WORKSHOP MANUAL

ROLLS-ROYCE CV 12 INDUSTRIAL ENGINES

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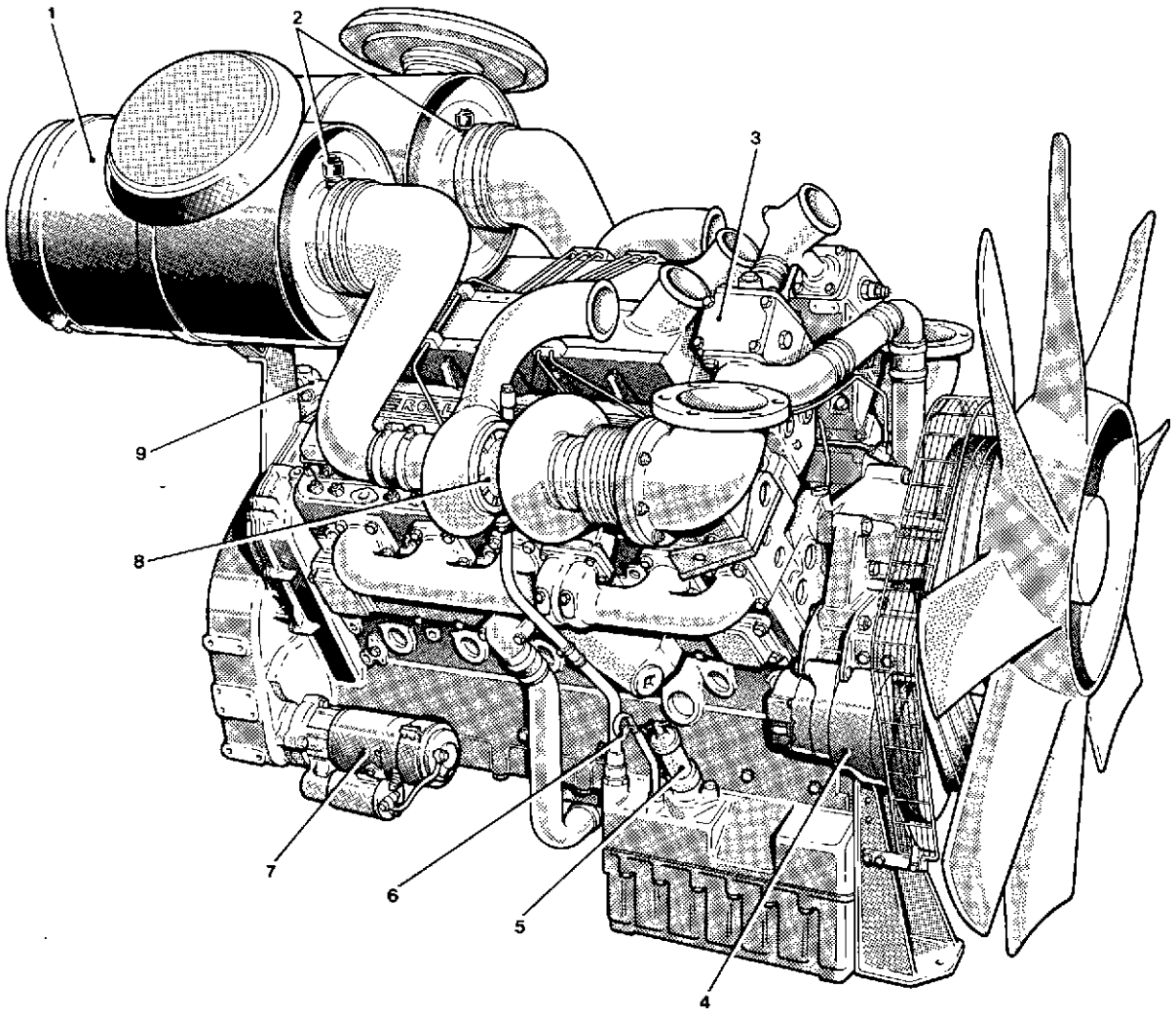
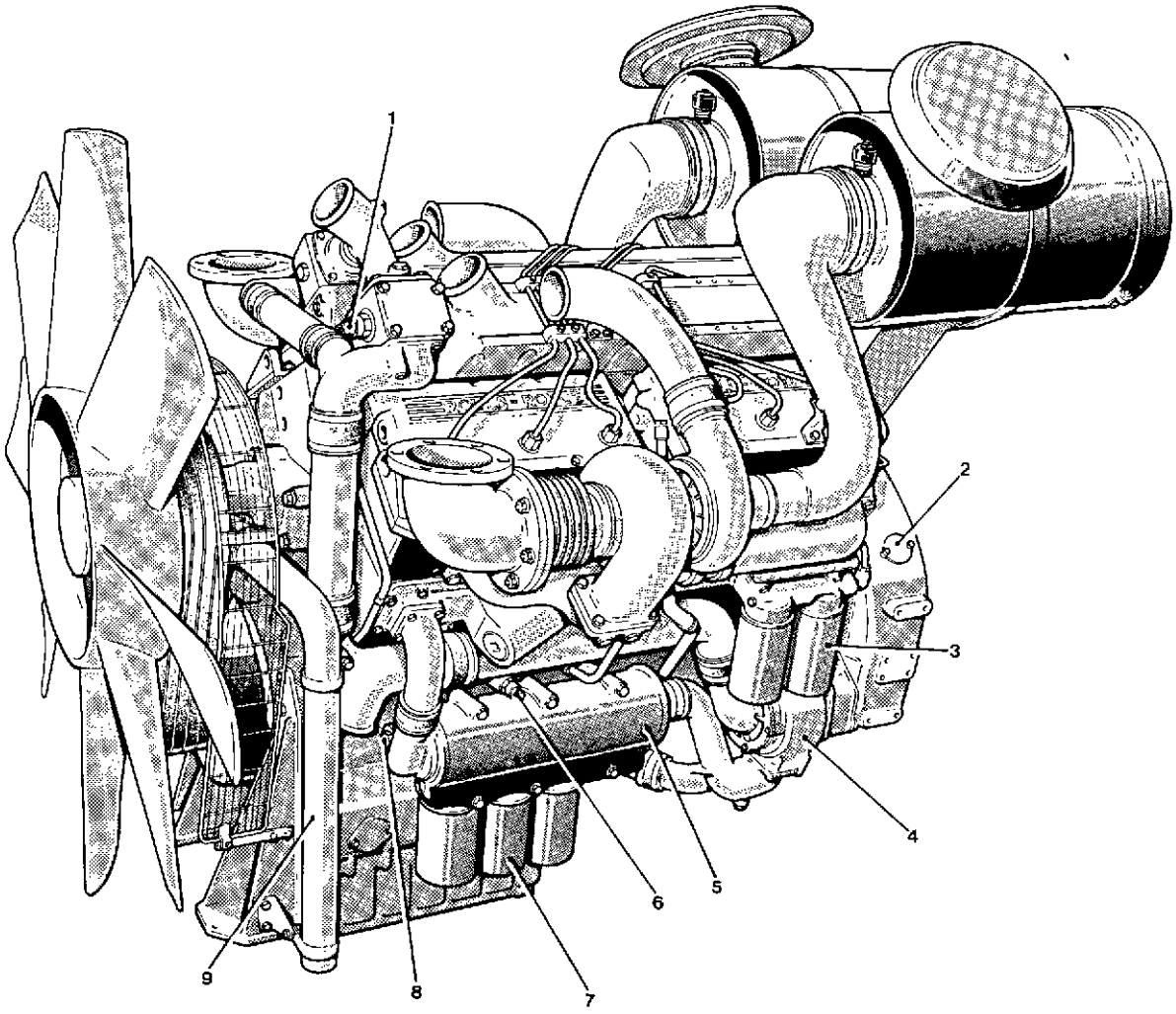


1 'A' bank air cleaner
2 Air restriction indicators
3 Thermostat housing
4 Alternator
5 Oil filler pipe
6 Dipstick
7 Starter motor
8 'A' bank turbocharger
9 Fuel feed pump

CV 12 Engine - View on 'A' bank side



1 Coolant temperature switch
2 Flywheel timing cover
3 Fuel filter
4 Coolant pump
5 Oil-to-coolant heat exchanger
6 Oil pressure switch
7 Lubricating oil filter
8 Oil pressure relief valve
9 Crankcase breather pipe

CV 12 Engine - View on 'B' bank side

NOTES TO USERS

The purpose of this Manual is to provide all the information necessary for the complete overhaul of Rolls-Royce CV 12 Industrial engines.

Since the varied applications of these engines necessarily involve differences in ancillary equipment, the illustrations accompanying the text may not correspond exactly to the engine being overhauled. The subject matter of the illustrations will, nevertheless, be correct unless otherwise stated.

Although these engines are designed to give maximum service with minimum maintenance, the inspections and servicing called for must not be delayed unduly or neglected.

Operators are advised to make use of the following services and facilities which are available to them.

Service network

Trained staff, advice and spare parts are available throughout the world from Dealers and Distributors, who are appointed by Rolls-Royce and constantly supplied with up-to-date information. When necessary, they can consult the area-based Rolls-Royce engineer or the Service Department of Rolls-Royce Motors, Shrewsbury.

When making enquiries, Operators should specify the Engine Number, Designation and Build Number (stamped on the data plate on the 'A' bank side wall of the crankcase) and the units recorded on the Engine Service Counter (E.S.C.). If a proprietary item such as the alternator, fuel injection pump, etc., is involved, the details on its data plate should be included.

Service Instructions and Bulletins

Service techniques and engine design are under constant review at the Factory and the results of this work are published as they occur. Changes in service techniques are issued as Service Instructions and sent to Dealers and Distributors for onward transmission to Operators, who should amend their Manuals accordingly. Engine design changes are published as Service Bulletins which are forwarded to Dealers and Distributors.

Instruction

A five day course on servicing and overhaul of CV 12 engines is provided at the Factory. For details, apply to : The Superintendent, Customer Training Centre, Rolls-Royce Motors Limited, Shrewsbury, Shropshire. SY1 4DP.

Service exchange

To avoid expensive 'down time', Operators are strongly recommended to take advantage of the Rolls-Royce Service Exchange Scheme, by which Dealers can speedily supply replacement units, fully reconditioned at the Factory and guaranteed for six months. Units available are listed overleaf.

Associated Publications for CV 12 engines

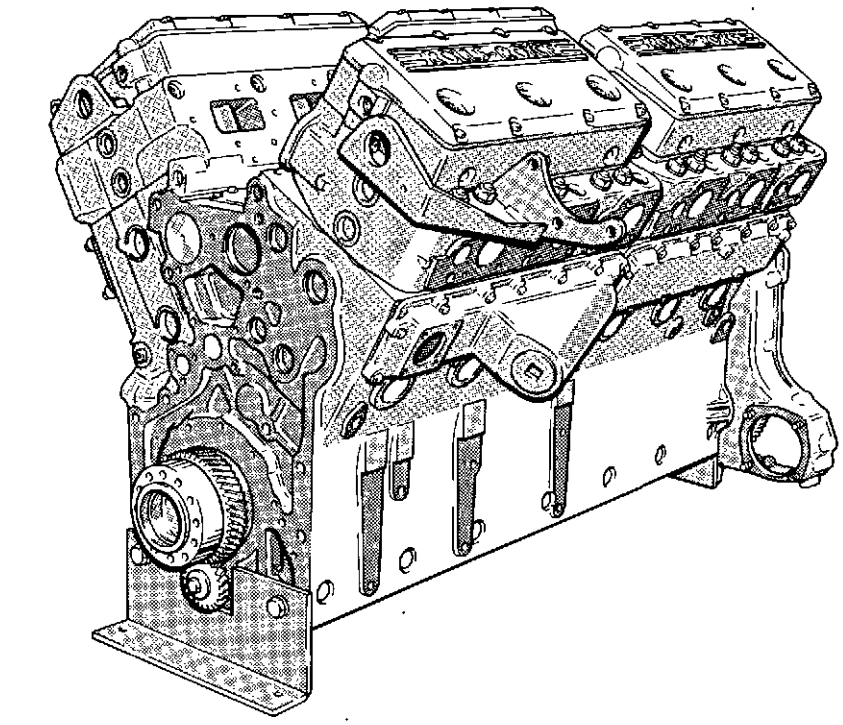
T.S.D. 3128	Service Instructions
T.S.D. 3129	Service Bulletins
T.S.D. 3138	Servicing Manual
T.S.D. 3146	Operator's Guide
T.S.D. 3148	Booklet, Essential information for Operators
T.S.D. 3153	Servicing Schedules - Wall chart
T.S.D. 3154a	Torque Loadings - Wall chart
T.S.D. 3154b	Fuel System - Wall chart
T.S.D. 3154c	Lubrication System - Wall chart
T.S.D. 3154d	Cooling System - Wall chart

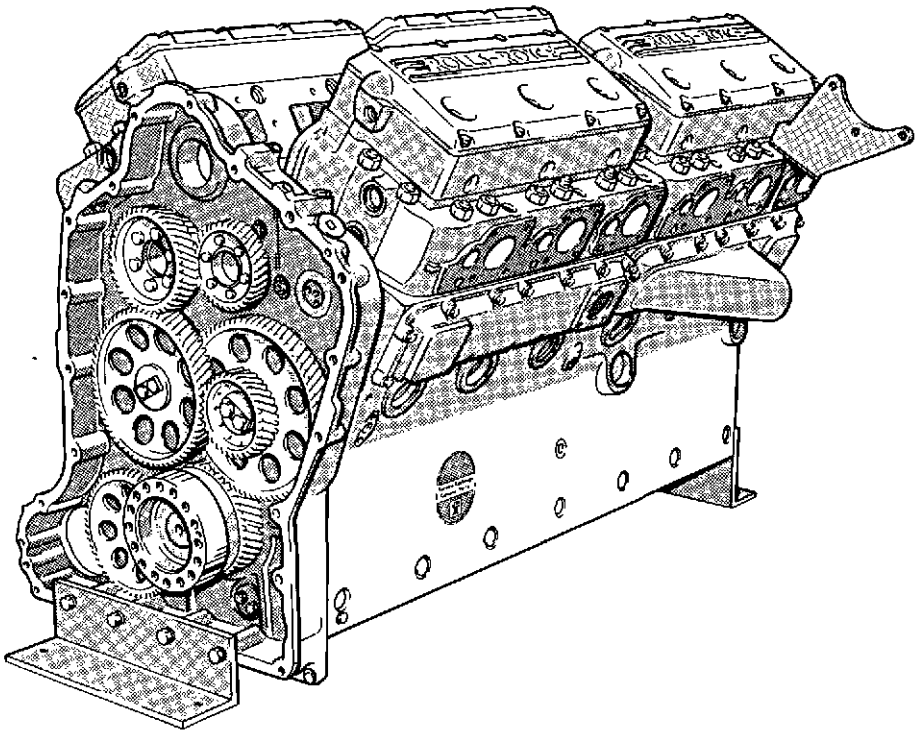
SERVICE EXCHANGE SCHEME

The information in this Manual will assist the Operator in carrying out any work, from minor repairs to complete engine overhaul, on the CV 12 range of engines. Occasionally however, personnel, equipment or time may not be available, which could result in delay before the engine returns to service. For this reason, Rolls-Royce Motors Limited have instituted a Service Exchange Scheme so that Dealers and Distributors can speedily supply a 'short engine' or major component, fully reconditioned at the Factory and guaranteed for six months. In certain circumstances, a reconditioned complete engine can be supplied.

The units available through the Scheme are listed below. Further details may be obtained from Dealers and Distributors; all enquiries should quote the Engine Number, Designation and Build Number, as stamped on the crankcase data plate. When applicable, the details on the data plate of a proprietary unit (e.g. turbocharger) should be included.

ALTERNATOR	FUEL INJECTION PUMP
COOLANT PUMP	FUEL FEED PUMP
CRANKSHAFT	LUBRICATING OIL PUMP
CYLINDER HEAD	STARTER MOTOR
FUEL INJECTOR	TURBOCHARGER





CV 12 - 'SERVEX' short engine.

CONTENTS

GENERAL INFORMATION

The following information, if kept in mind during repair or overhaul work, will ensure that the engine returns to duty in first-class order and can be relied upon to give long and trouble-free service, provided that it is properly used and maintained.

Cleanliness

The importance of cleanliness cannot be over-emphasized, particularly in respect of the fuel system. The ingress of dirt and foreign material is a major cause of rapid wear, damage and engine failure.

During dismantling, clean around the vicinity of the component concerned and ensure that all openings and disconnected pipes are blanked off without delay.

After removal, clean and inspect each component individually and, if serviceable, protect it against dirt, damage and corrosion until it is refitted. Special care is necessary with ball and roller bearings; after cleaning and inspection, they should be dipped in light-bodied oil and wrapped in clean paper.

When assembling, ensure that the ambient air is as dust-free as possible and that dirt does not enter the engine. Inspect each component immediately before fitting, wash all pipes and oilways and blow through them with dry compressed air before making connections.

Special tools

These are available for specific jobs and should be used, where recommended, to save time and to prevent damage to components. Where applicable, a list of special tools is given at the end of the relevant section.

Note : As with engine design and techniques, the special tools listed in this Manual are also under review. Customers ordering a special tool from their Dealer or Distributor may be given one of the latest tools, the Part Number of which may not correspond to that ordered. In such cases, the replacement tool will perform the same function as the original, usually at a great saving on cost to the Customer.

Hose connections

The practice of levering off a hose with a screwdriver causes damage to the adaptor or pipe connection. Cut through the hose with a sharp knife and afterwards, cut the ends of the hose from the adaptor or pipe connection. When fitting a new hose, an approved rubber lubricant may be used as an alternative to glycol, water or french chalk. Never lubricate a hose with oil or grease, which are injurious to rubber.

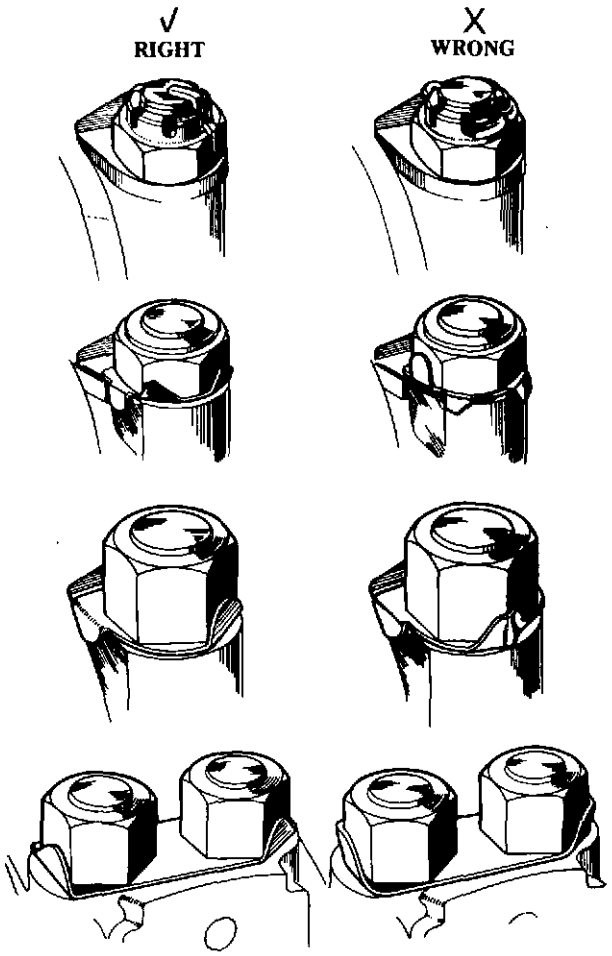


Fig. 1 Right and wrong methods of locking

Gaskets, joints and 'O' rings

It is false economy to re-use these items; their cost is trifling compared with the expense of rectifying leaks when the engine is back in service.

Where applicable, 'Wellseal' and 'Hylomar PL 32' jointing compounds are recommended for general use when making joints. As with any liquid jointing materials, they should be applied thinly to avoid the possibility of excess compound obstructing oilways and ducts.

'O' ring seals should be lightly coated with a suitable lubricant to prevent trapping during assembly.

Locking devices

Used split pins, locking plates and tab washers must never be refitted. The correct method of fitting locking devices is shown in figure 1.

All-metal stiffnuts may be re-used, provided that they have not lost their efficiency, i.e. they still offer noticeable resistance to movement against normal spanner leverage. At least one full thread of the bolt or stud should protrude through the stiffnut when it is fully tightened.

Do not re-use stiffnuts having nylon or fibre inserts.

Oil seals

Pack oil seals with petroleum jelly before fitting, and take care not to damage the lip of the seal on sharp edges. Unless otherwise specified, always fit the seal with the wiping edge facing in towards the bearing.

Torque loadings

Torque loadings are specified for certain setbolts and nuts where defect or failure could result from an incorrect degree of tightness. For joints such as cylinder head to crankcase, it is also essential that tightening is carried out evenly and progressively, as instructed in the assembly sequence.

The following torque wrenches, covering the torque loading requirements of the CV 12 engine, are available from Rolls-Royce Motors.

GA 5095 8 to 54 Nm (5 to 40 lbf.ft.)
GA 5096 30 to 150 Nm (20 to 110 lbf.ft.)
GA 5097 50 to 230 Nm (40 to 170 lbf.ft.)
GA 5098 50 to 500 Nm (50 to 350 lbf.ft.)

Fits and clearances

Where relevant, a table of fits and clearances is given at the end of each section dealing with the inspection and assembly of engine components.

The dimensions given are such that a part falling within the limits is acceptable for a full period of service. Certain parts, worn beyond these limits, may be reclaimed under approved repair schemes which are circulated to authorised Dealers and Distributors.

Crack detection

Whenever possible, highly stressed components such as crankshafts, connecting rods, gear wheels and cylinder liners should be tested for cracks during overhaul or, when they have been subjected to excessive loading or impact.

Ferrous components should be tested using the electro-magnetic method if possible. A portable electro-magnetic test rig is available from Radalloyd Ltd., Oadby, Leicester.

Non-magnetic components may be tested using a dye penetrant process such as 'Ardrox 996', available from Ardrox Limited, Brentford, Middlesex. The dye penetrant used must conform to one of the following standards :

MIL-STD 271-E
MIL-L 25135
B.S. 5750
D.T.D. 929

Exchange units

Unserviceable units should be returned complete to the same standard as the replacement unit. All apertures should be blanked off and joint faces protected. Where necessary, treat the unit internally and externally against corrosion.

Spares

To comply with the terms of the Rolls-Royce Guarantee, and to ensure maximum reliability, USE ONLY GENUINE ROLLS-ROYCE PARTS supplied by the Factory or an accredited Dealer. These parts are manufactured to the latest specification and are GUARANTEED for six months.

Customers are WARNED against using counterfeit spares, notably filter elements. These items may not conform to Rolls-Royce standards and their use could not only invalidate any current guarantee, but seriously reduce engine life and performance.

SECTION 1 - DESCRIPTION AND DATA

The Rolls-Royce CV 12 is a four stroke, turbocharged, direct injection, compression ingition, liquid cooled engine with air charge cooling. The 12 cylinders are arranged in two banks, in a 60 deg. 'V' configuration.

Engine identification

The engine number, designation and build line number are stamped on the Data Plate, attached to the crankcase.

Major assemblies such as the fuel injection pump, turbochargers and starter motor also carry their own identification plates.

These details should be quoted in full when ordering spare parts or raising a query.

Bank and cylinder bore identification

Viewed from the front (free end) of the engine, 'A' bank is to the left, 'B' bank is to the right.

The cylinders are numbered from front to rear, A1 to A6 and B1 to B6.

Crankcase

The crankcase is a monobloc casting in close grained, high duty iron dipped in a special sealing compound to seal all non-machined surfaces against contamination.

Each bearing assembly is held in place by a forged steel bearing cap; the centre and each end cap are attached with four bolt fixings, the remainder with two bolts per cap. Lateral security is by setbolts fitted through the crankcase side walls into location pads on each side of the bearing caps.

Two banks each of six cylinders are formed in a 60 deg. included angle 'V' formation. The cylinder bores are in a conventional staggered pattern with 'B' bank leading. The bores are machined to accept full length slip fit dry liners.

Studs are fitted into the crankcase with thread locking compound to locate and secure the four monobloc cylinder heads, with smaller diameter setbolts centrally disposed between each pair of tappet bores.

Cylinder liners

The full length, slip fit, pre-finished liners are made from centrifugally cast iron and machined to close tolerances.

Crankshaft

The crankshaft is made from a chrome molybdenum steel forging, nitride hardened, with the exception of the front and rear end faces, the dowel hole and the tapped holes.

The bearing surfaces consist of seven main journals and six crankpins, each crankpin serving two connecting rods.

Oil transfer is by centrally machined holes through the diameter of each main journal, with holes drilled through each crankshaft web to connect with the journal oilways. These holes open into conventional sludge traps, with oil flow to the crankpin bearings through two holes drilled from the crankpin periphery into each sludge trap.

Small holes are sealed, where necessary, with cup plugs. The larger sludge trap openings are blanked off with an aluminium disc and 'O' ring seal, secured with a spring clip.

Crankpins are disposed for each pair of cylinders in the following order : 1 and 6, 2 and 5, 3 and 4 with each pair 120 deg. out of phase with the others, giving a firing sequence of A1, B6, A4, B3, A2, B5, A6, B1, A3, B4 A5 and B2.

Around the flywheel end of the crankshaft a 45 toothed helical gear is machined, serving as the primary drive to the main gear train. The end face has 16 equally spaced, tapped holes and one dowel hole, with which to locate and secure the flywheel and starter ring assembly, using a dowel and socket head capscrews respectively.

Around the front end of the crankshaft, a helical gear is machined to drive the lubricating oil pump via an idler gear. The front end face is drilled and tapped to accomodate 12 equally spaced setbolts, which secure the viscous damper and drive belt pulleys to the shaft.

The crankshaft is balanced statically and dynamically at the machining stage, and requires no further compensation when assembled.

Main bearings

The main bearings consist of steel backed half bearing shells with a lead bronze lining, and a precision plated lead indium surface

The upper half of each bearing shell has an oil groove machined centrally around the inner surface. An oil transfer hole, drilled into the centre of the groove, aligns with an oil feed drilling in the crankcase.

The lower half bearing shells have shortened machined grooves to allow a smooth transfer of oil to the lower bearing surfaces.

Locating tangs, pressed out from the edge of each half shell, align with corresponding grooves machined in the crankcase and bearing caps.

Thrust washers

The thrust washers,which are steel backed with lead bronze faces, locate on on each side of the centre main journal, in recesses machined in the bearing cap and crankcase housing. The lower half of each thrust washer has an integral locating tang at one end.

Lubrication is from the centre main bearing, with grooves machined across the face of each washer to assist in oil flow.

Connecting rods

The connecting rods, manufactured from chrome molybdenum steel forgings, are machined to accept steel backed, lead bronze, small-end bearings. The bearings, constructed as rolled bushes with clinch butt joints, are pressed into the small-end eye with the joint located at 45 deg. in the upper portion of the bore. This, in turn, positions the bearing oil holes in a 120 deg. arc, adjacent to the connecting rod column.

The small-end of each rod is of wedge design to assist pressure loading of the small-end and piston. An oil hole, bored centrally through the column, allows pressurised oil to be fed intermittently from the crankpin, to provide small-end and gudgeon pin lubrication.

Four special bolts, with bi-hexagon nuts, are used to secure each big-end bearing cap to its associated rod. Markings on each connecting rod assembly give rod to cap correlation, weight and, when allocated, the cylinder bore number.

The big-end bearing shells are similar to the main bearings, but do not have machined grooves in the bearing surfaces.

When assembling, it is important to note that the large internal chamfer on one face of each big-end, is to the outside of each pair.

Pistons

The pistons are cast from high silicon aluminium alloy, with the crowns machined to form open toroidal combustion chambers. Each piston carries three compression rings and one oil control ring in machined grooves. To reduce wear, the top ring is carried in an austenitic iron insert. The ring sequence is as follows :

Top - Inlaid molybdenum surface

Second - Chrome plated

Third - Ferrox treated surface

Bottom - Composite chrome plated oil control ring

Each piston is tin-plated on all surfaces, after machining, except for the gudgeon pin bore.

The gudgeon pin is fully floating, and is secured by the conventional circlip method.

Camshafts

The camshafts are manufactured in an alloy cast iron, with chill hardened cam noses. The cam lobes are of the high lift, short duration type, with precision machined tapers across the contact faces.

The two shafts are unidentical, which is necessary to accomodate the off-setting of the cylinder bores.

The 'A' bank camshaft can be identified by the shorter bearing surface at the drive gear end. The flanged end accomodates the phasing gear, which is secured by six setbolts.

The 'B' bank camshaft flange end accomodates the phasing gear and drive gear, mounted in tandem, and secured by six setbolts.

Each shaft operates six pairs of exhaust and inlet valves, through conventional push rod and rocker assemblies.

The camshafts are high mounted inside the crankcase 'V', and positioned axially by thrust plates.

The camshaft bearings, which are pre-finished, steel backed, lead bronze rolled bushes with clinch butt joints, are disposed singly in the 'A' bank camshaft housings, with the exception of the central position, where two bushes are fitted. In the 'B' bank housings, two bushes are fitted in the central and rear locations. The bushes are drilled and grooved for lubrication and, to complete the assembly, the front end crankcase bores are sealed with cup plugs or, in the case of the 'A' bank, with a bobbin assembly, if necessary.

Push rods and tappets

The push rods are manufactured from medium steel bar, with forged spherical seating ends. Each end is induction hardened, with the convex foot end machine polished. The mating ends of the push rods and the rocker arm adjusting screws are radiused to allow maximum surface contact during angular operation.

The tappets are made from an alloy cast iron with chill-hardened bases. Each is fully machined with a spherical face, and subjected to a surface treatment to give an oil retaining finish. The tappets run in the parent crankcase metal, and are lubricated by pressure feed from the auxiliary oil galleries. The cam action is transmitted to the rocker arms via the tappets and push rods.

Gear train

The wheelcase, mounted on the rear of the crankcase, incorporates a train of helical gears, with the crankshaft pinion driving the main idler gear. Gear drive is transmitted through the compounded idler to the cam phasing gears, auxiliary drive gear and the coolant pump.

The timing gears are positioned across centres, using a machined spot on the side of one tooth, locating between two machined spots on the engaged gear. All the gears are secured by hexagon headed setbolts.

The cam phasing and drive gears are located on the camshaft flanges by spring dowels, and each assembly secured with six setbolts.

All gears are set to calculated backlash and end float parameters. The auxiliary drive shaft is supported in tapered roller bearings, with end float controlled by the use of shims.

The flywheel housing, attached to the wheelcase, forms the outer cover for the gear train, and houses the flywheel/starter ring assembly and the crankshaft rear end, lip type, oil seal.

Cylinder heads

The four identical cylinder heads are manufactured from high duty, close grained, cast iron and machined top and bottom, to provide joint faces for the rocker box and cylinder head gaskets respectively. Joint faces machined on the inner and outer edges, accomodate the induction and exhaust manifolds. Internal coolant passageways are cast around the valve guides and injector pockets.

The valve guides are cast in high quality nickel chrome alloy and inserted under pressure into the cylinder head castings.

Valve seat inserts are frozen into position, against machined shoulders, in the cylinder heads

The inlet valves are of forged steel with stellite seats. The exhaust valves are of solid nimonic material. Inlet and exhaust valves stems are chrome flashed.

All valves are secured with the conventional collet, spring and seat arrangement, the exhaust valves having rotators fitted in place of the upper spring seats.

Paired movement of the valves is controlled by valve bridges, with adjusting screws and locknuts on the outer arm of each bridge. A nitride hardened button inset into the top face of each bridge, connects with the rocker arm, pushrod and tappet and finally, the camshaft.

The rocker arms, with tappet clearance adjusting screws, are assembled in each rocker box on a main shaft. The rocker boxes, located by spring dowels, are secured to the cylinder heads with socket capscrews and setbolts, tightened to a specific torque loading. The rocker covers are of cast aluminium.

Three fuel injectors, carried in each cylinder head, are secured by finger clamps and socket capscrews. The fuel inlet and fuel spill connections are sealed at the rocker covers and rocker box side walls respectively, against oil leakage and the ingress of dirt.

Fuel system

The fuel injection pump, mounted on a platform in the crankcase 'V', is a conventional, 12 element, in-line unit, driven at 0.5 X engine speed from the main gear train.

A constant speed governor, integral with the injection pump, maintains engine speed throughout the egine load range. The stop control lever on the governor is coupled directly to a solenoid, used in the energised-to-run mode, which in turn, is actuated by the stop button and the engine protection devices. A vernier control, connected to the speed control lever, provides for fine adjustment of engine r.p.m.

Viewed from the rear of the engine, the fuel injection pump rotates anti-clockwise, with the pump elements operating in the following sequence : 1, 9, 4, 11, 2, 7, 6, 10, 3, 8, 5 and 12 at 30 deg. intervals, with No. 7 element at spill cut-off point (A6 firing).

The high pressure fuel pipes are made from special steel tubing, 8 mm diam. X 2 mm bore. Zinc plated nuts and collars are incorporated at both ends of each pipe, with cylinder numbers stamped on the nut, at the pump end of the pipe.

The low pressure fuel pipes are made from mild steel, with low pressure joints of tubing nuts and sleeves.

The fuel feed pump is cam driven from the rear end of the auxiliary drive shaft. Fuel is drawn through a primary filter from the supply tank and directed, through two canister type filters, to the injection pump gallery Two low pressure relief valves, mounted on the injection pump body, maintain a constant feed pressure to the pump gallery, and allow excess fuel to return to the supply tank.

Banjo unions, with interconnecting pipework, return spill fuel from the injectors to a spill block, where it merges with spill and excess fuel from the injection pump and returns unfiltered to the supply tank. A bleed screw, incorporated in the spill block, facilitates venting of the low pressure fuel system.

Cooling system

A gear driven pump, mounted at the rear end of 'B' bank side of the crankcase, delivers a flow of coolant throughout the system. The coolant flow is directed via a bifurcated pipe to both banks of cylinders, the flow to 'B' bank passing initially through an oil-to-coolant heat exchanger.

After passing through the cylinder block, the coolant is directed to the cylinder heads where it circulates around the valve guides and injector pockets. The coolant then enters galleries, integral with the induction manifolds, and is directed to the two thermostat valves, carried in housings at the front end of the manifolds. Dependent on the engine operating temperature, the coolant is then directed to the radiator or back to the coolant pump suction.

Lubrication system

The wet sump lubrication system incorporates a spur gear type pump, driven via an idler, from the front end crankshaft gearing. The oil is drawn directly from a strainer in the sump well, and delivered under pressure throughout the system.

The oil passes from the pump to the oil-to-coolant heat exchanger, mounted on the 'B' bank side of the crankcase. From the heat exchanger, the oil passes through three full flow canister type filters, which are screwed directly to the base of the heat exchanger housing, and into the main oil gallery. Drillings from the main gallery supply oil to the main bearings, idler gear axles and two auxiliary galleries, which in turn, supply oil to the camshaft bearings and valve gear.

Connecting rod big-end and small-end bearings are supplied with oil from the main bearings via drillings in the crankshaft, and holes bored longitudinally through the connecting rods.

Small pressure jets, bolted between the main bearings, supply cooling oil to the underside of the piston crowns.

External pipework delivers oil, from unions in the heat exchanger mounting adaptor, to the turbocharger bearings, injection pump and governor and returns drain oil to the crankcase and sump.

Oil-to-coolant heat exchanger

The heat exchanger, comprising a singletube pack in an alloy casing, is mounted on an adaptor assembly on the 'B' bank side of the crankcase. Coolant flows through the tubes whilst oil is directed over the outside of the tubes, by a series of baffles, to achieve maximum heat transference between the fluids.

Pressure relief valve

The oil pressure relief valve, integral with the heat exchanger mounting adaptor, is a conventional plunger and spring arrangement, and allows excess oil to return to the sump at pressures exceeding 4,2 kgf/sq.cm (60 lbf/sq.inch).

Oil filler and dipstick

The oil filler, consisting of a simple pipe with a sealing cap, is mounted over the 'A' bank side of the sump well.

The dipstick, held in a curved tube adjacent to the filler, consists of a flat, spring steel blade which is cranked to lie clear of the tube wall. Notches, machined in the blade edge, indicate maximum and minimum permissible lubricating oil levels.

Induction and exhaust system

Twin turbochargers, mounted alongside the two front end cylinder heads, draw the induction air through the two dry element type air cleaners and deliver it under pressure to engine. Charge coolers, integral with the radiator, cool the air before it is delivered to the induction manifolds.

The exhaust gases from each cylinder are directed, via a twin discharge on the front section of each exhaust manifold, to the turbine of each turbocharger. After passing through the turbines, the exhaust gases pass through flexible bellows units and elbow connections to which appropriate pipework and silencers may be fitted, dependent on installation requirements.

Electrical equipment

A Butec Type A 3024 alternator with integral regulator, or a Butec Type A13 alternator with separate Type R1 regulator, provides a 24 volt, 30 amp charging circuit for the starter batteries.

Engine starting is by a Butec Type MS6 starter motor, with an external solenoid control switch.

Two Teddington warning/shutdown switches connected to a solenoid control, protect the engine against low oil pressure and/or high coolant temperatures.

ENGINE DATA

GENERAL

Engine type	Direct injection, liquid cooled, four stroke compression ignition, pressure charged with charge cooling.
Number of cylinders	12
Arrangement	60 deg. included angle 'V' configuration.
Total swept volume	26.11 litres (1593.24 cu. inches).
Bore	135 mm (5.315 inches).
Stroke	152 mm (5.984 inches).
Compression ratio	14 : 1
Firing order	A1, B6, A4, B3, A2, B5, A6, B1, A3, B4, A5 and B2.
Rotation	Anti-clockwise viewed on flywheel.
Rated output	350 to 550 kW
Maximum rated speed	1800 r.p.m.
Valve tappet clearances (Hot or cold)	
Inlet valves	0,2 mm (0.008 inch).
Exhaust valves	0,5 mm (0.020 inch).
Injection timing	As stamped on engine data plate.
Dry weight of bare engine (Approx. for handling)	2120 kg (4674 lbs).

COOLING SYSTEM

Type	Liquid cooled.
Pump	Centrifugal, gear driven unit.
Coolant capacities	
Engine and pipework	68 litres (15 Imp. gallons).
Engine/radiator pack	164 litres (36 Imp. gallons).
System pressure	Up to 69 kN/sq. m (10 lbf/sq. inch).
Temperature (normal)	70 to 100 deg. C.
Thermostats	Two, Western Thomson wax capsule. Type 6-533.

Cooling fan	1400 mm (55 inch) diam. aluminium alloy, 8 blades, belt driven.
Approved coolant	See leaflet T.S.D. 3085 in rear cover pocket.
FUEL SYSTEM	
Type	Pressurised supply to injection pump with through flow return to tank.
Injection pump	C.A.V. Maximec. 12 element in-line unit.
Governor	C.A.V. mechanical, Type CS, Servo assisted integral with injection pump.
Feed pump	Bosch FP/KD cam operated.
Fuel feed pressure	100 to 170 kN/sq.m (15 to 25 lbf/sq.inch).
Fuel injectors	C.A.V. axial feed, low spring type. Six spray holes.
Injection pressure	240 bar (240 atmospheres).
Main fuel filters	Two, spin-on type expendable canisters.
LUBRICATION SYSTEM	
Type	Wet sump.
Capacities	
Sump	45 litres (10 Imp. gallons).
System total	66 litres (14.5 Imp. gallons).
Pressure	
Normal load conditions	415 kN/sq.m. (60 lbf/sq.inch).
Minimum at rated speed	*207 kN/sq.m. (30 lbf/sq.inch).
Pump	Spur gear type, gear driven.
Pressure relief valve	Spring loaded plunger, non-adjustable.
Heat exchanger	Tube pack and shell, baffled and finned.
Filters	3, spin-on type expendable canisters.
Maximum recommended bulk oil temperature	120 deg. C.
Approved lubricating oil	See leaflet T.S.D. 3085 in rear cover pocket.

*Important for the protection of turbocharger bearings.

INDUCTION/EXHAUST SYSTEM

Aspiration	Pressure charged by two, Garret Airesearch TV 61 turbochargers.
Charge coolers	Two, air-to-air type, integral with radiator.
Air cleaners	Two Donaldson paper element, Type FHG or EGB.

ELECTRICAL EQUIPMENT

Alternator	Butec, Type A 3024, with integral regulator. or Butec, Type A13, with Type R1 regulator.
Starter motor	Single, flange mounted Butec, Type MS6.
Stop control	Lucas C.A.V., solenoid operated, Type 368. or Synchro-Start solenoid, Type 2001.
Warning and shutdown switches	Teddington temperature switch, Type DCA/AB/096 96 deg.C. setting. Teddington pressure switch, Type DCA/BC/152 152 kN/sq.m. (22 lbf/sq.inch) setting.

LUBRICANTS AND FLUIDS APPROVED FOR USE DURING SERVICING AND OVERHAUL

(Equivalents of alternative manufacture are acceptable)

	Manufacturer	Brand or specification
ALTERNATOR		
Diode cleaning fluid	Applied Chemicals Ltd.	Fluid grade 8-23
Diode grease	-	Silicon MS200, MS4, MS5.
COOLING SYSTEM		
Hose and 'O' ring lubricant	-	Castor oil
EXHAUST SYSTEM		
Screw thread anti-seize compound	Slip Group	Copaslip
INDUCTION SYSTEM		
Emulsifying solvent	Morris's Shrewsbury	Pavan

JOINTS

Jointing compound	Wellworthy Ltd.	Wellseal
	Marston and Bentley Lubricants Limited.	Hylomar PL 32
Sealant and thread locking where specified	Douglas Kane Sealants	Loctite AVV, 601, 542, 290, 270 and 241

STARTER MOTOR

Commutator cleaning fluid	I.C.I. Ltd.	Genklene N
Spline lubricant	Shell Oil Limited	Aeroshell DID 5598
'O' ring lubricant	-	Glycerine
Lubricator wick	Various	Mineral oil SAE 5W/20

GENERAL CLEANING AND INHIBITION

Detailed information concerning all the products listed below, will be found on the Manufacturer's data sheets.

ARDROX 667 : Ardrox Limited, Brentford, Middlesex.

MAXAN 774 : Henkel Chemicals Limited, Edgeware Road, London.

These products are methylene chloride based and are safe to use on most metals for the removal of carbon build up and for paint stripping. They are harmful to rubber and most plastic materials.

Method of use

The components to be cleaned must be immersed in the cleaning fluid long enough to produce the required standard of cleanliness. After cleaning, the components must be thoroughly rinsed in clean water. In use, maintain a water seal of at least 76 mm (3 inches) above the cleaning fluid to prevent evaporation and the escape of toxic fumes.

Goggles and protective clothing must be worn at all times when using these fluids, and the container must be in a well ventilated area.

Do NOT smoke in the vicinity of the cleaning tank.

DUROCLEAN 150 POWDER : Diversey Limited, Northampton.

This product is an alkali based degreasing compound and is safe to use on brass, copper and ferrous metals. It must not be used on aluminiun, lead, tin and zinc.

Method of use

The components to be degreased must be immersed in a solution of the compound, heated to 65 deg. C., until all contamination has been removed. It is recommended that Duroclean 150 be used at the top concentration of 50 grammes per litre of water. Rinse off the concentrate with clean water; if desired, a suitable inhibitor may be added to the final rinse.

Goggles and protective clothing must be worn when using this product.

CRODAFLUID CR2 : Croda Chemicals Limited, Goole, Yorkshire.

This product is an inhibited, acid based solution for the derusting of ferrous components.

Method of use

Crodafluid CR2 must be held in a tank lined with, or made from, an acid resistant material. The components to be treated must be degreased before being immersed in the derusting solution. For medium to heavy deposits of rust, the solution may be heated to 70 deg. C. Inspect the components occasionally to check the derusting progress. Light rust may be removed in a few minutes. Finally, wash the components thoroughly in clean water.

Goggles and protective clothing must be worn at all times during the above process.

DIVERSPRAY 30 : Diversey limited, Northampton.

This product is a mild, alkali based cleaning compound containing rust inhibitors, and may be sprayed over the components to be cleaned, or held in a tank, for immersion of the components, with agitation. Diverspray 30 may be added to rinse water of components which require inhibiting after other treatments, e.g. derusting.

TORQUE LOADINGS

Note : The following torque loadings apply the threads in oil-wetted condition, unless the use of thread locking compound is specified.

It must not be assumed that application of the specified torque loading is, in itself, sufficient to ensure that the components concerned are adequately secured together. The recommended method of assembling and, where applicable, the tightening sequence must also be observed. This information is given in the relevant Section of this Manual.

Where a bolt or nut is secured with a lock washer, lockplate or split pin, the specified torque loading may be exceeded, if necessary, by the MINIMUM amount required to reach a locking position.

	Nm	lbf.ft.
ALTERNATOR		
Pulley nut	95	70
AUXILIARY DRIVE SHAFT		
Flange nut (18 mm 27 A/F)	200	148
(22 mm 32 A/F)	300	220
CAMSHAFTS		
Drive gear setbolts - 'A' bank	40	30
- 'B' bank	80	59
Thrust plate C/S head screws	70	52
CONNECTING RODS		
Big-end bearing nuts	60	44
CRANKCASE		
Main bearing cap setbolts		
Front, centre and rear	177	130
Intermediate	488	360
Lateral setbolts		
Front, centre and rear	114	84
Intermediate	177	130
Cylinder head studs	35	26
CRANKSHAFT		
Damper and pulley setbolts	71	52
Flywheel socket capscrews	315	232

	Nm	lbf.ft.
CYLINDER HEADS		
Securing setbolts	200	148
Securing nuts	200 (plus further 90 deg.)	148
Rocker box setbolts	41	30
Rocker box socket capscrews	35	26
Rocker cover setbolts	21	15
Bridge piece adjusting screw locknut	40	30
Tappet adjusting screw locknut	40	30
COOLANT PUMP		
Bearing locknut	100	74
Drive gear nut	88	65
EXHAUST MANIFOLDS		
Securing setbolts	47	35
FAN ADAPTOR		
Bearing securing nuts	280	207
FLYWHEEL HOUSING		
Securing setbolts	71	52
FUEL FEED PUMP (Mechanical)		
Cam securing nut	54	40
FUEL FILTER HEADER		
Bracket securing setbolts	54	40
FUEL INJECTION PUMP		
Adjustable coupling socket capscrews	69	51
Camshaft hub nut	149	110
Delivery valve holders	122	90
Pump mounting setbolts	41	30
Spring plate coupling nuts	120	88
FUEL INJECTORS		
Clamp socket capscrews	60	44
Nozzle cap nut	81	60
Spill connection	27	20

GEAR TRAIN		
Auxiliary drive gear setbolts	58	43
Compounded idler setbolts	40	30
Compounded idler axle setbolts	71	52
Main idler axle setbolts	71	52
Coolant pump idler axle setbolt	71	52
Oil pump idler axle setbolt	71	52
LUBRICATING OIL PUMP		
Casing setbolts	21	15
Drive gear securing nut	120	88
SUMP		
Securing setbolts	55	41
Drain plug insert	305 to 340	225 to 250
Drain plug	110 to 115	81 to 85
TURBOCHARGERS		
'V' band clamps		
*Multi-segment	13,5	10
Single segment	18	13
Turbine housing	13,5	10
Captive 'T' bolt	17	12.5
Quick release	9	7

* Tighten multi-segment to 13,5Nm plus a further 120 deg.; slacken and re-tighten to 13,5 Nm.

SECTION 2 - DISMANTLING THE ENGINE

SECTION 2 - DISMANTLING THE ENGINE

This Section deals briefly with the engine dismantling sequence

For a full overhaul, the engine must first be disconnected from its driven unit. This may be a an electrical generator, air compressor, rotary pump, etc., and instructions for disconnecting the unit will be found in the Manual of the particular Manufacturer. Once disconnected, proceed as follows :

1 If not already previously dealt with, the starter batteries must be isolated to prevent accidental turning of the engine.

2 Drain the lubricating oil from the engine by removing the drain plug from the base of the sump, place a container beneath the oil filter canisters, to catch the oil trapped in the heat exchanger, and remove and discard the three oil filter canisters.

3 Remove the coolant drain plugs from the radiator, coolant pump discharge pipe and crankcase, as necessary, to drain the cooling system.

4 Close the fuel supply cock and disconnect the fuel supply and return pipework. Remove and discard the two main fuel filter canisters.

5 Disconnect and remove the exhaust pipework from over the engine, as appropriate.

6 Disconnect the electric wiring between the shutdown solenoid, coolant temperature and oil pressure control switches, and the main control panel.

7 Remove all the coolant pipework and air ducting, between the radiator and engine. Lift out the thermostat valve assemblies.

8 Remove the air cleaners, support brackets and turbocharger inlet ducting.

9 Remove the fan belt guards and fan cowling, as necessary, to allow the engine to be lifted clear of the radiator.

10 Fit the Lifting Bracket, CV 8012, to the flywheel housing and secure it with two setbolts and spring washers.

11 Secure the engine assembly to a suitable hoist, using the Lifting Beam, GA 5072.

12 Remove the holding down bolts from the engine front end mounting, and disconnect the support brackets from the flywheel housing. Lift the engine assembly clear of the engine bed and lower it on to the workshop floor, with suitable wooden packing beneath the flywheel housing.

13 Before dismantling, clean the engine thoroughly and ensure that the cooling and lubrication systems are completely drained. Oil trapped in the oil-to-coolant heat exchanger can be drained by the removal of the lubricating oil filters.

To facilitate the refitting of components, it is recommended that smaller items, (e.g. low pressure fuel pipes, clips, brackets, etc.) are labelled, indicating their location and function, and stored in containers with associated engine parts.

Dismantling sequence

14 Slacken the fan belt tensioner pulley, support the fan using the hoist and rope strops and remove the fan securing setbolts; lift the fan away from the engine.

15 Re-tension the fan belts and slacken the fan belt pulley retaining nut; release the tensioner and lift off the fan belts and pulley.

16 Remove the twelve securing setbolts from the crankshaft pulley; lift off the pulley followed by the crankshaft damper.

Note: The damper is a heavy component and care must be taken not to drop it during removal, as dents in the casing will prevent the damper from functioning correctly.

17 Remove the fan belts, alternator belt guard and alternator drive belt.

18 Remove the alternator, belt adjusting link and fan belt tensioner pulley.

19 Disconnect and remove the crankcase breather pipe.

20 Remove the three retaining setbolts and withdraw the starter motor.

21 Disconnect and remove the coolant pipework between the 'A' bank coolant gallery, coolant pump and heat exchanger.

22 Disconnect and remove the coolant pipe between the 'B' bank front coolant gallery cover and the heat exchanger discharge.

23 Remove the exhaust elbows and bellows units from the turbochargers.

24 Disconnect and remove the turbocharger oil feed and oil drain pipework; bend back the lock washers on the turbocharger securing nuts, remove the nuts and lift each turbocharger away from the engine.

25 *In turn, bend back the lock washers on the twenty four setbolts securing* each exhaust manifold assembly to the cylinder heads. Unscrew the nut securing the captive sleeve lock plate, remove the setbolts and lift the two sections of manifold away from the cylinder heads.

26 Disconnect and remove the low pressure fuel pipework between the feed pump, filter header, spill block and injection pump, removing the auxiliary drive coupling guard as necessary.

27 Disconnect the lubricating oil supply pipe from the feed pump mounting.

28 Remove the heat shield and fuel filter header bracket.

29 Remove the four coolant gallery covers and fit the four engine mounting brackets over the coolant galleries as follows :

VP 6836.....'A' bank front
VP 6837.....'B' bank front
VP 5598.....'A' bank rear
VP 5597.....'B' bank rear

30 Using the lifting beam, locate the engine assembly in the Turn Over Build Stand, VP 5908, with the flywheel end facing outwards and secure the engine in the build stand with eight bolts and nuts. Remove the lifting beam.

31 Remove the fuel injector high pressure feed pipes, spill pipework, governor shutdown and speed control linkages, cross shaft assembly and stop solenoid

32 Disconnect all fuel supply, spill and lubrication pipes from the pump and governor. Fit dust caps to all the injection pump openings.

33 Unscrew all the injector spill connections from the rocker box side walls. Remove the four rocker box covers, release the finger clamp capscrews and withdraw all the fuel injectors. Temporarily refit each spill connection to its associated injector, and fit dust caps to all the openings.

Note: Sticking injectors may be removed using the Slide Hammer, GA 5100, and Adaptor, GA 5100-5.

34 Remove the auxiliary drive coupling guard, disconnect the fuel injection pump drive coupling from the drive end flange and remove the pump securing setbolts. Using the Lifting Beam, VP 878, lift the pump and governor assembly, complete with drive coupling, away from the engine.

35 Disconnect and remove the pipework between the coolant pump suction and the thermostat housings.

36 Unscrew the eight securing setbolts from the thermostat housings and remove the housings.

37 Remove the air balance pipe connecting the two induction manifolds, then remove the manifold securing setbolts and, in turn, lift off the manifold assemblies. Withdraw the three coolant transfer bobbins from each cylinder head.

38 Remove the six securing setbolts from the heat exchanger and lift the heat exchanger clear of the adaptor.

39 Remove the securing setbolts from the mounting adaptor and lift the assembly upwards, away from the crankcase. Retain the two oil transfer bobbins.

40 Withdraw the dipstick, remove the dipstick tube and the oil filler pipe assembly.

41 Slacken all the plugs and the priming valve on the fuel feed pump, then remove the feed pump complete.

42 If applicable, remove the Engine Service Counter from the feed pump mounting.

43 Remove the feed pump mounting and unscrew the cam retaining nut from the auxiliary drive shaft. Withdraw the feed pump drive cam.

44 Unscrew the drive flange retaining nut from the inner end of the auxiliary drive shaft, remove the plain washer and, using the Puller, GA 5090, and two Bolts, GA 5090-2, withdraw the flange; lift out the Woodruff key.

45 Unscrew the four oil seal housing securing setbolts, lift off the housing and laminated shim pack.

46 Unscrew two socket capscrews from horizontally opposite sides of the flywheel. Fit the two Guide Studs, GA 5060, into the crankshaft, remove the remaining capscrews and slide off the clamping ring. Ease the flywheel away from the crankshaft and, using the Lifting Bar, VP 517, lift the flywheel away from the engine. Withdraw the flywheel locating dowel from the crankshaft rear end.

47 Remove two securing setbolts from horizontally opposite holes in the flywheel housing, screw the two Guide Studs, GA 5058, into the bolt holes and, using the engine rear end lifting bracket, slide the flywheel housing clear of the wheelcase. Retain the roller race and the outer sleeve from the auxiliary drive shaft outer bearing. Remove and discard the crankshaft rear end oil seal.

48 Withdraw the auxiliary drive shaft assembly from the wheelcase. Remove the two outer bearing sleeves from the wheelcase and flywheel housing, and remove and discard the drive shaft oil seal.

49 Remove the four nuts and spring washers from the coolant pump securing studs and lift the pump clear of the wheelcase.

50 Unscrew and remove the securing setbolt and spring washer from the coolant pump idler gear axle. Lift off the gear wheel and axle assembly.

51 Secure the Barring Adaptor, VT 11144, to the crankshaft rear end face and turn the crankshaft sufficiently to allow the six securing setbolts in each camshaft gear to be slackened.

52 Turn the crankshaft until the cam gear locating dowels are facing away from each other, remove the retaining setbolts and gently lever the fuel pump drive gear and the two cam drive gears off the ends of the camshafts.

53 Bend back the tabs of the setbolt locking plates on the main idler gear, unscrew the setbolts and remove the axle assembly and gear wheel.

54 Remove the compounded idler gear and axle assembly in the same manner.

55 Remove two securing setbolts from horizontally opposite sides of the wheelcase and fit two locally made guide studs into the bolt holes.

56 Using the Lifting Hook, VP 8754, support the wheelcase and remove the remaining setbolts and nut. Ease the wheelcase off its locating dowels and lift it clear of the crankcase.

Turn the crankcase so that the sump is uppermost and proceed :

57 Remove the sump securing setbolts and lift the sump away from the sump adaptor. Lift out the lubricating oil pump suction bobbin.

58 Remove the oil gallery blanking flange from the 'B' bank side of the sump adaptor and withdraw the oil pump discharge bobbin.

59 Remove all the adaptor securing setbolts and lift the adaptor away from the crankcase.

60 Remove the lubricating oil pump securing setbolts and lift off the pump.

61 Unscrew the oil pump idler axle securing setbolt and remove the gear wheel and axle assembly.

Turn the crankcase to its normal operating position and proceed :

62 Remove the six setbolts and spring washers securing the engine front mounting. Lift the mounting away from the fan adaptor.

63 Remove the five large and nine small setbolts and washers securing the fan adaptor. Ease the fan adaptor assembly off the locating dowels and lift it clear of the crankcase. Remove and discard the crankshaft front end oil seal.

64 Fully slacken the rocker arm adjusting screws and, evenly and progressively, slacken the rocker box securing setbolts and capscrews. As the valve spring tension is released, lift off each rocker box and remove the valve bridge pieces.

65 Using the slide hammer and Adaptor, GA 5100-10, withdraw the 12 blanking plugs from the cylinder head induction ports.

66 Turn the crankcase until one bank of cylinder heads is horizontal and remove the 20 securing nuts and washers, and three securing setbolts from each of the two cylinder heads. Using the Lifting Bracket, VP 522, remove the two heads from the crankcase and lower them on to a soft topped workbench. Remove and discard the two cylinder head gaskets and retain the two oil transfer bobbins.

67 Fit four Liner Retaining Sleeves, VT 5093, over the appropriate cylinder head studs, and turn the crankcase until the cylinder heads on the other bank are horizontal.

68 Remove the two cylinder heads as previously described and secure the exposed cylinder liners with retaining sleeves.

69 Remove the two blanking plates and the fuel injection pump mounting plate from the crankcase 'V'.

70 Unscrew the four camshaft thrust plate securing capscrews. Lift out the thrust plate assemblies and carefully withdraw the two camshafts. If applicable, withdraw the bobbin type seal from the 'A' bank camshaft bore.

Turn the crankcase so that the lower half is horizontal, with the 'A' bank cylinders above the 'B' bank.

71 Turn the crankshaft until one of the 'A' bank pistons is at the bottom of its stroke, and remove the four big-end bearing nuts. Withdraw the bearing cap and shell and screw the Guide Pin, GA 5092, on to one of the protruding bolt threads.

72 Carefully push the piston/connecting rod assembly out through the top of the cylinder liner. Stand the assembly on the workbench, on the piston crown, withits associated bearing cap and shell.

73 Remove each piston/connecting rod assembly from the 'A' bank cylinders, transferring the guide pin as necessary.

74 Turn the crankcase so that the 'B' bank big-end bearings are accessible and remove all the piston/connecting rod assemblies as for 'A' bank.

Turn the crankcase so that the sump joint face is uppermost and proceed :

75 Slacken all the main bearing cap securing setbolts, and unscrew and remove the lateral setbolts.

76 In turn, remove the setbolts from each main bearing cap and insert the appropriate guide studs. Using the slide hammer with Adaptor, GA 5100-9, withdraw each main bearing cap and lower bearing shell, retaining the thrust washer halves when removing the centre main cap.

77 Slide the thrust washer upper halves from their recesses around the centre main journal and, using the Lifting Beam, VP 666, lift the crankshaft from the crankcase and rest it on wooden 'V' blocks. Remove the upper halves of the main bearing shells from the crankcase.

78 Unscrew the two retaining setbolts from the piston cooling jet assemblies and remove each assembly.

79 Turn the crankcase to its normal operating position and remove the cylinder liner retaining sleeves. Carefully withdraw each liner and place it with its associated piston assembly.

SPECIAL TOOLS

Tool No.	Description
GA 5072	Lifting beam, engine
CV 8012	Lifting bracket, engine (detachable)
VP 5597	Mounting bracket, crankcase
VP 5598	Mounting bracket, crankcase
VP 6836	Mounting bracket, crankcase
VP 6837	Mounting bracket, crankcase
VP 5908	Turn over build stand, engine
VP 878	Lifting beam, fuel injection pump
VP 517	Lifting bar, flywheel
GA 5060	Guide stud, flywheel to crankshaft
GA 5058	Guide stud, flywheel housing to wheelcase
VP 522	Lifting bracket, cylinder head
VP 8754	Lifting hook, wheelcase
VT 10716	Guide stud, wheelcase to crankcase
GA 5090	Puller
GA 5090-2	Bolt, 8mm thread
GA 5100	Slide hammer
GA 5100-5	Removal adaptor, injector
GA 5100-9	Removal adaptor, main bearing cap
GA 5093	Sleeve, liner retaining
GA 5092	Guide pin, piston/connecting rod assembly
GA 5100-10	Removal adaptor, blanking plug
VT 11144	Barring adaptor, crankshaft (rear end)
VT 11495	Guide stud, main bearing cap
VT 11496	Guide stud, main bearing cap
VP 666	Lifting beam, crankshaft
VP 7862	Lifting plate, crankcase

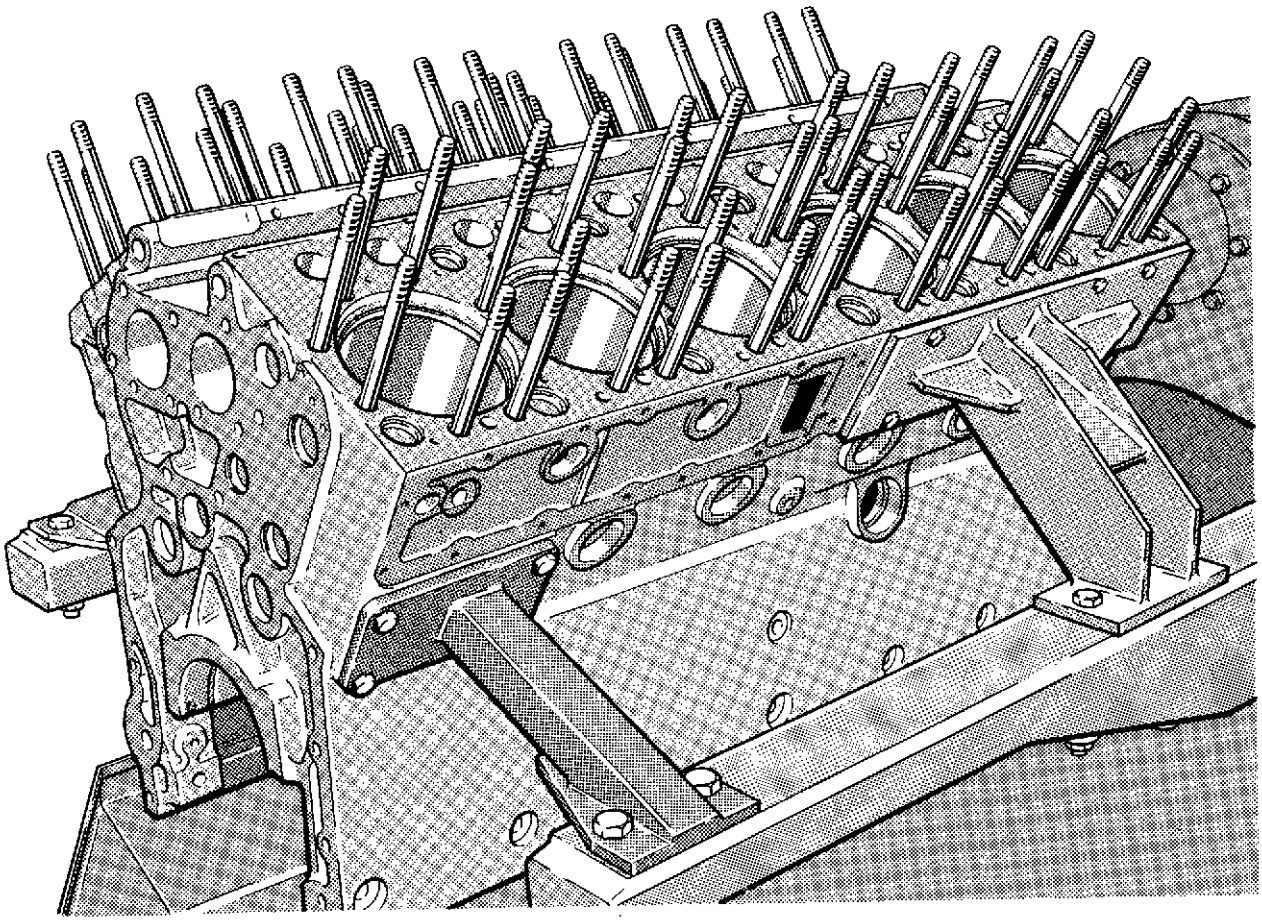


Fig. 1 Crankcase in build stand

SECTION 3 - ASSEMBLING THE ENGINE

This Section deals with the final assembly of the engine from sub-assemblies such as cylinder heads, coolant pump, etc., which have been reconditioned under their respective headings elsewhere in this Manual

When assembling major components, it will be found more convenient and time saving to fit support brackets and clips where applicable, (see introduction to SECTION 2 - DISMANTLING THE ENGINE). Ensure that the correct length bolts are fitted in each instance.

Attention is drawn to the instructions concerning assembly procedure which are given under 'GENERAL INFORMATION'. Observance of these instructions will do much to ensure long and trouble-free service from the engine.

ASSEMBLY DETAILS

1 Bolt the four mounting brackets to the crankcase, (see 'SPECIAL TOOLS' at end of Section), and secure the Lifting Plate, VP 7862, in the crankcase 'V'. Using a suitable hoist, position the crankcase in the Build Stand, VT 5908, with the gear train end facing outwards, as shown in figure 1. Fit the eight retaining bolts through the arms of the build stand, screw the nuts on and tighten securely. Turn the crankcase over so that the sump joint face is uppermost.

Crankshaft and main bearings

2 Fit the upper halves of the main bearing shells into their housings and smear them liberally with clean engine oil.

3 Liberally oil the main bearing journals of the prepared crankshaft assembly and, using the Lifting Beam, VP 666, lower the assembly into the crankcase (fig. 2), so that the 16 tapped holes in the end face of the shaft are facing outwards, i.e., at the gear train end of the crankcase.

4 Oil the upper halves of the thrust washers and feed them into their recesses on each side of the centre main bearing. Ensure that the bronze face of each washer faces towards its adjacent crank web.

5 Fit the lower halves of the main bearing shells into the bearing caps and smear the running faces with clean engine oil. Using the Guide Studs, VT 11495 or VT 11496, as necessary, fit all except the centre main bearing cap assemblies. Ensure that the correlation numbers on each cap coincide with the numbers stamped in the crankcase, (fig. 3).

6 Apply a light smear of grease to the side recesses of the centre main bearing cap and position the lower halves of the thrust washers into the recesses, with the bronze face of each washer facing outwards.

7 Using the Guide Studs, VT 11496, carefully fit the centre main bearing cap assembly, (fig. 4), ensuring that the thrust washer halves are not dislodged during the operation.

8 Oil wet the threads and underside of each bearing cap setbolt head and carefully fit each setbolt into its location. Do NOT drop the setbolts into the holes as this could damage the threads. Run each setbolt fully home, finger tight only.

9 Oil wet the thread and underside of each lateral setbolt head. Fit the washers and run each setbolt fully home, finger tight only, through the side walls of the crankcase.

10 Check that the machined side face of each main bearing cap is flush with the corresponding face in the crankcase, then lightly nip all the main setbolts followed by the lateral setbolts.

11 Tighten all the main setbolts in sequence, (fig. 5), in steps of 50 Nm (37 lbf.ft.), until a torque loading of 177 Nm (130 lbf.ft.) is achieved. At this stage, the front, centre and rear main bearing cap setbolts are fully tightened.

Note: During the tightening sequence, make continual checks on the crankshaft for freedom of rotation.

12 Continue tightening the intermediate main bearing cap setbolts, numbers 5 to 12 on the illustration, until a torque loading of 488 Nm (360 lbf.ft.) is achieved.

13 Tighten all the lateral setbolts, in alphabetical order, until a torque loading of 114 Nm (85 lbf.ft.) is achieved. At this stage, the front, centre and rear lateral setbolts are fully tightened.

14 Continue tightening the intermediate lateral setbolts, letters C to J on the illustration, in alphabetical order, until a final torque loading of 177 Nm (130 lbf.ft.) is achieved.

15 Mount a magnetic based dial test indicator (D.T.I.) on the end face of the crankcase, with the button resting on the end of the crankshaft as shown in figure 6. Lever the shaft backwards and forwards against the thrust washers and check the total readings on the D.T.I.. Permissible end float is 0,10 to 0,30 mm (0.004 to 0.012 inch).

Turn the crankcase to its normal operating position and proceed :

16 Using new gaskets, lightly coated with 'Wellseal' jointing compound, fit the two rear covers to the crankcase coolant gallery, ensuring that the coolant inlet flange on the 'A' bank cover is towards the front of the crankcase.

