space around the valve via holes drilled transversely in the valve. Axial movement of the metering valve varies the area of the metering port in the hydraulic head which registers with the annulus around the valve, the effective area of the port being that which is uncovered by the lower edge of the annulus.

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

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

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

Fuel Metering with Mechanical Governor

The mechanical governor is of the flyweight type, the weights being held in a retainer, which is clamped between the injection pump drive hub and the drive shaft and rotates as a single unit.

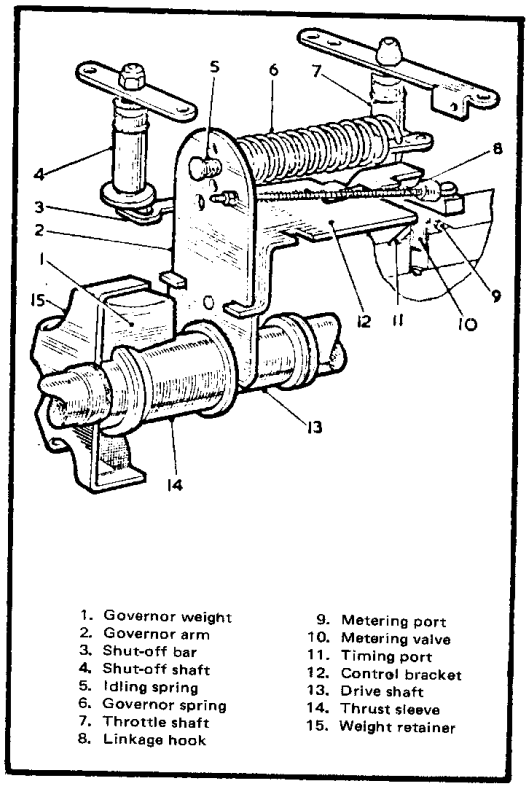


Fig.10 - Mechanical governor

The weights are a sliding fit in the retainer pockets and are so shaped that, when under the influence of centrifugal force, they pivot about one edge. A thrust sleeve, which is a sliding fit on the injection pump drive shaft is moved axially by the flyweights. Movement of the thrust sleeve is transmitted by means of the governor arm and the spring-loaded hook link to rotate the metering valve. The governor arm pivots about a fulcrum on the control bracket and is held in contact with the thrust sleeve by spring tension. Connection between the governor arm and the throttle arm and shaft assembly is made through the governor spring and the idling spring and its guide.

A shut-off bar, operated by an external lever, rotates the metering valve to close the metering port.

The metering valve is provided with a vertical slot along which fuel passes at transfer pressure into the metering port. The valve is situated in a chamber in the hydraulic head, into which the diagonally drilled metering port opens, and rotation of the valve varies the effective area of the metering port to regulate the flow of fuel to the pumping and distributing rotor.

When the throttle arm is moved to give increased speed, the light idling spring is compressed as the guide is drawn through the governor arm and the governor spring is tensioned. Tension of the governor spring, acting upon the governor arm and thrust sleeve, resists movement of the governor flyweight.

As the engine speed increases, the increasing centrifugal force moves the flyweight outwards, overcoming the governor spring tension to move the governor arm and the metering valve towards the closed position. When the selected speed has been attained it will be maintained by governor action. Should the engine speed fall, the flyweights will move inwards, causing an increase of fuelling which restores the selected engine speed.

When the throttle arm is in the idling position the governor spring is untensioned and governing action is controlled by the light idling spring.

The position of the metering valve depends upon the setting of the throttle arm, which varies the governor spring pressure on the governor arm. Any variation in pump speed is accompanied by an increase or decrease in transfer pressure, which assists in regulating the flow of fuel into the pumping section of the rotor. The volume of fuel passing into the pumping element is thus controlled by the transfer pressure, the position of the metering valve, and the time during which an inlet port in the rotor is aligned with the metering port in the hydraulic head.

Removing the pump from the engine

1. Disconnect the throttle and stop control cables from the control levers on the fuel injection pump.
2. Disconnect the fuel feed and return pipes from the pump.
3. Disconnect the high pressure pipes from the pump and the injectors and withdraw the pipes complete with clamps and damper bushes.
4. Seal the pump outlet unions and the inlet unions on the fuel injectors with Sealing caps 18G216.
5. Remove the securing nuts and withdraw the pump from the engine.

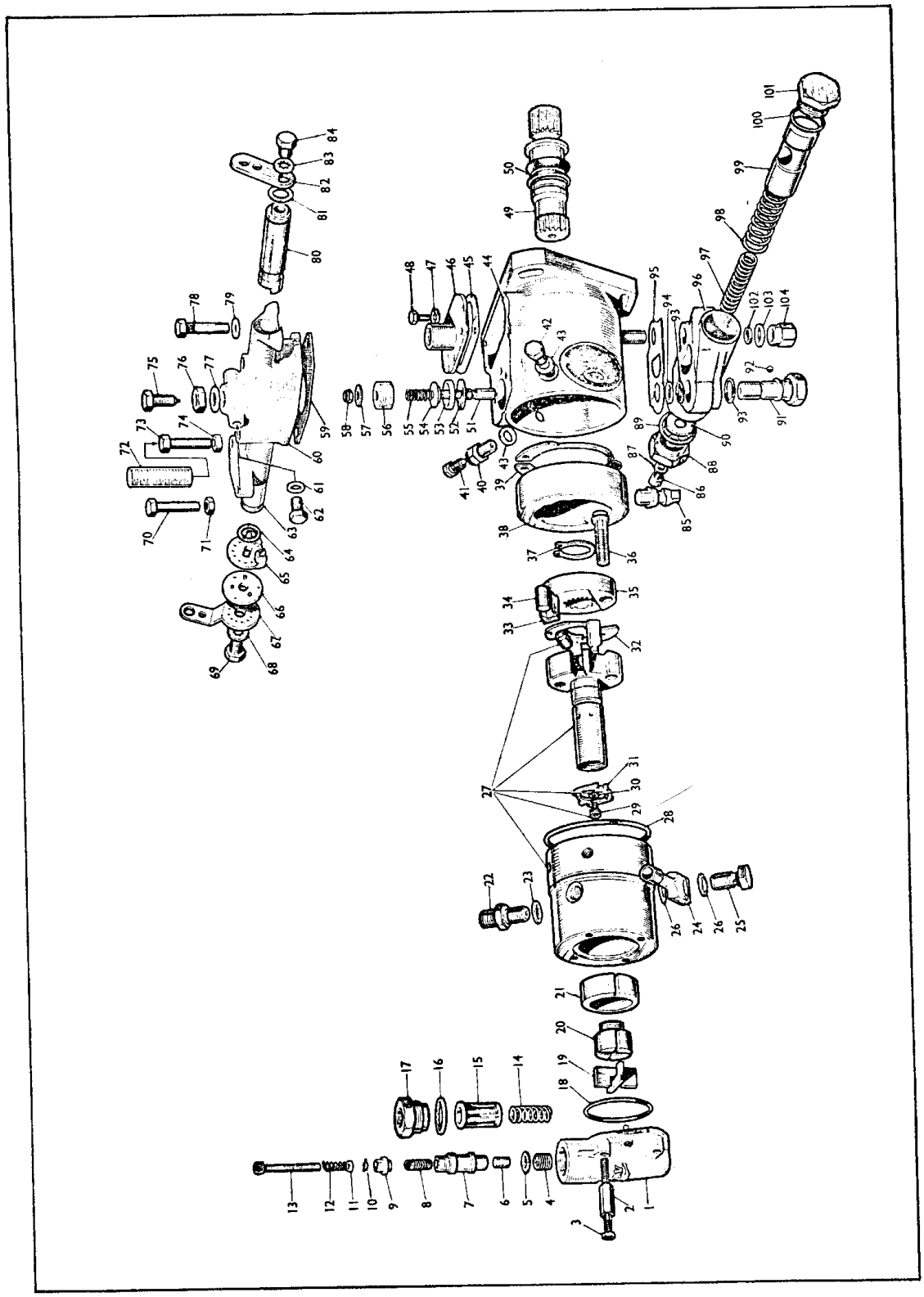


Fig.11 - Fuel injection pump with hydraulic governor (Captain and 1.5)

No.	Description

No.	Description
1	End plate
2	Stud for end plate
3	Nut for stud
4	Piston retaining spring
5	Washer for sleeve
6	Regulating piston
7	Regulating sleeve
8	Regulating spring
9	Plug for sleeve
10	Torsion spring for plug
11	Washer for plug
12	Spring for adjusting screw
13	Adjusting screw
14	Sleeve retaining spring
15	Filter
16	Washer for inlet connection
17	Fuel inlet connection
18	Seal for transfer pump
19	Transfer pump vanes
20	Transfer pump rotor
21	Transfer pump liner
22	Radial connection
23	Washer for connection
24	Banjo connection
25	Bolt for banjo connection
26	Washer for banjo bolt
27	Hydraulic head and rotor assembly
28	Seal for hydraulic head
29	End plug for rotor
30	Washer for plug
31	Bottom adjusting plate
32	Top adjusting plate
33	Shoe for roller
34	Roller
35	Drive plate

No.	Description
36	Screw for drive plate
37	Circlip for drive shaft
38	Cam ring
39	Circlip for cam ring
40	Hydraulic head locking screw (vented)
41	Vent screw
42	Hydraulic head locking screw (plain)
43	Washer for locking screw
44	Pump housing
45	Gasket for cover
46	Adjusting hole cover
47	Washer for screw
48	Screw for cover
49	Drive shaft
50	Seal for drive shaft
51	Metering valve
52	Damping valve seating washer
53	Damping valve centre washer
54	Damping valve spring plate
55	Governor spring
56	Control sleeve
57	Shut-off washer
58	Nut for metering valve
59	Gasket for governor housing
60	Governor housing
61	Washer for screw
62	Vent screw
63	Throttle shaft
64	Seal for shaft
65	Stop plate
66	Vernier plate
67	Throttle lever
68	Washer for screw
69	Screw for throttle lever
70	Idling stop screw

No.	Description
71	Locknut
72	Locking sleeve
73	Maximum speed stop screw
74	Locknut
75	Idling damper
76	Locknut
77	Sealing washer
78	Screw for governor housing
79	Washer for screw
80	Shut-off shaft
81	Seal for shaft
82	Shut-off lever
83	Washer for screw
84	Screw for shut-off lever
85	Cam advance screw
86	Screw for spring cap
87	Washer for screw
88	Spring cap
89	Seal for cap
90	Shim washer
91	Hydraulic head locating bolt
92	Non-return valve ball
93	Seal for locating bolt
94	Washer for locating bolt
95	Gasket for housing
96	Advance housing
97	Inner spring for piston
98	Outer spring for piston
99	Advance piston
100	Seal for end plug
101	End plug
102	Seal for cap nut
103	Aluminium washer for cap nut
104	Cap nut

Index to Fuel Injection Pump (hydraulic governor)

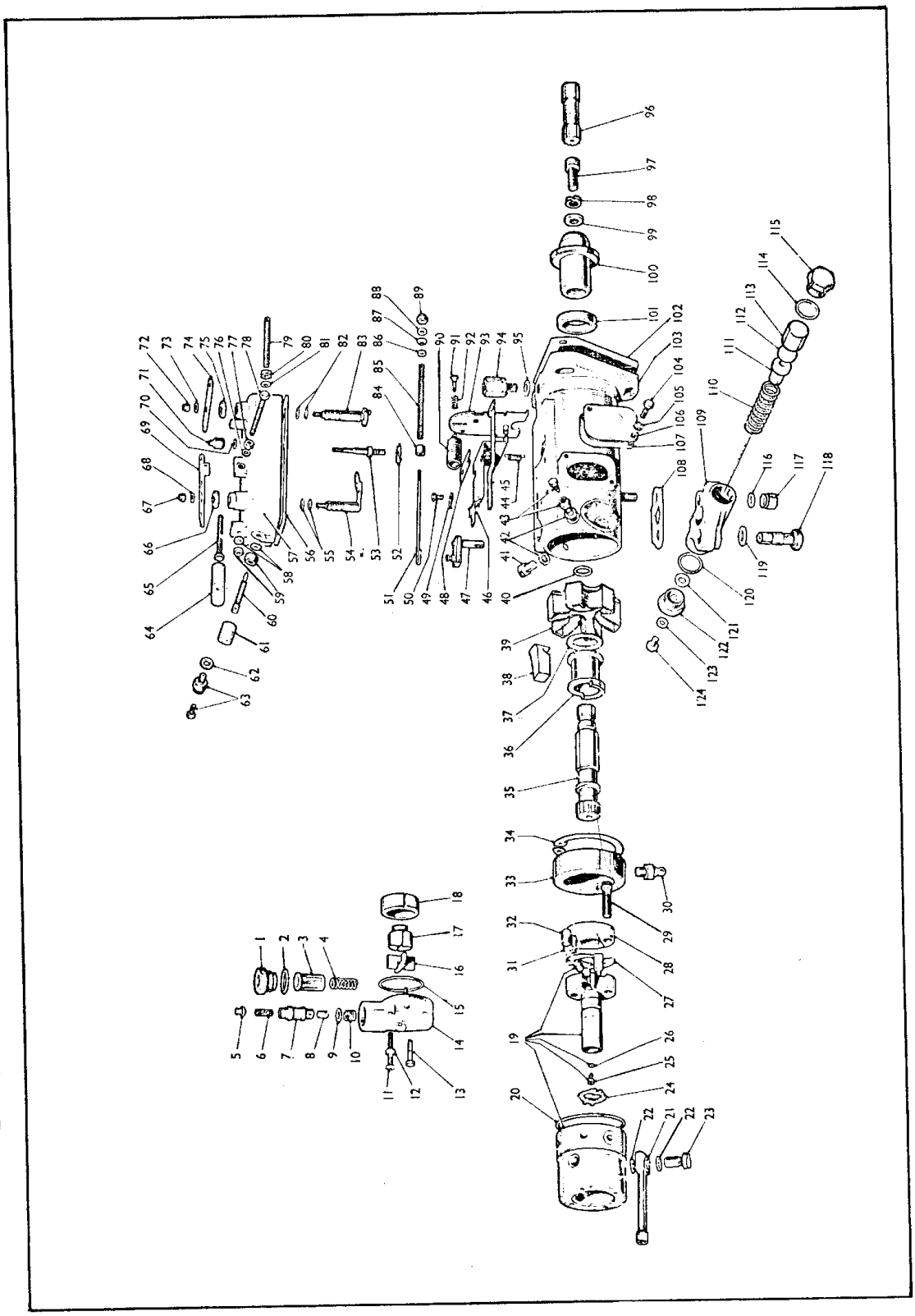


Fig.12 - Fuel injection pump with mechanical governor (Commander and 2.5)

No.	Description
1	Inlet connection
2	Washer
3	Filter
4	Sleeve retaining spring
5	Regulating plug
6	Regulating spring
7	Regulating sleeve
8	Regulating piston
9	Washer for sleeve
10	Piston retaining spring
11	Nut
12	End plate stud
13	End plate screw
14	End plate
15	Transfer pump seal
16	Transfer pump vanes
17	Transfer pump rotor
18	Transfer pump liner
19	Hydraulic head and rotor assembly
20	Hydraulic head seal
21	Banjo pipe
22	Washer
23	Banjo bolt
24	Adjusting plate (bottom)
25	Rotor plug
26	Washer
27	Adjusting plate (top)
28	Drive plate
29	Drive plate screw
30	Cam ring advance screw
31	Roller shoe
32	Roller
33	Cam ring
34	Circlip
35	Drive shaft
36	Thrust sleeve
37	Thrust washer
38	Governor weight
39	Governor weight retainer
40	Drive shaft 'O' ring
41	Hydraulic head locking screw
42	Washer
43	Hydraulic head locking screw and bleed screw assembly
44	Spring for governor arm and control bracket
45	Shut-off bar
46	Control bracket
47	Metering valve
48	Keep plate
49	Lock washer
50	Control bracket screw
51	Linkage hook
52	Lock washer
53	Control cover stud
54	Throttle shaft
55	'O' rings
56	Control cover gasket
57	Control cover
58	Washer
59	Locknut
60	Metering valve adjustment screw
61	Sealing cap
62	Washer
63	Air bleed screw assembly
64	Locking sleeve
65	Maximum speed stop screw
66	Dust cap
67	Throttle shaft nut
68	Washer
69	Throttle lever
70	Washer
71	Control cover nut
72	Shut-off shaft nut
73	Washer
74	Shut-off lever
75	Dust cap
76	Washer
77	Locknut
78	Idling stop screw
79	Anti-stall screw
80	Locknut
81	Washer
82	'O' rings
83	Shut-off shaft
84	Spring retainer
85	Linkage spring
86	Linkage washer
87	Pivot ball washer
88	Washer
89	Linkage nut
90	Governor spring
91	Idling spring guide
92	Idling spring
93	Governor arm
94	Drain connection
95	Washer
96	Quill shaft
97	Drive shaft screw
98	Spring washer
99	Support washer
100	Drive hub
101	Drive hub oil seal
102	Pump housing gasket
103	Pump housing
104	Screw
105	Washer
106	Housing cover-plate
107	Gasket for cover-plate
108	Gasket for advance housing
109	Advance housing
110	Spring
111	Maximum advance stop
112	Slide washer
113	Piston
114	'O' ring
115	End plug
116	Washer
117	Cap nut
118	Hydraulic head locating bolt
119	Washer
120	'O' ring
121	Shim
122	Spring cap
123	Washer
124	Screw for spring cap

Index to Fuel Injection Pump (mechanical governor)

Refitting and Re-timing

1. Position the crankshaft so that No. 1 piston is at 22° B.T.D.C. on its compression stroke (Captain and 1·5) or 25° B.T.D.C. on its compression stroke (Commander and 2·5). The notch on the crankshaft pulley will be aligned with the appropriate degree mark on the timing cover degree plate.
2. Fit the Injection timing gauge 18G629 (Captain and 1·5) or the Injection timing gauge 18G698 (Commander and 2·5) in place of the injection pump, apply gentle clockwise pressure to eliminate slack and set the timing pointer in line with the mark on the timing gauge. Secure the timing pointer and remove the gauge.

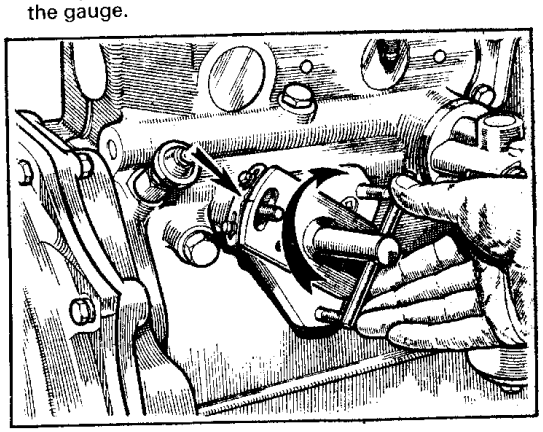


Fig.13 - Using Injection timing gauge 18G629

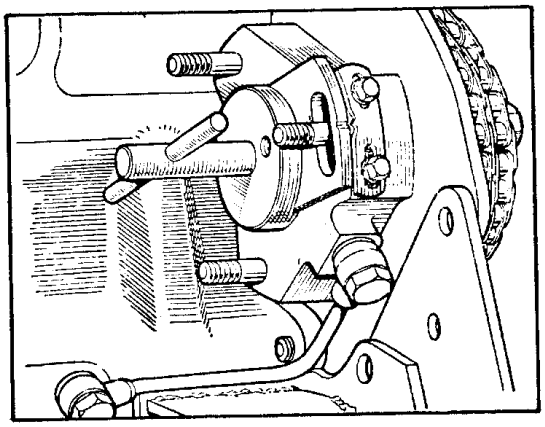


Fig.14 - Injection timing gauge 18G698

3. Position the master spline of the pump quill, or drive shaft to align with the opposite spline of the driving flange or driving spindle and fit the pump to the engine lining up the mark on the pump housing with the timing pointer. Include a new pump to hub joint.
4. Remove the sealing caps from the injection pump outlet unions and the injector inlet unions and reconnect the high pressure pipes and fuel feed and return pipes.
5. Reconnect the throttle and stop control cables to the respective levers on the governor housing or control cover, ensuring that both levers have a full range of movement when operated.
6. Bleed the fuel system as described and start the engine.

Maximum and Idling speed adjustments

After fitting either a new or overhauled pump the engine maximum light running speed and the idling speed should be checked, and if necessary, adjusted. Before making either of these adjustments, it is essential that the engine air cleaner is correctly serviced and fitted.

1. Run the engine until it has attained its normal running temperature – THIS IS MOST IMPORTANT.

Pump with hydraulic governor (Type D.P.A. 3246857)

2. Slacken the locknut and retract the idling damper on the top of the governor housing two complete turns. Tighten the locknut to secure the damper in this position. This will prevent the idling damper from interfering with the operation of the metering valve during the setting of the maximum speed.

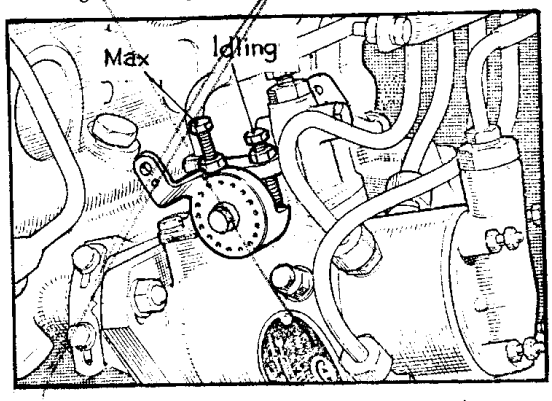


Fig.15 - Adjusting screws (hydraulic governor)

3. Using a tachometer to check the engine speed, adjust the maximum speed stop screw to give the maximum light running speed indicated on the pump nameplate. Fit the locking sleeve on top of the stop screw, and to discourage unauthorised adjustment seal with wire and lead seal, using Sealing pliers 18G541.
4. Adjust the spring loaded idling stop screw, located on the governor housing, to give an idling speed of between 500 and 600 rev/min.
5. Slacken the locknut, and screw in the idling damper assembly until the idling speed is increased slightly. Carefully retract the idling damper until the idling speed is restored, and then tighten the locknut to secure the damper in this position.

Pump with mechanical governor (Type D.P.A. 3248F80A)

2. Using a tachometer to check the engine speed, adjust the maximum speed stop screw (1) to give the maximum light running speed indicated on the pump nameplate. Tighten the locknut, fit the sleeve and seal it with wire and a lead seal using Sealing pliers 18G541.
3. Stop the engine and unscrew the anti-stall screw (2) until it is out of contact with the governor arm.
4. Start the engine and adjust the idling stop screw (3) to give an engine speed of 450 to 500 rev/min.
5. Screw in the anti-stall screw until a slight speed increase is noticed, then unscrew it one third of a turn.
6. Re-adjust the idling stop screw to give an engine speed of 500 rev/min and tighten the locknut.
7. Test the anti-stall screw setting by running the engine at 3000 rev/min and releasing the throttle:
   (a) If the engine stalls screw in the anti-stall screw slightly and re-test.
   (b) If the engine deceleration is sluggish, unscrew the anti-stall screw slightly and re-test.

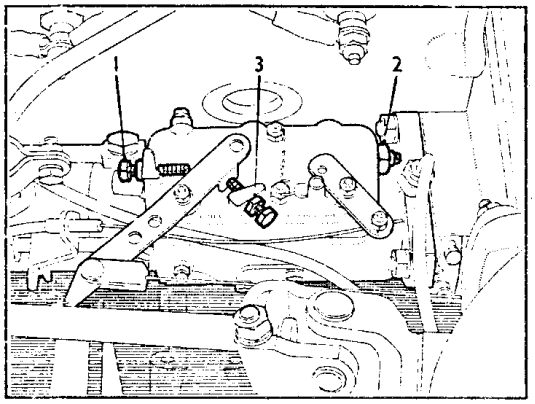


Fig.16 - Adjusting screws (mechanical governor)

8. Tighten the anti-stall screw locknut and check the operation of the stop control.
   NOTE: After every adjustment of the anti-stall screw ensure that the idling speed is controlled by the idling stop screw and not by the anti-stall screw.

OVERHAUL PROCEDURES

Dismantling (Pump with hydraulic governor type DPA3246857)

Immerse components in clean calibration fluid as they are removed.

1. Mount the pump on the D.P.A. assembly base 18G633A.
2. Remove the high-pressure connections.
3. Remove the adjusting hole cover.
4. Remove the governor housing and withdraw the securing screws.
5. Withdraw the throttle and shut-off shafts.
6. Withdraw the metering valve assembly.
7. Insert Assembly rod 18G637 through the transverse hole in the upper end of the metering valve stem, and, using the rod to hold the valve, unscrew the self locking nut from the valve to release the assembly.
8. Turn the pump to gain access to the advance unit, remove the unit, noting the non-return valve ball in the side of the hydraulic head locating bolt.
9. Remove the spring cap (note the adjusting shims), spring, piston, and end plug from the advance housing.
10. Remove the cam ring advance screw, using Torque spanner socket 18G646 and a standard ratchet wrench.
11. Remove the end plate from the hydraulic head.
12. Withdraw the transfer pump vanes and liner.
13. Remove the fuel inlet connection from the end plate and withdraw the regulating valve components.
14. Mount the Drive shaft holding tool 18G651 on the drive shaft and, using Assembly box spanner 18G634 in conjunction with a standard ratchet wrench, slacken the transfer pump rotor. The word 'OFF' and an arrow etched on the exposed face of the rotor indicate the direction in which the rotor is unscrewed.
15. Remove the two hydraulic head locking screws and withdraw the hydraulic head assembly.
16. Unscrew the transfer pump rotor.
17. Stand the hydraulic head assembly on the bench with the drive plate uppermost. Hold the drive plate with Assembly drive plate spanner 18G641 and remove the two drive plate securing screws; withdraw the drive plate and the top adjusting plate.
18. Remove the rollers and shoes.
19. Withdraw the rotor from the hydraulic head and remove the bottom adjusting plate.
20. Withdraw the cam ring.
21. Withdraw the cam ring circlip, using Circlip pliers 18G1004.
22. Remove the drive shaft circlip.
23. Withdraw the drive shaft from the pilot tube in the pump housing.
24. Renew all 'O' rings, oil seals, and gaskets.
25. Renew any springs which are damaged or of incorrect length when compared with new counterparts.
26. Examine the hydraulic head, rotor, pumping plungers, and metering valve. If any of these components are worn or damaged, renew the hydraulic head and rotor assembly.
27. Renew the cam ring and plunger rollers if they show signs of wear or flats.
28. Renew the regulating valve sleeve and piston if they are worn or if the piston is tight in the sleeve.
29. Renew the pump housing if the pilot tube bore is scored or worn.