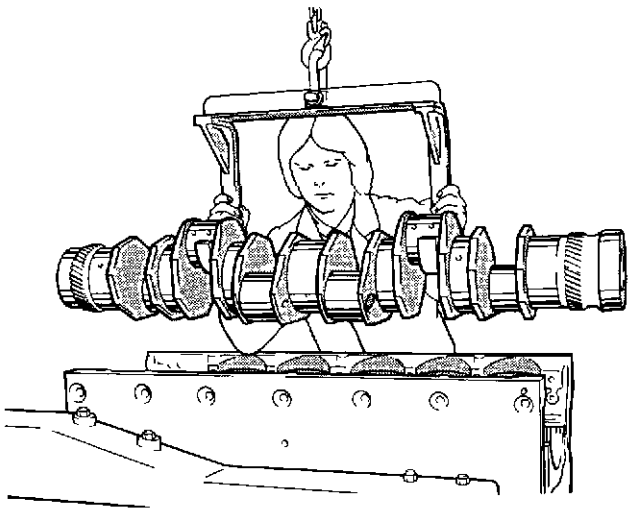


Fig. 2 Fitting crankshaft

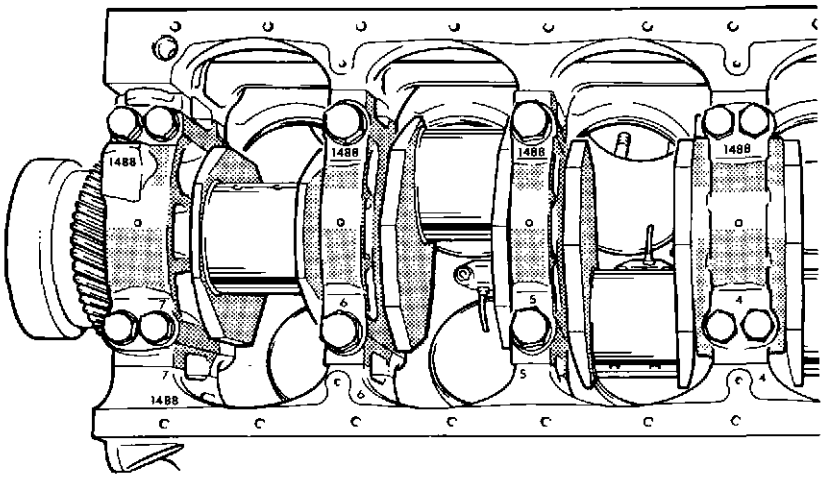


Fig. 3 Main bearing correlation

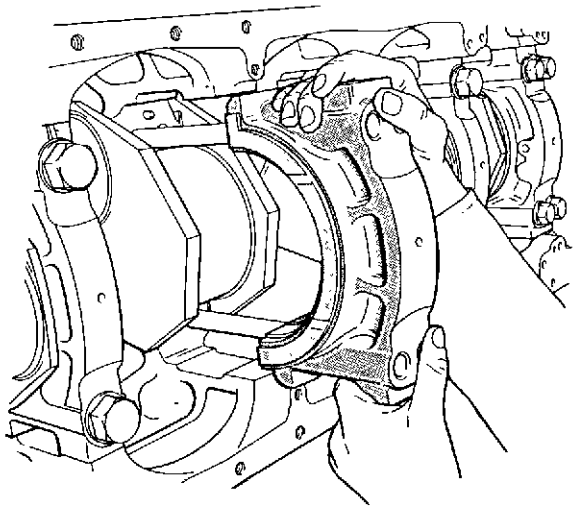


Fig. 4 Fitting centre main bearing

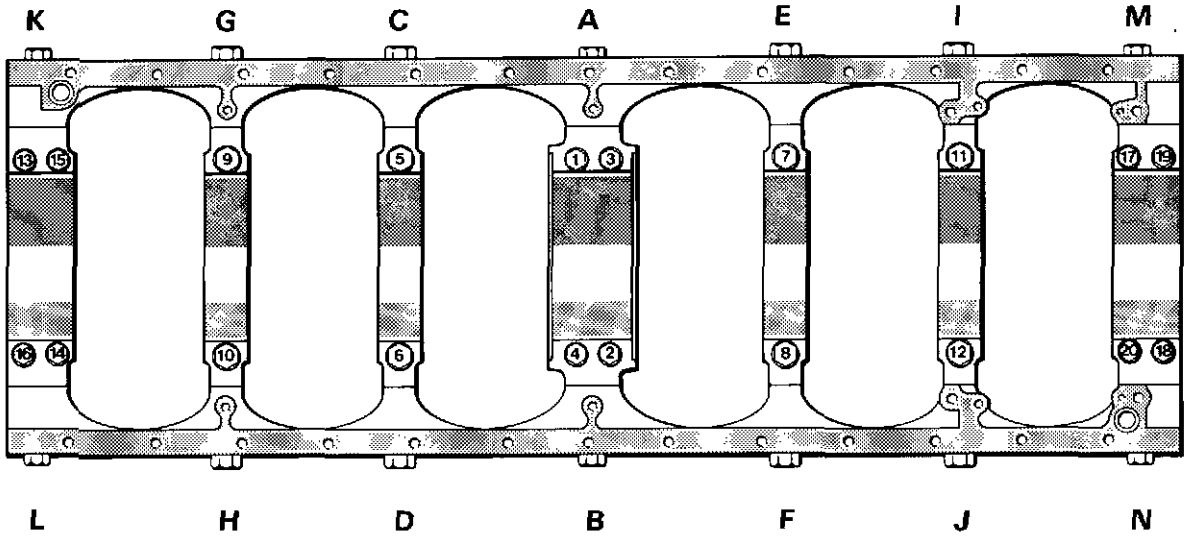


Fig. 5 Main bearing tightening sequence

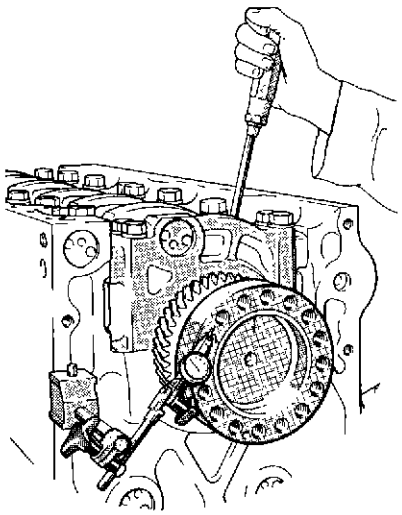


Fig. 6 Crankshaft end float

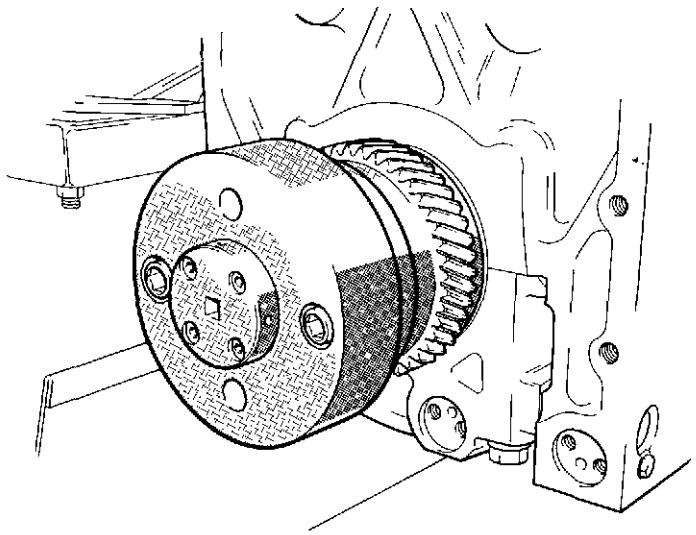


Fig. 7 Barring adaptor

Cylinder liners

17 Apply a light coating of 'Hylomar' to the underside of each cylinder liner and position each liner in its crankcase bore.

18 Fit eight Liner Retaining Sleeves, GA 5093, over the cylinder head studs, to prevent the liners being dislodged when fitting the piston/connecting rod assemblies.

Pistons and connecting rods

Turn the crankcase until the 'A' bank cylinders are horizontal and proceed :

19 Fit the crankshaft Barring Adaptor, VT 11144, to the rear end face of the crankshaft (fig. 7), and turn the shaft until the 'A1' crankpin is at B.D.C. Check that the upper half of the big end bearing shell is in position on the 'A1' piston/connecting rod assembly. Stagger the piston ring gaps as shown in figure 8, oil the crankpin, big end bearings and piston, and slide the Piston Ring Sleeve, GA 5094, over the piston to compress the rings. Screw the Guide Pin, GA 5092, on to one of the big end bearing bolts.

20 Carefully fit the piston/connecting rod assembly into its liner, ensuring that the cut out in the piston skirt is correctly positioned in relation to the piston cooling oil jet. Using the guide pin, pull the assembly through the liner, (fig. 9), until the big end bearing is seated on the crankpin. If the piston and connecting rod have been assembled correctly, the chamfered edge of the big end bearing bore will face the adjacent crank web.

Note: During the above operation, care must be taken not to damage the crankpin bearing surface or big end bearing shell through rough handling.

21 Remove the connecting rod guide pin, oil the half shell in the big end bearing cap and fit the cap on to the big end bolts. Ensure that the correlation letters are aligned, then fit and lightly nip up the four retaining nuts.

22 Repeat the above procedures for each of the 'A' bank piston/connecting rod assemblies.

Note: If a retaining sleeve has to be removed to give clearance for the piston ring sleeve, it must be refitted at each stage before turning the crankshaft.

Turn the crankcase until the 'B' bank cylinders are horizontal and proceed :

23 Fit all the 'B' bank piston/connecting rod assemblies as previously described.

When all the piston/connecting rod assemblies have been fitted, ensure that the liner retaining sleeves are in position,then turn the crankcase so that the sump joint face is uppermost.

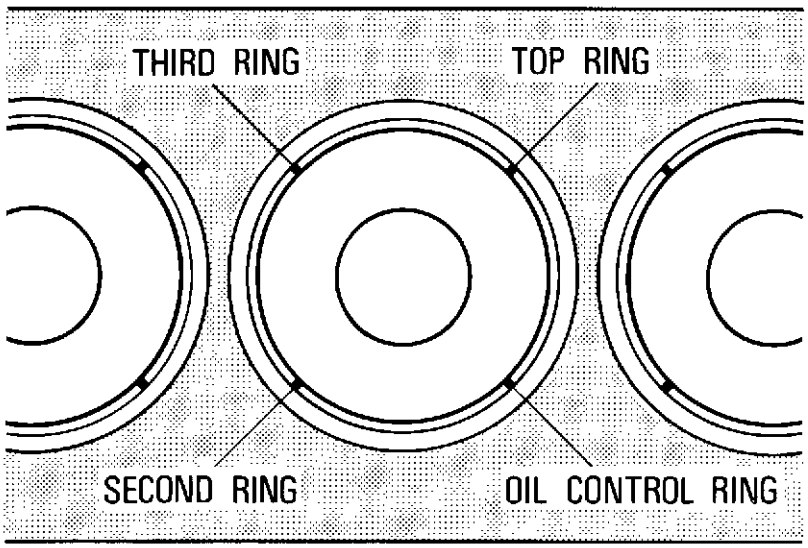


Fig. 8 Piston ring gaps

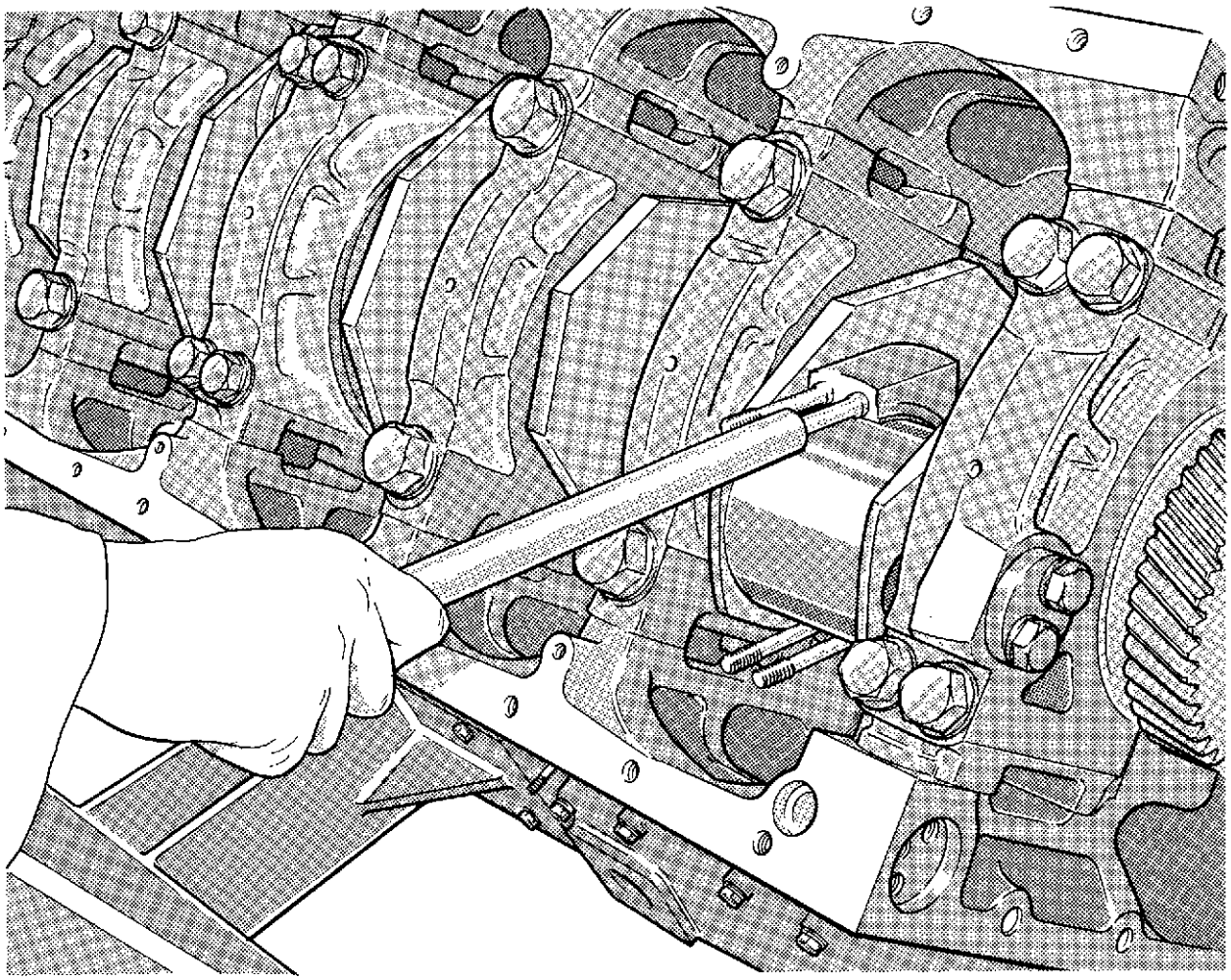


Fig. 9 Fitting connecting rod assembly

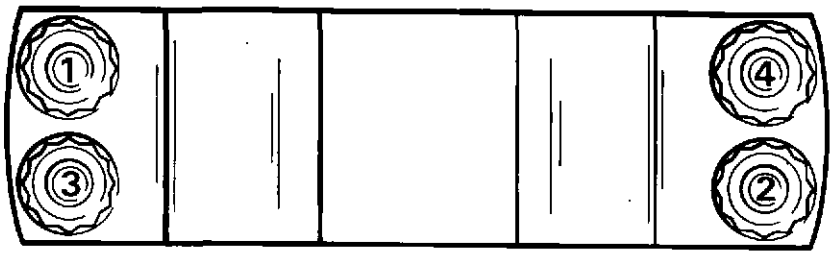


Fig. 10 Tightening sequence

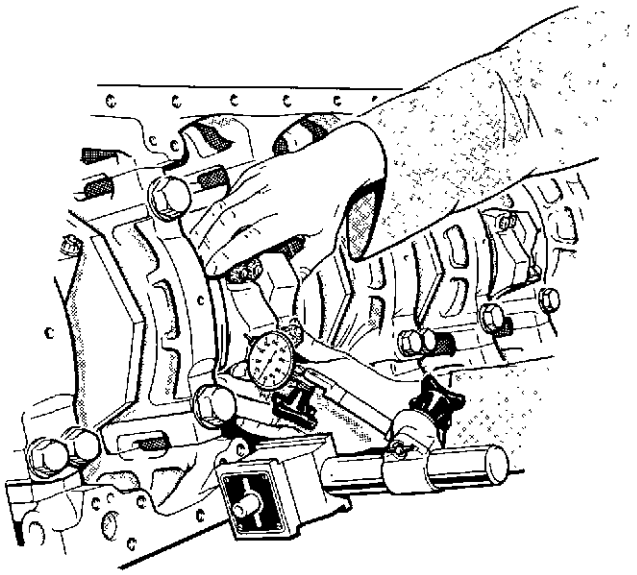


Fig. 11 Checking big end float

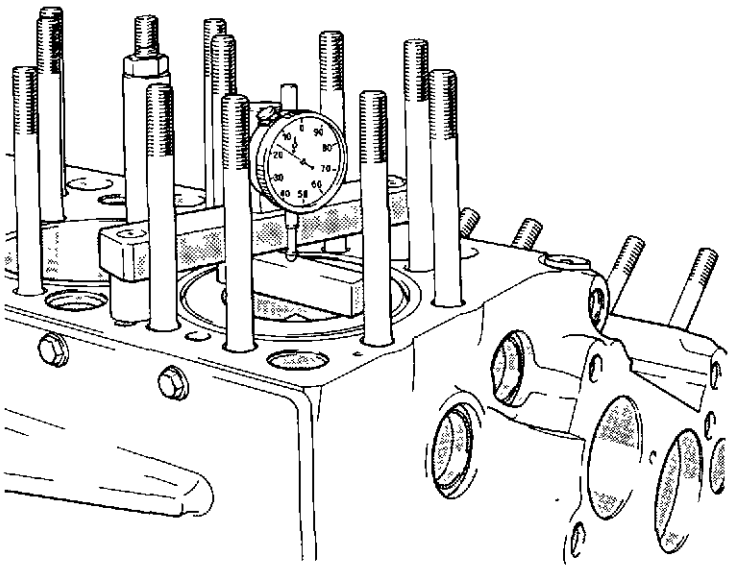


Fig. 12 Checking piston height

24 Tighten the big end bearing cap nuts, for each connecting rod, in a diagonal pattern as shown in figure 10, until a torque loading of 60 Nm (42 lbf.ft.) is achieved. As each unit is tightened, check the crankshaft for freedom of rotation.

25 Check the connecting rod end float with a D.T.I., as shown in figure 11. The clearance for each pair of connecting rod big ends, between their associated crank webs, must be 0,10 mm to 0,30 mm (0.004 to 0.012 inch).

Turn the crankcase until the 'A' bank cylinder head joint face is uppermost and check the piston crown/flame face clearance as follows :

26 Place the setting bar of the Height Gauge, GA 5031, on a clean, machined surface and locate the tool base assembly over it so that the D.T.I. button rests on the centre of the bar. Turn the D.T.I. bezel to zero the needle, then nip up the bezel locking screw.

27 Turn the crankshaft until one of the pistons is almost at the top of its cylinder and transfer the setting bar to the piston top landing. Rest the tool base on a convenient flat surface of the cylinder block flame face, as shown in figure 12.

28 Continue turning the crankshaft slowly, to allow the piston to pass its T.D.C. position. As the piston passes T.D.C., note the deflection on the gauge needle; the minimum deflection from zero indicates the piston/flame face clearance. The permissible clearance is from 0,31 to 0,38 mm (0.012 to 0.015 inch).

29 Check the clearance of each piston in the 'A' bank, then turn the crankcase until the 'B' bank cylinder head joint face is uppermost; check the clearance of each piston in 'B' bank, as previously described.

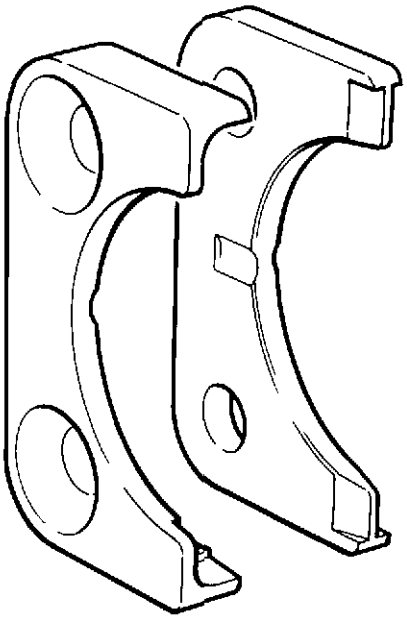
Note: If insufficient clearance is shown on the D.T.I., the piston crown must be machined using the equipment listed under 'Special Tools' at the end of this Section.

Wheelcase

Turn the crankcase to its normal operating position and proceed :

30 Coat the crankcase joint face of the wheelcase assembly with 'Wellseal' jointing compound and position a new gasket on the wheelcase so that the bolt holes are aligned. Screw two Guide Studs, VT 10716, into the bolt holes on opposite sides of the crankcase joint face.

31 Using the Lifting Hook, VP 8754, in the oil return gallery aperture in the wheelcase, carefully slide the wheelcase assembly over the guide studs, fit the ten setbolts and spring washers into the bolt holes, and one nut and spring washer on to the stud. Lightly nip up the nut and setbolts, remove the guide studs and fit the remaining two setbolts and spring washers.



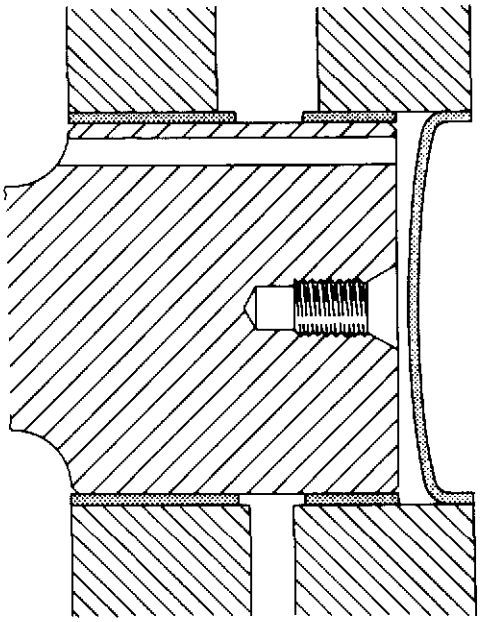


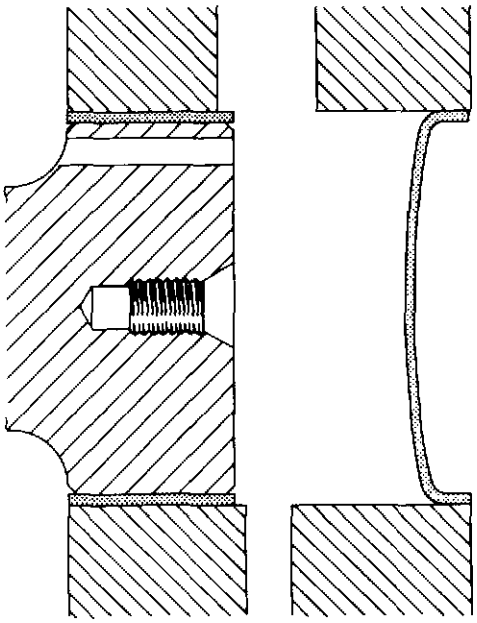
Fig. 13 Thrust plate assembly Fig. 14 Cam bore plug ('B' bank)

32 Press the two idler axles and the large dowel into their machined recesses in the crankcase end wall; ensure that each turns freely and does not bind in its wheelcase bore. Tighten the 12 setbolts and nut to a torque loading of 95 Nm (70 lbf.ft.). Check that the idler axles and dowel are still free to rotate. If there are any signs of binding, the wheelcase must be repositioned. Finally, remove the idler axles, fit the two dowel retaining setbolts, with spring washers, and tighten securely.

Camshafts

33 Fit the Lead-in Mandrel, VT 10707, to the rear end of the 'A' bank camshaft, smear the camshaft journals and bearings liberally with clean engine oil, and carefully insert the shaft into the crankcase bearings. Before the shaft is fully home, position the thrust plate assembly (fig. 13), around the camshaft collar. Insert, and firmly nip up, the two countersunk head setscrews.

34 Mount a magnetic based D.T.I. in the wheelcase, adjacent to the camshaft, with the button resting on the outer face of the camshaft flange and check the total axial movement of the shaft by levering backwards and forwards. Permissible limits are 0,10 mm to 0,55 mm (0.004 to 0.022 inch).



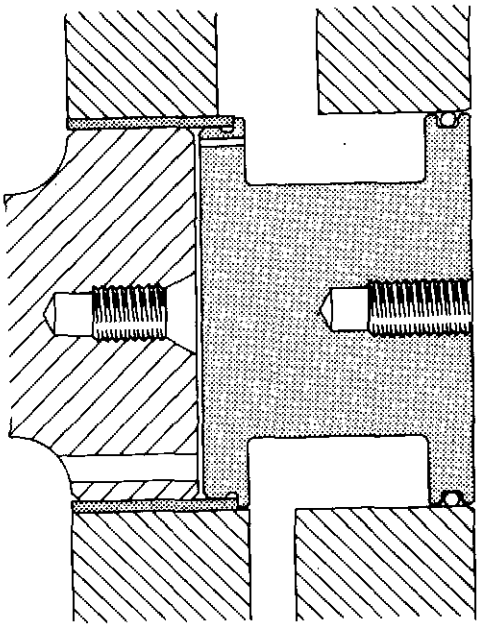


Fig. 15 Cam bore plug ('A' bank) Fig. 16 Bobbin type plug ('A' bank)

35 Remove the D.T.I. and release the two thrust plate screws. Withdraw the shaft approximately 12 mm (0.5 inch) whilst removing the thrust plate assembly. Coat the two running faces of the assembly with 'Molyslip', and the countersunk face of each screw, with 'Copaslip'. Refit the assembly around the camshaft collar, insert the two screws and tighten to a torque loading of 70 Nm (50 lbf.ft.).

36 Transfer the lead-in mandrel to the 'B' bank camshaft and repeat the above procedure.

37 Coat the outer wall of the camshaft bore cup plug with 'Loctite 542' and, using the insertion tool from the Cup Plug Kit, GA 5101-5, drive the plug into the 'B' bank camshaft bore until the lip of the plug is flush with the crankcase front end face, (fig. 14). Re-check the 'B' bank camshaft end float to ensure that the plug does not foul the end of the shaft.

38 Check the Part Number of the 'A' bank camshaft. For engines fitted with camshaft CV 7863 or CV 11571, the end of the camshaft bore must be sealed with a cup plug as for 'B' bank, (fig. 15). If camshaft CV 11569 is fitted, the camshaft bore must be sealed using the steel bobbin assembly, as shown in in figure 16.

Tappets

39 Turn the crankcase so that the 'A' bank cylinder head joint face is uppermost, liberally oil the tappets, and the tappet bores in the cylinder block, then slide each tappet into its respective bore.

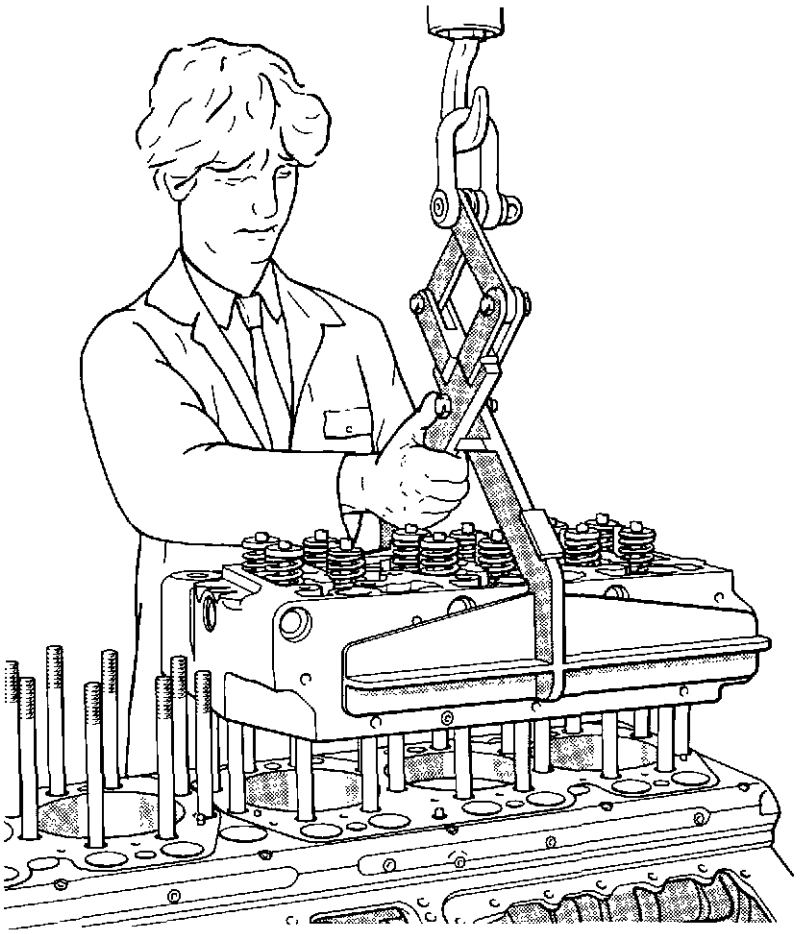


Fig. 17 Fitting cylinder head

Cylinder head assemblies

40 Remove the four liner retaining sleeves from the 'A' bank cylinder head studs and position two new cylinder head gaskets over the studs. Fit the two restrictor bobbins, with new 'O' ring seals, into their locations.

41 Using the Lifting Bracket, VP 522, carefully lower the two prepared cylinder head assemblies over the securing studs, (fig. 17).

42 Locate the 'A' bank engine lifting/ exhaust bellows mounting bracket over the appropriate studs. Oil the threads of each nut, fit the 40 nuts and plain washers on to the cylinder head studs and run them up, finger tight. Screw the six shouldered setbolts into the tapped holes, through the openings in the cylinder head induction ports.

43 Tighten the nuts and setbolts, in steps of 50 Nm. (37 lbf.ft.), following the sequence shown in figure 18, until a torque loading of 200 Nm (148 lbf.ft.) is achieved.

44 Using a pencil or scriber, mark the position of each nut in relation to the cylinder head. Tighten each nut a further 1/4 of a turn (90 deg.), in the correct sequence. Do NOT tighten the setbolts beyond the 200 Nm torque loading.

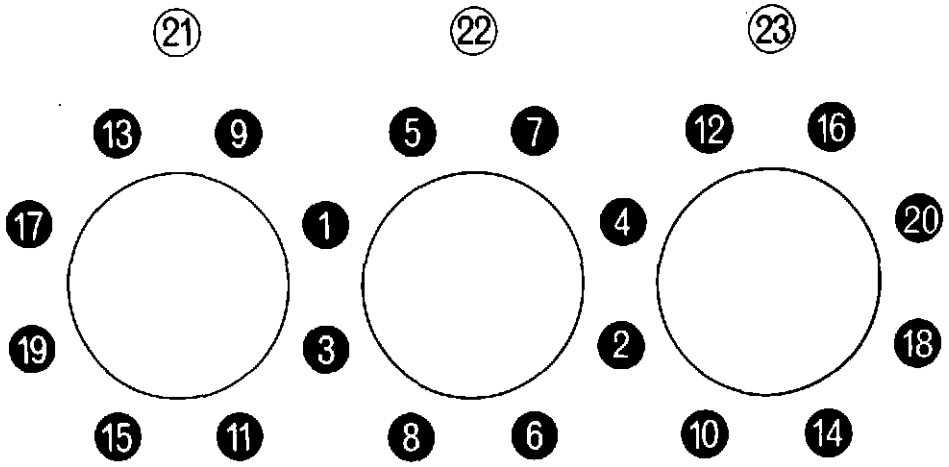


Fig. 18 Tightening sequence

45 Fit new 'O' ring seals to the six alloy blanking plugs and press each plug into its location in the induction ports.

46 Turn the crankcase until the 'B' bank cylinder head joint face is uppermost and fit the tappets, gaskets, bobbins, cylinder heads, lifting brackets and alloy blanking plugs, as described for 'A' bank.

Main gear train

Turn the crankcase to its normal operating position and proceed :

47 Rotate each camshaft until the gear locating dowel holes face in towards the centre line of the engine.

48 Fit the gear ring on the 'A' bank camshaft flange, tap in the locating dowel and secure with three slave setbolts.

49 Fit the 'B' bank gear ring to its shaft so that the timing mark on the gear tooth meshes with the two timing marks on the teeth of the 'A' bank gear. Tap in the locating dowel and secure the 'B' bank gear with three slave setbolts.

Check the backlash of the camshaft gears, in relation to each other, as follows :

50 Mount a magnetic based D.T.I. in the wheelcase so that the button rests on the side of a tooth of the 'A' bank gear (fig. 19). Hold the 'B' bank gear stationary and rotate the 'A' bank gear to the limit of its travel in both directions. Check the reading on the gauge; permissible backlash for the camshaft gears is 0,100 to 0,250 mm (0.004 to 0.010 inch).

Note: It is important that the 'B' bank gear is not allowed to move during this operation, as a false reading will be obtained.

51 Remove the three slave setbolts from the 'A' bank gear only, coat the threads of the six securing setbolts with 'Loctite 241' and fit the setbolts, complete with plain washers. Tighten each setbolt to a torque loading of 40 Nm (30 lbf.ft.). Do not remove the slave setbolts from the 'B' bank gear.

Turn the crankshaft until the 'A6' piston is at T.D.C. and fit the compounded idler gear assembly as follows :

52 Fit the axle/distance piece assembly into the wheelcase recess. Slide the inner thrust washer, gear assembly and outer thrust washer over the protruding axle. Holding the components in position, fit the thrust plate and locking plate against the end of the axle and secure the assembly with two setbolts. Ensure that the two timing marks on the large gear teeth mesh correctly with the single timing mark on the crankshaft, (fig. 20). Nip up the two securing setbolts.

53 Mount a magnetic based D.T.I. in a convenient position, with the button resting on one of the teeth of the large compounded gear. Check the backlash of the gear in relation to the crankshaft gearing. Permissible backlash is 0,100 to 0,240 mm (0.004 to 0.009 inch).

54 Re-position the D.T.I. so that the button rests on the front face of the smaller gear and check the total axial movement of the compounded gear assembly. Permissible end float is 0,100 to 0,425 mm (0.004 to 0.017 inch).

55 Tighten the two securing setbolts to a torque loading of 71 Nm (52 lbf.ft.) and tab up each end of the lockplate.

Fit the main idler gear assembly as follows :

56 Place the lockplate over the two securing setbolts followed by the thrust plate, axle, outer thrust washer, gear wheel and inner thrust washer. Enter the axle into its location in the crankcase end wall, ensuring that the gear timing mark meshes correctly with the two timing marks on the small compounded gear, (see figure 20 for the timing positions). Nip up the two setbolts.

57 Set up the D.T.I. with the button resting on one of the main idler gear teeth and, holding the compounded gear stationary, check the backlash of the main idler gear. Permissible limits are 0,100 to 0,270 mm (0.004 to 0.017 inch).

58 Re-position the D.T.I. and check the total axial movement of the main idler gear assembly. Permissible end float is 0,100 to 0,425 mm (0.004 to 0.017 inch). Tighten the two securing setbolts to a torque loading of 71 Nm (52 lbf.ft.).

Remove the three slave setbolts from the 'B' bank camshaft gear and proceed :

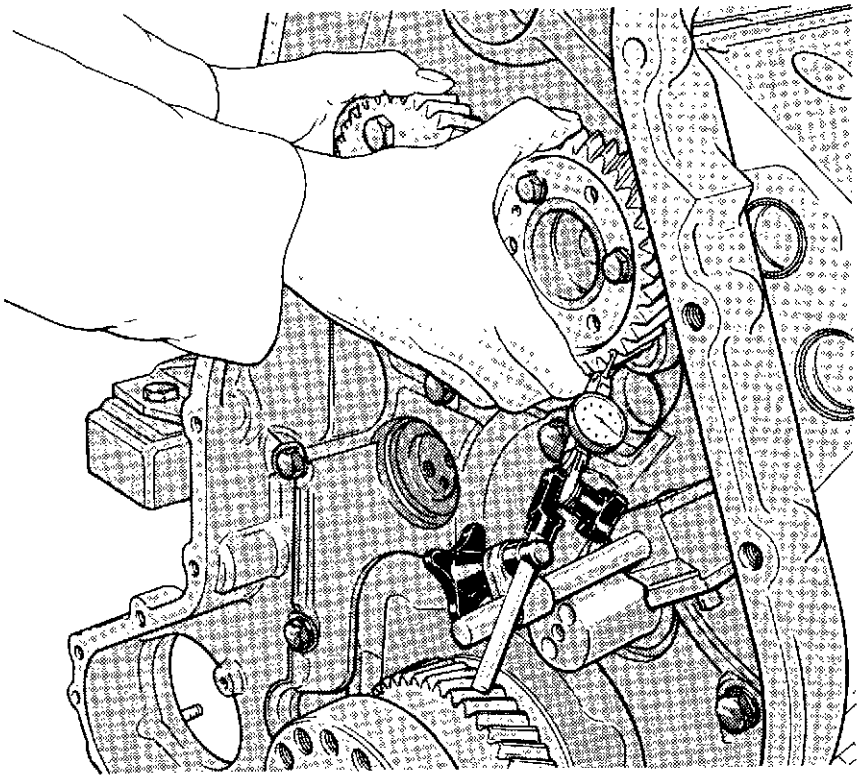


Fig. 19 Checking cam gear backlash

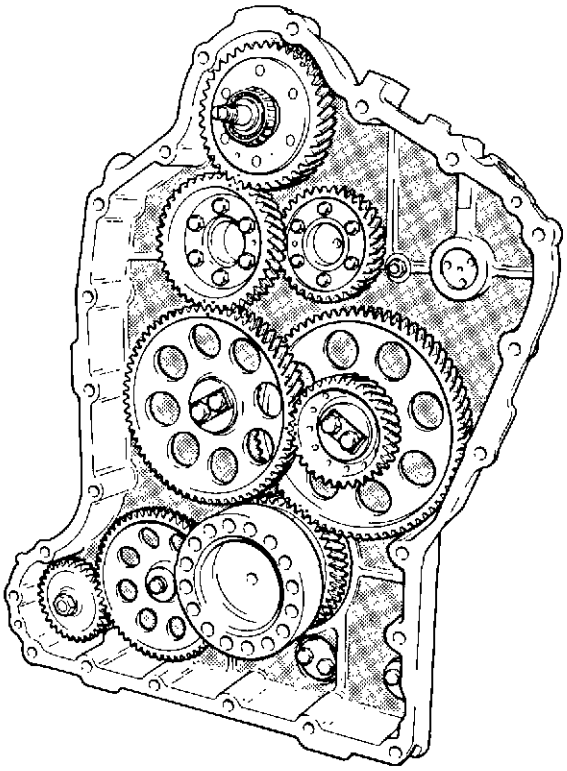


Fig. 20 Gear train timing marks

59 Ensure that the two locating dowels in the camshaft gears are facing in towards the centre line of the engine. Fit the fuel pump drive gear over the protruding dowel of the 'B' bank camshaft gear. One pair of timing marks on the fuel pump gear should be meshing correctly with the timing mark on the main idler gear. A second pair of timing marks should be correctly positioned to accept the auxiliary drive gear timing mark, (fig. 20). Secure the gear with three slave setbolts.

Note: Two extra pair of timing marks are provided on the fuel pump gear to enable two compressors to be correctly phased, in automotive applications only (fig. 21). Care must be taken to ensure that the correct timing marks are aligned during gear train assembly.

60 Set up a D.T.I. with the button resting on one of the teeth of the fuel pump drive gear. Hold the main idler and check the backlash reading of the fuel pump drive gear. Permissible limits are 0,100 to 0,270 mm (0.004 to 0.017 inch).

61 Remove the three slave setbolts, coat the threads of the six securing setbolts, for the fuel pump gear, with 'Loctite 241' and screw in each setbolt, complete with plain washers. Tighten each setbolt to a torque loading of 70 Nm (52 lbf.ft.).

62 Fit the coolant pump idler gear on to its axle, followed by the thrust washer. Position the axle in its location in the crankcase end wall and fit the securing setbolt, complete with spring washer. Nip up the setbolt.

63 Set up the D.T.I. with the button resting on one of the coolant pump idler gear teeth, and check the backlash in relation to the crankshaft gearing. Permissible backlash is 0,100 to 0,240 mm (0.004 to 0.009 inch).

64 Re-position the D.T.I. and check the total axial movement of the coolant pump idler gear. Permissible end float is 0,10 to 0,40 mm (0.004 to 0.016 inch). Tighten the securing setbolt to a torque loading of 71 Nm (52 lbf.ft.).

Coolant pump

65 Check the pump flange and wheelcase mounting for cleanliness, position a new gasket over the studs and secure the coolant pump assembly to the wheelcase with four nuts and spring washers.

Note: On industrial engines, the pump discharge connection faces downwards.

66 Set up the D.T.I. with the button resting on one of the coolant pump drive gear teeth and, holding the idler gear stationary, check the backlash of the coolant pump drive gear. Permissible backlash is 0,100 to 0,280 mm (0.004 to 0.011 inch).

67 Assemble the oil pump idler gear on its axle followed by the thrust washer and locate the axle in its recess in the front main bearing cap. Insert the securing setbolt, complete with spring washer. Nip up the setbolt.

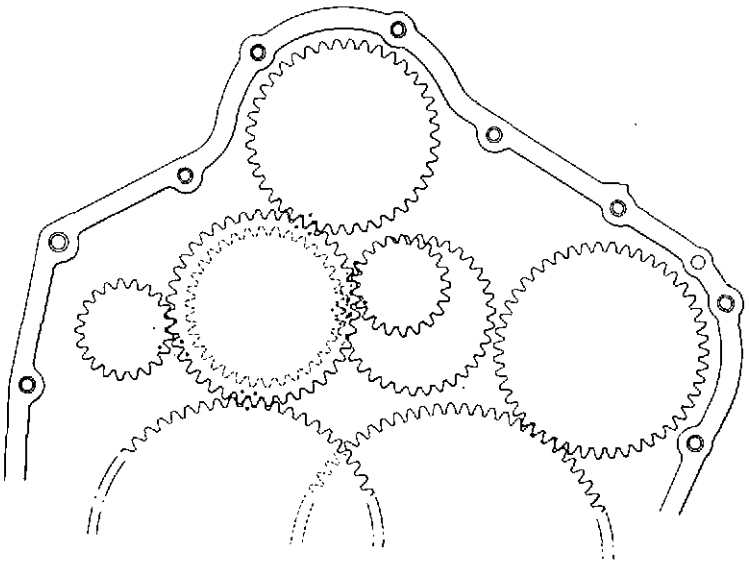


Fig. 21 Compressor gear timing marks (Automotive)

68 Set up the D.T.I. with the button resting on one of the teeth of the oil pump idler gear, and check the backlash in relation to the crankshaft gearing. Permissible backlash is 0,10 to 0,20 mm (0.004 to 0.008 inch).

69 Re-position the D.T.I. and check the total axial movement of the idler gear. Permissible backlash is 0,10.to.0,40 mm (0.004 to 0.016 inch). Tighten the securing setbolt to a torque loading of 71 Nm (52 lbf.ft.).

Rocker gear

Check that the four rocker box locating dowels are fitted into the cylinder heads, and position the new rocker box gaskets as follows :

70 If self adhesive gaskets are to be used, peel off the backing paper and carefully position the gaskets, adhesive side down, on each cylinder head. If dry gaskets are to be used, they may be accurately positioned using small dabs of 'Wellseal' in two or three places around the cylinder head joint face. Do NOT coat the gaskets, with jointing compound.

71 Insert the 12 push rods through the cylinder head apertures, so that the spherical foot of each rod seats in its tappet.

72 Liberally oil the push rods, valve bridge guides and bridge pieces, and fit the bridge pieces on to their guides.

73 Ensure that the rocker arm and bridge piece adjusting screws are fully slackened off, then fit the two rocker box assemblies on to their respective cylinder heads. Fit the eight securing setbolts, with plain and spring washers, followed by the 16 socket capscrews.

74 Check that each push rod cup and its associated rocker arm adjusting screw are correctly aligned, then tighten each setbolt and socket capscrew, evenly and progressively, to the following torque loadings :

Setbolts.....41 Nm (30 lbf.ft.).
Capscrews.....35 Nm (26 lbf.ft.).

75 Turn the crankcase so that the 'B' bank cylinder heads are uppermost and fit the push rods, bridge pieces, gaskets and rocker boxes as for 'A' bank.

Setting tappet clearances

Turn the crankcase to its normal operating position and set the valve bridge and tappet clearances as follows :

76 Turn the crankshaft in its normal direction of rotation, i.e. anti-clockwise, until the 'A1' piston is at T.D.C. on its compression stroke. The valves over the 'A6' cylinder will then be 'rocking', i.e. exhaust valves just closing, inlet valves just opening.

Note: When the two camshaft gear dowels are in the position shown in figure 20, and the crankshaft gear timing mark is correctly meshed with the timing marks on the compounded idler gear, the 'A1' piston is at T.D.C. on its compression stroke.

77 Commencing with the 'A1' inlet valves, press down firmly on the centre of the valve bridge piece, and screw down the bridge piece adjusting screw until it is felt to just touch the valve stem tip, (fig. 22). Turn the screw a further $^{1}/_{6}$ turn (60 deg.) and tighten its locknut to a torque loading of 40 Nm (30 lbf.ft.). Next, set the exhaust valve bridge piece in the same manner.

Caution : When tightening the locknuts, it is important that no side load is imposed on the valve stem tips.

78 Using the appropriate sized feeler gauges between the valve bridge button and the rocker arm pad, (fig. 23), set the tappet clearance for the 'A1' inlet valves to 0,20 mm (0.008 inch). Tighten the adjusting screw locknut to a torque loading of 40 Nm (30 lbf.ft.).

79 Set the 'A1' exhaust valve tappet clearance to 0,50 mm (0.020 inch), and tighten the adjusting screw locknut to a torque loading of 40 Nm (30 lbf.ft.).

After tightening the locknuts, re-check both tappet clearances before proceeding to the next unit.

To simplify tappet clearance setting, the crankshaft should be turned through 60 deg. in its normal direction of rotation, for each set of valves. This will allow the following sequence to be followed.

Valves rocking on	Set bridge piece and tappet clearance on
A6	A1
B1	B6
A3	A4
B4	B3
A5	A2
B2	B5
A1	A6
B6	B1
A4	A3
B3	B4
A2	A5
B5	B2

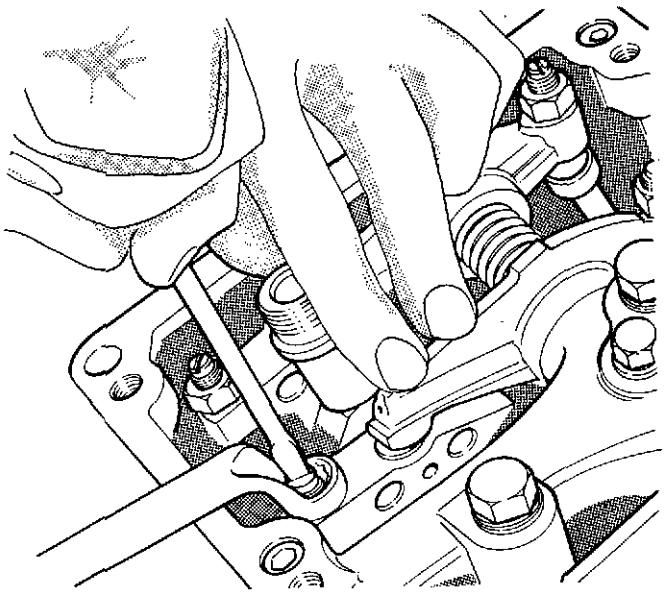


Fig. 22 Setting bridge pieces

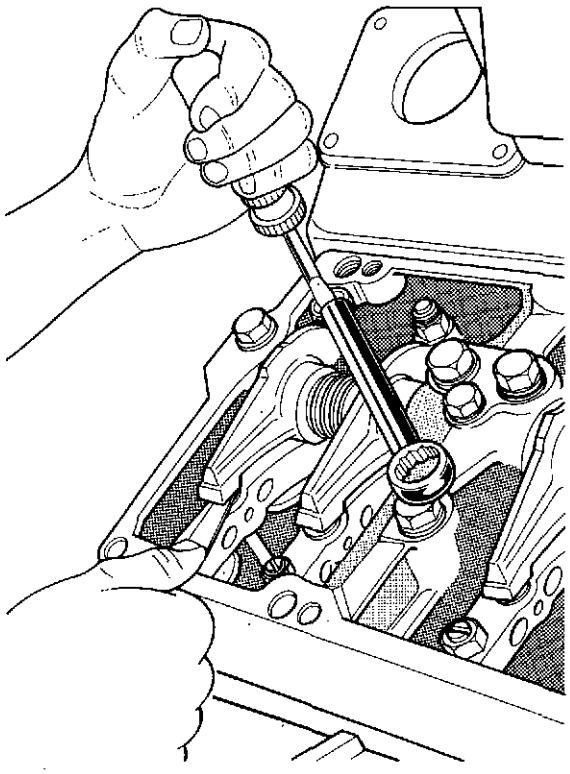


Fig. 23 Tappet clearance setting

Oil test

After setting bridge piece and tappet clearances, prepare the engine for an oil pressure test as follows :

80 Check that all auxiliary oil gallery plugs are fitted and screw two short setbolts, complete with plain washers, into the 'A' bank front and 'B' bank rear cover bolt holes, in the crankcase 'V'.

81 Ensure that the hexagonal headed brass plug is fitted in the oil gallery tapping, at the lower, rear corner of the crankcase 'A' bank side wall.

82 Fit a gasket and blanking plate over the open front end of the main oil gallery.

83 If the 'A' bank camshaft front end bore is sealed with a steel bobbin assembly,the bobbin must be secured in position during the oil test. Using a slave setbolt in an adjacent bolt hole, secure the bobbin assembly with a large plain washer or a locally made blanking plate.

84 Cover the induction and exhaust ports, in each cylinder head, with masking tape.

85 Screw the adaptor of the Oil Circuit Test Rig, VP 4000, into the oil feed connection in the crankcase side wall, above the coolant pump.

86 Turn the engine so that the main bearings and the connecting rods can be observed.

87 Ensure that the test rig supply tank contains an adequate quantity of clean engine oil, then switch on the electric pump.

88 Check for a steady jet of oil from each of the piston cooling jet assemblies.

89 Check for a supply of oil from both sides of each main bearing and each connecting rod big end bearing. At the same time, check that there is no oil leakage past the plugs in the crankshaft sludge traps.

90 Turn the crankshaft slowly and check for a supply of oil from each of the connecting rod small end bearings.

91 Check for a flow of oil from around the oil pump idler, coolant pump idler, main idler and compounded idler gear axles.

92 Turn the crankcase to its normal operating position and check for a flow of oil from both end drillings of each rocker arm, and from each rocker arm bush.

93 Check for a flow of oil from each camshaft bearing.

94 After checking the supply of oil to each component, inspect all oilway plugs for leakage and check the areas around each cylinder head oil transfer bobbin, for signs of oil seepage past the 'O' ring seals.

95 Switch off the test rig pump and rectify any leakages or oil flow restrictions.

96 Re-check the oil circuit, if necessary, before disconnecting the test rig.

97 Remove the two setbolts and washers from the cover plate bolt holes in the crankcase 'V'. Peel off the masking tape from the inlet and exhaust ports on each cylinder head. Remove the main oil gallery blanking plate and, if applicable, the bobbin securing setbolt and washer from the front end of the crankcase. Allow the oil to drain away from the engine, then carefully wipe dry all the joint faces.

Auxiliary drive and flywheel housing

Remove the crankshaft barring adaptor and assemble the auxiliary drive and flywheel housing as follows :

98 Fit the outer sleeve of the inner roller bearing in the wheelcase bore then position the auxiliary drive shaft assembly in the bearing sleeve, with the gear timing mark meshing correctly with the two timing marks on the fuel pump drive gear, (fig. 20).

99 Check that the two locating dowels are fitted in the joint face of the wheelcase. Brush a light coating of 'Wellseal' jointing compound over the joint face and position a new gasket over the dowels, ensuring that all the bolt holes are correctly aligned, and fit the two Guide Studs, GA 5058, into bolt holes on opposite sides of the wheelcase joint face.

100 Fit the outer sleeve of the auxiliary drive shaft outer bearing, into its recess in the flywheel housing. Using the Lifting Plate, CV 8012, carefully guide the flywheel housing up to the wheelcase gasket. Fit the securing setbolts and spring washers, removing the guide studs as necessary, and nip up each setbolt firmly.

Note: Three of the setbolts are also used to secure the auxiliary drive guard and the 'B' bank air cleaner rear support bracket. A small distance piece is necessary on each of the support bracket setbolts.

101 Fit the auxiliary drive shaft oil seal housing, complete with a full laminated shim pack, over the end of the shaft and secure it to the wheelcase with four setbolts. Do not press in the oil seal, or drive shaft Woodruff key, at this stage.

102 Secure the Checking Plate, VT 11352, to the drive shaft, using the drive flange nut. Position a magnetic based D.T.I. in the crankcase 'V', with the button resting on one of the checking plate datum faces. Rotate the checking plate backwards and forwards and note the readings on the gauge. Permissible backlash is 0,10 to 0,33 mm (0.004 to 0.013 inch). Remove the checking plate.

103 Re-position the D.T.I. and check the total axial movement of the auxiliary drive assembly. Permissible end float is 0,076 to 0,127 mm (0.003 to 0.005 inch). To adjust the end float, remove the oil seal housing and reduce the thickness of the laminated shim pack as necessary.

104 Secure the barring adaptor to the crankshaft rear end face and mount a magnetic based D.T.I. on the adaptor, with the gauge button resting on the inner machined wall of the flywheel housing.

105 Check the axial run-out of the housing by turning the crankshaft and noting the reading on the gauge. The total deflection on the indicator must not exceed 0,38 mm (0.015 inch). If the reading shows excessive run-out, the flywheel housing must be removed and the wheelcase carefully re-positioned to correct the flywheel housing alignment. Re-check the axial run-out, remove the D.T.I., and tighten the flywheel housing setbolts to a torque loading of 71 Nm (52 lbf.ft.). Remove the barring adaptor and the lifting plate.

106 Using the Insertion Tool, VT 10670, press a new oil seal into the auxiliary drive oil seal housing, with the lip of the seal facing the wheelcase. Fit the housing and selected shim pack over the shaft and screw in the four securing setbolts, with plain and spring washers. Tighten the setbolts securely.

Crankshaft rear end oil seal

Using the Insertion/Extraction Tool, GA 5059, (fig. 24), press in the rear end oil seal as follows :

107 Fit the flywheel locating dowel into the dowel hole in the crankshaft end face.

108 Align the seal guide section of the tool so that the dowel is positioned in the dowel clearance hole. Using a pencil or felt tipped marker, make alignment marks on the crankshaft flange for each of the three counterbored bolt holes in the guide.

109 Lift the guide clear and screw the three tapped plugs into the indicated bolt holes. Nip up each plug lightly and fit the guide to the crankshaft end face, with the dowel hole correctly located.

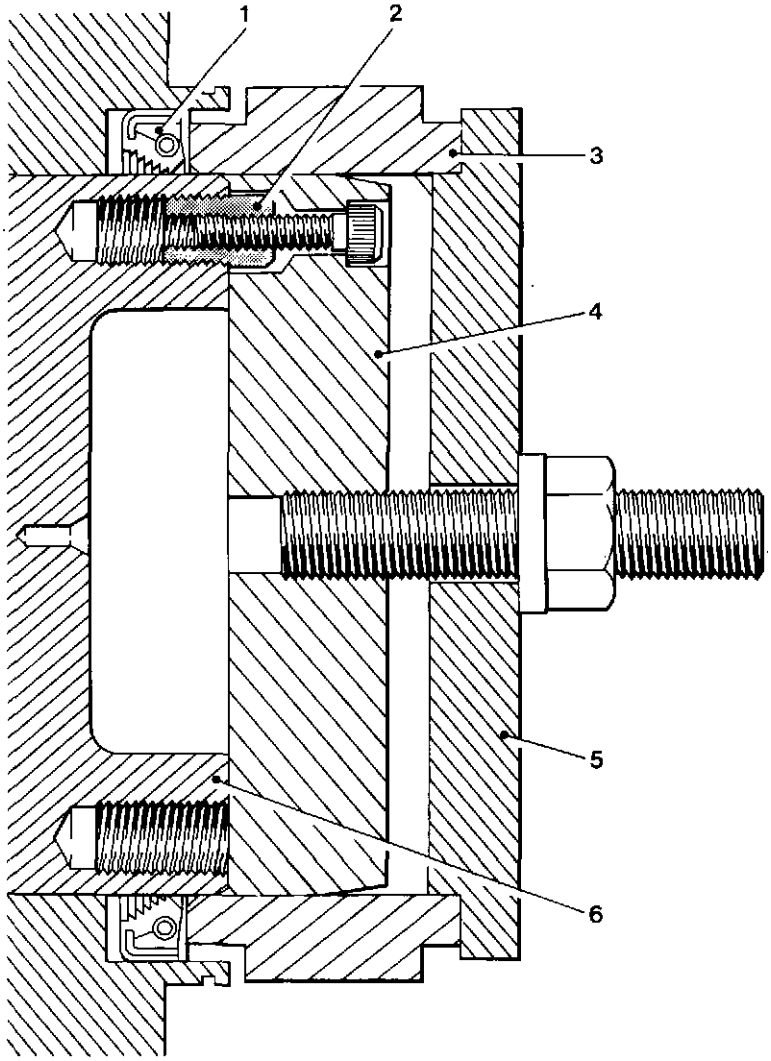
110 Insert the three socket capscrews through the guide into the tapped plugs; lightly nip up the capscrews.

Before fitting the oil seal, check the guide and crankshaft for dirt or irregularities on the machined areas, which could damage the lip of the seal.

111 Lightly coat the guide and crankshaft flange with clean engine oil and position the seal over the guide, with the lip of the seal facing in towards the crankcase.

112 Slide the collar over the guide so that the face of the collar presses against the outer face of the oil seal.

Note: This tool is designed for use on both CV8 and CV12 engines, and it is important that the collar is fitted correctly. For use on CV12 engines, the edge of the collar with the shorter machined shoulder must be against the oil seal. The body of the collar is stamped, during manufacture, to indicate which end must be used against the relevant oil seal.



1 Oil seal
2 Tapped plug
3 Collar
4 Oil seal guide
5 Top plate
6 Crankshaft

Fig. 24 Insertion/extraction tool, GA 5059

113 Fit the top plate over the centre stud, with its shoulder locating in the collar. Lightly oil the stud thread and thrust washer and run the nut and washer up to the top plate. Using the appropriate spanner, tighten the nut until the inner shoulder of the collar contacts the oil seal housing outer face. Remove the insertion tool completely.

114 Brush thin coatings of 'Wellseal' jointing compound on the three joint faces in the crankcase 'V' and position three new gaskets, with the bolt holes correctly aligned. Fit the front and rear cover plates in their respective locations and secure the two cover plates with setbolts, complete with Dowty washers. Tighten each setbolt to a torque loading of 22 Nm (16 lbf.ft.).

115 Position the fuel injection pump mounting plate in its location in the crankcase 'V',and secure it with six setbolts, complete with with spring washers. Tighten each setbolt to a torque loading of 40 Nm (30 lbf.ft.).

116 Check the auxiliary drive shaft taper for cleanliness and press the Woodruff key into its keyway. Fit the fuel pump drive flange on to the shaft, followed by the plain washer and retaining nut. Tighten the nut to the following torque loading, as appropriate :

18 mm nut.....200 Nm (148 lbf.ft.).
22 mm nut.....300 Nm (220 lbf.ft.).

Flywheel

117 Insert the two Guide Studs, GA 5060, into horizontally opposite holes in the crankshaft rear end face and, using the Lifting Bar, VP 517, position the flywheel assembly so that the dowel hole aligns with the dowel in the crankshaft end face. Insert 14 socket capscrews through the clamping ring, slide the ring over the guide studs and screw the capscrews into the flywheel securing bolt holes. Tighten the capscrews evenly and progressively to draw the flywheel up to the crankshaft end face; unscrew the guide studs and fit the two remaining capscrews. Tighten each capscrew to a torque loading of 315 Nm (232 lbf.ft.).

118 Screw the timing pointer fully home into its location in the flywheel housing and, using a new gasket, fit the timing pointer cover. Secure the cover with two setbolts and spring washers.

Induction manifolds

119 Press the 12 coolant transfer bobbins, complete with new 'O' ring seals, into their locations in the inner walls of the cylinder heads.

120 Place four new gaskets over the transfer bobbins and fit the induction manifold assemblies to their respective cylinder heads.

121 Secure each manifold assembly with 18 setbolts, complete with spring and plain washers. Tighten each setbolt to a torque loading of 40 Nm (30 lbf.ft.)

122 Temporarily fit the four rocker box covers and secure each with two slave setbolts.

Lubricating oil pump

Turn the crankcase until the sump joint face is uppermost and proceed :

123 Position the lubricating oil pump assembly in its location and align the dowel holes. Tap in the two dowels and fit the four securing setbolts, complete with new spring washers; nip up each setbolt firmly.

124 Set up a D.T.I. with the button resting on one of the oil pump drive gear teeth. Hold the idler gear and check the backlash reading on the D.T.I. permissible limits are 0,100 to 0,390 mm (0.004 to 0.015 inch). Tighten each setbolt to a torque loading of 55 Nm (40 lbf.ft.).

Sump adaptor

125 Lightly coat the crankcase sump joint face with 'Wellseal' jointing compound and position a new gasket on the joint face, ensuring that all the bolt holes are correctly aligned, and that the gasket butts up to the visible area of the wheelcase gasket.

Note: The replacement gasket for the crankcase/sump joint face is provided as a complete rectangle, i.e., with four sides. This is to prevent damage during transit and/or storage. Before the gasket can be fitted to the joint face, it must be carefully positioned on the relevant sump adaptor joint face, with the bolt holes correctly aligned, and the extra side must be trimmed off, so that the two side pieces of the gasket are flush with the outer edge of the end wall of the adaptor. Cutting of the gasket must be carried out with great care to ensure that oil leakage does not occur during engine operation

126 Run a line of 'Hylomar' PL 32 sealant along the two corners, where the two gaskets touch and, using Guide Studs, VT 10723, carefully lower the sump adaptor assembly into position.

127 Removing the guide studs as necessary, fit the 14 setbolts, with plain and spring washers into each side of the adaptor flange, and four setbolts, with plain and spring washers, into the front edge of the flange. Lightly nip up each setbolt.

128 Fit the five setbolts, with spring washers, through the bolt holes in the lower edge of the wheelcase flange. Nip up the setbolts firmly.

129 When all the adaptor securing setbolts have been nipped up, commencing with the four setbolts nearest to the corners, where the two gaskets abut, tighten the setbolts evenly and progressively to a torque loading of 55 Nm (40 lbf.ft.).

130 Fit new 'O' ring seals to the oil pump suction pipe, lubricate the pump suction connection with a little clean engine oil and insert the pipe into the aperture.

131 Fit new 'O' ring seals into the grooves in the oil pump pressure discharge bobbin. Liberally oil the 'O' rings, and insert the bobbin into the pump discharge port, through the aperture in the side of the sump adaptor. Ensure that the cross drillings in the bobbin are positioned inside the sump adaptor oil gallery.

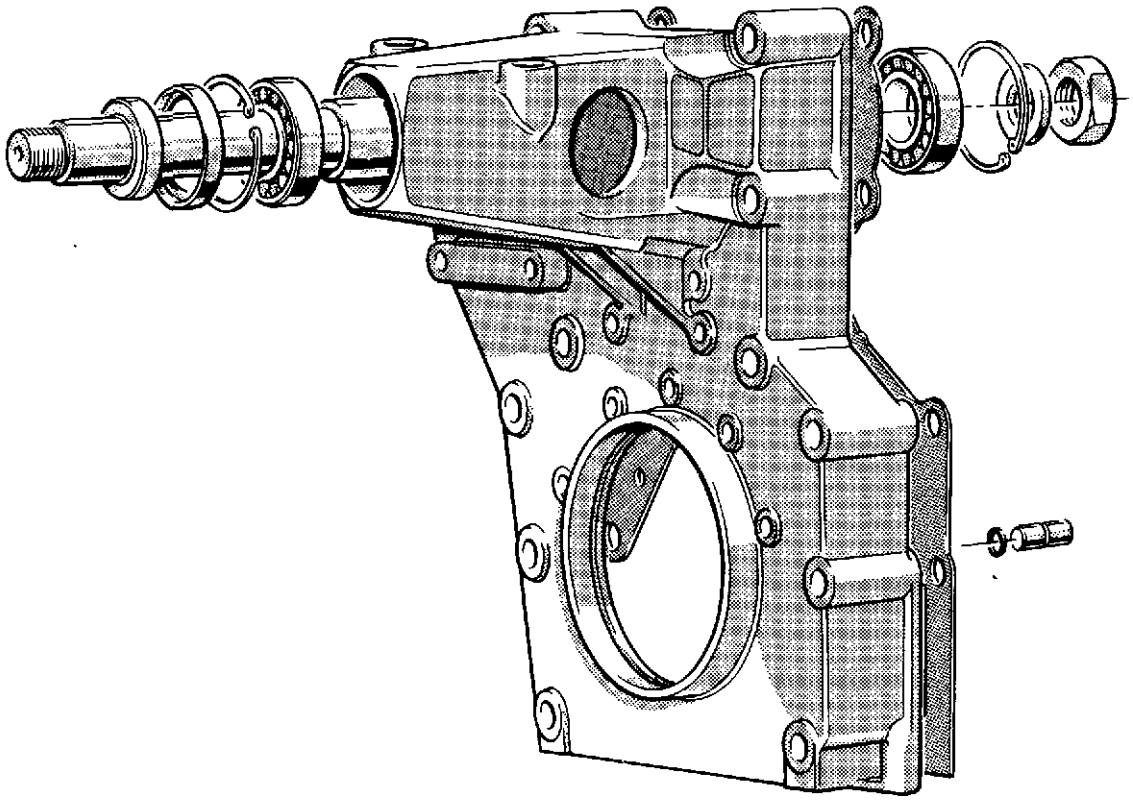


Fig. 25 Fan adaptor

132 Fit a new 'O' ring seal around the spigot of the oil gallery blanking flange, position the flange over the bobbin access opening and fit the two securing setbolts, with plain and spring washers. Tighten the setbolts securely.

Sump well

133 Lightly coat the joint face of the sump adaptor with 'Wellseal' jointing compound and fit a new gasket, with the bolt holes correctly aligned.

134 Oil the suction aperture in the sump well and, using the Guide Studs, VT 10723, carefully lower the sump well on to the adaptor, ensuring that the pump suction pipe is not dislodged during the process. Position the coolant pipe support bracket over the appropriate bolt holes, fit the securing setbolts, with plain and spring washers, and tighten to a torque loading of 55 Nm (40 lbf.ft.).

Fan adaptor

Turn the crankcase to its normal operating position and fit the fan adaptor assembly (fig. 25), as follows :

135 Lightly coat the joint face of the crankcase front end with 'Wellseal jointing compound, tap in the two spring ring locating dowels and position a new gasket on the crankcase front end, with all the bolt holes correctly aligned.

136 Position the alternator support bracket against the rear 'A' bank side of the fan adaptor and slide the two securing bolts, with a spring washer beneath each bolt head, through the bracket and adaptor. Temporarily secure the bracket to the adaptor with two nuts, finger tight.

137 Using locally made guide studs, fit the fan adaptor assembly over the dowels and the crankcase stud and secure with five large and nine small setbolts and the single nut, each with plain and spring washers.

138 Position the engine front mounting against the fan adaptor and fit six setbolts, complete with plain and spring washers, through the bolt holes, *into the crankcase front end. Tighten each setbolt securely.*

Crankshaft front end oil seal

Using the Insertion/Extraction Tool, GA 5161, press in the crankshaft front end oil seal as follows :

139 Select four bolt holes in the crankshaft front end face, at 90 deg. intervals, and screw in the four tapped plugs. Lightly nip up the plugs.

140 Locate the oil seal guide over the protruding plugs and loosely fit the four socket capscrews. Slide the tool collar over the guide and the crankshaft to align the guide. Lightly nip up the capscrews and remove the collar.

Check the guide and crankshaft for dirt or irregularities on the machined areas, which could damage the lip of the oil seal, and proceed :

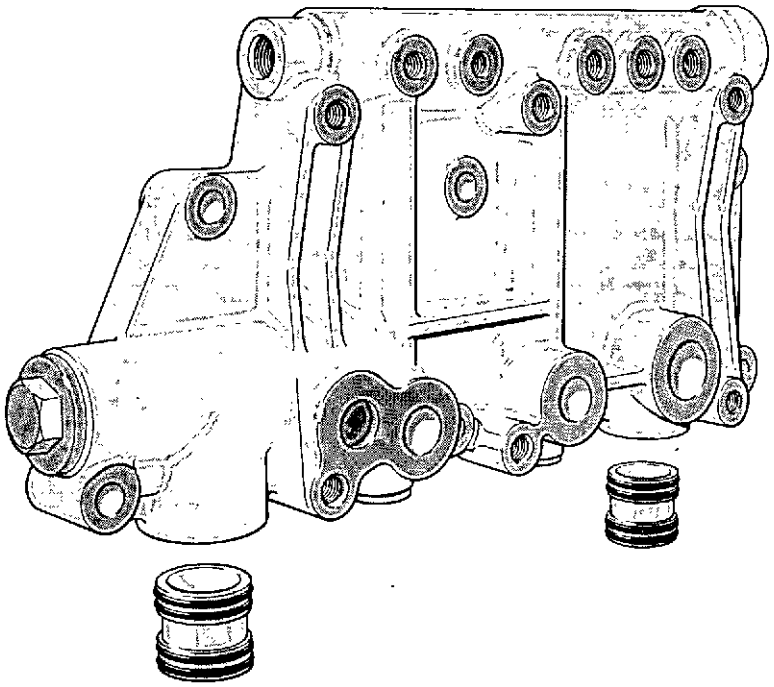


Fig. 26 Heat exchanger mounting adaptor

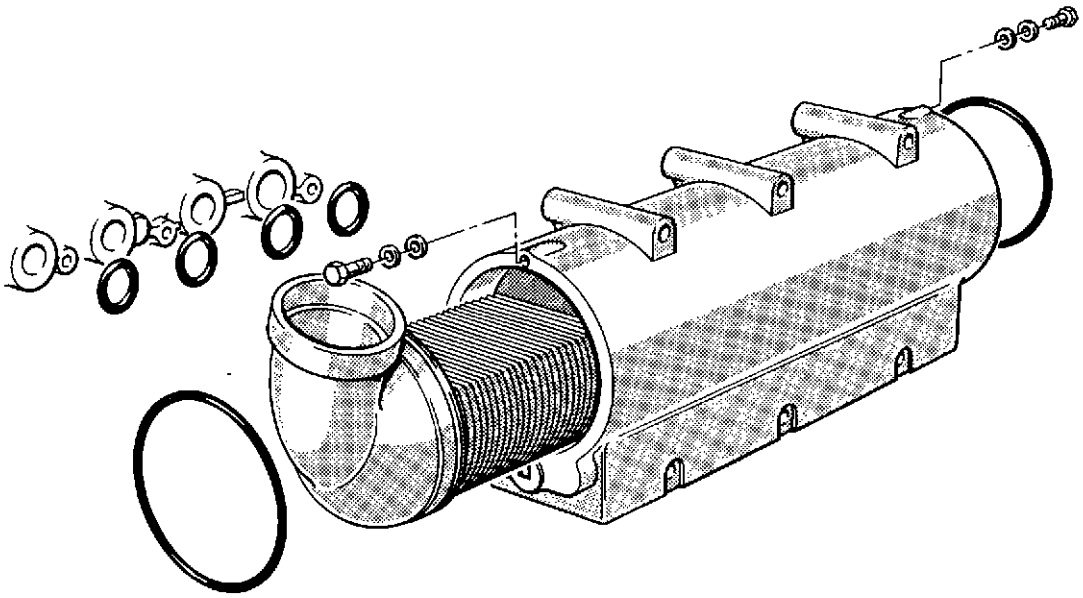


Fig. 27 Oil-to-coolant heat exchanger

141 Lightly oil the new seal and slide it over the guide, with the lip of the seal facing in towards the crankcase.

142 Slide the collar over the guide and fit the top plate over the central stud. Oil the thread of the stud and fit the thrust washer and nut. Using the appropriate spanner, tighten the nut until the oil seal is pressed fully home. Remove the insertion tool completely.

Heat exchanger adaptor

Turn the crankcase to its normal operating position and proceed :

143 Using clean engine oil, lubricate the two bobbin locations in the base of the heat exchanger adaptor assembly. Fit new 'O' ring seals to each of the bobbins and press the bobbins into the recesses in the assembly, (fig. 26). Lightly oil the bobbin recesses in the sump adaptor, position the adaptor assembly alongside the crankcase side wall and press it downwards to locate the bobbins in the sump adaptor. Fit the six assembly retaining setbolts, with plain and spring washers, and tighten securely.

144 Fit new 'O' ring seals to the oil delivery pipe and slide one end into the discharge connection in the rear end of the heat exchanger adaptor. Slide the elbow connection over the opposite end of the pipe and, using a new gasket, secure the elbow to the inlet gallery aperture in the crankcase side wall, with two setbolts and spring washers.

Oil-to-coolant heat exchanger

145 Check that four new 'O' ring seals are fitted into the locations in the oil-to-coolant heat exchanger mating face. Using locally made guide studs, position the heat exchanger assembly, (fig. 27), against the adaptor, insert the six securing setbolts, complete with plain and spring washers, and tighten securely.

Starter motor

146 Position the starter motor against the flywheel housing, fit the three setbolts and spring washers, and tighten securely.

147 Fit the detachable, rear end Lifting Bracket, CV 8012, to the flywheel housing and secure it with two setbolts and spring washers.

Using the Lifting Beam, GA 5072, and suitable overhead hoist, support the engine and remove the bolts securing the four crankcase mounting brackets to the build stand. Lift the engine out of the build stand and secure it in the Transportation Stand, OR 6408. If a transportation stand is not available, the engine will stand safely on its sump well, with wooden packing beneath the flywheel housing.

148 Remove the four build stand mounting brackets from the crankcase.

149 Check the two front coolant gallery joint faces for cleanliness and, using new gaskets lightly coated with 'Wellseal' jointing compound, fit the two covers, including the filter header heat shield on the 'A' bank cover, and secure with setbolts with plain and spring washers.