Re-assembling

1. Fit new oil seals to the drive shaft using the Hydraulic drive shaft protection cap 18G635 to pass the seals over the splines of the shaft. The seals are flat but assume a dished shape when in position.
2. Refit the drive shaft holding the oil seal with the Hydraulic shaft seal assembly tool 18G642A as shown.

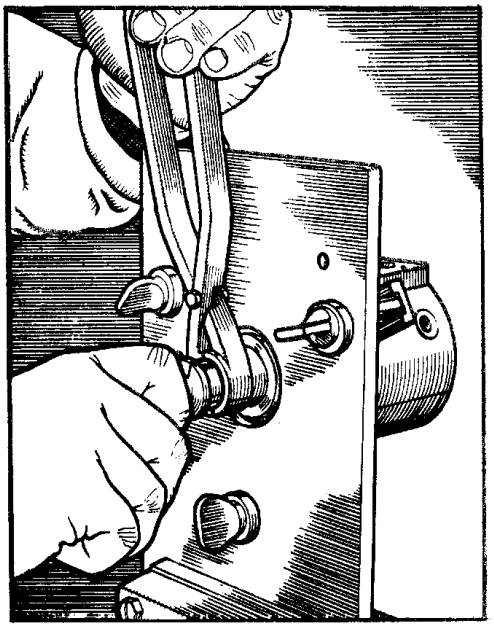


Fig.17 - Refitting the drive shaft

3. Secure the shaft in position with its circlip and th test the shaft for freedom of movement.
4. Compress the cam ring circlip, using the circlip plie and seat it against the shoulder in the bore of t pump housing.
5. Fit the cam ring (the directional arrow on its visil face should match that on the pump nameplate).
6. Fit the cam advance screw finger tight to locate t cam ring and check the ring for freedom of moveme
7. Fit the top adjusting plate and drive plate as shown Fig. 18
8. Fit the roller shoe assemblies.
9. Fit the bottom adjusting plate and insert the ro assembly into the hydraulic head.

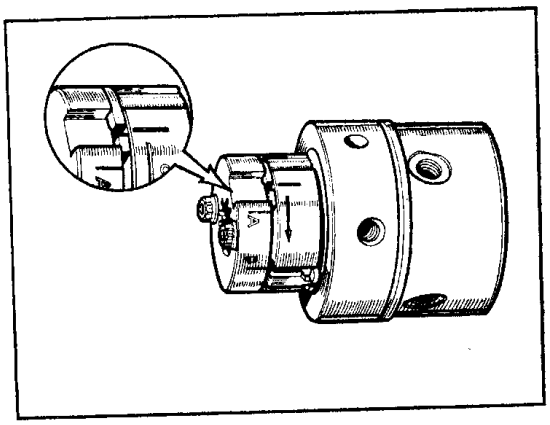


Fig.18 - Pumping and distributing rotor alignment marks

10. Fit the transfer pump rotor, but do not tighten.
11. Connect the Injector nozzle testing machine 18G109A, via the Relief valve timing adaptor 18G653A (pre-set to open at 15 atmospheres) to the high pressure outlet on the hydraulic head.
12. Operate the handle of the test machine and turn the pumping and distributing rotor in the normal direction of rotation until the plungers are forced outwards to the maximum fuel position.

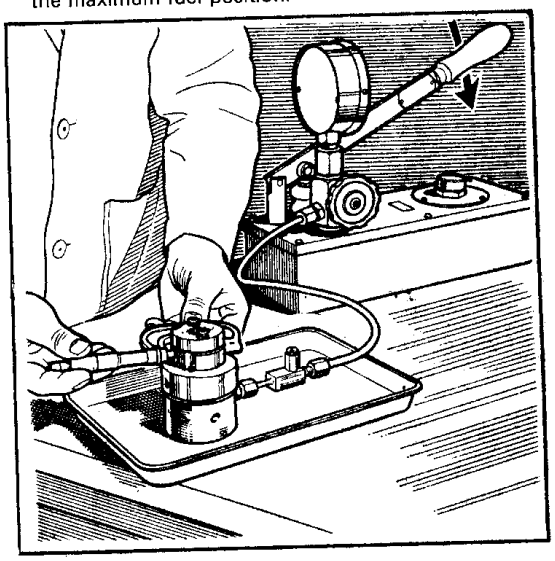


Fig.19 - Setting the roller to roller dimension

13. Set the roller-to-roller dimension to 1·98 in (50·29 mm) using the Maximum fuel adjusting probe 18G656. Move the adjusting plates clockwise to increase the dimension and counter clockwise to decrease the dimension.
14. Tighten the drive plate screws to the torque figure given in 'General Data', using the drive plate spanner.
15. Disconnect the test machine and the hydraulic adaptor from the hydraulic head.
16. Fit a new 'O' ring to the hydraulic head periphery and fit the hydraulic head to the pump body.
17. Fit both hydraulic head locking screws finger tight.
18. Tighten the transfer pump rotor to the torque figure given in 'General Data' using the Assembly box spanner 18G634 and the Drive shaft holding tool 18G651.
19. Fit the transfer pump liner and vanes.
20. Assemble the regulating valve components to the end plate in the order shown in fig. 21
21. Ensure that the transfer pump liner locating pin is fitted to position 'C' in the end plate.
22. Locate a new oil sealing ring on the hydraulic head face, and fit the end plate.

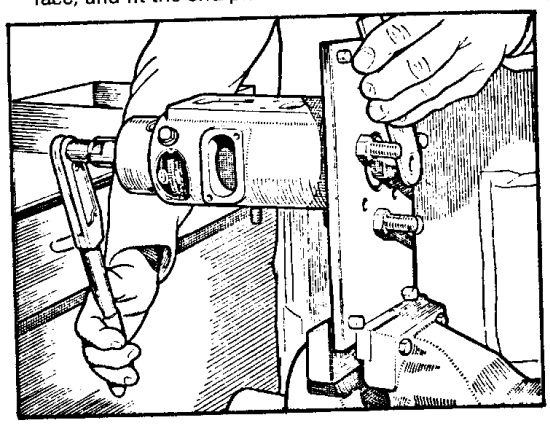


Fig.20 - Tightening the transfer pump rotor

23. Tighten the end plate screws and fuel inlet connection to the torque figures given in 'General Data'.
24. Tighten the cam ring advance screw to the torque figure given in 'General Data'.
25. Fit 'O' rings to the advance unit end plug and spring cap, using Protection cap 18G640 to pass the rings over the threads.

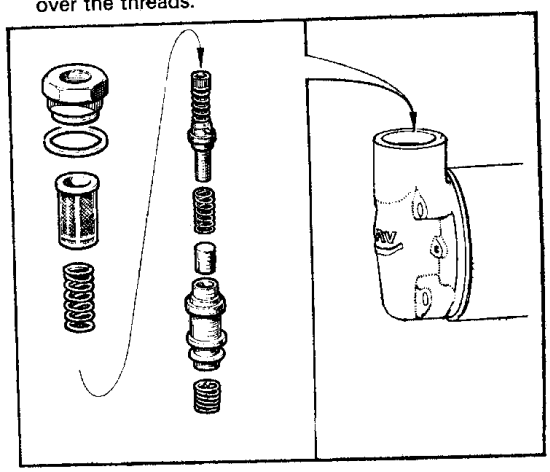


Fig.21 - Regulating valve assembly

26. Fit the end plug to the advance unit at the end where the fuel drilling enters the bore.
27. Insert the advance piston into its housing, then insert the springs into the piston.
28. Fit the original thickness of shims into the spring cap and fit the cap to the advance unit.
29. Fit the 'O' ring to the hydraulic head locating bolt, using Protection cap 18G639. Position the non-return valve ball on its seat in the side of the bolt and fit the bolt to the advance unit. Fit the 'O' ring to the shank of the head locating bolt using the Assembly cap 18G647 and fit the plain washer on top of the 'O' ring.
30. Fit the advance unit and include a new gasket.

31. Assemble the metering valve components as shown in Fig. 22 using Assembly rod 18G637, inserted through the hole in the valve stem to hold the assembly when tightening the nut.
32. Fit the 'O' rings to the throttle and shut-off shafts, using Protection cap 18G643A and Assembly cap 18G647.
33. Insert the metering valve into the governor housing and fit the throttle shaft with its end engaging between the shut-off washer and control sleeve.

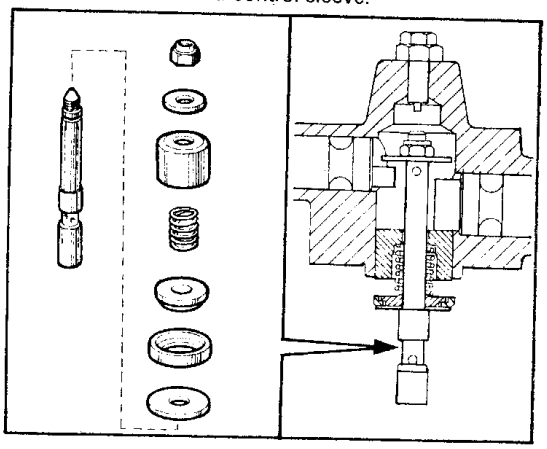


Fig.22 - Metering valve assembly

34. Fit the shut-off shaft.
35. Use the Pilot guide 18G691A to align the metering valve bore with the damping valve bore, and tighten both hydraulic head locking screws to the torque figure given in 'General Data'.
36. Tighten the advance unit cap nut, hydraulic head locating bolt, end plug, and spring cap to the torque figures given in 'General Data'.
37. Fit the governor housing and a new joint washer. The throttle lever should be on the nameplate side of the pump housing.
38. Fit the adjusting hole cover and include a new joint.
39. Mount the pump on a test bench.
40. Fit radial connections to the high-pressure outlets.
41. Remove the plain hydraulic head locking screw and fit Transfer Pressure adaptor 18G636.
42. Fit the End plate adjuster 18G690 to the inlet connection. Unscrew the adjuster fully then screw it in $1\frac{1}{2}$ turns.
43. Remove the screw from the advance unit spring cap and fit the Automatic advance gauge 18G638B. Zero the gauge.
44. Set the stop screws to give maximum throttle lever movement.
45. Make the following pump to test bench connections:
    (a) Radial connections to injectors.
    (b) Transfer pressure adaptor 18G636 to pressure gauge.
    (c) End plate adjuster 18G690 to feed pipe (with a 'T' coupling to vacuum gauge).
    (d) Adjusting hole cover, via a measuring glass, to drain pipe.
46. Prime the injection pump as follows:—
    (a) Turn on the fuel feed.
    (b) Slacken the feed pipe at the injection pump until the fuel is flowing from it free of air bubbles.
    (c) Air vent the pump from the hydraulic head vent screw.
    (d) Rotate the pump drive through 90° and again vent the hydraulic head.
    (e) Air vent the pump from the vent valve on the governor housing.
    (f) Ensure that the pump body is filled with fuel by removing and refitting the adjusting hole cover.
    (g) Run the pump at 100 rev/min (see pump nameplate for rotation) and bleed the high-pressure pipes until delivery is obtained from all injectors.
47. Test and adjust the pump.

Testing and Adjusting

1. The test bench must be set to run in the direction of the pump rotation.
2. Fuel available at injection pump inlet must be 1000 c.c. min. flow minimum or 2 lb.in^2 pressure maximum.
3. Test injectors should be a matched set with type BDN.12.SD.12 nozzles operating at 175 atmospheres.
4. Injector pipes should be 6 mm × 2 mm × 864 mm long.
5. The injection pump throttle and shut-off levers must be in the fully open position, except when otherwise stated.
6. Before taking fuel delivery readings the test oil in the measuring-glasses should be allowed to settle for 15 seconds, and the measuring glasses should be allowed to drain for 30 seconds between tests. All fuel delivery figures are for 200 shots.

TEST PLAN

Pump type DPA.3246857

Test No.	Description	Rev/min	Requirements	Action and/or Remarks
1	Transfer pump vacuum	100	16 in. Hg within 60 seconds	Fuel supply turned off. Air vent from hydraulic head vent screw at 100 rev/min after test.
2	Transfer pressure	100	11 lb. in² minimum	Exchange regulating sleeve guide plug (2 thicknesses available) to obtain this pressure.
3	Transfer pressure	1,700	50 to 62 lb. in²	Adjust as in Test 2 to obtain pressure.
4	Advance position	800	$\frac{1}{4}$ to 1°	Adjust by adding shims inside the advance unit spring cap to a maximum of 3·5 mm additional to the original 0·5 mm shim which must remain.
5	Transfer pressure	2,100	As Test 3 plus 22 lb. in²	Adjust by means of End plate adjuster 18G690.
6	Advance position	1,200	$1\frac{1}{2}$ to 2°	
7	Advance position	1,700	$2\frac{3}{4}$ to $3\frac{1}{4}$°	
8	Back-leakage	1,050	5 to 70 c.c. per 100-shot time cycle	
9	Maximum fuel delivery	1,050	*4·5 ± 0·1 c.c. average (spread between lines not to exceed 0·8 c.c.)	Adjust output by moving adjusting plate relative to drive plate with Maximum fuel adjusting probe 18G656. Tighten drive plate screws to correct torque using Drive plate screw torque adaptor 18G655A in conjunction with Torque wrench 18G537.
10	Fuel delivery	100	Average as Test 9 minus 1·4 c.c.	This is a minimum delivery figure.
11	Cut-off operation	200	Average 0·8 c.c. maximum	Shut-off lever fully closed.
12	Fuel delivery	1,700		Record delivery.
13	Governor setting	2,100	Average 0·8 c.c. maximum (no line to exceed 1·4 c.c.)	Set throttle lever with maximum speed adjustment screw.
14	Fuel delivery	1,700	Average as Test 12 minus 0·4 c.c.	This is a minimum delivery figure. Throttle lever set as in 13.
15	Timing	—		Relief valve timing adaptor 18G653A (set as 30 atmospheres) connecting Injector nozzle testing machine 18G109A to outlet 'V'. Timing mark 'G' visible through adjusting hole, apply fuel pressure. Rotate drive shaft with Universal flange marking gauge 18G648A (set at 208°) and mark pump flange with scriber.

*The maximum fuel delivery given is for sea-level conditions. For continuous use above sea-level the maximum fuel delivery should be set as follows:—

Altitude	Maximum fuel delivery
0 to 2000 ft	4·4 to 4·6 c.c.
2000 to 4000 ft	4·1 to 4·3 c.c.
4000 to 6000 ft	3·9 to 4·1 c.c.
6000 to 8000 ft	3·6 to 3·8 c.c.
8000 to 10,000 ft	3·3 to 3·5 c.c.
10,000 to 12,000 ft	3·1 to 3·3 c.c.

Dismantling (Pump with mechanical governor type DPA 3248F80A)

1. Remove the cover plate from the side of the pump housing and drain the pump.
2. Withdraw the quill shaft from the drive hub.
3. Check that the hub end-float is 0·010 in (0·254 mm). If the end-float is excessive renew the pump body and the governor weight retainer.
4. Mount the pump on the DPA assembly base 18G633A.
5. Remove the high-pressure connections.
6. Remove the throttle and shut-off levers and dust covers.
7. Remove the control cover and shut-off shaft, pushing the throttle shaft out of the cover as the cover is removed.
8. Remove the control bracket assembly and detach the metering valve from the assembly.
9. Remove the advance unit.
10. Remove the end plug, spring cap (note the adjusting shim), and internal components from the advance unit.
11. Remove the cam ring advance screw.
12. Remove the end plate from the hydraulic head.
13. Withdraw the transfer pump vanes and liner.
14. Remove the fuel inlet connection from the end plate and withdraw the regulating valve components.
15. Hold the drive hub with Drive shaft screw assembly tool 18G659 and, using Assembly box spanner 18G634 in conjunction with a standard ratchet wrench, slacken the transfer pump rotor. The word 'OFF' and an arrow etched on the exposed face of the rotor indicate the direction in which the rotor is unscrewed.
16. Remove both hydraulic head locking screws and withdraw the hydraulic head assembly.
17. Unscrew and remove the transfer pump rotor.
18. Stand the hydraulic head assembly on the bench with the drive plate uppermost. Hold the drive plate with the Assembly drive plate spanner 18G641 and remove the two drive plate securing screws. Remove the drive plate, lift off the top adjusting plate and withdraw the rollers and shoes.
19. Withdraw the rotor and remove the bottom adjusting plate.
20. Withdraw the cam ring.
21. Withdraw the cam ring circlip, using Circlip pliers 18G1004.
22. Hold the drive hub with Drive shaft screw assembly tool 18G659, and using Torque adaptor 18G664 with a standard socket wrench, remove the screw from the drive hub. The splined drive shaft complete with governor weights assembly may now be withdrawn from inside the housing.
23. Remove the 'O' ring and the governor weight assembly from the drive shaft.
24. Withdraw the drive hub from inside the pump housing and remove the spring washer, and support washer from their locations inside the drive hub. The washers are removed by turning them end on inside the hub and withdrawing them along the master spline. Two flats are machined on the outside diameter of the support washer to facilitate this operation.

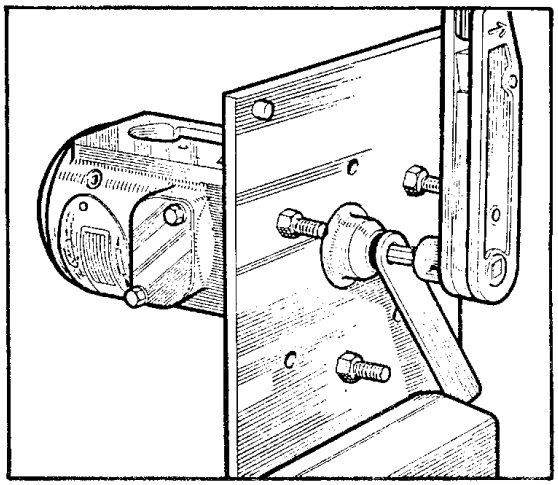


Fig.23 - Removing the drive hub screw

25. Remove the drive hub oil seal, using Oil seal extractor 18G658.
26. Renew all 'O' rings, oil seals and gaskets.
27. Renew any springs which are damaged or of incorrect length when compared with new counterparts.

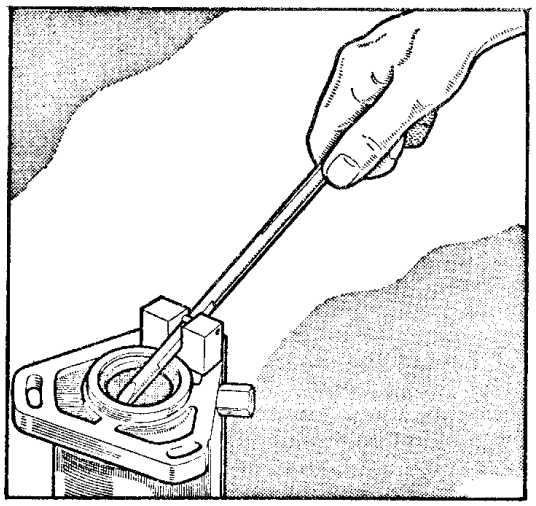


Fig.24 - Extracting the drive hub oil seal

28. Examine the hydraulic head, rotor, pumping plungers, and metering valve. If any of these components are worn or damaged, renew the hydraulic head and rotor assembly.
29. Renew the cam ring and plunger rollers if they show signs of wear or flats.
30. Renew the regulating valve sleeve and piston if they are worn or if the piston is tight in the sleeve.
31. Renew the governor thrust washer and sleeve if they are worn or damaged.

Re-assembling

1. Fit a new drive hub oil seal to the pump housing driving it onto its seat with Oil seal guide 18G663. Insert the transparent Oil seal inspection plug 18G660 into the oil seal to see if the seal is seating correctly. A correctly fitted oil seal will show a continuous black

line when viewed through the flange end of the oil seal inspection plug.

2. Fit the drive hub, complete with its support washer and spring washer.
3. Fit the governor weights, thrust washers and thrust sleeve to the weight retainer, using the Locating pin 18G667, and plate 18G662, as shown in Fig. 25

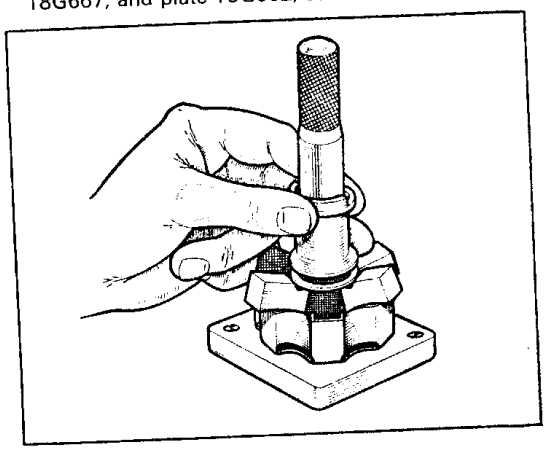


Fig.25 - Assembling the governor weights

4. Fit the drive shaft to the governor weight assembly.
5. Fit the Protection cap 18G657 over the drive shaft splines and fit a new 'O' ring in the machined groove on the shaft.
6. Fit the drive shaft assembly to the pump housing and drive hub and tighten the drive shaft screw to the torque figure given in 'General Data', using tools 18G659 and 18G664. Check the drive hub end-float.
7. Fit the cam ring circlip.
8. Fit the cam ring (the directional arrow on its visible face should match that on the pump nameplate).
9. Fit the cam ring advance screw finger tight to locate the cam ring and check the ring for freedom of movement.
10. Fit the top adjusting plate and drive plate.
11. Fit the roller shoe assemblies.
12. Fit the bottom adjusting plate and insert the rotor into the hydraulic head.
13. Fit the transfer pump rotor but do not tighten.
14. Set the roller to roller dimension to 50·29 mm (1·98 in) as described in 11, 12 and 13, page14 and shown in Fig. 19
15. Fit a new 'O' ring to the hydraulic head periphery and fit the hydraulic head to the pump body.
16. Fit both hydraulic head locking screws finger tight.
17. Tighten the transfer pump rotor to the torque figure given in 'General Data', using tools 18G634 and 18G659.
18. Fit the transfer pump liner and vanes.
19. Assemble the regulating valve components to the end plate in the order shown in Fig. 21
20. Ensure that the transfer pump liner locating pin is fitted to position 'C' in the end plate.
21. Locate the oil sealing ring on the hydraulic head face and fit the end plate.
22. Tighten the end plate screws, fuel inlet connection, and cam ring advance screw to the torque figures given in 'General Data'.
23. Fit the advance unit gasket (dry) to the pump housing.
24. Fit the advance unit housing to the pump housing.
25. Tighten the hydraulic head locating bolt, cap nut, and both hydraulic head locking screws to the torque figures given in 'General Data'.
26. Fit new 'O' rings to the spring cap and end plug, using Protection cap 18G640 to pass the rings over the threads.
27. Fit the slide washer, then the piston, into the advance unit on the side where the fuel drilling enters the bore. Screw in the end plug.
28. Fit the maximum advance stop, followed by the spring, into the advance unit. Screw in the spring cap and shim.
29. Tighten the spring cap and end plug to the torque figure given in 'General Data'.
30. Insert the metering valve into its bore in the hydraulic head.
31. Fit the assembled governor arm and control bracket to the pump housing, ensuring that the lower end of the governor arm engages the stepped face of the thrust sleeve flange.
32. Fit the keep plate (open end towards the shut-off bar), new lock washers, control cover studs and control bracket screw. Tighten the control cover studs and control bracket screw to the torque figures given in 'General Data'.
33. Fit the spring retainer, spring, and linkage washer to the linkage hook. Pass the threaded end of the hook through the governor arm and fit the pivot washer, backing washer, and linkage nut to the linkage hook.
34. Attach the linkage hook to the metering valve with the hook turned towards the valve.
35. Press the governor arm lightly towards the metering valve and, holding a vernier gauge parallel to the pump axis, as shown in Fig. 26 adjust the linkage nut to set the governor link length to 52·5 ±1 mm (2·064 ±0·039 in).

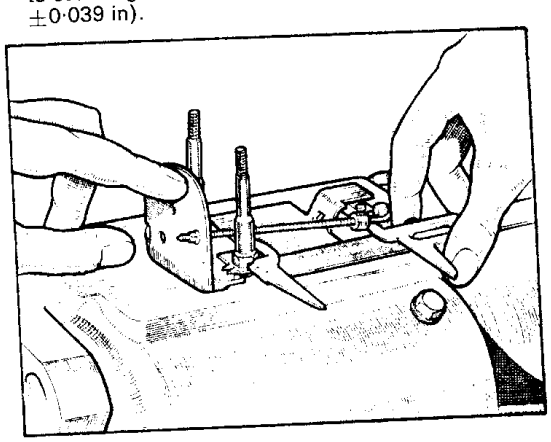


Fig.26 - Using the Vernier gauge

36. Fit the idling spring and guide to hole No. 2 in the governor arm (see Fig. 27) and connect the governo spring to the guide.
37. Insert the plain end of the shut-off bar into the contro bracket slot and position the bar under the tab of th control cover stud locking washer.
38. Fit the lower 'O' rings to the throttle and shut-o shafts, using Protection cap 18G654. Fit the upper 'O rings using Protection cap 18G665 and pack th groove between the 'O' rings with Shell Alvania No. grease.
39. Fit the shut-off shaft to the control cover, positionir the shaft peg close to the edge of the cover ar projecting slightly from the joint face.
40. Soak a new control cover gasket in calibration flu and fit it to the pump housing.
41. Connect the free end of the governor spring to ho No. 2 in the throttle shaft link (see Fig. 27) and fit t

throttle shaft to the control cover.

42. Fit the control cover, ensuring that the shut-off peg engages the shut-off bar, and tighten the cover cap nuts to the torque figure given in 'General Data'.

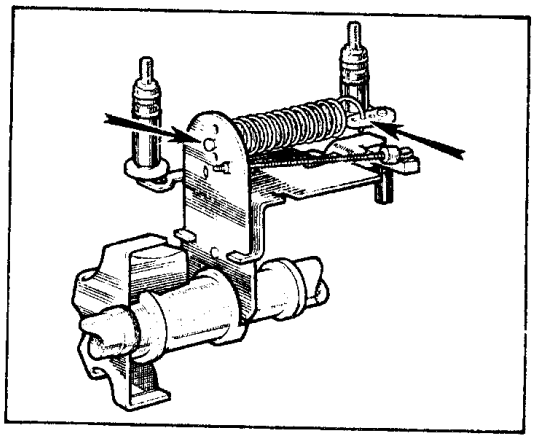


Fig.27 - Governor spring location holes

43. Fit the dust covers and levers to the control shafts.
44. Fit the cover plate to the pump housing and include a new joint.
45. Mount the pump on a test bench.
46. Fit radial connections to the high-pressure outlets.
47. Remove the plain hydraulic head locking screw and fit Transfer pressure adaptor 18G636.
48. Remove the screw from the advance spring cap and fit the Automatic advance gauge 18G638B. Zero the gauge.
49. Set the stop screws to give maximum throttle lever movement.
50. Make the following pump to test bench connections :—
    (a) Radial connections to injectors.
    (b) Transfer pressure adaptor 18G636 to pressure gauge. The adaptor is screwed into the hydraulic head in place of the plain locking screw.
    (c) Fuel inlet connection to feed pipe (with a 'T' coupling to vacuum gauge).
    (d) Drain (return) connection, via measuring glass, to drainpipe.
51. Fill and prime the injection pump as follows :—
    (a) Connect the fuel feed pipe to the drain connection on the pump.
    (b) Open both vent screws on the injection pump and turn on the gravity feed.
    (c) When test oil free of air bubbles flows from the hydraulic head vent screw close the screw.
    (d) When test oil free of air bubbles flows from the control cover vent screw close this also.
    (e) Rotate the pump drive through 180 degrees and repeat operations b, c, and d.
    (f) Fit the feed and return pipe to their resepctive connections.
    (g) Run the pump at 100 rev/min (see pump nameplate for rotation) and bleed the high-pressure pipes until delivery is obtained from all injectors.
52. Ensure that all joints, oil seals, and connections are oil-tight.
53. Test and adjust the pump.

Testing and Adjusting

Conditions of test

1. The test bench must be set to run in the direction of pump rotation.
2. Fuel available at injection pump inlet must be 1,000 c.c./min. flow minimum or 2 lb.in^2 (0·15 kg/cm^2) pressure maximum.
3. Test injectors should be a matched set with type BDN.12.SD.12 nozzle operating at 175 atmospheres.
4. Injector pipes should be 6 mm × 2 mm × 865 mm long.
5. The injection pump throttle and shut-off levers must be in the fully open position, except where otherwise stated.
6. Before taking fuel delivery readings the test oil in the measuring-glasses should be allowed to settle for 15 seconds, and the measuring glasses should be allowed to drain for 30 seconds between tests. All fuel delivery figures are for 200 shots.

TEST PLAN

Pump type DPA. 3248F80A

Test No.	Description	Rev/min	Requirements	Action and/or Remarks
1	Transfer pump vacuum	100	16 in. (406 mm) Hg within 60 seconds	Fuel supply turned off. After test, air vent from hydraulic head vent screw at 100 rev/min.
2	Transfer pressure	100	11 lb. in² (0·8 kg/cm²) minimum	
3	Transfer pressure	1,250	48 to 60 lb.in² (3·4 to 4·2 kg/cm²)	
4	Fuel delivery setting	,1250	6·0 to 6·8 c.c. average delivery	Obtain this delivery by adjusting the shut-off lever with Shut-off lever adjuster 18G697 fitted to the pump (Fig. 28). If necessary alter the setting of the metering valve adjustment screw to maintain a zero advance reading.
5	Advance setting	1,250	$1\frac{3}{4}$ to $2\frac{1}{4}$° advance	With shut-off lever set as in Test 4 use the metering valve adjustment screw to obtain this advance setting.
6	Fuel delivery check	1,250	6·0 to 6·8 c.c. average delivery	Shut-off lever set as in Test 4 and metering valve adjustment as in Test 5. Remove the Shut-off lever adjuster.
7	Advance check	1,250	$3\frac{1}{2}$ to $4\frac{1}{2}$° advance	Metering valve adjustment as in Test 5 and shut-off lever full closed. Lock metering valve adjustment screw and seal it, using Sealing pliers 18G541.
8	Back-leakage	700	5 to 50 c.c. per 100-shot time cycle	Throttle lever fully closed.
9	Maximum fuel delivery	700	*8·2 ±0·1 c.c. average (Spread between lines not to exceed 0·8 c.c.)	Adjust output by moving adjusting plate relative to drive plate with the Maximum fuel adjusting probe 18G656. Tighten drive plate screws to correct torque with Torque adaptor 18G655A and wrench 18G537.
10	Fuel delivery check	100	Average as Test 9 minus 1·0 c.c.	This is a minimum delivery figure.
11	Cut-off operation	200	Average 1·5 c.c. maximum	Shut-off lever fully closed.
12	Throttle operation	200	Average 0·8 c.c. maximum	Throttle lever fully closed and anti-stall screw unscrewed and locked.
13	Fuel delivery check	1,700		Record delivery.
14	Governor setting	1,950	Average 1·5 c.c. maximum (No line to exceed 2·5 c.c.)	Set throttle lever with maximum speed adjustment screw.
15	Fuel delivery check	1,700	Average as Test 13 minus, 0·4 c.c.	This is a minimum delivery figure.

TEST PLAN (cont'd.)

Pump type DPA. 3248F80A

Test No.	Description	Rev/min	Requirements	Action and/or Remarks
16	Timing	—		Relief valve timing adaptor 18G653A (set at 30 atmospheres) connecting Injector nozzle testing machine 18G109A to outlet 'V'. Apply fuel pressure, rotate drive hub with Universal flange marking gauge 18G648A (set at 86°) and mark pump flange with scriber.

*The maximum fuel delivery is for sea-level conditions. For continuous use above sea-level the maximum fuel delivery should be set as follows :—

Altitude	Maximum fuel delivery
0 to 2000 ft	8·1 to 8·3 c.c.
2000 to 4000 ft	7·6 to 7·8 c.c.
4000 to 6000 ft	7·1 to 7·3 c.c.
6000 to 8000 ft	6·6 to 6·8 c.c.
8000 to 10,000 ft	6·1 to 6·3 c.c.
10,000 to 12,000 ft	5·6 to 5·8 c.c.

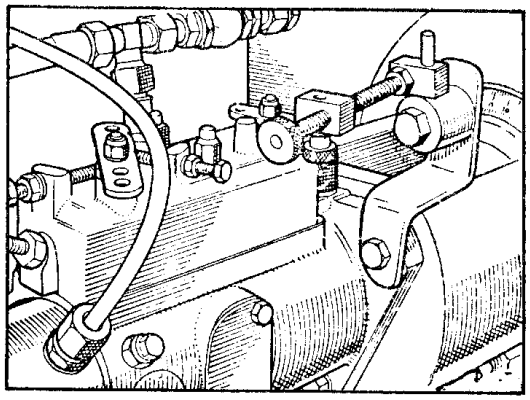
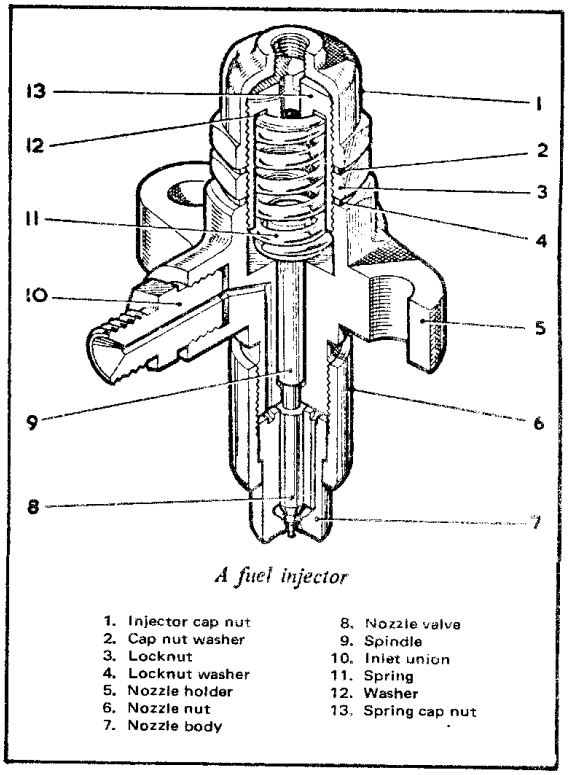


Fig.28 - Shut-off lever adjuster fitted to pump



A fuel injector

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

Fig.29 - Fuel injector assembly

D.6

FUEL INJECTORS

Description

The fuel injectors are located in water-cooled copper sleeves in the cylinder head and are fitted with four-hole long-stem injector nozzles.

Each nozzle consists of a nozzle body and a nozzle valve which are accurately lapped so that the valve is the closest possible fit in the body, yet sufficiently free to ensure correct operation. The lower end of the valve is reduced in diameter to form a stem, and a conical valve face is machined on the lower end of this stem.

A valve seat in the base of the nozzle body is lapped at a different angle to the valve face on the valve (see General Data) to ensure a knife-edged contact between valve and seat. Each nozzle is mounted on a nozzle holder and is attached to it by means of a nozzle nut. The mating faces of both nozzle and nozzle holder are lapped to ensure a high pressure seal when the nozzle nut is tightened. Contained in the nozzle holder are a spindle and spring which retain the nozzle valve on its seat. The upper end of the spring is located by a spring plate in an adjustable cap nut. By screwing the cap nut in or out the pressure on the spring (and therefore the injection pressure) can be adjusted as required. In operation, fuel under pressure from the injection pump passes into the nozzle holder through the inlet connection. Through drillings in the nozzle holder and nozzle body the fuel reaches an annular chamber in the nozzle body. The pressure in the annular chamber acts on the shoulder of the nozzle valve where its diameter is reduced. When the pressure is sufficient to overcome the spring setting the nozzle valve is lifted off its seat and fuel is sprayed into the engine cylinder through the holes in the tip of the nozzle body. As soon as the fuel pressure drops below the setting of the spring the nozzle valve is returned to its seat.

Lubrication is provided by allowing a small quantity of fuel to leak back past the nozzle valve into the nozzle holder. The fuel is then returned to the fuel system via a leak-off connection in the injector cap nut.

Removing and Replacing

1. Disconnect the spill rail from the injectors.
2. Disconnect the high pressure pipes from the injectors.
3. Remove the securing nuts and withdraw the injectors using the Impulse Extractor 18G284 with the Injector remover adaptor 18G284P.

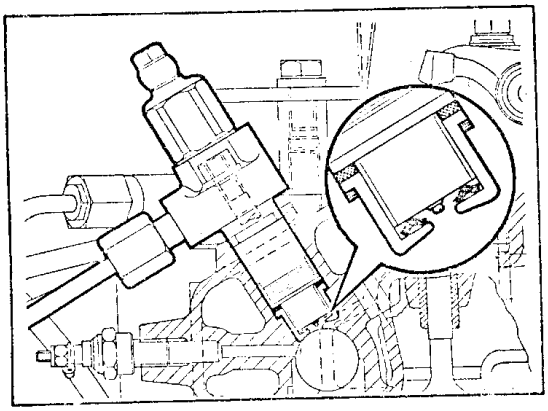


Fig.30 - Location of atomizer washers

4. Renew the atomizer seal washers, fitting the new washers as shown in Fig.30
5. Replace the injectors and tighten the securing nuts to the torque figure shown in General Data.
6. Re-connect the high pressure pipes to the injectors.
7. Re-connect the spill rail to the injectors.
8. Bleed the high pressure pipes.

Dismantling and Re-assembling

1. Mount the injector in the Injector nozzle dismantling fixture 18G388.
2. Remove the injector cap nut, spring cap nut, spring, and spindle.
3. Remove the nozzle nut and nozzle using the Injector nozzle nut spanner 18G210 in conjunction with Torque wrench 18G372.
4. Renew the spring if it shows any sign of weakness.
5. Renew the spindle if it is not perfectly straight.
6. Clean the nozzle and valve, using the Injector nozzle cleaning kit 18G487. Connect the Injector nozzle reverse flush adaptor 18G109E to the Injector nozzle testing machine 18G109A and connect the nozzle to the adaptor as shown. Reverse flush the nozzle.
7. Renew the nozzle assembly if the pintle clearance is excessive when checked as shown in Fig. 32

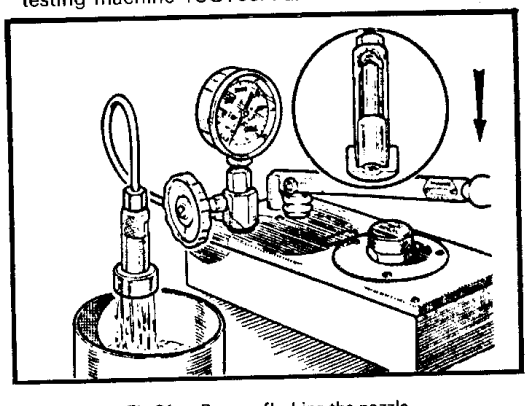


Fig.31 - Reverse flushing the nozzle

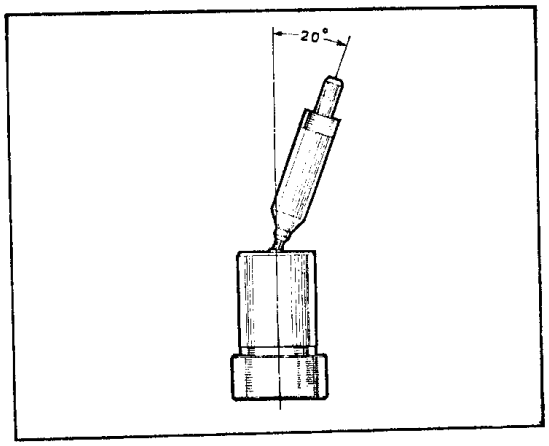


Fig.32 - Checking the pintle clearance

8. If necessary restore the nozzle and valve seats as described on page 24 The nozzle seat angle should be 59° and the valve seat angle should be 60°.
9. Check the needle lift against the figure in General Data.
10. Mount the nozzle holder in the dismantling fixture and reverse the procedure in 2 and 3, tightening the nozzle nut to the torque figure given in General Data.
11. Test and adjust the injector as detailed.

Testing the fuel injectors

If the injectors are to be tested correctly, or if it is desired to adjust the opening pressure then the use of the nozzle testing machine in conjunction with Nozzle testing adaptor 18G109B will be necessary. A fuel which does not affect the skin of the operator, e.g. Shell Calibration Fluid 'C' should be used in the machine.

Before using the test machine ensure that the fuel tank is full, and before removing an injector from the machine close the check valve to prevent damage to the pressure gauge which may result from a sudden drop in pressure.

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

Testing for spray

1. Connect the adaptor, which consists of an additional nozzle holder fitted with a special nozzle and a modified nozzle nut to the test machine.

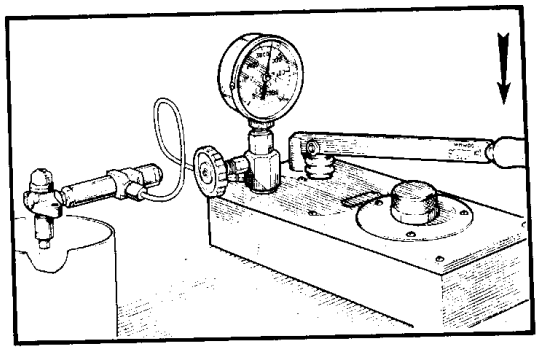


Fig.33 - Injector and adaptor connected to test machine

2. Open the check valve and operate the test machine lever. Note the reading on the pressure gauge at the instant the nozzle sprays – the reading should be 220 atmospheres. If the pressure is incorrect, adjust the nozzle nut accordingly.
3. Screw the injector to be tested into the adaptor; close the check valve to cut off the pressure gauge and operate the lever on the test machine to expel any air.

Auxiliary spray

4. With the pressure gauge out of circuit operate the test machine slowly at about 60 strokes per minute; it is possible to cut out the main spray almost entirely and produce only the auxiliary spray. When this condition has been achieved the auxiliary spray can be observed. This should be well formed and free from splits and distortions, although there may be present a slight central core, which may be disregarded.

Main spray

5. Operate the hand lever more rapidly at about 140 strokes per minute – the main spray can be observed. This should be well atomized and free from large splits or distortion. A slight centre core may be disregarded.

Seal-tightness test

1. Remove the test adaptor and connect the injector under test direct to the test machine. Open the check valve and observe the injector nozzle opening pressure. If necessary, remove the injector and adjust to open at 100 atmospheres as described under 'Injector final setting'.
2. Depress the lever of the test machine until a pressure of 90 atmospheres is obtained. Hold this pressure for 10 seconds and examine the nozzle seat, for moisture. Reject the seat if considerable moisture is present. If in doubt, maintain the pressure for a period of 60 seconds, and hold a piece of blotting paper below the nozzle tip to absorb any moisture. If the diameter of the wet spot exceeds 3·175 mm (⅛ in) change the nozzle.

Back-leakage test

Before making this test set the injector nozzle to open at between 160 and 170 atmospheres and ensure the pressure gauge is in circuit.

1. Operate the lever of the test machine until the gauge registers a pressure of 160 atmospheres. Release the lever and time the pressure drops from 150 to 100 atmospheres. For a nozzle in good condition, the time should not be less than 6 seconds, or greater than 40 seconds.
2. Ensure that no leakage occurs at the lapped joint of the valve. If leakage at the joint is suspected do not overtighten the nozzle nut in an effort to rectify, but dismantle the nozzle and re-examine the pressure face for signs of dirt or surface imperfections. Clean thoroughly, and if all appears in order replace the components, tighten the nozzle nut to the torque figure given in 'General Data' and re-test.
   If the pressure drop time is still low, excessive leakage past the lapped portion of the valve is indicated, and the particular nozzle and valve should be renewed as an assembly.

Injector nozzle final setting

On completion of the foregoing tests the Pintaux nozzle must be set to open at a pressure of 135 atmospheres as follows:—

1. Remove the injector from the test machine.
2. Remove the injector cap nut and copper joint washer.
3. Release the locknut and turn the spring cap nut clockwise to increase or counter clockwise to decrease the opening pressure.
4. Lock the spring cap nut and re-check the nozzle opening pressure on the test machine.
5. Repeat operations 3 and 4 until the correct opening pressure of 135 atmospheres is obtained.
6. Refit the injector cap nut and joint washer.

SUMMARY CHART

Test		Nozzle opening pressure	Adaptor (18G109B) opening pressure	Strokes per minute	Requirements
Spray	Auxiliary	135 atm.	220 atm.	60	Spray free of distortions. Slight core permissible.
	Main	135 atm.	220 atm.	140	Spray free of distortions. Slight core permissible.
Seat tightness		100 atm.	—	—	Dry nozzle after 10 seconds at 90 atm. pressure.
Back-leakage		160 to 170 atm.	—	—	Initial pressure 160 atm. Time for pressure drop from 150 to 100 atm. to be between 6 and 40 seconds.
Final setting		135 atm.*	—	—	—

*Add 5 atmospheres when setting new injectors or after fitting new springs.

Reclaiming Injector Nozzles

If after dismantling, cleaning and testing, 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-leagage.

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.

1. 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.
2. 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.
3. 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 surface 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.
4. 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 5 seconds at a time and the pressure applied to the nozzle should be light. Excessive pressure will cause grooving of the nozzle seat.
5. 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 $1\frac{1}{2}$ minutes of lapping time, but in the case of a badly worn nozzle seat it may be necessary to reduce this time.
6. Wipe the lap stem clean and re-coat it with tallow. Re-charge 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 the lap should be cleaned and examined after every 30 seconds of lapping time.
7. Thoroughly clean the nozzle by 'reverse-flushing' as described and dry out with compressed air. Make a final inspection of the nozzle seat under the microscope.
8. 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 face should be refaced on the nozzle grinding and lapping machine.
9. Ensure that the grinding-wheel is dressed correctly and that the refacing angle is set for the nozzle valve (see General Data).
10. 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.
11. 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 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.
12. 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 figures 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.
13. Re-assemble the injector and test and adjust as described.

SECTION E

ELECTRICAL EQUIPMENT

E.1

ALTERNATOR - LUCAS TYPE 11AC

Description

The Lucas Type 11AC alternator is an 8-pole three phase rotating field machine, with a star-connected output winding.

The 8-pole rotor carries the slip rings and the field winding and is supported by a ball bearing locating in the drive end bracket, and a needle roller bearing in the opposite, slip ring, end bracket.

A 24 slot 3 phase star-connected output winding on a ring-shaped lamination pack forms the stator which is housed between the slip ring end and drive end brackets.

Brush gear for the slip ring fed field winding is mounted on the slip ring end bracket, the two carbon brushes bearing against a pair of concentric brass slip rings carried on a moulded disc attached to the end of the rotor.

In addition to the brush gear the slip ring end bracket carries six silicon diodes connected in a three phase bridge circuit to give rectification of the generated a.c. output.

The diodes and stator windings are cooled by airflow through the alternator induced by a ventilating fan at the drive end.

A plastic strip coloured RED (positive) and BLACK (negative) is attached to the appropriate output terminals, each strip identifying the polarity of its associated terminal.

field winding energised and the main output cable disconnected, otherwise diode failure may result.

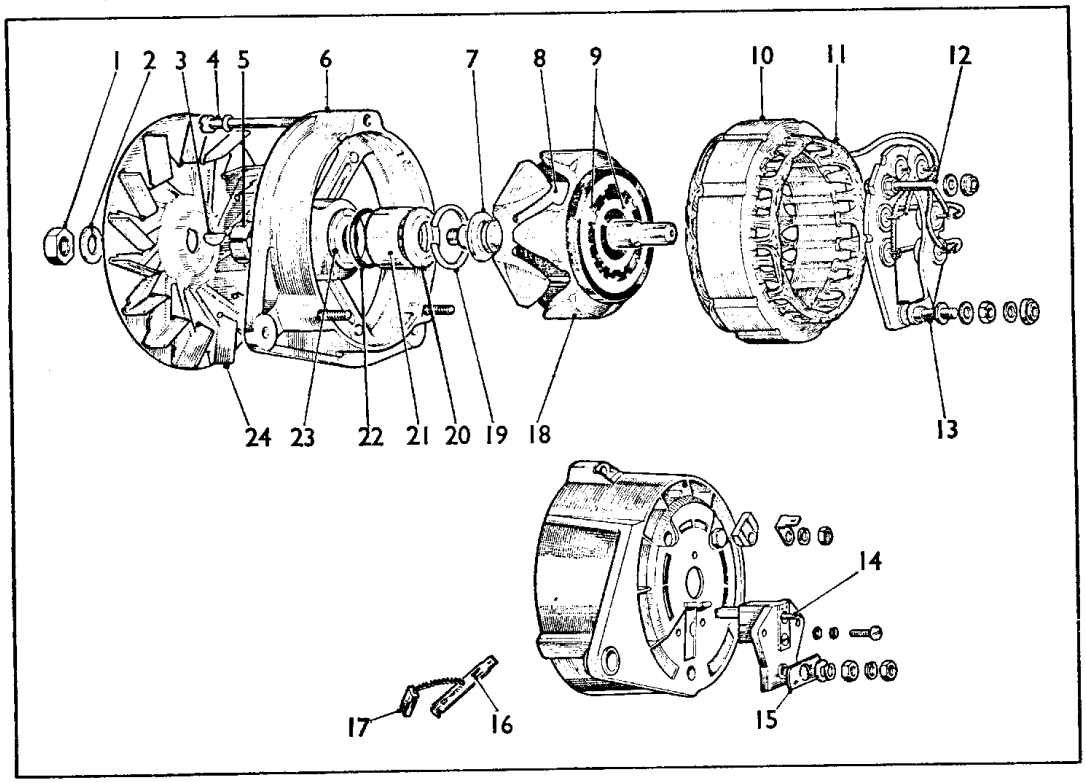


Fig.1 - Alternator assembly

1.	Shaft nut	9.	Slip-rings	17.	Brush
2.	Spring washer	10.	Stator laminations	18.	Rotor
3.	Key	11.	Stator windings	19.	Bearing circlip
4.	Through-bolt	12.	Warning light terminal	20.	Bearing retaining plate
5.	Distance collar	13.	Output terminal	21.	Ball bearing
6.	Drive end bracket	14.	Field terminal blade	22.	'O' ring oil seal
7.	Jump ring shroud	15.	Output terminal plastic strip	23.	'O' ring retaining washer
8.	Rotor (field) winding	16.	Terminal blade retaining tongue	24.	Fan

Output Control

The alternator output is controlled by an electronic voltage regulator unit model 4TR.

Field Isolating Device

The voltage regulator and the alternator field winding are isolated from the battery when the engine is stationary. This is achieved by the normally-open contacts of a model 6RA relay whose operating coil is fed via a standard ignition switch. The relay contacts are connected directly to the battery or to the ammeter, since the alternator output must respond to changes in battery voltage and not to conditions occurring elsewhere in the system.

Warning Light Unit

A further terminal marked 'AL' is provided for use with a model 3AW warning light control.

Fault Finding

In the event of a fault developing in the charging circuit the following procedure should be adopted to locate the cause of the trouble.