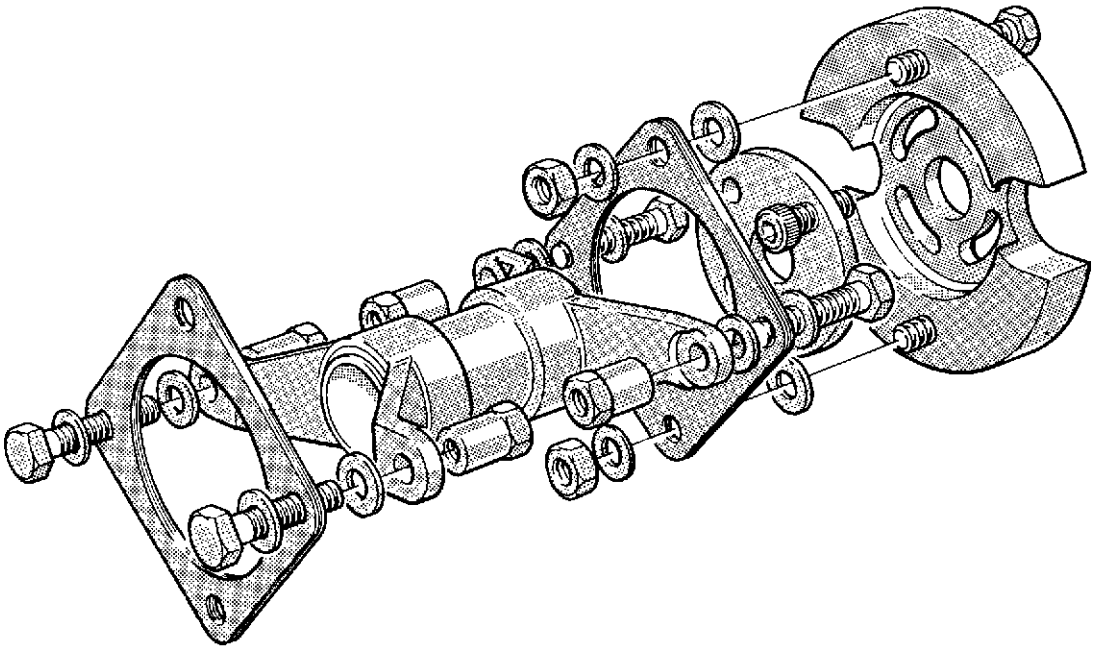


Fig. 28 Injection pump spring plate coupling

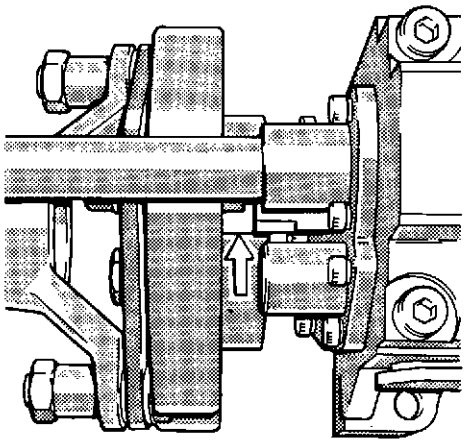


Fig. 29 Hub timing mark

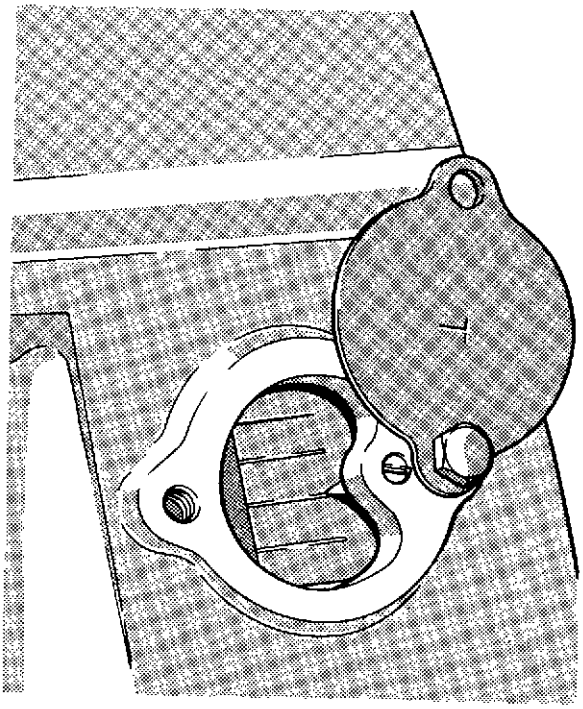


Fig. 30 Flywheel timing mark

Crankshaft pulley and damper

150 Fit two locally made guide studs into horizontally opposite bolt holes in the crankshaft front end face. Position the alternator pulley over the guide studs, followed by the damper. Insert ten setbolts, complete with spring washers, through the bolt holes and secure the assembly to the crankshaft. Remove the guide studs and fit the two remaining setbolts and spring washers. Tighten each setbolt to a torque loading of 71 Nm (52 lbf.ft.).

Fuel injection pump

Fit the Barring Adaptor, VT 12768, to the crankshaft damper and secure the fuel injection pump and governor assembly to the engine as follows :

151 Fit the two offset control rods to the governor speed and stop control levers.

152 Assemble the injection pump drive shaft, two packs of eight spring plates, adjustable coupling flange and the injection pump flywheel as shown in figure 28. Tighten the four long reach nuts and the two standard nuts to a torque loading of 120 Nm (88 lbf.ft.).

153 Align the spring plate drive coupling with the fuel injection pump hub and insert the four socket capscrews, through the adjustable coupling flange. Screw the capscrews into the hub finger tight. Turn the pump hub until the hub timing mark aligns with the timing pointer, (fig. 29).

154 If necessary, turn the crankshaft until the arm of the auxiliary drive flange, marked 'T', is pointing directly upwards. Insert the two drive bolts through the bolt holes, from the wheelcase side of the flange. Fit one of the special plain washers over the protruding thread of each bolt.

155 Using the Lifting Beam, VP 878, and a suitable hoist, carefully lower the fuel injection pump assembly into the crankcase 'V', and move it towards the auxiliary drive flange, so that the two drive bolts pass through the bolt holes in the spring plate pack. Fit a special plain washer over each bolt thread, followed by the long reach nuts. Holding the bolt heads with a ring spanner, tighten each nut to a torque loading of 120 Nm (88.5 lbf.ft.).

156 Insert the eight pump securing setbolts, complete with plain washers, through the bolt holes in the pump base. Tighten each setbolt to a torque loading of 41 Nm (30 lbf.ft.).

157 Slacken the four socket capscrews in the adjustable coupling flange, one or two turns, and turn the crankshaft until the flywheel timing mark is aligned with the pointer, (fig. 30).

158 Turn the fuel injection pump hub, by hand, in the normal direction of rotation, i.e., anti-clockwise viewed on drive end, so that the hub timing mark overshoots the timing plate. Turn the hub back slowly until the timing mark and the plate are correctly aligned. Tighten the four socket capscrews to a torque loading of 69 Nm (51 lbf.ft.).

159 Turn the crankshaft backwards, i.e., clockwise viewed on front end, a quarter of a turn (1/4 turn), then slowly forwards, until the flywheel timing marks are correctly aligned. Check the injection pump timing marks, these should be correctly aligned also. Adjust, using the same procedure, if necessary.

160 Ensure that the two 'O' ring seals have been fitted into the injection pump oil return fitting, at the drive end of the cambox. Slide the end of the oil return pipe into the fitting and locate the lower end in the boss on the crankcase 'V' cover plate. Tighten the union nut securely.

161 Fit the governor oil return pipe between the union on the servo valve cover, and the boss on the cover in the crankcase 'V'. Tighten each union nut securely.

Fuel feed pump and E.S.C.

162 Press the Woodruff key into its location in the auxiliary drive shaft. Slide the feed pump drive eccentric on to the drive shaft, followed by the plain washer and securing nut; tighten the nut to a torque loading of 54 Nm (40 lbf.ft.).

163 Lightly coat the wheelcase joint face of the fuel feed pump mounting with Wellseal jointing compound and, using a new gasket, position the mounting around the protruding drive shaft. Fit the four securing setbolts, with spring washers, and tighten securely.

164 Using a new gasket, position the fuel feed pump on its mounting and secure with three setbolts and spring washers.

On engines fitted with an E.S.C., proceed as follows :

165 Lightly oil the 'O' ring seal in the spigot of the E.S.C. and slide the E.S.C. into position with the window at the most convenient angle, and the drive shaft tongue engaging in the slot in the auxiliary drive shaft. Secure the E.S.C. to the feed pump mounting with four setbolts and clamps. Nip up the setbolts and wire lock the bolt heads.

166 If an E.S.C. is not fitted to the engine, seal off the opening in the feed pump mounting with the blanking flange and gasket. Fit the two setbolts, with spring washers, and tighten securely.

Fuel injectors

167 Remove the slave setbolts from the rocker covers, lift off each cover and check each injector sleeve for cleanliness.

168 Carefully fit each fuel injector into its sleeve, with the spill connection tapping facing outwards.

169 Fit the metal cup and rubber seal assembly against the head of each spill connection and fit a new copper sealing washer over the thread. Enter each spill connection through the openings in the rocker box outer walls and screw each connection into its fuel injector, finger tight.

170 Fit the injector clamps over each injector and place a spherical washer in its location in each clamp. Fit socket capscrews through the clamp and washer assemblies and tighten to a torque loading of 60 Nm (42 lbf.ft.).

171 When the clamp screws are all tight, tighten the spill connections to a torque loading of 27 Nm (20 lbf.ft.).

172 Check the rocker box joint faces for cleanliness and fit four new self-adhesive gaskets, with the bolt holes correctly aligned.

173 Fit a new 'O' ring seal around the groove near the top of each fuel injector body and carefully position the four rocker covers. Fit the 32 setbolts with plain and spring washers through the rocker cover bolt holes and tighten to a torque loading of 21 Nm (15lbf.ft.).

174 Fit plastic dust caps or plugs to all the fuel injector inlet and spill connections.

Thermostats

175 Using new gaskets, fit the by-pass connections to their respective thermostat housings and secure with setbolts with plain and spring washers. Tighten each setbolt to a torque loading of 40 Nm (30 lbf.ft.).

176 Using new gaskets, position each thermostat housing assembly on its induction manifold and fit the eight securing setbolts, with plain and spring washers; tighten the setbolts to a torque loading of 40 Nm (30 lbf.ft.).

177 Slide two hose connections with four hose clips over the thermostat by-pass connecting pipe. Position the pipe between the two by-pass connections, slide the two hoses over the joints and tighten the hose clips securely.

178 Assemble the air balance pipe, two 'O' ring seals and the balance connection and, using new gaskets, position the assembly between the two induction manifolds. Fit the four securing setbolts with spring and plain washers, check that the two brass plugs in the balance pipe are facing towards the rear of the engine and tighten the bolts securely.

179 Using a new gasket, fit the small blanking flange over the opening in the front inner wall of the 'A' bank induction manifold. Fit two setbolts with spring washers and tighten securely.

180 Using a new gasket, fit the blanking flange over the opening in the 'B' bank induction manifold, position the shut down solenoid mounting plate over the flange and secure both components with two setbolts and spring washers.

Exhaust manifolds

Ensure that the cylinder head and exhaust manifold joint faces are perfectly clean and undamaged, coat the threads of all the securing setbolts and lock plate nuts with 'Copaslip' anti-seize compound and fit the manifolds as follows :

181 Position the rear section of the 'B' bank exhaust manifold against the cylinder head and fit the 12 securing setbolts, with lock washers, into the bolt holes. Run the setbolts into the cylinder head, finger tight only.

182 Fit the captive sleeve into the recess in the manifold and position the front section of manifold up to the cylinder head. Fit the 12 setbolts and lock washers as for the rear section; check that the sleeve is free to rotate in the manifold recesses.

183 Tighten each setbolt to a torque loading of 47 Nm (35 lbf.ft.), fit the captive sleeve lock plate and secure it with a nut and spring washer. Finally, tab up the 24 lock washers.

184 Fit the 'A' bank exhaust manifold as for 'B' bank.

Turbochargers

185 Check the turbocharger and exhaust manifold joint faces for dirt or damage and coat the threads of the securing setbolts with 'Copaslip'. In turn, position each turbocharger on its manifold joint face and secure with four setbolts and lock washers. Tighten the setbolts securely and tab up the lock washers.

Crankcase breather

186 Slide a hose connection and two hose clips over the breather outlet on the 'B' bank side of the fan adaptor. Locate the breather pipe in the hose and fit the two pipe clips, with new rubber inserts around the pipe. Align and tighten the two hose clips and secure the two pipe clips to the three-way pipe and the engine front mounting, with bolts,nuts and spring washers.

Filter header bracket

187 Position the fuel filter header bracket against the bosses on the 'A' bank coolant gallery cover. Fit three setbolts, with plain and spring washers, and tighten to a torque loading of 54 Nm (40 lbf.ft.).

188 Fit the small bore oil feed pipe between the rear end of the 'B' bank auxiliary gallery, and the inlet connection on the side of the fuel feed pump mounting. Tighten the two union nuts securely.

189 If applicable, remove the three setbolts from the top of the flywheel housing in order to fit the auxiliary drive guard and air cleaner support bracket. Fit the guard and secure at one end with the setbolt and spring washer. Fit the support bracket, with distance pieces between guard and bracket, and secure with two setbolts of the correct length, and spring washers.

Fuel spill pipework

190 Position the fuel spill block on its location on the wheelcase. Fit the two setbolts with plain and spring washers and tighten securely.

191 Using a new copper washer each side of the banjo union, fit the bleed screw assembly through the tell-tale pipe banjo, and secure the assembly to the spill block.

192 Remove the dust caps from each injector spill connection and, using new copper sealing washers each side of the banjo type unions, fit the interconnecting pipework between the injectors and the spill block. Tighten each banjo bolt and union nut securely.

193 Fit the pipework between the two low pressure relief valves on the injection pump body, the spill connection on the rear end face of the pump body and the spill block. Tighten the 'T' piece and pipe union nuts securely. Fit the pipe clips, with new rubber inserts, where necessary.

Low pressure fuel feed pipes

194 Locate the fuel feed pipe between the fuel filter header bracket and the fuel inlet block on the injection pump body. Tighten the two pipe union nuts and secure the pipe to the 'A' bank induction manifold with a pipe clip and new rubber insert.

195 Position the fuel feed pipe between the feed pump discharge union and the inlet union on the filter header bracket. Tighten the two union nuts securely.

Coolant pipework

196 Secure the three-way pipe to its support bracket, on the 'B' bank front coolant gallery, with two setbolts and spring washers.

197 Slide a hose connection and two hose clips on to the coolant pump discharge elbow and another hose connection and two clips over the after end of the three-way pipe.

198 Fit the inter-connecting pipe between the three-way pipe and the coolant pump, slide the hoses over the joints and align and tighten the hose clips.

199 Slide hose connections and hose clips over the thermostat by-pass elbow and the top of the three-way pipe. Position each hose over the joint, and align and tighten the hose clips.

200 Slide a hose connection and two hose clips over each arm of the bifurcated pipe, position the flange of the pipe, with a new gasket, up to the coolant pump discharge flange. Fit four setbolts, with plain and spring washers, and tighten securely.

201 Slide the hose, on the upper arm, over the heat exchanger coolant inlet joint. Align and tighten the two hose clips.

202 Slide a hose connection and two hose clips over the heat exchanger coolant outlet and, using a new gasket, fit the coolant inlet pipe to the 'B' bank gallery front cover. Slide the hose over the joint and align and tighten the two hose clips.

203 Using a new gasket, fit the coolant inlet elbow to the 'A' bank rear coolant gallery cover. Screw in the four setbolts, with plain and spring washers, and tighten securely.

204 Slide a hose connection and two hose clips over the end of the coolant inlet elbow and position the connecting pipe between the elbow and the bifurcated pipe. Loosely support the pipe with two pipe clips, with rubber inserts, to the underside of the sump adaptor, using setbolts and spring washers. Slide each hose over its joint and align and tighten the hose clips; tighten the pipe clip setbolts securely.

Lubricating oil pipework

205 Using a new gasket, locate the flange of the 'B' bank turbocharger oil feed pipe over the turbocharger bearing housing. Fit the two setbolts, with spring washers, and locate the lower end of the pipe in the union in the heat exchanger adaptor. Tighten the two setbolts and union nut securely.

206 Slide a hose connection and two hose clips over the end of one of the two sections of the 'B' bank turbocharger oil drain pipe. Using new gaskets, fit the upper section to the base of the 'B' bank turbocharger bearing housing, and the lower section to the flange face on the sump adaptor. Secure each section of pipe with two setbolts and spring washers, slide the hose over the joint and align and tighten the two hose clips.

207 Using a new gasket on the 'A' bank turbocharger, fit the interconnecting pipework, via 'T' piece connections, between the turbocharger, injection pump and governor oil inlet connections, and the oil feed union on the rear end of the heat exchanger adaptor. Secure the turbocharger oil inlet flange pipe with two setbolts and spring washers, tighten all 'T' piece and union nuts securely and fit pipe clips, with new rubber inserts, where necessary.

208 Slide a hose connection and two hose clips over the end of one of the two sections of the 'A' bank turbocharger oil drain pipe. Using a new gasket, secure the upper section to the base of the turbocharger bearing housing, with two setbolts and spring washers. Fit the lower section into the union on the sump adaptor, and slide the hose connection over the joint. Tighten the union nut securely and align and tighten the two hose clips.

209 Using a new gasket, fit the oil filler pipe to the sump adaptor and secure it with two setbolts and spring washers.

210 Locate the dipstick tube in the union on the sump adaptor and tighten the union nut securely. Slide the dipstick into the tube.

Controls

211 Position the fuel control shaft assembly between the two induction manifolds. Secure each bearing housing flange to the relevant manifold wall with two setbolts with plain and spring washers.

212 Align the offset control rod, on the governor speed control lever, with the speed control lever on the cross shaft. Slide the clevis pin through the yoke and lever and fit a new split pin through the drilling; lock the pin.

213 Align the yoke end of the governor stop control rod with the bellcrank lever, slide in the clevis pin and fit a new split pin in its drilling; lock the pin.

214 Secure the shutdown stop solenoid to its bracket with four setbolts and spring washers.

215 Align the yoke end of the solenoid control rod with the bellcrank lever, slide in the clevis pin and fit a new split pin into its drilling; lock the pin.

Note: In the operating position, both arms of the bellcrank lever should point upwards.

216 Position the vernier speed control assembly against the 'A' bank induction manifold and secure its support bracket to the front end of the manifold, with two setbolts and spring washers.

217 Guide the threaded section of the ball and socket assembly through the hole in the speed control lever, fit a spring washer and nut and tighten securely.

High pressure fuel pipes

218 Remove the dust caps from the fuel injectors and the injection pump delivery valve unions.

219 Position each high pressure feed pipe between its delivery valve and injector. Ensure that each pipe lies naturally between its unions then run each securing nut on to its associated union. DO NOT bend or strain a pipe to make it fit between its unions. Tighten each nut securely.

Note: Each high pressure fuel pipe is identified by its cylinder number stamped on the pump-end union nut.

220 Fit new rubber dampers around each high pressure fuel pipe, locate the steel shrouds over the dampers and secure each shroud to its induction manifold, with setbolts and spring washers.

Fan belt tensioner pulley

221 Remove the two temporary securing nuts from the alternator bracket retaining bolts, position the tensioner pulley assembly against the fan adaptor, slide the two bolts through the outer bolt holes and fit a spring washer and nut to each bolt. Fit two setbolts, with a spring washer beneath each head, through the inner bolt holes of the pulley assembly. Tighten the two setbolts and two nuts securely.

Alternator

222 Position the alternator belt adjusting link against the front face of the engine front mounting and secure it loosely with its bolt, nut and spring washer.

223 Locate the alternator between the support bracket and the tensioner pulley assembly, and fit the securing setbolt, with a spring washer beneath the bolt head, through the bracket and alternator. Run the setbolt thread loosely into the tapped hole in the pulley assembly back plate. Fit a bolt through the lug in the alternator, with a plain washer beneath its head, and through the slot in the adjusting link. Loosely fit a plain washer, spring washer and nut to the bolt thread.

224 Fit the alternator drive belt over the crankshaft and alternator pulleys. Swivel the alternator on its support bracket to tension the drive belt. When the belt tension is correct, the deflection at mid-point of the belt run should be 12,5 mm (0.5 inch) under firm thumb pressure. Tighten the alternator support setbolt and the two adjusting link nuts securely.

Fan,fan belts and pulley

225 Ensure that the key is fitted into the fan adaptor shaft keyway. Guide the pulley on to the shaft and check that the shaft thread is clean and dry. Apply a coating of 'Loctite 542' to the thread and fit the plain washer and nut. Hold the pulley and firmly nip up the nut.

226 Check that the tensioner pulley is fully slackened, fit the four fan drive belts over the crankshaft, fan and tensioner pulleys and turn the adjusting screw until the correct belt tension is achieved. Under firm thumb pressure, the deflection at mid-point of the longest belt run of each individual belt should be 12,5 mm (0.5 inch).

227 When the belt tension is correct, continue tightening the fan pulley retaining nut until a torque loading of 280 Nm (205 lbf.ft.). is achieved.

Note; When replacing belts on multi-belt drives, it is important that the belts are refitted or renewed in matched sets. Do NOT mix old and new belts on any pulley.

228 Using a suitable hoist and strop, locate the fan against the fan pulley. Insert the six setbolts, with spring washers, through the fan pulley and screw them into the fan hub tapped holes. Tighten each setbolt securely.

Belt guards

229 Position the alternator belt guard over the alternator pulley and secure the guard to the tensioner pulley housing assembly and the engine front mounting, using four setbolts and spring washers.

230 Position the fan belt guard over the fan pulley and secure it to the top of the fan adaptor, with two setbolts and spring washers and to each side of the engine front mounting, using bolts, nuts and spring washers.

Exhaust bellows and elbows

231 Position the 'A' bank exhaust bellows unit against the turbocharger, with the flange bolt holes aligned with the support bracket. Fit the 'V' band clamp around the turbocharger outlet/bellows connection and tighten the clamp nut to a torque loading of 17 Nm (12.5 lbf.ft.).

232 Using a corrugated steel gasket, fit the exhaust elbow to the bellows unit and secure with six bolts, nuts and spring washers.

233 Fit the 'B' bank exhaust bellows unit and elbow as for 'A' bank.

Air cleaners

234 Dependent on application, secure the air cleaner support brackets to the induction manifolds, using setbolts and spring washers.

235 Mount the two air cleaner assemblies on the brackets and secure with four bolts, nuts and spring washers. Check that a restriction indicator is fitted to each air cleaner.

236 Fit a hose connection and two hose clips over each turbocharger compressor inlet, and hose connections and hose clips over the air cleaner, clean air outlets. Locate the air duct between each air cleaner and its associated turbocharger; align and tighten the eight hose clips.

Note: It may be necessary to slacken the turbocharger end hose clips, in order to align the compressor, when fitting the air charge cooler ducting.

Filter canisters

237 Screw two new fuel filter canisters on to the adaptors on the filter header bracket, until the rubber seal on each canister just touches the contact face. Tighten each canister a further $^{3}/_{4}$ turn by hand. Do NOT overtighten.

238 Temporarily fit three new lubricating oil filter canisters to the adaptors beneath the oil-to-coolant heat exchanger.

When the engine is being prepared for a test run, the oil filters must be removed, filled with clean engine lubricating oil and refitted to the heat exchanger header, by screwing each canister on to its adaptor until the rubber seal on the canister just touches the header face. Tighten each canister a further $^{3}/_{4}$ turn by hand. Do NOT overtighten.

239 Secure the rear engine mountings to the flywheel housing, as necessary, and, using the engine lifting beam, position the assembly on the engine bed. Ensure that the fan is clear of the fan cowling around the blade tips. Insert the holding down bolts, fit the nuts and washers, as applicable, and tighten securely. Remove the detachable lifting bracket.

240 Slide a hose connection and two hose clips over the ends of the thermostat-to-radiator coolant pipe. Position the pipe, slide the hose connections over the joints and align and tighten the four hose clips.

241 Fit the two radiator-to-manifold ducts with hose connections; tighten the hose clips securely

242 Fit a hose connection and two hose clips to the coolant elbow in the lower tank of the radiator. Fit a hose connection and two hose clips to the upper end of the connecting pipe and position the pipe between the radiator elbow and the three way pipe. Slide the hose connections over the two joints and align and tighten the four hose clips.

243 Build up the three sections of ducting between each turbocharger outlet and the charge cooler inlet connections, in the base of the radiator. Support each ducting with two pipe clips with rubber inserts.

244 Connect up the exhaust pipework and silencers, if applicable.

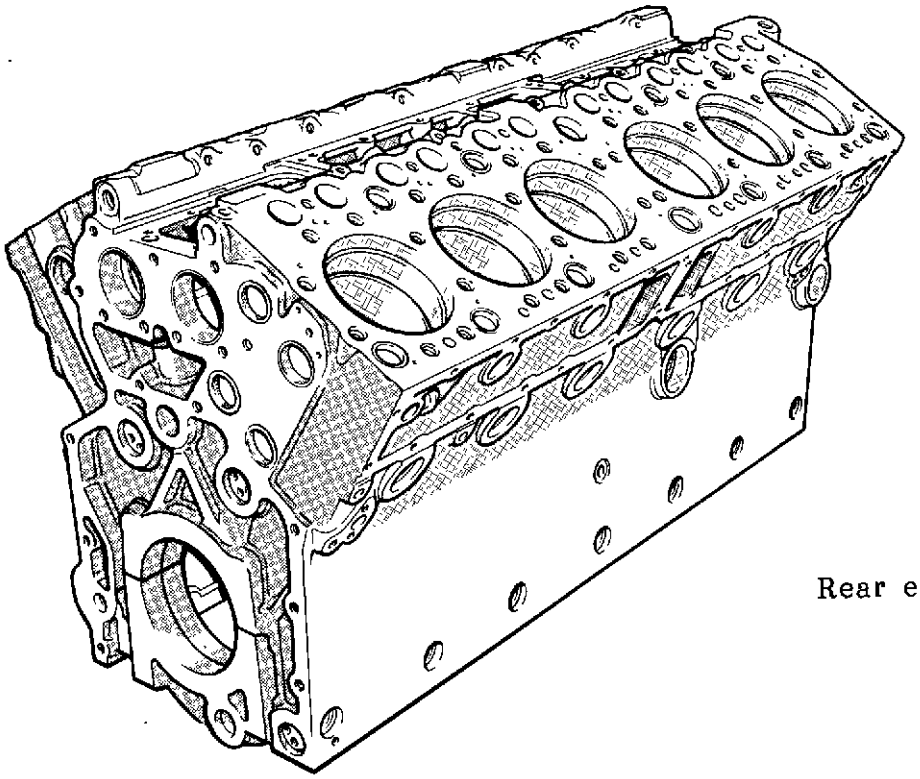
245 Reconnect the fuel pipework from the supply tank and make all the electrical connections.

246 Prepare the engine for its initial run as described in the Servicing Manual, T.S.D. Publication 3138.

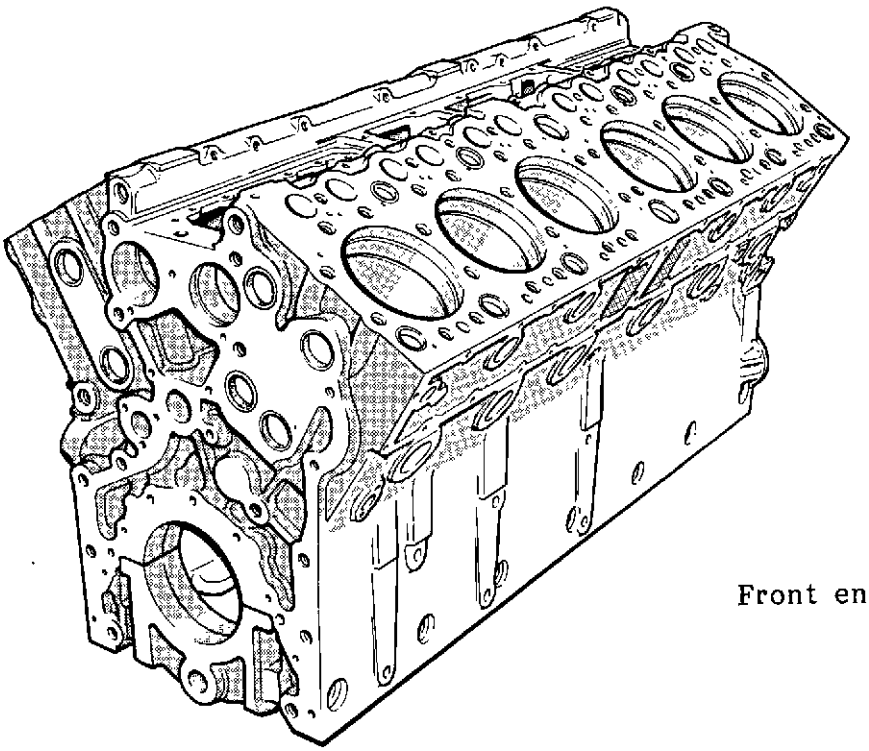
If, during engine rebuild, new bearings, piston rings, liners, etc. have been fitted, the engine should be subjected to the statutory running-in period outlined in Section 15, of this Manual.

SPECIAL TOOLS

Tool No.	Description
VP 5908	Turn over build stand, engine
VP 5597	Mounting bracket, engine
VP 5598	Mounting bracket, engine
VP 6836	Mounting bracket, engine
VP 6837	Mounting bracket, engine
VP 7862	Lifting plate, crankcase
VP 666	Lifting beam, crankshaft
VT 11495	Guide studs, main bearing cap
VT 11496	Guide studs, main bearing cap
VT 11144	Barring adaptor, crankshaft (rear end)
VT 12768	Barring adaptor, crankshaft (front end)
GA 5093	Sleeves, liner retaining
GA 5094	Compression sleeve, piston rings
GA 5092	Guide pin, piston/connecting rod assembly
GA 5031	Height gauge, piston
VT 10716	Guide studs, wheelcase to crankcase
VP 8754	Lifting hook, wheelcase
VT 10707	Lead-in mandrel, camshaft
GA 5101-5	Insertion kit, cup plugs
VP 522	Lifting bracket, cylinder head (vertical lift)
VP 4251	Lifting bracket, cylinder head (30 deg. lift)
VP 4000	Test rig, oil circuit
GA 5058	Guide studs, flywheel housing to crankcase
VT 11352	Checking plate, auxiliary drive shaft
VT 10670	Insertion tool, auxiliary drive shaft oil seal
GA 5059	Insertion/extraction tool, crankshaft oil seal
GA 5161	Insertion/extraction tool, crankshaft oil seal
GA 5060	Guide studs, flywheel to crankshaft
VP 517	Lifting bar, flywheel
VP 878	Lifting beam, fuel injection pump
VT 10723	Guide studs, sump adaptor and sump
CV 8012	Lifting bracket, engine (detachable)
GA 5072	Lifting beam, engine
OR 6408	Transportation stand, engine



Rear end view



Front end view

Fig. 1 Crankcase

SECTION 4 - CRANKCASE AND CYLINDER LINERS

Description

The close grained, high duty iron crankcase (fig. 1), is cast as a monobloc unit and dipped in a special compound to seal all non-machined faces against contamination.

The cylinder block, which forms the upper part of the crankcase, consists of two banks of six cylinders in a 60 deg. included angle 'V' configuration. The cylinder bores, arranged in a conventional staggered pattern, are machined to accept full length, slip-fit, dry liners. Galleries, cast into the cylinder block, direct a flow of coolant around each cylinder bore, whilst drillings in each flame face allow the coolant to continue on into the cylinder heads.

Seven crankshaft main bearing assemblies are retained by forged steel bearing caps, the front, centre and rear caps each being secured by four setbolts and the intermediate caps by two setbolts. Two lateral securing setbolts, passing through the crankcase wall into each main bearing cap, give added rigidity to the assembly.

All oil feed galleries are drilled for uniformity and cleanliness.

The twelve slip-fit, dry liners are flanged at the upper ends and are retained in their respective crankcase bores by the four cylinder heads. Each liner is manufactured from high quality, centrifugally cast iron, differentially hardened and pre-finished, with a fine honed oil retaining surface in the piston bore.

Drillings in the cylinder block flame face provide locations for the 24 bucket type, cam followers (tappets).

CRANKCASE

Cleaning and inspection

1 After the engine has been stripped down to the bare crankcase, carefully check each cup plug for signs of leakage. Remove any suspect plugs using the cup plug Replacement Kits, GA 5101-5 or DV 210, and clean out any traces of sealing compound from the plug bores.

2 Check around each of the cylinder head studs for signs of leakage. Extract any suspect stud and, using an 18 mm x 1,5 mm plug tap, remove all traces of sealing compound from the crankcase threads. Clean out the threads, using a proprietary brand of degreasing solvent, and blow dry with compressed air.

3 Using a degreasing solvent, remove any oil or grease from the extracted stud and blow dry with compressed air. Do NOT remove any existing thread sealant.

Subject the stud to a crack test and, if serviceable, refit the stud as follows :

4 Apply a coating of 'Loctite 270' to the stud thread, insert the stud into its crankcase location and, using a stud box, slowly screw the stud fully home by hand. Finally, tighten the stud to a torque loading of 35 Nm (26 lbf.ft.); remove any excess sealant from the crankcase top face. See 'NOTE' below.

If a new stud is to be fitted, proceed as follows :

5 Apply three lines of 'Loctite 270', at equally spaced intervals, over the crankcase thread of the stud and, using a stud box, slowly screw the stud fully home by hand. Tighten the stud to a torque loading of 35 Nm (26 lbf.ft.); remove any excess sealant from the crankcase top face.

Note: Ensure that the 'Loctite 270' is within its shelf life, as printed inside its box.

6 Unscrew all the oilway blanking plugs and clean out any traces of sealing compound from the crankcase threads. Using a proprietary brand of solvent, clean out all the oilways, coolant cavities and piston cooling jet assemblies. For this purpose, Rolls-Royce recommend the use of 'Ardrox' dichloromethane based solvent or 'Diverspray 30' inhibiting spray cleaner.

These products are safe to use on all ferrous and non-ferrous metals, but it is important that the directions for use are carefully followed.

7 When the crankcase is clean, check all machined faces for signs of wear or damage, particularly around the liner seating flanges and main bearing bores and thrust faces. Damaged liner seating flanges may be reclaimed by following the instructions given in S.R.S. 131. Similarly, any damage to the crankshaft main bearing bores and thrust faces may be rectified by following the instructions given in S.R.S. 136.

8 Using the appropriate cup plug replacement kit, fit new cup plugs, lightly coated with 'Loctite 542', as necessary. Coat the threads of the oilway blanking plugs with 'Loctite 542' and screw each one firmly into its location.

9 Using the Checking Gauge, VT 10700, check each piston cooling jet assembly to ensure that the two jets have not been knocked out of alignment.

Pressure test

10 Using locally made blanks, seal off all the coolant apertures and fit a suitable union into the crankcase coolant drain cock tapping, on one side of the crankcase. Connect an air supply line to the union and, using the Lifting Plate, VP 7862, lower the crankcase into a tank of water at 40 to 45 deg.C. (104 to 113 deg.F.). Apply air pressure at 2 kgf/sq.cm (30 lbf/sq.inch) to the crankcase and check for signs of leakage. If there is evidence of a fault in the casting, contact the Service Department of Rolls-Royce Motors.

11 Locate the piston cooling jet assemblies over the studs in the crankcase, fit the spring washers and nuts on the studs and lightly nip up the nuts. Mount the Checking Gauge, VT 10701, over the cylinder head studs and check the cooling jet alignment. Tighten each retaining nut securely.

CYLINDER LINERS

Cleaning and inspection

12 Remove any carbon build up by soaking the liners in 'Ardrox' solvent. Inspect the flanges for signs of fretting and, if necessary, restore the liner as described in S.R.S. 131.

13 Subject each liner to a crack test using the electro-magnetic method if available. Renew any unserviceable liners.

14 Check each liner seating by 'blueing' the underside of the flange before fitting it into its respective bore. Using light pressure, partially rotate the liner backwards and forwards in the crankcase and check the marking left on the crankcase shoulder. The contact must show a full bedding around the circumference and at least 50% across the landing width. If the contact area on the shoulder does not meet the above requirements, the liner flange must be bedded to the shoulder using a fine lapping compound. A Lapping Tool, VT 12230, is available to facilitate lapping and/or checking the bedding area.

Note: Do not lap in any liner more than is absolutely necessary to restore the seating face, as the liner protrusion may be adversely affected. The crankcase bore and the cylinder liner must be scrupulously cleaned after lapping, to ensure that no harmful lapping compound enters the lubrication system via the sump.

Liner protrusion

15 Check the crankcase flame faces for cleanliness and ensure that the Setting Plate, VT 14154, and Dial Gauge Holder, VT 14026, are clean.

16 Place the setting plate on a flat surface and position the dial gauge holder on the plate, so that the gauge buttons rest on the face of the setting plate. Set each dial gauge to zero and tighten the bezel locking screws.

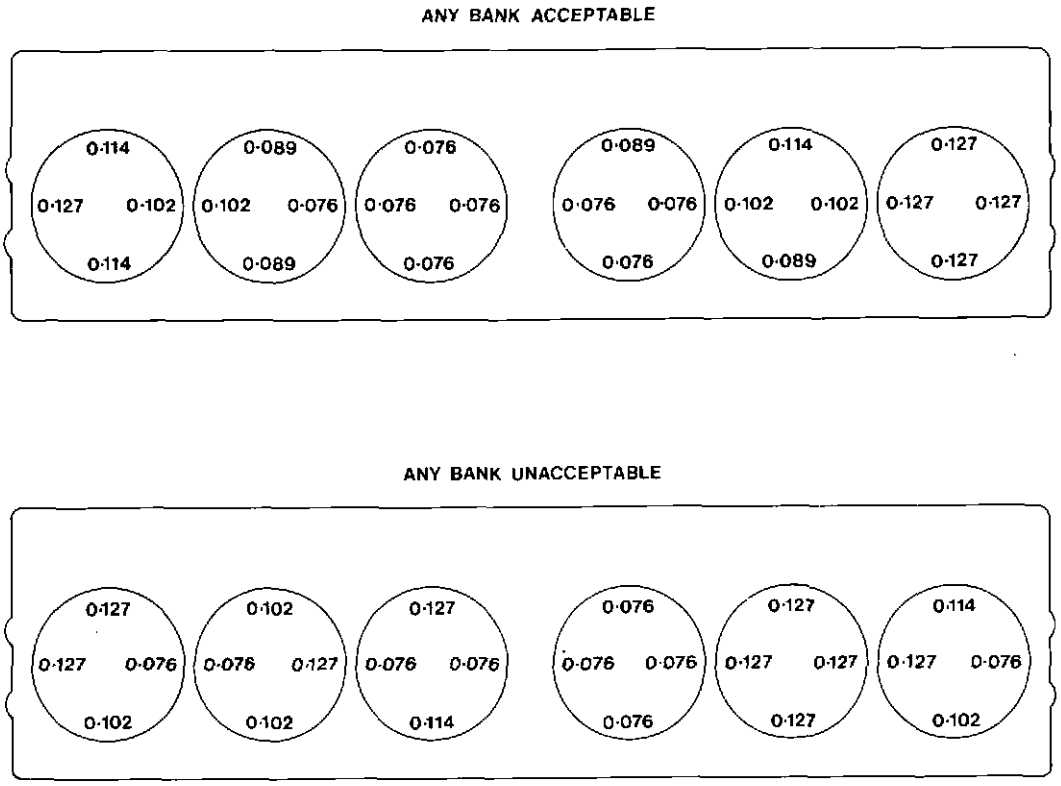


Fig. 2 Liner protrusions

17 Transfer the gauge holder to the flame face of the cylinder block, so that each gauge button rests on the top landing of the cylinder liner flange, in the locations indicated in figure 2. Note the deflections, from zero, on each gauge.

18 Without altering the dial gauge setting, transfer the gauge holder to each cylinder bore in turn, and check the liner protrusions as described. Compare the readings obtained with the protrusions shown in figure 2, and renew the liners as necessary.

Important :

(a) The protrusion for each liner must be between 0,076 mm and 0,127 mm (0.003 inch and 0.005 inch).

(b) Variation in protrusion around the circumference of any liner must not exceed 0,025 mm (0.001 inch).

(c) The difference in protrusion between the adjacent points of any two liners must not exceed 0,025 mm (0.001 inch).

Cylinder liner fitting

19 After checking protrusions during engine build, apply a light coating of 'Hylomar PL 32' to the underside of the liner flange immediately prior to its final fitting in the crankcase bore.

20 When fitting replacement liners, it is advisable to etch the correlation number on the lower section of the liner skirt.

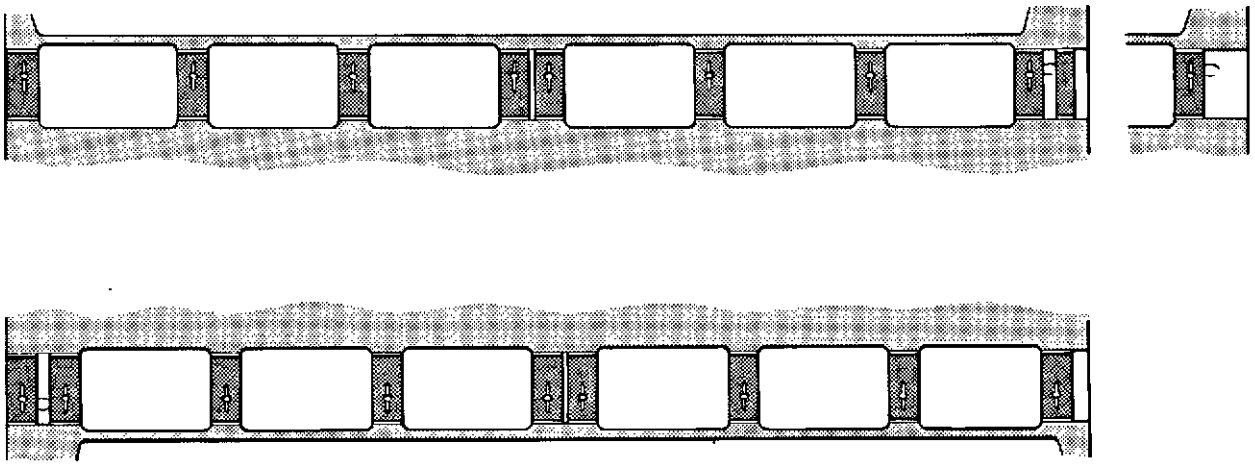


Fig. 3 Camshaft bearings

CAMSHAFT BEARINGS

Description

The camshaft bearings, disposed as shown in figure 3, are steel-backed, lead-bronze, rolled bushes, with clinch-butt joints. The bearings will not normally require any special treatment, other than ensuring that they are cleaned thoroughly during overhaul.

Damaged or worn bearings may be renewed using the Insertion/Extraction Tool, VT 660, in conjunction with the Drift, VT 13454. Full instructions for the use of these tools will be included in the kit.

SPECIAL TOOLS

Part Number	Description
GA 5101-5	Replacement kit, cup plugs
DV 210	Replacement kit, cup plugs
VP 7862	*Lifting plate, crankcase*
VT 10700	Checking gauge, piston cooling jets
VT 10701	Checking gauge, piston cooling jets
VT 12230	Lapping tool, cylinder liners
VT 14154	Setting plate, use with VT 14026
VT 14026	Holder, dial gauge
VT 660	Insertion/extraction tool, camshaft bushes
VT 13454	Drift, camshaft bush removal

SERVICE RECLAMATION SCHEMES

S.R.S. 131	Reclaiming liner flange seat
S.R.S. 136	Line boring and/or machining thrust faces

FITS AND CLEARANCES - CRANKCASE AND LINERS

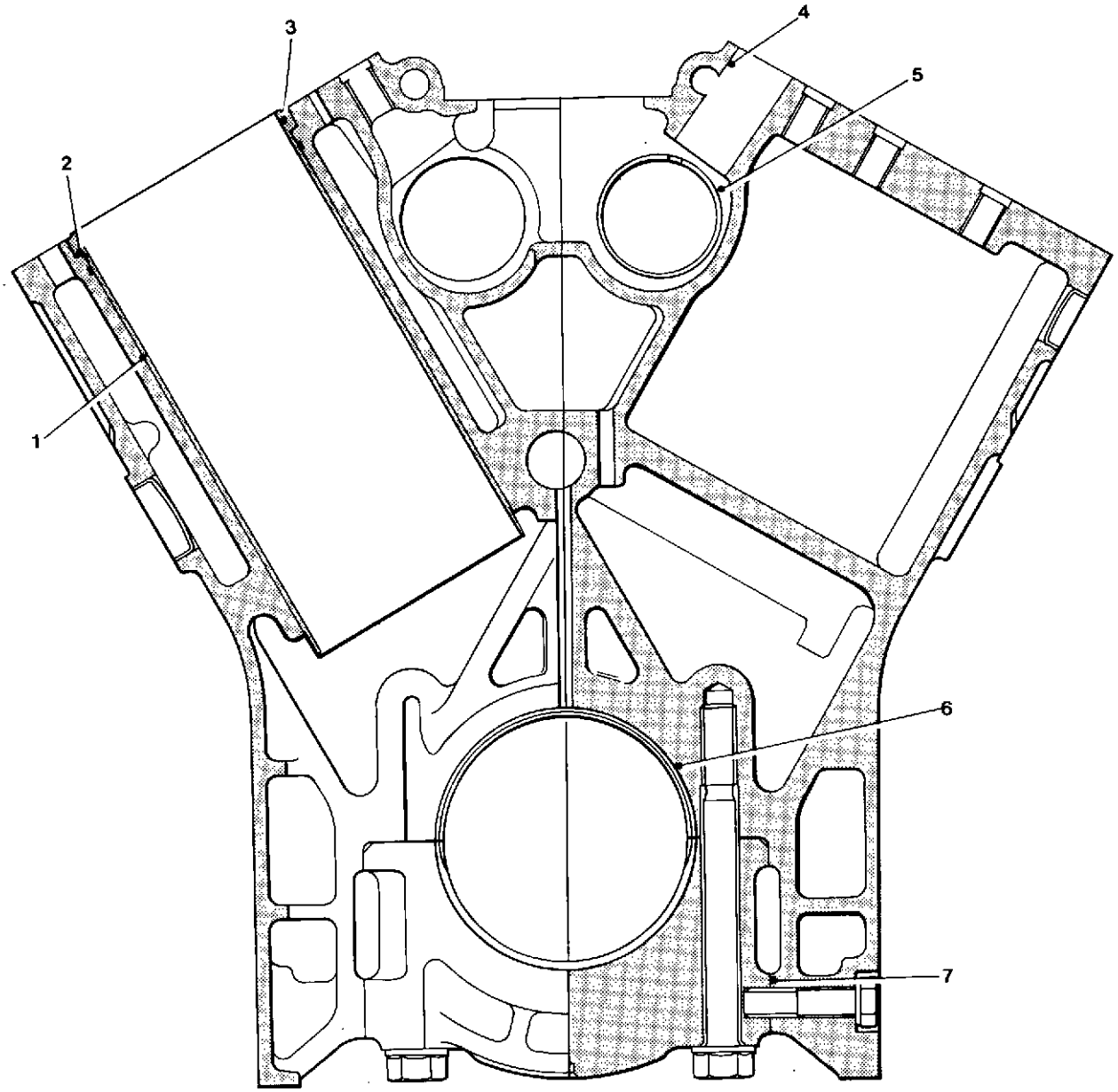


Fig. 4 Fits and clearances
Crankcase and liners

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	CYLINDER LINERS IN CRANKCASE									
1	Crankcase bore	140,488 to 140,513	5.431 to 5.532			0,013 to 0,064	0.0005 to 0.0025			
	Liner skirt diam.	140,449 to 140,475	5.5295 to 5.5305							
2	Liner protrusion									
	Crankcase counter-bore depth (Nominal)	11,900 to 11,930	0.468 to 0.469			Proud 0,076 to 0,127	0.003 to 0.005			Liners must be fitted selectively to obtain the correct protrusion parameters
	Liner flange depth (Nominal)	12,000 to 12,025	0.472 to 0.473							
	CYLINDER LINERS OUT OF CRANKCASE									
3	Liner bore	135,000 to 135,025	5.315 to 5.316	135,306	5.327					
	TAPPETS IN CRANKCASE									
4	Crankcase bore	36,000 to 36,025	1.417 to 1.418			0,025 to 0,066	0.001 to 0.0025	0,075	0.003	
	Tappet diameter	35,959 to 35,975	1.4155 to 1.416							

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	CAMSHAFT BEARINGS IN CRANKCASE									
5	Crankcase bore	71,500 to 71,530	2.185 to 2.186			Interferance 0,060 to 0,140	0.002 to 0.005			
	Camshaft bearing diameter	71,590 to 71,640	2.818 to 2.820							
	MAIN BEARING HOUSING IN CRANKCASE									
6	Bearing housing bore	149,000 to 149,100	5.866 to 5.870							
	BEARING CAPS IN CRANKCASE									
7	Bearing cap location width	236,000 to 236,025	9.2913 to 9.292			Interferance up to 0,013	0.0005			
	Bearing cap width	236,000 to 236,013	9.2913 to 9.2918							

SECTION 5 - CAMSHAFTS AND BEARINGS

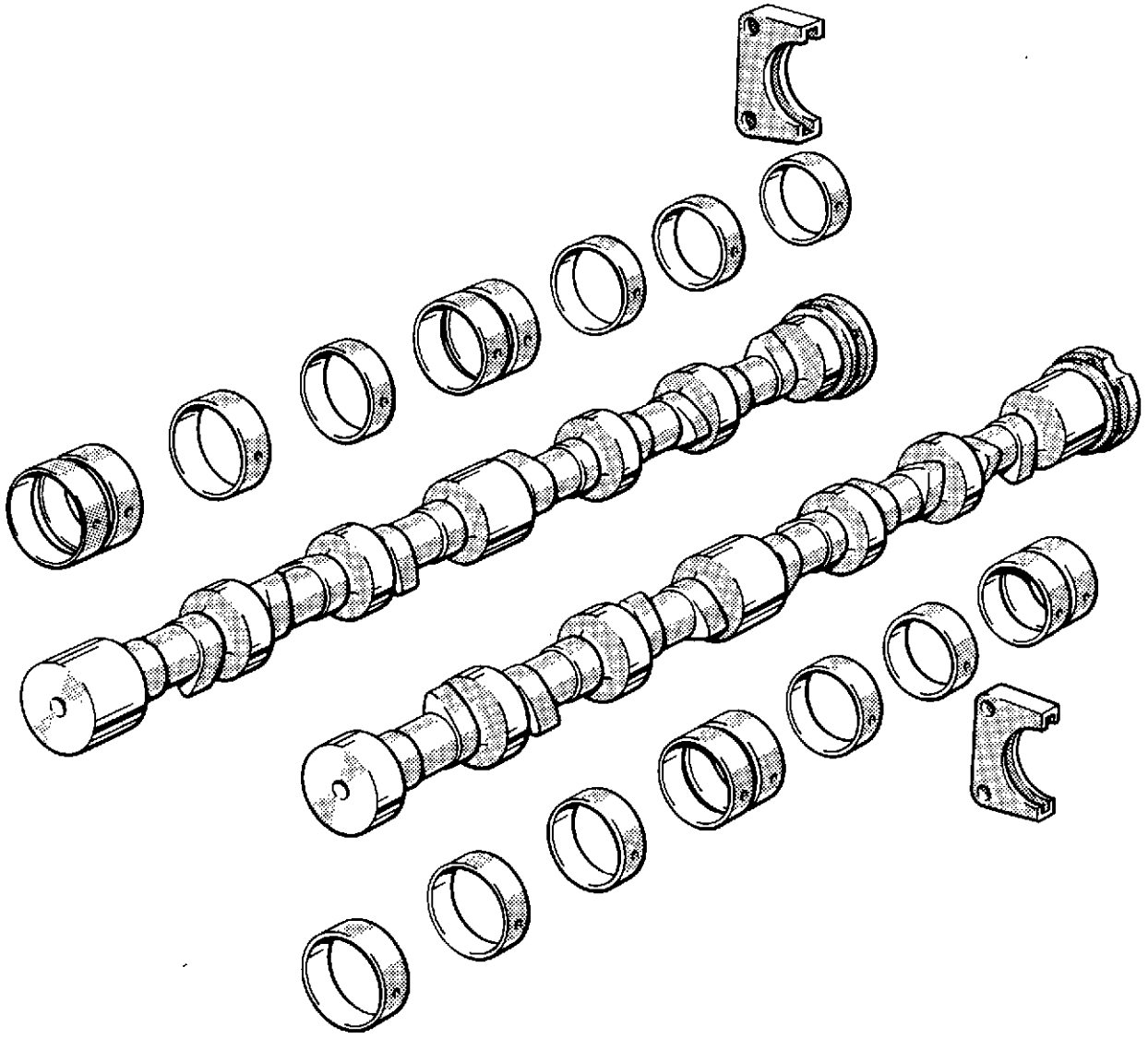


Fig. 1 Camshafts and bearings

SECTION 5 - CAMSHAFTS AND BEARINGS

DESCRIPTION

The two unidentical camshafts (fig. 1), are of high duty cast iron alloy, machined to fine tolerances, with the cam noses chill hardened.

Each camshaft, driven at half engine speed from the main gear train, is supported in steel-backed, lead-bronze bearings, high mounted in the crankcase 'V'. End float is controlled by thrust plate assemblies bolted to the crankcase rear end face, locating on collars machined around each shaft.

The cam drive gears, incorporating the fuel pump drive gear, are marked to ensure correct timing, and secured to each camshaft rear end flange with six setbolts.

The bearings, formed as rolled bushes with clinch butt joints, are drilled to accept pressure oil feed from the auxiliary oil galleries in each cylinder block.

The cam lobes are lubricated from troughs, cast in the crankcase, which trap oil spill from the camshaft bearing oil supply.

Cleaning and inspection

1 Prior to dismantling the camshaft assemblies, check each camshaft end float. If the end float exceeds 0,55 mm (0,022 inch), the thrust plate assemblies will have to be renewed during engine rebuild.

2 When the camshafts have been removed from the crankcase, clean them thoroughly using a proprietary brand of emulsifying solvent such as 'Pavan' and subject each shaft to a crack test, preferably by the electro-magnetic method, if not available, use the dye penetrant process.

3 Examine the cams and journals for wear or damage. Slight score marks may be removed using a fine oil stone, provided that the cam profiles are not affected.

4 Examine the thrust collars for wear or damage. If a collar is visibily worn, the shaft must be renewed, as the surface finish on the collar requires special treatment.

5 Check the thrust plate assemblies for wear or damage and renew if necessary.

6 Assemble the camshafts to the crankcase and check the end float and gear backlash as described in Section 3.

CAMSHAFT BUSHES

Camshaft bush renewal may be carried out using the special tools listed in Section 4 - Crankcase and cylinder liners.

SPECIAL TOOLS

As described in SECTION 3 - ASSEMBLING THE ENGINE

FITS AND CLEARANCES - CAMSHAFTS AND BEARINGS

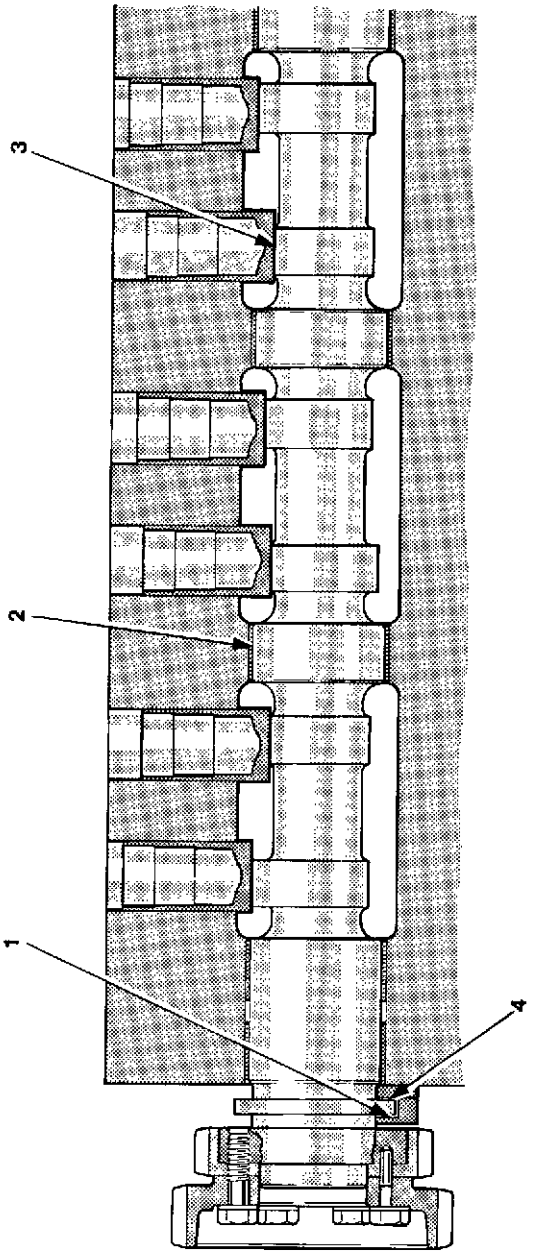
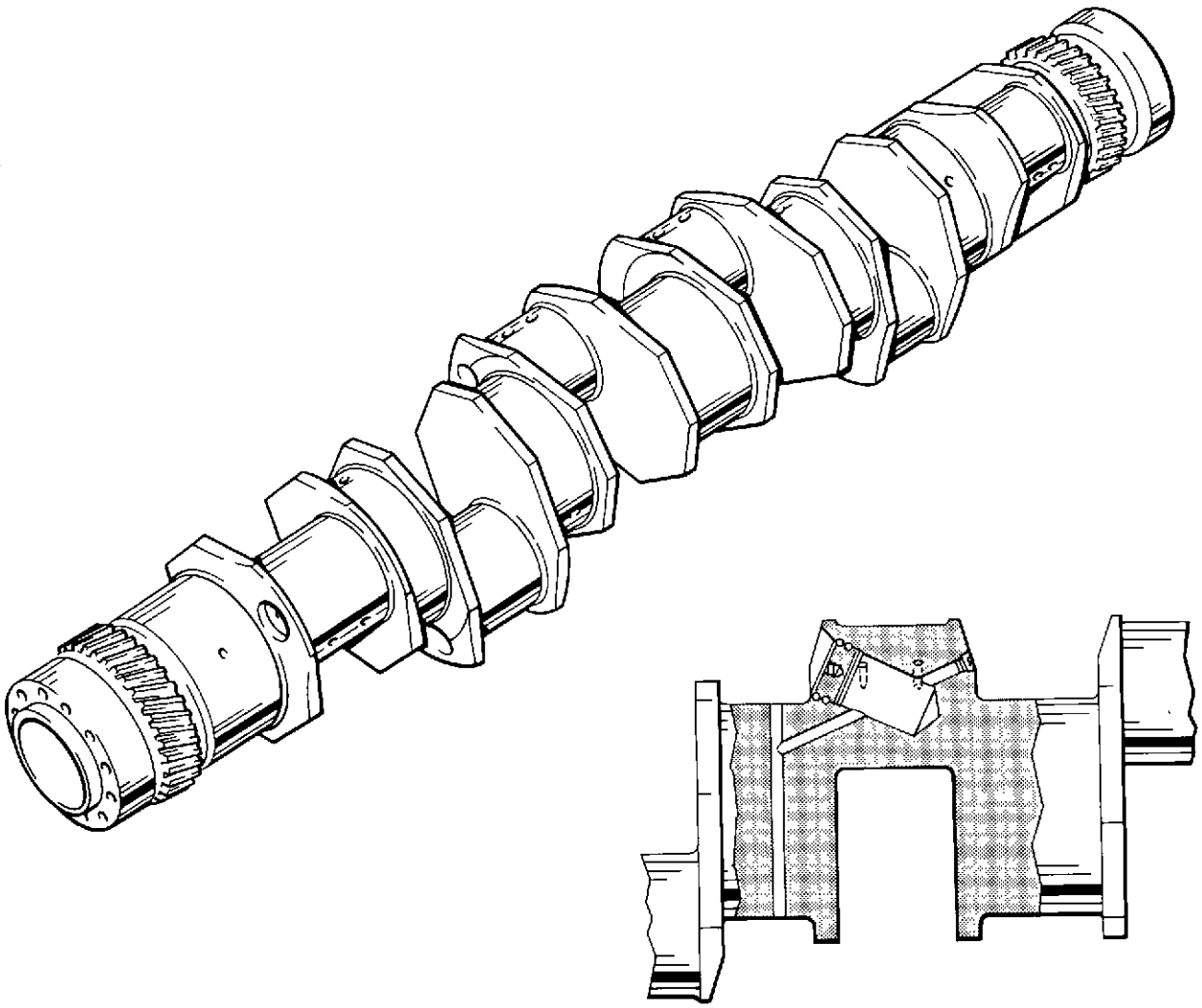


Fig. 2 Fits and clearances camshafts and bearings

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	CAMSHAFTS AND BEARINGS									
1	Camshaft end float					0,100 to 0,0550	0.004 to 0.022	0,550	0.002	End floats must be maintained within these limits. See also item 4
	Camshaft in bearings									
2	Bearing bore	67,577 to 67,602	2.660 to 2.6615			0,077 to 0,121	0.003 to 0.005	0,25	0.010	
	Camshaft journals diameter	67,481 to 67,500	2.656 to 2.657							
	CAMS									
3	Cam lift									
	Inlet cams	8,247 to 8,497	0.3246 to 0.3345	7,798	0.307					
	Exhaust cams	8,340 to 8,590	0.328 to 0.338	7,874	0.310					
	THRUST PLATES									
4	Width between thrust faces	8,050 to 8,250	0.317 to 0.325	8,250	0.325					

SECTION 6 - CRANKSHAFT, MAIN BEARINGS AND FLYWHEEL



Sludge trap detail

Fig. 1 Crankshaft

SECTION 6 - CRANKSHAFT, MAIN BEARINGS AND FLYWHEEL

CRANKSHAFT

Description

The crankshaft is manufactured from a chrome molybdenum steel forging, nitride hardened on all surfaces except the tapped holes, dowel holes and the front and rear end faces. Balanced statically and dynamically at the machining stage, the crankshaft requires no further compensation when assembled.

The 13 bearing surfaces consist of seven main journals and six crankpins, each crankpin serving two connecting rods.

A conventional sludge trap is incorporated in each crankpin, with an alloy plug in the crankweb to allow access for cleaning.

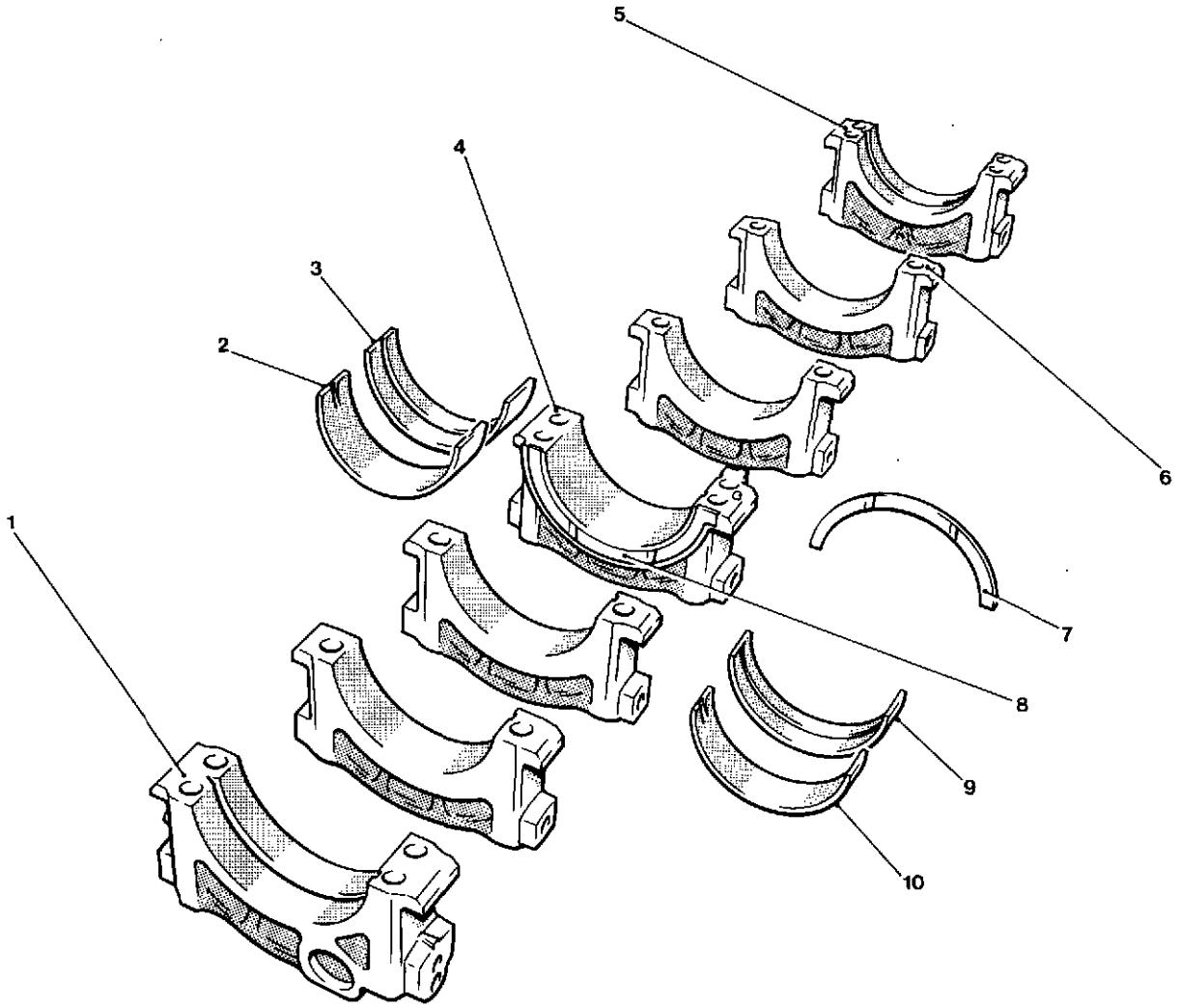
Drillings through the diameter of six of the main bearing journals, Number seven journal has no drilling, connect with drillings in each crankpin, via the sludge traps, to direct a supply of lubricating oil to the big-end bearings.

Thrust washers, located on either side of the centre main bearing, control the crankshaft end float.

The rear end face of the crankshaft is drilled and tapped with 16 equally spaced holes, to accept the flywheel securing screws. A spring dowel set in the end face locates the flywheel for timing mark alignment.

Helical gearing, machined around the front and rear ends of the crankshaft serve as primary drive for the lubricating oil pump and main gear train respectively.

The front end face of the crankshaft is drilled and tapped to accomodate the 12 equally spaced setbolts, which secure the damper and multi-groove pulley.



1	Rear bearing cap	6	Intermediate bearing cap
2	Lower half bearing shell	7	Upper thrust washer half
3	Upper half bearing shell	8	Lower thrust washer half
4	Centre bearing cap	9	Upper half bearing shell
5	Front bearing cap	10	Lower half bearing shell

Fig. 2 Main bearings, caps and thrust washers

Dismantling and cleaning

1 Screw the extractor into the tapped hole in each alloy sludge plug; press down on the plug and release the retaining circlip. Withdraw the plug a clean the components in a non-caustic cleaning solution.

2 Wash out the crankshaft oilways and sludge traps with paraffin and blow dry with compressed air. Ensure that the shaft is thoroughly cleaned.

Inspection

3 Subject the crankshaft to a crack test, preferably by the electro-magnetic method.

4 Examine the main journals, crankpins and thrust faces for wear and score marks; check the journals and crankpins for ovality. For reclamation of worn or damaged journals or crankpins, see S.R.S. 121 Issue 2.

5 Support the shaft on 'V' blocks under main journals Nos. 1 and 7 and check the amount of 'bow' at the centre main journal. The permissible bow must be progressive along the length of the shaft.

6 Check the front and rear end faces for damage and check for score marks on the flywheel and pulley circumferential locations.

Providing that the shaft is serviceable, slight scoring on the journals, crankpins, thrust faces and end locations may be removed using a very fine grade of oil stone.

MAIN BEARINGS AND THRUST WASHERS

Inspection

1 Check the bearing shells for wear, cracks and embedded foreign material. Renew any bearing shells in sets if there is the slightest doubt that the bearing will not complete a further full period of service.

2 Check the thickness of the thrust washers. Nominal new dimensions are : 2,93 to 3,0 mm (0.116 to 0.118 inch). If excessive wear is apparent on the thrust faces, when checked in conjunction with the crankshaft end float, new thrust washers must be fitted.

FLYWHEEL

Inspection

1 Check the bolt and dowel holes for elongation and examine the contact face for signs of fretting

2 Check the teeth of the starter ring for wear or damage. If excessively worn or damaged, the ring should be renewed as follows :

(a) Place the flywheel assembly horizontally on a drill table and drill holes through the ring body in diametrically opposite positions, until the ring is weakened sufficiently to be driven off. Do not attempt to drill holes through the flame hardened teeth. Care must be taken not to damage the flywheel during any of the preceeding operations.

(b) Check the flywheel and new starter ring for burrs; ensure that both components are clean.

(c) Heat the ring evenly to 200 deg. C., fit the ring on to the flywheel location and rotate it to ensure correct seating.

Important : Ensure that the chamfered edge of the teeth face away from the flywheel.

(d) Allow the ring to cool naturally, then check by feeler gauge that the ring is tight against the shoulder of the flywheel.

ASSEMBLING

Fit new 'O' ring seals to each of the alloy, sludge trap blanking plugs. In turn, coat each plug and its housing with clean engine oil and screw the insertion/extraction tool into the tapped hole in the plug. Press the plug fully home, fit the retaining circlip into its recess in the sludge trap and pull the plug back against the circlip. Unscrew the tool.

Refit the major components in the engine as described in Section 3 - Assembling the engine.

SPECIAL TOOLS

Part no.	Description
VT 10706	Insertion/extraction tool, sludge plug

Tools described in Section 3 - Assembling the engine.

SERVICE RECLAMATION SCHEMES

S.R.S. 121	Reclamation of crankshaft journals and crankpins.
S.R.S. 139	Reclamation of worn oil seal location

FITS AND CLEARANCES

CRANKSHAFT, MAIN BEARINGS AND FLYWHEEL

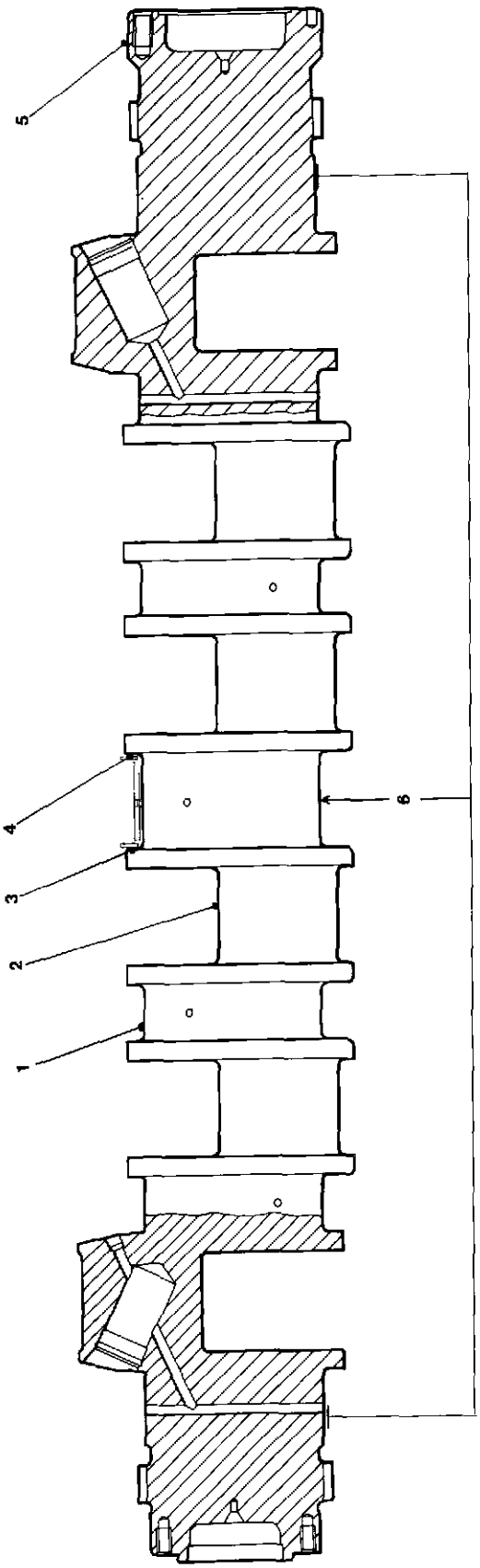


Fig. 3 Fits and clearances, crankshaft, main bearings and flywheel

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	CRANKSHAFT JOURNALS									
1	Diameter	145,975 to 146.000	5.747 to 5.748	145,910	5.7445					
	Ovality			0,076	0.003					S.R.S 121 Issue 2
	Journals in main bearings									
	Running clearance					0,076 to 0,145	0.003 to 0.0057			
	CRANKPINS									
2	Diameter	97,978 to 98.000	3.8573 to 3.8582	97,9145	3.8548					
	Ovality			0,076	0.003					S.R.S. 121 Issue 2
	CRANKSHAFT END FLOAT									
3	Centre journal width between crankwebs	46,50 to 46,55	1.8307 to 1.8326			0,10 to 0,30	0.004 to 0.012	0,0483	0.019	
4	Centre bearing width over thrust washers	46,25 to 46,40	1.8307 to 1.8326							

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	FLYWHEEL ON CRANKSHAFT									
	Flywheel bore	160,000 to 160,025	6.2992 to 6.3002			0,014 to 0,064	0.0006 to 0.0026			
5	Crankshaft diameter	159,961 to 159,986	6.2976 to 6.2986							
	CRANKSHAFT BOW									
6	Bow at center when supported on 'V' blocks under Nos. 1 and 7 journals	0,1000	0.0039							The bowing must be progressive, reading from the outer main to the centre main

SECTION 7 - PISTONS AND CONNECTING RODS

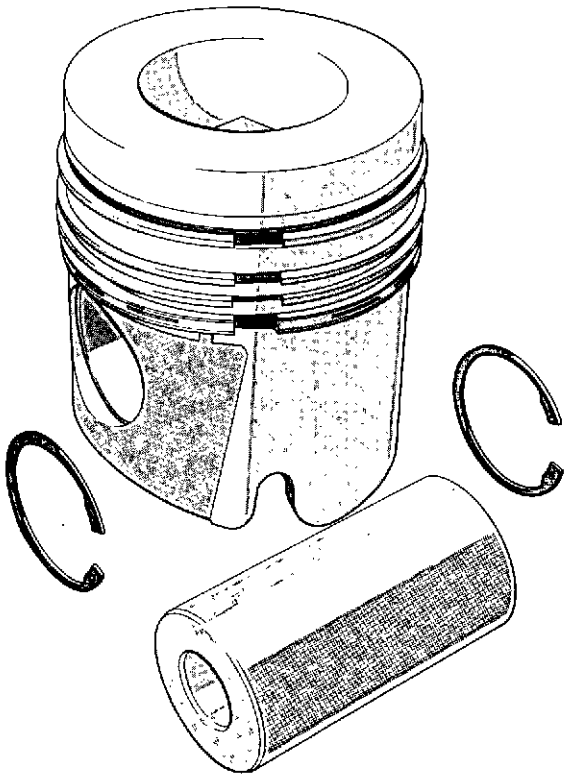


Fig. 1 Piston assembly

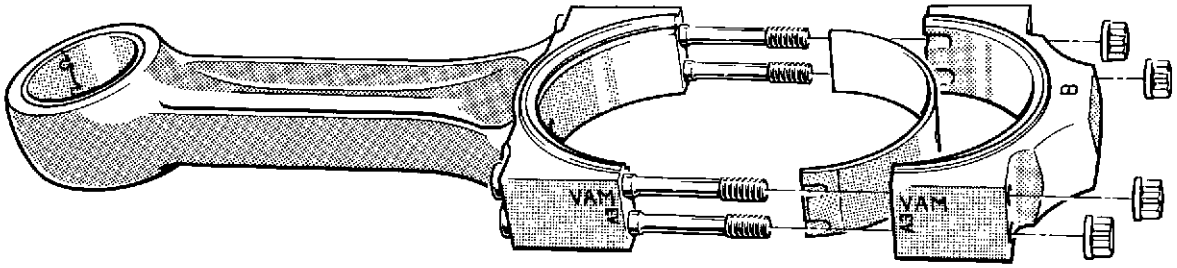


Fig. 2 Connecting rod assembly

SECTION 7 - PISTONS AND CONNECTING RODS

PISTONS

Description

The pistons (fig. 1), cast from high silicon aluminium alloy, have open toroidal combustion chambers machined into their crowns.

Three compression rings and one oil control ring are carried in grooves around each piston wall, the top ring being carried in an austenitic iron insert to reduce wear. All rings are fitted above the gudgeon pin.

Ring type and position is as follows :

Top - Inlaid molybdenum surface

Second - Chrome plated

Third - Ferrox treated surface

Bottom - Composite chrome plated oil control

Each piston is tin plated on all surfaces, except for the gudgeon pin bore.

The fully floating gudgeon pin is retained by circlips, carried in machined grooves in the gudgeon pin bore.

CONNECTING RODS

Description

The connecting rods (fig. 2), are chrome molybdenum steel forgings with pressed-in, steel backed, lead bronze, small-end bushes. Renewable, steel backed, lead bronze, half shells with lead indium flashed running faces, are fitted into the big-end bearing bore. Positioning of the shells is effectedf by grooves machined in each half shell, locating on shoulders around the centre of each big-end bearing bolt.

A hole bored centrally through the column of each rod, allows pressurised oil to be directed intermittently, from the crankpin to the small-end bush.

Markings on each connecting rod assembly provide rod to cap correlation, and cylinder bore number.

Each connecting rod, complete with small-end bush and big-end bolts and nuts, is weighed during manufacture and stamped with a group letter. All rods having the same group letter fall within a weight range of 0,980 N (0.22 lbf.). If for any reason, a connecting rod has to be renewed, it is important that the replacement rod is of the same group as the original.

Weight groups are as follows :

Y	40,697	to	41,678 N	(9.149	to	9.369 lbf.)
Z	41,678	to	42,659 N	(9.369	to	9.590 lbf.)
A	42,659	to	43,639 N	(9.590	to	9.810 lbf.)
B	43,639	to	44,620 N	(9.810	to	10.031 lbf.)
C	44,620	to	45,600 N	(10.031	to	10.251 lbf.)
D	45,600	to	46,581 N	(10.251	to	10.472 lbf.)
E	46,581	to	47,562 N	(10.472	to	10.692 lbf.)

Piston and connecting rod removal

1 Isolate the batteries, shut off the fuel supply and drain the oil from the sump.

2 Drain the cooling system.

3 Remove the cylinder heads as described in Section 8 - Cylinder heads and valve gear.

4 Disconnect and remove the coolant cross-over pipework between the coolant pump and the 'A' bank coolant gallery.

5 Remove the dipstick from its tube, unscrew the sump securing setbolts and lift the sump away from the adaptor.

6 Remove the lubricating oil pump suction pipe from the sump.

7 Remove the oil gallery blanking flange from the 'B' bank side of the sump adaptor and withdraw the oil pump discharge bobbin.

8 Unscrew all the setbolts securing the sump adaptor to the crankcase and wheelcase, and lift the adaptor clear.

9 If necessary, unscrew the lubricating oil pump securing setbolts and remove the pump.

10 Fit Liner Retaining Sleeves, GA 5093, to the cylinder head studs as necessary.

11 Bar the crankshaft round until the chosen piston/connecting rod assembly is at the bottom of its stroke and remove the big-end retaining nuts. Fit the Guide Pin, GA 5092, on to one of the big-end bolts and gently push the assembly out through the top of the cylinder.

Dismantling

12 Using the Piston Ring Pliers, GA 5039, with Locating Ring, GA 5107, carefully remove each ring (fig. 3) and lift out the backing spring from the oil control ring groove.

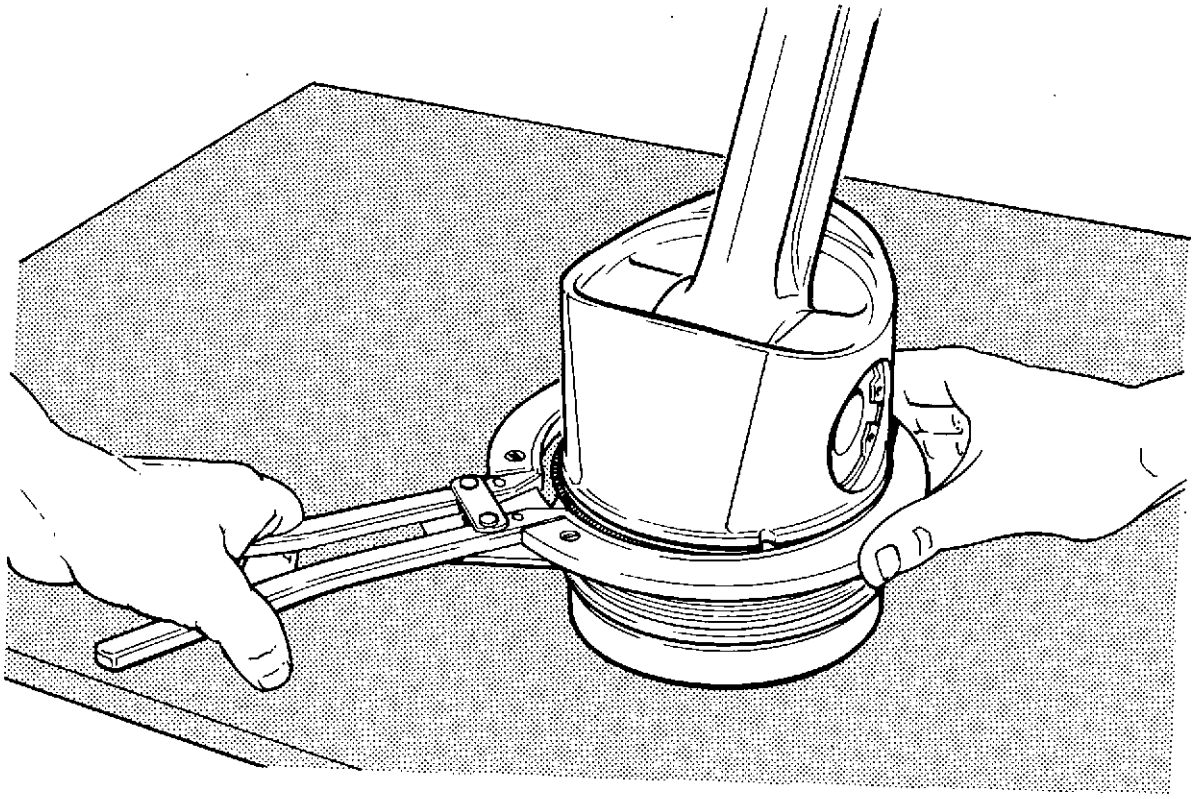


Fig. 3 Removing piston rings

13 Using a pair of Seeger pliers, remove the circlips from the gudgeon pin grooves.

14 Heat the piston assembly in a tank of hot water and push out the gudgeon pin to release the connecting rod. Keep each assembly together.

Cleaning and inspection

Piston and rings

15 Decarbonize the components by soaking in a proprietary solvent such as 'Maxan' or 'Ardrox 667'. Wash the components in clean water and blow dry with compressed air.

16 Inspect the piston for wear and score marks and check that the ring grooves are not worn beyond the permissible limits. If necessary, check the grooves using new piston rings.

17 Examine the piston crown. Radial cracks, extending from the edge of the combustion chamber, may occur in pistons manufactured from the material known as 'Lo-Ex'. These cracks are not detrimental to performance or reliability and, provided that they DO NOT extend to within 5 mm (0.2 inches) of the piston land circumference, the piston may be re-used. 'Lo-Ex' pistons may be identified by the number '109' embossed inside the piston skirt.

18 Examine the piston rings for score marks, wear and signs of leakage. Discard the top ring if the surface finish shows large pores or voids, or if the surface shows signs of breaking up. Compare the surface with that on a new ring if necessary.

19 Inspect the spring behind the oil control ring. If there is an appreciable shortening of the spring over its circumferetial length, the spring and oil control ring must be renewed as a set.

20 Check the gap of each ring in a new liner, or in an unworn portion of the original liner. Discard any ring having a gap in excess of the limits given at the end of the Section.

Notes : Where a new liner has been fitted, the piston rings must also be renewed.

Where a new piston ring is fitted into an original liner, the glaze in the liner bore must be broken by honing or lapping.

21 Crack test the gudgeon pin and check its fit in the piston. The gudgeon pin should be a push fit at 20 deg. C. (68 deg. F.). If the pin is slack in its bore, the assembly must be renewed.

Any piston/gudgeon pin assembly not conforming to the dimensions at the end of the Section, must be renewed.

Connecting rods and bearings

22 Clean each connecting rod assembly in paraffin or a degreasing solvent, then subject the rod, bearing cap and big-end bolts to a crack test. Check the bolts for stretching and signs of damage; renew any bolts which appear suspect.

Note: When refitting the big-end bolts, ensure that the flat, machined on the central shoulder of each bolt, faces away from the big-end bore otherwise, positive location of the bearing shells will not be possible. Replacement bolts do not have flats machined on the central shoulders and require no special fitting instructions.

23 Check the small-end bush for wear and score marks. If any bush is badly scored, it must be renewed as described below in this Section.

24 Inspect the big-end bearing shells for cracks, score marks and embedded foreign material. Renew the shells in pairs if there is any doubt that they may not complete a full period of service.

25 Check the big and small-end alignment of the rod in two planes. Do not attempt to correct a bent or twisted rod.

Small-end bush renewal

26 Using the Removal Tool, VT 11733, and a hand press, drive out the old small-end bush (fig. 4). Remove any burrs from the small-end eye and ensure that the oilway is clear.

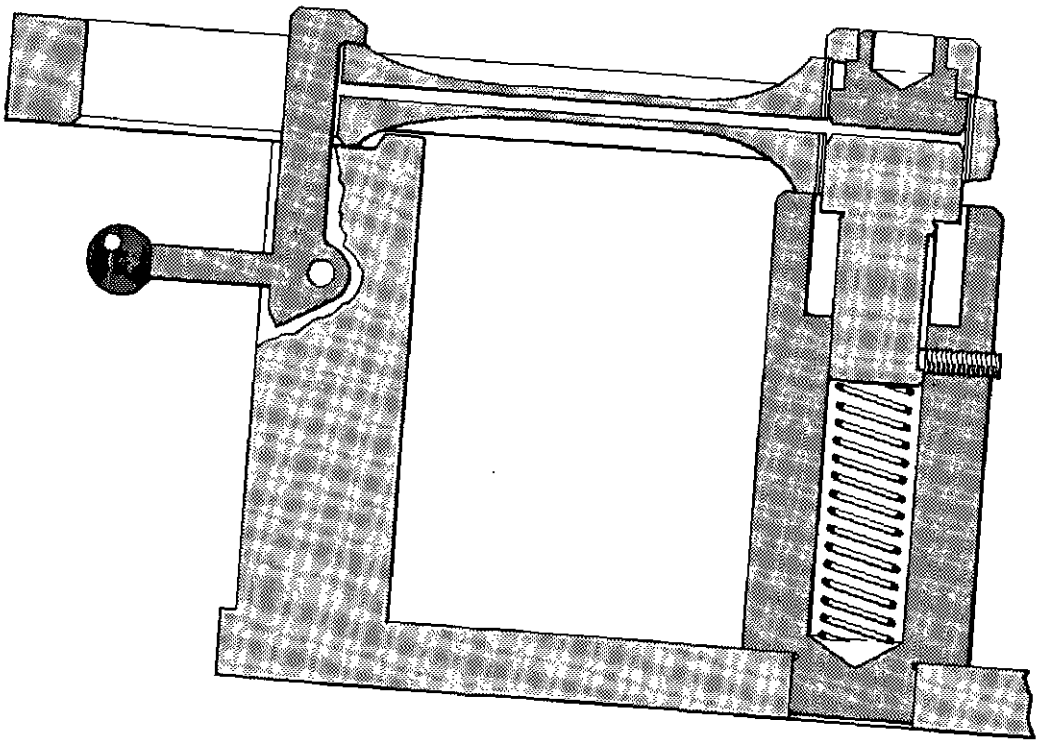


Fig. 4 Bush removal tool

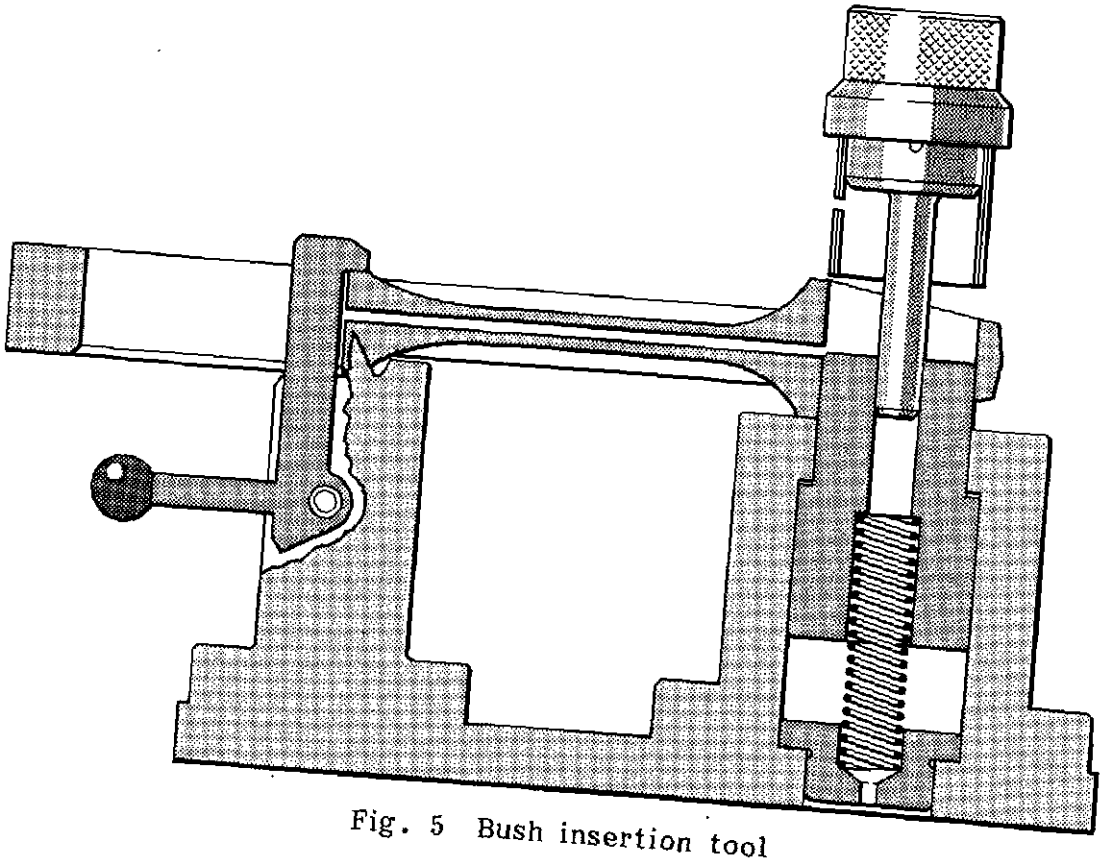


Fig. 5 Bush insertion tool

27 Position the connecting rod on the Insertion Tool, VT 12920, locate the new small-end bush on the pressing tool and press the bush into the eye of the rod, until the pressing tool flange contacts the side face of the rod.

28 Cut off the pritruding edges of the bush and dress up with a smooth file until the bush is flush with the angled faces of the connecting rod.

30 Secure the connecting rod to a boring machine and bore out the bush to the correct diameter, as given in 'FITS AND CLEARANCES' at the end of the Section.

Assembling

Before assembling, check the connecting rod oilway for dirt and swarf and blow through with a jet of compressed air.

31 Heat the piston by immersing it in hot water for a few minutes. Remove the piston and, using a piece of lint-free cloth, dry out the gudgeon pin bore. Fit one of the circlips into its groove.

32 Apply a coating of clean engine lubricating oil to the small-end bush, the gudgeon pin and the gudgeon pin bore.

33 Position the connecting rod small-end in the piston, ensuring that the cut-out in the piston skirt is on the opposite side to the chamfered rim of the big-end bore.

34 Slide the gudgeon pin into position through the small-end bush and fit the second circlip into its groove.

35 Stand the assembly on the piston crown, oil the ring grooves and carefully refit the piston rings, in the sequence given at the beginning of this Section, ensuring that non-reversible rings are fitted the right way up.

Note: The backing spring of the oil control ring must be opened up and fitted around its groove, before fitting the control ring to the piston.

36 Refit the assembly to the engine as described in Section 3, and rebuild the engine using new jointing gaskets and 'O' ring seals, where applicable.

New pistons

If, at any time, it is found necessary to renew a piston, the replacement piston must be checked to ensure that the correct clearance is maintained between the piston crown and the cylinder head flame face. A Height Checking Fixture, VT 18033, is available for this purpose (fig. 7).

To check the piston height, place the slider/ring assembly on top of the setting piece, and adjust the D.T.I. gauge on its column to obtain a zero reading on the needle. Without disturbing the D.T.I., remove the setting assembly and rest the slider, in its supporting ring, on the gudgeon pin. Carefully slide the piston beneath the D.T.I. gauge, as shown, and note the reading on the gauge.

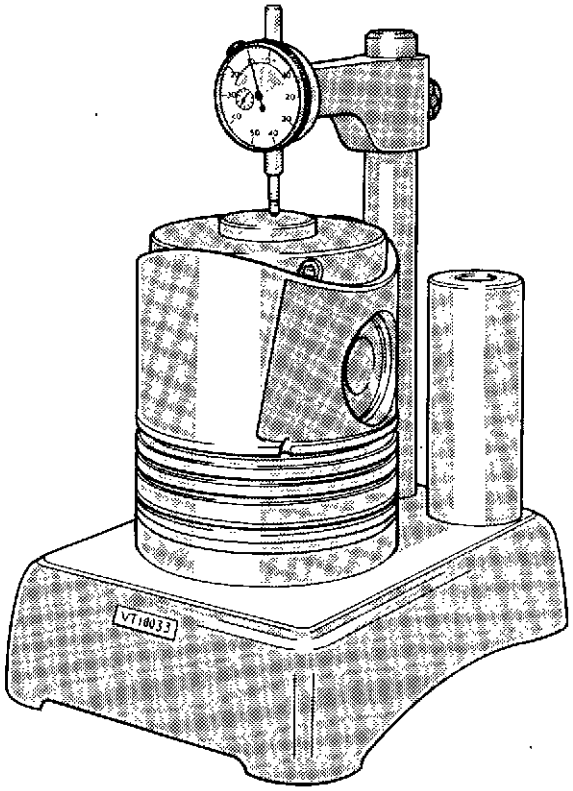


Fig. 7 Piston height checking fixture

Machine the excess material from the piston crown, on a milling machine. A Holding Fixture, VT 18036, Milling Cutter, VT 18035, and Facing Tool, VT 18297, are available for this purpose.

SPECIAL TOOLS

Part number	Description
GA 5039	Pliers, piston ring
GA 5107	Locating ring, use with GA 5039
VT 11733	Removal tool, small-end bush
VT 12920	Insertion tool, small-end bush
VT 18033	Checking fixture, piston height
VT 18036	Holding fixture, piston machining
VT 18035	Milling cutter, piston crown
VT 18297	Facing tool, piston crown

FITS AND CLEARANCES - PISTONS AND CONNECTING RODS

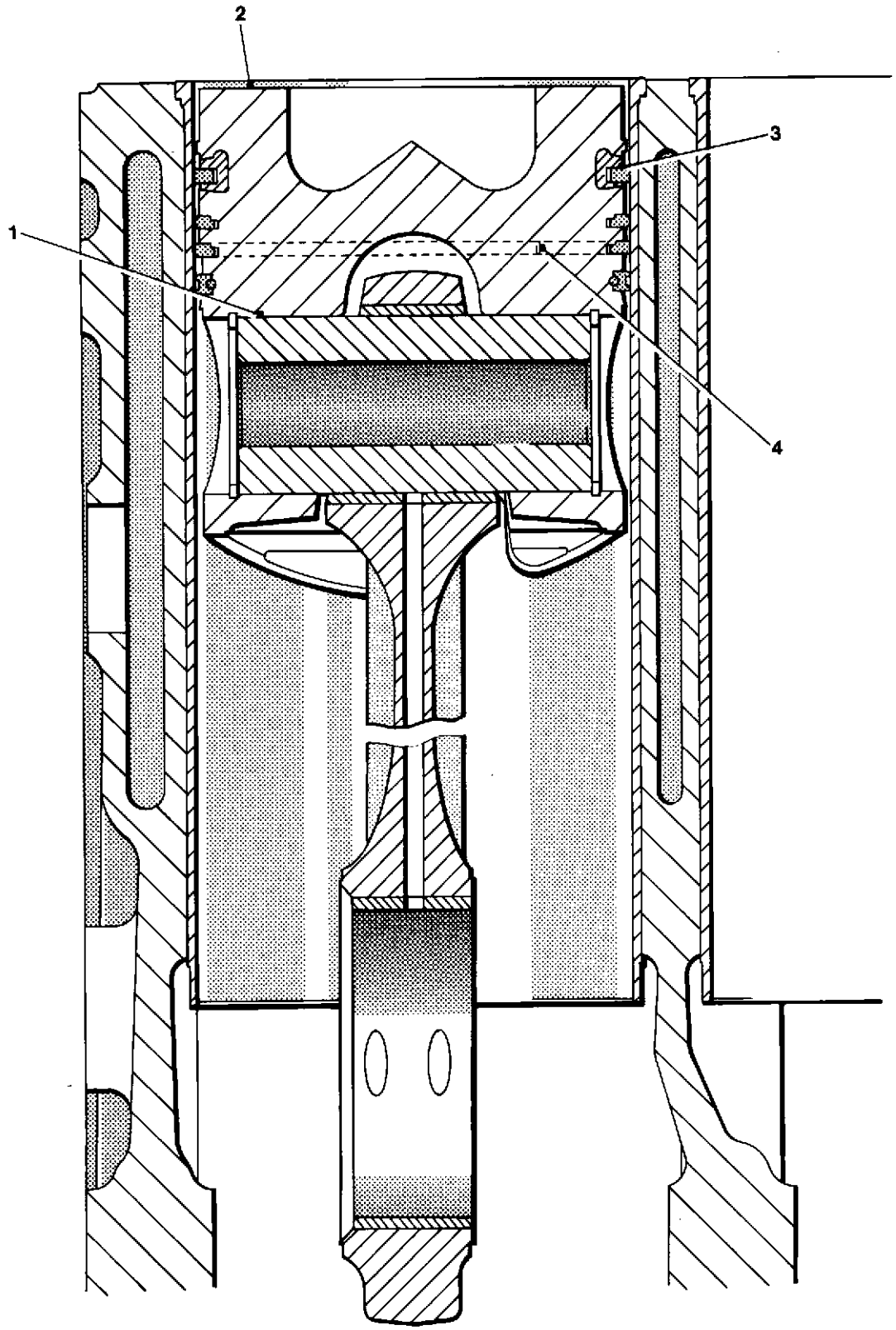


Fig. 8 Fits and clearances - Piston

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	GUDGEON PIN IN PISTON									
1	Piston bore	54,999 to 55,004	2.1653 to 2.1655			0,001 to 0,009	0.00004 to 0.00036			Non-selective assembly. To be a hand push fit at 20 deg. C.
	Gudgeon pin diameter	54,995 to 54,000	2.1652 to 2.1654							
	PISTON CROWN CLEARANCE AT T.D.C.									
2	Piston crown below crankcase top face					0,310 to 0,380	0.012 to 0.015			Maintain clearance by machining the piston crown as required
	PISTON RINGS									
3	Side clearance between ring and groove									
	Top ring *(wedge shaped)*					0,138 to 0,189	0.0054 to 0.0074	0,254	0.010	Ring CV 5907 fitted to early engines. Side clearance measured with piston assembly partly entered in liner
	Top ring					0,0559 to 0,0949	0.0022 to 0.00374	0,254	0.010	Ring CV 8517
	Second ring					0,0708 to 0,01015	0.0028 to 0.0039	0,152	0.006	Ring OE 41689

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	Third ring					0,063 to 0,1042	0.0024 to 0.0041	0,152	0.006	Ring OE 42641
	Oil control ring					0,049 to 0,086	0.0019 to 0.0034	0,152	0.006	Composite ring CV 5908
	Backing spring (free length)	423,96 to 426,34	16.691 to 16.785							
4	Ring gaps measured with ring in new liner									
	Top ring					0,050 to 0,070	0.0196 to 0.0275	1,397	0.055	Ring CV 5907
	or									
	Top ring					0,6604 to 0,8636	0.026 to 0.034	1,651	0.065	Ring CV 8517
	Second ring					0,432 to 0,693	0.017 to 0.027	1,524	0.060	Ring OE 41689
	Third ring					0,432 to 0,695	0.017 to 0.027	1,524	0.060	Ring OE 42641
	Oil control ring					0,430 to 0,810	0.0169 to 0.0318	1,016	0.040	Composite ring CV 5908

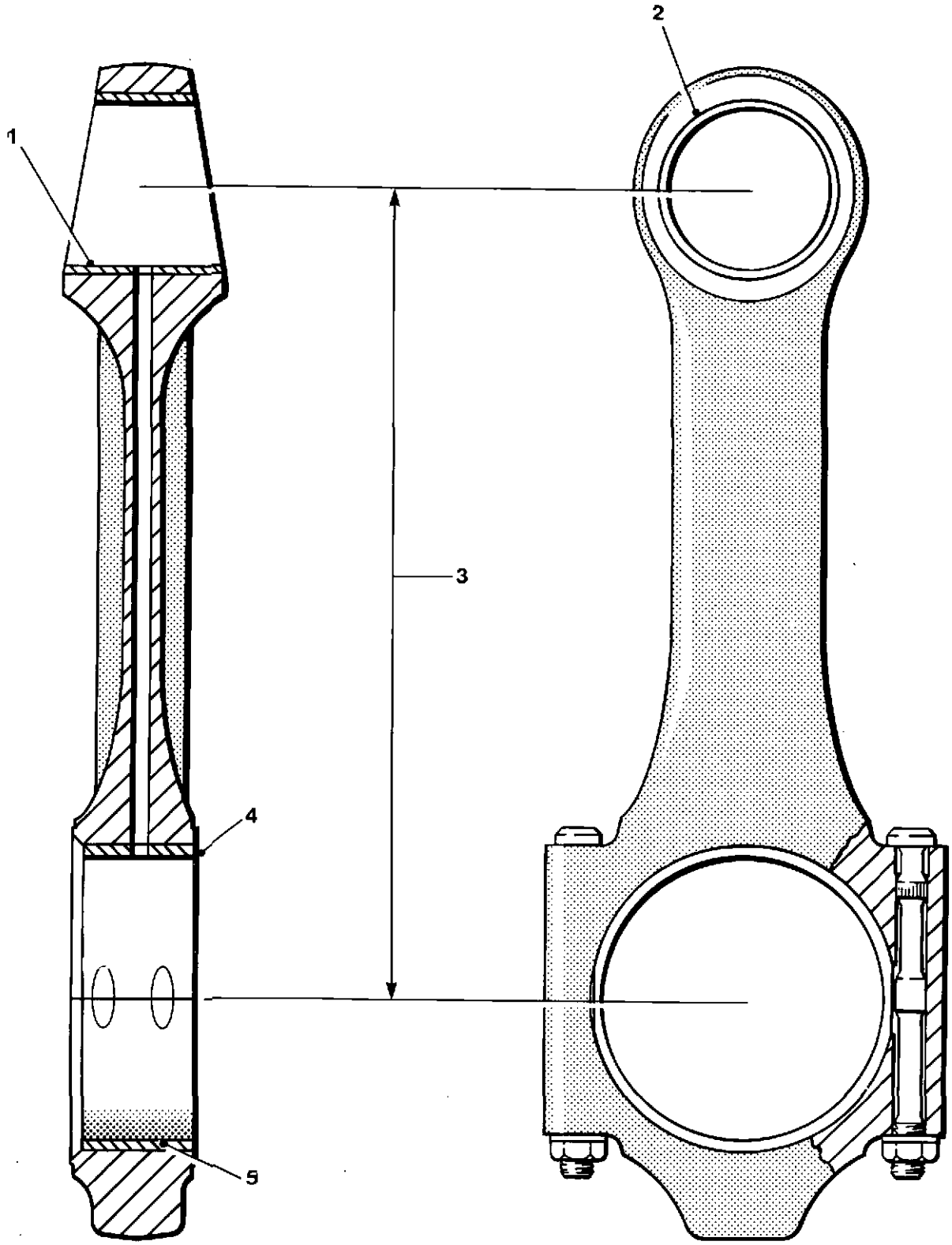
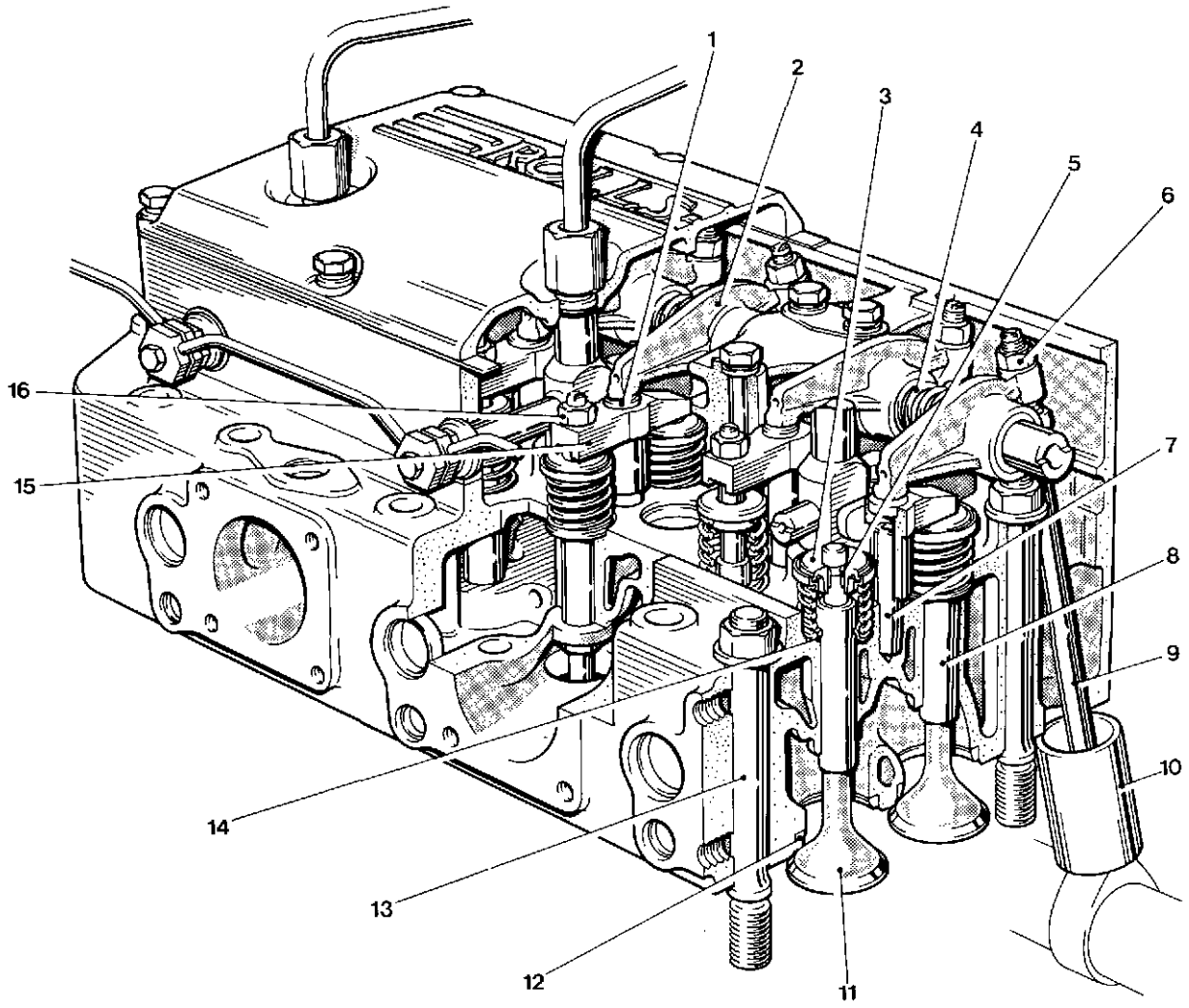


Fig. 9 Fits and clearances - Connecting rods

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	SMALL END									
1	Gudgeon pin in bush									
		55,035	2.1667							
	Bush bore	to	to							
		55,050	2.1673			0,035	0.0014			
						to	to	0,067	0.0026	Bush bored to size after being pressed into position
		54,995	2.1667			0,055	0.0022			
	Gudgeon pin diameter	to	to							
		55,000	2.1653							
2	Bush in small-end									
		60,00	2.3622			Interference				
		to	to							
		60,03	2.3633			0,042	0.0017			
						to	to			
		60,072	2.365			0,097	0.0038			
	Bush diameter	to	to							
		60,097	2.366							
	ERRORS IN ALIGNMENT									
3	Errors in alignment between big and small ends, per 25,4 mm (1 inch) of mandrel									
	Parallelism			0,025	0.001					

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	BIG-END									
4	Side clearance					0,200 to 0,400	0.008 to 0.016	0,558	0.022	Total end float for each pair of big ends between the crank webs
5	Running clearance					0,026 to 0,086	0.001 to 0.003			Check that crankpin is within the limits of of ovality

SECTION 8 - CYLINDER HEADS AND VALVE GEAR



1 Valve bridge button
2 Rocker arm
3 Valve rotator
4 Rocker shaft spring
5 Valve collets
6 Adjusting screw
7 Valve bridge guide
8 Valve guide
9 Push rod
10 Tappets
11 Exhaust valve
12 Valve seat insert
13 Cylinder head stud
14 Valve spring lower seat
15 Valve bridge
16 Adjusting screw

Fig. 1 Cylinder head assembly

SECTION 8 - CYLINDER HEADS AND VALVE GEAR

Cylinder heads may be removed individually from the engine and overhauled, whilst the engine is still connected to its associated driven unit. Under such circumstances, precautions must be taken to ensure that the starter batteries are disconnected.

Cylinder head removal

1 Drain the engine coolant, collecting the coolant in a clean container for subsequent re-use.

2 Disconnect the exhaust pipework from the elbow, as necessary, and remove the elbow and turbocharger bellows unit.

3 Remove the trunking between the radiator, air cleaner and turbocharger as appropriate. Disconnect and remove the air cleaner.

4 Disconnect and remove the coolant discharge and by-pass connections from the thermostat housings.

5 Disconnect the turbocharger oil feed and oil drain pipes. Bend back the lock washers on the turbocharger securing nuts, remove the nuts and lift the turbocharger away from the engine.

6 Bend back the lock washers on the twenty four setbolts securing the exhaust manifold assembly to the cylinder heads. Unscrew the nut securing the captive sleeve lock plate, remove the setbolts and lift the two sections of manifold away from the cylinder heads.

7 Remove the fuel injector high pressure feed pipes, governor shutdown and speed control linkages, cross shaft assembly and stop solenoid

8 Disconnect all fuel supply, spill and lubrication pipes from the pump and governor.

9 Remove the auxiliary drive coupling guard, disconnect the fuel injection pump drive coupling from the drive end flange and remove the pump securing setbolts. Using the Lifting Beam, VP 878, lift the pump and governor assembly, complete with drive coupling, away from the engine.

10 Remove the air balance pipe connecting the two induction manifolds, then remove the manifold securing setbolts and lift off the manifold assembly. Withdraw the three coolant transfer bobbins from each cylinder head.

11 Remove the injector spill return pipework from the appropriate bank, followed by the rocker cover.

12 Unscrew the injector spill connections, release the finger clamps and remove the injectors.

13 Remove the rocker box, collect the six valve bridge pieces, withdraw the six pushrods.

14 Remove the three blanking plugs to gain access to the concealed cylinder head securing setbolts.

15 Remove the twenty cylinder head securing nuts and three setbolts.

16 Using the Lifting Bracket, VP 4251, lift the cylinder head away from the engine, remove the oil restrictor bobbin from its location and discard the metal cylinder head gasket.

Note: The above lifting bracket is designed for use when the engine is in its normal operating position. When the crankcase is in the build stand and the cylinder heads are in the horizontal position, the Lifting Bracket, VP 522, must be used (see Section 3).

17 Place the cylinder head on a soft topped workbench, to avoid damage to the the flame face

Dismantling and cleaning

18 Visually check all cup plugs for signs of coolant leaks. Any suspect plugs may be removed using the appropriate cup plug kit.

19 Place the cylinder head, flame face down on the workbench and screw the Adaptor, GA 5000-1, into any convenient rocker box securing bolt hole in the cylinder head.

20 Screw the stud of the Valve Spring Compressor, GA 5000, into the adaptor, finger tight, and nip up the locknut; position the arm at a convenient height on the stud, using the two knurled locknuts.

21 Position the stirrup on the arm, directly over one of the valve assemblies (fig. 2), compress the valve spring and lift out the collets. Release the pressure on the spring and remove the upper spring seat or rotator, followed by the spring and the lower spring seat.

22 Re-position the compressor tool, as necessary, and repeat the operation until all the valve spring assemblies have been removed.

23 Turn the cylinder head on to its side and slide out all the valves.

24 Using an emulsifying solvent such as 'Pavan', thoroughly clean all the components. Heavy carbon deposits may be removed by soaking in a solution of 'Maxan' or 'Ardrox 667'.

Caution : Valve springs must not be subjected to soaking in 'Maxan' or 'Ardrox 667' as the surface finish can be adversely affected.

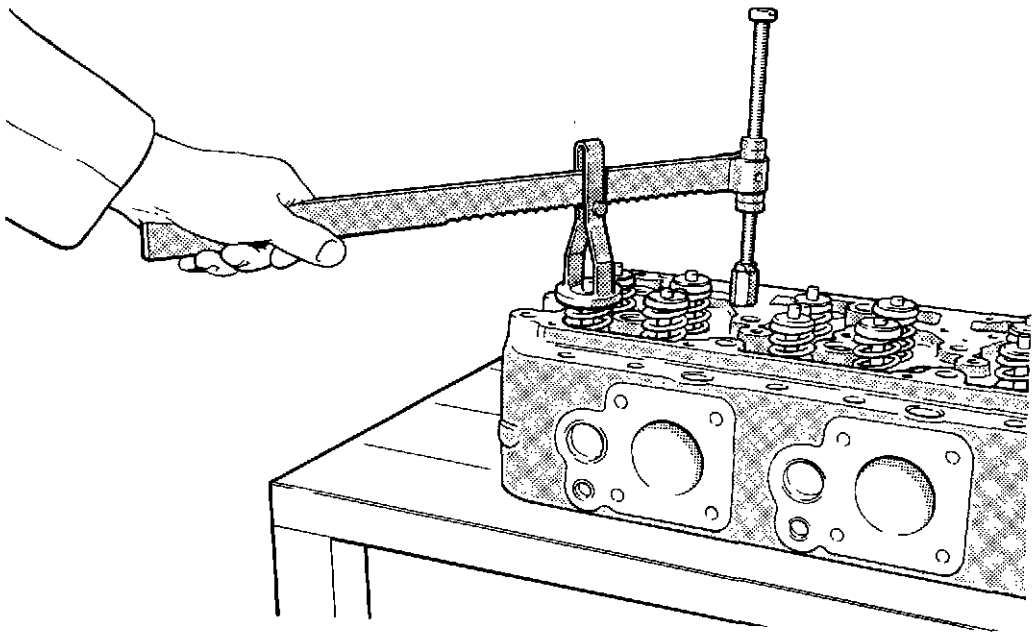


Fig. 2 Valve spring compressor

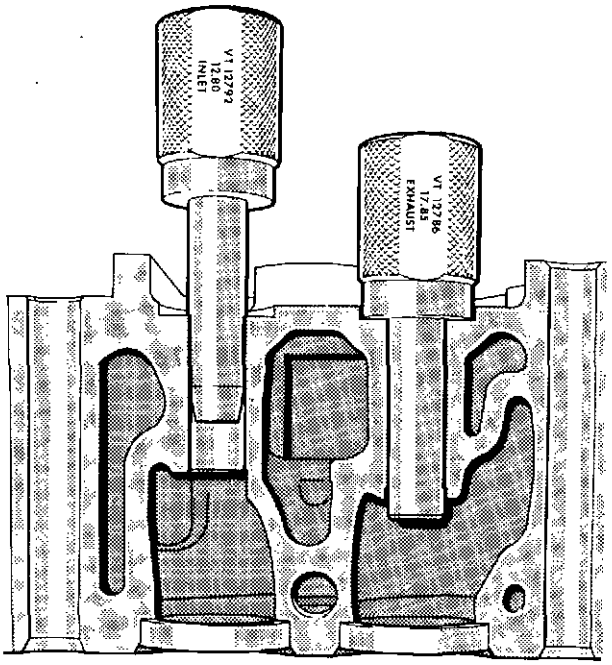


Fig. 3 Inserting valve guides

Inspection

25 The cylinder head should be subjected to a pressure test, if however any leaking cup plugs have been removed these must first be replaced.

26 Lightly coat the new plugs with 'Loctite 542' and insert them into the cylinder head using the appropriate cup plug kit, (see 'Special Tools' at the end of this Section).

27 Fit locally made blanks to all coolant apertures and connect an air supply at 207 k/N sq.m. (30 lbf/sq.inch), to the coolant galleries.

28 Immerse the cylinder head in a tank of water at 60 deg. C and check for air bubbles from around all cup plugs and injector sleeves. Renew any plugs or sleeves which are not air-tight.

29 Inspect the flame face for cracks, fretting or other damage. If necessary, the face can be reclaimed by surface grinding, in four stages, up to a maximum of 0.51 mm (0.020 inch); see S.R.S. 6, Issue 2, for the correct procedure. Etch details of any grinding on an area of the flame face not covered by the cylinder head gasket.

VALVE GUIDES

30 Check the clearance of each valve stem in its guide. This should be within the limits given in 'Fits and clearances', at the end of this Section. If the clearance appears excessive, re-check using a new valve. In the event of the clearance still being excessive a new valve guide must be fitted using the replacement tools listed at the end of the Section.

31 Press out the worn guide using the appropriate extractor. Check the cylinder head bore for wear or damage. Worn cylinder head bores may be reclaimed by following the instructions given in S.R.S. 135.

32 Coat the new guide with light machine oil before entering it into the top end of cylinder head bore.

Note: Inlet valve guides must be entered with the tapered end downwards, exhaust valve guides must be entered with the chamfered end uppermost.

33 Place the appropriate insertion tool over the guide and using a hand press, press the guide into position until the insertion tool contacts the valve spring seat landing. This will give the correct protrusions of 12.8 mm (0.5 inch) for inlet valve guides and 17.8 mm (0.7 inch) for exhaust valve guides.

34 Ream the new valve guide and check the bore with the appropriate plug gauge.

35 When new valve guides have been fitted, the associated valve seat inserts must be re-cut using the Refacing Tool, GA 5091, to ensure concentricity.

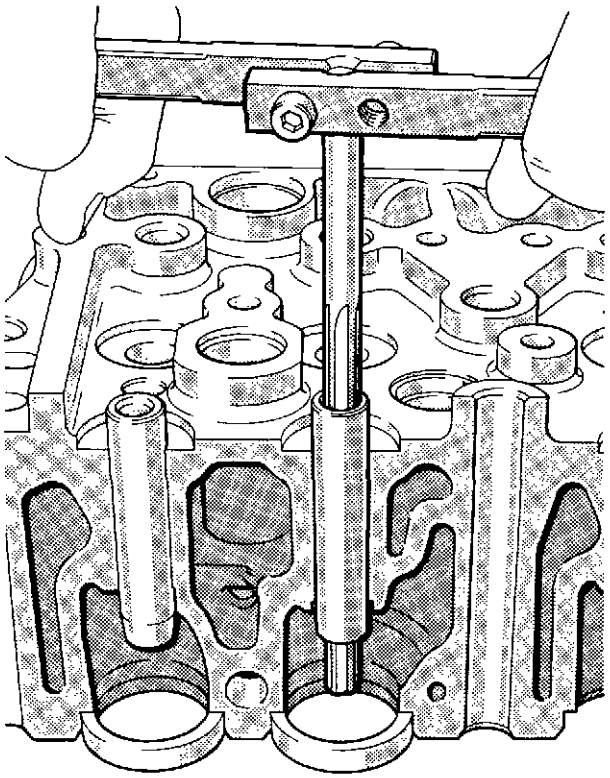


Fig. 4 Reaming the valve guide

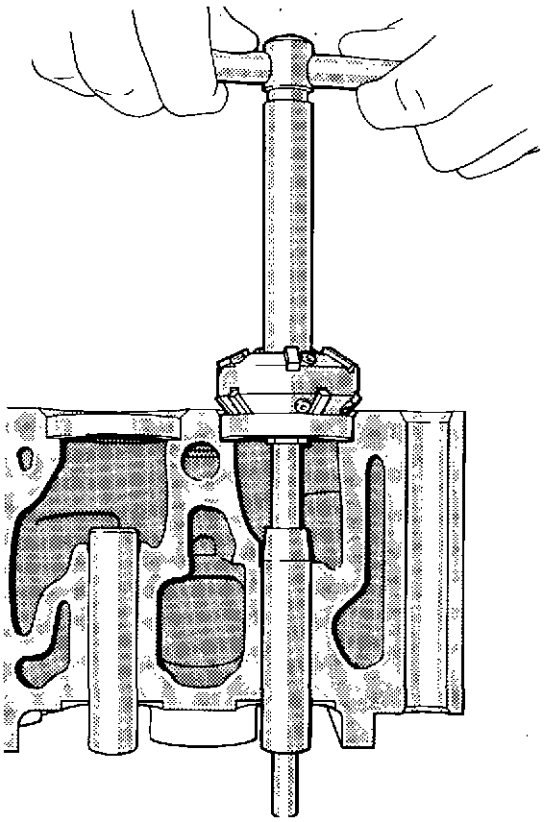


Fig. 5 Cutting valve seat insert

VALVE SEAT INSERTS

36 Inspect the inserts for pitting, cracks and valve bedding. The seating face may be restored by lapping, or in severe cases, by re-cutting the seat, as shown in figure 5. Ensure that the tool is set for the correct angle cut, (see under 'Valves' in this Section).

Note: When re-cutting a valve seat, it is important that only the minimum amount of metal is removed.

37 After re-cutting a valve seat and reconditioning the valve, (see under 'Valves' in this Section), fit the valve into the guide and check the clearance of the valve head below the flame face. If the clearance is beyond the limits specified in 'Fits and clearances' at the end of this Section, re-check, using a new valve. If this restores the clearance to within acceptable limits, a new valve must be fitted to the seat. If however the clearance is still beyond acceptable limits using a new valve, a new valve seat insert must be fitted.

Removing inserts

Note: Before an exhaust valve seat insert can be removed, the rolled over edge of the cylinder head casting must be cut away (fig. 6). A Hand Cutter, VT 13768, and Arbor, VT 13713, are available for this purpose.

38 Assuming that the relevant valve guide is in position and that it is not worn beyond the acceptable limits, turn the cylinder head on to its side and slide the dummy valve into the valve guide, until the disc is located in the valve seat insert. If the valve guide has been removed, fit the Sleeve, VT 12805, into the guide bore to centralise the dummy valve.

39 Using an arc welding kit, tack-weld the disc to the insert, in two or three equally spaced positions around the circumference of the disc, taking care not to damage the cylinder head casting.

40 Using a plastic mallet, give the end of the dummy valve stem a sharp tap, to drive out the old valve seat insert.

Note: The dummy valve may be re-used if the tack-welds are ground off and the disc dressed up after each insert removal.

Fitting new inserts

41 Valve seat inserts are available in two sizes, service and standard, the service insert being 0.05 mm (0.002 inch) larger on the outer diameter. If a service insert is to be fitted, the cylinder head recess wall must be machined prior to fitting, to maintain the correct interference fit as given in 'Fits and clearances' at the end of the Section. Before renewing inlet valve seats, see under 'Valves' in this Section.

42 The inserts should be chilled in liquid air immediately prior to fitting in the cylinder head. If this is not possible, the cylinder head must be heated in boiling water for a minimum of thirty minutes, after which the insert should be drawn into position as quickly as possible, using the valve seat Insertion Tool, VT 12803, for inlet or, VT 12804, for exhaust valves (fig. 7).

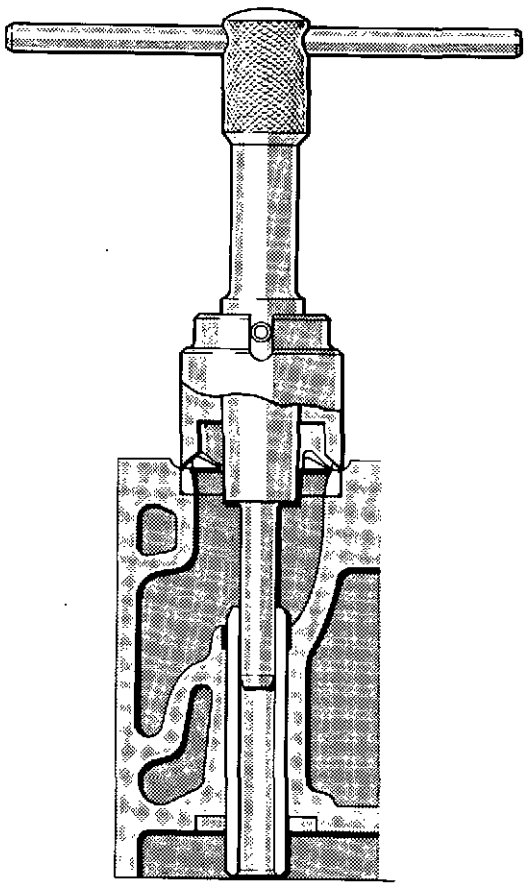


Fig 6 Cutting tool and arbor

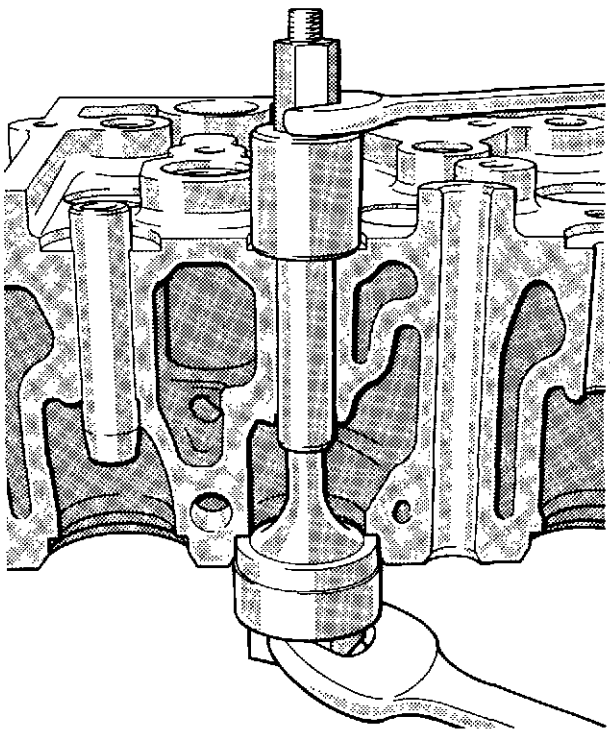


Fig. 7 Fitting insert with guide in position

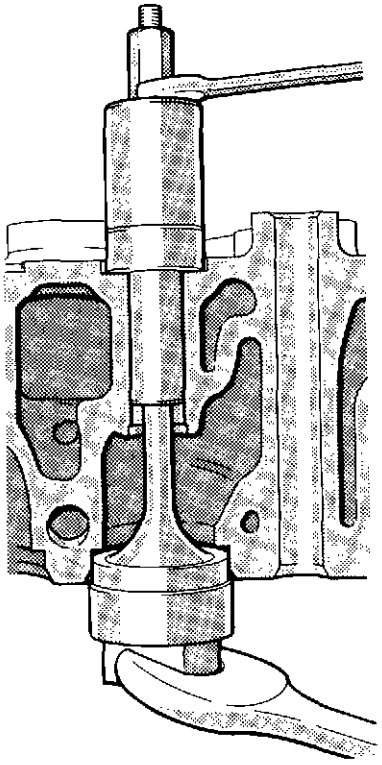


Fig. 8 Fitting insert, using sleeve

Note: If either of the relevant valve guides have been removed, the new insert must be fitted using the Insertion Tool, VT 12803, in conjunction with the Sleeve, VT 12805 (fig. 8).

43 Using a 0.04 mm (0.0015 inch) feeler gauge, check that the new insert is fully home.

If a new exhaust valve seat insert has been fitted, the edge of the cylinder head casting must be rolled over, around the periphery of the insert, as follows :

44 Position the Rolling Tool, VT 18340, in its Setting Ring, VT 18341, and slacken the roller holder securing screws and adjusting screw lock nuts (fig. 9).

45 Using the appropriate feeler gauge, adjust each roller, in turn, so that the clearance between the roller and the setting ring is 0.50 mm (0.020 inch). Tighten each roller securing screw and adjusting screw locknut.

Note: Ensure that the head of each adjusting screw is backed against the tool housing, when setting the clearance.

46 Re-check each roller clearance and reset any roller holder, if necessary, before using the tool on the cylinder head.

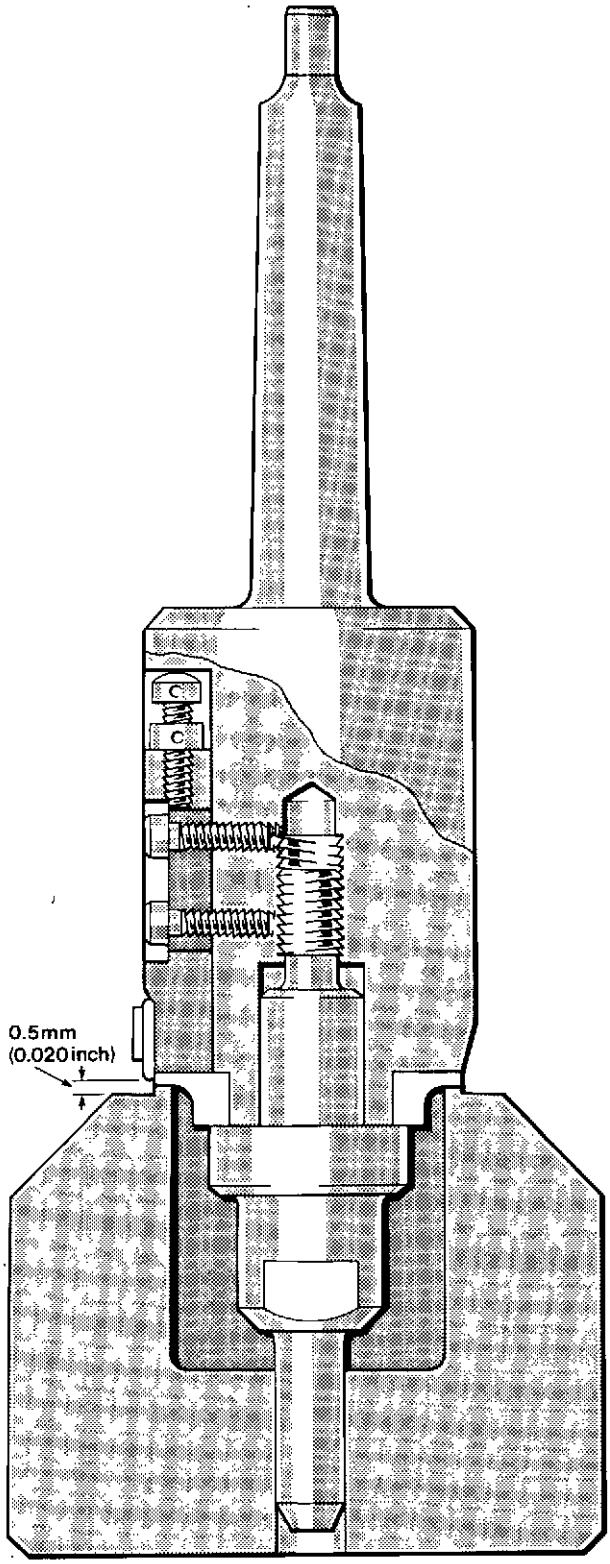


Fig 9 Rolling tool in setting ring

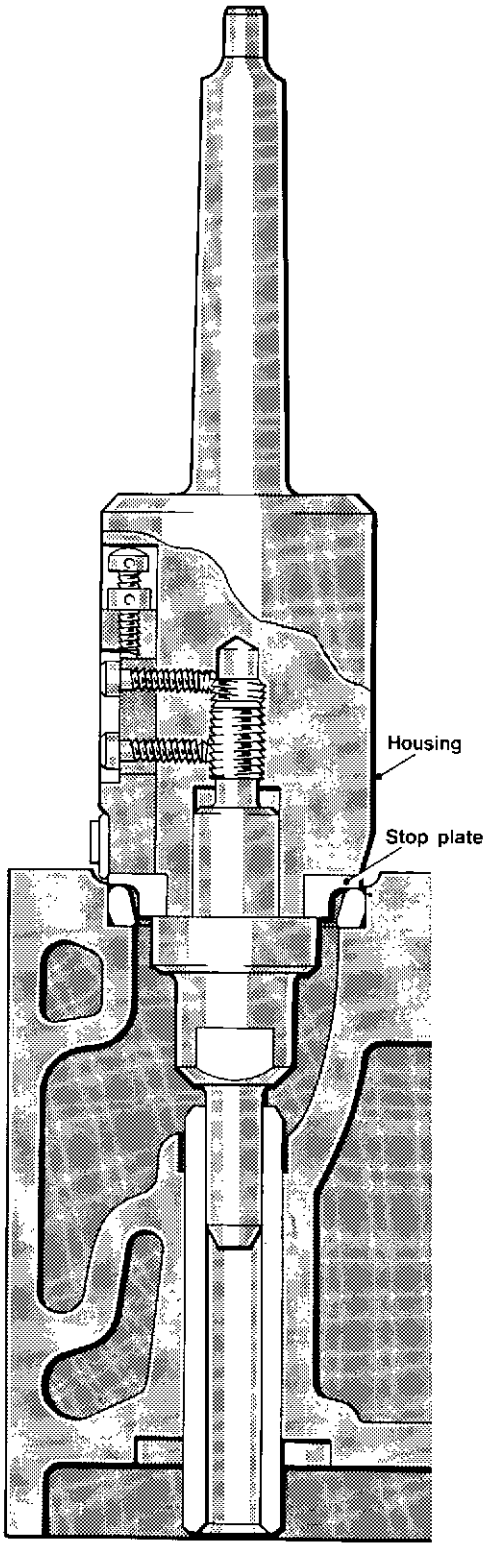


Fig 10 Rolling tool in cylinder head

Ensure that the valve guides are fitted and that the guide bores are within the limits given in 'Fits and clearances', at the end of the Section. Secure the cylinder head, flame face up, on a drill table and fit the rolling tool into the drill chuck.

47 Coat the rollers and the counterbore in the cylinder head with clean engine oil.

48 Locate the rolling tool in the valve guide and rotate slowly, applying sufficient pressure to 'spread' the cylinder head material into the valve seat insert chamfer. When the tool stop plate contacts the top face of the insert (fig. 10), the insert is fully rolled in, and the tool should be removed.

49 Cut or grind the seat to the correct angle, lap in the valve and check, using engineers marking blue, that the valves are seating around the full circumference of the contact faces.

50 Install the valve in the seat and using a straight edge and feeler gauge, check that the the clearance between the valve head and the flame face is within the limits, given in 'Fits and clearances' at the end of the Section.

VALVES

51 Thoroughly clean each valve and inspect for cracks, pitting or other damage to the valve head. Check the valve stems, collet grooves and stem tips for wear. Valve heads should be further checked for cracks using the dye penetrant method.

52 Check the valve face for 'dishing' by means of a straight edge and a feeler gauge. Scrap any valve if the clearance at the center of the valve exceeds 0.13 mm (0.005 inch).

53 Assemble each valve to the cylinder head and check its seating, lapping in the valve if necessary. Check, using engineers marking blue, that the valves are seating around the full circumference of the contact faces.

54 Using a straight edge and a feeler gauge check, that the clearance between the valve head and the flame face is within the permissible limits, given in 'Fits and clearances' at the end of the Section. If the clearance is excessive, a new valve must be fitted. If, after fitting a new valve, the clearance is still excessive, a new valve seat insert must be fitted. Insufficient clearance can be rectified by cutting the seat of the insert using the Refacing Tool, GA 5091.

55 If new valves are fitted, the cylinder number and valve position should be etched on each valve, above the collet groove, on the valve stem. Valves must not be stamped or pop marked, as this may initiate cracking.

Note :
If severe bedding or wear is experienced on the earlier type 45 deg. inlet valves and valve seat inserts, it is recommended that the valves and seat inserts be replaced by the later 30 deg. versions. These components must be renewed in sets.

VALVE SPRINGS

56 Check each valve spring for wear, damage and corrosion. Measure the free length and length under load, as specified in 'Fits and clearances' at the end of the Section. Scrap any spring which is unsatisfactory.

57 Renew springs in pairs beneath their associated bridge piece. Old and new springs must not be mixed on paired valves as this can cause wear to the valve bridge and guide.

Note : Ensure that new springs are correct for the engine, before fitting.

VALVE ROTATORS

58 Check the rotators for cracks and other damage, and ensure that the parts rotate freely, relative to each other.

59 Inspect the exhaust valve stem tips. If the wear pattern indicates that a valve has not been rotating, the rotator for that valve must be renewed even if it appears to be serviceable.

Note: Rotators are fitted in place of the upper spring seat on exhaust valves only

VALVE BRIDGES AND BRIDGE GUIDES

60 Inspect the valve bridges and adjusting screws for wear. Check the bridge bores using a new bridge guide as a gauge, similarly, check the bridge guides using a new valve bridge as a gauge. Renew any components which show excessive slackness.

61 Using the Extractor, GA 5123, withdraw any worn valve bridge guide (fig. 12), and clean out its cylinder head bore.

62 Lightly coat any new valve guides with machine oil and insert into the cylinder head using a hand press. To obtain the correct protrusion, each guide must be pressed into its bore until the top face is flush with the top face of the insertion sleeve.

PUSHRODS

63 Examine the ends of each pushrod for wear and damage and check each rod for 'bowing'. Any pushrod with a run of more than 0.2 mm (0.008 inch) over its overall length, must be renewed.

INJECTOR SLEEVES

Reconditioning injector sleeves

56 Using the Reamer, GA 5020, with Face Cutter, GA 5020-2, remove any build-up of carbon or damage to the seating face and nozzle of the sleeve.

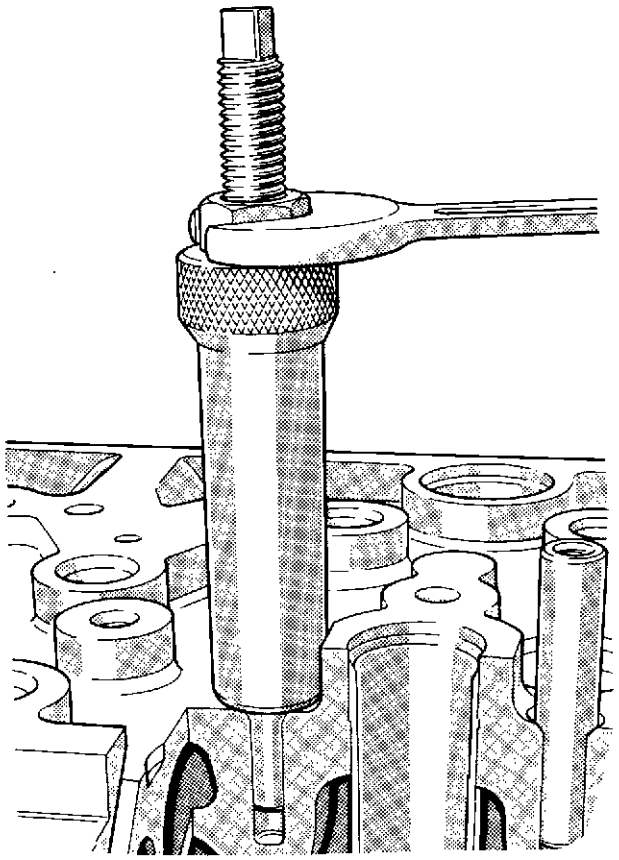


Fig. 11 Withdrawing valve bridge guide

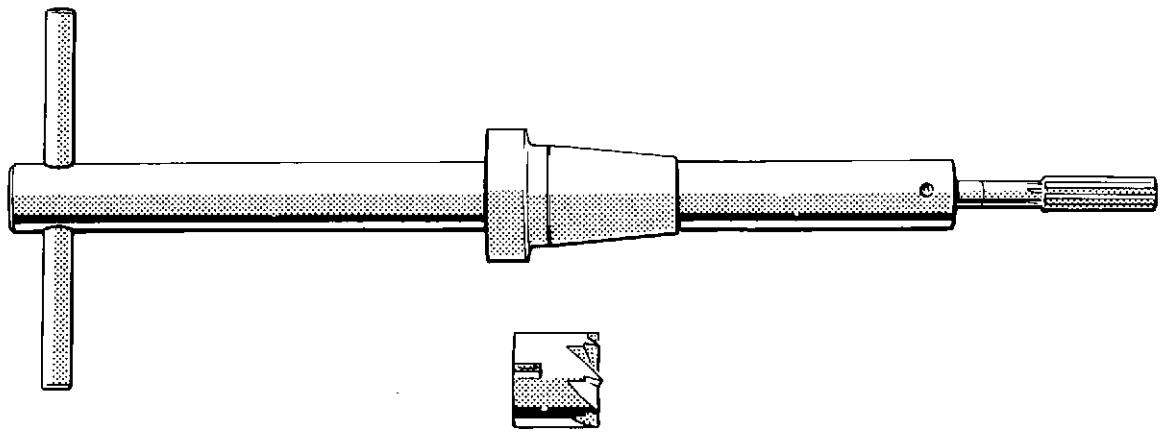


Fig. 12 Injector sleeve reamer and face cutter

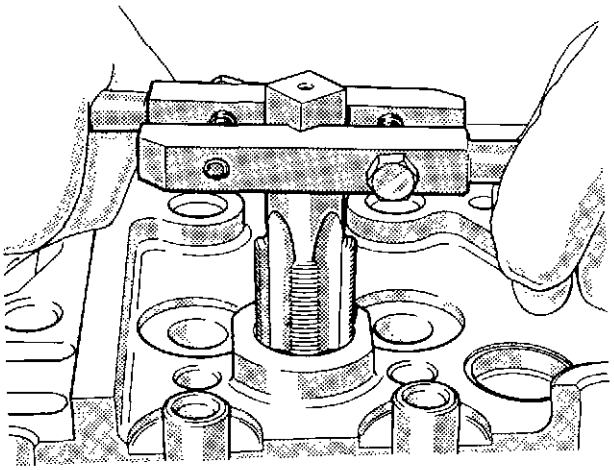


Fig. 13 Tapping injector sleeve

Caution : When using the seating face cutter (fig. 12), remove the minimum amount of metal necessary to restore the seating face. The maximum permissible depth of seating measured from the cylinder head top face is 104.25 mm (4.104 inches).

Renewing injector sleeves

Any sleeve which has been re-cut beyond the limit, or has been damaged, or is is leaking from the expanded joints and cannot be rectified by further expansion of the sleeve ends, must be renewed as described below.

57 Using the Tap, GA 5023, cut a thread in the sleeve (fig. 13), to a depth of at least 25 mm (1 inch).

58 Run the nut of the Extractor, GA 5022, to the top of its thread and run the stud fully into the injector sleeve tapping.

59 Tighten the nut down against the thrust face/housing assembly and draw out the injector sleeve.

60 Clean out the cylinder head bore and the sleeve expansion groove. Fit the new service sleeve into the pocket, ensuring that the new sleeve is fully home.

61 Rest the cylinder head, flame face down, on parallel supports on the bed plate of a hand press. Ensure that the supports are deep enough to allow the Expander Tool, VT 10601, to clear the bed plate.