1. Inspect the driving belt for wear and tension.
2. Start the engine and check that battery voltage is being applied to the rotor winding by connecting a voltmeter between the cable ends attached to the field terminals.
   If zero voltage is indicated, stop the engine and apply the control unit test procedure tabulated on page 5
   If battery voltage is indicated, stop the engine, withdraw the two brush box moulding retaining screws and remove the brushgear for examination. If the amount by which a brush or brushes protrudes beyond the brushbox moulding is less than 0·2 in. (5 mm), fit new brush and spring assemblies as described under 'Brushgear inspection'.
3. Re-start the engine and test the alternator output. If a zero reading is indicated on the ammeter, apply the alternator test procedure. Remove the alternator for overhaul if the trouble cannot be resolved, but before doing so, note the following :—
   (a) Observe battery polarity before removing any connections. Since alternators and transistorised regulators are polarity conscious immediate and irreparable damage can be caused if reverse polarity connections are made to the battery.
   (b) Never earth the brown/yellow cable, should it be necessary to disconnect it at 'AL' on the warning light control, otherwise a damaged alternator diode and wiring will result if the equipment is switched on.
   (c) Never earth the brown/green cable when disconnected at the alternator field terminal otherwise the control unit, relay and associated wiring may be damaged if the ignition is switched on.

Removing and replacing the Alternator

1. Disconnect the battery and alternator cables.
2. Slacken the adjusting link bolt and the mounting bolts, and pivot the alternator towards the engine. Remove the driving belt.
3. Remove the bolts and lift out the alternator from the engine.
4. Replace in the reverse order, and adjust the driving belt so that it is possible to deflect the belt 1 in. (25 mm) at the centre of its longest run.

MAINTENANCE AND OVERHAUL PROCEDURES

Dismantling the Alternator

1. From the drive end remove the shaft nut, spring washer, pulley and fan.
2. Unscrew and withdraw the three 'through' bolts.
3. Mark the drive end bracket stator laminations pack and slipring end bracket so that they may be reassembled in correct angular relation to each other.
4. Withdraw the drive end bracket and rotor from the stator. The drive end bracket and rotor need not be separated unless the drive end bearing requires examination or the rotor is to be replaced. In this event the rotor should be removed from the drive end bracket by means of a hand press, having first removed the shaft key and bearing collar.
5. From the slipring end bracket remove the terminal nuts, washers, insulating pieces, plastic identity strips and brushbox screws. Care should be taken not to misplace the two washers fitted between the brushbox moulding and the end bracket.
6. Withdraw the stator and heat sink assemblies from the slipring end bracket.
7. Close up the retaining tongue at the root of each field terminal blade and withdraw the brush spring and terminal assemblies from the moulded brushbox.

Brushgear Inspection

1. Measure the distance the brushes protrude beyond the brushbox moulding, when in the free position. This should exceed 0·2 in. (5 mm) and if the brushes are worn to, or below, this length they should be renewed. A new brush length is $\frac{5}{8}$ in. (15·9 mm).
2. Check that the brushes move freely in their holders. If at all sluggish, clean the brush sides with a petrol moistened cloth or if this fails to effect a cure, lightly polish the brush sides on a smooth file. Remove all traces of brush dust before re-housing the brushes in their holders.
3. Check the brush spring pressure using a push-type spring gauge. Push each brush in turn back against its spring until the brush face is flush with the housing. The gauge should then indicate 8-16 oz (227-454 g). Replace a brush assembly which gives a reading appreciably outside these limits.

New brushes are supplied complete with brush springs and Lucar terminal blades and fitting is a simple operation performed by merely pressing into position until the tongue registers. To ensure that the terminal is properly retained carefully lever up the retaining tongue with a fine screwdriver so that the tongue makes an angle of approximately 30° with the terminal blade.

NOTE: The brush which bears on the inner slipring is always associated with the positive pole of the electrical system, since the lower linear speed of the inner ring results in reduced mechanical wear and helps to offset the higher rate of electrical wear peculiar to the positive connected brush.

Slipring Inspection

The surfaces of the sliprings should be smooth and uncontaminated by oil or other foreign matter. If oil or foreign matter are present, clean the surfaces using a petrol moistened cloth, or if there is evidence of burning use very fine glass paper. On no account must emery cloth or similar abrasives be used.

No attempt should be made to machine the sliprings, as any eccentricity in the machining may adversely affect the high speed performance of the alternator. The small current carried by the rotor winding, and the unbroken surface of the sliprings mean that the likelihood of scored or pitted rings is almost negligible.

Rotor

1. Test the rotor winding by connecting either an ohmmeter (Fig. 2) or a 12 volt battery supply, in series with an ammeter (Fig. 3) between the sliprings.
   The reading of resistance should be approximately 3·8 ohms. If the alternative test has been made, the value of the current should be approximately 3·2 amperes.

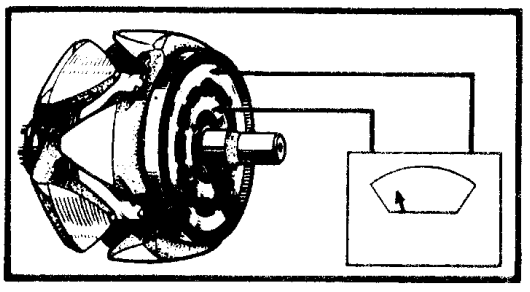


Fig.2 - Rotor winding resistance test using Ohmmeter

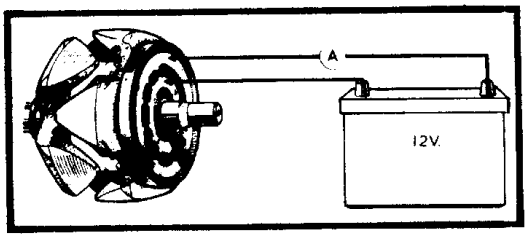


Fig.3 - Rotor winding resistance test using Ammeter

2. Test for defective insulation between one of the slip-rings and one of the rotor poles using a 110 volt a.c. mains supply and a 15 watt test lamp connected in the lead to the rotor (Fig. 4). If the lamp lights the coil is earthing and a replacement rotor/slipring assembly must be fitted.

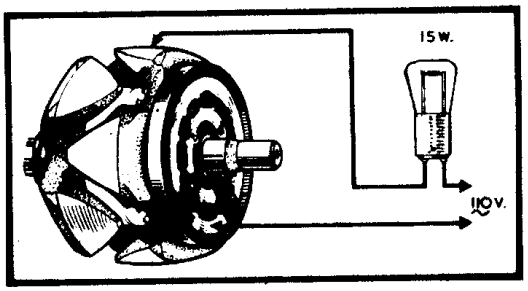


Fig.4 - Rotor winding insulation test

3. No attempt should be made to machine the rotor poles or to true a distorted shaft.

Stator

1. Unsolder the three stator cables from the heat sink assembly, taking care not to overheat the diodes. A pair of suitable long-nosed pliers should be used to lightly grip the diode pins and the three cables removed as quickly as possible. The pliers act as a thermal shunt.
2. Check the continuity of the stator windings by first connecting any two of the three stator cables, in series with a 1·5 watt test lamp (Lucas No. 280), to a 12 volt battery. Repeat the test, replacing one of the two cables by the third cable. Failure of the test lamp to light on either occasion means that part of the stator winding is open circuit and a replacement stator must be fitted.
3. Test for defective insulation between the stator coils and lamination pack with a 110 volt a.c. mains supply and a 15 watt test lamp. Connect the test lamp, in series with the mains supply, to the stator lamination pack using a suitable probe or cable. Connect a second probe or cable between any one of the three stator cable ends and the other mains supply terminal. If the lamp lights, the stator coils are earthing and a replacement stator must be fitted.
4. Before re-soldering the stator cable ends to the diode pins, a test for defective diodes on the heat sink assemblies should be carried out.

Diodes

Check each diode, in turn, by connecting in series with a 1·5 watt test lamp across a 12 volt battery supply. In the first instance the connections should be made as in Fig. 5 and then reversed. In one direction only the lamp should light. If the lamp lights in both directions or does not light at all the diode is defective and the appropriate part or both parts of the heat sink assembly must be replaced. Individual diodes are not replaceable.

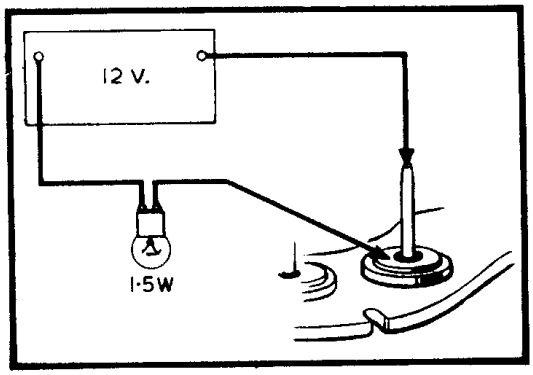


Fig.5 - Diode test connections

NOTE: Since the forward resistance of a diode varies with the voltage applied no realistic readings can be obtained with battery powered ohmmeters. An indication only will be given of a diode state, a diode in good condition yielding 'infinity' in one direction and some indefinite but much lower reading in the other.

WARNING: Ohmmeters of the type incorporating a hand-driven generator must never be used for checking diodes.

Diode Heat Sinks

The heat sink assembly consists of one part of positive polarity and the other part of negative polarity. The positive part is identified by red markings on the diodes and the negative part by black markings on the diodes. Replacement of the heat sink only requires re-soldering of the three stator leads, but, as with removal from the stator, great care should be exercised when soldering, a thermal shunt being used and the operation carried out as quickly as possible. M grade 45-55 tin-lead solder should be used.

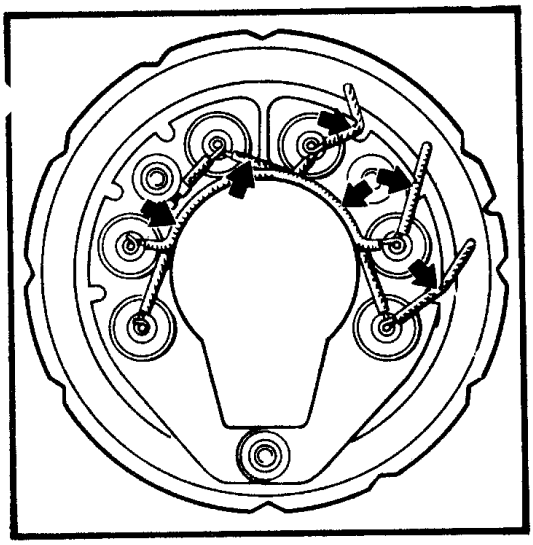


Fig.6 - Heat sink cable securing points

After soldering, the connections should be neatly arranged around the heat sink to ensure adequate clearance for the rotor, and be tacked down with MMM EC 1099 adhesive

where indicated in Fig. 6 The stator connections must pass through the appropriate notches at the edge of the heat sink.

Bearings

Bearings which are worn to the extent that they allow excessive movement of the rotor shaft must be renewed, but in the unlikely event of the needle roller bearing in the slipring end bracket becoming unserviceable a complete end bracket assembly must be fitted.

The drive end ball bearing is retained by a plate which is secured either by screws, rivets or a circlip, and the bearing may be removed in the following way.

1. Release the bearing plate by either withdrawing the screws, prising free the circlip with the top of a screwdriver, or filing away the rivet heads and punching out the rivets, according to the securing method used.
2. Press the bearing out of the bracket – noting the order of assembly of the pressure ring and plate when these are fitted.
3. Ensure the replacement bearing is clean and if necessary, pack it with high-melting point grease, such as Alvania No. 3 or an equivalent lubricant.
4. Locate the bearing in the housing and press it home. When refitting a circlip retained bearing plate, use a hand press to compress the assembly enough to allow the circlip to re-locate itself.
5. Replace the circlip, or refit new screws or rivets as necessary.

Re-assembling the Alternator

Re-assembly of the alternator is the reversal of the dismantling procedure, special attention being paid to the following :—

1. Carefully align the drive end bracket, lamination pack and slipring end bracket.
2. Tighten the three through bolts evenly. If the rotor and drive end bracket have been separated the inner journal of the drive end bearing must be supported by a suitably dimensionsed tube for the re-assembling operation. Do not use the drive end bracket as a support for the bearing while fitting the rotor.

TEST PLAN

Control Unit and Relay

Test	Procedure	Action and/or Remarks
1. Resistance		Check the resistance of the cables connected between points A and B shown on the wiring diagram. The total resistance should not exceed 0·1 ohm.
2. Battery charge		The battery must be fully charged.
3. Battery voltage to brush gear	Disconnect the two cables from the alternator field terminals. Connect a voltmeter between the cables, and run the engines.	The voltmeter should register battery voltage. If a zero reading is obtained check the circuit wiring and relay operation.
4. Relay operation	Remove the lead from terminal C2 and connect to terminal C1. Start the engine and check the alternator output.	If output is satisfactory renew the relay unit.
5. Voltage output	Connect an accurate voltmeter across the battery terminals and note the reading. Switch on sufficient auxiliary equipment to give a discharge reading on the ammeter of approximately 2 amps. Start the engine and run for at least eight minutes at an alternator speed of 3000 rev/min until the ammeter indicates a 10 amps charge.	At the engine speed indicated and ammeter reading of 10 amps, the voltmeter reading should be stable between 13·9 and 14·3 volts. If the voltmeter reading is unstable or has not risen above battery voltage, renew the control unit. If the reading is stable but outside the correct limits, adjust the control unit.
6. Control unit adjustment	Stop the engine. Detach the control unit from its mountings. Scrape out the compound sealing the potentiometer adjustment at the back of the unit. Ensure the connections on the unit are secure, and restart the engine. Run the engine at 3000 rev/min alternator speed with the condition of test as in 5. Turn the adjuster slot gradually until the voltmeter registers a stable reading within the correct voltage range.	Only a small adjuster movement is needed to effect an appreciable difference in the voltmeter reading.

TEST PLAN (cont'd.)

Test	Procedure	Action and/or remarks
7. Adjustment check	Stop the engine, and then restart it. With the alternator running at a speed of 3000 rev/min check the voltmeter reading. When stable within the given range, stop the engine, refit the control unit, and remove the meter.	Do not attempt to re-seal the adjuster hole. Application of undue heat will damage the control unit.
Type 11 AC Alternator		
1. Output	Disconnect the battery positive. Withdraw the cables from the field terminals and, using a suitable pair of auxiliary cables connect the field terminals to the corresponding battery terminals. Re-connect the battery positive start the engine and gradually increase its speed to about 4000 alternator rev/min.	The ammeter should register approximately 40 amps. If a zero reading is obtained, check the brush gear and repeat the test. If a zero reading is still obtained remove and dismantle the alternator. If a low reading is obtained check the wiring connections and repeat the test. If a low reading is still obtained proceed with Test 2.
2. Circuit voltage	Stop the engine and connect a low range voltmeter between alternator terminal B – and battery negative. Start the engine and note the voltmeter reading. Transfer the voltmeter connections to the alternator terminal B + (frame) and battery positive and again note the voltmeter reading.	If either of the two readings exceeds 0·5 volt there is a high resistance in the charging circuit. Trace and rectify this fault. If there is no undue resistance (although output is low) remove and dismantle the alternator.

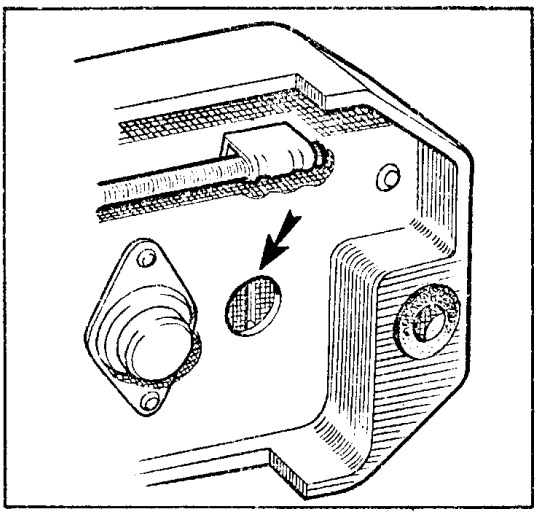


Fig.7 - Control unit potentiometer adjuster location

E.2

DYNAMO TYPE C40

Description

The dynamo is a shunt-wound, two-pole, two-brush, ventilated machine arranged to work in conjunction with a regulator unit, and comprises an armature with commutator, a field magnet system housed in a yoke (cylindrical frame), and the brush gear.

The brush holders are riveted to the commutator end bracket, which also houses the bearing for the armature shaft and other end of the armature shaft being supported by a ball race located in the drive end bracket. The two end brackets are clamped to the yoke by two through-bolts.

Rotation of the armature in the magnetic field produced by the field magnets induces alternating voltages in the armature windings which are converted into direct current by the action of the commutator and brushes.

The output of the dynamo depends upon the strength of the magnetic field and the speed at which the armature rotates. Normally, any variation of speed is accompanied by a change of output, and since the dynamo is driven at varying speeds, means must be provided to control the output. This is done by varying the strength of the magnetic field, the current value being controlled by the regulator unit.

A fan mounted behind the driving pulley draws cooling air through the dynamo, inlet and outlet holes being provided in the end brackets of the unit.

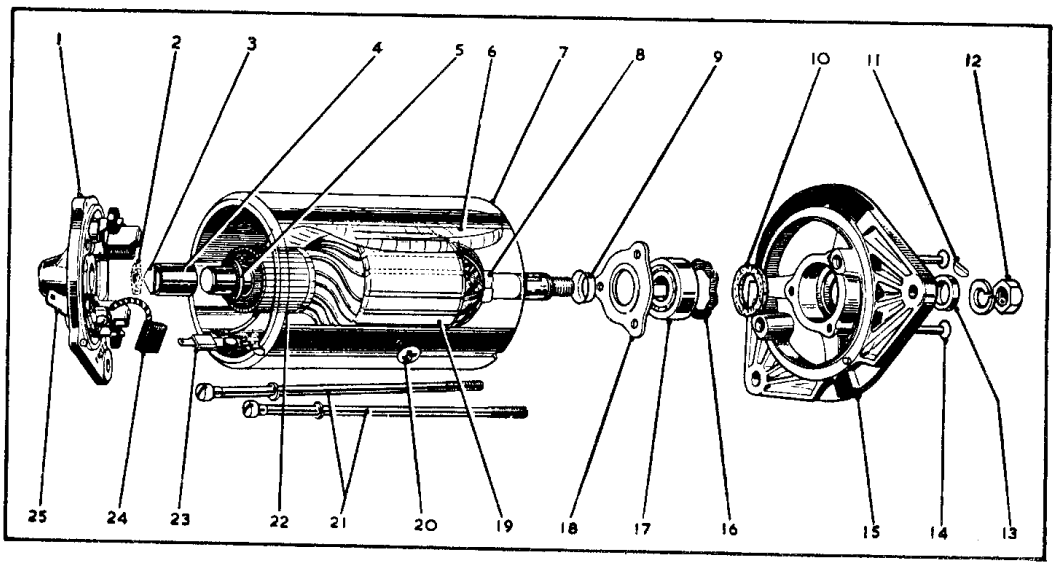


Fig.8 - Dynamo assembly

1.	Commutator end bracket	10.	Felt ring	18.	Bearing retaining plate
2.	Felt ring	11.	Shaft key	19.	Armature
3.	Felt ring retainer	12.	Shaft nut	20.	Pole-shoe securing screw
4.	Porous bronze bush	13.	Pulley spacer	21.	Through-bolts
5.	Fibre thrust washer	14.	Rivet	22.	Commutator
6.	Field coils	15.	Drive end bracket	23.	Field terminal 'F'
7.	Yoke	16.	Corrugated washer	24.	Brushes
8.	Shaft collar	17.	Ball bearing	25.	Output terminal 'D'
9.	Collar retaining cup				

Fault Finding

In the event of the dynamo failing to charge, or if the charging rate becomes intermittent, the following tests should be made to locate the cause of the trouble.

1. Check the dynamo driving belt for correct tension. It should be possible to deflect the belt $\frac{1}{2}$ in. (12·7 mm) at the centre of either run with normal thumb pressure. If the tension is incorrect the belt should be adjusted as described in Section C
2. Ensure the dynamo and control box are connected correctly. The dynamo terminal 'D' should be connected to the control box terminal 'D' and the dynamo terminal 'F' connected to the control box terminal 'F'.
3. Disconnect the cables from the dynamo terminals and bridge the two terminals with a short piece of copper wire. Start and set the engine to run at normal idling speed.
   Clip the negative lead of a moving-coil-type voltmeter, calibrated 0-20 volts, to one dynamo terminal and the other lead to a good earthing point on the dynamo yoke.
   Gradually increase the engine speed; the voltmeter reading should rise rapidly and without fluctuation. Do not allow the voltmeter reading to reach 20 volts. Do not race the engine in an attempt to increase the voltage. It is sufficient to run the dynamo up to a speed of 1000 rev/min.
   If there is no reading check the brush gear (see Page 8).
   If the reading is low (approximately 1 volt) the field winding may be faulty.
   If the reading is approximately 6 volts the armature winding may be faulty.
4. If the dynamo is in good order, test the cables connecting the terminals on the dynamo to the terminals on the control box for continuity.
5. Finally, remove the bridging wire from the terminals on the dynamo and restore the connections.

Removing and replacing the Drive Belt

1. Slacken the two bolts on which the dynamo pivots, and the bolt securing the dynamo to the adjusting link.
2. Pivot the dynamo towards the engine as far as it will go to relieve the drive belt of all tension. Ease the belt off the dynamo and fresh water pump pulleys, and withdraw it from the crankshaft pulley.
3. Refit the belt over the crankshaft pulley and then ease it over the water pump and dynamo pulleys. Pivot the dynamo away from the engine, using hand pressure only, to tension the belt and tighten the attachment bolts and nuts to secure the dynamo in this position. Over-tensioning of the belt must be avoided as this will impose an undue load on the dynamo bearings. A correctly tensioned belt can be deflected $\frac{1}{2}$ in. (12·7 mm) at the centre of either run by normal thumb pressure.

Removing and replacing the Dynamo

1. Disconnect the cables from the dynamo terminals.
2. Slacken the nut securing the dynamo adjusting link to the engine front plate.
3. Support the dynamo, and unscrew and remove the adjusting link to dynamo setscrew and the two bolts and nuts which secure the dynamo to the cylinder block
4. Disengage the drive belt from the pulley and withdraw the dynamo from the engine.
   Replacement is a reversal of the above procedure, but before tightening the dynamo attachment bolts ensure that the drive belt is tensioned correctly.

MAINTENANCE AND OVERHAUL PROCEDURES

Dismantling

1. Remove the nut and spring washer from the armature shaft and withdraw the pulley and dynamo fan.
2. Remove the key and distance collar from the armature shaft.
3. Remove the two through-bolts securing the drive and commutator end brackets to the yoke, and withdraw the commutator end bracket complete with brush gear.
4. Withdraw the armature complete with drive end bracket by tapping the bracket with a hide or wooden mallet. Take care of the fibre thrust washer from the commutator end of the armature shaft.
5. Press the armature out of the drive end bracket bearing.

Field coils

Testing

1. Measure the resistance using an ohmmeter connected between the field terminal and the dynamo yoke. A reading of 6·0 ohms should be indicated.
2. If an ohmmeter is not available, connect a 12 volt d.c. supply between the field terminal and the dynamo yoke with an ammeter in series. The ammeter reading should be approximately 2 amps.

An 'infinity' ohmmeter reading or a zero ammeter reading indicates an open circuit in the field winding, while an ohmmeter reading much below 6·0 ohms, or an excessive ammeter reading is an indication that the insulation of one of the field coils has broken down. In either event the field coils must be renewed.

Removing and Fitting

1. Drill out the rivet securing the field coil terminal assembly to the dynamo yoke. Remove the insulation sleeve from the terminal blade and unsolder the connections to the terminal blade and earthing eyelet.
2. Remove the insulation piece, which prevents the junction of the field coils contacting the yoke.
3. Mark the yoke and pole shoes so that the shoes may be refitted in their original positions and unscrew the two pole shoe retaining screws, using a wheel operated screwdriver.
4. Draw the pole shoes and coils out of the dynamo yoke and lift off the coils.

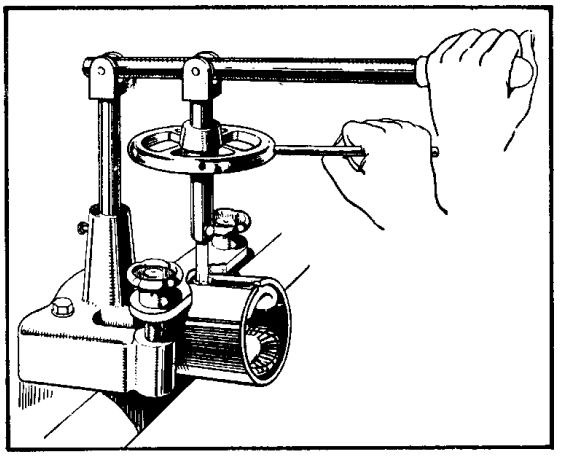


Fig.9 - Tightening the pole shoe securing screws

5. Locate new field coils, and pole shoes, in the yoke and lightly tighten the securing screws, ensuring that the taping of the coils is not trapped between the pole shoes and the yoke. Finally, tighten the screws with the wheel operated screwdriver.
6. Replace the insulation piece between the coil connections and the yoke.
7. Connect the coil leads to the terminal block and rivet the block assembly to the yoke.

Commutator End bracket and Brush gear

1. Assemble the commutator end bracket to the armature with the brushes held in position on the commutator by their springs. Hold back each of the brush springs in turn and check each brush for freedom of movement by pulling gently on its flexible connection.
2. To free sticking brushes, remove the endbracket from the armature, clean all the carbon deposit from the brush holders with petrol (gasoline) and if necessary, ease the brushes by lightly polishing the sides with a smooth file.
   Should the length of the brushes be less than $\frac{1}{4}$ in. (6·35 mm) fit new ones and bed them to the commutator.
3. Refit the commutator end bracket to the armature and, using a small spring balance, measure the spring tension. This should be 30 oz (850 gm) maximum with new brushes and not less than 13 oz (369 gm) with worn brushes.
4. Test the bush in the commutator end bracket for wear; if side movement of the armature shaft in the bush is evident the bush should be renewed in the following way:—*
   (a) Remove the lubricator cup, wick and spring and withdraw the bush with a suitable extractor.
   (b) Press the new bush into position, using a self-extracting tool as shown. The diameter of the mandrel portion of the tool fitting pin must be 0·5924 in. (15·05 mm) and highly polished.
   (c) After pressing in the bush, withdraw the tool by tightening the nut against the sleeve, preventing the fitting pin from turning by gripping its squared end. The visible end of the bush must be flush with the inner face of the end bracket.