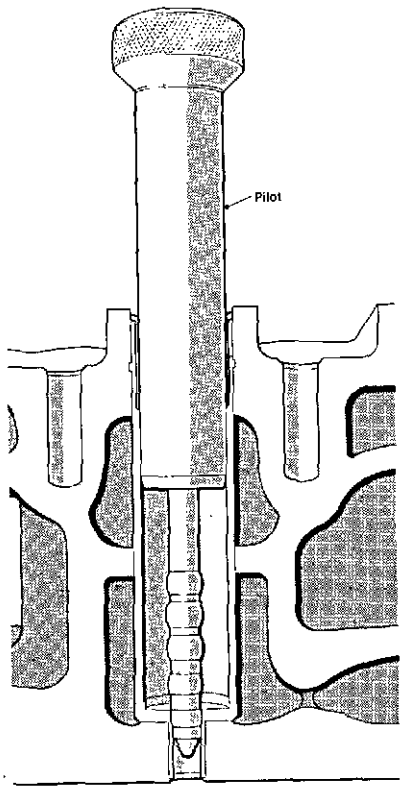


Fig. 14 Expanding injector sleeve nozzle

62 Smear the 'Ballizing' section of the tool with grease and slide the tool into the injector sleeve (fig. 14). Slowly press the tool down until the pilot reaches the injector seating face. Remove the 'Ballizing' section of the tool from beneath the flame face. The pilot section may be withdrawn from the top.

When the injector sleeve nozzle has been been expanded, the top of the injector sleeve must be rolled out using the Expander Tool, GA 5026, (fig. 15).

63 Insert the roller housing in the injector sleeve, with the shoulder resting on the cylinder head top face.

64 Slide the tapered shaft through the roller housing and, using a suitable socket spanner and speed brace, rotate the shaft, whilst applying a steady pressure on the end of the shaft.

65 Keep a continual check on the rolling out process. When the injector sleeve is rolled out sufficiently, a band of different coloured metal, where the sealing groove encircles the sleeve, will become visible.

CYLINDER HEAD ASSEMBLING

66 Oil the valve stems, fit each valve into its guide, then carefully lower the assembly on to the workbench, flame face down.

67 Place the lower spring seat, spring and spring retainer or valve rotator, as applicable, over each valve stem.

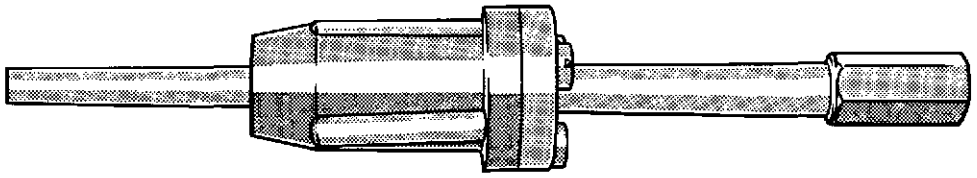


Fig. 15 Injector sleeve Expander Tool, GA 5026

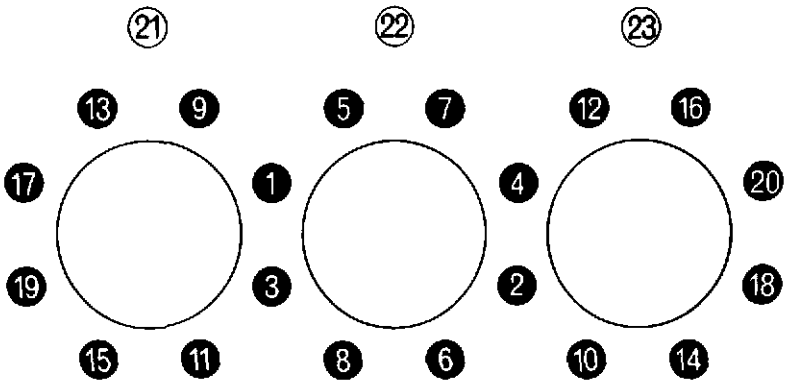


Fig. 16 Cylinder head tightening sequence

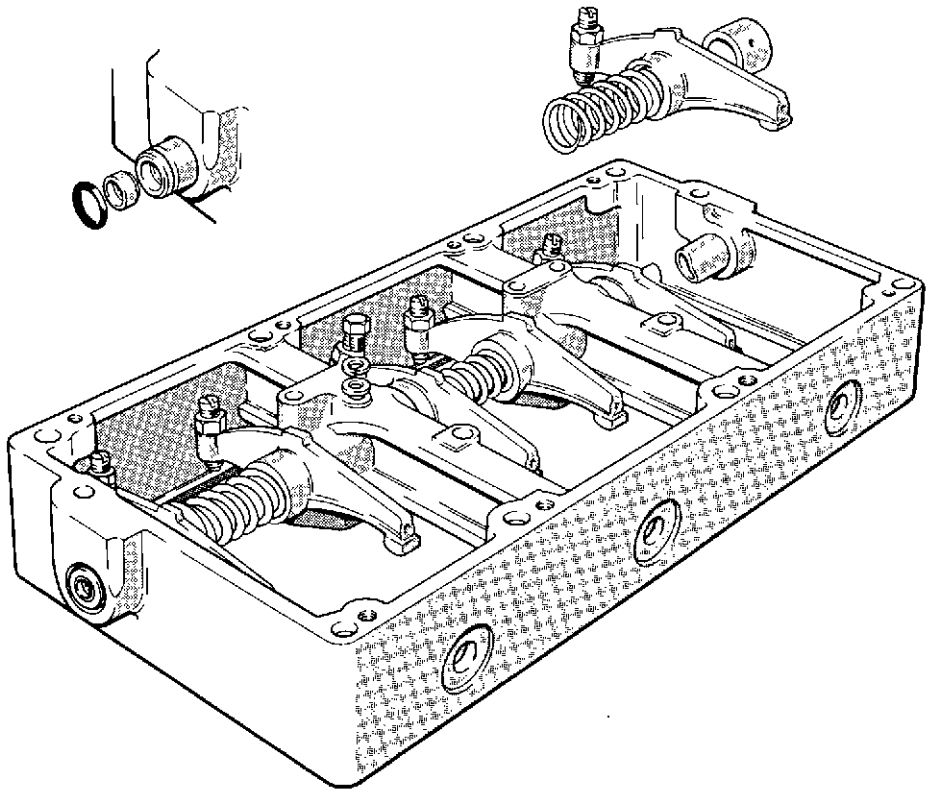


Fig. 17 Rocker box assembly

68 Fit the Valve Spring Compressor, GA 5000, into a convenient tapped hole, as previously described, with the stirrup over a valve spring assembly.

69 Compress the valve spring and fit the collets into valve stem locating groove. Release the valve spring carefully, check to ensure that the collets are correctly seated, then proceed to the next valve.

When all the valve assemblies are in place, fit the valve bridge pieces on to the bridge guides and set the adjustment as detailed in Section 3.

ROCKER BOX ASSEMBLY

Dismantling

70 If applicable, withdraw the cup plug from the rocker box shaft bore.

71 Remove the rocker shaft locating setbolt and push the shaft to the left, viewed from the outer edge of the box, until the 'O' ring seal can be removed from around the shaft. Continue withdrawing the shaft, lifting out each rocker arm and spring as it becomes free.

72 Where no cup plug is fitted in the rocker box shaft bore, push the shaft in either direction sufficiently to remove one 'O' ring seal from around the shaft, then push the shaft in the opposite direction to release the second 'O' ring.

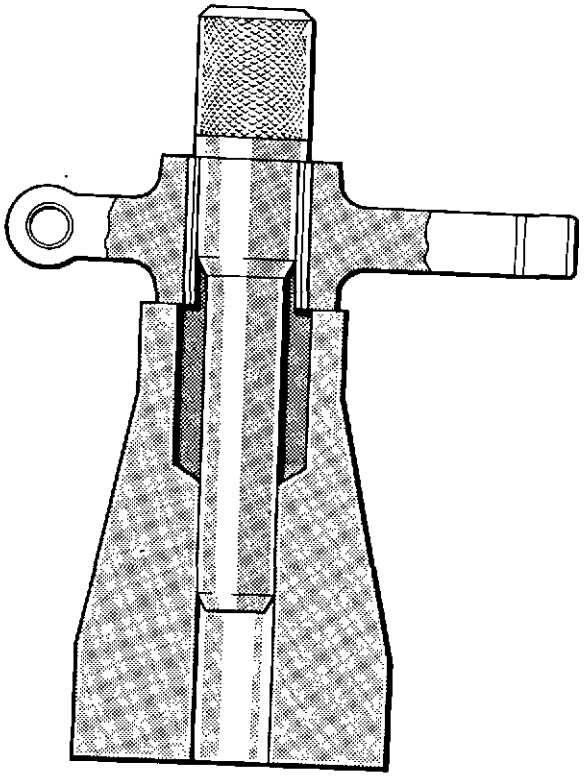


Fig. 18 Removing rocker arm bush

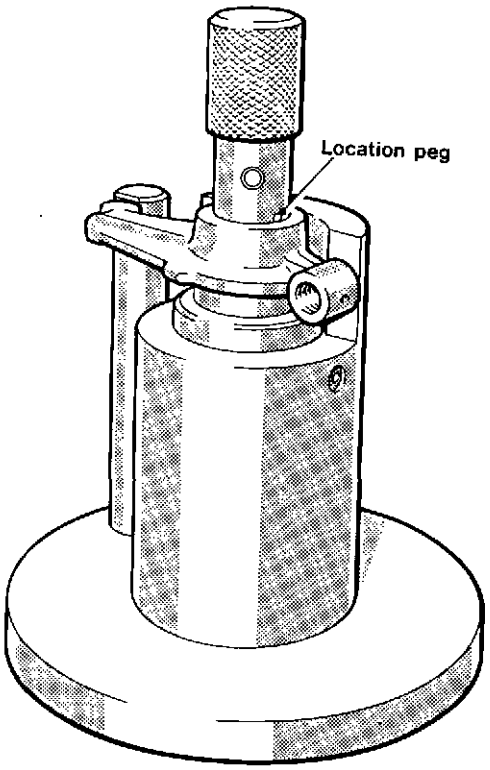


Fig. 19 Inserting rocker arm bush

73 Continue withdrawing the shaft, removing the rocker arms and springs as previously described.

Cleaning and inspection

74 Remove any grease and dirt from the components, using an emulsifying solvent, then wash and dry each item before inspection.

75 Inspect the rocker shaft for wear or damage around the rocker arm locations. If noticeable wear is detected, renew the shaft.

76 Fit each rocker arm on to the shaft and check the clearance in the rocker arm bush. If the clearance is excessive, drive out the bush using the Removal Tool, VT 12814, (fig. 18) and a hand press.

77 Check the rocker arm bore for scoring or other damage and, using the Insertion Tool, VT 10693, (fig. 19) and a hand press, fit a new bush into the rocker arm as described below.

78 Position the bush on the tool spindle, with the cut-out in the bush locating on the small peg. This ensures correct positioning of the oil hole in the bush.

79 Place the cap of the tool over the spindle and press the bush into the rocker arm bore, until the cap contacts the side face of the rocker arm.

Replacement bushes are pre-finished and do not require reaming during rocker gear assembling

80 Smooth any slight ridges on the rocker arm pads using a fine oil stone, ensuring that the finished surface is at 90 deg. to the sides of the pad.

Assembling the rocker box

81 If applicable, check the cup plug bore in the end of the rocker box for cleanliness. Coat a new cup plug with 'Loctite 542' and press the plug in, flush with the rocker box end wall.

82 Coat the rocker shaft with clean engine oil and insert the open end of the shaft into the rocker box bore, ensuring that the oil inlet hole in the shaft is facing directly donwards (towards the cylinder head).

83 Push the shaft through the end wall far enough to fit the first rocker arm on to the shaft. Continue pushing the shaft through the box and fit the spring and the second rocker arm, before the shaft enters the first pedestal. Fit the remaining arms and springs in correct sequence.

84 Before pushing the shaft fully home fit the 'O' ring seal around its groove in the shaft. Push the shaft in further until the locating bolt hole in the shaft is aligned with the tapped hole in the pedestal. Fit the locating bolt, with plain and spring washers, and tighten securely.

85 For rocker boxes with no cup plug in the shaft bore, enter the shaft in the bore from either end, with the oil inlet hole facing downwards. Fit the rocker arms and springs in correct sequence and before the shaft is fully home, fit a new 'O' ring seal in the groove in the outer end of the shaft.

86 Carefully push the shaft through the bore until the groove at the opposite end is just clear of the rocker box end wall. Fit the second 'O' ring seal and press the shaft back into its operating position. Ensure that the locating holes are aligned, fit the locating setbolt, with plain and spring washers, and tighten securely.

CYLINDER HEAD FITTING

87 Check all joint faces for cleanliness and ensure that the locating dowels in the crankcase top face are serviceable.

88 Fit the oil transfer bobbin, with a new 'O' ring seal, into its recess in the crankcase top face and position a new cylinder head gasket over the cylinder head studs.

89 Using the appropriate lifting bracket, lower the cylinder head assembly over the studs and fit washers and/or engine lifting brackets, as applicable, over the protruding stud threads. Screw the securing nuts on to each stud and fit the three setbolts in the induction manifold bolt holes.

90 Tighten each setbolt and nut in steps of 50 Nm (37 lbf.ft.), in the sequence shown in figure 16, until the correct torque loading is achieved

91 Lightly coat the valve bridge guides with 'Molyslip' and, with the adjusting screws and locknuts slackened off, place each bridge piece on to its guide with the adjusting screw nearer the outer edge of the cylinder head.

92 In turn, press down firmly on the centre of each bridge piece and turn the adjusting screw until it is felt to just touch the valve stem tip. Turn the screw a further 60 deg. ($^1/_6$ of a turn) and tighten the locknut to a torque loading of 40 Nm. (30 lbf/ft.)

Caution : It is important that no side load is placed on the valve stems when tightening the adjusting screw locknuts.

93 Fit the rocker box, with a new jointing gasket, to the cylinder head and adjust the tappet clearances, as detailed in Section 3.

94 Refit any components previously removed, in the reverse order to dismantling, checking fits and clearances where applicable.

SPECIAL TOOLS

Part Number	Description
GA 5100	Inertia extractor
GA 5100-1	Adaptor, fuel injector, use with GA 5100
GA 5100-10	Extractor, alloy bobbin
VP 522	Lifting bracket, cylinder head (vertical lift)
VP 4251	Lifting bracket, cylinder head (30 deg. lift)
GA 5000	Valve spring compressor

Part Number	Description
GA 5000-1	Adaptor, use with GA 5000
GA 5000-2	Stirrup, use with GA 5000
GA 5100-6	Extractor, cup plug, use with GA 5100
GA 5101	Drive handle
GA 5101-5	Insertion kit, cup plugs, use with GA 5101
GA 5122	Extractor, valve guide (inlet)
GA 5123	Extractor, valve guide (exhaust)
GA 5124	Insertion tool, valve guide (inlet)
GA 5125	Insertion tool, valve guide (exhaust)
VT 14049	Refacing tool, valve seat insert
VT 13768	Cutter, rolled edge, exhaust valve insert
VT 13713	Arbor, use with VT 13768
VT 12805	Sleeve, use with valve guide removed
GA 5131	Extractor, valve seat insert (Dummy valve)
VT 12803	Insertion tool, inlet valve seat
VT 12804	Insertion tool, exhaust valve seat
VT 18340	Rolling-in tool, exhaust valve insert
VT 18341	Setting ring, use with VT 18340
GA 5126	Extractor, valve bridge guide
GA 5127	Depth plate, valve bridge guide
GA 5023	Tap, injector sleeve
GA 5022	Extractor, injector sleeve
*VT 10601	Expander, injector sleeve nozzle
GA 5026	Expander, injector sleeve top
GA 5020	Reamer, injector sleeve nozzle
GA 5020-2	Facing tool, injector sleeve, use with GA 5020
VT 12814	Removal tool, rocker arm bush
VT 10693	Insertion tool, rocker arm bush

* **Note** : To enable an injector sleeve to be renewed, whilst the cylinder head is still attached to the crankcase, the Nozzle Expander, GA 5121, is available. This tool must be fitted to the new injector sleeve before it is inserted in the cylinder head, and the nozzle expanded by drawing the 'ballizer' upwards and out of the sleeve. The top of the sleeve must be expanded as described in the text.

SERVICE RECLAMATION SCHEMES

S.R.S. 6	Reclaiming cylinder head flame face
S.R.S. 135	Reclaiming valve bridge guide bore

FITS AND CLEARANCES - CYLINDER HEADS AND VALVE GEAR

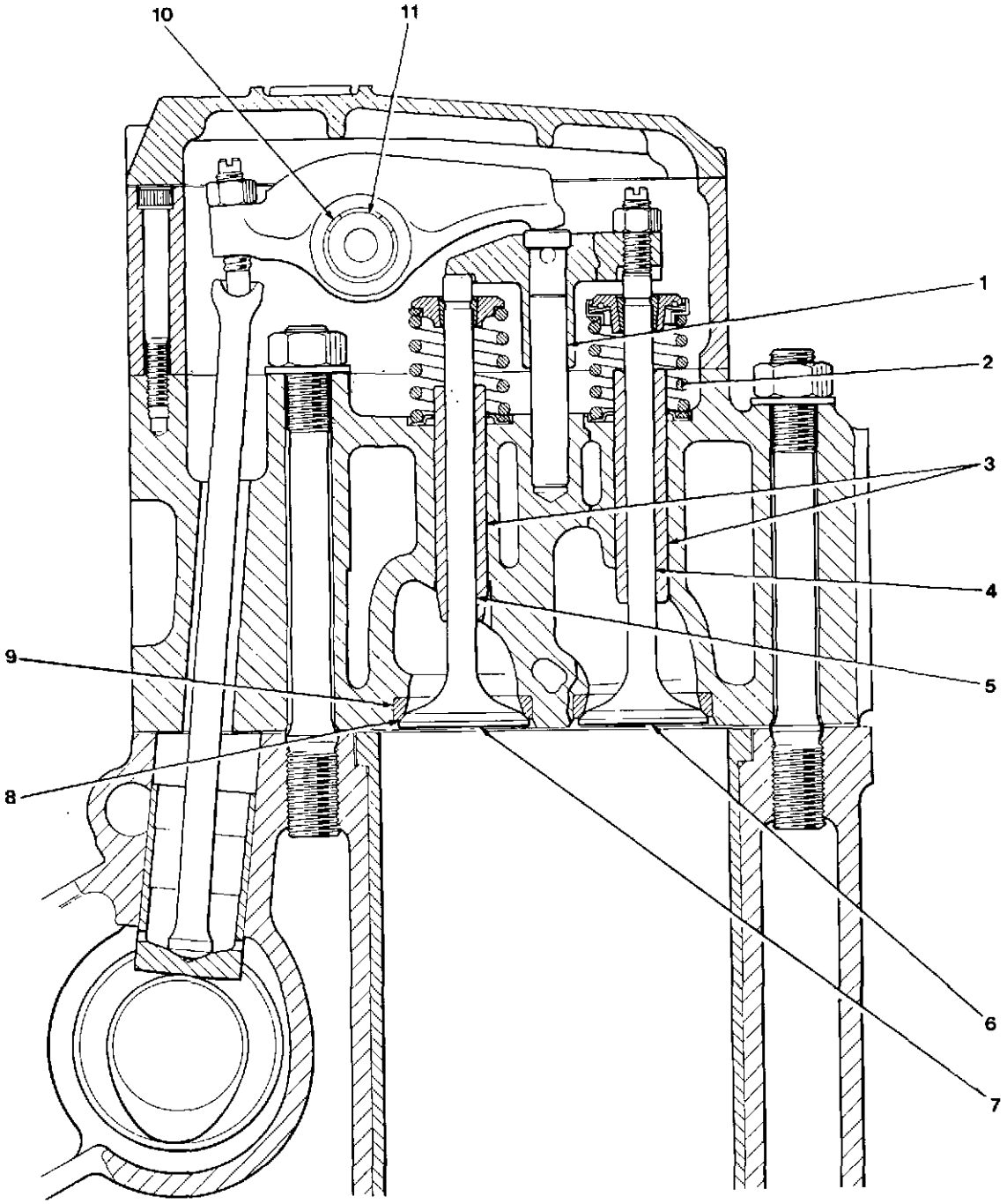


Fig. 20 Fits and clearances - Cylinder heads and valve gear

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	VALVE BRIDGES ON VALVE BRIDGE GUIDES									
1	Valve bridge bore	12,755 to 12,780	0.5021 to 0.5031			0,016 to 0,052	0.0006 to 0.002	0,10	0.004	
	Valve bridge guide diameter	12,728 to 12,739	0.5011 to 0.5015							
	VAVE SRINGS									
2	Free length (Nominal)	47,066	1.853	44,713	1.76					
	Load when compressed to 26,87 mm (1.0580 in)	0,571 kN to 0,5605kN	114 lbf to 126 lbf							
	VALVE GUIDES									
	Cylinder head valve guide bore	18,00 to 18,02	0.7086 to 0.7094			Interference 0,008 to 0,041	0.0003 to 0.0016	Interference 0.008	0.0003	
	Valve guide external diameter	18,028 to 18,041	0.7097 to 0.7102							

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	VALVES IN GUIDES									
5	Inlet valve stem diameter	9,4645 to 9,842	0.3725 to 0.0034			0,043 to 0,086	0.0016 to 0.0034	0,19	0.0075	Belling at lower end of guide bore not to exceed 0.051 mm (0.02 inch) on diameter
	Inlet valve guide bore	9,525 to 9,550	0.3749 to 0.3759							
4	Exhaust valve stem diameter	10,930 to 10,947	0.4203 to 0.4309			0,051 to 0,093	0.002 to 0.0036	0,20	0.008	Belling at lower end of guide bore not to exceed 0,051 mm (0.02 inch) on diameter
	Exhaust valve guide bore	10,998 to 11,023	0.4329 to 0.4339							
	VALVE IN SEATING									
7	Clearance below flame face Inlet valves					1,000 to 1,320	0.0393 to 0.0519			
6	Clearance below flame face Inlet valves					1,003 to 1,383	0.395 to 0.0544			

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	VALVE SEAT INSERTS									
8	Angle valve seat									
	Inlet	30 deg.								
	Exhaust	30 deg.								Late engines
		45 deg.								
9	Cylinder head	48,00	1.889			Interference				
	insert bore	to	to							
		48,016	1.890			0.038	0.0015			
						to	to			
		48,054	1,8919			0,065	0.0025			
	Insert diameter	to	to							
		48,065	1,8923							
	ROCKER ARMS									
		26,193	1.0312			Interference				
10	Rocker arm	to	to							
	bush bore	26,224	1.0324			0,040	0.0015			
						to	to			
		26,264	1.034			0,096	0.0037			
	Bush diameter	to	to							
		26,289	1.035							
		22,212	0.8745							
11	Rocker arm bush	to	to							
	shaft bore	22,225	0.875			0,026	0.0011			
						to	to	0,13	0.005	
		22,174	0.8729			0,051	0.0021			
	Shaft diameter	to	to							
		22,186	0.8734							

SECTION 9 - WHEELCASE AND TIMING GEARS

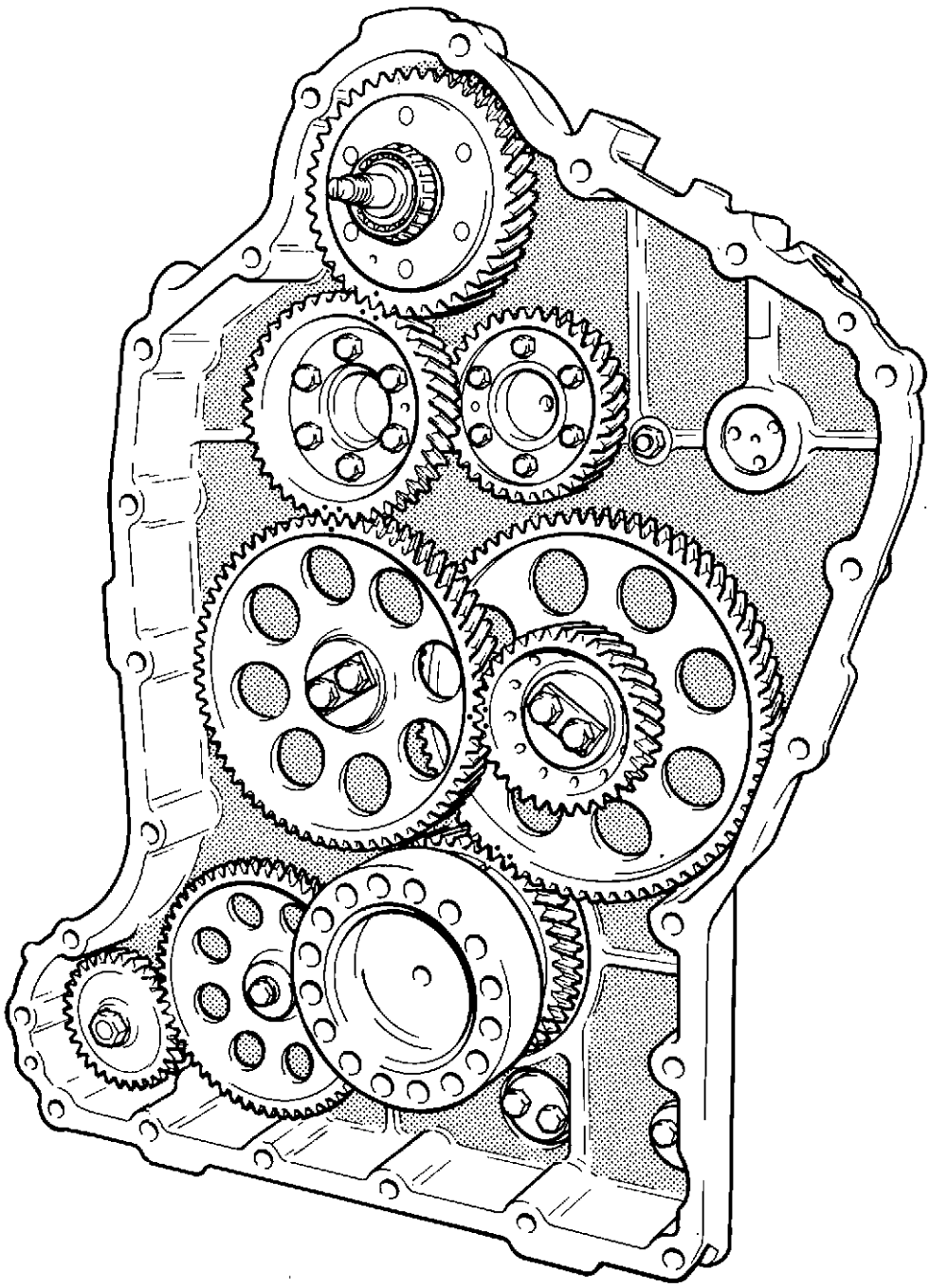


Fig. 1 Main gear train

SECTION 9 - WHEELCASE AND TIMING GEARS

WHEELCASE

Description

Protection for the main gear train is accomplished by means of a two section housing, the wheelcase proper, and the flywheel housing.

The wheelcase, of high duty cast iron, is bolted to the rear end wall of the crankcase, and provides mounting points for the fuel spill block, starter motor and coolant pump. The flywheel housing, of similar material, is bolted to the wheelcase and provides support for the auxiliary drive shaft end bearing, and a mounting point for the fuel feed pump.

Location of the assembly is by a large dowel and idler gear axles in the wheelcase.

TIMING GEARS

Description

The main gear train consists of the crankshaft drive gear, compounded idler, main idler, coolant pump idler, fuel pump drive gear, auxiliary drive gear and the two cam phasing gears, the fuel pump drive being mounted in tandem with the 'B' bank cam phasing gear.

The idler gear axles are secured to the crankcase rear end by setbolts, with the gear wheel end float being controlled by thrust washers.

Timing marks on the crankshaft, compounded idler, main idler, fuel pump drive, auxiliary drive and cam phasing gears are provided to ensure correct fuel injection and valve timing during engine operation.

Removal

To gain access to the gears, the engine must first be disengaged from its driven unit and radiator, and mounted in a build stand. This will entail the removal of the fan, air cleaners and support brackets, air ducting, coolant pipework and coolant gallery covers, as detailed in Section 2 - Dismantling the engine.

1 Remove the starter motor.

2 Open the timing cover on the flywheel housing and unscrew the timing

pointer.

3 Remove two of the flywheel securing socket capscrews on horizontally opposite sides of the flywheel. Screw in the two Guide Studs, GA 5060, remove the remaining socket capscrews and slide off the clamping ring. Ease the flywheel away from the crankshaft and, using the Lifting Bar, VP 517, lift the flywheel clear. Remove the guide studs.

4 Disconnect the fuel pipework from the feed pump and spill block assemblies, remove the auxiliary drive guard and disconnect the lubricating oil supply pipe between the crankcase and fuel feed pump.

5 Remove the feed pump mounting assembly and unscrew the cam retaining nut from the auxiliary drive shaft. Withdraw the feed pump drive cam.

6 Disconnect and remove the fuel injection pump as described in Section 2.

Before dismantling the engine any further, check the backlash of the auxiliary drive gear as described in Section 3.

7 Unscrew the drive flange retaining nut from the inner end of the auxiliary drive shaft (fig. 2), remove the plain washer and, using the Puller, GA 5090, and two Bolts, GA 5090-2, withdraw the flange; lift out the Woodruff key.

8 Unscrew the four oil seal housing securing setbolts, lift off the housing *and retain the laminated shim pack.*

9 Remove two securing setbolts from horizontally opposite holes in the flywheel housing, screw the two Guide Studs, GA 5058, into the bolt holes and, using the engine rear end lifting bracket, slide the flywheel housing clear of the wheelcase. Retain the roller race and the outer sleeve from the auxiliary drive shaft outer bearing. Remove and discard the crankshaft rear end oil seal.

10 Withdraw the auxiliary drive shaft assembly from the wheelcase. Remove the two outer bearing sleeves from the wheelcase and flywheel housing, and remove and discard the drive shaft oil seal.

11 Remove the six gear retaining setbolts from the auxiliary drive gear, and withdraw the gear from the shaft spigot.

As the dismantling proceeds, check the backlash of each gear, as described in Section 3. To check the cam gear backlash, the rocker boxes must be removed to release the valve spring tension.

If it is necessary to examine the lubricating oil pump gearing, the sump and sump adaptor must first be removed.

12 Slacken back the coolant pump gear retaining nut, one or two turns. Remove the four nuts and spring washers from the pump securing studs and lift the pump clear of the wheelcase. Remove the gear retaining nut and, using the Puller, GA 5090, withdraw the gear from the pump shaft.

13 Unscrew and remove the securing setbolt and spring washer from the coolant pump idler gear axle. Lift off the gear wheel and axle assembly.

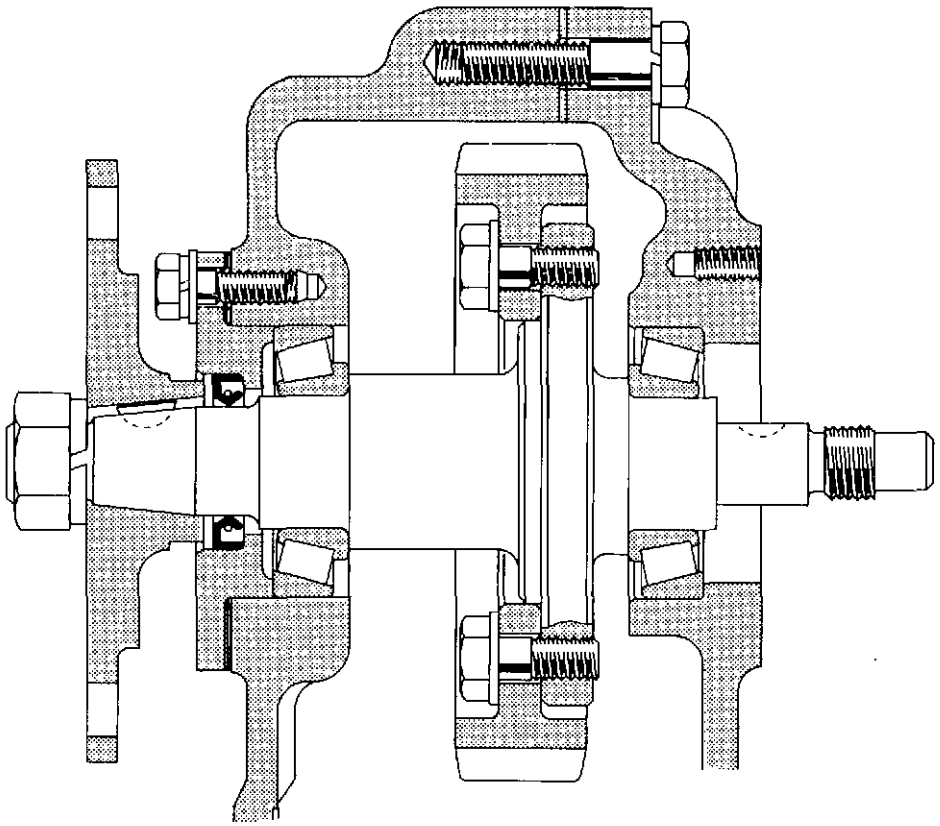


Fig. 2 Auxiliary drive assembly

14 Secure the Barring Adaptor, VT 11144, to the crankshaft rear end face and turn the crankshaft sufficiently to allow the six securing setbolts in each camshaft gear to be slackened.

15 Turn the crankshaft until the cam gear locating dowels are facing away from each other, remove the retaining setbolts and gently lever the fuel pump drive gear and the two cam drive gears off the ends of the camshafts.

16 Bend back the tabs of the setbolt locking plates on the main idler gear, unscrew the setbolts and remove the axle assembly and gear wheel.

17 Remove the compounded idler gear and axle assembly in the same manner, unscrew the 12 setbolts from the large gear and separate the two gears.

18 Remove two securing setbolts from horizontally opposite sides of the wheelcase and fit two locally made guide studs into the bolt holes.

19 Using the Lifting Hook, VP 8754, support the wheelcase and remove the remaining setbolts and nut. Ease the wheelcase off its locating dowels and lift it clear of the crankcase.

Cleaning and inspection

20 Clean the wheelcase and flywheel housing in a non-caustic degreasing solution. Remove all traces of gasket material and check the joint faces and oil seal housing for damage.

21 Wash all the gears in paraffin, remove all traces of thread sealing compound and examine the teeth for wear.

Wear on the tooth profile is acceptable provide that there is no sign of pitting, and that the backlash is within the permissible limits.

22 Crack test all gears, using the electro-magnetic method, if possible.

23 Check the idler gear bushes and axles for wear. New bushes may be fitted using the tools listed at the end of the Section. Replacement bushes are pre-finished and require no further treatment after fitting.

24 Check the idler gear end floats and inspect the thrust washers. Thrust washers must be renewed if the oil grooves begin to disappear in the thrust faces.

Assembling compounded idler gear

25 Ensure that the two gears are clean and dry. Locate the larger gear on the spigot of the small gear, and tap in the locating dowel. Coat the threads of the 12 securing setbolts with 'Loctite 241' and insert the setbolts, with plain washers, into the bolt holes. Tighten each setbolt to a torque loading of 40 Nm (30 lbf.ft.).

Note: If the gear bush needs renewing, it may be more convenient to carry out this operation whilst the two gears are separated.

Assembling auxiliary drive gear

26 Position the gear ring on the shaft spigot and, if necessary, refit the locating dowel. Coat the threads of the six retaining setbolts with 'Loctite 241' and insert the setbolts, with plain washers, in the gear bolt holes. Tighten the setbolts evenly, to a torque loading of 40 Nm (30 lbf.ft.).

Fitting new bushes

If new bushes have to be fitted, the old bushes must be pressed out of the idler gears as follows :

27 For the oil pump or coolant pump idler gears, position Bush Removal Tool, VT 12819, on the table of a hand press. Locate the gear on the tool body and fit the drift into the bush bore. Press down on the drift to drive out the old bush.

28 Check the gear bore for cleanliness, position the Bush Insertion Tool, VT 12037, on the press table and locate the gear over the guide. Place the new bush around the top of the guide and fit the tool cap over the bush. Press the bush into the gear wheel bore until the tool cap contacts the face of the gear. Remove the gear and check for burrs and swarf.

29 Using the Removal Tool, VT 12818, and Insertion Tool, VT 12036, renew the bushes in the main and small compounded idlers in the same manner, if necessary.

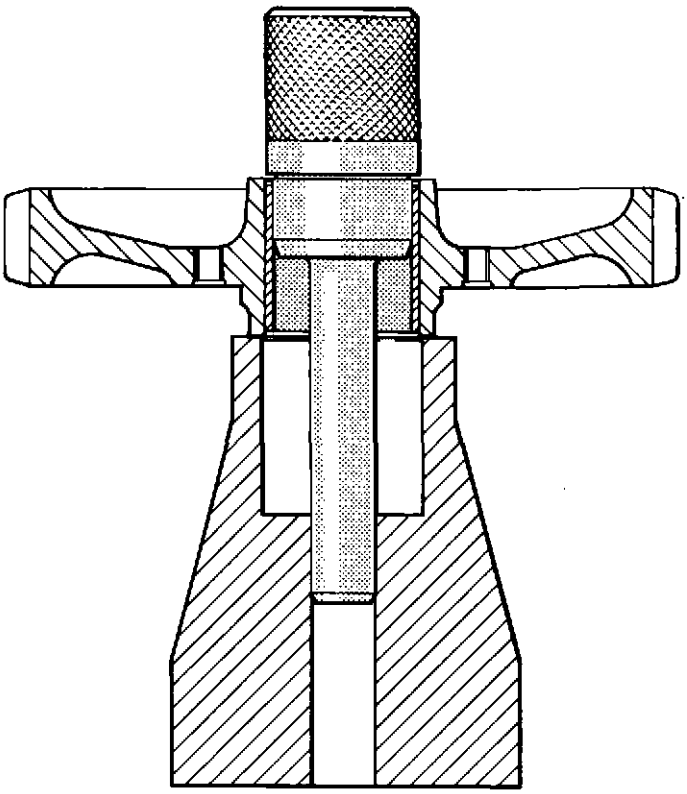


Fig. 3 Removing idler gear bush

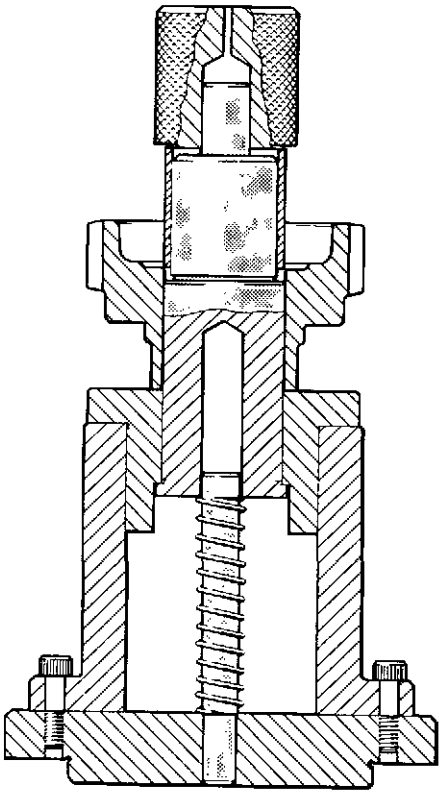


Fig. 4 Inserting small compounded idler gear bush

Assembling the gear train

30 Check that the camshaft drive end flanges are clean and undamaged and rebuild the main gear train as described in Section 3 - Assembling the engine.

SPECIAL TOOLS

Tool Number	Description
GA 5060	Guide stud, flywheel to crankshaft
VP 517	Lifting bar, flywheel
GA 5090	Puller
GA 5090-2	Bolt
GA 5058	Guide stud, flywheel housing
VT 11144	Barring adaptor, crankshaft
VP 8754	Lifting hook, wheelcase
VT 12818	Removal tool, idler bush
VT 12819	Removal tool, idler bush
VT 12036	Insertion tool, idler bush
VT 12037	Insertion tool, idler bush

FITS AND CLEARANCES - GEAR TRAIN

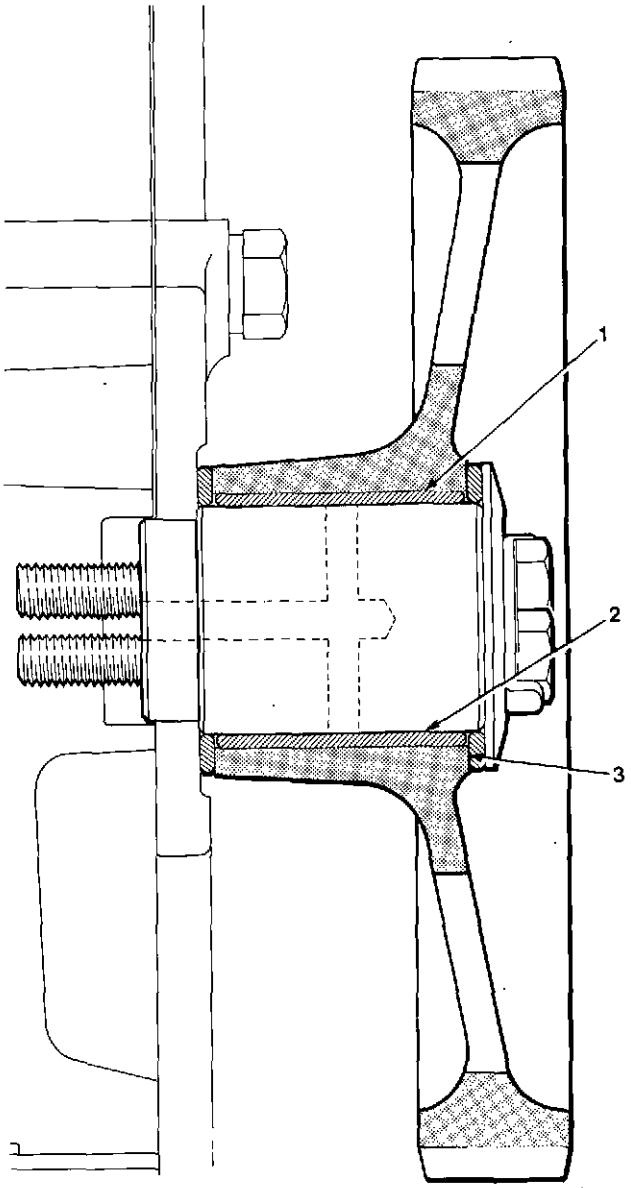


Fig. 5 Fits and clearances - Main idler gear

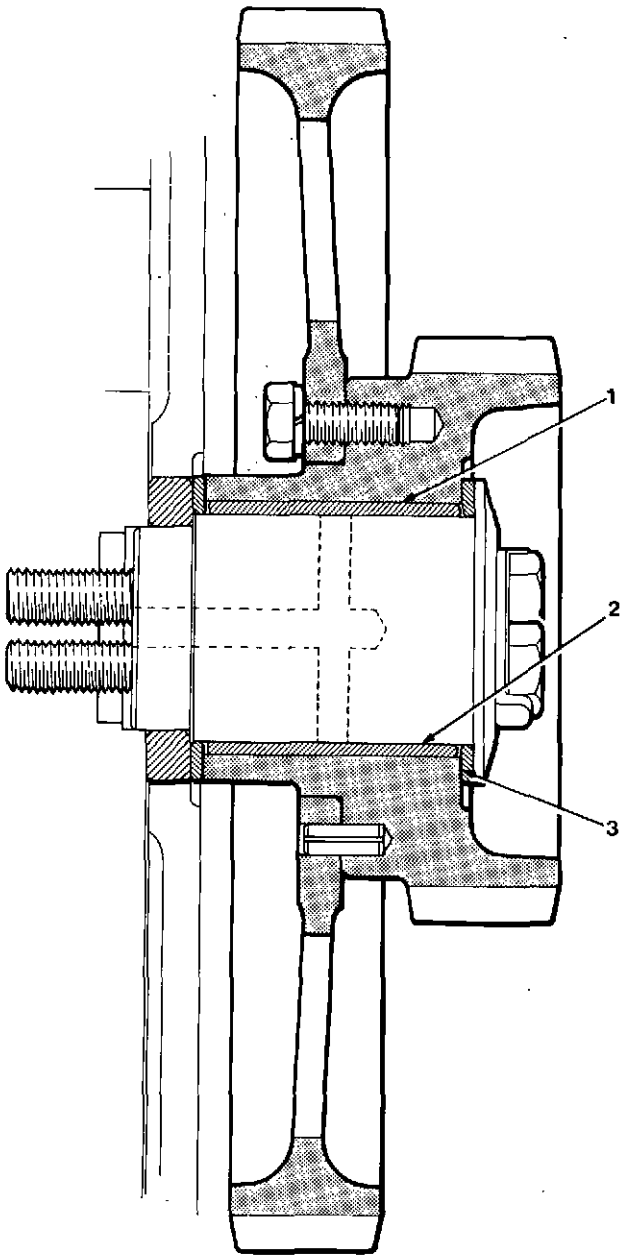


Fig. 6 Fits and clearances - Compounded idler gear

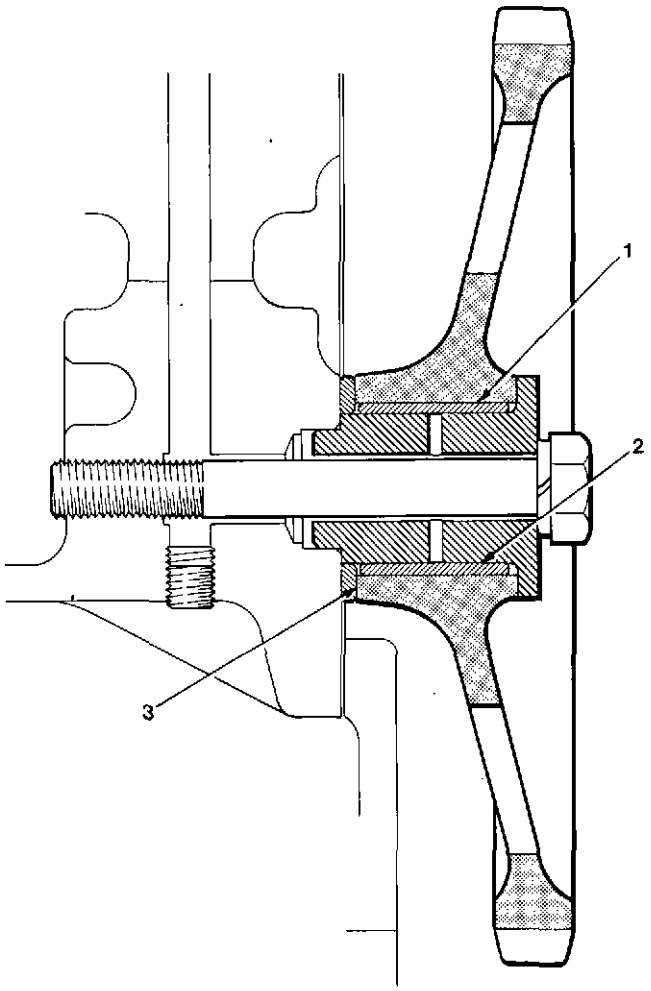


Fig. 7 Fits and clearances - Coolant pump idler

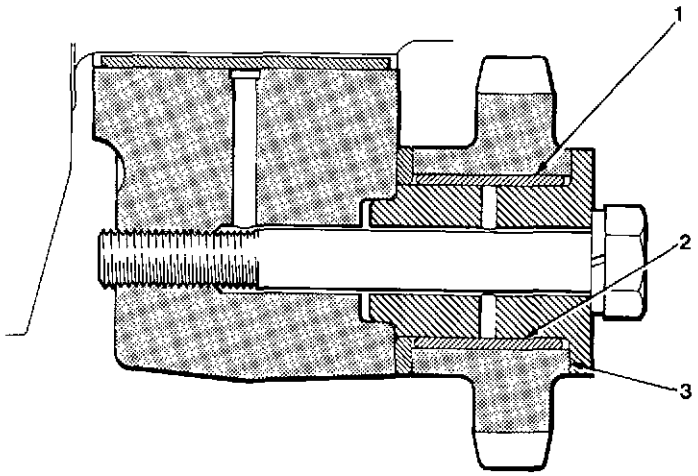


Fig. 8 Fits and clearances - Oil pump idler

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	BACKLASH BETWEEN GEARS									
	Camshaft-camshaft					0,100 to 0,250	0.004 to 0.010			
	Aux.drive-fuel pump					0,100 to 0,330	0.004 to 0.013			
	Fuel pump-main idler					0,100 to 0,270	0.004 to 0.017			Imperial dimensions are 'rounded up' to nearest 1/1000 for convenience
	Main idler-compounded					0,100 to 0,270	0.004 to 0.017			
	Compounded-crankshaft					0,100 to 0,240	0.004 to 0.009			
	Crankshaft-coolant idler					0,100 to 0,240	0.004 to 0.009			
	Coolant idler-pump					0,100 to 0,280	0.004 to 0.011			
	Crankshaft-oil pump idler					0,100 to 0,200	0.004 to 0.008			

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	BACKLASH BETWEEN GEARS (Cont.)									
	Oil pump idler-pump					0,100 to 0,390	0.004 to 0.015			
	IDLER GEARS ON AXLES									
Fig. 5	Main idler									
1	Gear bore	50,000 to 50,025	1.9685 to 1.9695			Interference 0,064 to 0,127	0.0025 to 0.0049			
	Bush diameter	50,089 to 50,127	1.9720 to 1.9735							
2	Bush bore	44,983 to 45,034	1.7709 to 1.7729			0,033 to 0,124	0.0013 to 0.0048	0,199	0.0078	
	Axle diameter	44,910 to 44,950	1.7681 to 1.7697							

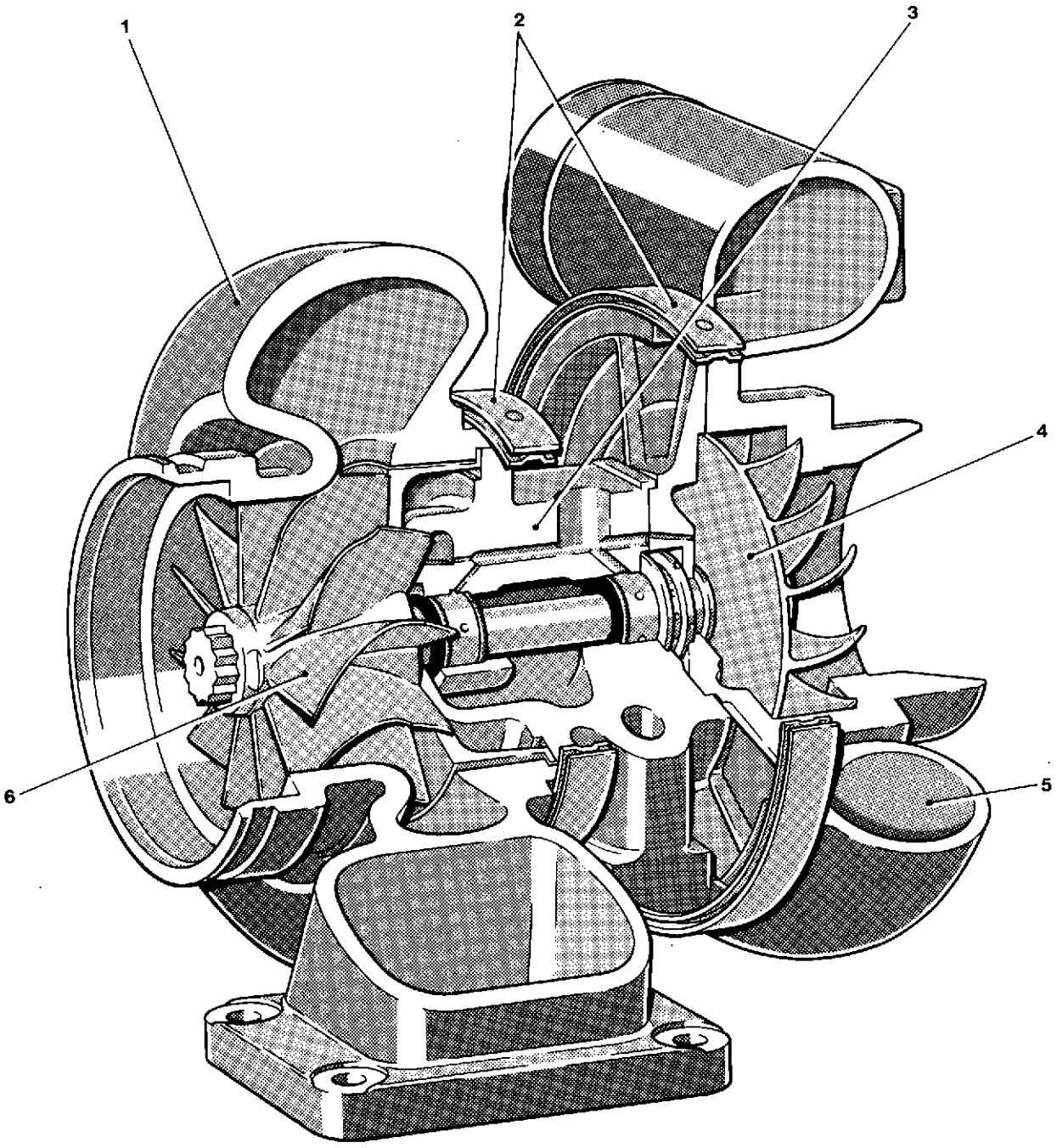
No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	IDLER GEARS ON AXLES (Cont.)									
Fig. 6	Compounded idler									
1	Gear bore	50,000 to 50,025	1.9685 to 1.9695			Interference				
	Bush diam.	50,089 to 50,127	1.9720 to 1.9735			0,064 to 0,127	0.0025 to 0.0049			
2	Bush bore	44,983 to 45,034	1.7709 to 1.7729			0,033 to 0,124	0.0013 to 0.0048	0,199	0.0078	
	Axle diameter	44,910 to 44,950	1.7681 to 1.7697							
Fig. 7	Coolant pump idler									
1	Gear bore	34,000 to 34,025	1.3385 to 1.3395			Interference				
	Bush diameter	34,087 to 34,125	1.3420 to 1.3435			0,062 to 0,125	0.0024 to 0.0049			
2	Bush bore	29,985 to 30,112	1.1805 to 1.1855			0,025 to 0,165	0.001 to 0.006	N/A	N/A	
	Axle diameter	29,947 to 29,960	1.1790 to 1.1795							

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	IDLER GEARS ON AXLES (Cont.)									
Fig. 8	Oil pump idler									
1	Gear bore	34,000 to 34,025	1.3385 to 1.3395			Interference				
	Bush diameter	34,087 to 34,125	1.3420 to 1.3435			0,062 to 0,125	0.0024 to 0.0049			
2	Bush bore	29,985 to 30,112	1.1805 to 1.1855			0,025 to 0,165	0.001 to 0.006			
	Axle diameter	29,947 to 29,960	1.1790 to 1.1795							
	IDLER GEAR END FLOAT									
Fig. 5	Main idler									Check thrust washer oil grooves and renew the washers before the grooves blend into the thrust faces. Nominal depth of grooves 0,18 to 0,38 mm (0.007 to 0.015 inch) *These dimensions take into account slight 'bowing' of the thrust washers
3	Axle length	56,150 to 56,200	2.2106 to 2.2126							
	Gear hub width	50,875 to 51,000	2.0029 to 2.0079			*0,100 to 0,425	*0.004 to 0.017	See 'REMARKS' column		
	Thrust washer thickness	2,450 to 2,500	0.0965 to 0.0984							

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	IDLER GEAR END FLOAT (Cont.)									
Fig. 6	Compounded idler									
3	Axle length	56,150 to 56,200	2.2106 to 2.2126							
	Gear hub width	50,875 to 51,000	2.0029 to 2.0079			*0,100 to 0,425	*0.004 to 0.017	See 'REMARKS' column		
	Thrust washer thickness	2,450 to 2,500	0.0965 to 0.0984							
Fig. 7	Coolant pump idler									
3	Axle length	35,200 to 35,300	1.3858 to 1.3897							
	Gear hub width	32,450 to 32,500	1.2775 to 1.2795			0,200 to 0,400	0.0078 to 0.0157	N/A	N/A	
	Thrust washer thickness	2,450 to 2,500	0.0965 to 0.0984							

No on diag.	DESCRIPTION	DIMENSIONS NEW		PERMISSIBLE WORN DIMENSIONS		CLEARANCE NEW		PERMISSIBLE WORN CLEARANCE		REMARKS
		mm	inch	mm	inch	mm	inch	mm	inch	
	IDLER GEAR END FLOAT (Cont.)									
Fig. 8	Oil pump idler									
3	Axle length	35,200 to 35,300	1.3858 to 1.3897							
	Gear hub width	32,450 to 32,500	1.2775 to 1.2795			0,200 to 0,400	0.0078 to 0.0157	N/A	N/A	
	Thrust washer thickness	2,450 to 2,500	0.0965 to 0.0984							

SECTION 10 - INDUCTION AND EXHAUST SYSTEM



1 Turbine housing
2 'V' band clamps
3 Bearing housing
4 Compressor wheel
5 Compressor housing
6 Turbine wheel

Fig. 1 Cut-away view of turbocharger

SECTION 10 - INDUCTION AND EXAUST SYSTEM

Description

Two Garret Airesearch Type TV 61 turbochargers, mounted on the exhaust manifolds, are driven by the exaust gases from each bank of cylinders. Each turbocharger compressor wheel, which is part of the rotor assembly, draws air through paper element type air cleaners, and delivers it under pressure to the induction manifolds.

Air-to-air charge coolers, incorporated in the coolant radiator matrix, lower the temperature of the compressed induction charge before it passes to the engine.

Restriction indicators, carried on the clean air side of each air cleaner assembly, give visual indication of fouling of the cleaner elements.

TURBOCHARGERS

Removal

1 Remove the trunking between the air cleaner, turbocharger and radiator.

2 Disconnect the turbocharger oil feed and oil drain pipes.

3 Disconnect and remove the exhaust pipework from the elbow and remove the elbow and bellows unit.

4 Bend back the tab washers on the four nuts securing the turbocharger to the exhaust manifold; remove the nuts and lift the turbocharger away.

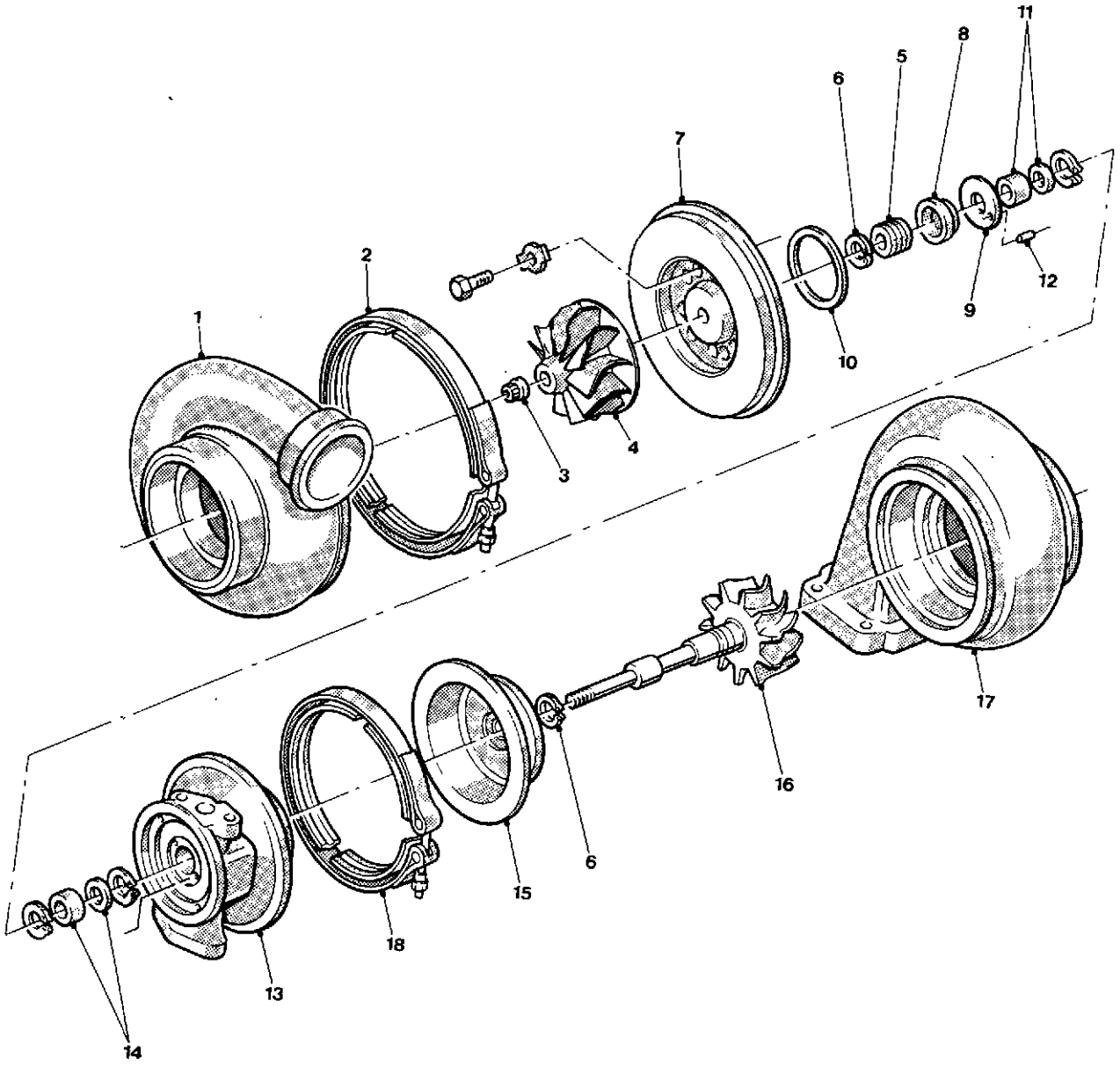
Dismantling

5 Clean the exterior of the unit and scribe correlation marks on the bearing housing, compressor housing and the turbine housing.

6 Remove the 'V' band clamps and separate the three turbocharger housings, taking care not to damage the compressor and turbine wheels.

7 Support the bearing housing in a vice and, holding the turbine wheel hub with a socket spanner, carefully remove the compressor wheel retaining nut, taking care not to distort the shaft.

8 Support the bearing housing under a press, compressor wheel uppermost and press the turbine shaft out of the housing. The turbine shroud will come away with the shaft.



1	Compressor housing	10	Sealing ring
2	'V' band clamp	11	Bearing and washer
3	Compressor wheel nut	12	Spting dowel
4	Compressor wheel	13	Bearing housing
5	Spacer	14	Bearing and washer
6	Piston ring	15	Turbine shroud
7	Backplate	16	Turbine shaft and wheel
8	Thrust collar	17	Turbine housing
9	Thrust bearing	18	'V' band clamp

Fig 1 Turbocharger (Exploded)

9 Bend back the tab washers and remove the bolts securing the backplate; lift off the backplate and sealing ring. Push the spacer and the piston ring out of the backplate bore.

10 Remove the thrust collar, bearings and circlips from the centre housing, working from the compressor end. Do not remove the spring dowels from the centre housing.

Cleaning and inspection

11 Before cleaning the components, inspect all parts for burning, rubbing and other damage that might not be evident after cleaning.

12 Soak all the components in a non-caustic cleaning solution and remove all loosened deposits, using a plastic scraper or a bristle brush. Ensure that all surfaces are clean, especially the bearing surfaces and bearing housing bores; blow away loose particles with dry compressed air.

Shaft and turbine wheel

13 Inspect the bearing journals for wear and score marks. Minor scratches may be polished out using a mild abrasive. Heavy score marks and ridges, due to wear render the assembly unserviceable. Inspect the piston ring seal grooves for wear and score marks. Minor scratches are acceptable. Maximum permissible groove width is 1,74 mm (0.0685 inch)

14 Inspect the turbine wheel for distortion, erosion, cracks, impact damage and signs of rubbing. Slight erosion is acceptable provided that the blade tip thickness is not less than 0,6 mm (0.025 inch), and no other damage is present. Do NOT attempt the straighten bent blades.

Bearings

15 Discard and renew the bearings and thrust washers.

Bearing housing

15 Renew the bearing housing if the bearing or piston seal bores are scored or worn. Minor scratches are acceptable.

Backplate and spacer

16 Ensure that the backplate is unworn in the piston seal area; check that the thrust face is clean and smooth. Check the ring groove in the spacer and fit a new piston ring.

End housings

17 Inspect the compressor and turbine housings for distortion, cracks and signs of rubbing. Slight rubbing marks may be polished out, more severe damage indicates that the housings must be replaced.

Compressor wheel

18 Renew the wheel if there are any signs of damage, as minor nicks in the wheel can result in failure.

Assembling the turbocharger

Note: Lightly coat all bearing surfaces with clean engine oil before assembly. The bearing retaining circlips are rounded on one side. They must be assembled so that the rounded side is towards the bearings or the intervening thrust washer, as applicable.

19 Working from the compressor end, fit a circlip to the bore of the bearing housing at the turbine end of the bore.

20 Oil and fit a new bearing and thrust washer and secure in position with a second circlip.

21 Fit a third circlip, to the bearing housing bore and assemble a new piston ring seal to the turbine shaft.

22 Secure the turbine shaft vertically in a vice, gripping the wheel hub and fit the turbine shroud. Carefully lower the bearing housing into position, guiding the shaft through the bearing bore. Do NOT force the piston ring into position; a gentle rocking action is adequate.

23 Oil and fit the thrust washer and bearing, followed by the thrust bearing. Fit the thrust collar, with the larger outside diameter facing outwards. Press the sealing ring into its groove in the bearing housing.

24 Assemble a new piston ring to the spacer, and insert the spacer into the bore of the backplate, with the piston ring towards the compressor.

25 Align the oil feed holes in the backplate and the bearing housing and lower the backplate over the turbine shaft, until it rests in the bearing housing recess. Hold in this position and fit the retaining bolts with new tab washers. Tighten the bolts evenly to a torque loading of 4 to 4.7 Nm (3 to 3.5 lbf.ft.).

26 Heat the compressor wheel in an oven or oil bath to a maximum of 121 deg.C. (250 deg.F), for ten minutes. Fit the wheel to the shaft and tighten its securing nut to a torque loading of 13.6 Nm (10 lbf) whilst the wheel is hot.

27 Allow the wheel to cool, remove the nut and check that the contact faces of the nut and the wheel are smooth. Oil the faces and the screw thread, refit the nut and tighten it until the shaft has stretched 0.20 to 0.23 mm (0.008 to 0.009 inch). If measuring equipment is not available, tighten the nut to 2 Nm (1.5 lbf.ft.), and then a further one-third of a turn.

28 If heating facilities are not available, fit the wheel to the shaft and draw it into position using the nut. When the wheel contacts the shoulder of the shaft, continue tightening the nut for a further one-third of a turn, or until the shaft has stretched 0.20 to 0.23 mm (0.008 to 0.009 inch).

29 Check the axial and radial movement of the rotor assembly as detailed in the Servicing Manual, T.S.D. 3138.

30 Measure the clearance between the turbine and its shroud with the rotating assembly at each limit of its end float. With the turbine pressed towards the shroud, clearance should be 0.063 to 1.32 mm (0.025 to 0.052 inch). With the turbine pressed away from the shroud, clearance should be 0.86 to 1.40 mm. (0.034 to 0.055 inch).

31 Loosely fit the 'V' band clamp to the bearing housing and assemble the compressor housing to the bearing housing, taking care to align the corellation marks. Tighten the clamp nut to a torque loading of 13.5 Nm (10 lbf.ft.).

32 Fit the 'V' band clamp to the turbine housing in the same manner.

33 Push the rotor assembly to one limit of its end float and check that it rotates without binding. Repeat this check, pushing the rotor assembly to the other limit of its end float.

Refitting the turbocharger

Note: If exhaust manifold inspection is to be carried out, it must be done whilst the turbocharger is removed. Induction manifold inspection may be carried out at the same time. The sequence for removing and refitting these components will be found in Section 8 of this Manual.

34 Ensure that the induction and exhaust manifolds are free from dirt and loose articles, and check that all the joints are sound. Check that the oil feed and drain pipes are clear and undamaged.

35 Refit the turbocharger in the reverse order to dismantling.

36 Before starting the engine, prime the turbocharger bearings by pouring 0,2 litre (1/3 pint) of clean engine oil into the filler pipe on the bearing housing.

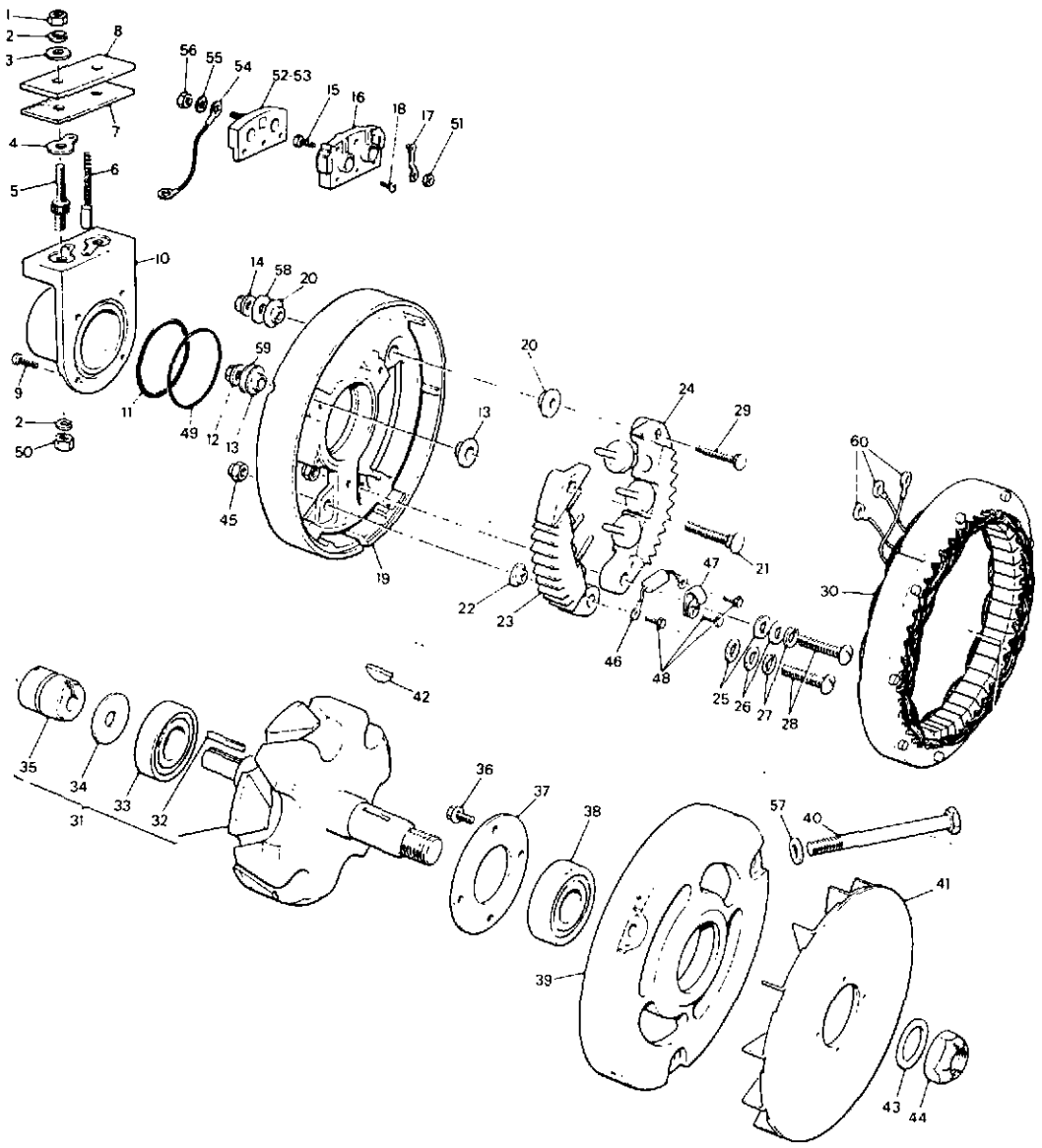
Caution : After engine overhaul, a special temporary filter must be fitted into each turbocharger lubricating oil inlet connection. The special filters are not reusable, and must be removed and discarded after the initial running period of the engine.

Exhaust manifold

37 Before cleaning, inspect the manifold for cracks and signs of blowing which will not be apparent after cleaning. Pay particular attention to the mating faces on the manifold, cylinder head and turbocharger.