*NOTE: Before fitting a new bush immerse it in thin engine oil for 24 hours to fill the pores of the bush with lubricant. Do not open out the bush after fitting as this will interfere with its porosity and impair lubrication.

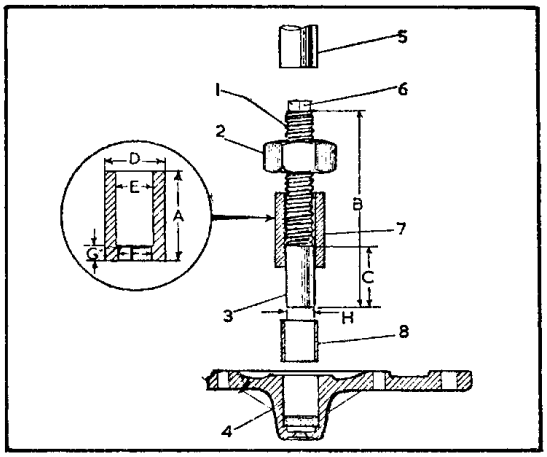


Fig.10 - Commutator end bracket bush and self extracting type tool assembly

1. 0.625 in(15.875 mm) BSF truncated thread
2. Extracting nut
3. Fitting pin
4. Bearing housing
5. Hand press
6. Squared end
7. Sleeve
8. Bush

A. 1.5 in.(38 mm)
B. 4in.(101.6 mm)
C. 1.25 in.(31.8 mm)
D. 1.3125 in.(33.3 mm)
E. 0.625 in.(15.87 mm)
F. 0.605 in.(16.51 mm)
G.0.25 in.(6.35 mm)
H. 0.5924 in.(15.05 mm)

Armature Assembly

To make a thorough check on the condition of the armature the use of a voltage drop test and growler is essential. If these are not available, the armature should be checked by substitution. No attempt should be made to machine the armature core or to true a distorted armature shaft.

1. Clean the commutator with a cloth moistened with petrol. If this is ineffective carefully polish with a strip of fine glass paper (not emery). Pass the glass paper round the commutator and draw it backwards and forwards while slowly rotating the armature.
2. Should skimming be necessary, ensure that the finished diameter is not less than 1·450 in. (36·83 mm). Renew the armature if the commutator cannot be cleaned up without going below that diameter. The process of re-skimming consists of
   (a) rough turning
   (b) undercutting and
   (c) diamond turning, in that order.
   Remove only the minimum amount of material when rough turning, and undercut the insulation between the commutator segments to a depth of 1/32 in. (0·8 mm). Finally take a light skim using a diamond tipped cutting tool. If the cutting tool does not have a diamond tip polish the commutator with very fine glass paper.

Drive end bearing

If the drive end ball bearing is worn to such an extent that it will allow side movement of the armature shaft, renew the bearing in the following way:—

1. Drill out the rivets which secure the bearing retaining plate to the end bracket and remove the plate.
2. Press the bearing out of the end bracket and remove the corrugated washer and felt ring.
3. Thoroughly clean the new bearing and pack it with a high melting point grease.
4. Place the felt ring and corrugated washer in the end bracket bearing housing.
5. Locate the bearing in the housing and press it home by means of a hand press.
6. Fit the bearing retaining plate, and secure in position by riveting, inserting the rivets into the endbracket from the outside.

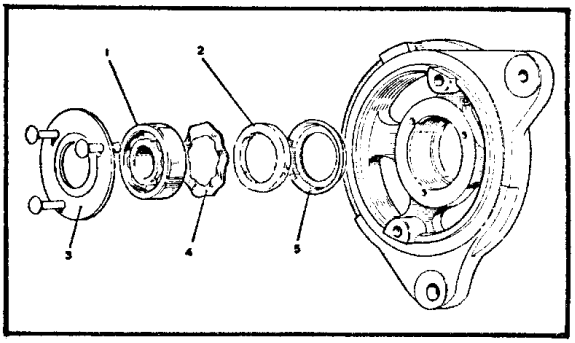


Fig.11 - Drive end bracket assembly

1. Ball bearing
2. Felt washer
3. Retaining plate
4. Corrugated washer
5. Oil-retaining washer

Re-assembling

1. Press the drive end of the armature shaft into the ball bearing in the drive end bracket. During the pressing operation support the bearing inner race, using a length of suitable tubing. Do not use the drive end bracket to support the bearing.
2. Refit the armature and drive end bracket to the yoke ensuring the dowel in the end bracket engages the slot in the yoke.
3. Replace the fibre thrust washer and refit the commutator end bracket, partially withdrawing the brushes from the brush boxes to clear the commutator and ensuring the dowel engages the slot in the yoke. Ensure the brushes are correctly located when the end bracket is in position.
4. Replace the two through bolts and secure.
5. Refit the fan and pulley.

Bench testing

After re-assembling, mount the dynamo on a power driven test bench and check the dynamo performance against the following data.

1. Cutting-in speed ..1450 rev/min (maximum) at 13·0 dynamo volts.
2. Maximum output ..22 amps at 2250 rev/min (maximum) at 13·5 dynamo volts and a resistance load of 0·61 ohm.
3. Field resistance ....6·0 ohms.

E.3

CONTROL BOX

Description

The control box contains two units – a voltage regulator and a cut-out. Although structurally combined, the regulator and cut-out are electrically separate (see Fig.13). Both are accurately adjusted during manufacture, and the cover protecting them should only be removed if the unit is faulty or suspect.

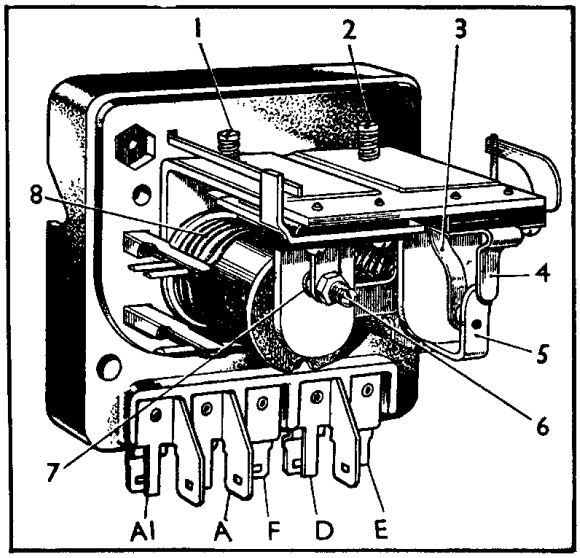


Fig.12 - Control box

1. Regulator adjusting screw
2. Cut-out adjusting screw
3. Fixed contact blade
4. Stop arm
5. Armature tongue and moving contact
6. Regulator fixed contact screw
7. Regulator moving contact
8. Regulator series windings

Regulator

The regulator is set to maintain the dynamo output between close limits at all speeds above the regulating point, the field strength being controlled by the automatic insertion and withdrawal of a resistance in the dynamo field circuit. When the dynamo output reaches a predetermined value the magnetic flux in the regulator core, induced by the shunt or voltage winding, becomes sufficiently strong to attract the armature to the core. This causes the contacts to open, thereby inserting the resistance in the dynamo field circuit.

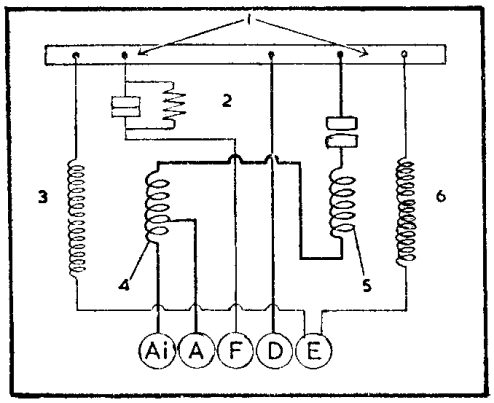


Fig.13 - Regulator and cut out schematic

1. Regulator and cut-out frame
2. Field resistance
3. Shunt coil
4. Tapped series coil
5. Series coil
6. Shunt coil

The consequent reduction in the dynamo field current lowers the dynamo output, and this in turn weakens the magnetic flux in the regulator core. The armature therefore returns to its original position, and with the contact closed the dynamo output rises again to its regulated maximum. This cycle is then repeated, and an oscillation of the armature is maintained.

As the speed of the dynamo rises above that at which the regulator comes into operation, the periods of contact separation increase in length, and as a result the mean value of the dynamo output undergoes practically no increase once this regulating speed has been attained.

The series or current winding provides a compensation on this system of control, for if the control were arranged entirely on the basis of voltage there would be a risk of seriously overloading the dynamo when the battery was in a low state of charge, particularly if the lamps were in use simultaneously.

Under these conditions, with a battery of low internal resistance the dynamo output rises and, but for the series winding, would exceed its normal rating. The magnetism due to the series winding assists the shunt winding, so that when the dynamo is delivering a heavy current into a discharged battery the regulator comes into operation at a somewhat reduced voltage, thus limiting the output accordingly. As shown in Fig. 13 a split series winding is used, terminal 'A' being connected to the battery and terminal 'A1' to the lighting and ignition switch.

By means of a temperature compensation device the voltage characteristic of the dynamo is caused to conform more closely to that of the battery under all climatic conditions. In cold weather the voltage required to charge the battery at a given rate increases, whilst in warm weather the voltage required is lower. The compensation device is in the form of a bi-metal spring located behind the tensioning spring of the regulator armature. By causing the operating voltage of the regulator to be increased in cold weather and reduced in hot weather the bi-metal spring compensates for the changing temperature characteristics of the battery and prevents undue variation of the charging current which would otherwise occur. The bi-metal spring also compensates for effects due to increases in resistance of the copper windings from cold to working values.

Cut-out

The cut-out is an electro-magnetically operated switch connected in the charging circuit between the dynamo and the battery. It automatically connects the dynamo with the battery when the dynamo output exceeds that of the battery and disconnects the two when the dynamo output falls below that of the battery, and so prevents the battery from discharging and possibly damaging the dynamo windings.

The cut-out consists of an electro-magnet fitted with an armature which operates a pair of contacts. The electro-magnet employs two windings – a shunt winding of many turns of fine wire and a series winding of a few turns of heavier-gauge wire. The contacts are normally held open and are closed only when the magnetic pull from the armature is sufficient to overcome the tension of the adjusting spring.

The shunt coil is connected across the dynamo. When starting, the speed of the engine and thus the output of the dynamo rises until the electro-magnet is strong enough to overcome the spring tension and close the cut-out contacts. The effect of the charging current flowing through the cut-out windings creates a magnetic field in the same direction as that produced by the shunt winding. This increases the magnetic pull on the armature so that the contacts are firmly closed and cannot be separated by vibration. When the speed of the dynamo falls to a point where its output is lower than that of the battery, current flows from the battery through the cut-out series winding and dynamo in a reverse direction to the charging current. This reverse current through the cut-out

will produce a differential action between the two windings and partly demagnetize the electro-magnet. The spring, which is under constant tension, then pulls the armature away from the magnet and so separates the contacts and opens the circuit.
Like the regulator, the operation of the cut-out is temperature-controlled by means of a bi-metal tensioning spring.

Regulator adjustment
The regulator is carefully set before leaving the Works to suit the normal requirements of the standard equipment, and in general it should not be necessary to alter it. If, however, the battery does not keep in a charged condition, or if the dynamo output does not fall when the battery is fully charged, it may be advisable to check the setting and, if necessary, to readjust it.
It is important, before altering the regulator setting, when the battery is in a low state of charge, to check that its condition is not due to a battery defect or to the dynamo belt slipping.

Electrical setting (with unit cold)
The electrical setting of the control unit can be checked without removing the cover, using a good-quality moving-coil voltmeter (0-20 volts).
Withdraw the cables from the control box terminals 'A' and 'A1' and connect these cables together.
Connect the negative lead of the voltmeter to the control box terminal 'D' and connect the other lead to terminal 'E'.
Slowly increase the speed of the engine until the voltmeter needle flicks and then steadies. This should occur at a voltmeter reading between 15·8 and 16·7 volts according to the ambient temperature.
If the voltage at which the reading becomes steady occurs outside these limits the regulator must be adjusted in the following way:—
(a) Switch off the engine and remove the control box cover.
(b) Slacken the voltage adjusting screw locknut and turn the adjusting screw (Fig.14) in a clockwise direction to raise the setting or in an anti-clockwise direction to lower the setting. Turn the screw only a fraction of a turn at a time. Repeat as above until the correct setting is obtained and tighten the locknut.

The adjustment of the regulator open-circuit voltage should be completed within 30 seconds, otherwise heating of the shunt winding will cause false settings to be made.
A dynamo run at high speed on open circuit will build up a high voltage. Therefore, when adjusting the regulator increase the engine speed slowly until the regulator operates, otherwise a false setting may be made.
Reconnect the cables to the respective terminals 'A' and 'A1'.

Mechanical setting
The mechanical or air gap settings of the regulator shown in Fig.14 are accurately adjusted before leaving the Works, and, provided that the armature carrying the moving contact is not removed, these settings must not be tampered with. If, however, the armature has been removed the regulator will have to be reset. To do this proceed as follows:—
(a) Slacken the fixed contact adjustment screw locking nut and turn the screw until it is quite clear of the armature moving contact.
(b) Unscrew the voltage adjusting screw until it is well clear of the armature tension spring.
(c) Slacken the two armature assembly securing screws.
(d) Using a 0·021 in. (0·533 mm) thick feeler gauge, wide enough to cover completely the core face, insert the gauge between the armature and the core shim as shown, taking care not to turn up or damage the edge of the shim.
(e) Press the armature squarely down against the gauge and retighten the two armature assembly securing screws.
(f) With the gauge still in position, screw the adjustable contact down until it just touches the armature contact.
Retighten the locking nut.
(g) Reset the voltage adjusting screw as described under 'Electrical setting (with unit cold)'.

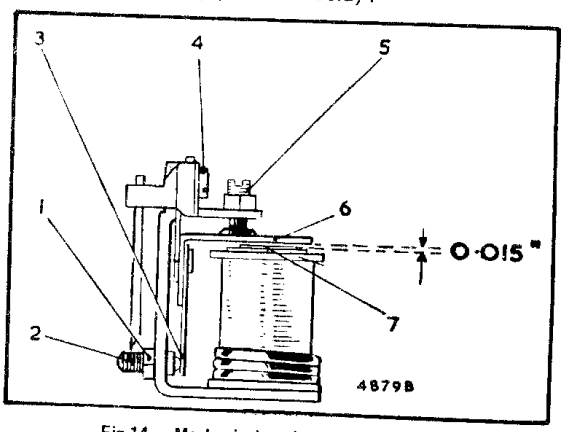


Fig.14 - Mechanical setting of the regulator

1. Locknut
2. Voltage adjusting screw
3. Armature tension spring
4. Armature securing screws
5. Fixed contact adjustment screw
6. Armature
7. Core face and shim

Cleaning contacts
After long periods of service it may be found necessary to clean the regulator contacts. Clean the contacts by means of a fine carborundum stone or fine emery-cloth.
Carefully wipe away all traces of dust or other foreign matter with methylated spirits.

Cut-out adjustment
Electrical setting
If the regulator is correctly set but the battery is still not being charged the cut-out may be out of adjustment. To check the voltage at which the cut-out operates remove the control box cover and connect the voltmeter between terminals 'D' and 'E'.
Start the engine and slowly increase its speed until the cut-out contacts are seen to close, noting the voltage at which this occurs. It should be between 12·7 and 13·3 volts. If the contacts close outside these limits it will be necessary to adjust the unit in the following way:—
(a) Turn the cut-out adjusting screw in a clockwise direction to raise the voltage setting or in an anticlockwise direction to reduce the setting. Turn the screw only a fraction of a turn at a time.
(b) Test after each adjustment by increasing the engine speed and noting the voltmeter readings at the instant of contact closure. Electrical settings of the cut-out, like the regulator, must be made as quickly as possible because of the temperature rise effects.

If the cut-out does not operate there may be an open circuit in the wiring of the cut-out and regulator unit, in which case the units should be removed for examination or renewal.

Mechanical setting
If for any reason the cut-out armature has to be removed from the frame care must be taken to obtain the correct air gap settings on re-assembly. These can be obtained as follows:—

(a) Unscrew the cut-out adjusting screw until it is well clear of the armature tension spring.
(b) Slacken the two armature securing screws.
(c) Press the armature squarely down against the copper-sprayed core face and retighten the armature securing screws.
(d) Using a pair of thin-nosed pliers, adjust the gap between the armature stop arm and the armature tongue by bending the stop arm. The gap must be 0·030 in. (0·762 mm) when the armature is pressed squarely down against the core face.
Similarly, the fixed contact blade must be bent so that when the armature is pressed squarely down against the core face there is a 'follow through' of blade deflection of 0·010 to 0·020 in. (0·254 to 0·508 mm). See Fig. 15
(e) Reset the cut-out adjusting screw in accordance with the instructions already given.

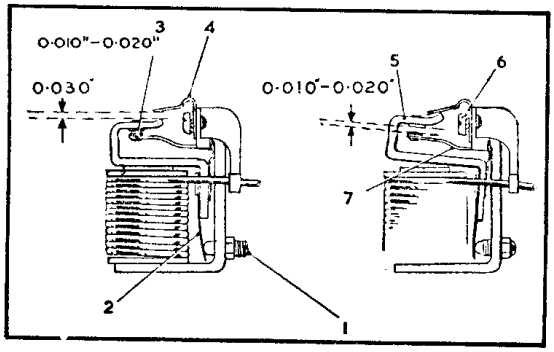


Fig.15 - Mechanical setting of the cut-out

1. Cut-out adjusting screw
2. Armature tension spring
3. 'Follow through' - 0.010 to 0.020 in.(0.254 to 0.508 mm)
4. Stop arm
5. Armature tongue and moving contact
6. Armature securing screws
7. Fixed contact blade

Cleaning contacts

Do not use emery-cloth or a carborundum stone for cleaning cut-out contacts. If the contacts appear dirty, rough, or burnt, place a strip of fine glass-paper between the contacts and then, with the contacts closed by hand, draw the paper through. This should be done two or three times with the rough side of the glass-paper towards each contact.
Wipe away all dust or other foreign matter, using a clean, fluffless cloth moistened with methylated spirits.

E.4

STARTER MOTOR – TYPE M45G

Description

The Type M45G starter motor is a series parallel wound, four-pole, four brush, solenoid-operated pre-engaged drive type machine.
A roller clutch incorporated in the drive assembly allows torque to be transmitted from starter motor to engine, but not in the reverse direction. This ensures that the armature is never driven at high speed by the engine; thus, in the event of the starter drive pinion remaining in mesh with the flywheel starter ring after the engine has fired, the armature is adequately protected as the drive pinion is free running in this direction. The clutch unit is sealed and cannot be dismantled for subsequent re-assembly.
A pair of moulded brake shoes, driven by a cross-peg in the armature shaft, are spring loaded against a steel ring inserted in the commutator end bracket to ensure a rapid return to rest of the armature when the engine fires and the starter switch is released.
The solenoid unit consists of a closing coil, a hold-on coil, and a plunger operating the starter switch contacts. Like the clutch unit the solenoid is sealed and cannot be dismantled for subsequent re-assembly.

Operation

When the starter switch is operated the solenoid is energised and the starter pinion moves into mesh with the flywheel starter ring. The first and second stage switch contacts close and full torque is exerted by the armature.
In the event of tooth to tooth abutment, axial movement of the drive and pivoting of the engagement lever is stopped, but the solenoid plunger casing continues its travel, compressing the engagement spring located within it to close the first pair of contacts. The closing of these contacts energises one of the four field windings, resulting in partial torque being exerted by the armature. Immediately the pinion clears the abutment, the engagement spring meshes the pinion with the starter ring and moves the solenoid plunger to close the second pair of contacts. The closing of these contacts connects the remaining field windings in parallel with the first, and full torque is exerted by the armature.
A lost motion spring ensures that, when the starter switch is released, the contacts in the solenoid are opened before withdrawal of the pinion from the starter ring commences. The spring is interposed between the solenoid plunger casing and the engagement lever, and, as it is weaker than the solenoid plunger return spring, the initial movement of the plunger casing by the return spring opens the contacts and compresses the lost motion spring before moving the engagement lever.

Fault finding

If the starter motor does not operate, or is sluggish, the following points should be checked prior to removal.

1. Ensure that the battery is in a healthy, well charged condition and that the terminals and earth connections are clean and tight.
2. Connect a voltmeter (0-20) across the battery terminals and operate the starter switch.
   A minimum voltmeter reading of 10 volts indicates a satisfactory circuit, but if the starter motor does not operate the indications are that current is flowing through the motor windings, with the armature stationary, and the motor should be removed from the engine for examination. If the starter operates sluggishly proceed as in 3.
3. Connect the voltmeter between the starter main terminal and yoke and operate the starter motor for two or three seconds. A maximum voltage drop of 0·5 volt from that obtained in 2 indicates a satisfactory circuit, but if the voltage drop is excessive continue as in 4.
4. Connect the voltmeter between the starter terminal and battery negative, and operate the motor for two or three seconds.
   If the meter reading drops to above 0·5 volt proceed to test the solenoid, as in 5, but if the meter reading drops to or below 0·5 volt proceed as in 6.
5. Connect the voltmeter across the solenoid switch and operate the starter for two or three seconds.
   (a) If the reading is the same as in 4, a faulty switch or connection is indicated.
   (b) If the reading is zero or fractional, suspect a poor connection at the battery, starter switch or starter main terminal.
   (c) If the solenoid operation is sluggish, check that the voltage drop in the operating switch circuit is not excessive.
6. Connect the voltmeter between the starter yoke and battery earthed terminal and operate the motor for two

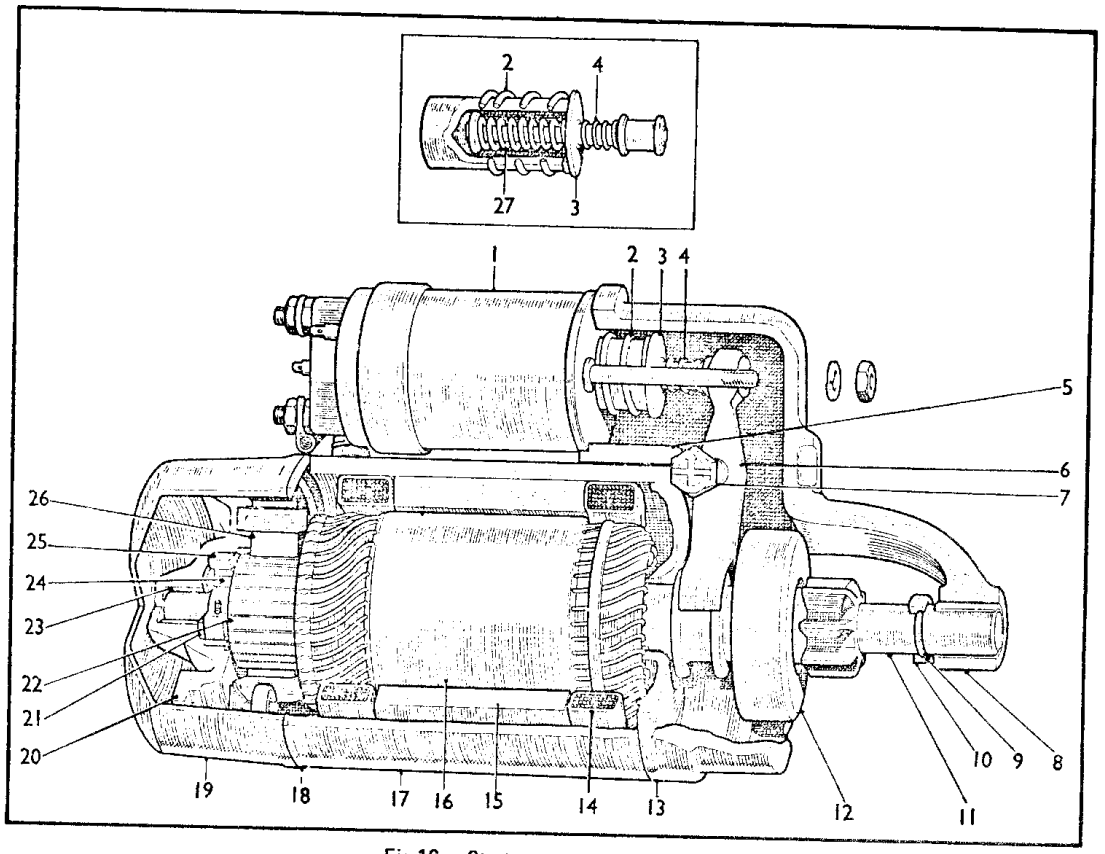


Fig.16 - Starter motor components

1.	Solenoid	10.	Thrust collar	19.	End cover
2.	Return spring	11.	Armature shaft	20.	Commutator end bracket
3.	Solenoid plunger	12.	Roller clutch	21.	Thrust washer
4.	Lost motion spring	13.	Intermediate bracket	22.	Commutator
5.	Oil seal	14.	Field coils	23.	Bush
6.	Engagement lever	15.	Pole-shoe	24.	Brake-shoe
7.	Engagement lever pivot pin	16.	Armature	25.	Brake ring
8.	Drive end bracket	17.	Yoke	26.	Brush
9.	Retaining ring	18.	End cover oil seal	27.	Drive engagement spring

or three seconds.

(a) A zero reading will indicate that the earth line is satisfactory.

(b) If the meter reading reaches 0·5 volt check the battery earth connections and the engine to frame cable connections.

If the motor is heard to operate but does not attempt to crank the engine, a damaged drive is indicated and the motor should be removed for examination.

Removing and Replacing the Motor

1. Disconnect the battery to prevent possible short circuiting and detach the heavy and light cables from the terminals on the base of the starter solenoid.
2. Remove the oil filter, unscrew the two bolts with spring washers securing the starter motor to the flywheel housing, gearbox distance piece or engine backplate and withdraw the motor forward and away from the engine.

Replacement of the starter motor is a reversal of the above procedure. If however, a replacement motor is to be fitted, or in the event of the driving end bracket being renewed during overhaul, the pinion out-of-mesh clearance must be checked before assembling the starter to engine. The clearance should be $\frac{1}{8}$ in. (3·2 mm) between the leading edge of the starter pinion and the flywheel starter ring.

MAINTENANCE AND OVERHAUL PROCEDURES

Dismantling

1. Disconnect the copper link from the terminal 'STA' on the solenoid and the terminal on the starter motor yoke. Remove the two securing nuts with spring washers and withdraw the solenoid and solenoid plunger spring from the driving end bracket, lifting the solenoid plunger upwards to disengage it from the upper end of the drive engagement lever.
2. Remove the commutator band cover, hold back the brush springs, and withdraw the brushes from their holders.
3. Unscrew and remove the two through-bolts and withdraw the commutator end bracket from the yoke.
4. Withdraw the yoke complete with field coils from the armature and drive assembly.
5. Slacken the drive engagement lever pivot pin locknut and remove the pin.
6. Remove the drive end bracket.

7. Carefully drive the thrust collar off its retaining ring on the armature shaft. Withdraw the retaining spring and remove the thrust collar and drive assembly from the armature shaft.
8. Remove the intermediate bracket from the armature assembly.

Field coils

Insulation test

Ensure that the brushes are clear of the yoke and connect a 110 volt a.c. supply in series with a 15 watt test lamp to the terminal post. Connect the neutral side of the supply to a clean part of the motor yoke. Lighting of the test lamp will indicate that the field coils are earthed to the yoke and must be renewed.

Continuity test

Connect a 12 volt battery and a 1·5 watt test lamp between the terminal post and each brush in turn. If the lamp does not light an open circuit is indicated and the coils must be renewed.

Removing and Fitting

1. Remove the nut, spring washer, plain washer and insulating washer from the terminal post.
2. Using a wheel operated screwdriver, remove the four pole shoe retaining screws. Withdraw the inter-coil connector insulating piece and lift the field coils complete with terminal and poleshoes out of the yoke. Withdraw the insulator from the field coil terminal and separate the pole shoes from the coils.
3. Assemble the new coils to the pole shoes and position them inside the yoke. Do not forget to fit the insulator to the coil terminal.
4. Insert and lightly tighten the pole shoes, retaining screws, ensuring that the field coil taping is not trapped between the pole shoes and the yoke. Replace the inter coil connector insulation piece and, with the pole shoes held in position by means of a pole shoe expander, tighten the retaining screws with a wheel operated screwdriver.

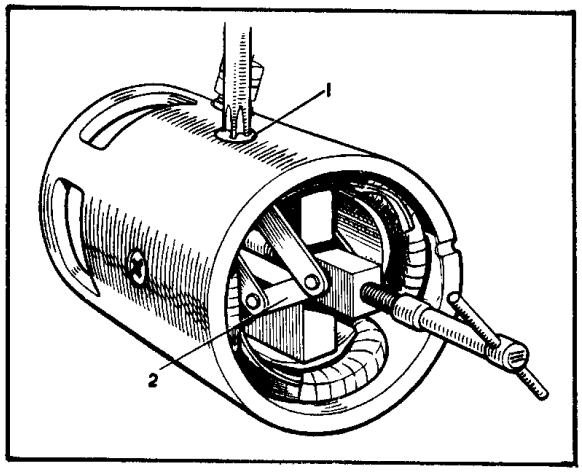


Fig.17 - Field coils - assembly procedure

1. Pole-shoe retaining screw 2. Pole-shoe expander

Commutator End bracket and Brush Gear

1. Check the condition of the two moulded brake shoes. If excessive wear is evident carefully prise the shoes and springs from their housing, and renew. Take care not to lose the hardened steel washer fitted beneath the brake shoes.
2. Hold back each brush spring in turn and move the brush by gently pulling on its flexible connector. If the movement is sluggish, remove the brush from its holder and ease the sides by lightly polishing on a smooth file. Renew the brushes if they have worn to approximately 5/16 in. (8·0 mm) in length. Two of the brushes are connected to the insulated brush holders on the commutator end bracket and two are connected to tappings on the field coils.
3. To renew the brushes release the flexible connectors from the brush holders and field coil tappings using a hot soldering iron, and secure the flexible connections of the new brushes by soldering. New brushes are preformed so that bedding to the commutator is unnecessary.
4. Ensure the brush holders are secure on the commutator end bracket and using a 110 volt a.c. supply and 15 watt test lamp, test the insulation of the two insulated brush holders. Clean off all traces of carbon deposits before testing. Connect the supply and test lamp between each brush box in turn, and the commutator end bracket. If the lamp lights, the insulation is faulty and the end bracket must be renewed.
5. With the armature located in the yoke and the commutator end bracket fitted to the armature, use a spring balance to check the spring tension. With new brushes the tension should not be less than 43 oz. (1·219 kg).
6. Check the bracket bearing for wear. If excessive side play of the armature shaft is experienced, renew as follows :—
   (a) Screw a suitable tap squarely into the bearing and then withdraw the tap complete with bearing.
   (b) Press a new bush into position using a shouldered, highly polished mandrel 0·0005 in. (0·013 mm) greater in diameter than the shaft which is to run in the bush.

   NOTE: Before fitting new bushes, immerse them in thin engine oil for 24 hours. This period may be shortened by heating the oil to 100°C (212°F) for two hours and allowing it to cool before removing the bushes. Porous bronze bushes must not be reamed after installation, as the porosity of the bearing will be impaired.

Drive end and Intermediate brackets

The drive end bracket and intermediate bracket bearings should be checked for wear and if necessary renewed in the same way as for the commutator end bracket. A new bush fitted to the intermediate bracket should be lubricated with Rocol 'Molypad' molybdenized non-creep oil (or equivalent) after fitting.

Armature Assembly

1. Inspect the winding for signs of burning or damage and check that the conductors have not lifted from the commutator risers; conductors which have lifted would indicate overspeeding of the motor due to a faulty roller clutch drive. If the conditions of the winding is doubtful an insulation test should be made using a 110 volt a.c. supply and 15 watt test lamp.
2. Connect the supply between each commutator segment, in turn, and the armature shaft. If the test lamp lights when contact is made with any segment the insulation is faulty and the armature must be renewed. To make a thorough check on the armature a 'growler' should be used, but in the absence of any test equipment a suspect armature should be checked by substitution.
3. Remove any traces of oil, carbon or dirt from the commutator with a petrol moistened cloth. Should this be ineffective spin the armature and polish the commutator with fine glass paper, removing all abrasive dust with a dry air blast.

4. If the commutator is badly worn, mount the armature between centres in a lathe, rotate at high speed, and make a light cut with a very sharp tool. Do not remove more metal than is necessary. Finally, polish with very fine glass paper. THE INSULATORS BETWEEN THE COMMUTATOR SEGMENTS MUST NOT BE UNDERCUT.

Re-assembly

1. Lubricate all moving parts with Rocol 'Molydest' starter motor grease (or an equivalent).
2. Refit the intermediate bracket, and the drive assembly to the armature shaft. Ensure that the roller clutch takes up instantaneous drive in one direction and rotates freely and smoothly in the other direction. Ensure also that the drive unit travels along the shaft splines without roughness or tendency to bind.
3. Refit the retaining ring and thrust collar to the armature shaft.
4. Refit the drive end bracket.
5. Replace the drive engagement lever pivot pin and locknut.
6. Fit a new rubber seal to the intermediate bracket and refit the yoke.
7. Refit the commutator end bracket to the yoke, fit new rubber washers to the through bolts, gold size seal the threads of the through bolts, replace the bolts and secure.
8. Fit a new rubber seal to the commutator end cover and refit the cover to the yoke.
9. Refit the solenoid to the drive end bracket and include a new gasket.
10. Before fitting the copper link to the solenoid and yoke, set the pinion travel and check the operation of the switch contacts:
    (a) Connect terminal 'STA' to earth.
    (b) Connect a 6 volt supply, with a switch in circuit, between the small unmarked solenoid terminal and earth.
    (c) Close the switch to move the pinion into the engaged position (the period of energisation should be as brief as possible to avoid overheating the series winding).
    (d) Lightly press the pinion towards the armature and rotate the engagement lever pivot pin to set the pinion to thrust collar clearance to between 0·005 in. (0·127 mm) and 0·015 in. (0·381 mm).
    (e) Tighten the pivot pin locknut, ensuring that the arrow on the pivot pin is within the arc on the drive end bracket.
    (f) Remove the 6 volt supply and replace it with a 10 volt supply.
    (g) Connect a separately energised test lamp circuit across the solenoid main terminals.
    (h) Insert a stop in the drive end bracket to restrict the pinion travel to that of the normal out-of-mesh clearance.
    (j) Close the switch (the period of energisation should be as brief as possible to avoid overheating the series winding). The test lamp should now give a steady light indicating that the solenoid contacts are remaining closed.
    (k) Switch off and remove the stop.
    (l) Switch on, hold the pinion in the fully engaged position and switch off. The test lamp should now go out, indicating that the solenoid contacts have opened.
11. Remove the test equipment and fit the copper link.
12. Check the starter motor performance.

Performance tests

1. Fit the starter motor to a starter test rig, and connect a fully charged 120 amp-hour (20 amp rate) 12 volt battery via a suitably rated ammeter and a switch to the solenoid and starter as shown.
2. Close the switch and check the light running current and the armature speed against the values given in the following table.

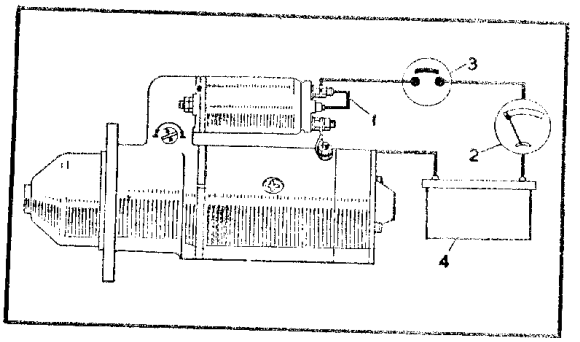


Fig.18 - Test equipment - light running current

1. Connecting link
2. Ammeter
3. Switch
4. 12-volt battery

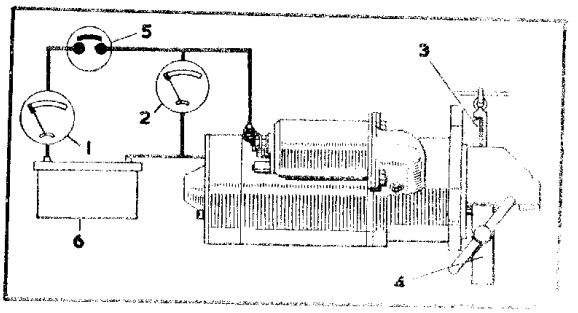


Fig.19 Test equipment - lock torque

1. Ammeter
2. Voltmeter
3. Spring balance
4. Torque arm pinion clamp
5. Switch
6. 12-volt battery

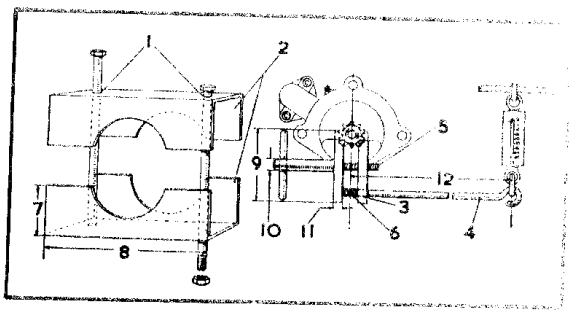


Fig.20 - Apparatus for lock torque test

1. 0.5 in (12.7 mm) diameter holes
2. 3 in. (76.2 mm) channel iron machined to suit yoke
3. 0.375 in. (9.5 mm) clearance
4. 0.375 in. (9.5 mm) mild steel rod
5. 0.375 in. (9.5 mm) B.S.F. Thread
6. Spring
7. 3in. (76.2 mm)
8. 10 in. (254 mm)
9. 3 in. (76.2 mm)
10. 0.625 in. (15.9 mm)
11. 0.375 in. (9.5 mm)
12. 12 in. (304.8 mm)

3. Connect a voltmeter into circuit and assemble the torque measuring apparatus as shown. Check the running and lock torque against the figures given.

Test	Amps	Voltage at starter terminal	Rev/min	Torque
Light running	100	—	5000 to 6000	—
Running torque	500	8	1000	13·5 lbf.ft
Lock torque	800	5·6	—	26 lbf.ft

Solenoid test

To test the solenoid, a resistance check should be made on the windings using a 'Wheatstone' bridge. Alternatively a current flow measurement can be made using a 4 volt supply and two separate ammeters, one calibrated 0-40 and the other calibrated 0-10, may be used. The test should be made with the windings cold, and when using a Wheatsone bridge the resistance value for the closing winding should be between 0·13 and 0·15 ohm, and for the hold-on winding between 0·63 and 0·73 ohm.

Closing winding

Using the current flow measurement method, connect the 4 volt supply and the 0-40 range ammeter in series between terminal S2 and the Lucar terminal. Adequately rated cables, preferably 44 strand 0·012 gauge, should be used, and a current flow of 26 to 31 amperes should be indicated on the ammeter.

Hold-on winding

Connect the 4 volt supply and the 0-10 range ammeter in series between the Lucar terminal and the solenoid body. A current flow of 5·5 to 6·5 amps should be indicated on the ammeter.

A solenoid with faulty or suspect windings should be renewed.

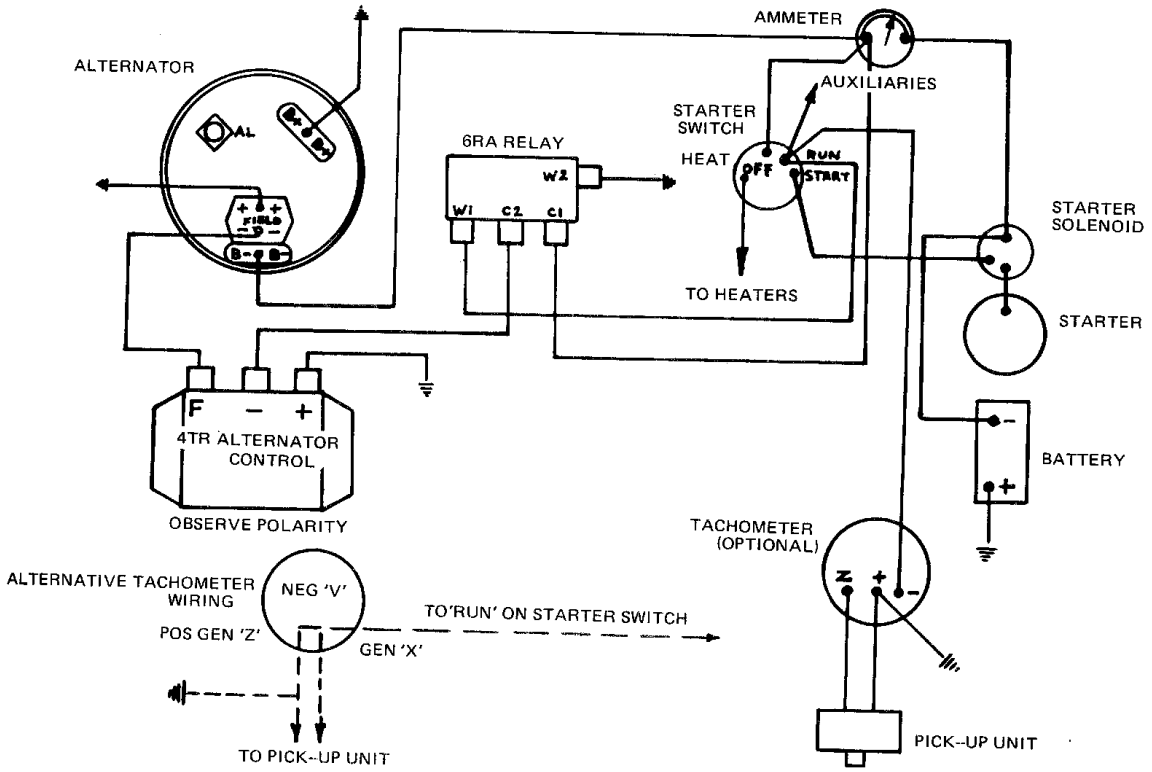


Fig.21 - Wiring diagram - Alternator positive earth system (Captain)

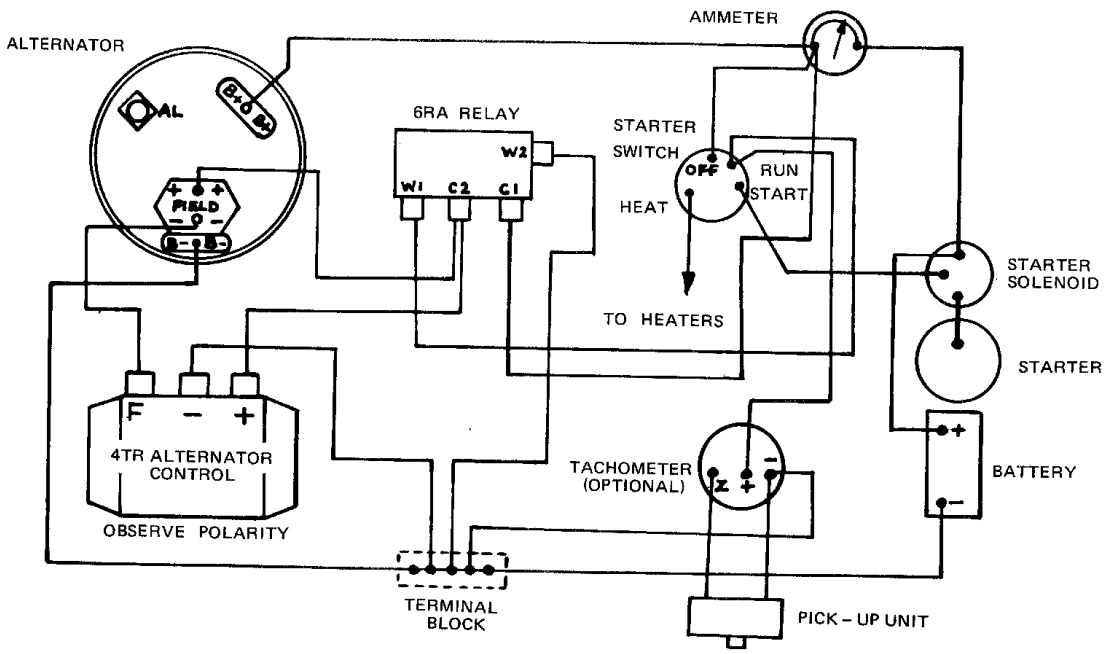


Fig.22 - Wiring diagram - Alternator insulated return system (Captain)

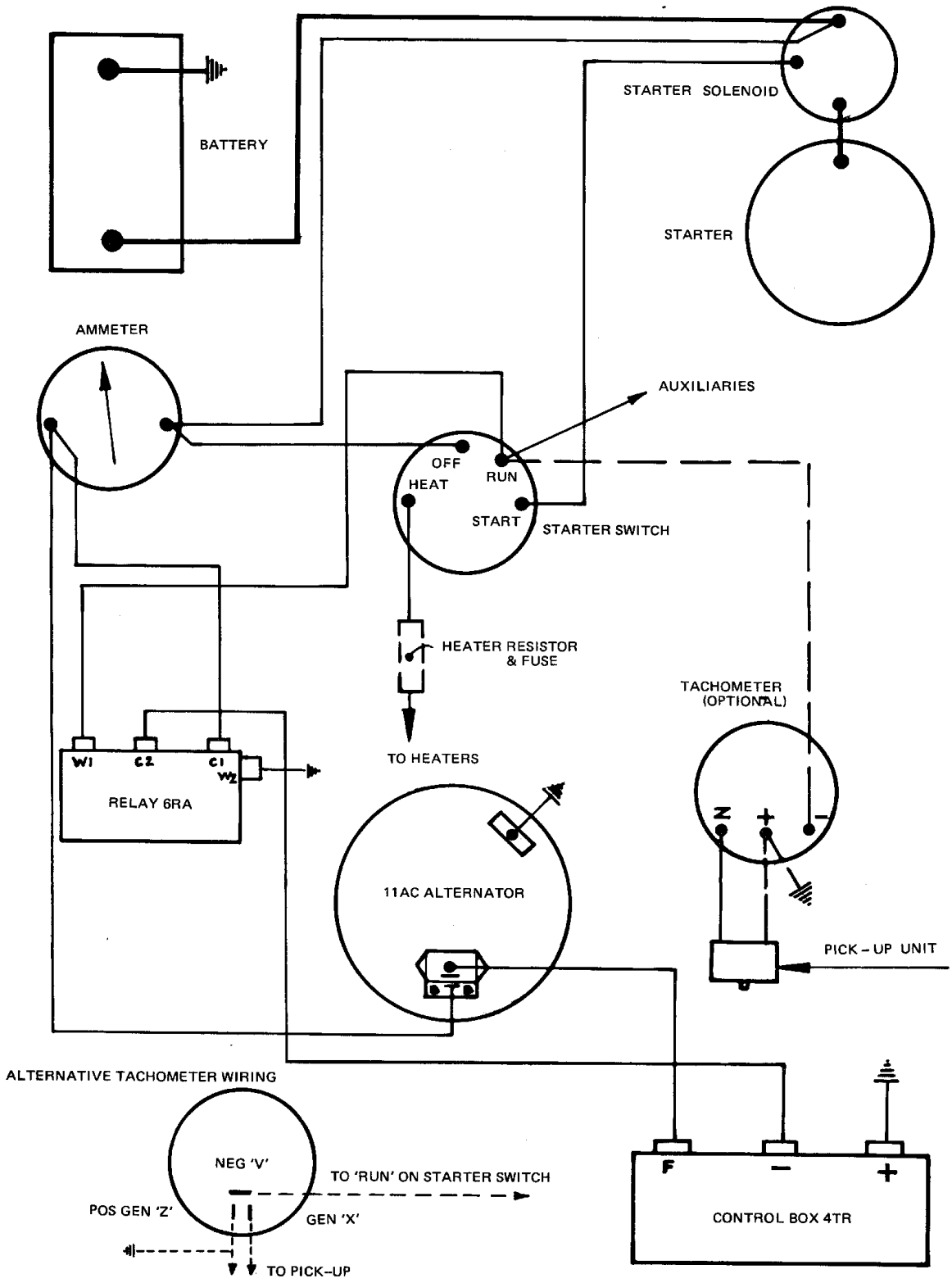


Fig.23 - Wiring diagram - Alternator positive earth system (Commander)

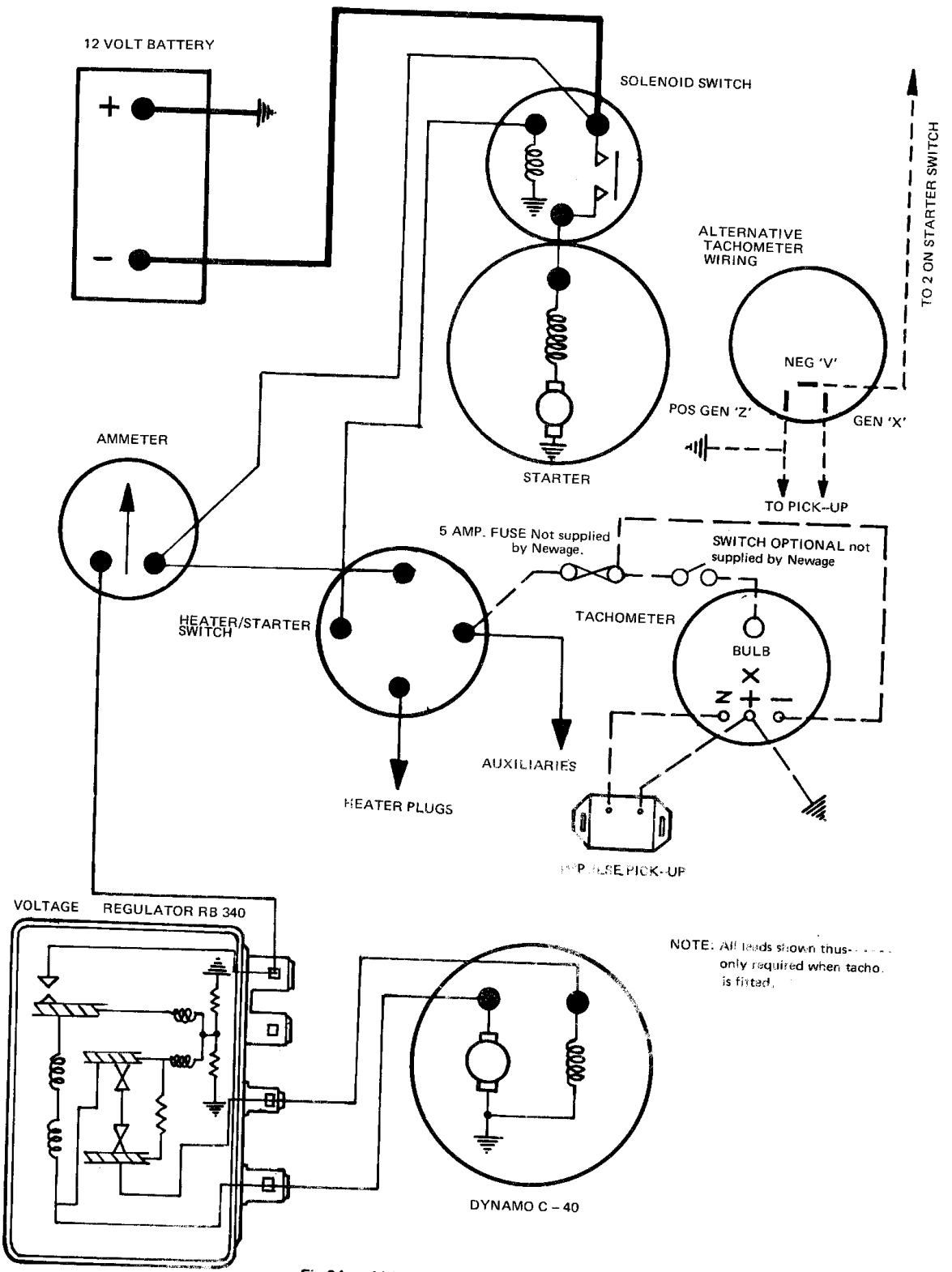


Fig.24 - Wiring diagram - Dynamo positive earth system

SECTION E

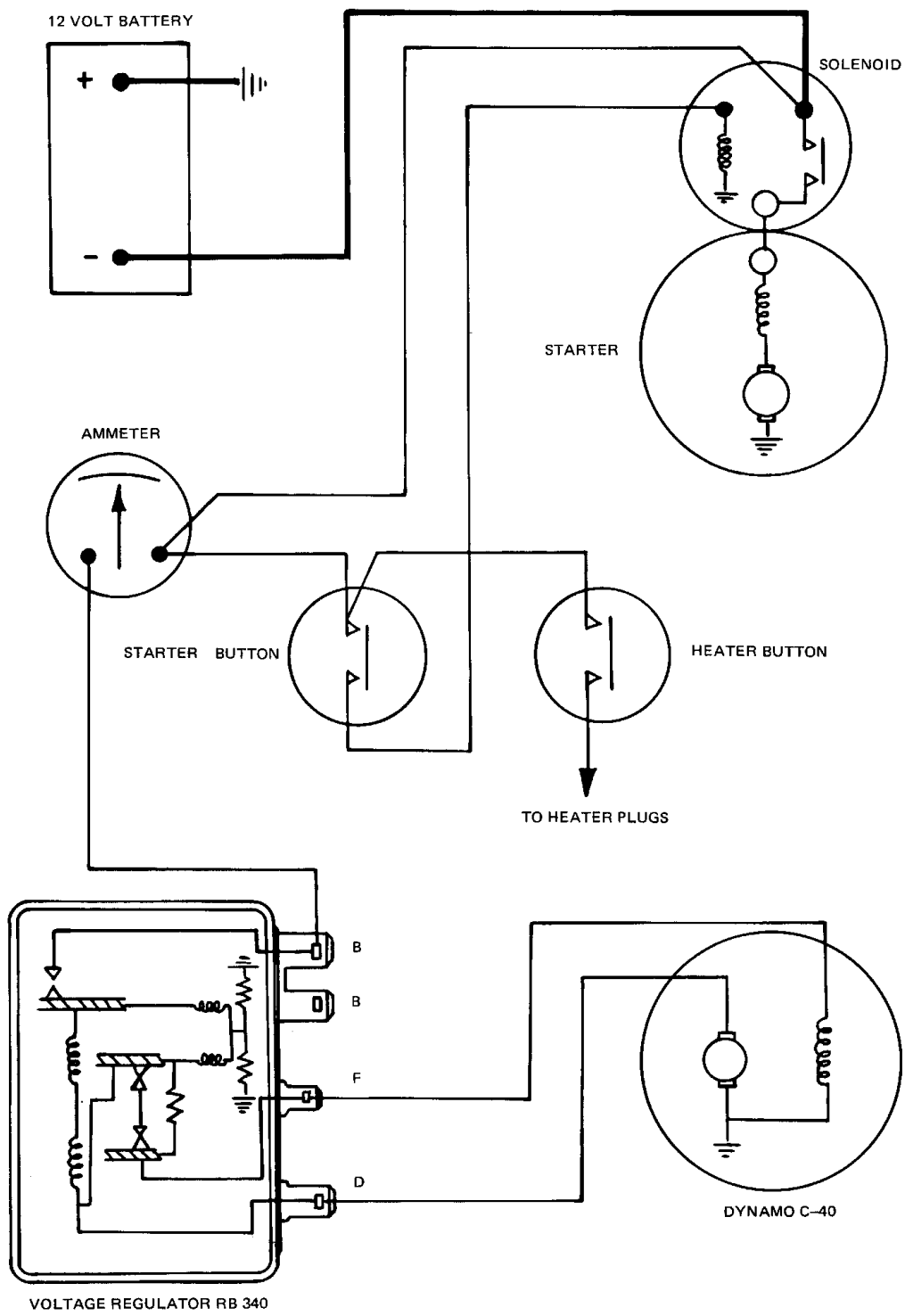


Fig.25 - Wiring diagram - Dynamo positive earth system (1.5 Industrial)