38 Soak the manifold in an approved cleaning solvent, and remove all traces of loosened carbon.

39 Inspect the captive sleeve counterbores, in each section of the manifold, check for signs of blowing and fretting and ensure that the sleeve is a close fit in each recess.



1 Nut
2 Lockwasher
3 Washer
4 Jumper
5 Terminal stud
6 Brush assembly
7 Gasket
8 Cover
9 Screw
10 Brush housing
11 Sealing ring
12 Nut
13 Insulation bush
14 Nut
15 Screw
16 Insulator
17 Jumper assembly
18 Screw
19 Housing
20 Insulation bush
21 Terminal screw
22 Insulation bush
23 Rectifier assembly (+)
24 Rectifier assembly (−)
25 Insulation washer
26 Washer
27 Lockwasher
28 Screw
29 Terminal screw
30 Stator assembly
31 Rotor assembly
32 Wedge
33 Bearing
34 Insulation washer
35 Slip ring assembly
36 Screw
37 Retainer-bearing
38 Bearing
39 Housing
40 Bolt
41 Fan assembly
42 Woodruff key
43 Washer
44 Nut
45 Nut
46 Capacitor assembly
47 Clamp
48 Screw
49 Sealing ring
50 Nut
51 Nut
52 Diode Capsule
53
54 Lead assembly
55 Washer
56 Nut
57 Washer
58 Washer
59 Washer
60 Terminal

SECTION 11 - ELECTRICAL EQUIPMENT

PART 1 - BUTEC TYPE A13 ALTERNATOR

Description

The three phase, delta connected alternator (fig. 1) is of the rotating field, stationary armature (stator) type, with a self limiting current output. Rectification is by six, replaceable, heavy duty silicon diodes, carried in suitably finned heat sinks. Three auxiliary, field sensing diodes, attached to the A.C. terminals, allow the use of a warning light. The rotor bearings are sealed for life, and the slip ring assembly and brush gear are shielded to prevent ingress of dirt. A centrifugal type fan, mounted on the drive end of the rotor shaft, draws cooling air through the alternator and over the heat sink fins.

Technical data

Maximum rated output (hot).....30 amps at 28 volts.
Cut-in speed (hot).....750 rpm.
Max. continuous operating speed.....10 000 rpm.
Stator phase resistance (assembled).....0.454 to 0.494 ohms at 20 deg.C.
Rotor coil resistance.....13.0 to 14.2 ohms at 20 deg.C.
Rotation.....Reversible.
Max. ambient temperature.....93 deg.C.

VOLTAGE REGULATOR

The Type R1 regulator is fully transistorised and requires no servicing. To suit Operator's requirements, the output voltage may be varied by means of an adjusting screw, mounted beneath a sealing plug in the regulator cover. Turn the screw clockwise to increase the voltage, and anti-clockwise to reduce the voltage. Replace the sealing plug after adjustment.

Dismantling alternator

1 Remove the pulley nut, withdraw the pulley and remove the fan. Remove the Woodruff key from the shaft.

2 Remove the diode capsule, brush cover and withdraw the brushes; remove the brush housing.

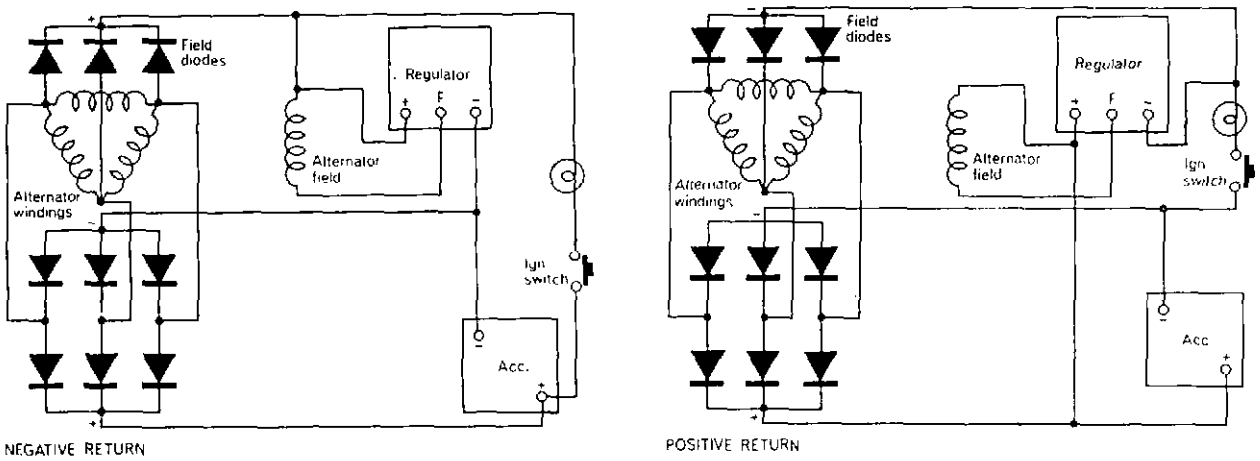
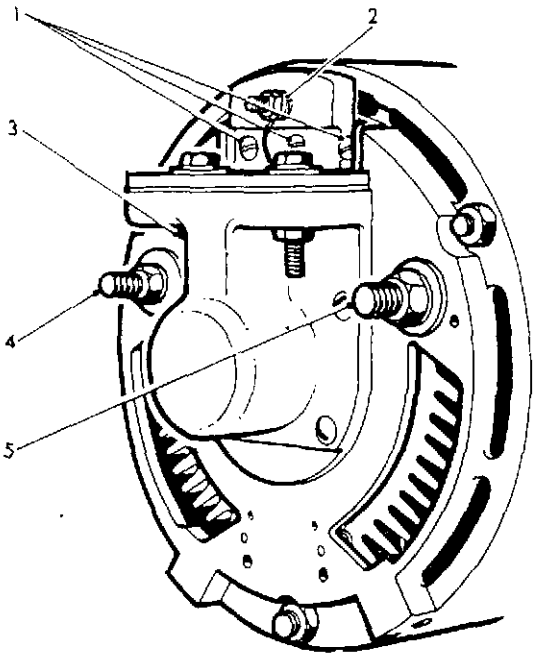


Fig. 2 Regulator and 9 diode alternator wiring



1 AC output tappings
2 Sensing diode terminal
3 Field terminal
4 Negative DC terminal
5 Positive DC terminal

Fig. 3 Alternator terminals

3 Remove the three through bolts and, using a brass drift, gently tap on the slip ring end of the rotor shaft to separate the slip ring end housing from the stator. Disconnect the three AC terminals before fully separating the units.

4 Support the drive end housing and carefully press out the rotor.

Stator

5 Clean the stator, using a cloth moistened with 'Genklene N', and blow out any dirt and carbon from all the components.

6 Inspect the windings and, using a 12 volt test lamp, check the wiring between each of the three terminals and the stator frame. The lamp should not light.

7 Using the test lamp, check the continuity between each terminal and the other two, in turn. The lamp should light up.

Bearings

8 Check the rotor bearings for wear. One bearing is retained by a plate in the drive end housing, the other is carried behind the slip rings on the rotor shaft. Both bearings are sealed and do not require lubrication. The bearings should not be removed unless renewal is necessary.

Rotor

9 Check the resistance between the slip rings. Limits are 13.0 to 14.2 ohms. If the resistance is beyond these limits, or if the rotor coil is open circuited or earthed, the rotor must be renewed.

Inspect the slip rings for wear or damage. Unserviceable slip rings may be renewed as follows :

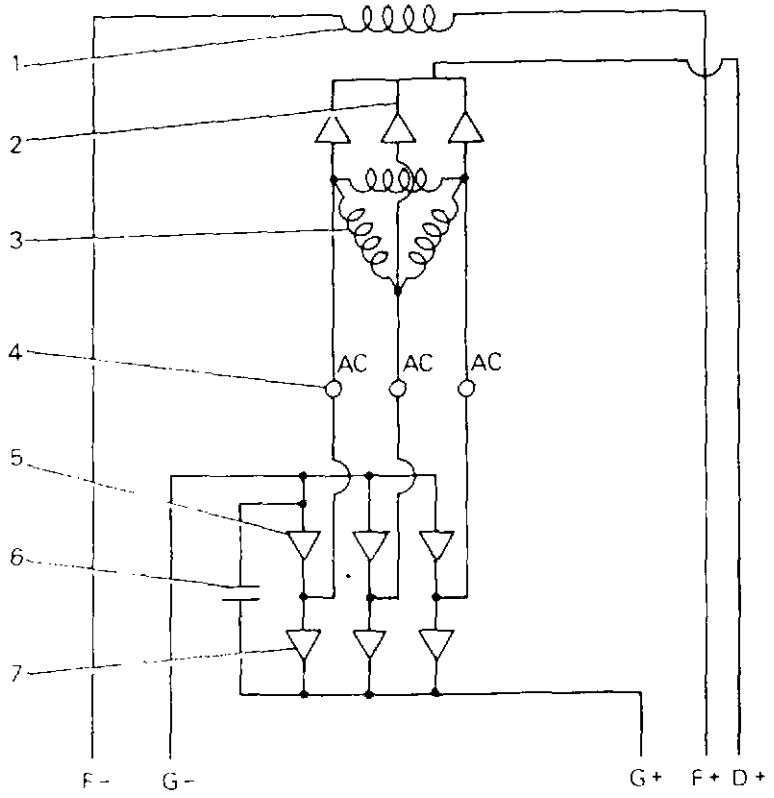
10 Unsolder the wire connecting the rotor coil to the outer slip ring. Bend the wire parallel to the shaft and unsolder the wire from the inner slip ring. Pull off the slip rings and remove the insulating washer.

11 Gently warm the new slip ring assembly to avoid cracking during fitting.

12 Assemble a new insulating washer and position the slip ring assembly so that its slots are aligned with the rotor coil wires.

13 Carefully press the assembly up to the shoulder on the rotor shaft; solder the coil wires to the new slip rings.

14 Set up the rotor assembly in a lathe and take a light, smooth cut from the faces of the slip rings, to ensure that they are concentric with the shaft to within 0,05 mm (0.002 inch) total indicator reading.



1 Rotor field coil
2 Positive sensing diode
3 Stator winding
4 AC terminals
5 Negative diodes
6 Capacitor
7 Positive diodes

Fig. 4 Alternator circuit

Brushes

15 Renew the brushes if they are damaged or worn beyond the minimum permissible length of 4,8 mm (0.19 inch).

Rectifier

16 Using a 12 volt battery and test lamp, check each diode in turn by holding the lamp probes on the terminal post and the corresponding heat sink, then reverse the probes and re-check.

(a) If the lamp lights in one direction, the diode is satisfactory.

(b) If the lamp lights in both directions, the diode is 'shorted'.

(c) If the lamp does not light in either direction, the rectifier circuit is 'open'.

Assembling

17 Press the drive end housing on to the rotor shaft.

18 Position the stator against the drive end housing and align the bolt holes

19 Connect the stator terminals to the insulator, in the slip ring end housing.

20 Position the slip ring end housing against the stator, with the bolt holes aligned and loosely fit the three through bolts and nuts.

21 Carefully press the assembly together and tighten the through bolts to 7,5 to 9,5 Nm (5.5 to 7.0 lbf.ft.).

22 Secure the brush housing to the end housing and fit the two brushes.

23 Fit the sensing diode capsule, and connect the lead wire to the field terminal.

24 Refit the Woodruff key into the shaft. Fit the fan, drive pulley and securing nut and tighten the nut to a torque loading of 88 to 95 Nm (65 to 70 lbf.ft.).

25 Spin the rotor and check for freedom of rotation.

INSPECTION AND REPAIR

All parts should be thoroughly cleaned prior to inspection. Clean by blowing off dirt and carbon dust and wiping with a cloth moistened with 'Genklene N'.

Rotor

9 Check for damage to threads, keyways and bearing surfaces.

10 Using a 110 volt, 15 watt test lamp carry out an insulation test between the slip rings and windings, and the rotor body.

11 Using an ohmmeter, check the resistance of the rotor windings. Resistance is to be 14 ohms ± 0.2 ohm at 20 deg.C (68 deg.F) ambient temperature.

12 Check that the slip rings are concentric and not worn or scored. If necessary the rings may be lightly skimmed (after checking the tightness of the retaining screw) to a minimum diameter of 24.69 mm (0.972 inch).

13 If the slip rings are badly worn or scored they should be replaced as follows :

(a) Carefully unsolder the leads from the slip ring pegs.

(b) Remove the slip ring retaining screw and washer.

(c) Pull the slip ring assembly away from the shaft.

(d) Line up the rotor leads with the slots in the new slip ring assembly.

(e) Press the new slip ring assembly on to the shaft.

(f) Fit the retaining screw and washer. Tighten to 2.3 Nm (20 lbf. inch).

(g) Wrap the rotor leads approximately three turns around the slip ring pegs and solder the joints.

(h) Trim off any surplus peg and cable and remove any surplus solder so that the form of pins and cable can be seen.

Rectifiers and auxiliary diodes

Individual diodes cannot be changed. If a diode is found to be faulty the complete rectifier assembly must be replaced. The diodes can be readily checked by using an ohmmeter or a 12 or 24 volt D.C. power supply and a low wattage test lamp.

To test

Using an ohmmeter

(a) Connect one probe to the rectifier body and the other probe to the three soldered diode connections in turn.

(b) Reverse the probes and repeat this procedure.

(c) These checks should show a low resistance in one direction and a very high resistance in the other, when the probes are reversed.

(d) A low resistance in both directions indicates a short circuited diode.

(e) A high resistance in both directions indicates an open circuit diode.

Using a test lamp

(a) The bulb should light in one direction only.

(b) If the bulb lights in both directions, the diode is short circuited.

(c) If the bulb does not light in either direction, the diode is open circuited.

Auxiliary diodes

The auxiliary diodes can be checked using the same equipment as for the main diodes. Place one probe on the terminal post (at the point where D+ cable is soldered), and the other on the three soldered main diode connections in turn. To complete the check reverse the probes.

Slip ring end housing - removing rectifier

14 Unsolder the D+ lead from the auxiliary diode post.

Note: Do not attempt to turn the round section of the negative terminal as this bolt is splined to the negative rectifier.

15 From inside the housing, remove the small nut, two spring washers and the square-ended barrel insulator.

16 From outside the housing remove the small nut, the Belleville washer and the Lucar terminal from the negative rectifier.

17 Remove the rectifier and retrieve the two insulating washers, square-headed bolt and the remaining square-headed barrel insulator.

Refitting rectifier

18 From inside the housing locate the square-headed bolt and barrel insulator; place the insulator washer on the bolt from the outside.

19 Fit the insulating washer to the negative terminal bolt on the rectifier and insert it in the housing.

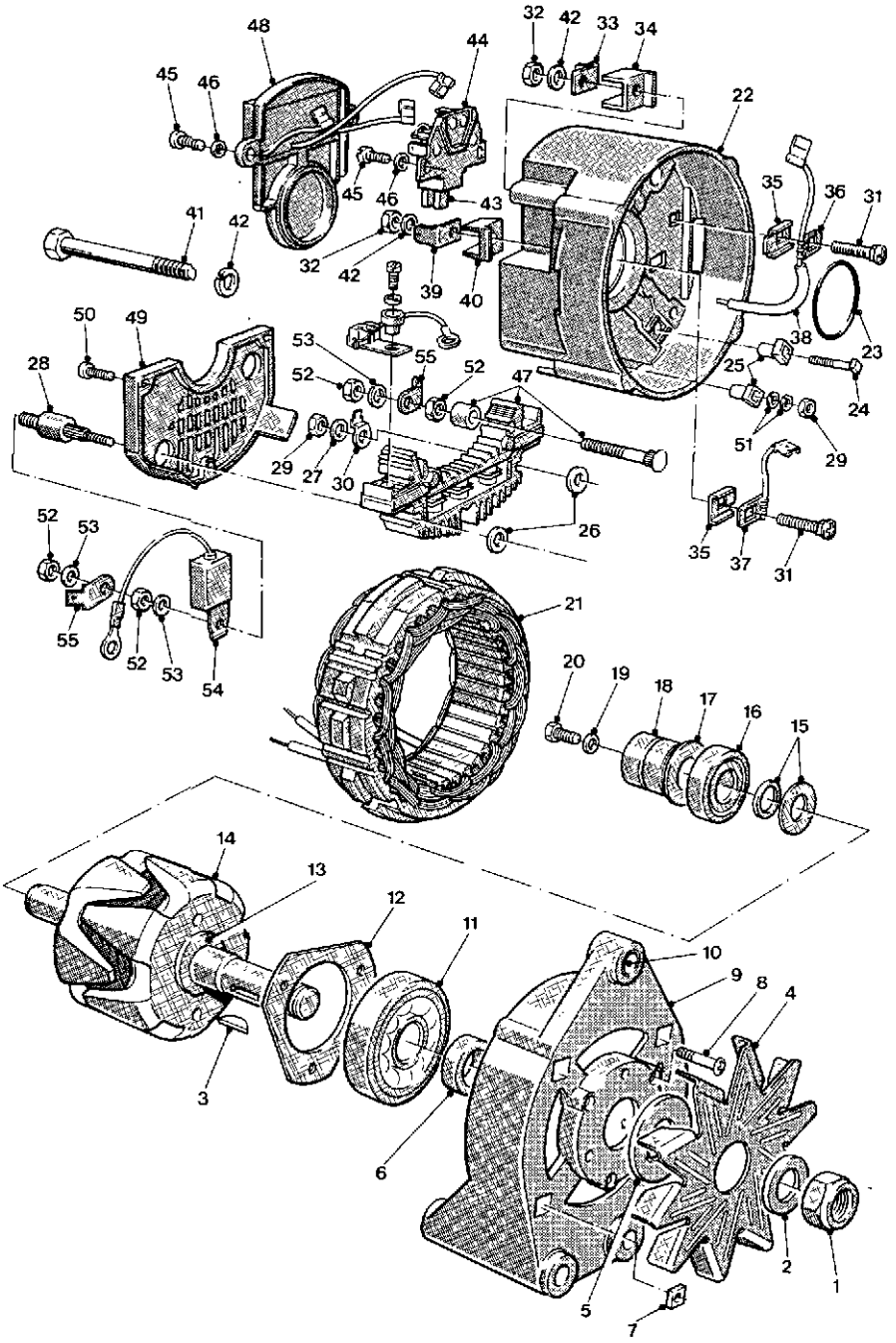


Fig. 1 Butec Type A3024 alternator

20 Fit the Lucar terminal, Belleville washer and nut to the square-headed rectifier retaining bolt.

21 From inside the housing locate the barrel insulator correctly on the negative terminal bolt, refit the two spring washers and nut and tighten to 3.11 Nm (26.5 lbf.inch).

22 Tighten the rectifier mounting to 2.0 Nm (17 lbf.inch), ensuring that the Lucar terminal has adequate clearance from the auxiliary diode post when the leads are refitted.

23 Solder the D+ lead onto the auxiliary diode post.

D+ and F- leads, removing and refitting

Note : Do not attempt to turn screws from inside the housing.

24 From the outside the housing remove the nut, Belleville washer, Lucar terminal and the terminal guard. Remove the screws, terminal, and the terminal insulator from inside the housing.

25 Check the continuity and insulation of D+ and F- leads.

Key to figure 1 (opposite)

1 Nut
2 Washer
3 Key
4 Fan
5 Fan washer
6 Distance piece
7 Nut
8 Screw
9 Housing, D.E.
10 Liner bush
11 Bearing, D.E.
12 Bearing retaining pl
13 Distance piece
14 Rotor assembly
15 Distance piece
16 Bearing, S.R.E.
17 Deflector
18 Slip ring
19 Spring washer
20 Screw
21 Stator assembly
22 Housing, S.R.E.
23 'O' ring seal
24 Screw
25 Barrel insulator
26 Spacer insulator
27 Washer
28 Terminal -ve
29 Nut
30 Terminal -ve Lucar
31 Terminal, D+, F-
32 Nut, D+, F-
33 Terminal, Lucar D+
34 Terminal guard D+
35 Insulator, terminal
36 Cable assembly D+
37 Cable assembly F-
38 Insulation sheath
39 Terminal Lucar F-
40 Terminal guard F-
41 Through-bolt
42 Spring washer
43 Brush
44 Brush box
45 Screw
46 Washer
47 Rectifier assembly
48 Regulator
49 Cover
50 Screw
51 Spring washer
52 Nut, main terminal
53 Washer, main terminal
54 Capacitor assembly
55 Terminal (Lucar)

26 From inside the housing fit the terminal insulator, with extension towards the bearing. Fit lead terminal with connecting lugs towards bearing and open ends upward. Correctly locate the squared section of the screw fully into the insulator.

27 From outside the housing fit the terminal guard, Lucar terminal, Belleville washer and the nut, tighten to 3.11 Nm (26.5 lbf.inch).

Brush holder assembly

28 Check the brush holder for signs of damage, in particular cracking.

29 Check the brushes for damage and serviceability. Minimum brush length to be 10.0 mm (0.394 inch).

Brushes - renewal

30 Unsolder the brush leads at the terminal posts and withdraw from holders. Retain the insulating sleeving if serviceable.

31 Fit the sleeving to the new brush leads and thread through the centre of the spring and the small exit hole.

32 Pull on the brush lead so that a maximum of 15.0 mm (0.590 inch) of the brush is protruding, make one complete turn of the lead around the terminal post and resolder. Trim off any excess lead.

Stator and housing

33 Check the stator windings for burned or broken wires and damage to the insulation.

34 Using a 110 volt, 15 watt test lamp carry out an insulation test between the stator body and each of the three cables in turn.

35 Check the resistance between pairs of leads in turn. Resistance across two phases to be 0.485 ohms.

Bearings

Bearings are sealed for life and cannot be serviced.

Slip ring end bearing - replacement

36 Remove slip ring assembly - see Rotor section.

37 Remove deflector washer.

38 Using a gear puller or a press remove the bearing from the shaft. Remove the spacer and the thin washer.

39 Examine the leads, relocate into grooves and refit washer and spacer.

40 Press the new bearing onto the shaft, applying pressure to the inner track only.

41 Replace the deflector washer and refit slip ring assembly, see Rotor section.

Drive end bearing - replacement

42 Using a gear puller or a press, remove the bearing from the shaft. Secure the spacer and note that the tapered side is towards the bearing.

43 Press the new bearing into the drive end housing, applying pressure to the outer track only.

44 Fit the bearing retainer plate and tighten the three screws to 1.69 Nm (15.0 lbf.inch), using Loctite 242 on screw threads.

Note: Original bearings should be checked for wear or roughness in operation. The drive end bearing incorporates integral seals which should be checked for damage or distortion. If there is any doubt as to the condition of the original bearings, new bearings should be fitted.

ASSEMBLING

45 Fit the spacer to rotor shaft with the large diameter next to the rotor. Press the drive end housing and bearing on to the rotor shaft, applying pressure to the inner track only.

46 Fit a new bearing 'O' ring to the slip ring end housing.

47 Examine the insulation sleeving and renew if necessary. Fit the stator assembly to the slip ring end housing, taking care to align the correlation marks and the through-bolt holes.

48 Carefully fit the rotor and drive end housing assembly into the stator and slip ring end housing assembly, taking care to align the correlation marks and the through-bolt holes.

49 Fit the four through-bolts with a Belleville washer beneath the head of each bolt. Tighten the bolts evenly to the correct clamping torque of 4.9 Nm (44.0 lbf.inch).

50 Refit the brush box assembly, fit the screws and Belleville washers and tighten to 1.69 Nm (15.0 lbf.inch). Ensure that brushes move freely in their holders.

51 Connect D+ and F- leads to the Lucar terminals as in figure 2. Ensure that both leads are located under the internal cast lugs.

52 After making the connections (fig. 2), fit the regulator, using two screws and Belleville washers. Tighten the screws evenly to 1.69 Nm (15.0 lbf.inch).

53 Bend the negative diode tags down towards the heat sink. Bend each stator wire down and solder to its tag, together with the auxiliary diode lead. Tin the underside of each positive tag and bend the tags over the stator wires and solder.

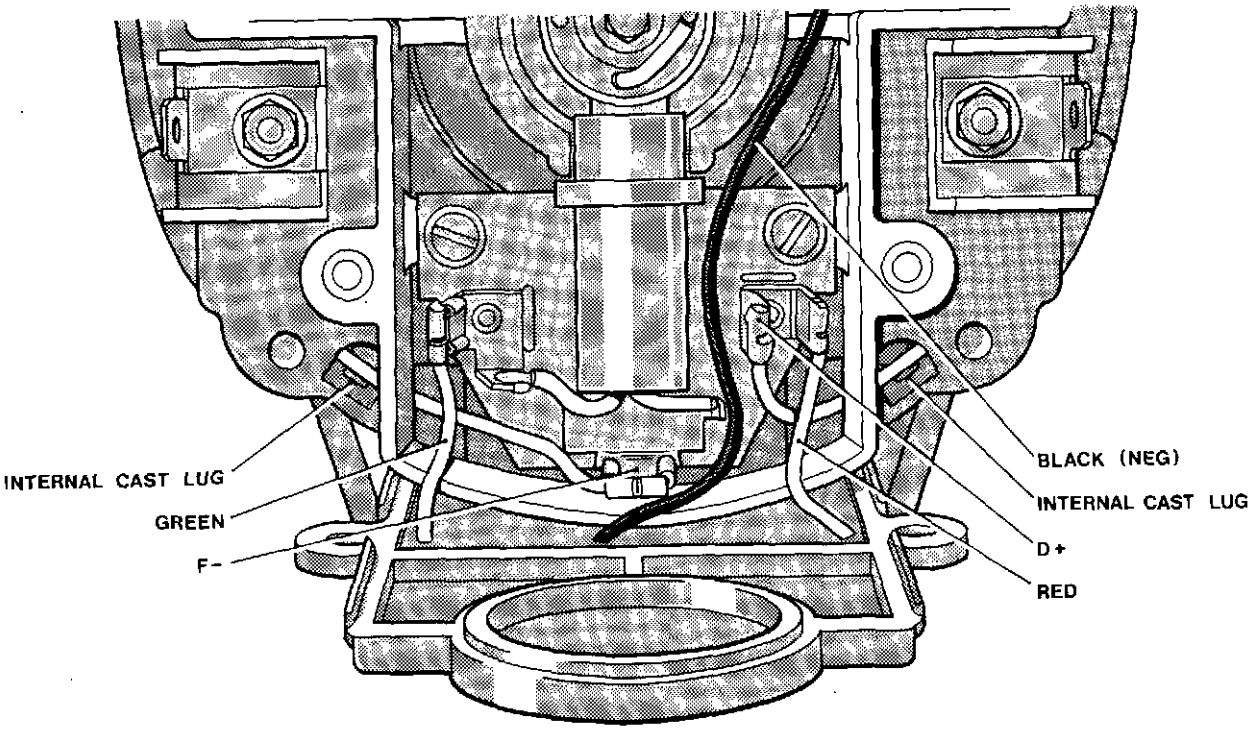


Fig. 2 Regulator connections

52. Fit the plastic end cover and tighten the three screws to 1.69 Nm (15.0 lbf. inch).

53. Refit the suppression capacitor.

PART 3 - BUTEC TYPE MS6 STARTER MOTOR

Description

The flange mounted starter motor is of the heavy duty type, operating on a 24 volt supply. An externally mounted solenoid switch actuates the armature assembly, via a lever arm. The pinion assembly incorporates a positive engagement device, an overload clutch and a freewheel ratchet.

Operation

Pressure on the starter button energises two coils around the solenoid plunger, the pull-in coil and the hold-in coil, which causes the lever arm to move the starter pinion into mesh with the starter ring. If the pinion teeth do not engage immediately, the pinion moves back against its spring and rotates slightly until engagement occurs.

On engagement, the starter contacts close in parallel with the pull-in coil, cutting the circuit in the pull-in coil. Current will continue to flow through the hold-in coil until the starter button is released.

The over-running clutch, incorporated in the pinion assembly, prevents damage to the starter ring teeth, pinion teeth and the armature when the engine fires. When the starter button is released, a return spring drives the pinion back along the splined armature shaft to its original position.

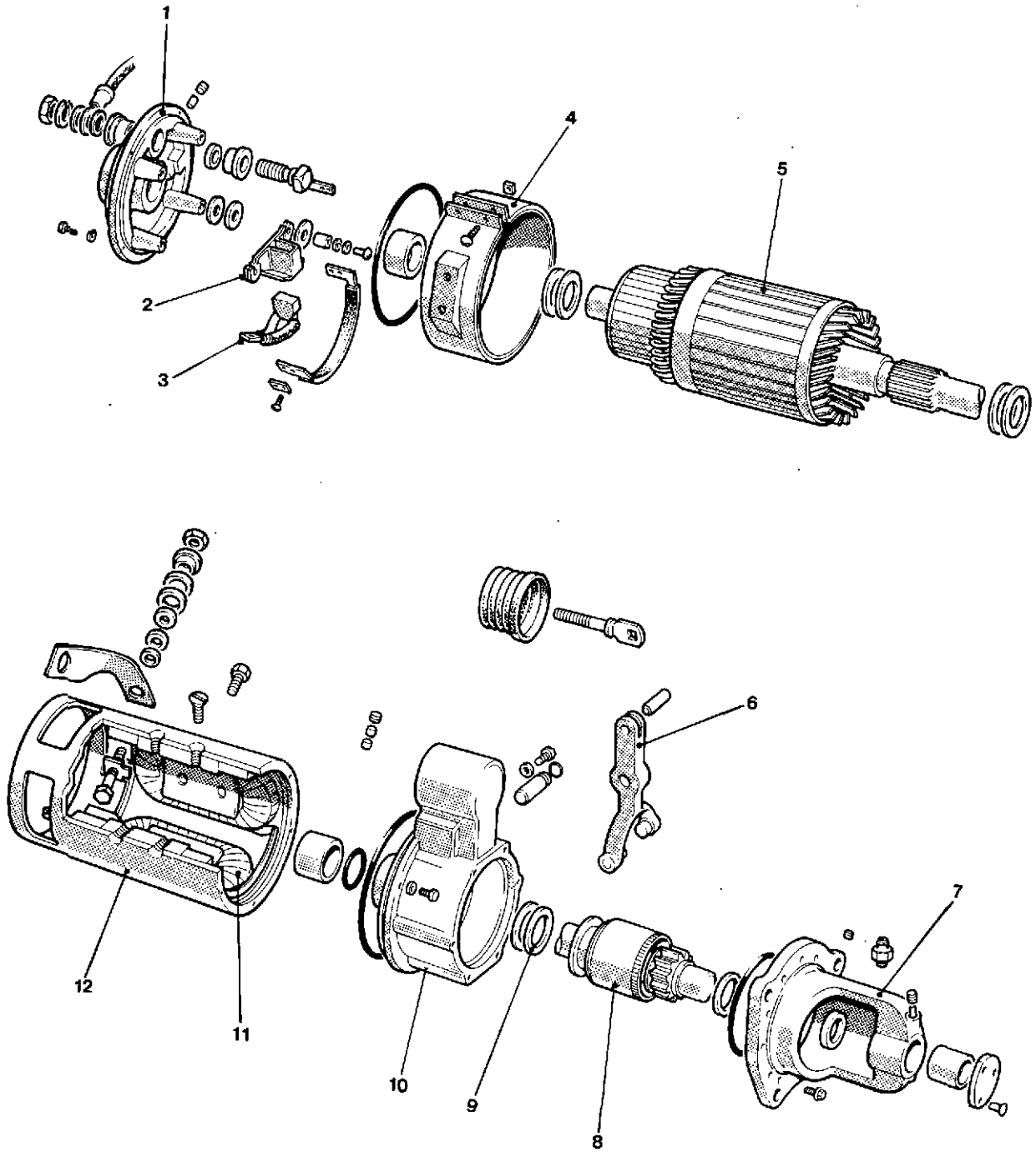
Dismantling solenoid

1 Holding the stud locknuts, where necessary, disconnect both jumpers from the solenoid terminals and starter body.

2 Remove the rubber plug from the centre of the switch end housing and, using the Special Tool, Part No. TO 69017, unscrew the plunger from the lever arm and shaft assembly. Remove the two securing setbolts and lift the solenoid away from the starter body.

3 Remove the terminal nuts, washers and sealing rings; remove the switch end cover and disconnect the coil lead.

4 Unscrew the retaining nut and withdraw the contactor and associated components; withdraw the adjusting shaft and return spring from the opposite end.



1 Commutator end housing
2 Brush box
3 Brush
4 Brush opening band
5 Armature
6 Shift lever
7 Nose housing
8 Torque drive unit
9 Fibre washers
10 Shift housing
11 Field coils
12 Field ring assembly

Fig. 1 Butec Type MS6 starter

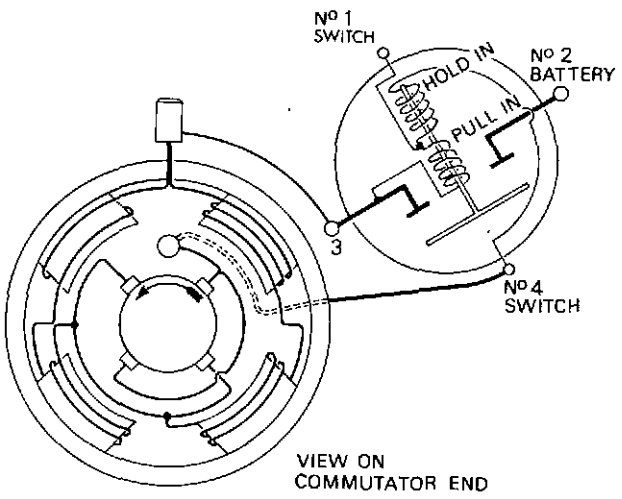


Fig. 2 Starter and switch circuitry

Dismantling starter

Before dismantling, scribe correlation marks across the adjacent edges of each section of the starter, to ensure correct alignment during assembling.

5 Remove the brush cover, disconnect the brush tabs and carefully withdraw the brushes.

6 Disconnect the two field leads, unscrew the four retaining setbolts and remove the commutator end cover, complete with brush holders.

7 Unscrew the six socket capscrews and remove the pinion housing; disconnect the shift lever and remove the lever and pinion assembly.

8 Withdraw the armature and detach the shift housing from the field ring.

Cleaning

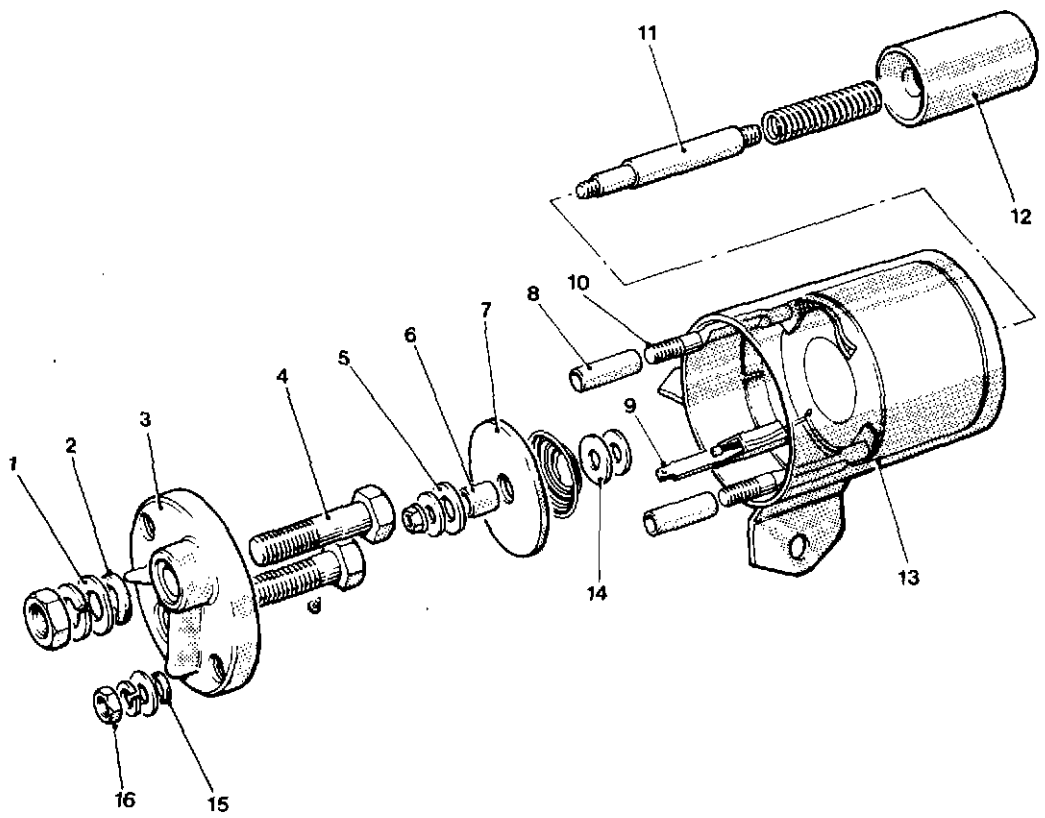
9 Clean all the components using 'Genklene N' solvent. Do NOT immerse the pinion assembly in the solvent, as the special lubricant in the assembly will be destroyed.

Inspection

10 Using an Avometer, check the resistance of the pull-in coil and hold-in coil; these should be 1.34 and 2.7 ohms respectively, at 20 deg. C. Renew the solenoid switch if the coils are defective.

11 Examine the starter field ring and housings for damage and, using a flash tester at 500 volt setting, check the field coils for insulation failure and open circuits. Renew the field ring if any coil is defective.

12 Inspect the armature for wear and damage, particularly the splines, and check the shaft for bowing and the commutator for concentricity. Renew the shaft if run-out exceeds 0,13 mm (0.005 inch).



1	Thrust washer	9	Terminal
2	Sealing ring	10	Terminal stud
3	Base	11	Shaft
4	Contact screw	12	Plunger
5	Insulation washer	13	Magnet assembly
6	Insulation bush	14	Insulation washer
7	Contactor	15	Sealing ring
8	Terminal insulator	16	Nut

Fig. 3 Solenoid switch

13 Using a 'growler' and 230 volt test lamp, check the armature windings for earthing, continuity and open circuits.

The commutator should have a highly burnished finish in a deep copper colour, and should be concentric to within 0,08 mm (0.003 inch). If the armature is otherwise serviceable, the commutator surface may be restored by skimming to a minimum diameter of 52,375 mm (2.063 inches).

14 Test the insulation of the brush holders and renew the brushes if damaged or worn. Minimum permissible brush length is 15,9 mm (0.625 inch).

15 Inspect the bushes in the commutator end cover and pinion housing. If worn, withdraw the old bushes using a 13/16 BSF taper tap as a puller, and press in new bushes as necessary.

16 Using an end mill, cut a groove in the new bush to align with the oil wick, (using the old bush as a pattern).

17 Set up the end cover or pinion housing in a lathe and ream out the new bush, concentric with the locating shoulder, to 19,100 to 19,152 mm (0.752 to 0.754 inch) diameter.

18 Inspect the shift lever housing bush. If necessary, renew the bush and, using an end mill, cut an oil groove as in the old bush. Set up the housing in a lathe and bore out the bush, concentric with the housing locating shoulder, to the following limits : 22,200 to 22,250 mm (0.874 to 0.876 inch) diameter.

19 Examine the lever arm and shaft for wear and damage, and check that the nylon locking insert in the screwed position of the shaft, is effective.

20 Check the contactor for burning or pitting. If necessary, clean up the face with fine emery. The face may be reclaimed by skimming a maximum of 0,5 mm (0.002 inch) from the contact face. Badly pitted contactors must be renewed.

21 Check the contact bolt heads. Renew the bolts if badly burned or pitted.

22 Inspect the pinion assembly and renew if excessively worn or damaged.

Assembling

Ensure that all components are clean and dry before assembling. Coat new 'O' ring seals with glycerine, and smear all bearing bushes with clean SAE 5W/20 engine oil. Soak the fibre washers and lubricator wicks in clean SAE 5W/20 oil.

23 Fit a new 'O' ring seal around the commutator end cover and align the correlation marks with those on the field ring. Coat the threads of the four securing setbolts with 'Loctite AVV' and fit the setbolts, with new spring washers. Tighten each setbolt to a torque loading of 12,4 to 17 Nm (9.0 to 12.5 lbf.ft.).

24 Fit a steel thrust washer, then a fibre washer, on to the commutator end of the armature shaft, and position the shaft in the field ring assembly. Fit a steel washer followed by a fibre washer on to the splined end of the shaft and coat the shaft and splines with 'Aeroshell Grease No. DID 5598'

25 Fit a new 'O' ring seal around the shift housing and grease the shift lever cam pivots.

26 Position the shift housing over the protruding end of the shaft and fit two fibre washers on to the shaft. Engage the two shift lever cams in the collar of the pinion assembly and slide the assembly and housing further on to the shaft. Align the correlation marks on the housing and field ring, and coat the threads of the five socket capscrews with 'Loctite AVV'. Insert the capscrews, with new spring washers, and tighten to a torque loading of 12,4 to 17 Nm (9.0 to 12.5 lbf.ft.).

27 Fit the steel thrust washer over the end of the shaft, against the pinion assembly. Fit a new 'O' ring seal around the pinion housing and position the housing over the pinion, with the locating marks on the shift lever housing correctly aligned with those on the pinion housing. Insert six new special lockpatch type capscrews through the pinion housing and tighten evenly, to a torque loading of 12,4 to 28,3 Nm (9.0 to 20.9 lbf.ft.).

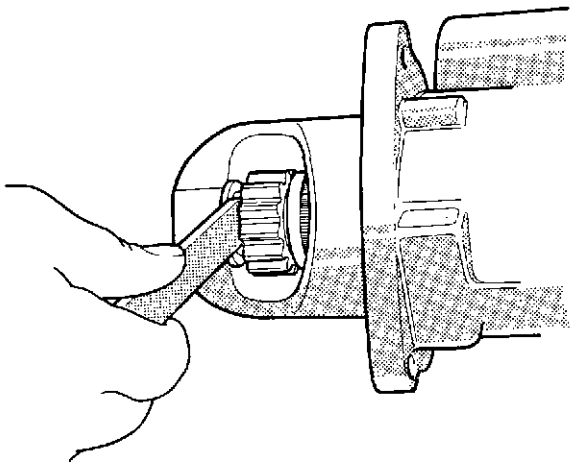


Fig. 4 Checking pinion clearance

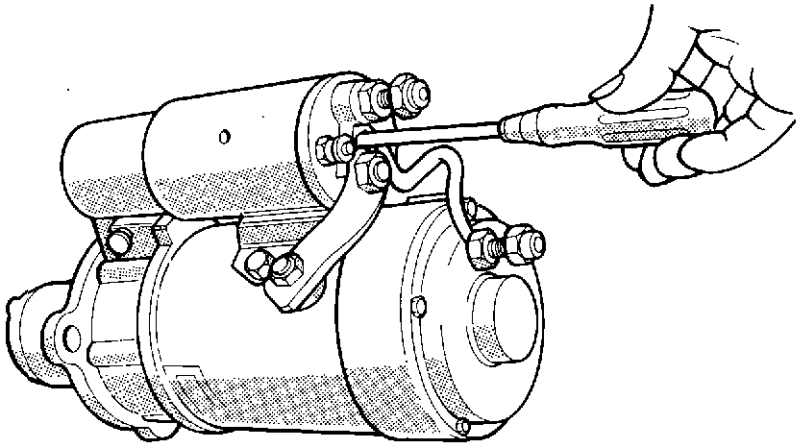


Fig. 5 Adjusting pinion clearance

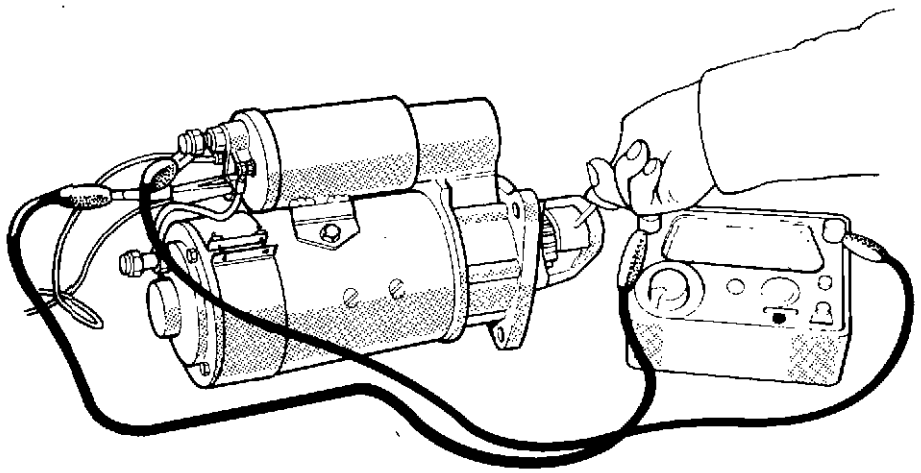


Fig. 6 Testing operating sequence

28 Check that the armature turns freely and fit the brushes into their holders. Ensure that the brushes slide freely in the holders and tighten the brush retaining screws to a torque loading of 1,6 to 2,0 Nm (14 to 18 lbf.inch). Check that the brush leads do not become trapped.

29 Coat the cover band gasket with glycerine and fit the band over the brush gear, with the ends of the band across one of the rib sections of the field ring. Tighten the two securing screws to a torque loading of 1,13 to 1,70 Nm (10 to 15 lbf.inch).

30 Using a spring balance, check the brush spring loading. Renew the springs if the loading is beyond the limits of 1,42 to 1,68 kgf (50 to 59 ozf), when the pressure end of each spring is held in the new brush length position.

Refitting solenoid switch

31 Fit a new rubber boot to the shift housing, ensuring that the lip is fully engaged in the locating groove. Align the screw link assembly with the tapped hole in the solenoid plunger and insert the Special Tool, Part No. TO 69017, through the access hole in the switch end housing. Turn the plunger clockwise until it 'bottoms', enter the switch into the shift housing, fit the two retaining bolts and tighten to a torque loading of 34,0 to 39,5 Nm (25.0 to 29.0 lbf.ft.), then back off the plunger anti-clockwise approximately five turns.

32 DO NOT refit the flexible jumper lead and the heavy motor field jumper until after the solenoid adjustment has been completed.

Bench test

Warning : When carrying out the following tests, ensure that the 24 volt supply is connected to the correct terminals and that the insulation on the connecting wires is undamaged.

33 Connect a 24 volt supply to the switch terminals 1 and 3 (see fig. 2) and, with the solenoid energised, gently push in the pinion assembly against the shift lever cams. Using the Gauge, Part No. GO 14001 (fig. 4), check that the gap between the face of the pinion and the thrust washer is 4,76 mm (0.187 inch).

34 If adjustment is necessary, de-energise the solenoid and using the Special Tool, Part No. 69017 (fig. 5), turn the plunger shaft until the gauge is a slide fit between the pinion and thrust washer.

Caution : Adjustments must not be made whilst the solenoid is energised. Do NOT leave the solenoid energised for more than 30 seconds at any time.

35 Refit the rubber plug in the access hole in the switch end cover, and secure the two jumpers between the solenoid and starter body.

36 Test the solenoid switch for the correct operating sequence by placing the Special Tool, Part No. GO 14003, on the pinion shaft to retain the pinion in the rest position (fig. 6). Connect an avometer to terminals 2 and 3, and a 24 volt supply to terminals 1 and 3. The avometer should give no reading on the dial.

PART 3 - SHUTDOWN AND WARNING SWITCHES

SHUTDOWN SOLENOID

Description

The solenoid switch, which may be either of two types, a Synchro-Start Type 2001, or a C.A.V. Type 368, is mounted on the inner wall of the 'A' bank induction manifold. The solenoid is used in the energised-to-run mode, and is connected, via a linkage, to the governor stop control lever.

On energising, the dual circuits in the solenoid actuate a plunger which, in turn, moves the stop control lever to the RUN position.

A pull-in coil draws the plunger in the direction of the arrow (fig 1) until the internal switch contacts are open. This breaks the circuit in the pull-in coil and leaves a low consumption hold-in coil energised, maintaining the stop lever in the RUN position. On de-energisation, a coil spring returns the plunger to its rest position and the stop control lever to STOP. This occurs when the STOP button is pressed, when an engine protection device breaks the circuit or as the result of an electrical failure.

Adjustments

Both types of unit require accurate adjustment of the control linkage between the solenoid and the stop control lever. Incorrect setting can cause damage to the fuel injection pump or, cause the pull-in windings to overheat and eventually burn out.

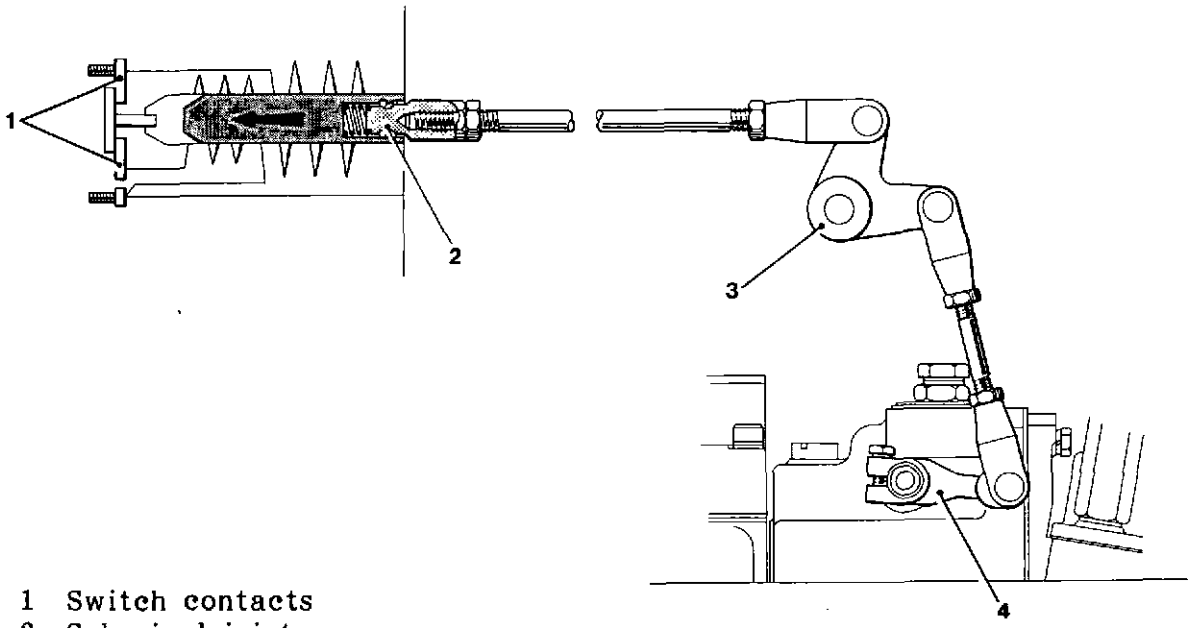
Before the electrical connections are made, adjust the solenoid linkage as follows :

C.A.V. Type 368

1 Ensure that the stop control lever is positioned on its shaft so that in the NO FUEL position, the lever dips just below the horizontal line taken through the centre of the shaft.

2 Remove the rubber boot from the terminal block to observe the switch and connect the solenoid control rod to the bellcrank lever. Operate the unit manually to check that the switch opens when the plunger is pressed fully home, with a further 0,5 to 0,8 mm (0.02 to 0.03 inch) travel to compress the spring in the spherical joint

3 Adjust the control rod length to achieve the above requirements then tighten the locknuts.



1 Switch contacts
2 Spherical joint
3 Bellcrank lever
4 Stop control lever

Fig. 1 C.A.V. solenoid linkage

4 Connect the electrical wiring to the terminals and fit the rubber boot, ensuring that the securing clips are tightened.

Synchro-Start Type 2001

1 Position the stop control lever as for the C.A.V. type solenoid.

2 Connect the control rod to the solenoid so that when the stop control lever is in the RUN position, the plunger 'bottoms' in the solenoid housing. This is to ensure that the internal switch contacts are open in the energised position. Tighten the locknuts.

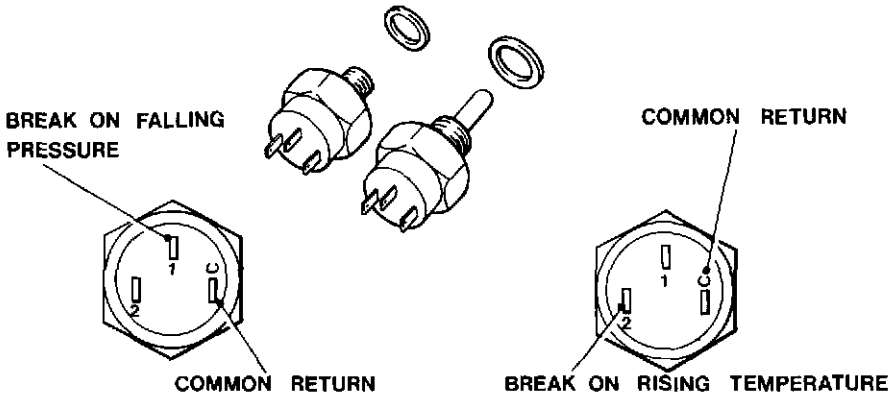
3 Connect the electrical wiring, secure the terminal cover and check that the rubber boot at the linkage end of the solenoid is correctly located.

Caution : Solenoids are available in a variety of voltages and settings to suit individual applications, and it is essential that a replacement unit corresponds exactly to the original.

WARNING AND SHUTDOWN SWITCHES

Description

Two Teddington Type DCA switches, incorporated in the cooling and lubrication systems, provide engine protection should the coolant temperature or oil pressure extend beyond the permissible limits. The switches may be wired to operate on rising or falling temperatures or pressures to suit individual applications.



Oil pressure switch Coolant temperature switch

Fig. 2 Teddington control switches

The switches are factory set to operate within a selected range of temperatures and pressures, and no attempt must be made to alter the settings.

No maintainence is necessary on the switches other than periodic checks on their serviceability, as given in the Servicing Manual, T.S.D. 3138.

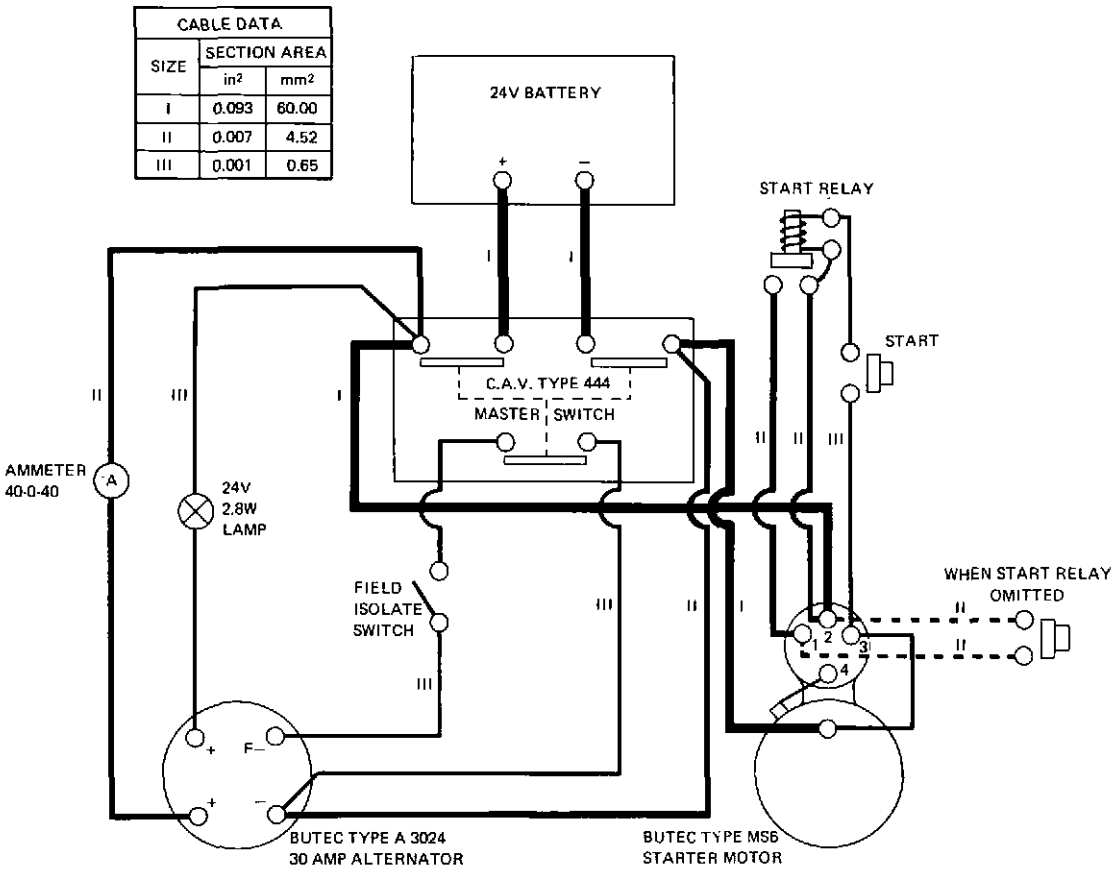
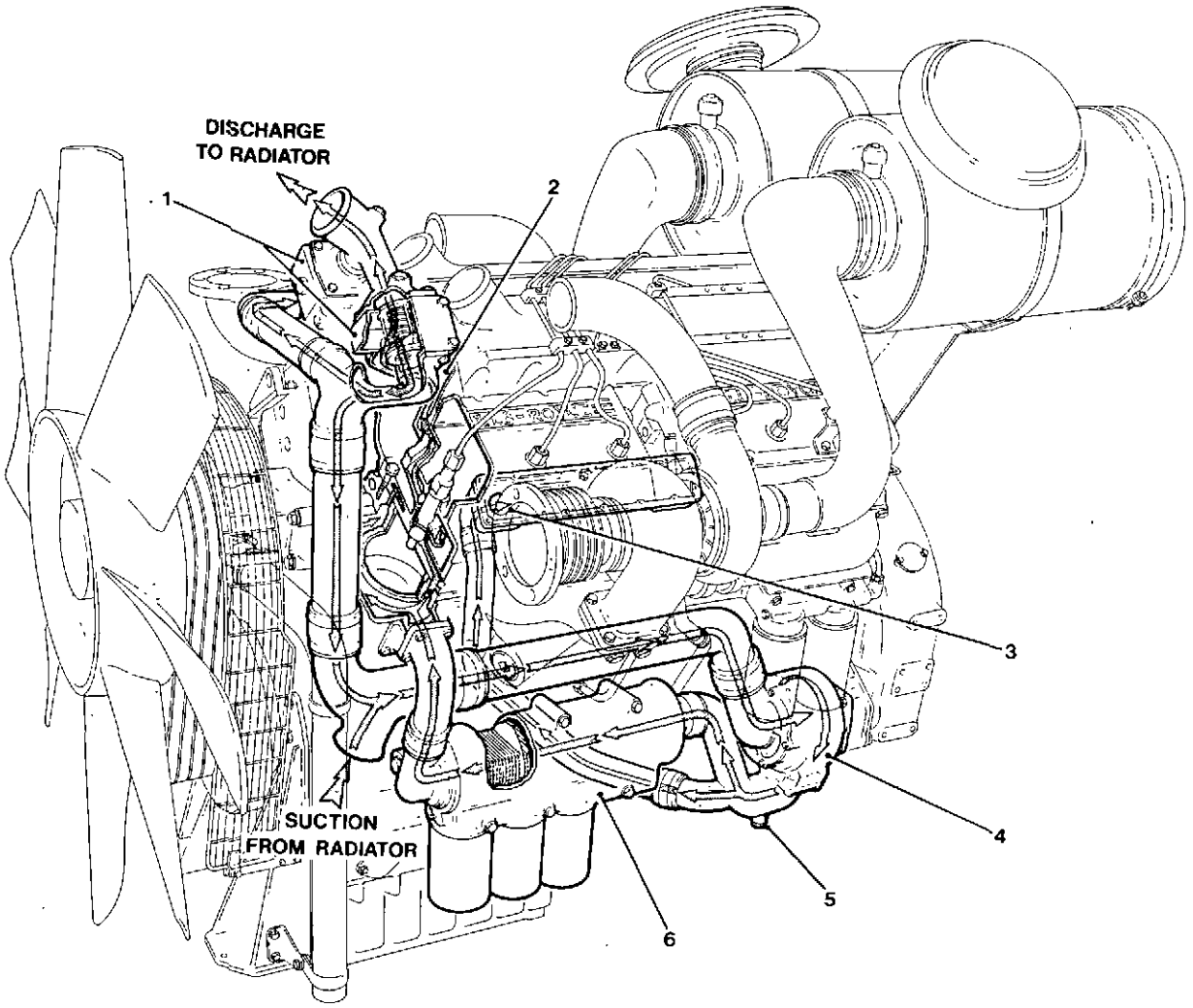


Fig.3 Typical wiring diagram CV12 engine

SECTION 12 - COOLING SYSTEM



1 Thermostats
2 Induction manifold coolant gallery
3 'A' bank coolant inlet
4 Coolant pump
5 Coolant drain
6 Oil-to-coolant heat exchanger

Fig. 1 Cooling system

SECTION 12 - COOLING SYSTEM

Description

Coolant is drawn from the radiator by a gear driven pump and delivered, via a bifurcated pipe, to the coolant galleries in each bank of cylinders, the 'B' bank coolant having first passed through the engine oil-to-coolant heat exchanger.

From the cylinder block, the coolant is directed through the cylinder heads and into galleries integral with each induction manifold. Wax capsule type thermostats, mounted at the front of each manifold, then direct the coolant to the radiator or back to the pump suction for recirculation of the engine.

RADIATOR

Cleaning

1 Using a bristle brush and a detergent solution, remove oil and dirt from the tube fins. Rinse with clean water and blow dry with a compressed air jet.

If, during engine operation, the radiator or the integral air charge cooler have become contaminated with engine oil, the air and coolant chambers, and the tubes, must be cleaned as follows :

2 Soak the assembly in an approved emulsifying solvent for 10 or 15 minutes. Thoroughly wash the assembly in clean water and allow to dry before use.

Note: As it may be impractical to immerse the complete assembly, the radiator must be partially dismantled to enable the solvent to be sprayed into each tube and chamber. Ensure that all components are thoroughly wetted and allowed to soak for 10 to 15 minutes. Wash the tubes and chambers with a steam cleaner or a high pressure water jet. Dry the components before reassembly.

Inspection

3 If possible, test the radiator for leaks by liberally coating the outside with a soft soap solution. Apply air pressure at 1.4 kgf/sq.cm (20 lbf/sq.inch) to the engine coolant section or, 2.1 kgf/sq.cm (30 lbf/sq.inch) to the air charge cooler section, of the radiator assembly. Check for bubbles, especially at each end of the tubes. Leaking radiators must be repaired by a radiator specialist firm, or renewed.

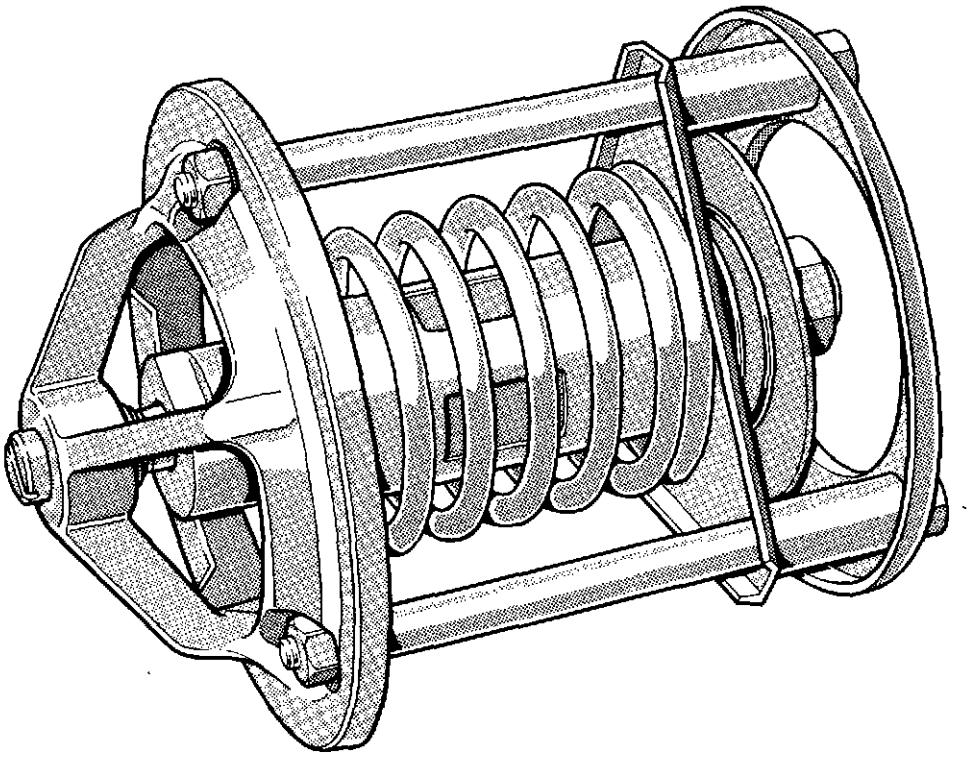


Fig. 2 Thermostat valve

THERMOSTATS

Removal

4 Drain the coolant to below the level of the thermostat housings. Disconnect and remove the coolant pipe between the radiator inlet and the bifurcated discharge connection on the 'B' bank thermostat. Remove the discharge connection and hose from the thermostat housings as necessary. Withdraw the thermostat (fig. 2).

Cleaning and inspection

5 Thoroughly clean each thermostat using a bristle brush and mild detergent. Check for distortion, cracks, damage and sticking valves. A sticking valve may often be rectified by applying silicone grease to the spindle and operating the valve manually to work the grease into the gland. If the thermostat is apparently serviceable, carry out the following tests:

Note: Silicone grease should be applied, as above, to the valve spindles of replacement thermostats, or to the thermostats of an engine which is to stand with the cooling system drained.

6 Place the unit in a tank of water at a constant 20 deg. C. for five minutes, then plunge the unit into a tank of water at a constant 100 deg. C. Note the time taken for the valve to open sufficiently to admit a 0.05 mm (0.002 inch) feeler gauge; this should be between 30 and 40 seconds. Note the time taken for the valve to open 12.7 mm (0.5 inch);

this should be between 90 and 120 seconds. Finally plunge the unit into the tank containing water at 20 deg. C. and note the time taken for the valve to close completely; this should be between 25 and 35 seconds.

The thermostat is extremely reliable, so incorrect operating characteristics indicate a loss of wax. In such cases the unit must be renewed.

Refitting

7 Remove all traces of old gasket material from the housing and discharge connection flanges. Place each thermostat in its housing, ensuring that the unit engages correctly with the locating pin.

8 Fit new hose connections over the thermostat discharge connections and, using new gaskets, lightly coated with 'Wellseal', fit the thermostat discharge connections as described in Section 3 - Assembling the engine.

9 Refit the radiator coolant inlet pipe, with new hose connections, and check that all coolant drain plugs are fitted.

10 Refill the cooling system with the approved coolant mixture and run the engine to check that the thermostats are operating correctly. Ensure that the system is free from leaks.

COOLANT PUMP

Removal

11 Drain the engine cooling system.

12 Unscrew and remove the two main fuel filter canisters.

13 Disconnect and remove the bifurcated coolant discharge pipe, from the base of the pump, and cut the hose connection from the pump suction elbow.

14 Release the four nuts securing the pump to the wheelcase and lift the pump assembly away from the engine.

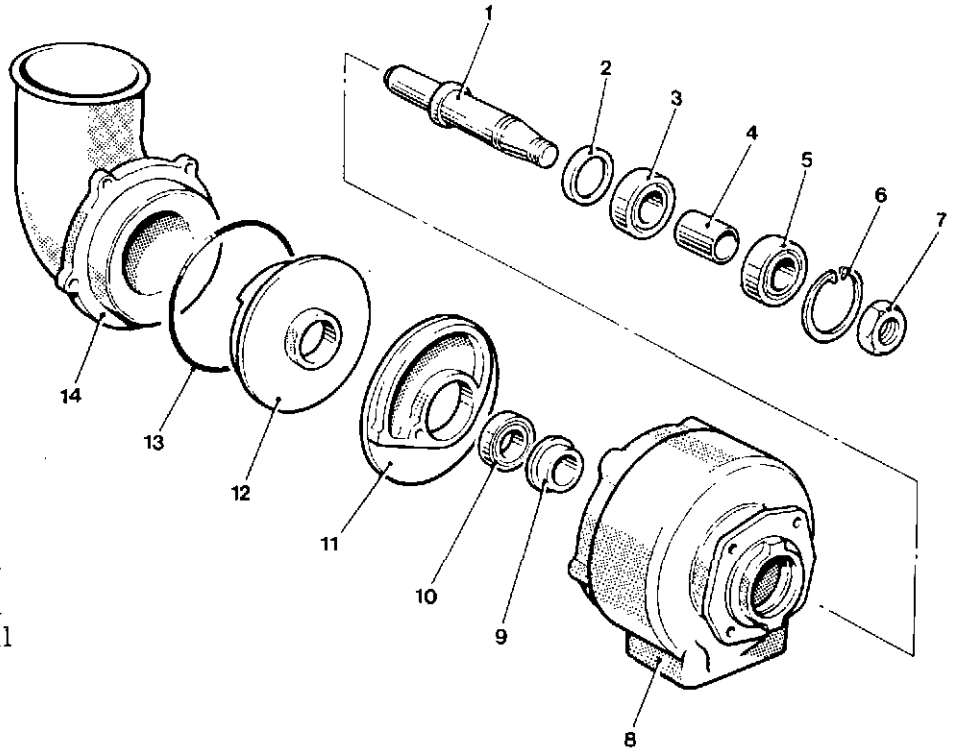
Dismantling

Note: Dismantling and reassembling the coolant pump requires the use of a number of special tools. It is recommended that the pump should be returned to the Factory for overhaul. However, if the special tools are available, proceed as follows:

15 Unscrew the five setbolts securing the pump end cover to the casing; remove the end cover and discard the 'O' ring seal (fig. 3).

16 Using three setbolts, secure the locking plate, VT 10681, to the pump assembly with the slot in the peg engaging with the end of the impeller shaft. Secure the locking plate in a vice (fig. 4).

17 Remove the drive gear securing nut and, using a suitable puller (fig. 5), remove the drive gear from the pump shaft.



1 Shaft
2 Oil seal
3 Bearing
4 Spacer
5 Bearing
6 Circlip
7 Locknut
8 Pump casing
9 Coolant seal
10 Ceramic seal
11 Backplate
12 Impeller
13 'O' ring seal
14 End cover

Fig. 3 Coolant pump assembly

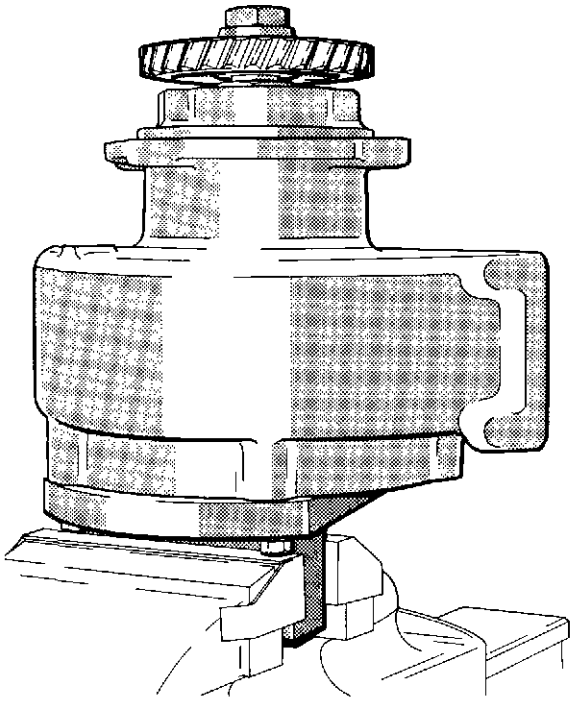


Fig. 4 Using the locking plate

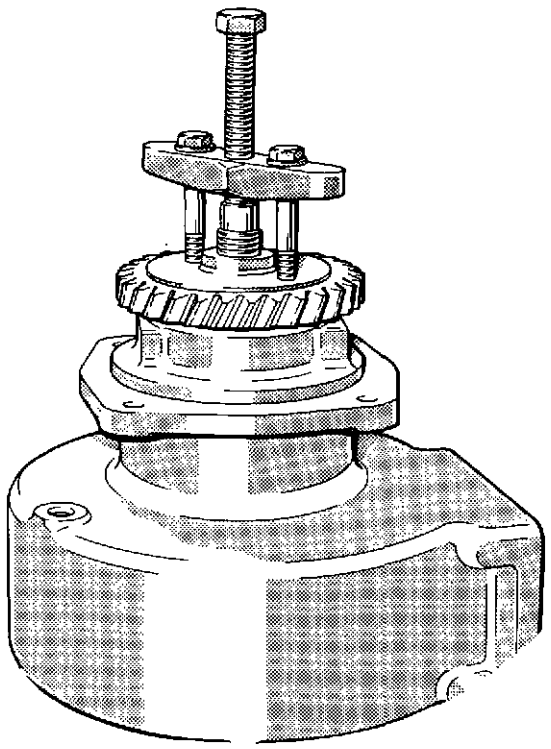


Fig. 5 Withdrawing the drive gear

18 Remove the bearing retaining nut and extract the circlip from its recess.

19 Remove the countersunk head screw from the volute and lift out the volute

20 Place the Support Base, VT 10682, on the bed of a press and place the Extension, VT 13845, on the jig. Mount the pump assembly on the extension, drive end downwards (fig. 6) and, using the Drift, VT 13966, on the end of the pump shaft, press the shaft assembly out of the impeller.

21 Lift out the impeller from the pump casing and remove the ceramic counterface seal from its seating in the impeller.

22 Using a soft drift, drive out the coolant seal and the oil seal from the pump body and, using the appropriate type puller, remove the two ball bearings from the pump shaft.

Inspection

23 Wash the components in paraffin and examine the impeller housing and the end casing for cracks and scoring. Check the impeller for damage, erosion and corrosion.

24 Examine the pump shaft for scoring and wear, particularly around the seal rubbing area.

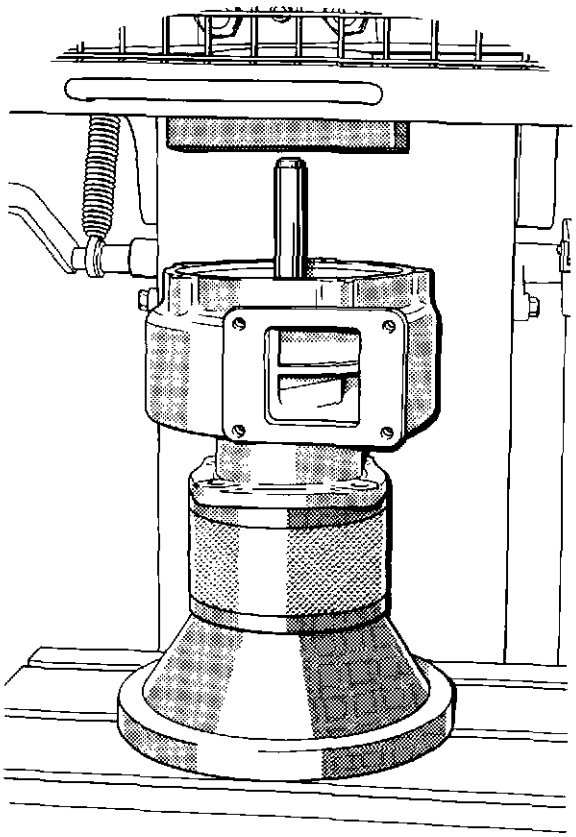


Fig. 6 Pressing out impeller shaft

25 Check that the bearings are free running and free from excessive wear. The end float of the pump shaft is controlled by the free play of the bearings and should not exceed 0.13 mm (0.005 inch)

26 Check the condition of the oil and coolant seals, particularly the ceramic counterface. If any doubt as to their condition exists, they should be renewed.

27 Check the volute disc for erosion and corrosion. Renew if necessary.

Assembling

28 Locate the volute disc in the pump casing, fit the countersunk head screw and tighten securely.

29 Place the base and guide pillar assembly of the oil seal Insertion Tool, VT 10677, on the press bed. Lower the pump casing over the assembly, drive end uppermost (fig. 7).

30 Slide the oil seal over the pillar, with the lip facing the pump drive end. Fit the sleeve of the insertion tool over the end of the pillar and press the oil seal into its location, until the shoulder on the sleeve contacts the bearing shoulder in the pump casing. Remove the tool.

31 Place the base and guide pillar of the bearing Insertion Tool, VT 13821, on press bed. Lower the pump casing over the assembly, drive end uppermost.

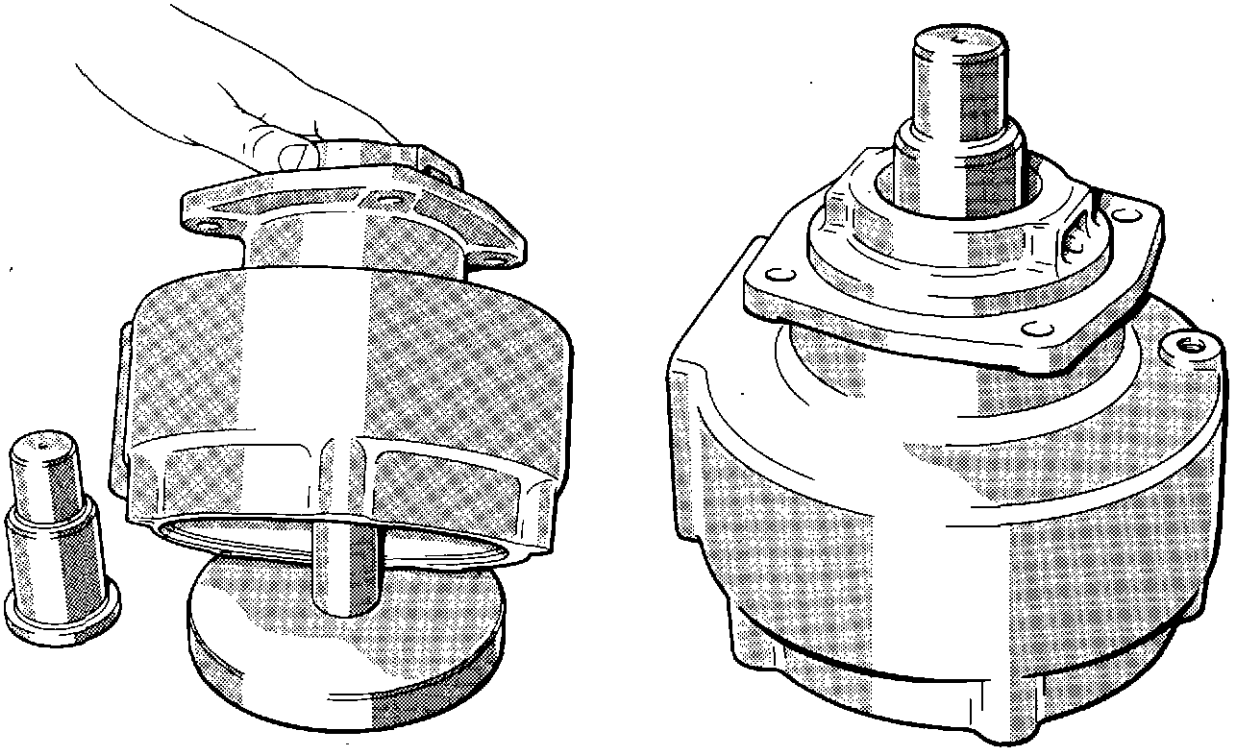


Fig. 7 Oil seal insertion tool

32 Slide the inner ball bearing over the pillar and, using the tool sleeve, press the bearing fully home.

33 Lift off the sleeve and fit the distance piece, followed by the outer ball bearing, over the pillar. Once more, press the bearing home with the sleeve. Remove the tool.

34 Stand the Support Base, VT 10682, on the press bed. Position the Assembly Base, VT 10679, on top of the support base, with the boss uppermost.

35 Position the pump casing assembly on the assembly base, drive end downwards, with the outer bearing locating on the boss.

36 Enter the shaft into the inner ball bearing, tapered end downwards, and press the shaft down through the inner bearing, distance piece and outer bearing until the shoulder on the shaft contacts the inner ball bearing.

37 Place the coolant seal around the impeller end of the shaft, with the seal face uppermost.

38 Fully slacken back the ball-end screw of the seal Insertion Tool, VT 10680, and secure the tool to the pump casing using three setbolts. Screw in the ball-end screw to press the coolant seal fully home. Remove the insertion tool.

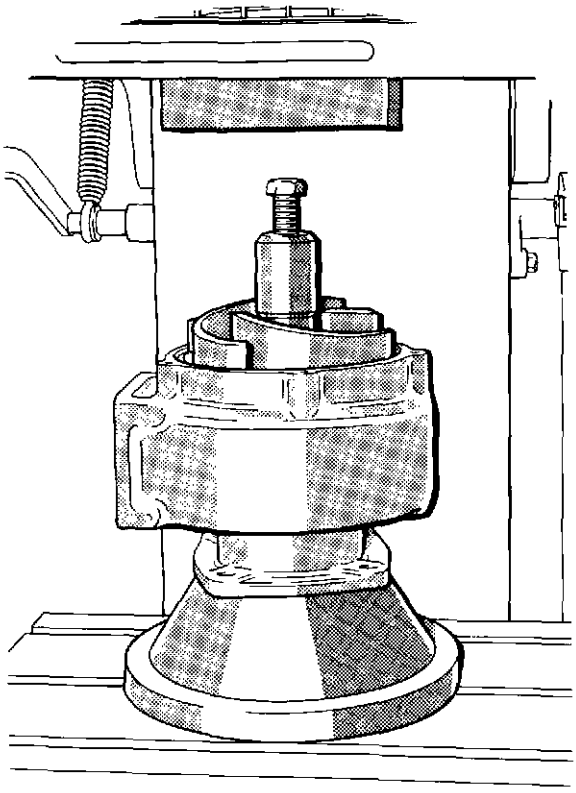


Fig. 8 Refitting the impeller

39 Secure the pump assembly once more to the locking plate, with the slot engaging with the impeller shaft tongue. Secure the locking plate in a vice.

40 Fit the circlip into its groove adjacent to the outer ball bearing. Coat the threads of the bearing lock nut with 'Loctite 241', screw the nut on the shaft and tighten to a torque loading of 100 Nm (74 lbf.ft.).

41 Fit the drive gear on to the shaft taper, apply a thin coating of 'Loctite 241' to the shaft thread and run the gear securing nut on to the shaft. Tighten the nut to a torque loading of 88 Nm (65 lbf.ft.). Remove the pump assembly from the locking plate.

42 Press the ceramic face seal into its location in the back face of the impeller, with the ceramic face outwards.

43 Place the Assembly Base, VT 10682, on the press bed and stand the pump assembly in the base, drive end downwards.

44 Fit the impeller on the end of the shaft, place the Insertion Tool, VT 12205, on the boss of the impeller (fig. 8) and, adjusting the insertion tool stop screw as necessary, press the impeller down, until the upper face of the boss is flush with the shoulder on the shaft.

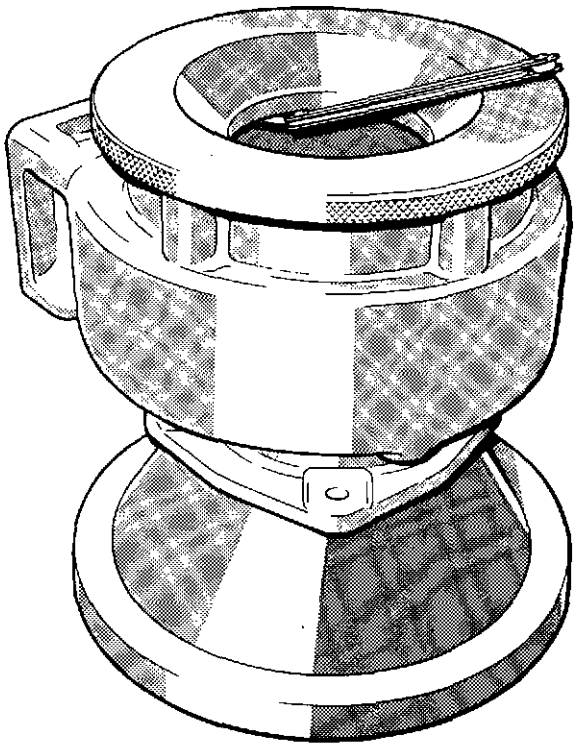


Fig. 9 Checking impeller clearance

45 Lift the insertion tool off the impeller and locate the Checking Gauge, VT 13976, in the pump casing. Using feeler gauges (fig. 9), check the clearance between the impeller blades and the gauge. Permissible clearance is 0,8 to 1,5 mm (0.030 to 0.060 inch). If the clearance is excessive, carefully readjust the insertion tool stop screw, and press the impeller further on the shaft until the correct clearance is achieved.

46 Using a new 'O' ring seal, fit the end cover to the pump assembly, ensure that the cover is correctly aligned and fit the five setbolts, with plain and spring washers. Tighten each setbolt securely.

47 Spin the shaft assembly and check for any signs of binding or rubbing in the casing; rectify, if necessary, before fitting the pump to the wheelcase.

Refitting

48 Slide a new hose connection and two hose clips over the pump suction elbow and, using a new gasket, locate the pump assembly on the four wheelcase studs. Fit the four nuts and spring washers and tighten securely. Slide the hose connection over the pipe joint and align and tighten the two hose clips.

49 Slide a new hose connection and two hose clips over each arm of the bifurcated pipe and, using a new gasket, position the pipe against the pump discharge flange. Fit the four setbolts with plain and spring washers and tighten securely.

50 Slide the two hose connections over the pipe joints and align and tighten the four hose clips.

51 Refit the two main fuel filters.

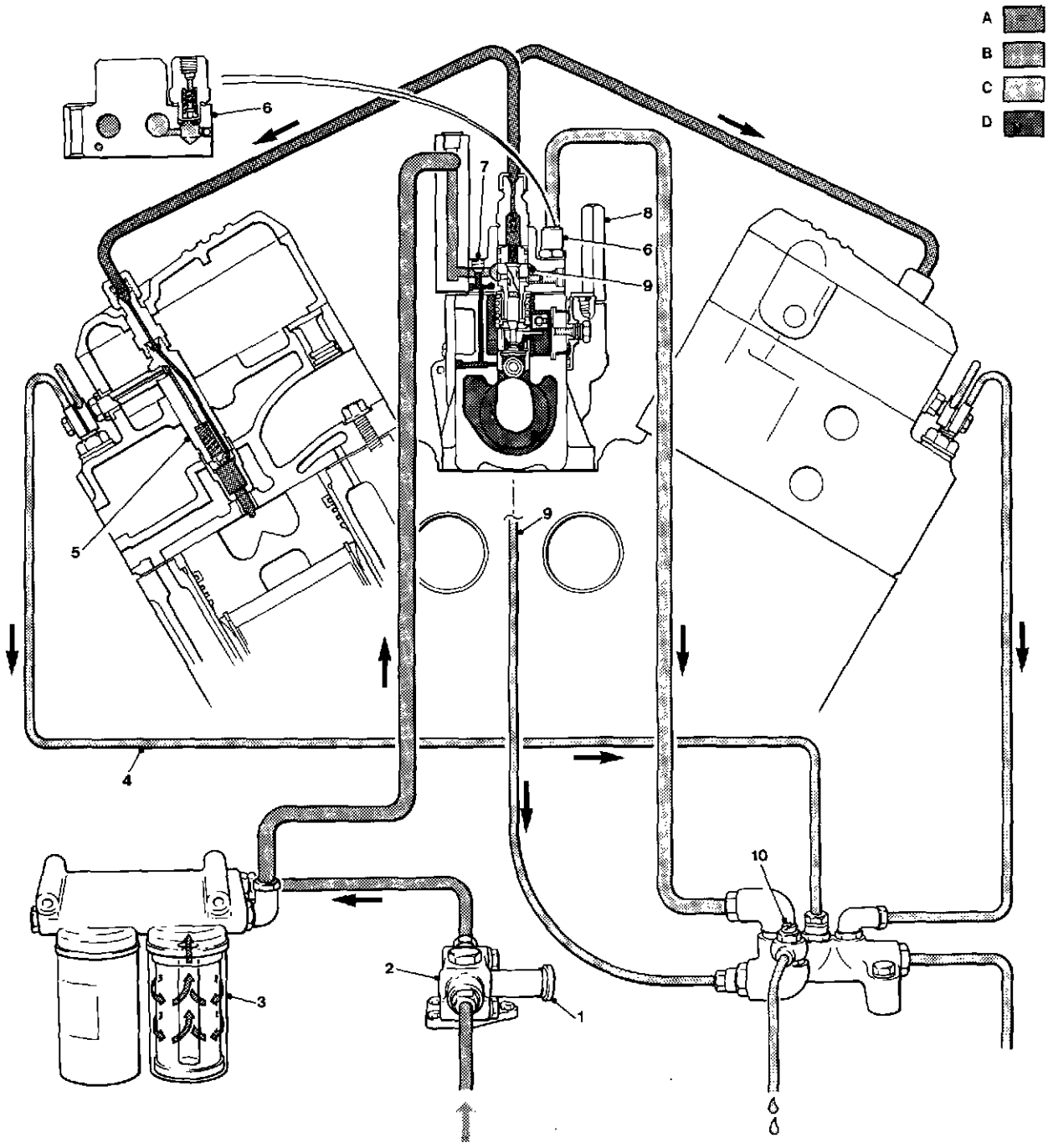
SPECIAL TOOLS

Part number	Description
VT 10681	Locking plate, impeller shaft
VT 10682	Support base
VT 13845	Extension, use with VT 10682
VT 13966	Drift, shaft assembly removal
VT 10677	Insertion tool, oil seal
VT 13821	Insertion tool, ball bearing
VT 10679	Assembly base, impeller shaft
VT 10680	Insertion tool, coolant seal
VT 12205	Insertion tool, impeller to shaft
VT 13976	Checking gauge, running clearance

SERVICE RECLAMATION SCHEMES

S.R.S. 133 Reclaiming damaged thread in coolant connection

SECTION 13 - FUEL SYSTEM



1	Hand priming pump	6	Relief valve	A	High pressure fuel
2	Feed pump	7	Lub. oil inlet	B	Low pressure fuel
3	filters	8	Governor oil inlet	C	Spill return to tank
4	Injector spill	9	Injection pump spill	D	Lubricating oil
5	Fuel injector	10	Bleed screw		

Fig. 1 Fuel system (Schematic)

SECTION 13 - FUEL SYSTEM

Description

Depending on application, a mechanical or electrically driven fuel feed pump draws fuel through a primary filter and delivers it, via the main filters, to the injection pump gallery. The gallery pressure is maintained at a constant pressure of 90 to 117 kN/sq.m (13 to 17 lbf./sq.inch) by two low pressure relief valves mounted on the injection pump casing.

Fuel enters the pump elements from the gallery, and is delivered at high pressure to the 12 low spring type injectors, which are set to operate at 240 bar (240 atmospheres).

A spill block, mounted on the 'B' bank side of the wheelcase, returns excess fuel and spill from the injection pump, and spill from the fuel injectors, back to the supply tank.

A bleed screw and drip pipe assembly is housed in the spill block to facilitate venting of the low pressure fuel system.

Overhaul instructions

Scrupulous cleanliness and careful handling of the components must be observed at all times when overhauling or servicing items in the fuel system.

Thoroughly clean each component and its surrounding area before dismantling, and fit sealing caps or plugs to all unions immediately following any disconnections.

FUEL FEED PUMP (Mechanical)

Feed pump removal

1. Before removing the feed pump from its mounting, slacken each of the blanking plugs over the three valves, the priming pump body and the large cap plug over the pump plunger (fig. 2). Disconnect the fuel pipes, if applicable, and remove the feed pump securing bolts. Lift the pump clear of its mounting.

Dismantling and inspection

2 Remove the priming pump, plugs, valve springs, valves and pump plunger. Check all the components for wear and damage, and check the tension of each spring.

Note: The pump plunger and spring are supplied as a matched pair, identified by a colour code, and must be renewed as a pair if necessary.

3 Remove the circlip from the pump body and withdraw the roller/tappet assembly. Dismantle the assembly and inspect the components for wear and damage. Renew any items in doubtful condition.

4 Check the action of the hand priming pump and replace as a unit if found to be unserviceable.

5 Clean out the pump body and inspect the bores for score marks; check the condition of the valve seats.

Assembling

6 Apply a light coating of clean engine oil to all the components and assemble the pump, using new joint washers. Tighten the plugs and priming pump securely.

Testing

7 Carry out a leakage test by blanking off the delivery connection and applying air pressure at 193 kN/sq.m (28 lbf/sq.inch) to the suction connection, with the pump immersed in fuel oil. Check for air bubbles and, at the same time, operate the pump plunger to ensure that there is no leakage from the tappet bore.

8 Check the feed pump output during testing of the fuel injection pump. The low pressure relief valves, mounted over the injection pump fuel gallery, are set to open at 90 to 110 kNf/sq.m (13 to 17 lbf/sq.inch); feed pump pressure should easily exceed this. Details of further tests, involving special apparatus, are available from the pump manufacturer, if required.

FUEL INJECTORS

Removal

1 Disconnect and remove the high pressure and fuel spill pipework. Remove the rocker box cover as necessary and unscrew the injector spill connection through the rocker box side wall. Release the injector clamp bolt and withdraw the injector. Sticking injectors may be freed by using the inertia extractor GA 5100 and adaptor GA 5100-5. Care must be taken to avoid slackening the copper injector sleeve in its housing, when using the extractor.

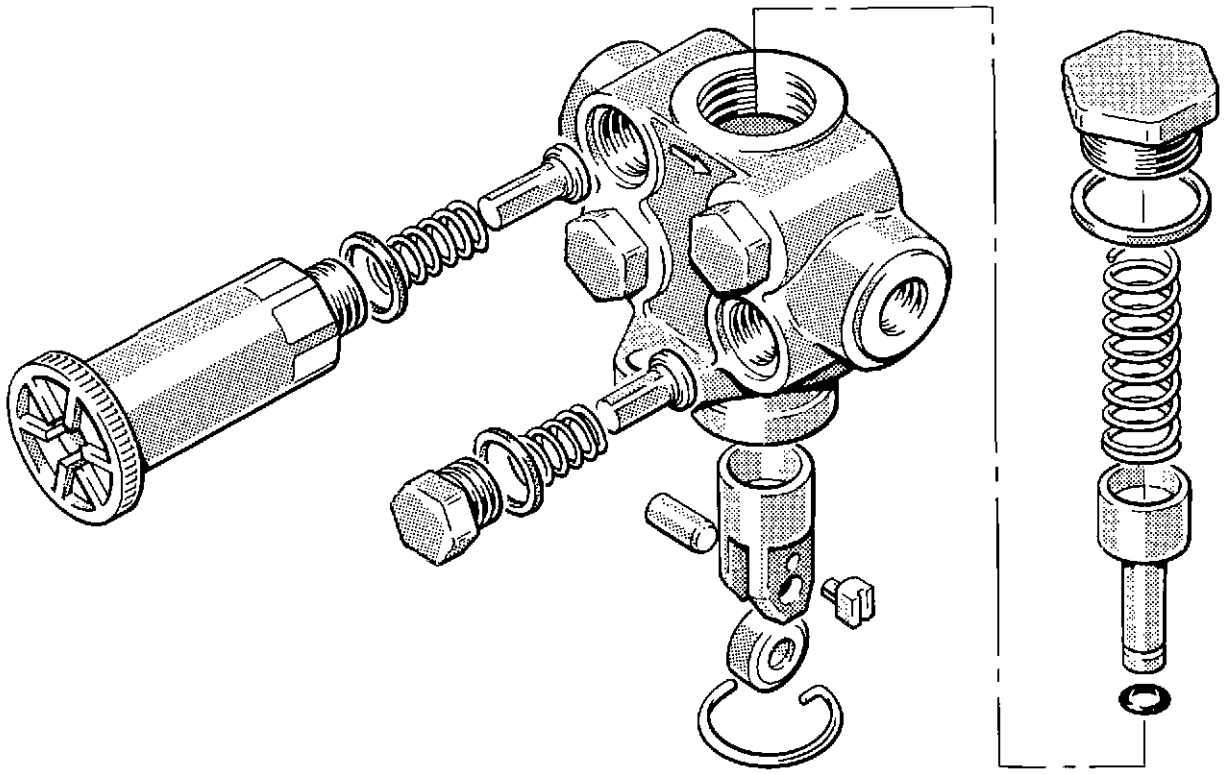


Fig 2 Fuel feed pump

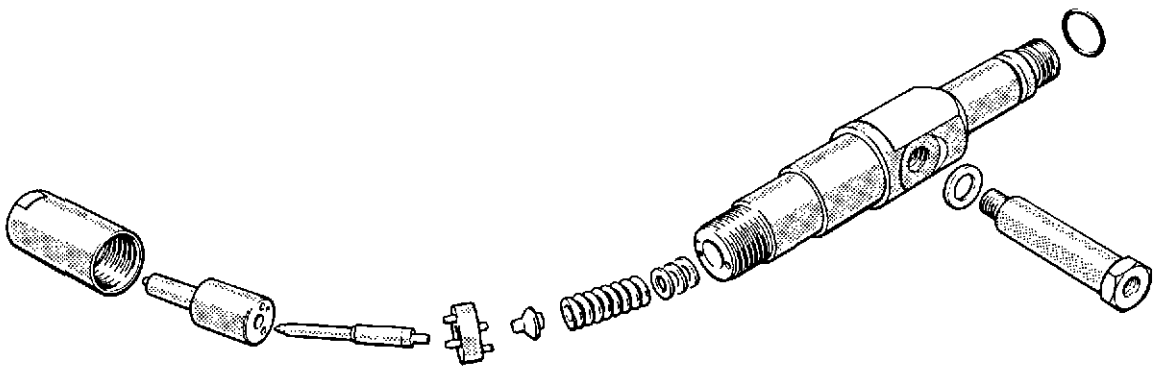


Fig 3 Fuel injector

Dismantling and cleaning

2 Lightly grip the injector body in a vice and unscrew the nozzle cap nut. Withdraw the nozzle assembly together with the transfer block, spring cap, valve spring and adjusting shims. Keep all the components of each separate injector together, in individual trays.

Note: Each needle valve is ground to its individual nozzle body and is not interchangeable with any other nozzle body.

3 Wash the components of each injector in fuel oil or paraffin, and blow dry with compressed air. Soak the nozzle assembly in a carbon solvent such as 'Maxan 774', obtainable from Henkel Chemicals Limited, Edgware Road, London. Remove any remaining carbon from the nozzle and valve using the cleaning kit, KRP 1089, see figures 4 to 8 inclusive. It is important that all carbon is removed from the bores of the spray holes and that the correct size cleaning wires are used. The cleaning wires are 'D' section in shape, their size being measured across the full diameter. Fit the cleaning wire into its holder so that not more than 1,5mm (0.0625 inch) protrudes from the chuck. Longer protrusions increase the risk of wire breakage and it is extremely difficult to remove a broken wire from a spray hole. Insert the wire into each spray hole with a twisting, scraping action, until the hole is clear.

Caution : Do not attempt to clean the nozzle assemblies with implements other than those provided in the cleaning kit.

When all the spray holes are clear, re-soak each nozzle in 'Maxan' 774, rinse in clean water and blow dry with compressed air. Assemble each nozzle in turn, to the Flushing Device OD 5178, attach it to the Setting Outfit OD 16849, and flush through in reverse flow direction to remove any loose particles.

Inspection

4 Using a magnifying lens, check each valve for hammered or rough seats, or other damage. Check each nozzle for seat damage or worn spray holes. If the valve face or nozzle are discoloured due to overheating, both components must be renewed. DO NOT attempt to lap a needle valve to its seat as their angles are not identical. Dip the needle valve into clean test oil and insert it into its nozzle bore. Slide the valve fully home then, holding the nozzle almost vertical, withdraw the valve approximately one third of its length out of the nozzle. When released the valve should slide back down on to its seat, under its own weight.

5 Inspect the pressure faces between the injector body, transfer block and nozzle for signs of scratches or damage which could cause leakage under high pressure.

6 Check the shims for damage and inspect the spring for distortion, damage or corrosion.

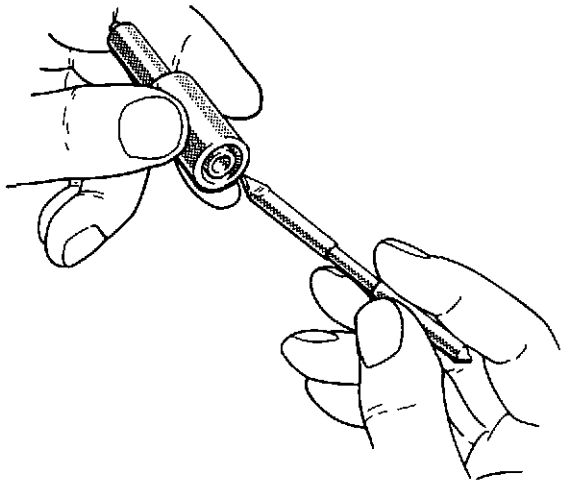


Fig 4 Nozzle seat scraper

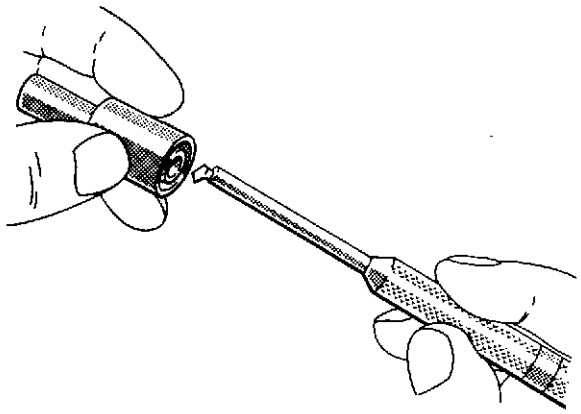


Fig 5 Gallery scraper

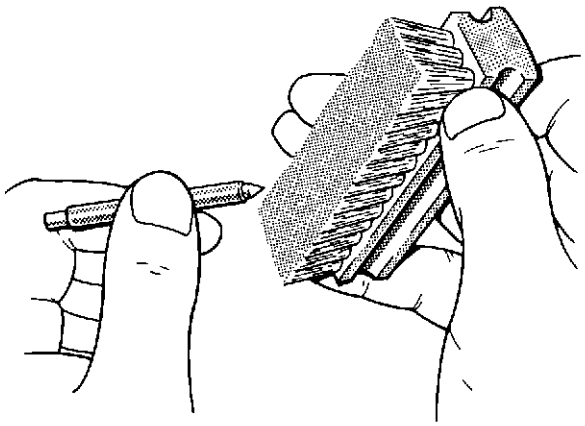


Fig 6 Use of brass wire brush

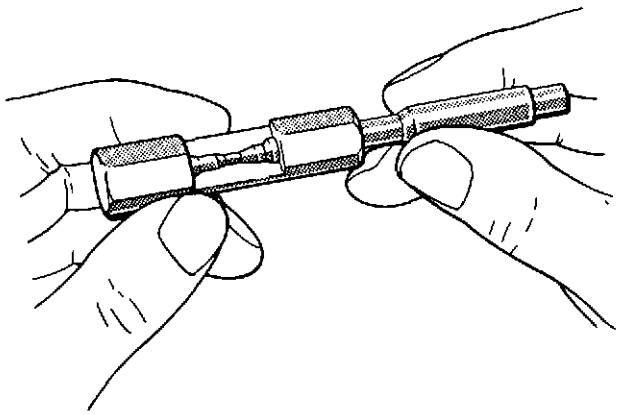


Fig 7 Needle valve scraper

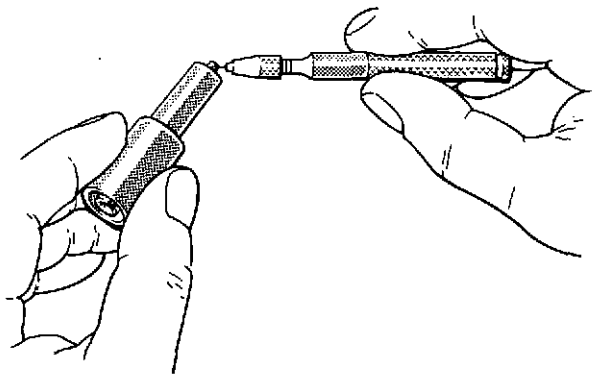


Fig 8 Use of cleaning wire

Assembling

7 Lightly grip the injector body in a vice and insert the correct adjusting shims, followed by the valve spring and spring seat. Locate the transfer block around the spring seat.

8 If the nozzle and valve are not assembled, immerse the components in clean test oil and slide the valve fully home. Locate the assembly on the transfer block and fit the nozzle cap nut. Tighten the nut to a torque loading of 80 Nm (60 lbf.ft).

9 Screw the spill connection into the injector body and nip it up. Do not tighten at this stage.

Setting and testing

Warning : When testing an injector, the nozzle must be turned away from the operator as the spray has sufficient force to penetrate human skin.

10 Ensure that the container of the Nozzle Setting Outfit, OD 16849, is filled with clean test oil (see following page). Slacken the vent screw and operate the hand lever until bubble-free oil emerges. Tighten the screw and continue operating the hand lever until bubble-free oil runs from the discharge connection.

11 Screw the discharge connection to the injector inlet and tighten securely. Close the pressure gauge valve to prevent damage to the gauge and operate the hand lever vigorously to expel air from the injector. Open the gauge valve 1/4 of a turn, operate the lever slowly and note the pressure at which the gauge needle 'flicks', indicating nozzle valve opening. Unless otherwise stated, this should be 240 bar (240 atmospheres) $\pm$ 5 bar.

12 If the injection pressure is incorrect, the injector must be dismantled and the shims adjusted accordingly; to increase pressure, add extra shims; to reduce pressure, remove shims.

13 When the correct setting is achieved, dry the nozzle tip and pump up the pressure slowly until the gauge needle indicates 220 bar (220 atmospheres). Maintain this pressure for 10 seconds then inspect the nozzle tip; slight dampness is acceptable but there should be no droplets of oil.

Note: Do not attempt to rectify leakage by overtightening the nozzle cap nut.

14 For the back leakage test, pump up the pressure slowly until the gauge needle indicates 230 bar (230 atmospheres). Release the hand lever and note the time taken for the pressure to fall naturally to 150 bar (150 atmospheres). If the time taken is less than six seconds the nozzle assembly must be rejected. Continue monitoring the gauge and check the total time taken for the gauge to register 100 bar (100 atmospheres); this must not be less than 45 seconds.

Before rejecting a nozzle assembly, ensure that leakage is not due to carbon or dirt on the pressure faces and, in the event of a high number of rejections, check that the fault does not lie within the setting outfit. At regular intervals, depending on usage, the filter element must be renewed and, if necessary, the test oil changed. It is advisable to have the equipment checked for accuracy at a service depot, at intervals not exceeding two years.

15 For the atomisation check, close the pressure gauge valve and operate the hand lever at approximately two strokes per second. Check that each nozzle hole emits a spray of fully atomised oil and that each of the sprays are equal in volume. After spraying, the nozzle tip should be dry.

Storage

16 Following satisfactory completion of tests, wipe the injectors dry and fit protective caps over the nozzles, inlet and spill connections. Store the injectors in a dry, warm place until required for use.

APPROVED NOZZLE TEST OILS

SHELL (UK)	Calibration fluid C
SHELL (OVERSEAS)	Calibration fluid B
ESSO	Calibration fluid IL 1838
CASTROL	Calibrating oil 8327

SPECIAL TOOLS

Rolls-Royce Part Number	Description
OD 16849	Nozzle setting outfit
OD 5178	Nozzle flushing tool
OD 18745	Spanner adaptor, nozzle cap nut
*KRP 1089	Nozzle cleaning kit

*The nozzle cleaning kit comprises the following :

OD 5167	Brass wire brush
OD 12504	Nozzle seat scraper
OD 12505	Scraper holder
OD 12506	Cavity scraper, 1,2 mm diam.
OD 17243	Cavity scraper, 1,8 mm diam.
OD 5169	Body groove scraper
OD 5179	Needle valve seat cleaner
OD 5180	Cleaning wire holder

Cleaning wires are available in tubes of ten, and are ordered separately.

OD 13156	Cleaning wire, 0,30 mm diam.
OD 17891	Cleaning wire, 0,32 mm diam.

FUEL INJECTION PUMP AND GOVERNOR

Removal

Before the fuel injection pump can be lifted from the engine, various other components must first be removed as follows :

1 Disconnect and remove :

(a) The 12 high pressure, fuel injector feed pipes.

(b) The speed control linkage.

(c) The stop control linkage and solenoid assembly.

(d) The control lever cross shaft assembly.

(e) The spill and excess fuel pipework, from the injection pump gallery.

(f) The low pressure fuel feed pipework, from the feed pump.

(g) The lubricating oil feed and return pipework, from the cambox and governor housing.

2 Remove the two long reach nuts from the auxiliary drive flange spring plate coupling (fig. 10), and withdraw the two coupling bolts towards the wheelcase.

3 Unscrew and remove the eight pump securing setbolts and washers.

4 Attach the Lifting Beam, VP 878, to two of the delivery valve holders and carefully lift the pump, complete with spring drive coupling and governor, clear of the crankcase. Lower the pump on to a clean, metal faced or linoleum covered workbench.

5 Unscrew the four adjustable coupling socket capscrews; remove the clamping ring and the flywheel/drive coupling assembly.

6 Using rope strops and a hoist, lift the pump assembly clear of the workbench and, holding it over a suitable receptacle, tilt the assembly to allow the lubricating oil to drain from the cambox and governor housing.

Dismantling

Note : Before starting to dismantle the injection pump and governor, thoroughly clean the exterior of the assembly with paraffin or fuel oil and blow dry with compressed air.

7 Grip the Mounting Bracket, ST 228, in a vice, secure the fuel pump assembly on to the bracket and remove the lifting beam.

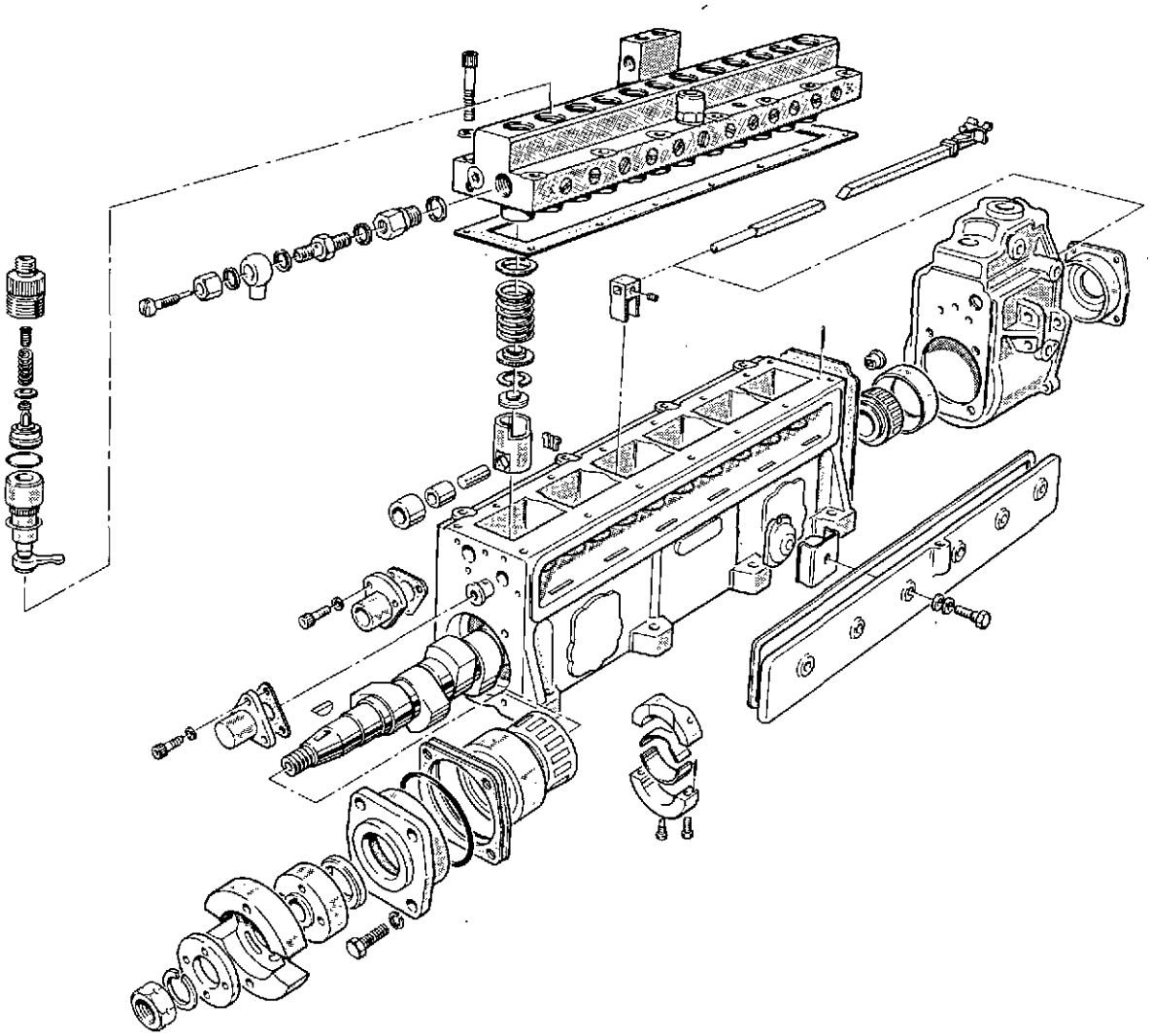


Fig. 9 Fuel injection pump assembly

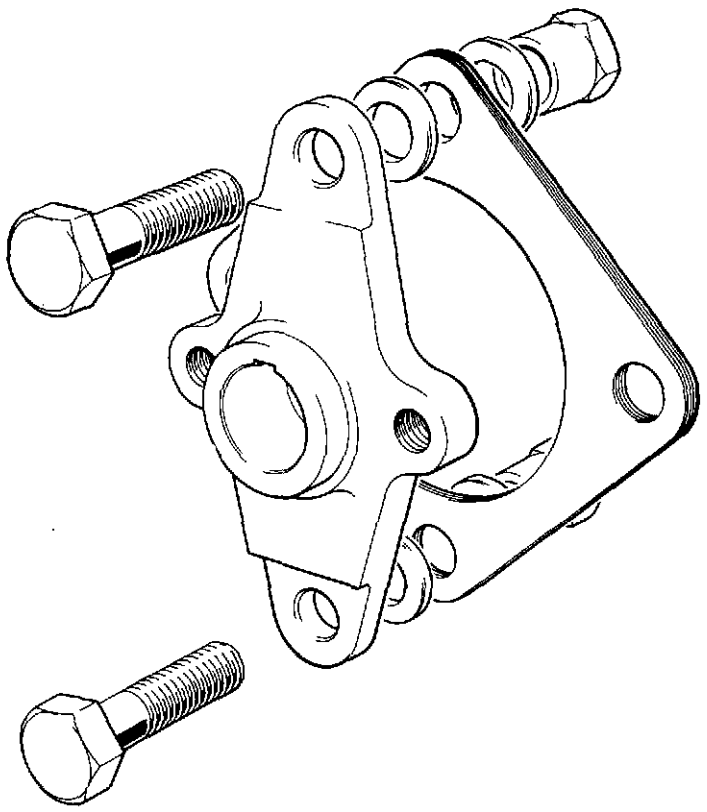


Fig. 10 Auxiliary drive flange

8 Remove all wire locks from the assembly, unscrew the six inspection cover securing setbolts and remove the cover and gasket.

9 Remove the six locating clips, turn the bridge plates 90 deg. and release them from the cambox.

10 Using the Socket Spanner, No.7044-661, slacken each of the delivery valve holders one or two turns. Do NOT remove the valve holders at this stage.

11 Unscrew the pump body securing socket capscrews evenly and progressively, maintaining a light downward pressure on the body whilst the screws are being removed. Do NOT lift off the pump body at this stage.

12 Release the vice and place the pump assembly, complete with mounting bracket, onto the workbench.

13 Carefully lie the pump assembly on its side with the inspection aperture facing downwards.

14 Ease the pump body away from the cambox so that the pump plungers do not fall out of their respective barrels.

15 Withdraw each plunger, complete with its spring and upper and lower spring plates (fig. 11).

Note: As each plunger assembly is removed it must be placed in a separate container marked with the pump element number. This is to ensure that the components of one element do not become mixed with those of another element.

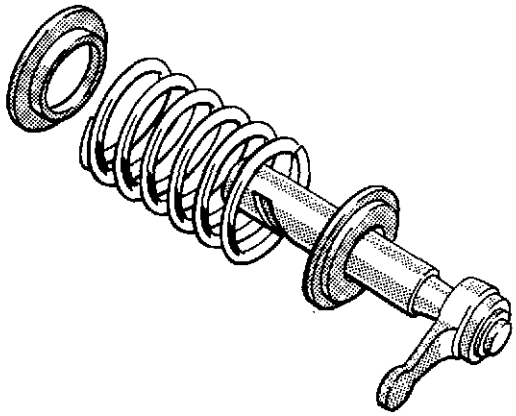


Fig. 11 Plunger assembly

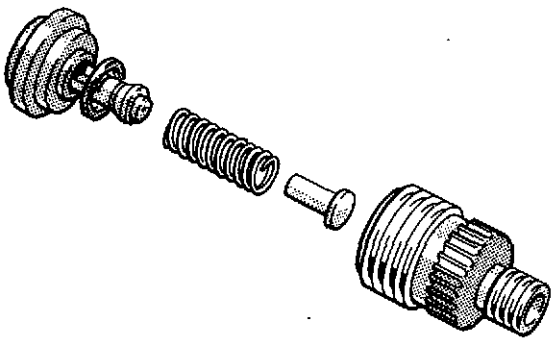


Fig. 12 Delivery valve assembly

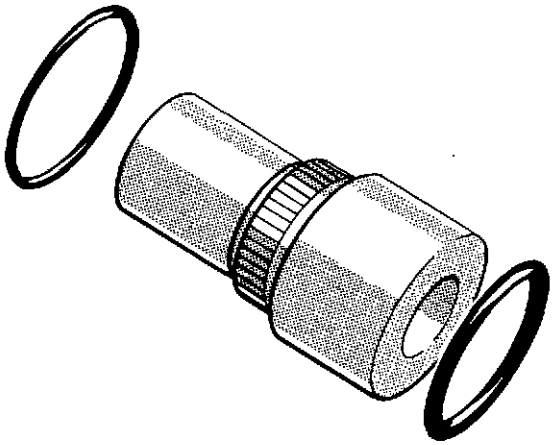


Fig. 13 Barrel assembly

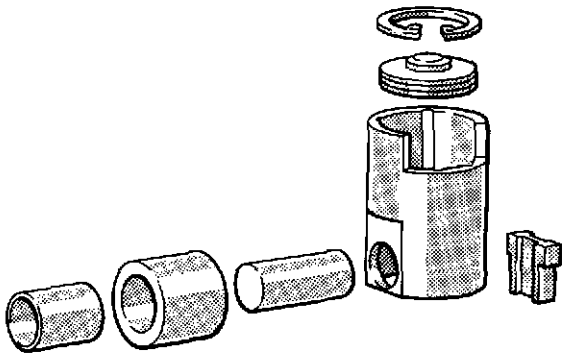


Fig. 14 Roller tappet assembly

16 Unscrew and remove each of the previously slackened delivery valve holders, complete with spring and volume reducing peg (fig. 12). Place each assembly in its respective container along with the plunger assembly.

17 Lift out and discard the metal sealing washers from the top of each valve guide.

18 Withdraw each valve and valve guide from the pump body. Place each assembly in its respective container.

19 Using a plastic mallet, sharply tap the bottom end of each barrel to free it from the pump body. Place the barrels in their respective containers. Discard the seating washers and 'O' ring seals (fig. 13).

20 In turn, immerse the plungers and barrels in clean test oil and assemble each plunger to its mated barrel to prevent damage to the lapped surfaces. Replace each assembly in its respective container.

21 Lift out each tappet assembly (fig. 14), from the cambox and dismantle as follows :

(a) Push out the roller pin from the tappet guide and withdraw the roller and bush.

(b) Remove the circlip from the guide and withdraw the tappet (phasing) spacer.

22 Place each tappet assembly in its respective container.

23 Slide out the tappet locating 'T' pieces from between the tappet bores and note the order of removal for correct re-assembly.

The end cover on CS governors may vary in design, depending on application. Each cover incorporates a servo valve assembly and, where a fixed ramp is used, the ramp is secured to the inner wall of the cover. The more obvious differences are the positions of the lubricating oil inlet and outlet connections and the provision of an access plug for ramp adjustment, where necessary (fig. 15).

Secure the pump/mounting bracket assembly in the vice once more and proceed:

24 Release the locknut and fully slacken the maximum fuel stop screw, in the top of the governor housing (fig. 16a). Unscrew the seven setbolts which secure the governor end cover to the housing; remove the cover and gasket.

25 Swing the variable ramp upwards and lift out the ramp roller assembly from the roller control lever fork.

26 Note the primary spring and ramp arrangement, for purposes of re-assembly, then tap out the fulcrum pin from the side opposite to the pump inspection cover; slide off the primary spring and variable ramp.

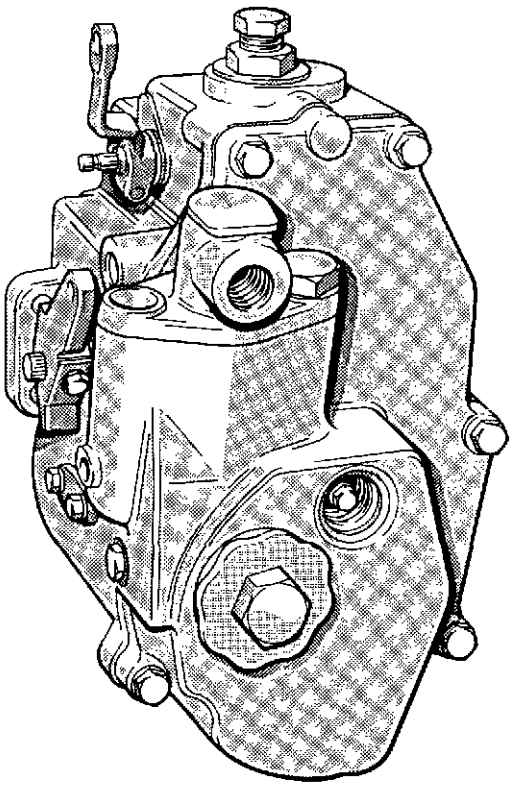


Fig. 15a Governor end cover (Early engines)

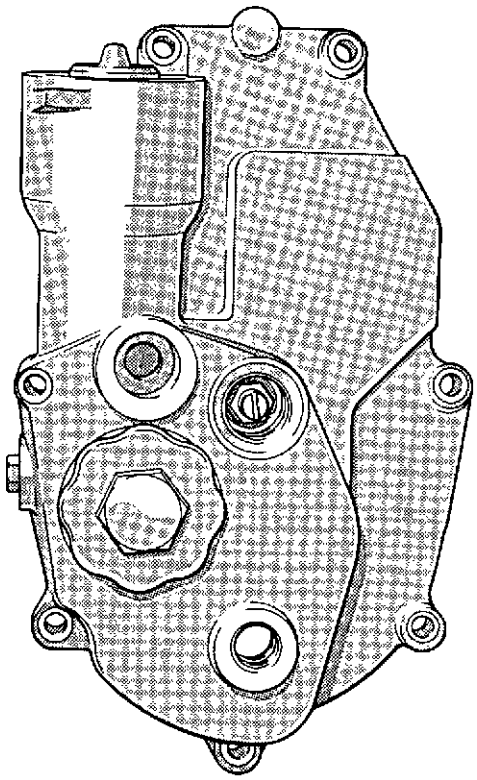
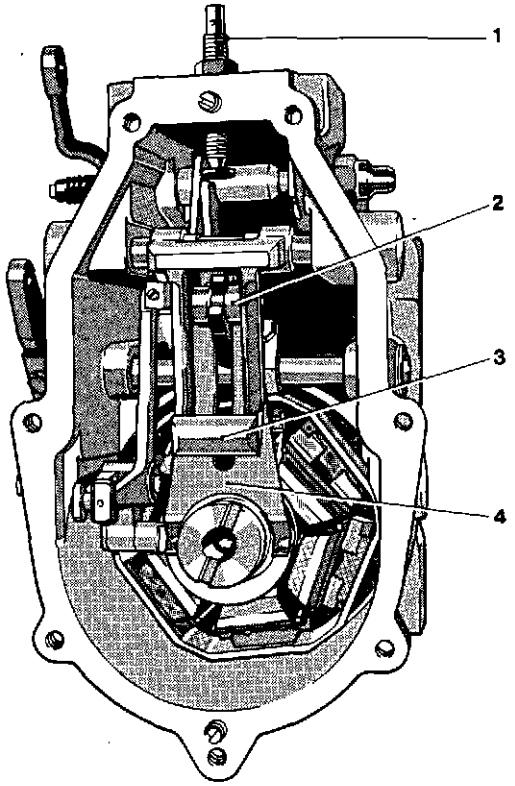
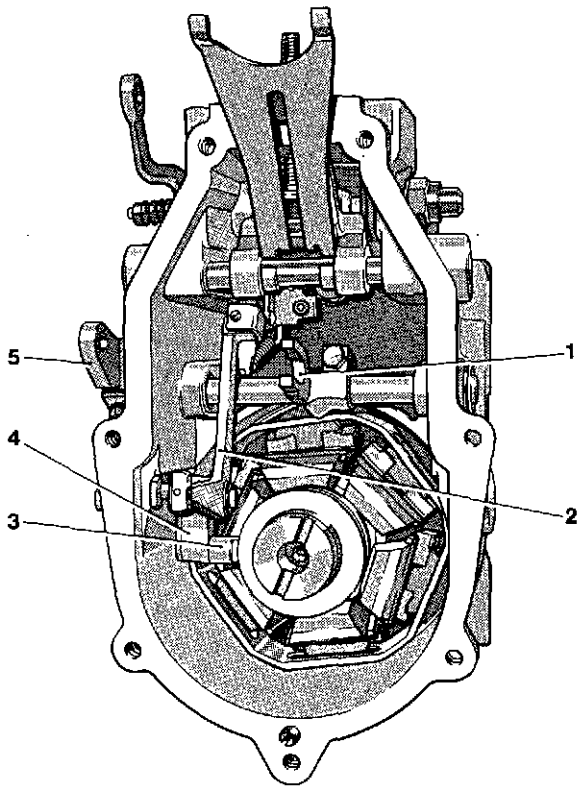


Fig. 15b Governor end cover (Latest engines)



1 Maximum fuel stop screw
2 Ramp roller
3 Variable ramp
4 Primary spring

Fig. 16a Governor components



1 Roller control lever
2 Connecting lever
3 Slipper pin
4 Servo valve lever
5 Speed control lever

Fig. 16b Governor components

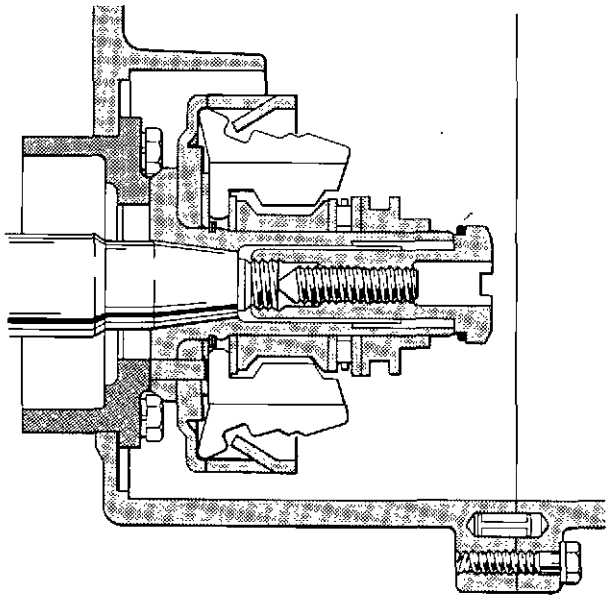


Fig. 17 Governor hub assembly

27 Remove the setbolts and spring washers from the flange of the pivot pin and lever off the 'E' type spring clip from the inner end of the pin; lift off the shim washer from behind the spring clip.

28 Hold the servo valve lever, spacer shims and connecting lever assembly and withdraw the pivot pin, complete with gasket. Remove the shims.

29 Move both levers to the left and forward to free the slipper pin from the thrust pad groove; withdraw the pin and separate the two levers.

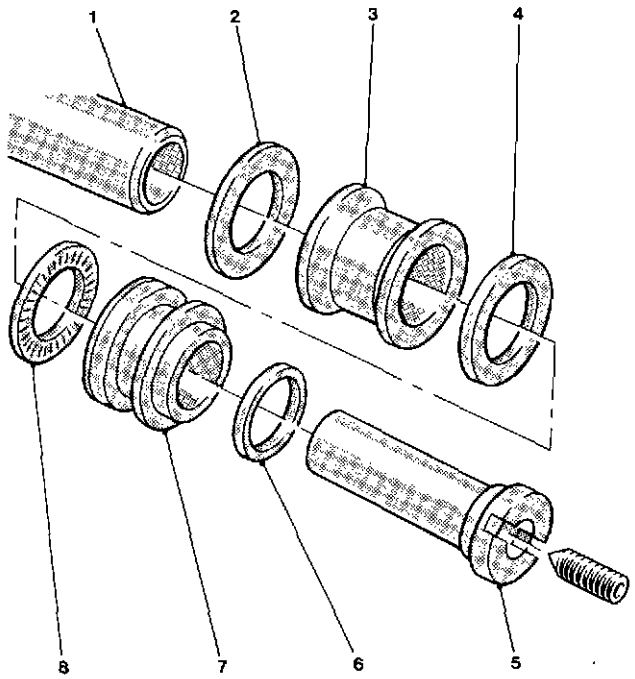
30 Remove the two extension springs from the anchor points on the fuel control rod and connecting lever (fig. 16b). Lift out the lever.

31 Using a suitable holding wrench on the injection pump drive hub, slacken the grub screw in the centre of the governor hub nut.

32 Using Hub Key, ST 200, unscrew and remove the hub nut, complete with spacer ring(s).

33 Using the Hub Extractor, ST 202, withdraw the complete governor hub assembly (fig. 17), from the camshaft tapered end and separate the components (fig, 18).

34 Using a sharp pointed implement, unwind the Spirolox ring from its groove in the governor hub, lift off the retaining plate and weight cage and press out the six rubber pads from the slots in the cage.



1 Governor hub
2 Thrust washer (48,3 *mm* diam.)
3 Sleeve
4 Thrust washer
5 Hub nut
6 Spacing ring(s)
7 Thrust pad
8 Needle thrust bearing

Fig. 18 Hub components

Carefully note the position of the speed control lever in relation to the roller control lever, to facilitate re-assembly, and proceed :

35 Slacken the clamping bolts and withdraw the speed control lever and stop quadrant.

36 Slacken the clamping bolt on the roller control lever (fig. 16b), and slide the lever along the shaft, to enable the Woodruff key to be extracted.

37 Remove the spring clip, plain washers and bowed spring washer from the quadrant end of the speed control shaft. Withdraw the shaft and lift out the roller control lever.

38 Extract and discard the 'O' ring seals and Quad rings from the speed control shaft bushes.

39 Punch out the Groverlok pin securing the maximum stop lever assembly to the excess fuel shaft, see fig. 29, and remove the shroud followed by the stop control lever.

40 Unscrew the cap at the opposite end of the shaft and remove the return spring and washer.

41 Remove the spring ring, washer and 'O' ring seal, slide out the excess fuel shaft and remove the quad ring, maximum stop lever assembly, sealing washer, stop shaft assembly, thrust washer and bush.

42 To inspect the servo valve and piston assembly, the valve cover must be removed from the governor end cover. Dependent on the type of end cover fitted, proceed as follows :

(a) If the earlier type end cover is fitted (fig. 15a), remove the vent bolt and the oil inlet connection from the servo cover flange. Lift off the servo cover, discard the gasket, remove and discard the 'O' ring seal from the groove in the servo cover body. Lift out the valve assembly.

(b) If the modified type servo cover is fitted, remove the vent bolt and oil inlet connection, as above, and push the piston assembly upwards to remove the alloy plug, fitted directly beneath the cover flange. Discard the 'O' ring seal and cover gasket.

(c) If the later type governor end cover is fitted (fig. 15b), remove the circlip securing the cone topped alloy plug in the top of the piston bore, withdraw the plug and remove the 'O' ring seal. Remove the circlip securing the internal alloy plug in the piston bore and push the servo valve and piston assembly upwards, to remove the plug. Discard the 'O' ring seal.

After dismantling the governor, continue dismantling the injection pump as follows :

43 Remove the three socket capscrews and spring washers securing the fuel control rod cover to the drive end of the cambox. Remove the cover and gasket.

44 Slacken each of the socket capscrews, securing the forks to the fuel control rod, and slide the rod out through the governor housing, lifting out the forks as they become free.

45 Using the Holding Wrench, 500037, on the pump drive hub, unscrew the hub retaining locknut and, using the Hub Puller, 77808, withdraw the hub from the camshaft taper and remove the Woodruff key.

46 Slacken the locknuts and remove the two intermediate bearing securing setbolts from the underside of the cambox.

47 Remove the four 'Tuflok' bolts and the four setbolts and spring washers, securing the front and rear roller bearing housings to the cambox; lift off the timing indicator.

48 Using a plastic or hide mallet, tap the rear end of the camshaft to dislodge the front end bearing housing from the cambox. Withdraw the housing and detach the shims; discard the oil seal and 'O' ring seal. Tap the front end of the shaft to dislodge the rear bearing housing and withdraw the camshaft from the cambox, complete with the two intermediate bearing assemblies.

49 Remove the two setbolts, securing each pair of bearing caps, and detach the bearing caps and shells from the camshaft.

Note: Each mated bearing cap is stamped with a correlation number to ensure correct assembly.

50 Using the Extractor, 7244-430, remove the inner bearing tracks from each end of the camshaft and, using the Extractor, ST 219, withdraw the outer bearing tracks from the front and rear bearing housings. Store the inner and outer tracks together in their respective assemblies.

51 If required, remove the remaining setbolt from inside the governor housing to separate the housing from the cambox. Discard the jointing gasket.

Pump Inspection

Wash all the pump components in clean test oil and dry with compressed air, then check each part for wear and damage as described below :

52 Inspect the plunger and barrel for scoring. Fine score marks are acceptable, but heavy score marks and roughness on the upper edge of the spill groove indicate excessive wear. In such circumstances, it is recommended that all the pump elements are renewed.

53 If the components are lightly scored, assemble each pump element in clean test oil and whilst holding the assembly upright, rotate the plunger in both directions. If serviceable, the plunger will turn freely without binding and, when released, the plunger will fall slowly under its own weight, when rotated to any position.

54 Examine the plunger return spring for cracks and corrosion and check the spring length against a new spring. If defective, renew the springs as a set.

55 Check the barrel seats in the pump body for pitting or other damage. If necessary, clean up the seats using the Cutting Tool, ST 146 (fig. 19). Remove only the minimum amount of metal necessary to restore the seating face.

56 Check the delivery valve assemblies for pitting and residue, caused by contamination of fuel oil; renew if necessary.

57 Check the camshaft for damage or pitting. Excessive wear on the cams will affect the injection characteristics.

58 Check the camshaft bearings for wear or discoloration caused by overheating and check for slackness in the bearing tracks. If slack, renew both inner and outer tracks.

59 Examine the tappet walls for wear and check the cambox bores, particularly around the 'T' pieces; renew any worn components.

60 Check the roller assemblies for wear. If necessary, fit new rollers, pins and bushes.

61 Using the appropriate feeler gauges, check the clearance between each control fork and its respective pump plunger arm (fig. 20). Permissible limits are 0,01 to 0,20 mm (0.0004 to 0.008 inch). If the gap is excessive, renew the element and/or control fork as necessary.

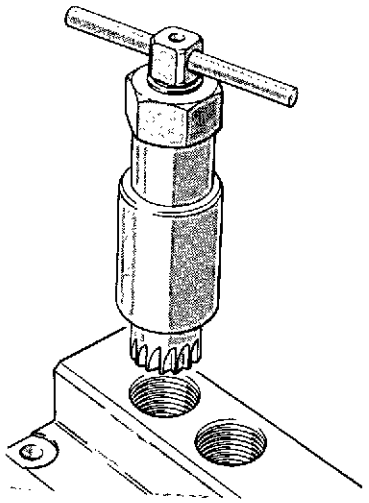
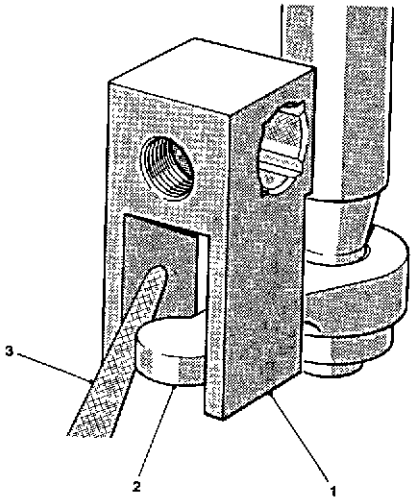
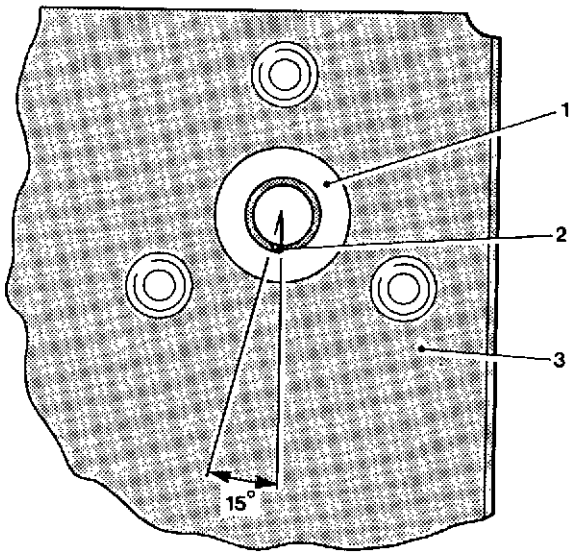


Fig. 19 Seat cutting tool



1 Control fork
2 Plunger arm
3 Feeler gauge

Fig. 20 Plunger arm clearance



1 Control rod front end bush
2 'V' groove in bush
3 Cambox housing

Fig. 21 Bush positioning

62 Check the control rod bushes for wear and/or ovality by temporarily fitting a new control rod. If the clearance is excessive, withdraw the control rod, drive the locking pin into the rear bush and carefully tap out both bushes.

63 Fit a new rear end bush, ensuring that the locking pin holes in the cambox and bush are correctly aligned, then tap the locking pin into position through the cambox top face. Ensure that the pin locates in the bush but does not protrude into the bush bore.

64 Press in the new front end bush, ensuring that the 'V' groove on the front face of the bush is positioned 15 deg. to either side of B.D.C. (fig. 21).

65 Check that the control rod moves freely in the new bushes then withdraw the rod.

Assembling the injection pump

66 Position a new gasket on the cambox, governor end face, ensuring that the oil transfer ports are not obstructed. Lightly secure the governor housing to the cambox, using the central 'Tuflok' bolt.

67 Using a hollow drift, assemble the inner tracks of the bearings to each end of the camshaft.

68 Lightly oil the outer tracks of the bearings and press them into their respective bearing housings.

69 Fit the rear bearing housing into the governor housing, lightly coat the threads of the four securing setbolts with Loctite 241 and fit the bolts, complete with new spring washers, into the bolt holes. Tighten each setbolt to a torque loading of 25,75 Nm (19 lbf.ft). Tighten the 'Tuflok' bolt to a torque loading of 16 to 20 Nm (12 to 15 lbf.ft).

70 Remove the cambox assembly from the vice and stand it on end on the governor housing. Carefully lower the camshaft assembly into position, fit the shims to the drive end of the cambox and temporarily fit the bearing housing. Fit the four 'Tuflok' bolts and tighten to a torque loading of 16 to 20 Nm (12 to 15 lbf.ft). Refit the assembly in the vice.

71 Set up a magnetic based D.T.I. gauge with the button resting on the end of the camshaft. Check the total axial movement of the shaft. Permissible end float is 0,05 to 0,127 mm (0.002 to 0.005 inch). If necessary, the end float may be adjusted by varying the shim pack thickness. Shims available for this purpose are listed below :

Part No.	Shim thickness
509582	0,19 mm (0.0076 inch)
509583	0,27 mm (0.0108 inch)
509584	0,38 mm (0.0148 inch)

72 Slacken the four 'Tuflok' bolts and stand the assembly on the governor housing once more. Remove the bolts followed by the bearing housing and shim pack. Withdraw the camshaft.

73 Coat the intermediate bearing shells with clean engine lubricating oil. Fit each bearing assembly on to the camshaft, ensuring that the correlation marks are correctly aligned. Fit the locating dowels and securing setbolts and tighten the setbolts to a torque loading of 6 to 7,5 Nm (4.5 to 5.5 lbf.ft).

74 Refit the camshaft assembly into the cambox with the intermediate bearings aligned so as to locate with the locking bolt holes in the base of the cambox. Fit the two locking bolts, with their locknuts, through the base of the cambox, into the bearing caps. Run each setbolt in until it is felt to 'bottom' in the bearing cap. Slacken off each setbolt half a turn and tighten the locknuts to a torque loading of 16 to 20 Nm (12 to 15 lbf.ft.), ensuring that the setbolts do not turn during tightening.

Secure the cambox assembly in the vice and proceed :

75 Press a new oil seal into the bearing housing, with the lip of the seal facing in towards the centre of the pump. Place the selected shim pack over the housing spigot, smear a little silicon grease around the spigot and fit a new 'O' ring seal into the groove.

76 Fit the bearing housing to the cambox, align the bolt holes and fit the four 'Tuflok' bolts and timing indicator plate. Tighten the bolts evenly and progressively to a torque loading of 16 to 20 Nm (12 to 15 lbf.ft).

77 Fit the Woodruff key into the keyway, slide the hub on to the camshaft taper and fit the spring washer and securing nut. Grip the hub with a suitable holding wrench and tighten the nut to a torque loading of 150 Nm (110 lbf.ft.).

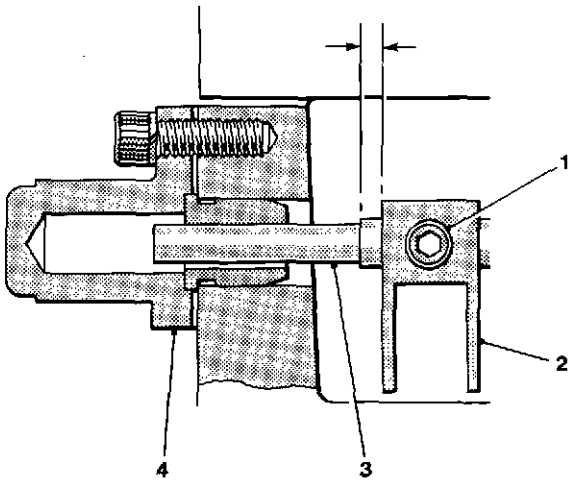
78 Ensure that all the pump body components have been thoroughly cleaned, then dip each component in clean test oil and proceed :

79 If the gallery end plugs have been removed, refit them, using new sealing washers. Tighten each plug to a torque loading of 115 to 136 Nm (85 to 100 lbf.ft).

80 If the spill plugs have been removed, dry the threads, apply 'Loctite 241' to each plug thread, fit new sealing washers and insert the plugs into the pump body. Tighten each plug to a torque loading of 32,5 to 40,5 Nm (24 to 30 lbf.ft.).