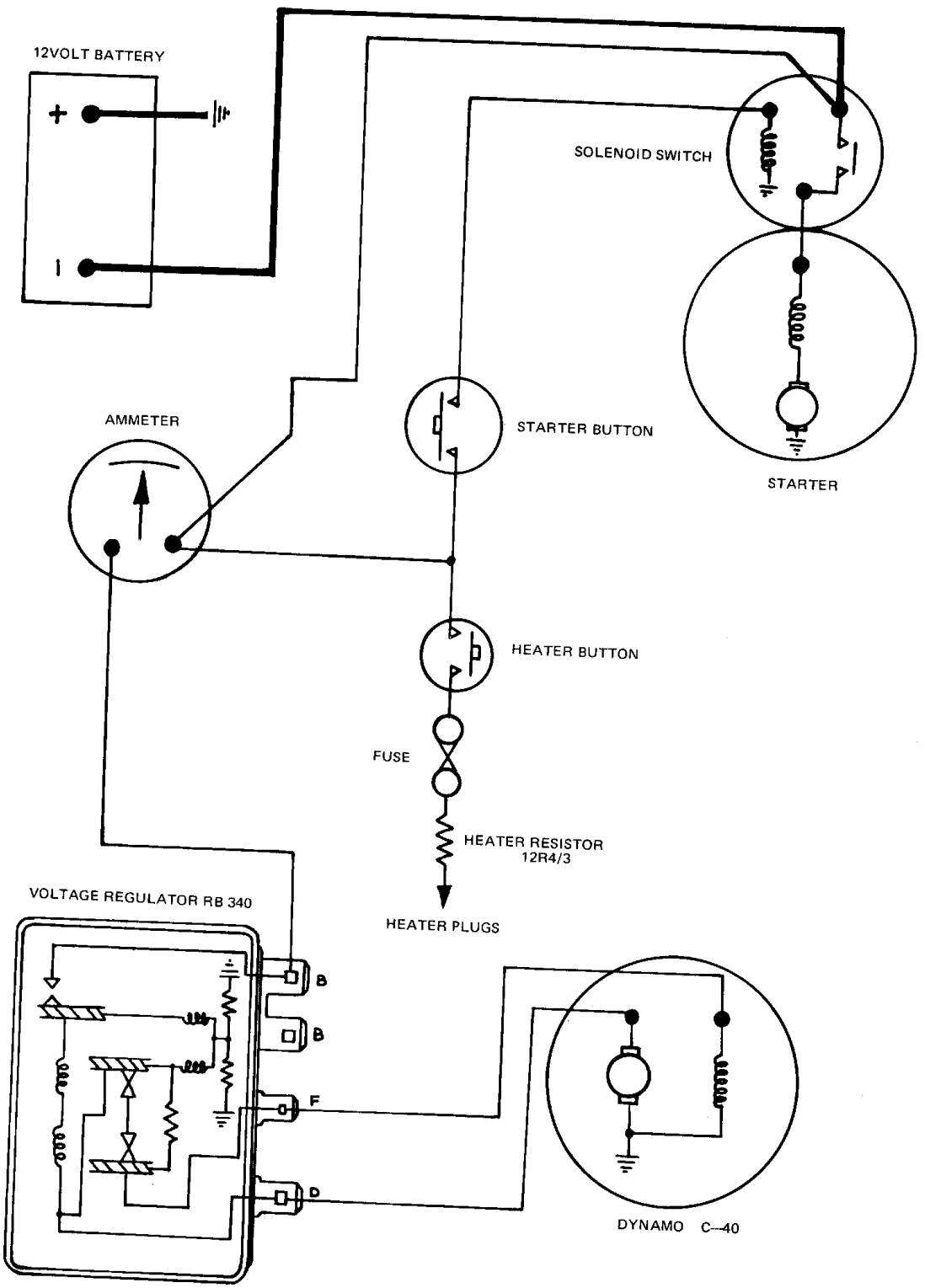


Fig.26 - Wiring diagram - Dynamo positive earth system (2.5 Industrial)

SECTION F

CLUTCH ASSEMBLIES

F.1

AUTOMOTIVE CLUTCH 8 in. (203·2 mm) and 9 in. (228·6 mm)

General Description

The 8 in. clutch used with the industrial automotive 1·5 litre engine and the 9 in. clutch used with the industrial automotive 2·5 litre engine are of the single plate dry disc type, mechanically operated with provision made for adjustment on the operating lever.

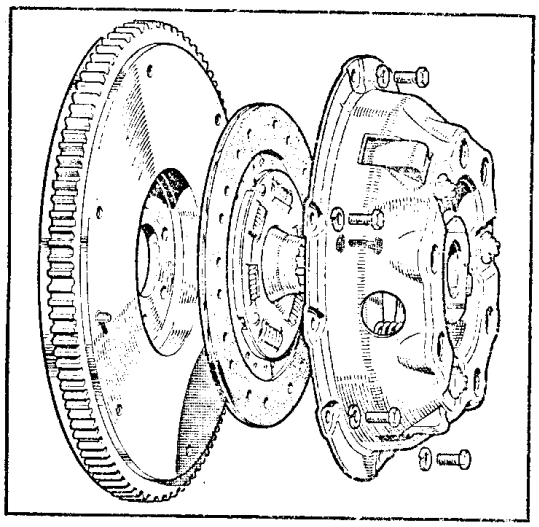


Fig.1 - Flywheel and Clutch

Driven Plate Assembly

The driven plate assembly consists of a splined hub and flexible steel driven plate to the outer diameter of which is fixed the annular friction facings. This plate is attached to the splined hub by a spring mounting which provides a torsional cushion.

Bearing Assembly

The withdrawal bearing assembly comprises a graphite release bearing mounted in a cup attached to the throw-out fork and a release plate attached to the inner ends of the release levers by means of retainer springs. Release is accomplished by moving the release bearing forward into contact with the release plate, thus applying pressure to the release levers.

Cover Assembly

Each release lever is pivoted on a floating pin which remains stationary in the lever and rolls across a short flat portion of the enlarged hole in the respective eyebolt. The outer ends of the eyebolts extend through holes in the clutch cover and are fitted with adjusting nuts by means of which each lever is located in its correct position. The outer or shorter ends of the release levers engage the pressure plate lugs by means of struts which provide knife edge contact between the outer ends of the levers and the pressure plate lugs, eliminating friction at these points. As pressure is applied to the clutch the pressure plate is withdrawn from the driven plate, compressing the thrust coil springs which are assembled between the pressure plate and clutch cover.

When pressure is removed from the clutch, the clutch springs force the pressure plate forward against the driven plate, gradually and smoothly applying the power of the engine to the transmission.

Adjustment

Adjustment of the control lever should rarely be necessary except when the friction linings have worn down, or after overhaul.

1. To check the clearance on the release bearing inside the clutch housing, depress the clutch pedal until the actual spring pressure is felt. Measure the travel at the pedal pad; this should be 1 in. (25·4 mm), which corresponds to a clearance of 1/16 in. (1·6 mm) on the release bearing.
2. If the clearance differs from the figure given, increase or decrease the length of the operating rod by rotating the nut at the trunnion in the operating lever.

Removing and Replacing

1. Remove the gearbox and clutch housing.
2. Mark the relative positions of the clutch cover and the flywheel, and gradually remove, a turn at a time and in diagonal sequence, the setbolts securing the clutch cover to the engine flywheel; withdraw the cover and the driven plate assembly.
   Before installing the clutch assembly it is advisable to check the flywheel for misalignment.
3. Hold the clutch cover assembly and driven plate on the flywheel and screw in the cover securing bolts finger tight. Note that the splines in the hub of the driven plate are chamfered at one end to permit ready entry of the stem wheel shaft splines. The longer side of the driven plate hub with the chamfered splines should be towards the rear.
4. Insert the clutch centralising tool 18G628 (1·5 litre) or 18G554 (2·5 litre) through the clutch cover and driven plate hub so that the pilot enters the spigot bearing in the rear end of the engine crankshaft. This will centralise the driven plate.
5. Tighten the clutch cover securing bolts a turn at a time in diagonal sequence, to avoid distortion.
6. Remove the centralising tool and install the gearbox.
7. Adjust the free movement of the clutch pedal.

OVERHAUL PROCEDURE

Dismantling

When dismantling the clutch cover assembly the following parts should be suitably marked so that they can be re-assembled in exactly the same relative positions to each other to preserve the balance and adjustment – the cover, the lugs on the pressure plate, and the release levers.

The Clutch assembly gauging fixture 18G99A shown in Section G provides an efficient and speedy means of dismantling, re-assembling and adjusting the clutch with a high degree of accuracy. The tool is universal, and a chart detailing the sizes of spacing washers and distance pieces for particular types of clutch is provided on the inside of the metal container lid.

Proceed as Follows

1. Detach the retaining springs from the release lever plate and remove the springs and plate.
2. Rest the clutch assembly tool base plate on a flat surface, ensure that it is clean, and place upon it spacing washers as directed by the chart.
3. Position the clutch on the spacing washers so that the holes in the clutch cover align with the tapped holes in the base plate, with the release levers as close to the spacing washers as possible.
4. Insert the tool setscrews, tightening them a little at a time in a diagonal pattern, until the cover is firmly and evenly secured to the base plate. This is most import-

ant if the best results are to be achieved.

5. Remove the four eyebolt adjusting nuts, sheering away the peening by initial pressure.
6. Unscrew, in a diagonal pattern, the setscrews securing the clutch cover to the base plate releasing the pressure on the clutch springs gradually and evenly. Lift off the cover and remove the pressure springs.
7. To remove the release levers, remove the anti-rattle springs, grasp the lever and eyebolt between the thumb and fingers, so that the inner end of the lever and the threaded end of the eyebolt are as near together as possible, keeping the eyebolt pin seated in its socket in the lever. The strut can then be lifted over the ridge on to the end of the lever, making it possible to lift the eyebolt off the pressure plate.

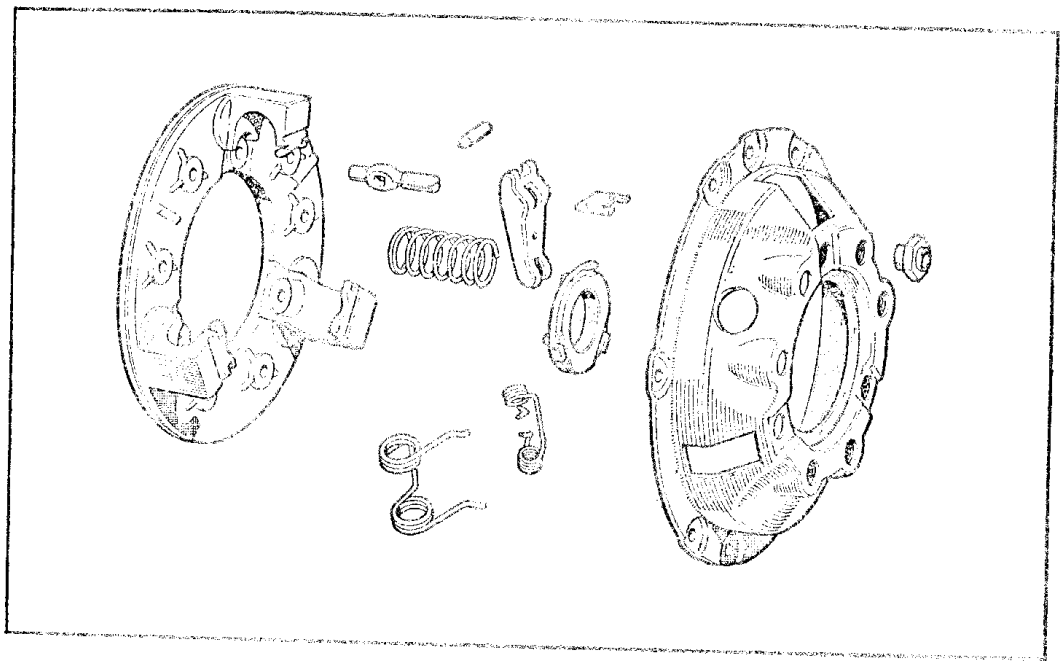


Fig.2 - Clutch assembly

8. Clean the clutch parts carefully. If the linings are to be used again they should not be allowed to come into contact with cleaning fluids.
9. Examine the friction linings for wear or loose rivets and check the driven plate for uneven or worn splines, distortion or signs of fatigue cracks. Generally, it is not desirable to fit new friction linings on the original driven plate because refaced driven plates often are distorted or otherwise impaired and produce unsatisfactory clutch action. If renewing linings, the rivets should be drilled out, not punched out.
10. After refacing, mount the driven plate on a mandrel between centres and check for 'run-out' by means of a dial gauge set as near to the edge as possible. Where a 'run-out' exceeds 0·015 in. (0·38 mm), true the plate by prising it in the requisite direction after finding the high-spots.
11. Examine the machined face of the pressure plate. If this is badly grooved and rough, the surface may be reground until the grooves disappear.
12. Examine the machined surface of the release lever plate. If this is badly grooved, renew the plate. A new plate will also be necessary if the surfaces on the reverse side of the plate, which are in contact with the tips of the release levers, are worn down.
13. Examine the tips of the release levers which bear on the back of the release lever plate. A small amount of worn flat surface is permissible, but if this is excessive the lever should be renewed. Check for excessive wear in the groove in which the strut bears. Examine carefully the 'U'-shaped depression in the lever into which fits the eyebolt floating pin. If the metal here has worn at all thin, the lever must be renewed as there is a danger of it breaking under load, with disastrous results to the whole mechanism.
14. Examine each eyebolt for flats on the surface which fits into the pressure plate. If it is a loose fit it must be renewed. The same applies to the eyebolt floating pin where it passes through the eyebolt. It should be a free fit, but not too loose.
15. Examine the release bearing for cracks or bad pitting, also measure the amount of bearing standing proud of the metal cup. If the bearing is cracked or badly pitted or there is 1/16 in. (1·6 mm) or less of bearing standing proud of the cup, the cup and bearing must be renewed.
16. Examine the pressure springs for weakness or distortion and if necessary renew. Renew in sets only.
17. Examine the clutch withdrawal shaft for sloppiness in the bushes. If necessary, renew the bushes.

Re-assembling

Before reassembly note the position of the marked parts and make sure to replace them in their original locations unless the parts have been renewed.

1. Position the pressure plate on the three spacing washers on the base plate as previously described.
2. Apply a slight smear of grease to the release lever pins, contact faces of the struts, eyebolt seats in the clutch cover, drive lug sides on the pressure plate and the plain ends of the eyebolts.
3. Install the release lever, eyebolt and pin, holding the

threaded end of the eyebolt and the inner end of the lever as close together as possible. With the other hand insert the strut in the slots in the pressure plate sufficiently to allow the plain end of the eyebolt to be inserted in the hole provided in the pressure plate. Move the strut upwards into the slots in the pressure plate lug, over the ridge on the short end of the lever, and drop it into the groove formed in the lever.

4. Fit the remaining release levers in a similar manner.
5. Place the pressure springs on the bosses on the pressure plate.
6. Lower the cover over the assembled parts, ensuring that the anti-rattle springs are in position and that the tops of the pressure springs are directly under their seats in the cover. In addition the machined portions of the pressure plate lugs must be directly under the slots in the cover through which they will pass.
7. Insert the gauging fixture setscrews through the cover holes and screw them into the base plate in a diagonal pattern, a little at a time, to prevent distortion. Guide the eyebolts and pressure plate lugs through the holes in the clutch cover during this gradual tightening down.
8. Screw the adjusting nuts on to the eyebolts.

Release Lever Adjustment

Satisfactory operation of the clutch is dependent upon accurate adjustment of the release levers, so that the pressure plate face is maintained parallel to the flywheel face. This cannot be accomplished by setting the levers parallel to the face of the release bearing after the clutch has been assembled to the flywheel, because of the variations in the thickness of the driven plate.

For an accurate adjustment the gauging fixture must be used.

1. Screw the gauge fixture actuator into the base plate and pump the handle a dozen times to settle the clutch mechanism. Remove the actuator.
2. Screw the tool centre pillar into the base plate and select a distance piece as shown on the accompanying

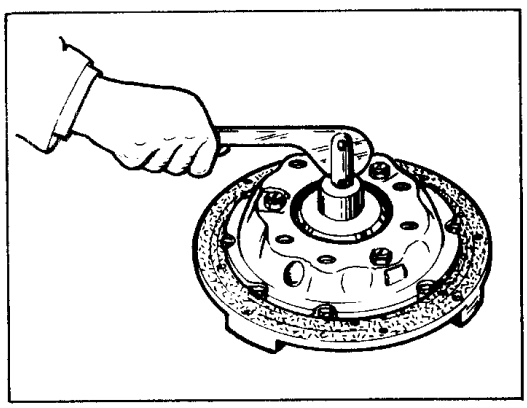


Fig.3 - Using the actuator to compress the clutch springs

chart. Place the distance piece over the centre pillar with its recessed face downwards.

3. Place the gauge height finger over the centre pillar.
4. Adjust the height of the release levers by tightening or loosening the eyebolts until the height finger, when rotated, just contacts the highest point on the tips of the release levers. Press downwards on the height finger to ensure that it bears squarely on the adaptor while rotating.
5. Remove the height finger and pillar, and screw in the actuator to the base plate. Operate the clutch several

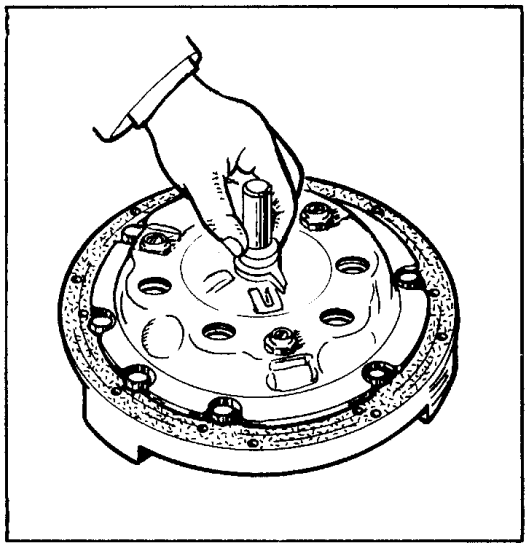


Fig.4 - Using the height finger to check the release lever adjustment

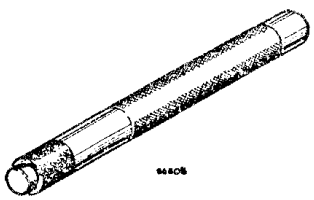
times to enable the components to settle on their knife-edges.

6. Remove the actuator and replace the centre pillar, distance piece, and height finger; if necessary, re-adjust the release levers. Repeat the procedure to ensure that the release levers are finally seated, and gauge once more.
7. Remove the centre pillar, distance piece, and height finger and peen over the release lever adjusting nuts.
8. Fit the release lever plate on the tips of the release levers and secure it by the three retaining springs. Release the tool setscrews in diagonal sequence a little at a time, relieving pressure slowly and evenly. Remove the clutch assembly from the base plate.