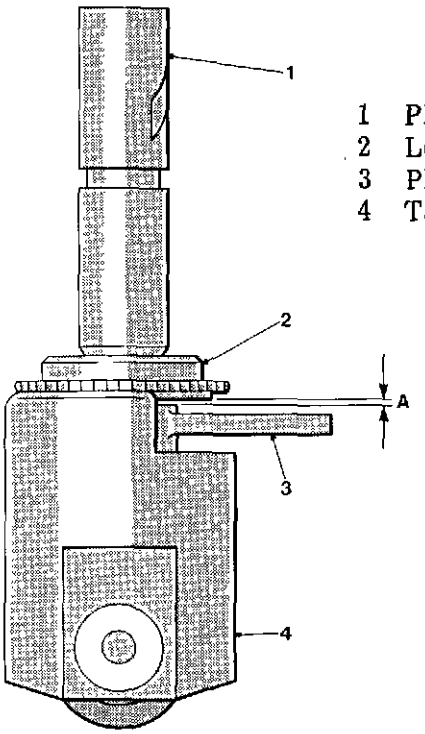
81 Temporarily secure the pump body to the cambox and fit new seating washers into each barrel bore in the pump body. Assemble each barrel in its correct location by aligning the serrations with those in the pump body.

82 Smear new 'O' ring seals with silicon grease and position one on top of each barrel. Fit the delivery valve guides, delivery valves and new metal sealing washers.



1 Grub screw
2 Control fork
3 Control rod
4 End cover

Fig. 22 Fork setting



1 Plunger
2 Lower spring plate
3 Plunger arm
4 Tappet guide

Fig. 23 Plunger/tappet clearance

83 Fit the delivery valve springs followed by the volume reducing pegs.

84 Coat the threads of the delivery valve holders with Castrol Grease 5903, screw each holder into its respective location and, using the socket spanner, Part No. 7044-661, tighten each delivery valve holder to a torque loading of 115 to 129 Nm (85 to 95 lbf.ft). Remove the pump body assembly from the cambox.

85 Slide the control rod through the rear end bush into the cambox whilst fitting the forks on to the rod in correct sequence.

86 Position the control fork for No 1 element, 3,0 mm (0.118 inch) from the end of the square section of the rod (fig. 22), and tighten its grub screw to a torque loading of 4,75 to 6,0 Nm (3.5 to 4.5 lbf.ft).

87 Slide the control rod backwards a little to align the No 1 fork with the centre of its tappet bore. Align the remaining 11 forks with their respective tappet bores and tighten the grub screws as for No. 1 control fork.

88 Fit the control rod end cover, complete with new gasket and spring washers, and tighten the three socket capscrews to a torque loading of 2,70 to 4,0 Nm (2 to 3 lbf.ft). Check that the control rod slides freely in its bushes.

89 Assemble the tappet roller, bush and roller pin into each tappet body. Insert the tappet (phasing) spacer and fit the retaining circlip with the convex side adjacent to the spacer.

90 Check the clearance between each plunger arm and its respective tappet (phasing) spacer, dimension 'A' in figure 23, as follows :

91 Assemble the lower spring seat to the plunger and hold the seat firmly in position in its associated tappet body. Using the appropriate feeler gauges, check the clearance between the bottom face of the spacer and the shoulder on the plunger arm. Permissible clearance is from 0,05 to 0,20 mm (0.002 to 0.008 inch). If the clearance is beyond these limits, the lower spring plate must be replaced by one of suitable thickness. See end of Section.

Tilt the pump mounting bracket in the vice so that the camshaft is approximately 20 deg. from the horizontal, with the drive end of the shaft at the lower point, then proceed :

92 Insert No. 1 tappet into its cambox bore with the cut-out in the tappet body facing the control fork. Carefully fit the tappet locating 'T' piece in position alongside the tappet. The 'T' piece will rest against the side of the tappet, reducing the risk of it falling into the cambox. Fit the remaining tappets and 'T' pieces in sequence.

93 When all the tappets have been fitted into the cambox, remove the assembly from the vice and lie it on its side, with the inspection aperture facing downwards, to enable the pump body to be fitted. Align the control forks with their respective tappet assemblies.

94 Insert the pump plungers into their respective barrels and fit a plunger locking plate to the pump body, to retain the plungers. Connect an air pressure supply to the fuel inlet connection and blank off all other openings in the fuel gallery.

95 Immerse the pump body completely, in a container of clean test oil and turn on the air supply. Ensure that the air pressure does NOT exceed 345 kN/sq.m (50 lbf/sq.inch). Check for air bubbles forming. Slight leakage from around the plungers is acceptable but any other leakages must be rectified before proceeding.

96 When the pressure test is completed satisfactorily, remove the assembly from the oil container, disconnect the air supply and remove any temporary blanking plugs. Allow excess oil to drain from the pump body.

97 Lie the pump body on its side, with the fuel inlet connection uppermost. Fit the lower spring plate, plunger return spring and upper spring plate to each plunger. Insert the plungers into their respective barrels, with the plunger arms facing vertically downwards.

98 Position a new jointing gasket on the top face of the cambox and carefully fit the pump body, ensuring that the plunger arms engage correctly in their control forks. Insert four socket capscrews, complete with new sealing washers, into the corner bolt holes in the pump body; tighten the capscrews securely.

99 Mount the partly assembled pump on a Hartridge HA 3000 Test Rig or similar equipment, and connect a low pressure oil supply to the pump body inlet adaptor. Ensure that the oil pressure does NOT exceed 14 kNf/sq.m (2 lbf/sq.inch). Do not turn on the oil supply at this stage.

100 Remove the delivery valve holder, volume reducing peg, delivery valve spring and delivery valve from the No. 1 pump element.

101 Using the Adaptor, No. 89558/10, and Gauge Holder, ST 184, fit the D.T.I. No. 23764, in place of the No. 1 delivery valve holder.

102 Slide the fuel control rod to the maximum fuel position,i.e., towards the governor end of the assembly, and turn the camshaft until the No. 1 plunger is at the bottom of its stroke, i.e., with the tappet roller on the back of the cam.

103 Turn on the oil supply to the pump body and check the oil flow from the base of the gauge holder. Turn the camshaft slowly in its normal direction of rotation until the oil flow ceases; this is commonly known as the spill cut-off point, and is also the point at which the No. 1 element fuel injection commences during engine operation. Check the timing mark on the camshaft hub, this should be in correct alignment with the mark on the indicator plate. If the spill cut-off point has been correctly noted and the timing marks are not aligned, a new timing mark should be made on the camshaft hub to correspond with the indicator plate.

104 Check the reading on the D.T.I. and note the distance travelled by the plunger from the bottom of its stroke to the spill cut-off point. Compare this reading with the correct inlet stroke given in the Test Schedule.

105 To adjust the stroke length, remove the pump assembly from the test rig and unscrew the four body retaining, socket capscrews. Lie the assembly on its side with the inspection aperture facing downwards and carefully withdraw the pump body and plunger assemblies.

106 Withdraw and dismantle the No. 1 tappet assembly and replace the phasing spacer with one of appropriate thickness, to give the correct plunger travel.

Note: If a thicker spacer is fitted to the tappet assembly, a correspondingly thinner, lower spring plate must be fitted, and vice versa. This is to ensure that the original clearance between the spacer and lower spring plate is maintained. A list of phasing spacer and spring plate sizes is given at the end of this Section.

107 Reassemble the pump body to the cambox as previously described and mount the pump on the test rig. Recheck the No. 1 plunger travel and if correct, set the degree plate on the test rig to zero. This will provide a datum setting for checking the remaining elements.

108 Turn off the oil supply and remove the D.T.I., gauge holder and adaptor from the No. 1 element and refit the delivery valve assembly. Using the Socket Spanner, Part No. 7044-661, tighten the delivery valve holder to a torque loading of 115 to 129 Nm (85 to 95 lbf.ft).

109 Remove the delivery valve components from the next element in the injection sequence, i.e., No. 9 element, and connect a swan neck pipe to the delivery valve holder as shown in fig. 24. Turn on the oil supply.

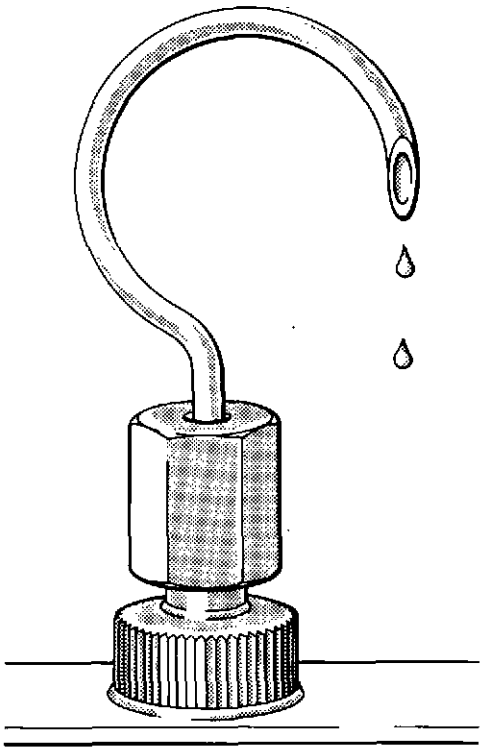


Fig. 24 Swan neck

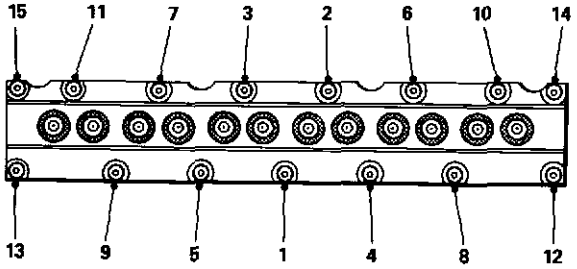


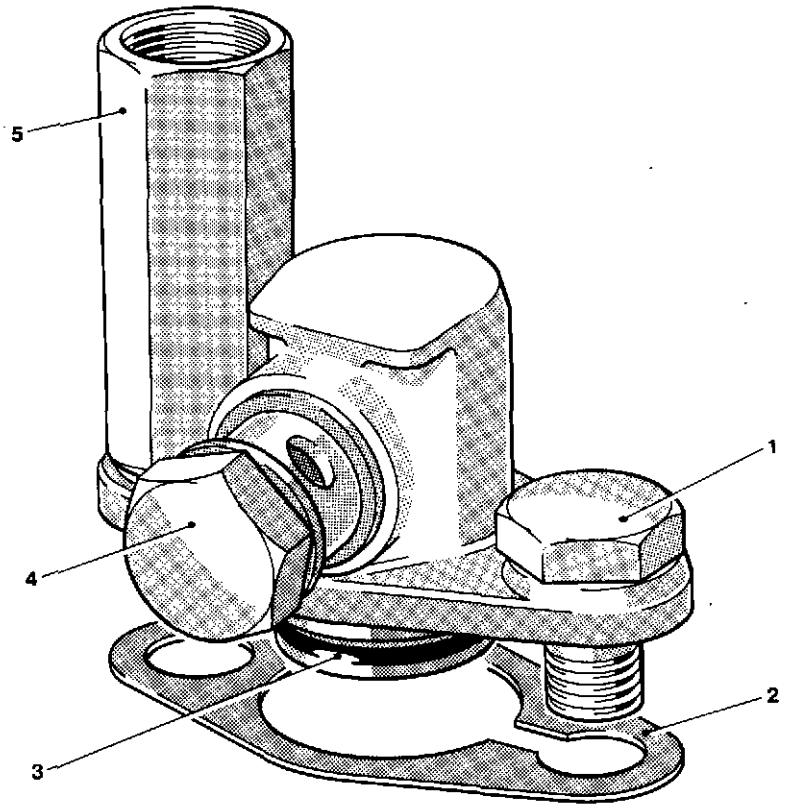
Fig. 25 Tightening sequence

110 Turn the camshaft slowly in its normal direction of rotation and check the flow of oil from the swan neck. As the plunger begins to close the inlet port, the oil flow will gradually diminish. Continue turning the camshaft very slowly, until the oil flow stops completely. Check the reading on the degree plate. If the spill cut-off point is correct, the plate should indicate 30 deg. If the degree plate reading is not within 30 $\pm$ 1/2 deg., note the reading on the plate, so that the phasing spacer can be changed later. Turn off the oil supply, remove the swan neck and reassemble the delivery valve components. Tighten the delivery valve holder to the correct torque loading.

111 Repeat the procedure for each of the remaining elements, in steps of 30 deg., following the sequence given below.

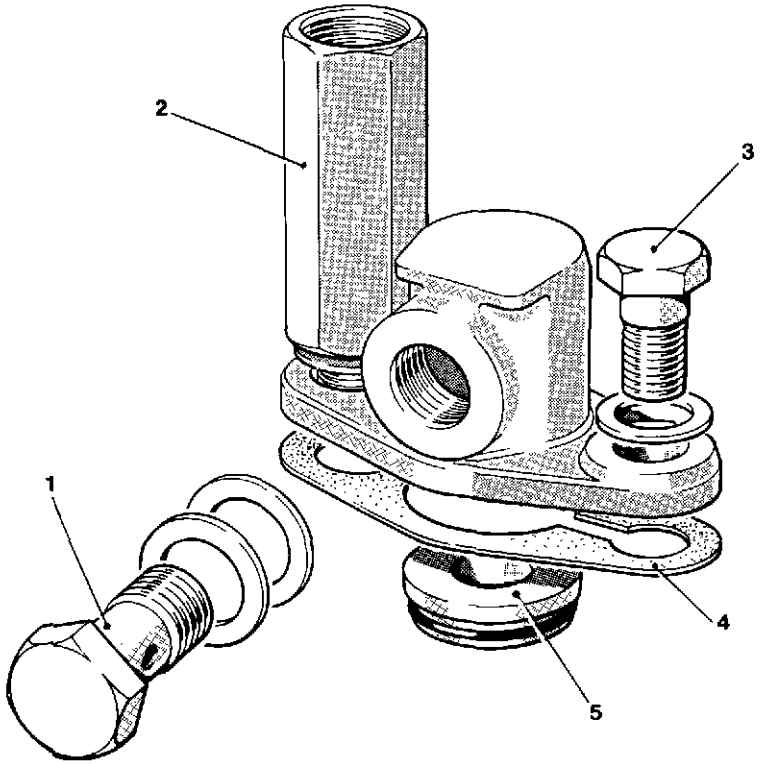
Sequence..	1	9	4	11	2	7	6	10	3	8	5	12
Degrees...	30	60	90	120	150	180	210	240	270	300	330	360

112 Disconnect the oil pipe and remove the pump from the test rig. If any of the pump element injection timings were incorrect, replace the phasing spacers and lower spring plates with those of the correct thickness, and recheck the pump on the test rig.



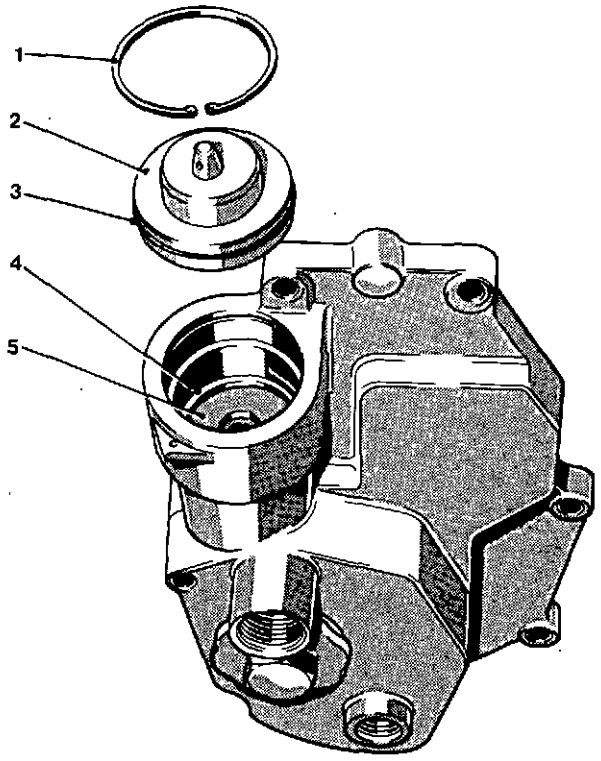
1 Vent bolt
2 Gasket
3 'O' ring seal
4 Oil return banjo bolt
5 Oil inlet connection

Fig. 26 Servo cover (Early engines)



1 Oil return banjo bolt
2 Oil inlet connection
3 Vent bolt
4 Gasket
5 Servo guide

Fig. 27 Servo cover (Intermediate)



1 Circlip
2 Servo cap
3 'O' ring seal
4 Circlip
5 Servo guide

Fig. 28 Servo cover (Latest engines)

113 Secure the pump assembly on its mounting plate in the vice and slacken the four socket capscrews. Insert the remaining 11 capscrews, complete with new sealing washers and tighten each capscrew, evenly and progressively, in the sequence shown in fig. 25, to a torque loading of 20,3 to 20,4 Nm (15 to 17 lbf.ft).

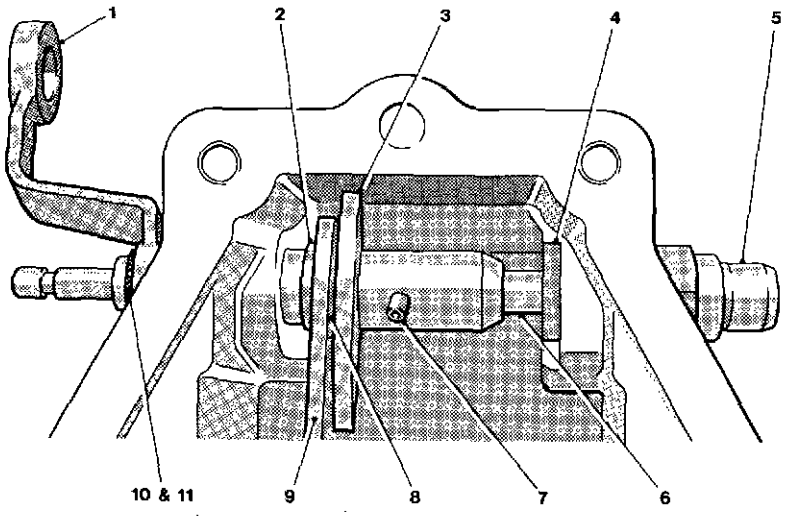
114 Check that all the lower spring plates are correctly seated on their tappet assemblies and that the fuel control rod moves freely.

Assembling the governor

115 Before assembling the governor, check all the components for wear or damage, especially the thrust and bearing surfaces; renew components and/or assemblies as necessary.

116 Check the tension of the coil spring in the servo valve assembly and renew if necessary. Dip the assembly in clean test oil and slide it into the servo piston, then fit the piston into the piston bore in the governor cover, aligning the piston slot to accept the guide screw.

117 Fit a new 'O' ring seal, coated with silicon grease, into the groove in the servo cover and, dependent on the type of servo cover fitted, assemble the cover to the piston bore as shown in figs. 26, 27 and 28. Where applicable, fit new jointing gaskets and sealing washers. Tighten the vent bolt and servo inlet connection to a torque loading of 27,0 to 34,0 Nm (20.0 to 25.0 lbf.ft).



1 Stop control lever
2 Thrust washer
3 Max stop lever assembly
4 Bush
5 Cap
6 Excess fuel shaft
7 Groverlok pin
8 Sealing washer
9 Stop shaft assembly
10 Spring ring
11 Washer

Fig. 29 Stop shaft assembly

118 Fit a new Quad ring and two new 'O' ring seals to the excess fuel shaft. Lubricate the shaft and the bore of the stop control shaft, with Molyslip anti-scuffing compound and slide the excess fuel shaft, with the machined flat facing downwards, through the side wall of the governor housing.

119 Fit the thrust washer, stop shaft assembly, sealing washer, maximum stop lever assembly and the locating bush on to the excess fuel shaft. Continue sliding the shaft through the governor housing, positioning the bush in the housing bore as shown in fig. 29.

120 Apply a coating of 'Loctite 241' to the thread of the bush, fit a new washer around the bush thread and insert the return spring in the cap. Fit the cap onto the bush and tighten to a torque loading of 20 to 23 Nm (15 to 17 lbf.ft).

121 Push the excess fuel shaft fully home and press the Groverlok pin into the maximum stop lever assembly. Fit the stop control lever and tighten the securing setbolt to a torque loading of 4,5 to 5,5 Nm (3.5 to 4.0 lbf.ft). Fit the rubber shroud over the end of the shaft.

122 Insert two rubber cush pads into each slot in the base of the weight cage. Stand the governor hub on the workbench and carefully fit the cage over the hub so that the cush pads locate on each side of the three drive pegs. Care must be taken to ensure that the pads are not distorted or damaged during this operation.

123 Position the retaining plate over the protruding drive pegs and fit the Spirolox ring into its groove in the body of the hub.

124 Fit the six governor weights into the weight cage, with the 48,3 mm diam. thrust washer resting on the thrust faces of the weights, and the bobbin type sleeve resting on the thrust washer. See figs. 30 and 31.

125 In sequence, fit the thrust washer(s), needle thrust bearing, thrust pad and spacing ring(s) on to the governor hub and position the hub assembly on the camshaft tapered end.

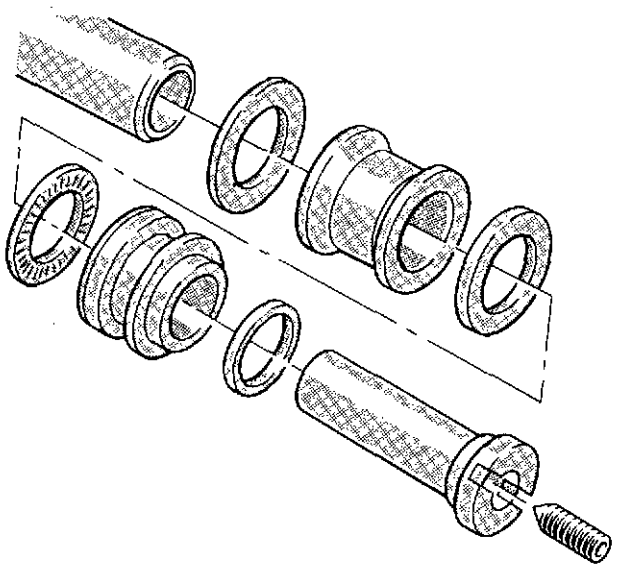


Fig. 30 Hub assembly

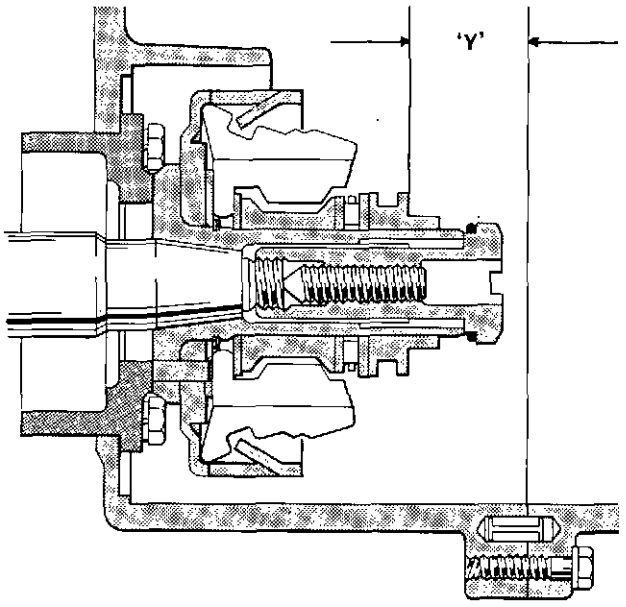


Fig. 31 Hub (Sectional view)

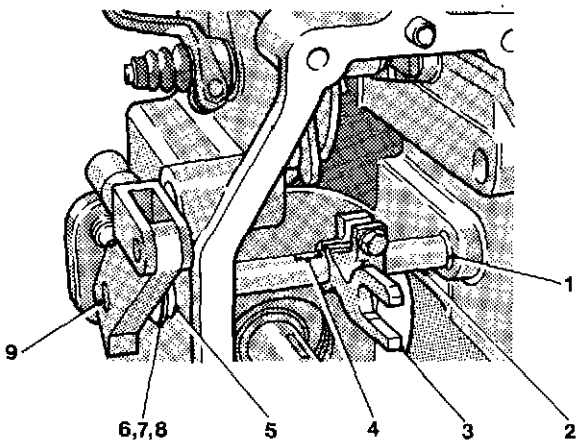
126 Secure the camshaft hub with the Holding Wrench, No. 500037, fit the governor hub nut and, using the Hub Key, ST 200, tighten the nut to a torque loading of 38,0 to 43,5 Nm (28 to 32 lbf.ft).

Check that the governor housing joint face is clean and ensure that the governor weights are in the fully 'closed' position, then proceed :

127 Using a depth gauge, accurately measure the distance from the housing joint face to the outer flange face of the thrust pad (fig. 31). Check the pump test schedule to verify the measurement. If the reading is incorrect, the existing thrust washer(s) may be replaced by new washers of the appropriate thickness.

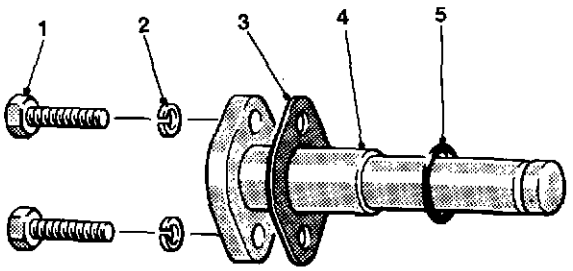
128 Coat the threads of the hub nut grub screw with 'Loctite 241' and fit the screw into the tapped bore of the nut.Tighten the screw to a torque loading of 20 to 27 Nm (15 to 20 lbf.ft).

129 Press the 'E' type spring clip into its groove in the control lever end of the speed control shaft (fig. 32). Fit the outer washer, bowed spring washer and inner washer, up to the inner face of the 'E' clip. Fit new Quad rings and 'O' ring seals into the shaft support bushes in the governor housing. Lubricate the bushes with silicon grease and slide the shaft into the housing from the control lever side. Fit the roller control lever onto the shaft and guide the shaft through the second bush, in the opposite side of the housing. Fit the plain washer, bowed washer and the second 'E' type clip to the protruding end of the shaft.



1 Bush
2 Shaft
3 Roller control lever
4 Woodruff key
5 Bush
6 'E' type clip
7 Washers
8 Bowed spring washer
9 Speed control lever

Fig. 32 Speed control shaft



1 Setbolt
2 Spring washer
3 Gasket
4 Pivot pin
5 'O' ring sael

Fig. 33 Pivot pin

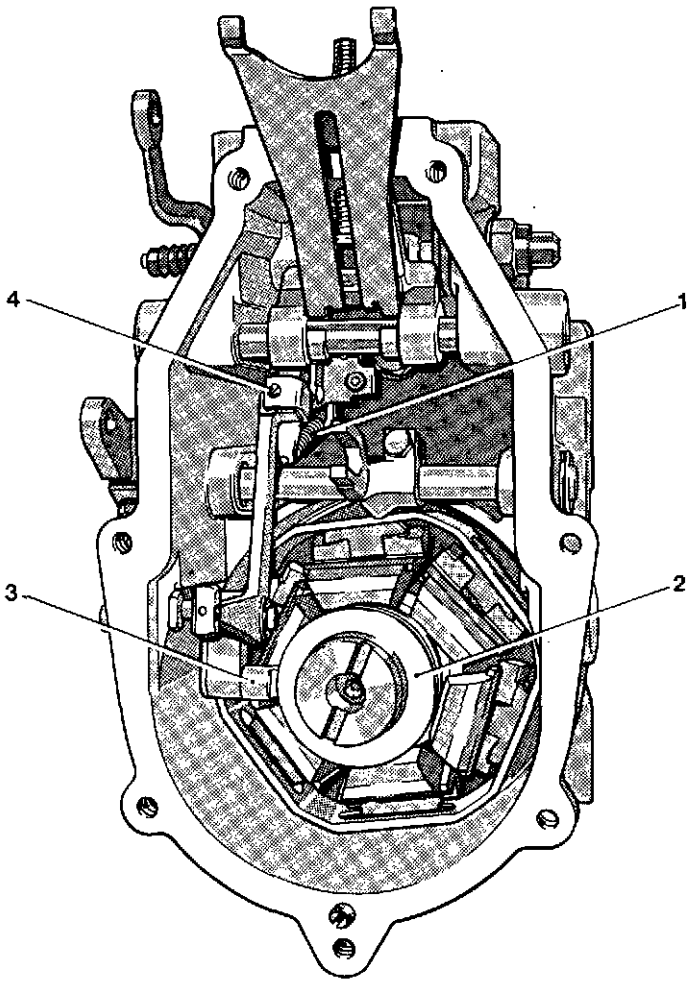
130 Slide the speed control lever, on to the splined end of the shaft and tighten the securing setbolt to a torque loading of 4,5 to 5,5 Nm (3.5 to 4.0 lbf.ft.).

131 Press the roller control lever key into the shaft and slide the lever into position, over the key. The centre line of the lever fork must be within 0,25 mm (0.010 inch) of the vertical centre line of the governor housing. When the lever is correctly positioned, tighten the securing setbolt to a torque loading of 4,5 to 5,5 Nm (3.5 to 4.0 lbf.ft.).

132 Using a small wire hook, attach the two extension springs to the control rod spring anchor points.

133 Fit a new 'O' ring seal and gasket on the pivot pin (fig. 33). Partially enter the pin into the governor housing and fit the thrust washers over the protruding inner end of the pin.

134 Fit the slipper pin into the servo valve lever (fig. 34), and assemble the connecting lever to the servo valve lever, with the dowel correctly located. Position both levers in the housing, with the slipper pin engaging in the groove in the thrust pad. Press the pivot pin through the bores of the two levers and fit the shim washer and the 'E' type clip over the protruding end of the pin. Fit the two securing setbolts, with new spring washers, through the flange of the pivot pin and tighten to a torque loading of 4,0 to 7,0 Nm (3 to 5 lbf.ft.). Attach the free ends of the two extension springs to the connecting lever assembly.



1 Extension springs
2 Thrust pad
3 Slipper pin
4 Adjusting screw

Fig. 34 Governor components

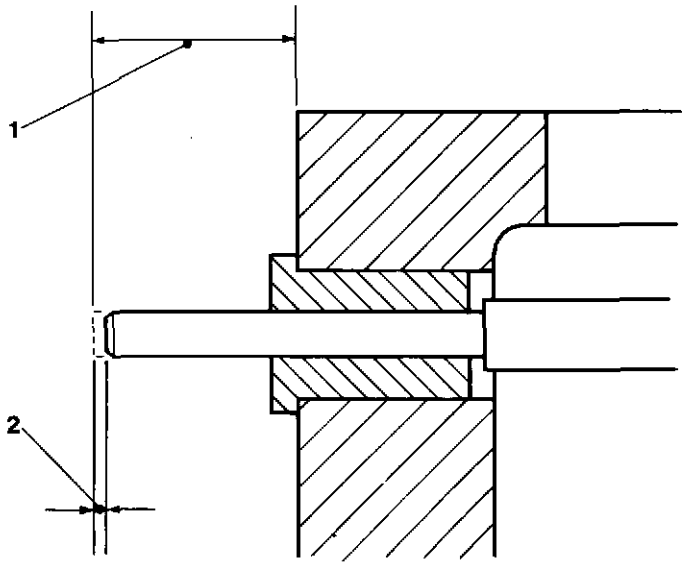


Fig. 35 Control rod adjustment

135 Fit a new 'O' ring seal to the governor spring fulcrum pin. Assemble the leaf spring and variable ramp in the governor housing. Insert the fulcrum pin into its bore, in the control lever side of the housing and pass the pin through the eyes of the leaf spring/ramp assembly. Push the fulcrum pin fully home until the ends are flush with the governor housing.

At this stage, set the injection pump control rod as follows :

136 Remove the three socket capscrews, securing the control rod end cover to the cambox. Lift off the cover and remove the gasket.

137 Slacken the adjusting screw in the top of the governor connecting lever (fig 34). Hold the governor weights in the fully open position and turn the adjusting screw until the square section of the fuel control rod just touches the face of the bush, in the cambox drive end.

138 Accurately measure the protrusion of the turned portion of the control rod, from the outer face of the pump cambox, (fig. 35, dimension 1). Note the measurement, then slacken back the adjusting screw to reduce the measurement by 0,1 to 0,5 mm (0.004 to 0.020 inch), dimension 2, fig. 35. Nip up the adjusting screw locknut, then re-check the protrusion. If the protrusion is correct, tighten the locknut fully.

139 Hold the governor weights in the fully closed position, press in the excess fuel button and check the control rod travel. The control rod travel must not be less than 24 mm (0.94 inch).

140 Refit the control rod end cover and gasket, and tighten the socket capscrews to a torque loading of 2,70 to 4,0 Nm (2.0 to 3.0 lbf.ft.).

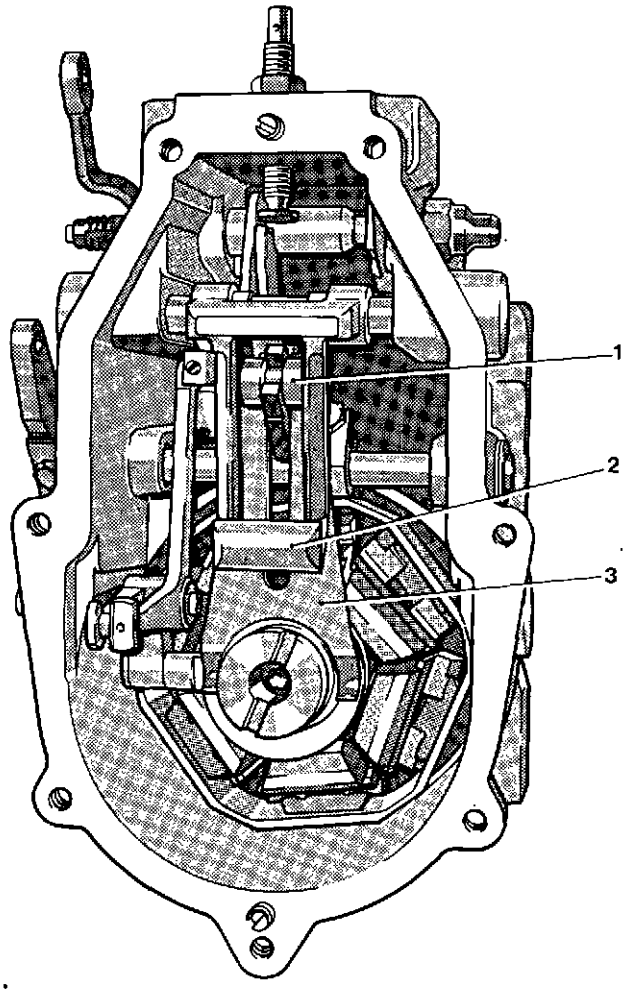
With the control rod travel correctly set, continue assembling the governor as follows :

141 With the convex bottom end of the spring resting against the face of the thrust pad, swing up the variable ramp and place the roller assembly in the roller control lever fork, so that the large diameter of the roller rests against the outer face of the spring; lower the ramp (fig. 36).

142 Apply a coating of grease to both sides of a new cover gasket and position the gasket on the housing joint face. Remove the large access plug from the governor end cover and carefully fit the cover to the housing, ensuring that the connecting and servo valve levers are correctly positioned in the recess in the servo piston and servo valve. Fit the seven cover securing setbolts, with new spring washers and tighten each setbolt to a torque loading of 5,5 to 8,0 Nm (4.0 to 6.0 lbf.ft.).

Before fitting the access plug, ensure that the lever assembly is correctly located in the servo valve and piston, checking that all the moving parts of the governor operate freely over their full range.

Warning : Failure to observe these precautions could result in an overspeeding engine, with resulting serious consequences.



1 Ramp roller
2 Variable ramp
3 Primary spring

Fig. 36 Governor components

143 Using a new gasket, fit the access plug and tighten to a torque loading of 38,0 to 41,0 Nm (28.0 to 30.0 lbf.ft.). Wire lock the plug.

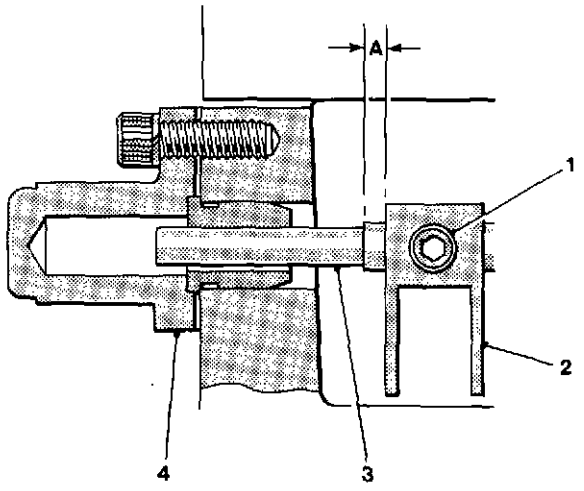
Calibrating the injection pump

144 Accurate measurement and adjustment of the fuel delivery from each pump element, can only be effected using special equipment, operated by skilled personnel. Unless this equipment and the skilled personnel are available, the fuel injection pump must be returned to the Manufacturer for calibration.

Read paras. 136 to 153 in conjunction with the Test Schedule, at the end of this Section.

145 Mount the pump assembly onto the test rig, ensuring that there is a minimum clearance of 0,5 mm (0.02 inch) between the pump and test rig coupling.

146 Connect the lubricating oil delivery and return pipework to the pump and governor.



1 Grub screw
2 Control fork
3 Control rod
4 Control rod end cover

Fig. 37 Control fork setting

147 Connect the test oil delivery pipe to the pump fuel gallery and the return pipework to the low pressure relief valve outlets.

148 Turn on the test oil supply and slacken the relief valve outlet connection unions. When bubble free oil emerges, tighten the unions securely.

149 Check the distance between the end face of the No 1 element control fork and the square shoulder of the control rod, (fig. 37). If necessary, slacken the control fork securing grub screw and slide the fork along the rod to give a reading of 0,30 mm (0.012 inch) at dimension 'A'. Tighten the grub screw to a torque loading of 4,75 to 6,0 Nm (3.5 to 4.5 lbf.ft.).

150 Secure the speed control lever in the maximum fuel position, and the stop control lever in the run position. Start the test rig and drive the injection pump at the speed specified in the Test Schedule. Note the test oil delivery from the No. 1 element for the specified number of shots in the Schedule.

151 Adjust the maximum fuel stop screw until the delivery from No. 1 element is as specified; nip up the locknut.

152 Check the delivery from No. 1 element two or three times. If the delivery is consistent, tighten the stop screw locknut securely.

153 Check the delivery from the remaining 11 elements and adjust the control forks accordingly. To increase the output from any element, slide its control fork fractionally towards the governor end of the pump. To decrease the output, slide the fork towards the drive end of the pump. Tighten the control fork locknut to its correct torque loading after each adjustment.

154 Remove the pump assembly from the test rig and fit the inspection cover bridge plates into the recesses in the cambox; secure them with the locating clips.

155 Fit new 'O' ring seals, smeared with 'Midland Silicons' lubricating fluid, MS 550, around each of the inspection cover securing setbolts.

156 Fit a new gasket to the inspection cover and position the cover on the cambox. Insert the cover securing setbolts, complete with plain washers, and tighten the setbolts evenly and progressively to a torque loading of 8,0 to 9,5 Nm (6.0 to 7.0 lbf.ft).

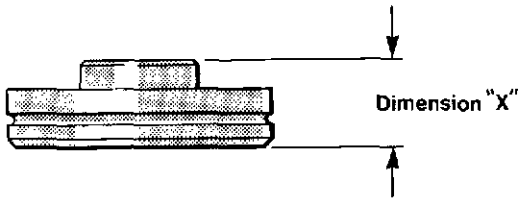


Fig. 38 Tappet spacer

Sizes of tappet spacers available

Part Number	Dimension 'X'	Identifying Mark No.
509459	5,65 to 5,70 mm (0.222 to 0.224 in)	1
509460	5,75 to 5,80 mm (0.226 to 0.228 in)	2
509461	5,85 to 5,90 mm (0.230 to 0.232 in)	3
509462	5,95 to 6,00 mm (0.234 to 0.236 in)	4
509463	6,05 to 6,10 mm (0.238 to 0.240 in)	5
509464	6,15 to 6,20 mm (0.242 to 0.244 in)	6B
509465	6,25 to 6,30 mm (0.246 to 0.248 in)	7
509466	6,35 to 6,40 mm (0.250 to 0.252 in)	8
509467	6,45 to 6,50 mm (0.254 to 0.256 in)	9B
509468	6,55 to 6,60 mm (0.258 to 0.260 in)	10
509469	6,65 to 6,70 mm (0.262 to 0.264 in)	11
509470	6,75 to 6,80 mm (0.266 to 0.268 in)	12
509471	6,85 to 6,90 mm (0.270 to 0.272 in)	13
509472	6,95 to 7,00 mm (0.274 to 0.276 in)	14
509473	7,05 to 7,10 mm (0.278 to 0.280 in)	15
509474	7,15 to 7,20 mm (0.281 to 0.283 in)	16B
509475	7,25 to 7,30 mm (0.185 to 0.287 in)	17
509476	7,35 to 7,40 mm (0.289 to 0.291 in)	18B
509477	7,45 to 7,50 mm (0.293 to 0.295 in)	19B
509478	7,55 to 7,60 mm (0.297 to 0.299 in)	20
509479	7,65 to 7,70 mm (0.301 to 0.303 in)	21
509480	7,75 to 7,80 mm (0.305 to 0.307 in)	22
509481	7,85 to 7,90 mm (0.309 to 0.311 in)	23
509482	7,95 to 8,00 mm (0.313 to 0.315 in)	24
509483	8,05 to 8,10 mm (0.317 to 0.319 in)	25
509484	8,15 to 8,20 mm (0.321 to 0.323 in)	26
509485	8,25 to 8,30 mm (0.325 to 0.327 in)	27
509486	8,35 to 8,40 mm (0.329 to 0.331 in)	28
509487	8,45 to 8,50 mm (0.333 to 0.335 in)	29
509488	8,55 to 8,60 mm (0.337 to 0.339 in)	30
509489	8,65 to 8,70 mm (0.341 to 0.343 in)	31
509490	8,75 to 8,80 mm (0.344 to 0.346 in)	32
509491	8,85 to 8,90 mm (0.348 to 0.350 in)	33

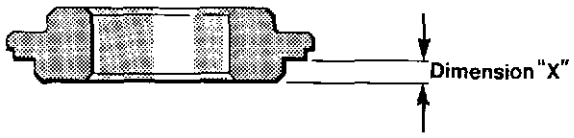


Fig. 39 Lower spring plate

Sizes of lower spring plates available

Part Number	Dimension 'X'	Identifying Mark No.
509498	0,60 to 0,65 mm (0.024 to 0.026)	1
509499	0,70 to 0,75 mm (0.028 to 0.030)	2
509500	0,80 to 0,85 mm (0.031 to 0.033)	3
509501	0,90 to 0,95 mm (0.035 to 0.037)	4
509502	1,00 to 1,05 mm (0.039 to 0.041)	5
509503	1,10 to 1,15 mm (0.043 to 0.045)	6B
509504	1,20 to 1,25 mm (0.047 to 0.048)	7
509505	1,30 to 1,35 mm (0.051 to 0.053)	8
509506	1,40 to 1,45 mm (0.055 to 0.057)	9B
509507	1,50 to 1,55 mm (0.059 to 0.061)	10
509508	1,60 to 1,65 mm (0.063 to 0.065)	11
509509	1,70 to 1,75 mm (0.067 to 0.069)	12
509510	1,80 to 1,85 mm (0.070 to 0.073)	13
509511	1,90 to 1,95 mm (0.075 to 0.077)	14
509512	2,00 to 2,05 mm (0.079 to 0.081)	15
509513	2,10 to 2,15 mm (0.083 to 0.085)	16B
509514	2,20 to 2,25 mm (0.087 to 0.089)	17
509515	2,30 to 2,35 mm (0.091 to 0.093)	18
509516	2,40 to 2,45 mm (0.094 to 0.096)	19
509517	2,50 to 2,55 mm (0.098 to 0.100)	20
509518	2,60 to 2,65 mm (0.102 to 0.104)	21
509519	2,70 to 2,75 mm (0.106 to 0.108)	22
509520	2,80 to 2,85 mm (0.110 to 0.112)	23
509521	2,90 to 2,95 mm (0.114 to 0.116)	24
509522	3,00 to 3,05 mm (0.118 to 0.120)	25
509523	3,10 to 3,15 mm (0.122 to 0.124)	26
509524	3,20 to 3,25 mm (0.126 to 0.128)	27
509525	3,30 to 3,35 mm (0.130 to 0.132)	28
509526	3,40 to 3,45 mm (0.134 to 0.136)	29
509527	3,50 to 3,55 mm (0.138 to 0.140)	30
509528	3,60 to 3,65 mm (0.142 to 0.144)	31

TEST PROCEDURE

TEST RIG CONDITIONS

Test oil

The following test oils have been approved by C.A.V. for pump testing :

Shell (UK)	Calibration fluid C
Shell (Overseas)	Calibration fluid B
Esso	Calibration fluid IL 1838
Castrol	Calibrating oil 8327

Test oil should be changed, and filters renewed, every six months or after testing 50 pumps, whichever occurs first.

High pressure pipes

These must be of solid drawn steel tubing, 8 mm OD X 3 mm Bore and 760 mm long. The minimum bend radius should be 50 mm.

Test oil pressure

As the fuel injection pump does not have an integral feed pump, the test oil supply must be provided via the test rig. Pressure of the test oil must be maintained, during calibration, at 207 to 241 kN/sq.m (30 to 35 lbf/sq. inch).

Lubricating oil

The lubricating oil is to be Shell Rotella TX 30, and must be delivered to the inlet connection of the servo mechanism at a pressure of 207 kn/sq m (30 lbf/sq. inch). The lubricating oil temperature is to be controlled at between 30 and 50 deg. C.

The oil return is to be from the servo unit outlet connection. This is in the form of a standard banjo union, but it is most important that the banjo is fitted facing downwards. A separate drain in the governor end cover must be provided to maintain the lubricating oil level in the governor to approximately the centre line of the camshaft.

Fill the pump cambox to the level of the lubricating oil return connection.

Maximum spread

The term 'Maximum spread' as used in the test schedule, is defined as 'The greatest permissible difference between the highest and lowest readings, after calibration, within the delivery tolerances given'.

TEST SCHEDULE

Test rig

Hartridge 1100 test machine

Test injectors

These are supplied in flow-matched sets under C.A.V. Part No. 6731502, and nozzle Part No. BDN8S2P, and are designed for test purposes only, having an operating pressure of 175 atmospheres. They are NOT interchangeable with injectors fitted to the CV 12 engine, which operate at 240 atmospheres.

When ordering these injectors, quote the test rig Type and Serial Numbers.

Pump specification

Type - SPE1212MX130

Rotation - Anticlockwise, viewed on drive end.

Firing order - 7, 6, 10, 3, 8, 5, 12, 1, 9, 4, 11 and 2.

Governor

Type - GCSVMX400-750S9

Governor weights - 'Y' dimension - 26 to 26,7 mm (1.02 to 1.05 inch)

PROCEDURE

1 Set the end of the ramp adjusting screw to 6,90 to 7,00 mm (0.272 to 0.276 inch) from the machined face of the governor end cover.

2 Set both the quadrant stop screws flush with the governor housing bracket, so that the quadrant has full angular travel. Wire the two stop screw locknuts.

3 Set No. 7 tappet at the drive end to 3,90 to 4,10 mm (0.154 to 0.161 inch), from the bottom of its stroke, to close of inlet port.

4 Phase the remaining elements to within $\pm$ 0,50 mm (0.020 inch) of No. 7, using the appropriate tappet spacers.

5 Fit the appropriate spring plates to give each plunger a vertical end float of 0,05 to 0,20 mm (0.002 to 0.008 inch)

Calibration

6 Run the test rig to give a pump speed of 750 r.p.m. Adjust the maximum fuel stop screw to give a delivery of 30,8 to 31,0 cc per 100 strokes, at the No. 1 element. Adjust the remaining forks to give a similar delivery.

7 Run the pump at 1200 r.p.m. and check that delivery from all elements stops at 1,0 mm (0.040. inch) control rod travel.

Caution : Where a setting code plate is fitted to the pump, the maximum fuel stop must be adjusted to the quoted figure after calibration. In all other cases, the nominal maximum fuel setting is the same as the calibration setting.

Idling

8 Run the pump at 400 r.p.m. The average delivery from each element should be 10,0 cc per 200 strokes.

Excess fuel

9 With the control rod in the excess fuel position, run the pump at 100 r.p.m. The average delivery from each element should be a minimum of 33,0 cc per 100 strokes. The maximum spread must not exceed 7,0 cc. Check the stop controls.

10 With the control rod in the excess fuel position, ensure that the inlet port closure occurs at a minimum of 3 deg. later than at the phasing position.

Governor test

11 Adjust the maximum speed stop screw so that fuel cut-off occurs at 810 r.p.m. Re-check the adjustment to ensure that the speed remains unchanged.

12 Check that the control rod starts to move at speeds between 760 and 790 r.p.m.

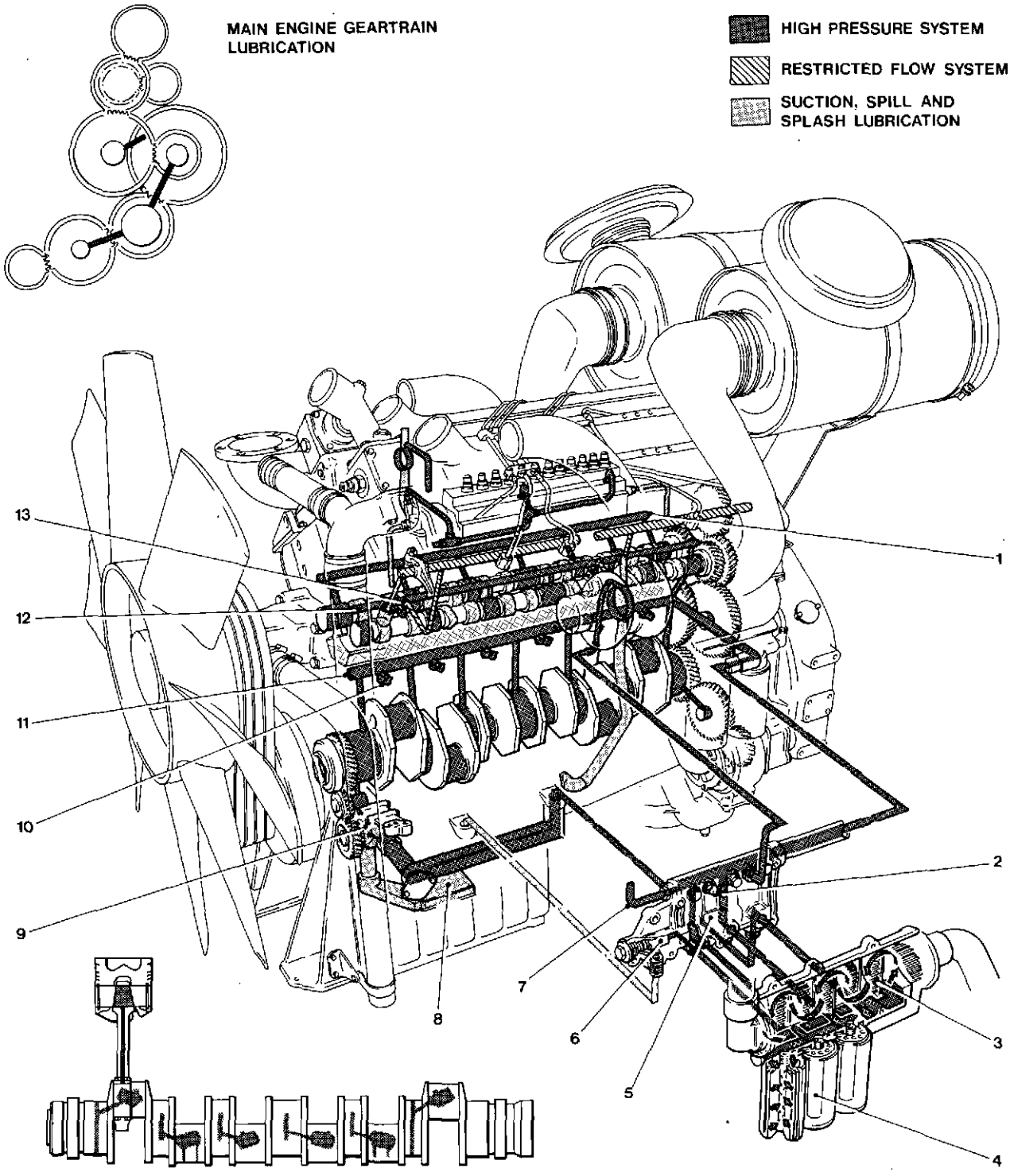
Note: If necessary, the ramp adjusting screw and the maximum speed stop screw may have to be re-set to obtain the above speeds. Re-check the idling speed delivery and re-set if necessary.

13 Check that fuel delivery ceases at 880 r.p.m., when the lubricating oil supply to the governor is cut off.

Timing

14 With the control rod in the maximum fuel position, set No. 7 element to point of inlet port closure. Set the timing pointer to the mark on the pump hub and tighten the securing setbolts.

SECTION 14 - LUBRICATION SYSTEM



1 'A' bank aux. gallery
2 Warning switch
3 Heat exchanger
4 Filter
5 Mounting adaptor
6 Pressure relief valve
7 Governor oil feed
8 Suction strainer
9 Oil pump
10 Piston jets
11 Main oil gallery
12 'B' bank aux. gallery
13 Restrictor bobbin

Fig.1 Lubrication system

SECTION 14 - LUBRICATION SYSTEM

Description

The spur gear type lubricating oil pump, driven via an idler gear from the crankshaft front end gearing, delivers oil, via the oil-to-coolant heat exchanger and oil filters, to a main gallery running through the centre of the crankcase 'V'. Drillings from the main gallery provide oil to each of the main bearings, idler axles and auxiliary galleries in each bank of cylinders. Separate jet assemblies in the crankcase provide cooling oil to the underside of each piston crown.

Camshaft bushes, rocker gear and fuel feed pump are supplied with oil from the auxiliary galleries, with oil drain troughs, cast beneath each camshaft, providing oil to the cam lobes.

External pipework, with connections on the heat exchanger mounting oil gallery, provides oil to the turbochargers, fuel injection pump and governor.

LUBRICATING OIL PUMP

Removal

If there is sufficient clearance beneath the engine, the sump and lubricating oil pump may be removed whilst the engine is attached to its driven unit with normal safety precautions being observed, i.e., isolate the starting circuit.

1 Remove the sump oil drain plug, collecting the oil in a suitable container; replace the drain plug and tighten to the correct torque loading.

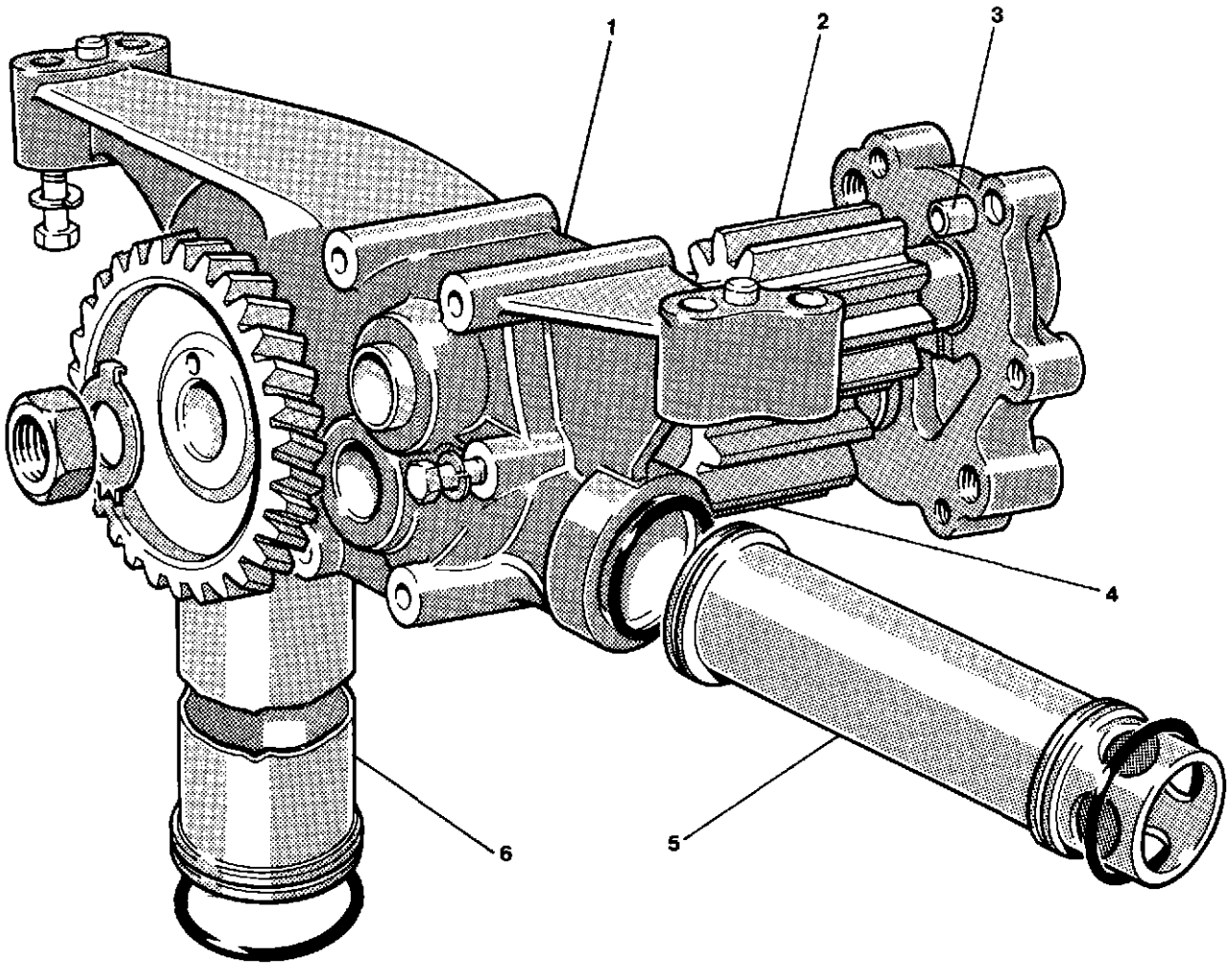
2 Remove the blanking flange from the 'B' bank side of the sump adaptor and withdraw the oil pump pressure discharge bobbin.

3 Remove the setbolts and washers, securing the sump to the adaptor,and carefully lower the sump to allow access to the oil pump. Secure the bobbin connection between the pump suction and the sump locatiuon. Remove and discard the sump jointing gasket.

4 Remove the four setbolts and washers, securing the oil pump to the crankcase. Lift the oil pump clear of its locating dowels.

Dismantling

5 Remove the drive gear retaining nut and lock washer and, using a suitable puller, withdraw the drive gear.



1 Pump casing
2 Idler gear
3 Ring dowel
4 Driven gear
5 Discharge bobbin
6 Suction pipe

Fig. 2 Lubricating oil pump

6 Remove the six bolts securing the end cover to the pump casing and, using a plastic mallet, tap the end cover away from the pump casing.

7 Withdraw the idler axle, idler gear and the driven gear assembly, from the pump body.

Inspection

8 Wash all the components in paraffin and blow dry with compressed air.

9 Carefully inspect the casing, end cover, gears and bearing surfaces for wear. Minor blemishes and burrs may be removed by careful stoning. Renew all worn components.

10 If the bearings are to be renewed, press out the old bushes and insert the new bushes, with the open end of the oil grooves facing in towards the spur gears. Press in each bush until it is flush with the casing or end cover inner face, as applicable.

11 Locate the idler shaft in its bore in the casing and fit the idler gear around the shaft. Using a straight edge and feeler gauges, check the clearance between the gear and the casing end face. Permissible clearance is 0,175 to 0,250 mm (0.007 to 0.010 inch).

12 Assemble the pump without the ring dowel, and lightly nip up the six securing setbolts. Using a D.T.I., check the end float of the pump drive shaft. Permissible end float is 0,175 to 0,250 mm (0.007 to 0.010 inch). Remove the end cover.

Assembling

13 Fit the ring dowel into its bolt hole counterbore and locate the cover over the drive shaft. Position the pump on a machined surface, such as the bed plate of a milling machine, ensuring that the four mounting feet of the pump are in close contact with the bed plate. Insert the six setbolts, with new spring washers, and tighten evenly to a torque loading of 21 Nm (15 lbf.ft.). Check that the pump mounting feet are all in full contact with the bed plate and check that the drive shaft turns freely in the casing.

14 Fit the drive gear on to the drive shaft, followed by a new lock washer. Coat the threads of the shaft with 'Loctite 241', and fit the securing nut. Holding the gear in a soft jawed vice, tighten the nut to a torque loading of 120 Nm (88 lbf.ft.). Tab up the lock washer.

Sump

15 Clean the sump thoroughly with paraffin and blow dry. Check that the oil strainer is free from sediment, and undamaged. Inspect the sump for cracks or other damage, and remove all traces of old gasket material from the joint face.

Refitting the oil pump and sump

16 Position the oil pump assembly against the crankcase with the dowels correctly located, and the drive gear in mesh with its idler. Fit the four setbolts, with new spring washers, and tighten to a torque loading of 55 Nm (40 lbf.ft.).

17 Renew the 'O' rings on the suction pipe, discharge bobbin and blanking flange. Slide the discharge bobbin through the sump adaptor and into the pump discharge, with the oil ports at the outer end; fit the blanking flange to the sump adaptor. Insert the two setbolts, with new spring washers, and tighten securely.

18 Lightly coat the sump joint face with Wellseal jointing compound and position a new gasket on the sump, with the bolt holes correctly aligned.

19 Fit the suction pipe into its location in the sump and, using the Guide Studs, VT 10723, lift the sump up to the adaptor, ensuring that the suction pipe is not dislodged during the operation. Fit the sump securing setbolts, with plain and new spring washers, and tighten to a torque loading of 55 Nm (40 lbf.ft.).

OIL-TO-COOLANT HEAT EXCHANGER

Removal

20 Drain the engine coolant into a drum and place a suitable container beneath the lubricating oil filters. Using the Strap Wrench, GA 5074, remove the filter canisters to drain the heat exchanger.

21 Release the hose clips and remove the pipe between the front (coolant discharge) end of the tube pack and the 'B' bank coolant gallery.

22 Release the hose clips and slide the coolant inlet hose connection away from the rear end of the tube pack.

23 Remove the six heat exchanger retaining setbolts and lift the assembly clear of its mounting adaptor.

Dismantling and cleaning

24 Remove the two small locating screws from the ends of the housing. Push the tube pack to the rear and remove the 'O' ring seal from its groove in the rear end of the pack. Push the tube pack forwards and out of the housing; remove the second 'O' ring seal.

Caution : Do not push the tube pack out without lifting out the rear end 'O' ring seal as the seal will jam in the housing oilways. If the tube pack is tight in the housing, it may be freed by positioning a medium soft wooden drift through the coolant inlet opening, with the end grain resting on the end of the tubes. Using a mallet, gently tap the tube pack free. DO NOT knock the thin end casing to free a sticking tube pack. After removal, check that the tubes are clear and undamaged.

25 Wash the pack in paraffin, taking care not to damage the fins. Blow through the tubes with compressed air then wash the pack in hot water.

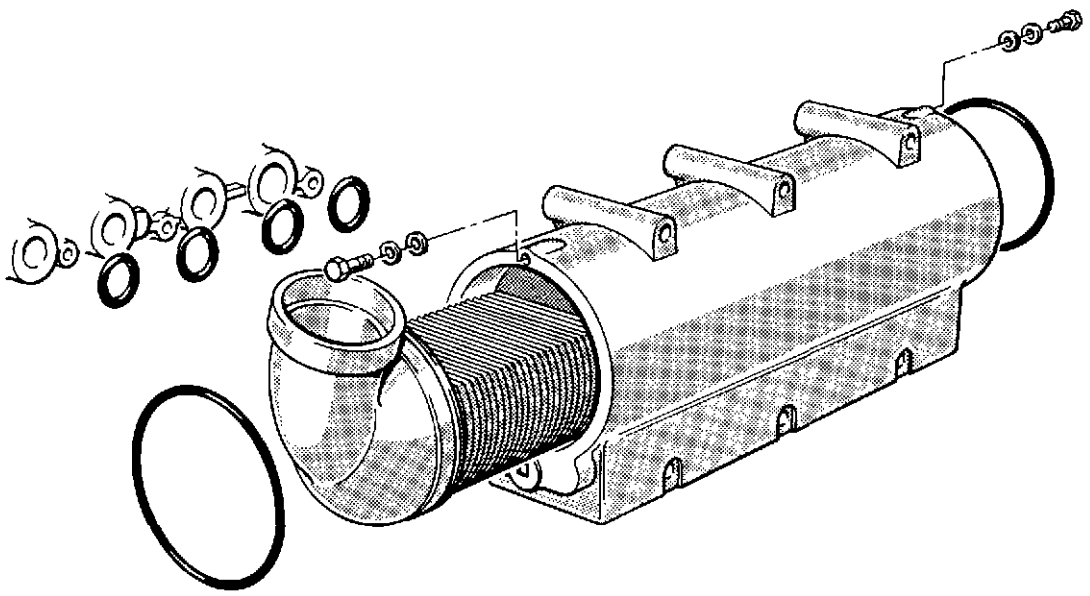


Fig. 3 Oil-to coolant heat exchanger

26 Hard deposits in the tubes may be loosened by soaking the pack in a solution of one part inhibited hydrochloric acid to three parts fresh water. When the frothing ceases, immerse the pack in a solution of washing soda (sodium carbonate) in hot fresh water, 0,5 kg.to 25 litres (1 lb.to 5 Imp. Gallons). Finally blow through the tubes with compressed air.

27 Clean the heat exchanger housing in a non-caustic solvent and wash in hot fresh water.

Inspection

28 Check the housing for damage and score marks. Inspect the pack for corrosion, cracks and damage. The pack should be pressure tested by blanking off one end of the pack and applying air to the tubes at 2,14 kg/sq.cm (30 lbf/sq.inch), with the pack immersed in water at 80 deg. C.

Assembling

29 Apply a smear engine oil to the bore at both ends of the housing.

30 Fit a new 'O' ring seal to the groove in the front end of the tube pack. Insert the tube pack into the front end of the housing, with the locating screw holes correctly aligned, and push it through far enough to expose the groove in the rear end of the pack. Fit a second new 'O' ring seal into the groove and carefully push the pack into its correct position. Insert the two locating screws, with plain and new spring washers, and nip up securely.

PRESSURE RELIEF VALVE

Description

The spring and plunger type relief valve is housed in the front end of the heat exchanger mounting adaptor. The spring cap consists of a brass screwed plug with a copper sealing washer.

32 Unscrew the cap and withdraw the relief valve assmbly. Check the plunger and housing for score marks and damage. If deeply scored, renew the assembly complete.

33 Check the spring for distortion and measure its free length. A new spring conforms to the following requirements :

Free length	123,2 mm (4.85 inches)
Length under load of 39,5 kgf (87 lbf)	74,0 mm (2.91 inches)

To ensure correct operating pressure, it is advisable to always fit a new spring.

34 Lightly oil the plunger and ensure that it slides freely in the casing bore. Fit the spring and screw in the cap, with a new copper washer; tighten securely.

Refitting heat exchanger assembly

35 Press a new hose connection, and the two hose clips, over the end of the coolant pump discharge pipe.

36 Press four new 'O' rings seals into the recesses in the rear face of the heat exchanger housing. Position the heat exchanger against its mounting adaptor, ensuring that the seals are not dislodged during the operation. Insert the six securing setbolts, with plain and new spring washers, and tighten evenly and securely.

37 Fit a new hose connection, and the two hose clips over the end of the heat exchanger coolant discharge elbow.

38 Check the coolant gallery and inlet pipe flanges for cleanliness. Fit the pipe to the coolant gallery, using a new gasket, insert the four securing setbolts, with plain and new spring washers, and tighten securely.

39 Slide the two hose connections over the joints and align and tighten the four hose clips.

40 Fill three new filter canisters with clean engine oil and screw them on to the adaptors, in the lower face of the heat exchanger housing, until the rubber sealing rings just touch the contact faces of the housing. Tighten the canisters a further 3/4 turn by hand. Do NOT over-tighten.

41 If re-usable, return the lubricating oil to the engine sump, and replenish to the FULL mark on the dipstick, if necessary.

42 Check that the coolant drain plugs are secure and refill the cooling system, topping up if necessary, with coolant to the same specification as that already in use.

SPECIAL TOOLS

Tool Number	Description
GA 5074	Strap wrench, filter canister
VT 10723	Guide stud, sump to adaptor

SECTION 15 - RUNNING-IN AND TESTING

SECTION 15 - RUNNING-IN AND TESTING

Every new or reconditioned engine supplied by Rolls-Royce is run and tested before being despatched from the Factory. It requires no special treatment when put into service, but the Operator is recommended to follow the instructions given in Chapter 2 of the Servicing Manual T.S.D. 3138,

When a CV 12 engine in service has been completely overhauled or built up from a 'short engine', or when a partial overhaul has involved the renewal of cylinder liners, piston rings and bearings, a running-in schedule applicable to the engine rating should be carried out as described in the following text.

Caution : Prior to running an engine, ensure that temporary oil filters, Part No. OE 43712, are fitted into the oil feed connection in each turbocharger bearing housing. After the running-in period, the filters MUST be removed and discarded, and normal jointing gaskets fitted in their place before the engine goes into service.

RUNNING-IN

1 Prepare the engine for running as described in Chapter 2 of the Servicing Manual, T.S.D. Publication 3138.

2 Start the engine, run it off load, and check that the correct oil pressure is registered on the gauge. Inspect all the fluid systems for leaks and shut the engine down. Rectify any leaks and top up the lubricating oil and coolant to the correct levels.

3 At the satisfactory conclusion of the running-in schedule, carry out an oil consumption test in the manner described.

Running-in schedule

CV 12 engines rated at 1500 rpm. or 1800 rpm.

Period	R.p.m.	Load or rated power	Duration (minutes)
1	1500/1800	Minimum brake load	5
2	1500/1800	25 %	10
3	1500/1800	50 %	10
4	1500/1800	75 %	10
5	1500/1800	Full load	10

At the start of period 5, load and speed must be checked to prevent possible overload.

During the running-in period, the cause of any obvious noise or vibration should be sought and the engine checked for leaks, which should be rectified after the running-in is completed.

Engine shutdown must only take place at the end of a period, or in the case of an emergency.

OIL CONSUMPTION CHECK

Where practicable, it is advisable to carry out the following check which is suitable for both the 1500 and 1800 rpm. rated engines.

1 Ensure that the engine oil level is exactly to the MAXIMUM mark on the dipstick.

2 Run the engine at rated speed and power until the normal coolant outlet and engine oil temperatures are reached :

Coolant outlet	68 to 85 deg.C.
Engine oil	90 to 105 deg.C.

3 Run the engine at minimum brake load for two minutes. Stop the engine and check the oil level on the dipstick. Replenish to the MAXIMUM mark if necessary.

4 Drain the oil from the sump and heat exchanger **immediately** into separate containers for exactly 20 minutes. The heat exchanger should be drained via the drain plug in the end of the housing, this being the lowest point.

5 Weigh each container with its contents separately and record the weights.

6 Refit the sump and heat exchanger drain plugs and pour the oil back into the engine sump. Weigh the empty containers and record the weights.

7 Subtract the weight of the two empty containers from the total weight recorded in paragraph 5. Record the total weight of the oil.

8 Run the engine at rated speed with 90 % load, for a period of two hours.

Note: If for any reason the engine is stopped during this period, the test must be re-started from paragraph 1.

9 At the end of the two hours run, allow the engine to run off load for two minutes. Stop the engine and repeat the procedures in paragraphs 4 to 7 inclusive.

The method for calculation of oil consumption, where the oil weights are recorded in pounds (lbs), is as follows :

$$\frac{\text{Initial total oil weight - Final total oil weight}}{2.2} = \text{litres/hour}$$

Acceptable consumption limit is up to 1,02 litres per hour.

PERKINS ENGINES (SHREWSBURY) LIMITED
successor to the business of
Rolls-Royce Motors Limited, Diesel Division.

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T.S.D. Publication 3169

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