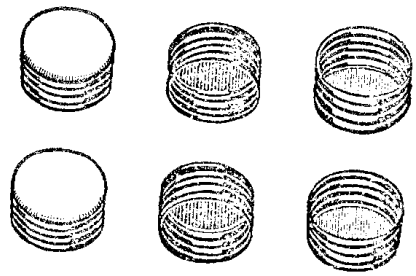
SECTION G

SERVICE TOOLS

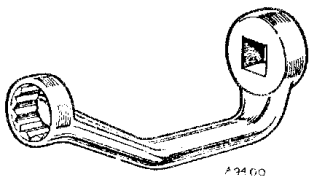
ENGINE 1·5 LITRE



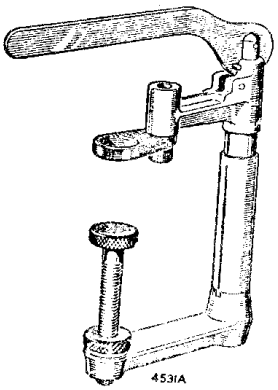
Oil pressure relief valve grinding-in tool 18G69



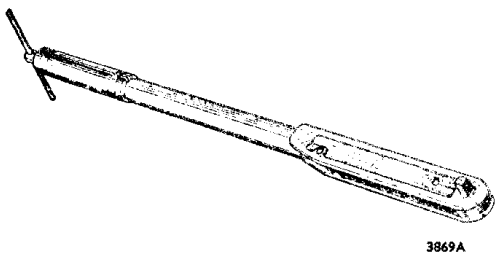
Fuel injection pump outlet sealing caps 18G216



Cylinder head nut spanner 18G694



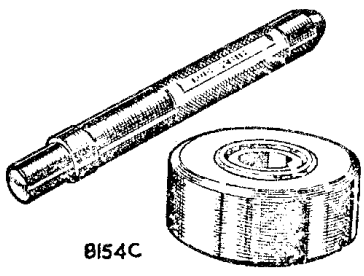
Valve spring compressor 18G45



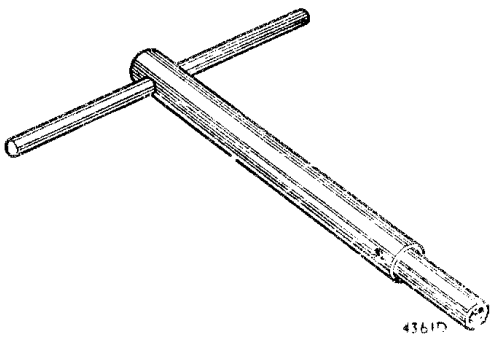
Torque wrench 18G372 – 30 to 140 lbf.ft

Valve grinding-in tool 18G29

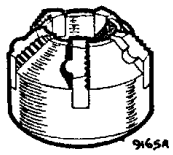
Suction pad – valve grinding-in tool 18G29A



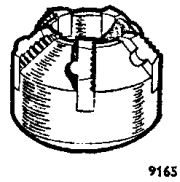
Valve rocker bush remover and replacer 18G226



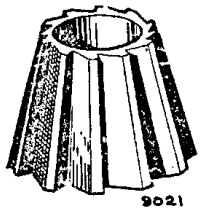
Valve seat cutter and pilot handle 18G27



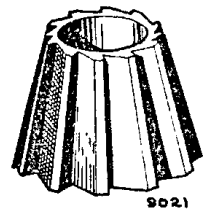
Valve seat glaze breaker 18G25A – inlet



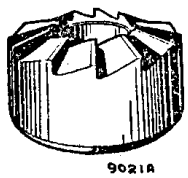
Valve seat glaze breaker 18G167A – exhaust



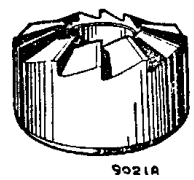
Valve seat narrowing cutter (bottom) 18G25C – inlet



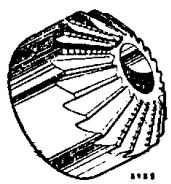
Valve seat narrowing cutter (bottom) 18G167C – exhaust



Valve seat narrowing cutter (top) 18G25B

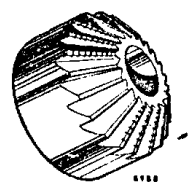


Valve seat narrowing cutter (top) 18G167B – exhaust

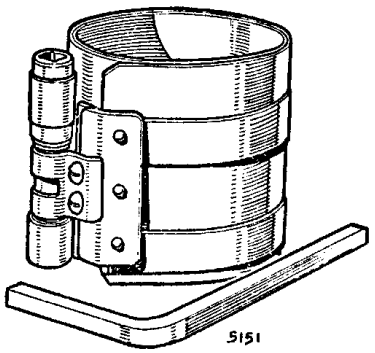


Valve seat finishing cutter 18G25 – inlet

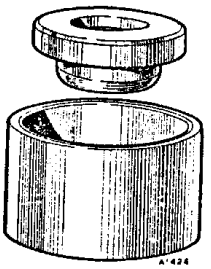
Valve seat cutter pilot 18G174D



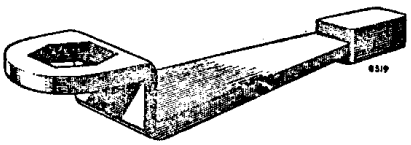
Valve seat finishing cutter 18G167 – exhaust



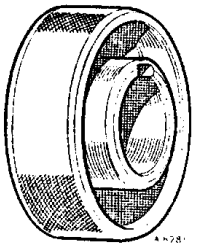
Piston ring compressor 18G55A



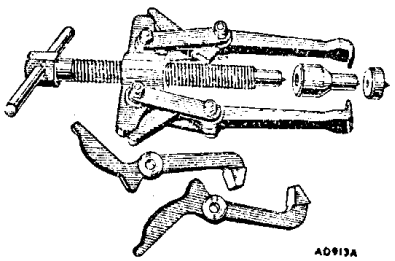
Timing case oil seal replacer adaptor 18G134BD



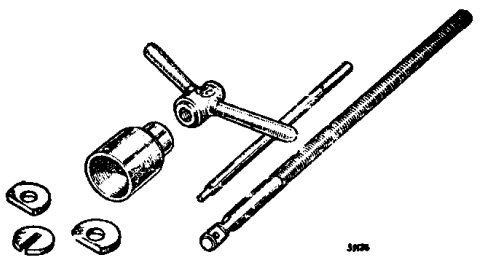
Starting nut spanner 18G98A



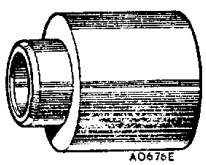
Engine front cover centraliser 18G1046



Crankshaft gear and pulley remover 18G2



Camshaft liner remover and replacer (basic tool) 18G124A



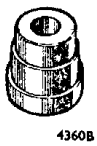
Bearing and oil seal replacer 18G134

Camshaft liner remover adaptor 18G124F

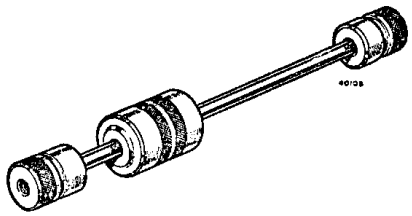
SECTION G

Camshaft liner remover adaptor 18G124B

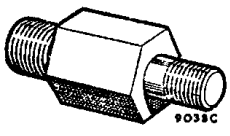
Camshaft liner remover adaptor 18G124C



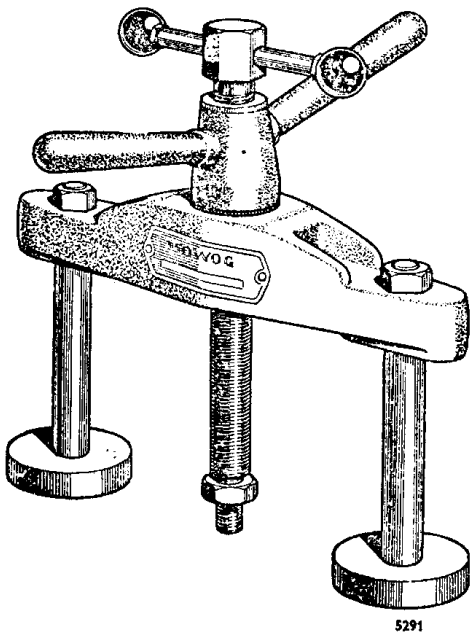
Camshaft liner remover adaptor 18G124H

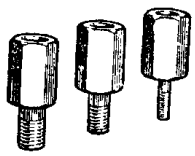


Impulse extractor (basic tool) 18G284



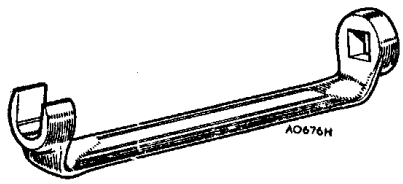
Main bearing cap remover adaptor 18G284A



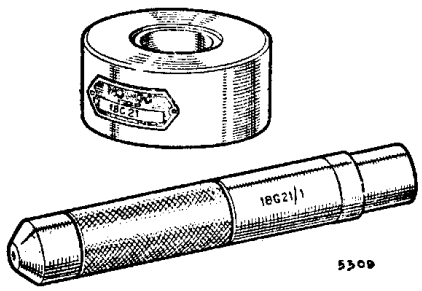


Main bearing cap remover (basic tool) 18G42A
Main bearing cap remover adaptor 18G42B

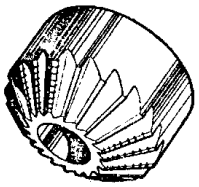
ENGINE 2·5 LITRE



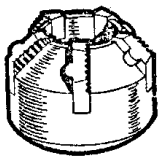
Cylinder head nut spanner 18G545



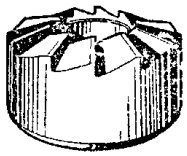
Valve rocker bush remover and replacer 18G21



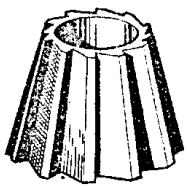
Valve seat finishing cutter 18G28



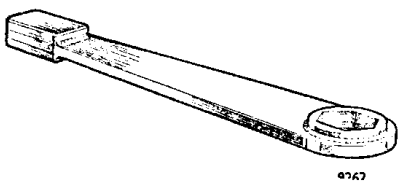
Valve seat glaze breaker 18G28A



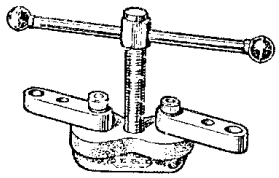
Valve seat narrowing cutter (top) 18G28B



Valve seat narrowing cutter (bottom) 18G28C

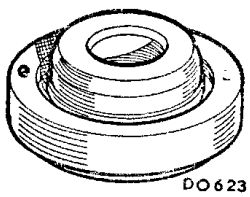


Starting nut spanner 18G391

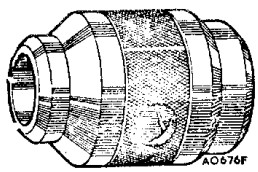


Gear and pulley remover (basic tool) 18G231

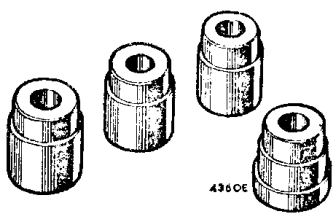
Oil pump driving gear remover adaptors 18G231B



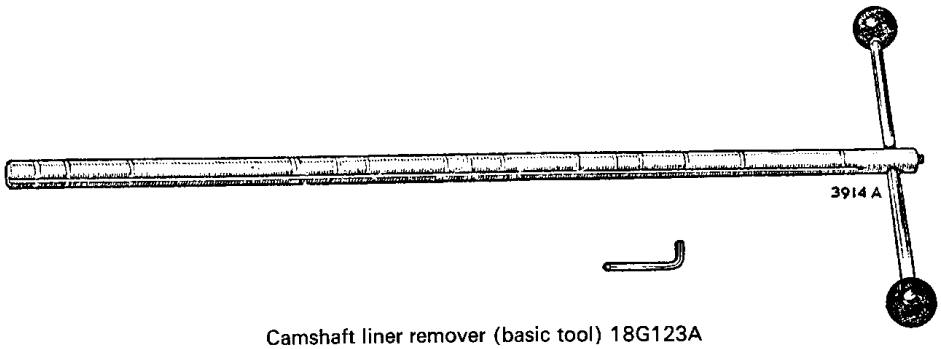
Oil seal replacer adaptor 18G134CR



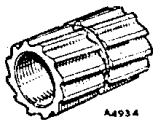
Engine front cover locating bush 18G3



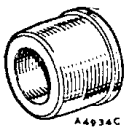
Camshaft liner remover adaptor 18G124D



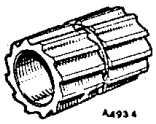
Camshaft liner remover (basic tool) 18G123A



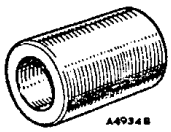
Camshaft liner cutter 18G123B



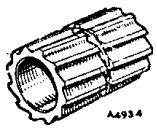
Camshaft liner reamer pilot 18G123T



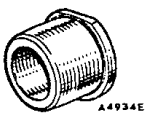
Camshaft liner cutter 18G123C



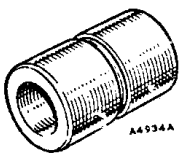
Camshaft liner reamer pilot 18G123AC



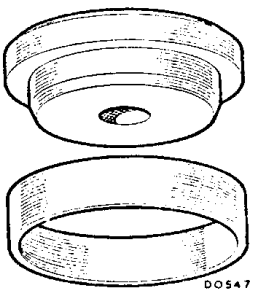
Camshaft liner cutter 18G123E



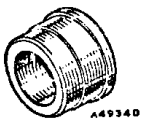
Camshaft liner reamer pilot 18G123AD



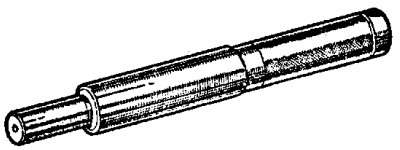
Camshaft liner reamer pilot 18G123L



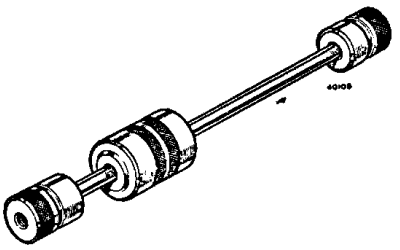
Oil Seal replacer adaptor 18G134CQ.



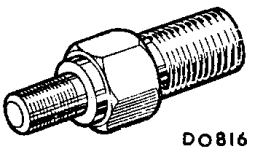
Camshaft liner reamer pilot 18G123M



Clutch centraliser 18G554

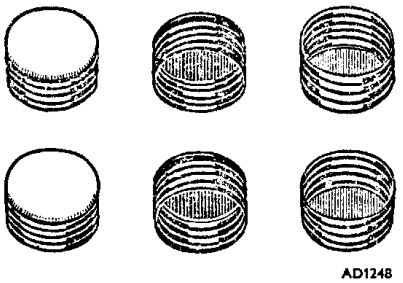


Impulse extractor (basic tool) 18G284

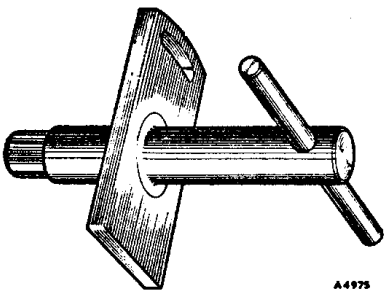


Main bearing cap remover adaptor 18G28A AJ

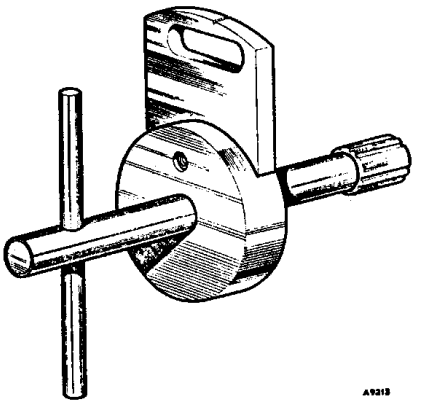
FUEL SYSTEM



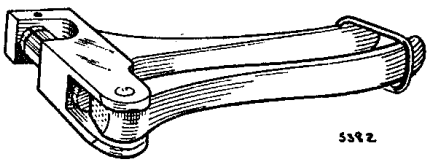
Fuel injection pump outlet sealing caps 18G216



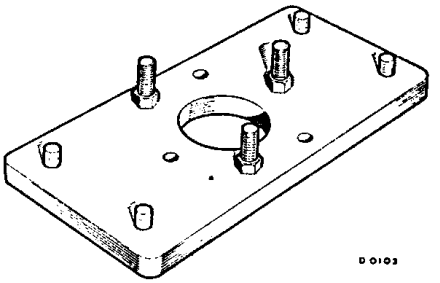
Injection timing gauge 18G629



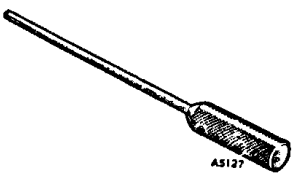
Injection timing gauge 18G698



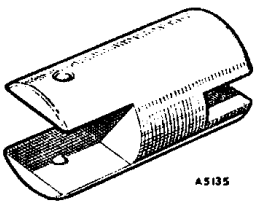
Venturi and fuel injection pump sealing pliers 18G541



DPA assembly base 18G633A



Assembly rod 18G637



Torque spanner socket 18G646

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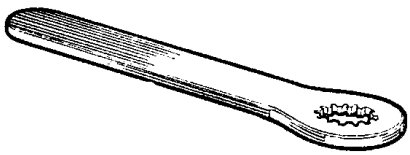
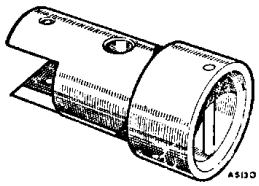
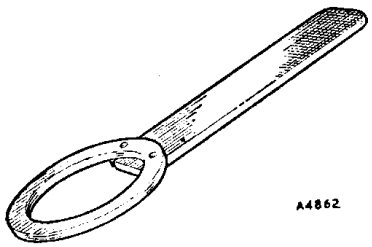


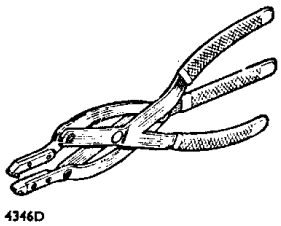
Drive shaft holding tool 18G651



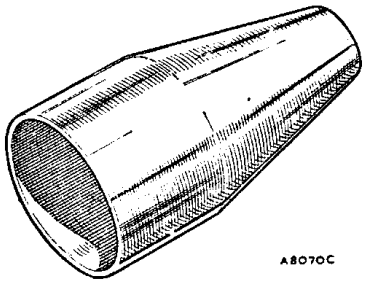
Assembly box spanner 18G634



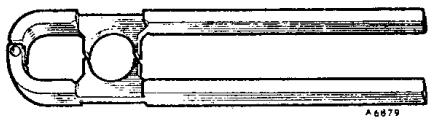
Assembly drive plate spanner 18G641



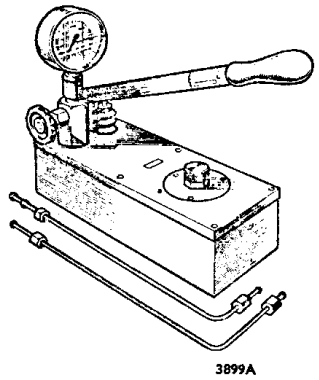
Circlip pliers 18G1004



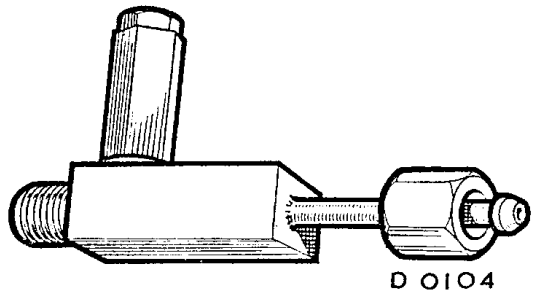
Hydraulic drive shaft protection cap 18G635



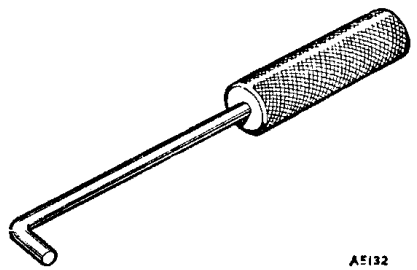
Hydraulic shaft seal assembly tool 18G642A



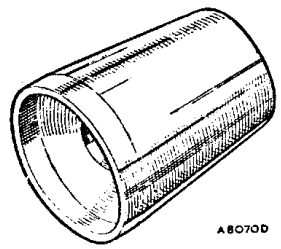
Injector nozzle testing machine 18G109A



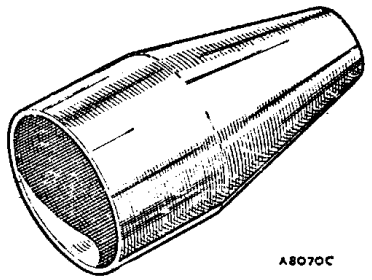
Relief valve timing adaptor 18G653A



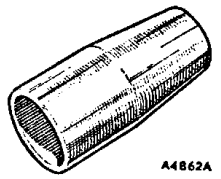
Maximum fuel adjusting probe 18G656



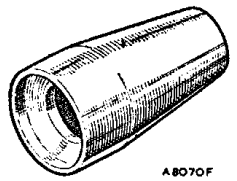
Protection cap for automatic advance plug 18G640



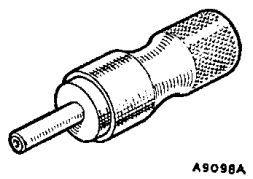
Protection cap for head locating fitting 18G639



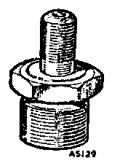
Assembly cap 18G647



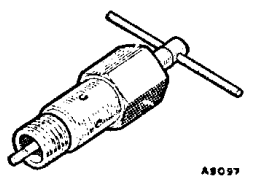
Protection cap for metering valve pinion 18G643A



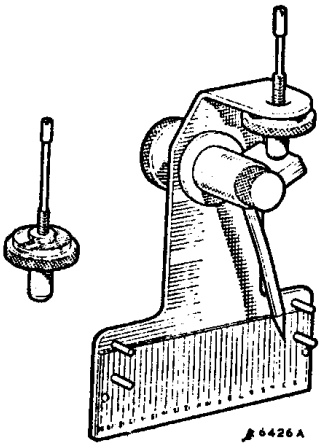
Pilot guide 18G691A



Transfer pressure adaptor 18G636

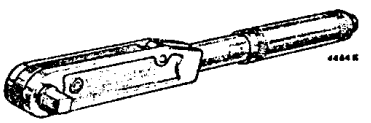


End plate adjuster 18G690

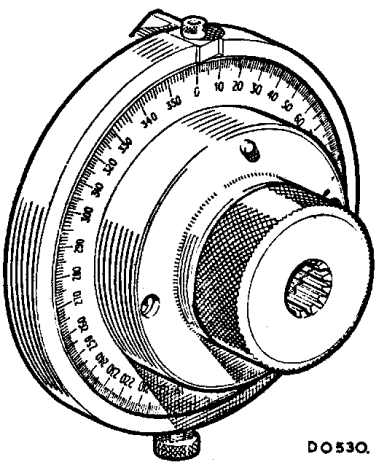


Automatic advance gauge 18G638B

Drive plate screw torque adaptor 18G655A

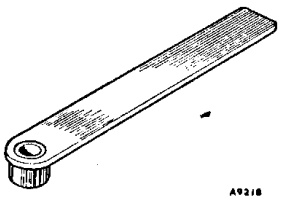


Torque wrench 10 to 15 lbf.ft – 18G537

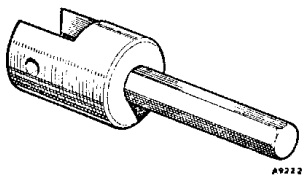


Universal flange marking gauge 18G648A

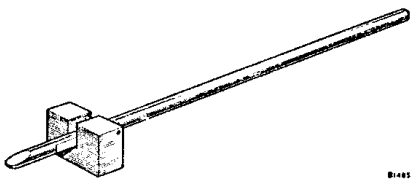
SECTION G



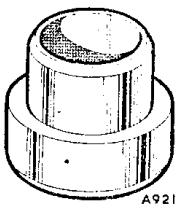
Drive shaft screw assembly tool 18G659



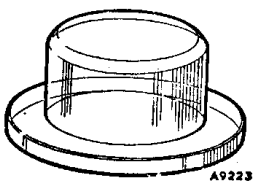
Torque adaptor 18G664



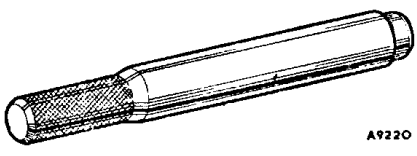
Assembly oil seal extractor 18G658



Oil seal guide 18G663



Oil seal inspection plug 18G660



Locating pin 18G661

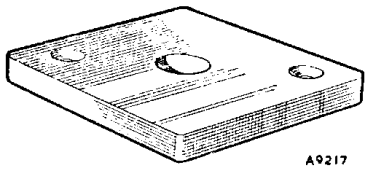
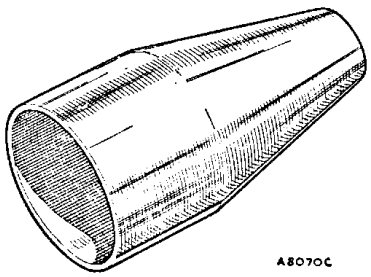
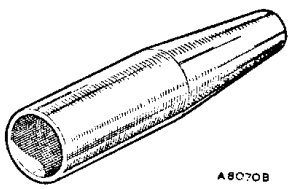


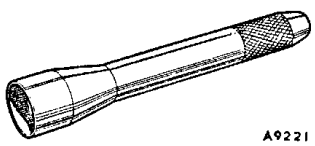
Plate 18G662



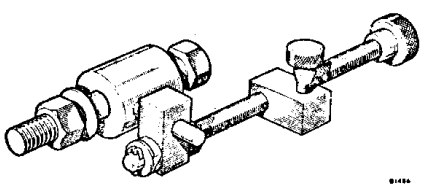
Protection cap for mechanical drive shaft 18G657



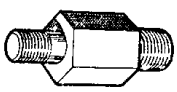
Protection cap for shut-off spindle 18G654



Throttle and shut-off protection cap 18G665



Shut-off lever adjuster 18G697



Injection remover adaptor 18G284P

SECTION H

RECOMMENDED LUBRICANTS

Marine Engines

Engine and B Type Mechanical Epicyclic Gearbox

Climatic Conditions	Esso	Mobil	Shell	B.P.	Filtrate	Duckhams	Castrol	Sternol
Above 90°F (32°C)	Esso Extra 20W/30 or Essofleet H.D.30	Delvac Oil 930	Rotella 30	Energol D.D.30	Filtrate Diesel 30	Duckhams Multigrade Q20/50	Castrol C.R.30	Auto Deso H.D.30
90°F (32°C) down to 10°F (—12°C)	Esso Extra 20W/30 or Essofleet H.D.20	Delvac Oil 920	Rotella 20/20W	Energol D.D.20W	Filtrate Diesel 20	Duckhams Multigrade Q20/50	Castrol C.R.20	Auto Deso H.D.20
10°F (—12°C) down to 0°F (—18°C)	Esso 10W or Essofleet H.D.10W	Delvac Oil 910	Rotella 10W	Energol D.C.10W	Filtrate Diesel 10W	Duckhams Q20/50	Castrol C.R.10	Auto Deso H.D.10
Below 0°F (—18°C)						Duckhams Q5W30		
PRM100 Gearbox								
Above —10°C (14°F)	Uniflow or Essolube H.D.10 W30	Mobiloil Super or Mobil Delvac Special	Shell Super 100 or Rotella M or Rotella S 20W/20	B.P. Vanellus 20W			Castrol GTX	
Borg Warner Gearbox								
All Conditions	Esso Automatic Transmission Fluid	Mobilfluid 200	Shell Donax T.6	Automatic Transmission Fluid Type A	A.T.F. Type A	Nolmatic	Castrol T.G.	Sternol Lynx

Fresh Water Pump

All Conditions	Esso Multipurpose grease H	Mobilgrease M.P.	Shell Retinax A	Energrease L2	Filtrate Super Lithium Grease	Duckhams LB10 Grease	Castrolease L.M.	Ambroline L.H.T.
Sea/River-Water Pump, and Stern Tube Greasers								
All Conditions	Esso Multipurpose grease H	Mobilgrease M.P.	Shell Retinax A	Energrease L.2	Filtrate Super Lithium Grease	Duckhams L.B.10 Grease	Castrolease L.M.	Amboline L.H.T.
Utility Lubricant Oilcan Points								
All Conditions	Essolube H.D.20	Delvac Oil 910	Shell Rotella 20/20W	Energol Diesel D S.A.E.20W	Filtrate Diesel 20	Duckhams NOL Diesel Twenty	Castrol C.R.20	Auto Deso H.D.20

Multigrade Diesel Motor Oils

In addition to the above recommended lubricants, we approve the use of the oils listed below, for all conditions down to 0°F (—18°C), unless the engine is old and in poor mechanical condition.

Engine Sump

All Conditions down to 0°F (—18°C)		Mobiloil Special	Rotella 10W/30	Energol Diesel Multigrade 10W/30	Filtrate 10W/30 Multigrade		Castrol C.R.20W/30	Sternol Minx 10/30 S.I.